

DE BEERS GROUP

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Government of the Northwest Territories
Email transmittal

September 1, 2023

Dear Ms. Njerere:

Re: Air Quality and Emissions Monitoring and Management Plan Version 6

De Beers Canada Inc. (De Beers) is pleased to provide the updated Snap Lake Air Quality and Emissions Monitoring and Management Plan (AQEMMP) Version 6, as required by the Snap Lake Environmental Agreement (items 7.1b and 7.2b).

The AQEMMP was previously submitted to the Government of the Northwest Territories (Department of Environment and Natural Resources) on July 15, 2022, updated for closure and post-closure. De Beers has since received the following comments:

- Government of Northwest Territories (GNWT) on October 3, 2022; and
- Snap Lake Environmental Monitoring Agency (SLEMA) on October 17, 2022.

The AQEMMP Version 6 has been updated to address the above reviewers' comments, in addition to aligning with the updated Final Closure & Reclamation Plan Version 1.3 (submitted to the Mackenzie Valley Land and Water Board on May 19, 2023).

Should you have any questions or comments, or would like to meet to discuss the plan, please feel free to contact me by phone at (867) 679-6392 or by email at Lisa.Tran@debeersgroup.com.

Sincerely,



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SNAP LAKE MINE

Air Quality and Emissions Monitoring and Management Plan

July 12, 2023



DE BEERS GROUP

REVISIONS HISTORY

Version	Date	Notes/Revisions
1	October, 2007	Air Quality and Emissions Monitoring and Management Plan (De Beers, 2008). The 2007 AQEMMP harmonized the AQMP and EMP into one document and documented early 2008 (De Beers, 2008).
2	October, 2017	Report addresses the change in monitoring equipment, including the: location, species monitored and monitoring frequency to reflect current site operations and extended care and maintenance (ECM) phase of the Mine. Action levels for the ECM phase included in the report. Report updates the emission factors utilized in the calculation of emissions to current values. Various minor improvements to text completed throughout the document.
3	March, 2019	Updated to account for Closure and Post-Closure phases.
4	July, 2020	Updated to align with the approved Water Licence (MV2019L2-0004) and Land Use Permit (MV2017D0032) renewal.
5	May, 2022	Updated to align with the updated Final Closure and Reclamation Plan Version 1.2.
6	July, 2023	Updated to address comments from GNWT (received Oct. 3, 2022), SLEMA (received Oct. 17, 2022), and align with the updated Final Closure and Reclamation Plan Version 1.3 (submitted to MVLWB on May 19, 2023).



EXECUTIVE SUMMARY

The Snap Lake Diamond Mine's (Mine) Environmental Agreement (INAC et al., 2004) contains a requirement to develop an Air Quality Monitoring Program (AQMP) and an Emissions Management Plan (EMP). Both the AQMP and EMP have undergone a number of revisions to incorporate feedback from the Government of the Northwest Territories (GNWT) and Environment and Climate Change Canada (ECCC). The 2007 Air Quality and Emissions Monitoring and Management Plan (AQEMMP) harmonized the AQMP and EMP into one document and reported early 2008 (De Beers, 2008). This integrated approach demonstrates the linkages between the two programs and shows how the data from each program will be presented together each year in the annual report. The 2017 AQEMMP (De Beers, 2017) was an update to the 2007 document to reflect conditions at the Mine during extended care and maintenance (ECM). The 2019 AQEMMP (De Beers, 2019a) was an update to reflect the changes for the Closure and Post-Closure phases. The 2020 AQEMMP (De Beers, 2020) was updated to reflect the new Water Licence (MV2019L2-0004) granted on May 20, 2021 and the Land Use Permit (MV2017D0032) renewal that was issued on March 20, 2020. The 2022 AQEMMP was updated to reflect the updates made to the Final Closure and Reclamation Plan Version 1.2 (FCRP) (De Beers, 2022a). The 2023 AQEMMP is an update to reflect the changes in the FCRP Version 1.3 (De Beers, 2023a) and to address additional comments from the GNWT and Snap Lake Environmental Monitoring Agency (SLEMA).

The AQMP component will be used to monitor air quality at the Mine. This ambient air quality monitoring will be compared to applicable air quality criteria or any subsequent predictions and analyzed for trends each year in the annual report. The AQMP will provide an indication of the Mine's performance with respect to air quality.

The EMP component presents the approaches that will be used in the annual report to provide a summary of Mine emissions. The emission calculation methodology for each of the main Mine sources is discussed in detail in this document. The calculated emissions will be compared to those in the Snap Lake Mine 2007 Air Modelling Update for operations (Golder, 2007) and subsequent applicable predictions, to evaluate Mine emissions performance.

An important outcome of evaluating Mine emissions performance is to identify potential areas for emissions mitigation. Recommendations for emissions mitigation will be made each year if necessary, using a pro-active approach that considers the annual emissions and monitoring data against pre-determined action levels.



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ACRONYMS AND ABBREVIATIONS

AAAQG	Alberta Ambient Air Quality Guidelines
Ambient	Existing or present in the surrounding air
AQEMMP	Air Quality and Emissions Monitoring and Management Plan
AQMP	Air Quality Monitoring Program
CH ₄	Methane
CO ₂	Carbon Dioxide
CO ₂ e	Carbon Dioxide Equivalent
De Beers	De Beers Canada Inc.
EAR	Environmental Assessment Report
ECCC	Environment and Climate Change Canada
ECM	Extended Care and Maintenance
EMP	Emissions Monitoring Program
ENR	Environment and Natural Resources
FCRP	Final Closure and Reclamation Plan
GHG	Greenhouse gas
GNWT	Government of the Northwest Territories
INAC	Indigenous and Northern Affairs Canada
Mine	Snap Lake Mine
MVEIRB	Mackenzie Valley Environmental Impact Review Board
N ₂ O	Nitrous oxide
NAAQO	National Ambient Air Quality Objectives
NO ₂	Nitrogen dioxide
NO _x	Oxides of nitrogen
NPRI	National Pollutant Release Inventory
NWT	Northwest Territories
Partisol	Dichotomous Partisol sampler
PM ₁₀	Particulate matter concentrations less than 10 micrometres
PM _{2.5}	Particulate matter concentrations less than 2.5 micrometres
QA/QC	Quality assurance/quality control
SLEMA	Snap Lake Environmental Monitoring Agency
SNP	Surveillance network program
SO ₂	Sulphur dioxide



TSP	Total suspended particulate
U.S.EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VMP	Vegetation Monitoring Program

UNITS OF MEASURE

%	Percent
°C	Degrees Celsius
cm	Centimetres
g/GJ	Grams per gigajoule
g/year	Grams per year
GJ/kg	Gigajoules per kilogram
kg	Kilogram
kg/kmol	Kilograms per kilomol
kg/m ² /day	Kilograms per squared metre per day
kg/m ³	Kilograms per cubic metre
kg/year	Kilograms per year
km	Kilometre
kph	Kilometres per hour
m/s	Metres per second
m ³	Cubic metres
Mg	Megagram
mg/dm ² /30 days	Milligrams per square decimetre per 30 days
ppmw	Parts per million weight
VKT	Vehicle kilometres travelled
VMT	Vehicle miles travelled
µg/m ³	Micrograms per cubic metres
µm	Micrometre



1 INTRODUCTION

De Beers Canada Inc. (De Beers) owns and operates the Snap Lake Diamond Mine (Mine). The Mine is located in the Northwest Territories (NWT) approximately 220 kilometres (km) northeast of Yellowknife and 30 km south of MacKay Lake (Figure 1-1). Final regulatory approvals for construction and operation of the Mine were granted in May 2004, and construction began in April 2005. Mining processing began in August 2007 and was expected to continue for 22 years. On December 4, 2015, the Mine was placed into temporary closure termed “Care and Maintenance”. In December 2017, De Beers announced the Mine will begin preparations for final Closure. The activities undertaken during De Beers’ Care and Maintenance, Closure and Post-Closure phases are completed to maintain compliance with the Water License MV2019L2-0004 and Land Use Permit MV2017D0032, and the Environmental Agreement for the Mine (INAC et al., 2004).

This Air Quality and Emissions Monitoring and Management Plan (AQEMMP) is a requirement of the Mine’s Environmental Agreement (Article VI, Section 6.3 items d and e and Article VII, Section 7.2 item a) (INAC et al., 2004) and also fulfills the air quality and meteorological monitoring requirements in the Mine’s Water License.

1.1 Legislation, Regulatory and Policy Requirements

An Environmental Assessment Report (EAR) for the proposed Mine (De Beers, 2002) was completed and submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) in February 2002. The Board in turn completed a review, and recommended that the Mine proceed subject to the implementation of measures to mitigate environmental impacts (MVEIRB, 2003). The MVEIRB’s report and recommendation was submitted to the Minister of Indian and Northern Affairs (now termed Crown-Indigenous Relations and Northern Affairs Canada, CIRNAC) in July 2003 and received ministerial approval in October 2003. De Beers received the necessary Water License, Land Use Permit, Land Leases, and Environmental Agreement in May 2004 to begin construction and operation of the Mine. Since this time and as-required, De Beers has renewed their Water License and Land Use Permit prior to their expiry.

De Beers must meet the following requirements regarding air quality, meteorological monitoring, and emissions monitoring:

1. the development of an Air Quality Monitoring Program (AQMP), as outlined in Article VI, Section 7.2 of the Environmental Agreement. The AQMP is also necessary to meet the meteorological monitoring requirements specified in the Annual Water Licence Report Conditions (Schedule 1) and the Surveillance Network Program (SNP) section of the Mine’s Water License (MV2019L2-0004); and,
2. the development of an Emissions Management Plan (EMP), as outlined in Article VI, Section 6.3 items d) and e) and Article VII, Section 7.2 item a) of the Environmental Agreement.



1.2 Scope

An initial draft of the AQMP was prepared in September 2003 and updated in September 2005 based on feedback from the Government of the Northwest Territories (GNWT) and Environment and Climate Change Canada (ECCC). A draft of the EMP was submitted to the Snap Lake Environmental Monitoring Agency (SLEMA), GNWT and ECCC in February 2006. Upon receipt of feedback on this draft (GNWT and Environment and Climate Change Canada, 2006), the AQMP and EMP were harmonized into one document (AQEMMP) in 2007 and documented early 2008 (De Beers, 2008). This was done to demonstrate the linkages between the two monitoring programs and to allow the data from the two programs to be presented together each year in the annual report.

The overall purpose of this integrated document is to provide an overview of the activities involved in the AQMP and EMP and a template for the annual monitoring reports. This report is a “living” document that may need to be adapted as the Mine itself evolves, consistent with the Mine’s Adaptive Management Plan (De Beers, 2004). As such, this AQEMMP was updated to reflect operations and monitoring at the Mine during the final Closure and Post-Closure phases.

This AQEMMP document has been prepared to address the two monitoring requirements in the Environmental Agreement (INAC et al., 2004). The AQMP is presented in Section 2 of this document and the EMP is presented in Section 3.

An important component of the AQEMMP is the comparison of annual monitoring data to emission estimates and dispersion modelling predictions initially presented in the Mine EAR (De Beers, 2002). An updated air quality assessment was completed in 2007 based upon more recent design information (Golder, 2007). Additional updates were completed in 2017 to address the ECM phase (ARKTIS, 2018a), and in 2018 to address the Post-Closure phase (ARKTIS, 2018b). The ECM and Post-Closure air dispersion modelling followed a similar approach to that completed during the EAR and the 2007 re-modelling. Examples of notable assumptions used in the models include:

- Use of conservative input parameters, such as the use of the same erosion rate for the North Pile during ECM and Post-Closure (e.g., for sand/processed kimberlite sized material rather than the granular size material of the North Pile cover Post-Closure);
- All source terms are constantly applied for set time durations (e.g., half a year or full year);
- Zero occupancy compared to occupancy timeframes at the Mine have distinct source terms that were selected to best represent site conditions (i.e. emissions rates from point sources such as power generators, emission rates from area sources such as roads with and without vehicle traffic).

A comparison of the Mine’s Post-Closure air dispersion model assumptions and inputs to the conditions presented in the Final Closure and Reclamation Plan Version 1.3 (FCRP; (De Beers, 2023a), is provided in Appendix D, was completed to assess whether the model remains valid or warrants update. The evaluation found the air dispersion model is considered to provide a conservative prediction of the air quality at the Mine during Post-Closure and thus remains valid. No updates or revisions to the model are required.

In this document, the 2007 operations model, ECM model and the Post-Closure model are referred to as the basis for comparing with monitoring data.



This AQEMMP addresses the modifications to the monitoring plan for the Mine to reflect anticipated operations during Closure and Post-Closure. The duration and scope of activities during the Closure and Post-Closure phases will follow the schedule laid out in the FCRP (Sections 8.1 and 8.2;(De Beers, 2023a).

During Mine construction and operation, activities were typically greater in type and magnitude compared to Closure and Post-Closure, with extensive earthworks conducted to construct the Mine, in addition to the ongoing construction and deposition activities at the North Pile associated with the actual mining. A summary of the general activities or emission sources with relevance to air quality during the Closure and Post-Closure phases are compared to the operating mine in Table 1-1. As noted from Table 1-1, the activities and emissions sources reduce in type and magnitude over time (e.g., when the Closure and Post-Closure phase is reached).

Table 1-1 Summary of activities and emission sources during mine operation, Closure and Post-Closure

Emission Source Type	Operations	Closure	Post-Closure
Movement of vehicles/ equipment	Active	Active, reduced rate compared to operations	Minimal
Airstrip operations	Active	Active, reduced rate compared to operations	Not active
Underground mining	Active	Not active. Underground mine flooded and closed.	Not active
Construction/ demolition activities	Active	Active, reduced rate compared to operations.	Not active
Combustion (i.e. power generation, heating, incineration, etc.)	Active	Active, reduced rate compared to operations	Minimal
Wind erosion	Active	Active	Active, reduced rate compared to operations

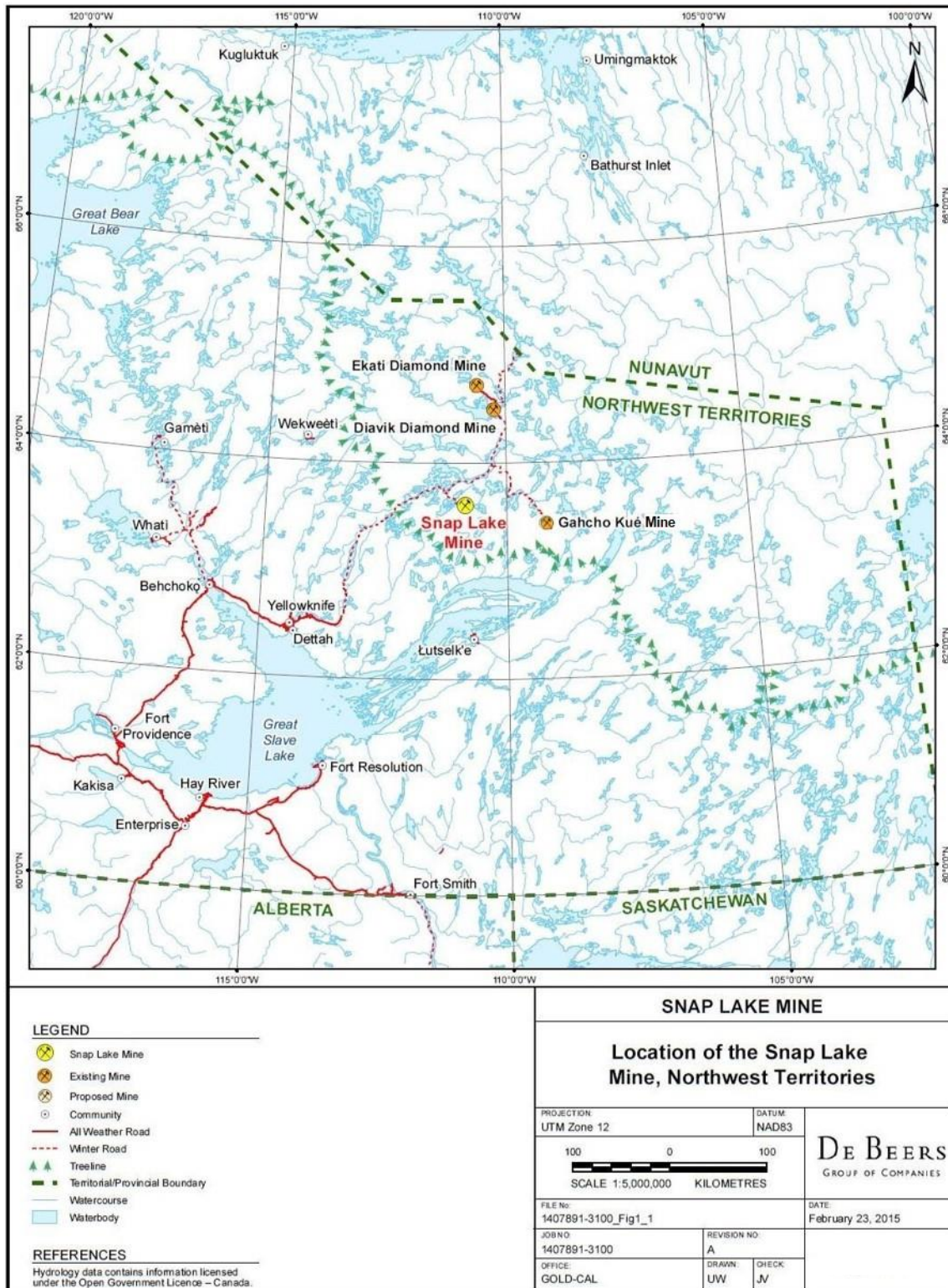
1.3 Goal

The goal of the Mine's AQMP and EMP is to comply with relevant Articles in the Environmental Agreement (e.g., Articles VI and VII), the Water License, legislation and related corporate environmental policies. Accordingly, De Beers has designed these plans in consultation with the GNWT, ECCC and SLEMA.

Conformance tables outlining where the requirements of the Environmental Agreement and Water Licence are addressed within the AQEMMP are provided within Appendix A.



Figure 1-1 Location of the Snap Lake Mine, NT



1.4 Objectives

This document has been developed to address the following objectives:

- Demonstrate compliance with applicable Federal, Provincial and Territorial ambient air quality standards;
- Track trends in ambient air quality and Mine emissions;
- Provide information required to protect air quality;
- Outline response plans to respond to increasing trends, exceedances of air quality criteria or occurrences above emission estimates and dispersion modelling predictions presented in predictive modelling of air dispersion;
- Provide data that can make a meaningful contribution to regional cumulative effects monitoring data bank;
- Identify strategies for emissions tracking and monitoring;
- Document fuel use as it relates to air quality management; and,
- Under the ECCC regulations, facilitate data gathering necessary to develop an approach for emissions mitigation, which includes the fugitive dust abatement program.

To achieve these objectives the AQMP was initially designed to concentrate on the following five main components:

1. On-site meteorological monitoring;
2. On-site hydro-meteorological monitoring;
3. Ambient monitoring of Total Suspended Particulate (TSP) and fine particulate matter concentrations less than 10 micrometres (μm) (PM_{10}) and less than 2.5 μm ($\text{PM}_{2.5}$);
4. Ambient monitoring of dustfall; and,
5. Passive monitoring of sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).

Since the initial AQMP design in 2007, modifications to the monitoring program have occurred at the approval of the applicable regulators and stakeholders.

The EMP focuses on the following three main components:

- Emissions estimates;
- Fuel use summary; and
- Emissions mitigation strategies, which includes the fugitive dust abatement program.

1.5 Methodology and Approach

De Beers has conducted ambient air quality and meteorological monitoring at the Mine since 1998 when the Advanced Exploration Program began. De Beers understands the need for adaptive management of



the monitoring programs and acknowledges that the monitoring sites may change as the Mine evolves. However, an effort is made to maintain consistency in the monitoring locations as this is an important consideration in conducting trend analysis.

Monitoring activities at the Mine consist of a combination of “on-site” and “off-site” monitoring; “on-site” monitoring is defined as monitoring that occurs within the active Mine area, whereas “off-site” monitoring occurs outside of the active Mine area (Figure 2-1).

The focus of the AQEMMP is monitoring to provide an indication of the ambient concentrations of air emissions to which humans, or other components of the receiving environment, may be exposed. The effectiveness of the AQEMMP is dependent, in part, on selecting appropriate criteria against which Mine emissions, the resulting ambient air concentrations, or any subsequent predictions should be compared. Currently no provision for air quality is included in permits for mines in NWT, and there is no requirement to monitor for compliance within permit limits. In lieu of air quality permit requirements, the Mine is required to comply with the relevant NWT Ambient Air Quality Standards (AAQS) for TSP, PM_{2.5} (24-hour and annual), NO₂ and SO₂ (1-hour, 24-hour and annual) (GNWT, 2014). Adjustments have been made to these requirements since 2014 and are reflected in the current monitoring program. Table 1-2 presents the relevant air quality criteria.

In addition to demonstrating that Mine emissions and ground-level concentrations are consistent with the NWT AAQS and other applicable air quality criteria provided in Table 1-2, it is De Beers’ intent to manage emissions and ground-level concentrations in keeping with the principles of “Continuous Improvement” and “Keeping Clean Areas Clean”, as described in the Canada-Wide Standards for Particulate Matter and Ozone (CCME, 2000a). These include, but are not limited to, the following:

- Selection of highly-efficient combustion equipment;
- Underground and wet primary ore crushing;
- Conveyor-based, covered ore transport systems;
- Short haul route to the North Pile;
- Investigation of alternate energy sources to offset diesel combustion;
- Incineration facilities and waste segregation policies;
- Worker education;
- On-site recycling programs; and,
- Development of management plans to guide actions and documentation needs around air quality.



Table 1-2 Relevant Ambient Air Quality Criteria

Parameter	NWT Standards ^(a)	Canada-Wide Standards ^(b)	Canadian Ambient Air Quality Standards ^(c)			Other Criteria	
			2015	2020 ^(d)	2025 ^(d)	Alberta Objectives ^(e)	British Columbia Objectives ^(f)
SO₂ (µg/m³)							
1-Hour	450	-	-	183.1	170.1	450	196
24-Hour	150	-	-	-	-	125	-
Monthly	-	-	-	-	-	30	-
Annual	30	-	-	13.1	10.5	20	13
NO₂ (µg/m³)							
1-Hour	400	-	-	112.8	79	300	188
24-Hour	200	-	-	-	-	-	-
Annual	60	-	-	32	22.6	45	60
TSP (µg/m³)							
24-Hour	120	-	-	-	-	100	120
Annual ^(d)	60	-	-	-	-	60	60
PM₁₀ (µg/m³)							
24-Hour	-	-	-	-	-	-	50
PM_{2.5} (µg/m³)							
1-Hour	-	-	-	-	-	80	-
24-Hour	28 ^(g)	30	28	27	-	29	25
Annual	10	-	10	8.8	-	-	8

Notes:

a) Source: GNWT (GNWT, 2014).

b) Source: CCME (CCME, 2000a). Replaced by Canadian Ambient Air Quality Standards.

c) Source: CCME (CCME, 2017).

d) SO₂ and NO₂ converted from ppb to µg/m³ based on an air temperature of 25 °C.

e) Source: Government of Alberta (AEP, 2019).

f) Source: Government of British Columbia (Government of British Columbia, 2020).

g) The NWT Ambient Air Quality Standards for PM_{2.5} changed from 30 µg/m³ to 28 µg/m³ in 2014.

µg/m³ = micrograms per cubic metres; SO₂ = sulphur dioxide; NO₂ = nitrogen dioxide; TSP = Total Suspended Particulate; PM₁₀ = particulate matter nominally less than or equal to 10 micrometres aerodynamic diameter; PM_{2.5} = particulate matter nominally less than or equal to 2.5 micrometres aerodynamic diameter; NWT = Northwest Territories; - = not applicable.

The AQEMMP covers the three main phases of the Mine, which are the construction and operations phase, followed by the Closure and Post-Closure phases. This report has evolved to focus on the Closure and Post-Closure phases. Results of this monitoring will be presented and discussed in the annual Air Quality and Emissions Monitoring Report (herein referred to as the 'annual report' and discussed in Section 5 of this document).



2 AIR QUALITY MONITORING PROGRAM

2.1 Introduction

The AQMP monitoring will be compared to applicable air quality criteria and predictions and will be subsequently analyzed for trends each year in the annual report. In this fashion, the AQMP will be able to provide an indication of the Mine's performance with respect to air quality.

The main components of the AQMP and the sections in which they are discussed are as follows:

- Meteorological monitoring (Section 2.2);
- Hydro-meteorological monitoring (Section 2.3);
- Particulate monitoring (Section 2.4);
- Dustfall monitoring (Section 2.5);
- Vegetation dustfall monitoring (Section 2.6);
- Passive SO₂ and NO₂ monitoring (Section 2.7); and
- Quality assurance/quality control (QA/QC) (Section 2.8).

For each of the AQMP components, the details of the monitoring station locations, methods, parameters, frequency and data analysis are presented in the following sections. Monitoring station locations for the Closure and/or Post-Closure phases are shown in Figure 2-1 below.

Figure 2-1 Air Quality and Meteorological Monitoring Stations



2.2 Meteorological Monitoring

Meteorological monitoring serves as part of the basis for interpretation of air quality data. Meteorological parameters are also used by other disciplines (e.g., hydrology) to aid in project design and the analysis of monitoring data. Meteorological monitoring is a vital input for any subsequent emissions dispersion modelling assessments that may be required during the Mine lifetime. The data plays a crucial role in the characterization of general air quality trends and specific meteorological conditions at the Mine site.

2.2.1 Monitoring Station Locations

A single meteorological station, known as Hill Station, is installed at the Mine site (Figure 2-1). It is located approximately 100 metres (m) south of the access road from the air strip to the camp, near the height of land and west of the water management pond (Universal Transverse Mercator [UTM] Zone 12 NAD83 – 506 052E, 7 052 492N). There is a secondary weather station located at the communications building that can provide back-up data if the meteorological station fails.

2.2.2 Monitoring Methods

Meteorological monitoring sensors are mounted on a 10-metre tower, consistent with current accepted practice in Canada. The station operates independently using a battery/solar panel power supply. The sensors are also equipped such that data can be retrieved remotely.

2.2.3 Monitoring Frequency

Meteorological monitoring will be conducted throughout the year during the Closure phase. Meteorological data are measured continuously and are recorded hourly. Meteorological monitoring may be discontinued for the Post-Closure phase of the Mine since the data is not needed to interpret the remaining environmental monitoring programs. Meteorological data collected regionally from Yellowknife or other nearby communities is considered sufficient to support evaluation of monitoring results and has been used in this capacity throughout the life of Mine.

A summary of the rational for changes in the meteorological monitoring is provided in Table 2-1.

Table 2-1 Meteorological Monitoring Program Change Rational

Parameter	Station	Reason for Monitoring	Program Change	Rational
Meteorological (various)	Hill Station	Provide environmental conditions at the Mine.	No change. Monitoring to continue throughout Closure as during ECM.	Meteorological stations are set up for remote monitoring, allowing for continued collection of data during periods of zero occupancy during Closure.
			No monitoring Post-Closure.	During Post-Closure, meteorological data collected regionally from Yellowknife or other nearby communities is sufficient to support evaluation of other monitoring programs. Data from Yellowknife or other nearby communities has been used throughout Mine life to support evaluation of other monitoring programs to the same or greater extent than on-site data.

2.2.4 Monitoring Parameters

The tower system continuously measures the following meteorological parameters:

- Wind speed at 10 m above the ground;
- Wind direction at 10 m above the ground;

- Temperature at 2 m above the ground;
- Relative humidity at 2 m above the ground;
- Solar radiation at 2.5 m above the ground; and,
- Rainfall at 2 m above the ground.

2.2.5 Data Analysis

Data will be analyzed regularly during Closure. A summary of the meteorological monitoring will be presented each year in the annual report. Discussion of extreme meteorological events and trends will be included as part of the annual report. Data will also be given to the Aquatic Effects Monitoring team to support site characterization and provide supporting environmental variables to assist in the interpretation of the component-specific AEMP results (De Beers, 2022b). No data is collected during the Post-Closure phase; thus, no data analysis will occur.

2.3 Hydro-Meteorological Monitoring

Hydro-meteorological monitoring is designed to measure parameters that allow for the calculation and recording of lake evaporation rates at the site and aid with the ongoing management of the site water balance. This monitoring component was introduced in the spring of 2005 to fulfill the SNP requirements outlined in the Mine Water License (Part C.1.item a through g).

The hydro-meteorological monitoring is linked to the meteorological component of the AQMP and ties in with the former Hydrology Monitoring Program (since incorporated into the Aquatic Effects Monitoring Program during Closure and Post-Closure). The station management will be administered and reported under the AQMP; however, the processed data will also be provided to the aquatic effects team for processing, storage, analysis, and reporting as required.

2.3.1 Monitoring Station Locations

The station, known as Lake Station, is installed on the south shore of the west arm of Snap Lake near the Mine fresh water intake (UTM Zone 12 NAD83 – 506 484E, 7 053 277N), as shown in Figure 2-1.

2.3.2 Monitoring Methods

Hydro-meteorological monitoring is being conducted using Campbell Scientific- supplied monitoring equipment. The measured parameters will be used to calculate evaporation. Sensors are mounted on a three-metre tripod consistent with current industry practice.

2.3.3 Monitoring Frequency

Hydro-meteorological monitoring will be conducted throughout the year during Closure (depending upon weather conditions and activity at site that may impede access). Meteorological and hydrological data will be measured continuously and will be recorded hourly. The data are downloaded weekly. Hydro-meteorological monitoring will be discontinued for the Post-Closure phase since the data is not needed to interpret the remaining environmental monitoring programs, as discussed in Section 2.2.3.

A summary of the rationale for changes in the hydro-meteorological monitoring is provided in Table 2-2.

Table 2-2 Hydro-Meteorological Monitoring Program Change Rationale

Parameters	Station	Reason for Monitoring	Program Change	Rationale
Hydro-meteorological (various)	Lake Station	Provide environmental conditions at the Mine.	No change. Monitoring to continue throughout Closure as during ECM.	Meteorological stations are set up for remote monitoring, allowing for continued collection of data during periods of zero occupancy during Closure.
			No monitoring Post-Closure.	During Post-Closure, meteorological data collected regionally from Yellowknife or other nearby communities is sufficient to support evaluation of other monitoring programs. Data from Yellowknife or other nearby communities has been used throughout Mine life to support evaluation of other monitoring programs to the same or greater extent than on-site data.

2.3.4 Monitoring Parameters

The tripod is fitted with a solar/battery power supply for the continuous monitoring of the following parameters:

- Precipitation 2 m above ground;
- Wind speed and wind direction at approximately 2.5 m above the water surface;
- Air temperature at approximately 1 and 2 m above the water surface;
- Relative humidity at approximately 1 m above the water surface;
- Water temperature at approximately 1 and 2 m below the surface;
- Solar radiation at 2.5 m above the water surface, and
- Water level.

2.3.5 Data Analysis

During Closure, the data will be given to the Aquatic Effects Monitoring team to support site characterization and provide supporting environmental variables to assist in the interpretation of the component-specific AEMP results (De Beers, 2022b). No data is collected during the Post-Closure phase; thus, no data analysis will occur.

During Closure and Post-Closure, calculation of lake evaporation and a water balance for Snap Lake using monitoring data from the hydro-meteorological station and other data on water gains/losses to the lake will no longer be completed. Throughout the operations and ECM phases, Mine-related influences on the hydrology and water level of Snap Lake have been indiscernible from natural variation. During Closure and Post-Closure, the primary sources of Mine-related influences on lake hydrology and water level, including Mine water withdrawals and treated and/or untreated water releases, are significantly reduced in magnitude compared to ECM and operations or no longer present. For these reasons, continued calculation of evaporation and the associated water balance for Snap Lake is not considered warranted during Closure or Post-Closure.

2.4 Total Suspended Particulate, PM₁₀ And PM_{2.5} Monitoring

Suspended particulate matter (dust) emissions are generated by wind erosion of local landscapes, movement of vehicles/equipment, airstrip activities, construction/demolition activities, the combustion of diesel fuel, and solid waste incineration.

Suspended particulate matter emissions are generally grouped into three size fractions. The particulate matter size fractions are as follows:

- TSP – which includes particulate matter nominally less than 100 µm;
- PM₁₀ – which includes particulate matter nominally less than 10 µm; and,
- PM_{2.5} – which includes particulate matter nominally less than 2.5 µm.

Current understanding is that those particles small enough to readily enter the lower respiratory tract (i.e., lungs and bronchi) are of the most concern. These particles are typically PM_{2.5}.

Currently, PM_{2.5}, dustfall (see Sections 2.5 and 2.6), and emissions (see Section 3) monitoring is completed to address the AQEMMP requirements outlined in Section 6.3 (Item e) (ii & iii) and Section 7.2 (Item a) of the Environmental Agreement for the Mine:

6.3 (e) DBCMI shall prepare and provide to the Parties and the Monitoring Agency an Air Quality and Emissions Management annual report summarizing and analyzing the emissions and ambient monitoring information, including:

- i. Comparisons of ambient air quality and deposition monitoring results to previous years, the predictions of the Environmental Assessment Report dispersion modeling and all applicable federal and territorial ambient air quality criteria, standards, objectives and guidelines.*
- ii. Analysis of emissions and ambient air quality trends and effectiveness of strategies employed to minimized emissions.*

7.2 (a) The Air Quality Monitoring Program shall include but not be limited to:

- iii. Monitoring total suspended particulate (TSP), PM₁₀ and PM_{2.5};*
- iv. Monitoring of fugitive dust to determine the effects of dust deposition on the surrounding environment;*

- v. *Documentation of quality assurance and quality control (QA/QC) procedures used to ensure valid data collection; and*
- vi. *Contingency plans to respond to increasing trends or exceedances of air quality criteria/dispersion modelling predictions.*

The PM₁₀ monitoring was discontinued in July 2014, when the Dichot Partisols at the airstrip and explosives emulsion plant sites were decommissioned as part of a technical memorandum petitioning the replacement of the ageing Dichot Partisol samplers (Golder, 2012). In November 2014, the equipment was replaced with 5030 SHARP PM_{2.5} monitors. The SHARP monitors continuously and exclusively record PM_{2.5}. TSP monitoring was continued until the end of 2015 when, due to ongoing technical problems, it was decommissioned as well. Monitoring of TSP and PM₁₀ will remain discontinued, as site activities during Closure and Post-Closure will be substantially reduced compared to operations (Table 1-1). PM_{2.5} monitoring will continue to fulfill regulatory requirements given that it is the particulate of most concern and thus will satisfy the primary particulate monitoring purpose of providing an indicator of human health effects during periods of occupation.

At the approval of the GNWT in 2017, the following adjustments to the monitoring for PM_{2.5} were implemented as per ARKTIS (2017):

- SHARP Monitor located near the airstrip (PM001) was discontinued in 2020.
- SHARP Monitor located near the emulsion plant (PM002) was relocated to near the communications building in September 2018.

Monitoring locations were reduced and moved to account for a reduction in personnel presence at the Mine following the conclusion of operations.

Additional changes to the monitoring of PM_{2.5} for the Closure and Post-Closure are presented herein.

2.4.1 Monitoring Station Locations

Previous on-site monitoring locations were selected during early construction to provide a conservative management approach to monitoring ambient particulate concentrations. These locations were selected based on areas of maximum particulate predictions produced by the dispersion modelling assessment (De Beers, 2002). The demonstration of compliance with ambient air quality benchmarks at these locations could be extrapolated to represent compliance at off-site locales. In 2015, the last of these stations was decommissioned when the on-site TSP Partisol was removed.

The previous off-site monitoring locations, located directly adjacent to the facility boundary by the airstrip and explosives emulsion plant, were selected because they provided a representative estimate of particulate concentrations away from high intensity mining activities. These locations were identified as areas of potentially higher off-site particulate concentrations by dispersion modelling predictions. The availability of electrical power was also a key consideration for these locations.

In 2018, the off-site particulate monitoring station at the emulsion plant was relocated to an on-site location near the communications building. This location was selected because of its proximity to the power generators, considered to be the primary sources of PM_{2.5} generation until the Post-Closure phase. This is

also the only location where continuous power can be provided to the SHARP monitor to enable ongoing monitoring during Closure. The remaining off-site SHARP monitor at the airstrip location was decommissioned prior to Closure. Based on predictive modelling for ECM (ARKTIS, 2018a), the former and current PM_{2.5} SHARP monitoring locations are positioned within areas representative of the overall elevated particulate concentrations at the Mine. The locations of the former PM_{2.5} stations were representative of the local study area. This is also the case for the current SHARP monitoring location (near the communications building adjacent to power generation and within areas subject to reclamation activities including revegetation). The location for the single remaining monitoring station for the ambient particulate monitoring program is shown in Figure 2-1.

No exceedances of the NWT standard were predicted at the 1-hour, 24-hour or annual timeframes at the new monitoring location (ARKTIS, 2018a). Nor were exceedances predicted at the 1-hour or annual timeframe within the remainder of the local study area. The only predicted exceedances of the NWT standard for 24-hour maximum PM_{2.5} concentration are localized to an isolated area within the vicinity of the quarry. In the past ten years of PM_{2.5} monitoring at the Mine (inclusive of operation and ECM phases), the annual average concentrations remained below the ambient air quality criteria and no triggered management actions occurred. With reduced activity during Closure compared to operations (Table 1-1), a single on-site station is considered sufficient to address human health considerations. During Post-Closure, the source of PM_{2.5} emissions will be reduced significantly compared to operations and Closure. Should applicable PM_{2.5} action level triggers be exceeded during the Closure phase, the associated action level responses will be implemented (Section 4). Monitoring will cease in Post-Closure, unless deemed necessary per the adaptive management framework for PM_{2.5}.

2.4.2 Monitoring Methods

The 5030 SHARP is a continuous monitor capable of providing real-time measurements. It operates on the principles of aerosol light scattering (nephelometer) and beta attenuation to measure ambient particulate matter concentrations. When a particle enters the instrument, it scatters light which is emitted by a beam. The amount of light which is scattered is dependent on the size of the particle. The particle is then deposited onto a glass fibre filter tape, which accumulates mass up to a threshold value. When this value is reached, the tape is advanced so that sampling can be done on a clean portion of the tape. The mass of the sample is then derived from the beta radiation. The instrument concurrently measures the volume of the sample, thus allowing calculation of the ambient concentration.

2.4.3 Monitoring Frequency

PM_{2.5} monitoring using the 5030 SHARP began in November 2014 and occurs continuously, providing a daily average measurement of PM_{2.5} concentration.

The SHARP monitor will not operate if Mine site personnel are absent – potentially between the months of October and March - throughout Closure. With reduced operations, the air dispersion modelling predicted zero exceedances of ambient air quality criteria during the winter (ARKTIS, 2018a), thus not operating the SHARP monitor during potential shut-down periods and site vacancy over the winter months was considered an appropriate response. This is also supported by historical monitoring data from operations and ECM phases, with annual average concentrations remaining below the ambient air quality criteria and no

triggered management actions. Furthermore, the instrumentation requires a continuous power source, which will not be available when the site is shut down. The monitor will operate for the remainder of the year – approximately between the months of April and September – as well as during winter if site personnel are present, and data will be downloaded bi-weekly.

PM_{2.5} monitoring will be discontinued for the Post-Closure phase if the applicable ambient air quality criteria is achieved during Closure. Otherwise, monitoring will continue into Post-Closure until criteria are met. In Post-Closure, the primary sources of PM_{2.5} will no longer be active at the Mine or will be reduced substantially in magnitude. Further, reclamation activities, such as placement of a rock cover at the North Pile, and promoting revegetation on disturbed areas, will mitigate PM_{2.5} generation during the Post-Closure phase. This reduction in PM_{2.5} is reflected in the air dispersion modelling which predicted no exceedances to ambient air quality criteria Post-Closure (ARKTIS, 2018b). Furthermore, as discussed previously, the past ten years of PM_{2.5} monitoring at the Mine (inclusive of operation and ECM phases) had annual average concentrations below the ambient air quality criteria and no triggered management actions. Thus, concern for the Post-Closure phase is low when the on-site presence is limited to short durations associated with monitoring and maintenance, activities which do not warrant monitoring of PM_{2.5}. Lastly, the SHARP monitor requires a constant power source which will not be available Post-Closure.

A summary of the rational for changes in the suspended particulate matter monitoring is provided in Table 2-3.

Table 2-3 Suspended Particulate Matter Monitoring Program Change Rational

Parameter	Station	Reason for Monitoring	Program Change	Rational
TSP	Three stations (Airstrip, Emulsion Plant and Tankfarm)	Indicate suspended particulate matter (dust) emissions from various Mine sources.	Decommissioned in operations phase	PM _{2.5} measurements address health considerations (Golder, 2012). Emission sources are no longer present or significantly reduced during Closure and Post-Closure.
PM ₁₀	Two stations (Airstrip and Emulsion Plant)	There is evidence linking inhalable particles (PM ₁₀) to health concerns.	Decommissioned in operations phase	PM _{2.5} measurements address health considerations (Golder, 2012). Emission sources are no longer present or significantly reduced during Closure and Post-Closure.
PM _{2.5}	Two stations (Airstrip and Emulsion Plant)	Scientific studies have indicated that there are health effects associated with PM _{2.5} .	No monitoring during periods of zero occupancy during Closure phase.	Emission sources are reduced to wind erosion only during zero occupancy. No predicted exceedances of ambient air quality criteria

Parameter	Station	Reason for Monitoring	Program Change	Rational
				<p>during the winter (ARKTIS, 2018a).</p> <p>Annual average concentrations have been below air quality criteria throughout life of Mine.</p> <p>No power availability during zero occupancy.</p>
			Reduced to one station during Closure phase.	<p>No predicted exceedances of ambient air quality criteria during ECM except at localized, non-representative areas (ARKTIS, 2018a).</p> <p>Annual average concentrations have been below air quality criteria throughout life of Mine.</p> <p>Emission sources are significantly reduced during Closure.</p>
			Station relocated to communications building.	<p>Communications building is a representative location within the local study area based on air dispersion modelling (ARKTIS, 2018a).</p> <p>Proximity to primary source of PM_{2.5} (power generators) and within areas subject to reclamation during Closure.</p> <p>Only location with continuous power availability.</p>
			No monitoring Post-Closure	<p>Annual average concentrations have been below air quality criteria throughout life of Mine.</p> <p>No predicted exceedances of ambient air quality criteria during Post-Closure (ARKTIS, 2018b).</p> <p>Emission sources are no longer present or significantly reduced during Post-Closure.</p>

Parameter	Station	Reason for Monitoring	Program Change	Rational
				<p>No power availability during Post-Closure.</p> <p>Monitoring will continue if necessary until applicable air quality criteria are achieved.</p>

2.4.4 Monitoring Parameters

The 5030 SHARP monitor will provide daily average measurements of ambient PM_{2.5} concentrations.

2.4.5 Data Analysis

Particulate matter data will be analyzed to identify potential air quality concerns, including, increasing trends or measured concentrations above the 2007 Air Modelling Update (Golder, 2007) for the Closure phase, and subsequent predictions and applicable ambient air benchmarks. During the Post-Closure phase, PM_{2.5} monitoring will be discontinued.

Analysis of temporal trends and comparison to applicable ambient air criteria helps to identify consistent patterns in the measured particulate concentrations on an annual basis. The response planning and action levels to deal with increasing trends are described in Section 4. Managing these trends annually is appropriate given the scale of the Mine and the long-term nature of the monitoring program.

2.5 Dustfall Monitoring

The main dust generation processes at the Mine will be wind erosion of fugitive sources, rock crushing, deposited kimberlite and movement of vehicles/equipment on-site. When the particles are large enough they can settle from the air onto vegetation or water bodies. The Dustfall Monitoring Program, required under Section 7.2 a) of the Environmental Agreement, measures the quantities of dust deposited near the Mine.

2.5.1 Monitoring Station Locations

The locations of the Closure and Post-Closure phase dustfall monitoring stations are shown in Figure 2-1 as well as Figure 2-3. A total of seven dustfall stations were in operation during active mining in response to concerns raised regarding dust emissions from the North Pile (rock crushing and construction) including two on-site stations:

- North of the tankfarm (DF008), and
- West of the tankfarm (DF009)

and five off-site locations:

- West end of Snap Lake (DF006)

-
- North shore of Snap Lake (DF007)
 - South of the airstrip (DF011)
 - South of the airstrip (DF013), and
 - South of the bulk emulsion plant (DF012)

The on-site locations were selected to be in and around the active mine area near future dust generating activities. Off-site locations were selected to be outside the active mine area but inside the zone of influence of Mine activities (the possible sphere of Mine effects) so as to help assess effects on surrounding soils and vegetation. One exception is station DF006 on the west end of Snap Lake, which is beyond the anticipated zone of influence and used as a reference location. Access constraints at DF006 and DF007 stations have made it difficult for site personnel to collect samples and will only be monitored if safe to do so.

The sample locations used during mine operation and ECM will continue to be used during Closure and Post-Closure, since they are already established and have historical data that may be of use to inform future results. Stations DF008 and DF009 are located within the tankfarm area, which is subject to reclamation. The locations for these stations will be adjusted during Closure to be outside the reclamation area, but maintained within the general vicinity of the tankfarm. Each station is proposed to be shifted further west onto areas that are not expected to be disturbed during Closure, as shown in Figure 2-2.

In the course of regular environmental inspections when personnel are present at site, any locations with notable dust accumulation will be identified and flagged for continued observation and potential mitigation action such as watering of roads during periods of occupancy. The visual assessments are intended to identify the presence of dustfall on vegetation growing at or near the Mine, and notable observations of dustfall (i.e., clearly visible dusting on vegetation) will be recorded along with photographs of the impacted vegetation. Visual dust observations provide an action level for additional adaptive management, mitigation measures and/or triggered monitoring programs as discussed in Section 4.

Figure 2-2 Proposed Monitoring Locations for Dustfall and Passive Gas Stations DF008/PS008 and DF009/PS009



2.5.2 Monitoring Methods

Dustfall data are collected in open vessels containing a purified liquid matrix. Particles are deposited and retained in the vessel, which is then sent to a laboratory where total and fixed dustfall are quantified. Total dustfall includes everything that falls into the collection vessel, and fixed dustfall is the non-combustible subset. The dustfall program is a complement to the particulate monitoring program.

Dustfall canisters will be used to collect ambient dustfall for analysis of deposition rates of dust. Dustfall collection is a passive monitoring program that provides a measure of particulates that would be directly deposited onto vegetation, soil and water in the vicinity of the Mine.

Visual dust observations will be conducted during routine site inspections when personnel are present at site. Notable dust accumulation on vegetation (i.e., visible dusting on vegetation observed with the unaided eye) will be identified and recorded during site inspections and photographs will be taken of the impacted vegetation. Areas with notable dust accumulation will be flagged for continued observation and potential mitigation. The results of the visual dustfall observations, photographs, and any mitigation measures (e.g., watering of roads) taken will be reported in the annual report (Section 5).

2.5.3 Monitoring Frequency

Dustfall canisters are exposed in the field for a period of 30 days to allow for a sufficient sample size for analysis. During Closure, dustfall monitoring will only occur in the snow-free season (4 months between May and September). During winter months the site will be snow covered which limits dust generation. In addition, there have been no Mine-related on or off-site exceedances of the action levels for dustfall including years when mine activities were greater in type and magnitude, including construction and

operations. The only recorded exceedance in 2005 occurred off-site on the western extent of Snap Lake (well outside the potential zone of influence). It is not known why dustfall levels were elevated at this site and all other monitoring stations remained within action levels. For these reasons, the activities during the winter Closure period are not expected to exceed the action levels set out in Section 4 and monitoring only during the snow-free season was considered appropriate. If dustfall levels are consistently less than or greater than applicable ambient air standards during Closure, or are static, the frequency of monitoring may be adjusted.

Following the end of the Closure phase, the primary sources of dustfall will not be present, or will be reduced in magnitude significantly (Table 1-1). As noted above, over the past ten years, dustfall monitoring at the Mine had concentrations below adopted action levels. Since the Post-Closure dustfall sources are less than during operations, and the Post-Closure surfaces are less susceptible to wind erosion compared to operations, it is not anticipated that dustfall concentrations will be exceeded. Therefore, the Dustfall Monitoring Program will be reduced to 2 months of the snow-free season (July and August) and will continue until the applicable closure criteria outlined in the FCRP have been achieved for three consecutive years during Post-Closure, which is considered sufficient to demonstrate the closure landforms are stable against the dust effects. Confirmatory sampling for 2 months of the year will also be completed once between year 3 to year 5 of Post-Closure. If confirmed that no Mine-related impacts remain or are of negligible risk, and the applicable closure criteria outlined in the FCRP have been achieved, the program will be terminated.

Dustfall monitoring will also be performed across the site via visual observations that will be performed as part of routine site inspections when personnel are present at site.

A summary of the rationale for changes in the dustfall monitoring is provided in Table 2-4.

Table 2-4 Dustfall Monitoring Program Change Rationale

Parameter	Station	Reason for Monitoring	Program Change	Rationale
Dustfall	Seven stations (5 off-site, 2 on-site)	To evaluate the effects of dust deposition on the surrounding vegetation.	No monitoring during winter months.	Primary sources of dustfall are generally snow covered which limits dust generation. No Mine-related exceedances of adopted action levels have occurred throughout life of Mine. Emission sources are reduced during Closure.
			Reduced to 2 months annual monitoring during Post-Closure phase.	No Mine-related exceedances of adopted action levels have occurred throughout life of Mine. Emission sources are no longer present or significantly reduced during Post-Closure.

Parameter	Station	Reason for Monitoring	Program Change	Rational
				Duration of people at the mine site Post-Closure will be temporary (i.e., less than 1 week in duration in a season).
			Terminate Post-Closure monitoring once 3 consecutive years of closure criteria are achieved and confirmed again in year 3 to year 5 of Post-Closure	No Mine-related exceedances of adopted action levels have occurred throughout life of Mine. Emission sources are no longer present or significantly reduced during Post-Closure.

2.5.4 Monitoring Parameters

The dustfall samples will be analyzed for the total and fixed dustfall collected over the sampling period. Ambient dustfall nominally includes particles large enough to settle out of the air column.

2.5.5 Data Analysis

The dustfall rates measured at the seven dustfall stations will be analyzed for indications of air quality concerns (e.g., increasing trends or measured concentrations above the applicable ambient air standards) as well as spatial and temporal trends. The conclusions of this analysis will be presented each year in the annual report and will be used to update and modify the Mine’s operational dust management procedures as required. Notable visual observations of dustfall and photographs will also be included in the annual report, along with any mitigation measures and adaptive management that may have been implemented in response or is considered warranted for potential future implementation.

As there is no NWT dustfall guideline, during Closure the on-site dustfall readings will be compared to the Alberta industrial guideline of 158 milligrams per square decimetre per 30 days (mg/dm²/30d; AEP, 2019). The off-site data will be compared to the more restrictive Alberta recreational guideline of 53 mg/dm²/30d (AEP, 2019). During the Post-Closure phase, both on-site and off-site dustfall data will be compared to the recreational guideline (53 mg/dm²/30d), as recreational land use better reflects the future land use of the Mine in Post-Closure, compared to industrial land use.

Analysis of spatial dustfall trends will include comparisons between the dustfall stations. Unusual differences may trigger investigation and examination of mitigation measures.

The analysis will also monitor for consistently increasing trends in the measured dustfall rates on an annual basis. The response planning and action levels for increasing trends are described in Section 4.

Action levels for dustfall include exceeding the Alberta Ambient Air Quality Objective (AEP, 2019) for dustfall over a three-month period, and/or if visual observations in the course of daily operations indicate that

dusting of vegetation has become a persistent and significant problem. In the event that three months of dustfall data is not obtained in a single year, the dustfall measured over the reduced time period, over a single year, will be used in the evaluation.

A dustfall “trigger” may produce a response that would include enhanced dust suppression such as some of the operational mitigations described in the Fugitive Dust Abatement Program (Section 3.4). Additional triggered monitoring programs may also be initiated (see Section 4). If studies show evidence that dustfall is the cause of significant changes in vegetation community or active layer characteristics, then the appropriate changes during Closure and/or Post-Closure would be applied.

2.6 Vegetation Dustfall Monitoring

Dust accumulation on vegetation is considered to be the main potential effect on vegetation around the Mine site; thus, it was determined in 2013 that the Vegetation Monitoring Program (VMP) should be adjusted to provide a means of comparing dustfall volume and chemistry with vegetation community effects (De Beers, 2023b). As a result, the Vegetation Dustfall Monitoring Program was developed. In an effort to consolidate the various dustfall monitoring programs at site into a single document for ease of understanding, the dustfall component of the VMP’s Vegetation Dustfall Monitoring Program has been integrated into the AQEMMP. The vegetation and soil monitoring components of the Vegetation Dustfall Monitoring Program remain within the VMP.

2.6.1 Monitoring Station Locations

A transect consisting of nine dustfall stations and associated vegetation sampling areas was established and sampled in 2013. The locations of the vegetation dustfall monitoring stations are shown in Figure 2-1 as well as Figure 2-3. Based on prevailing winds, sample plots were established starting from the edge of the Mine site and oriented in a west-west-northwest direction extending to a distance of 20 km from the Mine. The station nearest the Mine (DVD105) is considered an on-site station, all others are considered off-site locations. The station located at 20 km from the Mine (DVD113) is considered to be the reference plot because this location is expected to be outside of the predicted extent of dust deposition from the Mine.

2.6.2 Monitoring Methods

Dustfall canisters will be used to collect ambient dustfall for analysis of deposition rates of dust. Dustfall collection is a passive monitoring program that provides a measure of particulates that would be directly deposited onto vegetation, soil, and water in the vicinity of the Mine. Dustfall data are collected by using open vessels containing a purified liquid matrix. Particles are deposited and retained in the vessel, which is then sent to a laboratory where total and fixed dustfall, as well as metals content, are quantified. Total dustfall is everything that falls into the collection vessel, and fixed dustfall is the non-combustible subset. Dustfall canisters are exposed in the field for a period of 30 days to allow for a sufficient sample size for analysis. Samples are collected and analyzed monthly for the period of July to October to provide 3 months of data.

2.6.3 Monitoring Frequency

Vegetation dustfall stations were first assessed in 2013 and then again in 2018.

During Closure, dustfall will be monitored per the Dustfall Monitoring Program at the stations described in Section 2.5. Additional dustfall monitoring during Closure through the Vegetation Dustfall Monitoring Program, which primarily consists of off-site stations, is not considered necessary since there have been no Mine-related off-site exceedances of the action levels for this program including years when mine activities were greater in type and magnitude.

The vegetation dustfall stations will only be assessed once more after all earthworks have been completed for Closure to evaluate the potential impacts of dust on vegetation that was generated from reclamation activities. Samples will be collected and analyzed monthly for the period of July to October to provide 3 months of dustfall data. If confirmed that no Mine-related impacts remain or are of negligible risk, and the applicable closure criteria have been achieved, the program will be terminated. During Post-Closure, vegetation dustfall monitoring will only occur if closure criteria are not met following completion of reclamation activities.

A summary of the rationale for changes in the vegetation dustfall monitoring is provided in Table 2-5.

Table 2-5 Vegetation Dustfall Monitoring Program Change Rational

Parameter	Station	Reason for Monitoring	Program Change	Rational
Vegetation Dustfall	Nine stations along 20 km transect	To evaluate the effects of dust deposition on the surrounding vegetation.	One confirmatory sampling program will be done on the vegetation dustfall plots after earthworks are completed to evaluate the potential impacts of dust on vegetation that was generated from reclamation activities.	Sampling will occur after earthworks are completed in order to capture peak dust accumulation associated with closure activities.
			Post-Closure sampling will only occur if closure criteria are not met following completion of reclamation activities.	No Mine-related exceedances of adopted action levels have occurred throughout life of Mine. Emission sources are no longer present or significantly reduced during Post-Closure. Monitoring will continue if necessary until closure criteria are achieved, as there will no

Parameter	Station	Reason for Monitoring	Program Change	Rational
				longer be any dust generating activities on site.

2.6.4 Monitoring Parameters

Dustfall stations are set up to sample fixed and total dustfall, as well as the metals content of the dust.

Additional vegetation and soil monitoring parameters are also collected from sample plots adjacent to each dustfall station to help assess if dustfall is affecting vegetation, and are described in further detail within the Mine’s VMP (De Beers, 2023b).

2.6.5 Data Analysis

The dustfall rates measured at the nine vegetation dustfall stations will be analyzed for indications of air quality concerns (e.g., increasing trends or measured concentrations above the applicable ambient air standards), as well as spatial and temporal trends. Analysis of spatial dustfall trends will include comparisons among the various dustfall stations at different distances from the Mine to identify where the zone of influence (ZOI) actually lies. The conclusions of this analysis when it is completed in Post-Closure will be presented in a final AQEMMP report and will be used to update and modify the dust management procedures as required.

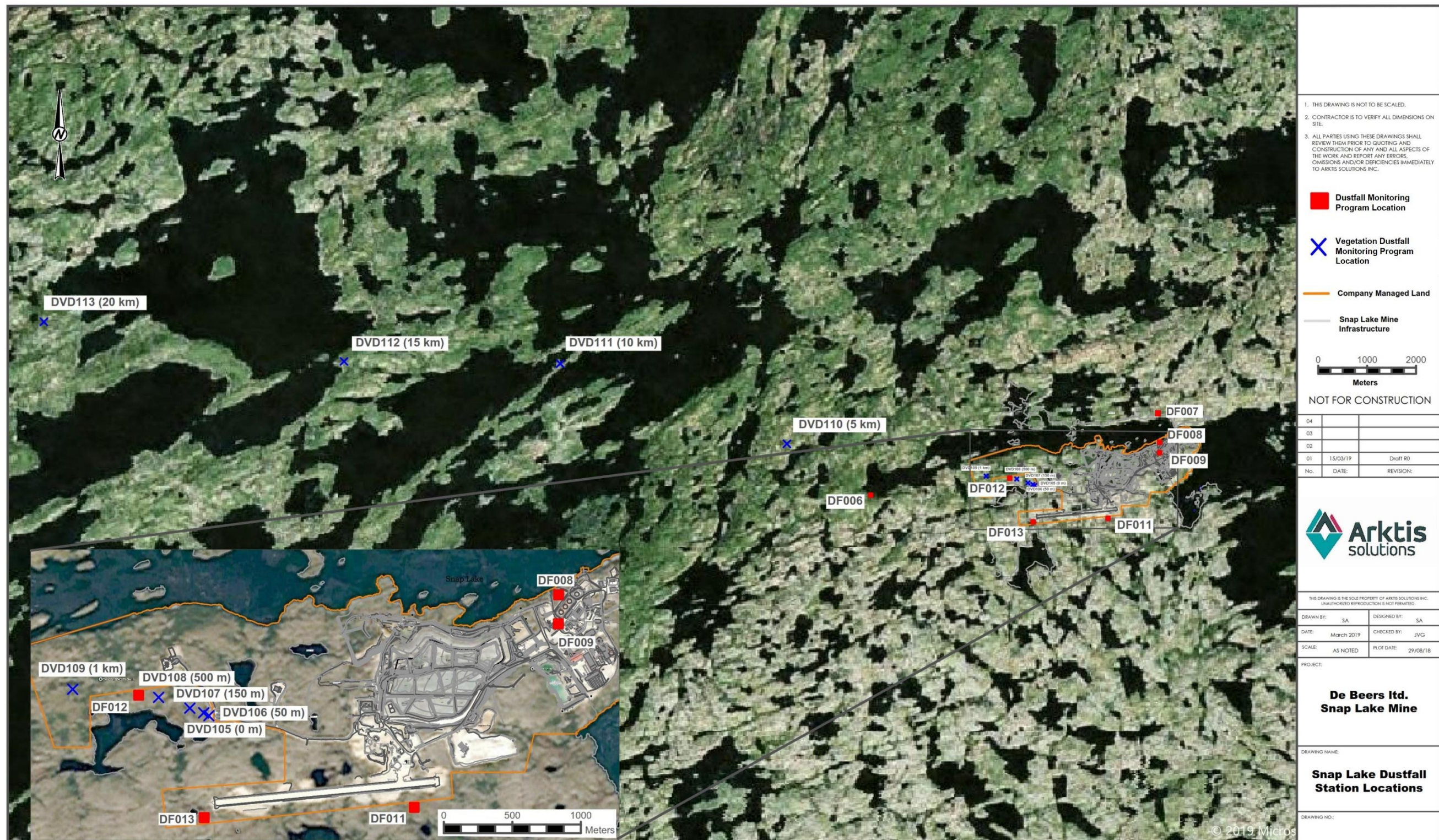
As there is no NWT dustfall guideline, the on-site and off-site dustfall readings will be compared to the more restrictive Alberta recreational guideline of 53 mg/dm²/30d (AEP, 2019), as recreational land use better reflects the future land use of the Mine in Post-Closure, compared to industrial land use.

Dustfall volume and chemistry will be compared with vegetation and soil data within the Mine’s VMP (De Beers, 2023b), including a comparison of individual parameters, such as species diversity and cover, and metal and PAH concentrations in soil, between plots to determine if dustfall is affecting vegetation community composition, abundance, and vigour in the area surrounding the Mine. Unusual differences may trigger investigation and examination of mitigation measures.

The action level (critical effect size) for determining a difference between plots would be two standard deviations from the mean. If this action level is exceeded, follow-up studies would be conducted to gather a weight of evidence for examination of cause/effect relationships between the vegetation response and alternative causes (natural factors versus dustfall).

A dustfall “trigger” may produce a response that would include enhanced dust suppression such as some of the operational mitigations described in the Fugitive Dust Abatement Program (Section 3.4). Additional triggered monitoring programs may also be initiated (see Section 4). If studies show evidence that dustfall is the cause of significant changes in vegetation community or active layer characteristics, then the appropriate changes during Closure and/or Post-Closure would be applied.

Figure 2-3 Vegetation Dustfall Monitoring Locations



2.7 Passive Monitoring of SO₂ and NO₂

The main sources of SO₂ and NO₂ emissions from the Mine will be the generators for electricity, vehicles/equipment, and the incinerators. Passive monitoring of SO₂ and NO₂ compounds was previously conducted to demonstrate compliance with the NWT standards (GNWT, 2014) and National Ambient Air Quality Objectives (NAAQOs) (Environment and Climate Change Canada, 2011). However, no exceedances of ambient air benchmarks have occurred throughout the Mine’s monitoring history and they have remained well below adopted action levels including during mine construction and operations. Additionally, predictive modelling for ECM (ARKTIS, 2018a) indicated no exceedances of ambient air benchmarks, with only one exception for annual maximum NO₂ concentrations. However, the exceedance occurs within localized areas (i.e., immediately adjacent emission sources) and is limited in duration and not considered reflective of conditions across site. For these reasons, passive monitoring of SO₂ and NO₂ during the Closure phase will be discontinued.

During Post-Closure, there are no sources of SO₂ and NO₂ emissions except during brief periods of monitoring and maintenance (Table 1-1). However, emissions from these activities will be negligible compared to anything during operations, ECM or Closure and do not warrant continued monitoring. Thus, SO₂ and NO₂ monitoring will not occur Post-Closure.

A summary of the rationale for changes in the passive gas monitoring is provided in Table 2-6.

Table 2-6 Passive SO₂ and NO₂ Monitoring Program Change Rationale

Parameter	Station	Reason for Monitoring	Program Change	Rationale
SO ₂ and NO ₂	Seven stations (5 off-site, 2 on-site)	To demonstrate compliance with the NWT standards (GNWT, 2014) and NAAQOs (Environment and Climate Change Canada, 2011).	Discontinued during Closure and Post-Closure	<p>No exceedances of ambient air benchmarks have occurred throughout life of Mine.</p> <p>No predicted exceedances of ambient air benchmarks during ECM except at localized, non-representative areas (ARKTIS, 2018a).</p> <p>Emission sources are reduced during Closure.</p> <p>Emission sources are no longer present or significantly reduced during Post-Closure.</p>

2.8 Quality Assurance/Quality Control Procedures

Quality Assurance (QA) refers to plans or programs that encompass a wide range of internal and external management and technical practices designed to ensure the collection of data of known quality that matches the intended use of the data. Quality Control (QC) is a specific aspect of QA that refers to the

internal techniques used to measure and assess data quality (American Public Health Association et al., 1989). Given that QC procedures implemented as part of the AQMP are variable and program-specific, the procedures have been summarized in this section on a program component basis. De Beers has a Quality Assurance and Quality Control (QA/QC) Plan (De Beers, 2019b) and applicable procedures will be followed for the AQMP.

2.8.1 Meteorological and Hydro-Meteorological Monitoring

QA/QC procedures for the meteorological and hydro-meteorological monitoring program include the following:

- Data are to be downloaded from the station weekly and manually surveyed by qualified personnel for anomalous data that may indicate problems with the system.
- Sensors will be calibrated on a schedule consistent with each sensor's requirements (generally every 24 months).
- When personnel are at site, the station will be attended weekly as well as following snowfalls (as weather conditions permit) to ensure that sensors and solar panels are free of debris, frost, snow or damage that may prevent accurate measurement of meteorological data. A checklist has been developed that allows a comprehensive approach to determining the fitness of the station.
- Data will be downloaded consistent with detailed written operating instructions from qualified personnel.
- The desiccants at the stations are to be changed monthly and a visual inspection performed.
- Before freeze-up, 1 jug (4 L) of Rain Gauge solution (a mix of methyl alcohol and propylene glycol) is to be poured into the Rain Gauge (Pluviometer) at the Weather Station on the Hill. Afterwards, 50 mL of Voltesso 35 base oil is added to protect the gauge from the elements.

Should meteorological monitoring continue during the Post-Closure phase the same QA/QC procedures will be used as during Closure until the meteorological monitoring is discontinued

2.8.2 PM_{2.5} Monitoring

QA/QC procedures for the particulate monitoring program include the following:

- Data are to be downloaded from the station bi-weekly and manually surveyed by qualified personnel for anomalous data that may indicate problems with the system.
- SHARP Monitors will be calibrated and maintained according to the manufacturer specifications.
- When personnel are at site, the station will be attended weekly (as weather conditions permit) to ensure that sensors are free of debris, frost or damage that may prevent accurate measurement of PM_{2.5} data. Spot data readings will also be collected to validate the daily average PM_{2.5} data. A checklist has been developed that allows a comprehensive approach to determining the fitness of the station.
- Data will be downloaded consistent with detailed written operating instructions from qualified personnel.

- For the instruments to not freeze, small space heaters are to be plugged in when the weather gets cold. If the site closes for the winter season with no available power source, the station is to be unplugged and wrapped with Desiccant. Should power remain available over the winter, the station stays plugged in and heated all winter, even during times of no occupancy.

During the Post-Closure phase of the Mine, there are no QA/QC procedures as PM_{2.5} monitoring will be discontinued.

2.8.3 Dustfall Monitoring

QA/QC procedures for the Dustfall Monitoring Program and Vegetation Dustfall Monitoring Program include the following:

- Travel blanks (laboratory prepared samples that travel with the samples that have not been exposed to the atmosphere) will be used.
- An accredited laboratory will be used for pre-sample preparation and analysis
- Samples will be collected consistent with detailed written operating instructions from qualified personnel.
- Qualified personnel will calculate ambient dustfall deposition rates based on laboratory results.
- Sample cannisters for the Dustfall Monitoring Program are to use a purified liquid copper sulfate solution to prevent fungal growth that could impact results.
- Sample cannisters for the Vegetation Dustfall Monitoring Program are to use an isopropanol solution to prevent freezing as well as permit metals analysis of the dust.

During the Post-Closure phase, the same QA/QC procedures will be used as during Closure until the dustfall monitoring is discontinued when applicable closure criteria have been achieved.

3 EMISSIONS MONITORING PROGRAM

3.1 Introduction

The EMP will be used to coordinate the monitoring of Mine emissions during Closure. Emissions calculated for these phases will be compared to the 2007 operations model (Golder, 2007) emission estimates, or any subsequent predictions to evaluate the Mine emissions performance. This process will be done on an annual basis during the Closure phase and will be summarized in the annual report. If the results of the EMP and AQMP suggest that further mitigation is necessary, then this will be incorporated into the emissions mitigation strategies, which includes the fugitive dust abatement program. Annual emission monitoring and management will be conducted during Closure phase until no longer required by the regulatory reporting thresholds of the federal National Pollutant Release Inventory (NPRI) and Greenhouse Gas (GHG) Reporting Programs. De Beers will communicate to Environment and Natural Resources (ENR) within the annual report when the decision is made to end emissions monitoring and management.

The three main components of the EMP, and the sections in which they are discussed, are as follows:

- Emission estimates (Section 3.2);
- Fuel use summary (Section 3.3); and,
- Emission mitigation strategies, which include the dust abatement program (Section 3.4).

There is no monitoring of Mine emissions during the Post-Closure phase.

3.2 Emission Estimates

This section presents the approaches that will be used in the annual report to provide a summary of Mine emissions. This section identifies the various types of emissions from the Mine, as described in Section 3.2.1.1, and provides examples of approaches for calculating these emissions, as described in Section 3.2.2. The calculated emissions will be compared to those in the 2007 operations model (Golder, 2007) or any subsequent predictions, to evaluate Mine emissions performance during the Closure phase.

The emissions estimate component of the EMP has the following objectives:

1. To demonstrate De Beers' commitment to ongoing monitoring of emissions at the Mine;
2. To provide an overview of the appropriate methodology for calculating emissions from the Mine;
3. To show that Mine emissions do not exceed those modelled in the Air Modelling Update and subsequent predictions
4. To demonstrate De Beers' commitment to ongoing minimization of emissions.

3.2.1 Types of Emissions

3.2.1.1 Combustion Emissions

Combustion is the process of burning fuels of various types and using the energy released to produce electricity, provide heat or facilitate on-site transportation and incineration. There are three primary combustion sources during Closure:

- Power generators;
- Surface fleet; and,
- Incinerators

During the Post-Closure phase, there are limited sources of primary combustion present at the Mine. Combustion sources will only be present during execution of short-term monitoring programs.

Compounds such as SO₂, oxides of nitrogen (NO_x), particulates and greenhouse gases (GHGs) are common combustion by-products. These by-products are the subject of regulatory guidance which limits the release amounts of the compounds to protect the receiving environment. De Beers has committed to meet the relevant NWT standards, NAAQO, Canadian Ambient Air Quality Standards, Canada-Wide standards or other criteria that apply to these compounds. The applicable criteria are provided in Table 3-1.

Table 3-1 Air Quality Criteria

Air Quality Parameter	Hourly [$\mu\text{g}/\text{m}^3$] ^(a)	24-Hour [$\mu\text{g}/\text{m}^3$]	Annual [$\mu\text{g}/\text{m}^3$]
SO ₂ (GNWT) ^(b)	450	150	30
NO ₂ (GNWT) ^(b)	400	200	60
TSP (GNWT) ^(b)	120	–	60
PM ₁₀ (Newfoundland and British Columbia) ^(c)	–	50	–
PM _{2.5} (GNWT) ^(b)	–	28	10

(a) $\mu\text{g}/\text{m}^3$ =micrograms per cubic metre.

(b) (GNWT, 2014).

(c) British Columbia and Newfoundland have a 24-hour objective of 50 $\mu\text{g}/\text{m}^3$ (Government of British Columbia, 2020, Government of Newfoundland and Labrador, 2004)

In addition to the ambient air quality criteria for common combustion compounds (i.e., SO₂, NO_x, and suspended particulates), there also exist Canada-Wide Standards for other combustion by-products, such as dioxins, furans, and mercury that may be released during on-site waste incineration (CCME, 2001). A summary of the Canada-Wide Standards for dioxins, furans and mercury is presented in Table 3-2. These standards apply to municipal waste incineration at new facilities such as the Mine. The achievement of these Canada-Wide Standards requires that the best available control techniques, such as a waste diversion program, be used.

Table 3-2 Canada-Wide Standards for Municipal Waste Incineration Emissions

Municipal Waste Incineration Compound	Emission Limit
Dioxins and Furans ^(a)	80 picograms of International Toxic Equivalents per cubic metre
Mercury ^(b)	20 micrograms per cubic metre ($\mu\text{g}/\text{m}^3$)

(a) (CCME, 2001).

(b) (CCME, 2000b).

By calculating and reporting annual combustion emissions, De Beers can assess whether emissions are at or below these standards and emission estimates provided in the 2007 operations model (Golder, 2007) for the Closure phase.

3.2.1.2 Fugitive Emissions

Fugitive emissions are substances that are released to the atmosphere from various locations and include unintentional losses of compounds to the atmosphere that do not pass through a stack, vent or functionally equivalent opening. Fugitive emissions can occur as a result of the Mine construction, operation and reclamation activities and are expected to consist primarily of fugitive dust.

Fugitive dust emissions can result from Mine sources through either mechanical or natural processes. Examples of the main mechanical processes that can generate fugitive dust during Closure include building demolition, crushing, materials handling, earthworks and contouring, capping the North Pile, ditch and spillway construction, excavation, blasting and material placement for storage pond construction (if required), scarifying roads and mine surfaces, placing organic materials for revegetation, vehicle fleet operation, heavy equipment operation, combustion of diesel fuel, and solid waste incineration, and the take-off and landing of aircraft from the airstrip. The main natural process that generates fugitive dust is wind erosion. The main potential fugitive emission sources at the Mine during Closure are:

- the roads and airstrip;
- the quarry;
- the influent storage ponds; and,
- the North Pile.

As the Mine enters the Post-Closure phase, fugitive emissions are expected to occur exclusively through natural processes. Monitoring of fugitive emissions will continue during Closure. Should applicable $\text{PM}_{2.5}$ action level triggers be exceeded during the Closure phase, the associated action level responses will be implemented (Section 4). Monitoring will cease in Post-Closure, unless deemed necessary per the adaptive management framework.

3.2.2 Methods

This section describes three methods that can be used to estimate Mine emissions (depending on the compounds). The methods are:

- using a mass balance approach;

- using an emission factor approach (published or calculated); or,
- using available intermittent source stack testing data.

The mass balance approach is based on the law of conservation of mass in a system. Essentially, if there is no accumulation within the system, then all the materials that go into the system must come out. Fuel analysis data is a good example of the mass balance approach in predicting emissions. For example, if the sulphur content of a fuel is known, then the emissions of sulphur (in the form of SO₂) can be calculated by assuming that all of the sulphur in the gas is emitted from the system.

The second approach proposed for estimating Mine emissions is the use of emission factors. Emission factors are available for many emission source categories and are based on the results of source tests performed at one or more facilities within an industry. An emission factor is the contaminant emission rate relative to the level of source activity. Generic emission factors are commonly used when site-specific source monitoring data are unavailable.

The use of source-specific stack testing data is appropriate for emission sources or compounds that may be difficult to characterize using either mass balance or emission factors. A stack test measures the amounts of specific compounds present in the stack exhaust gas.

The methods that can be used for estimating Mine emissions are as follows:

- SO₂ – mass balance approach;
- NO_x – emission factor approach;
- Particulates – emission factor approach;
- GHGs – emission factor approach; and,
- Dioxins, furans and mercury – stack testing approach.

The following sections provide examples of how Mine emissions will be calculated using each of the aforementioned approaches.

3.2.2.1 SO₂ Emission Calculation Methods

SO₂ Combustion Emissions

The diesel fuel used at the Mine contains sulphur. When the fuel is burned, the sulphur oxidizes to form SO₂. To estimate SO₂ emissions from the Mine, the mass balance approach should be used. An example calculation of using this approach for a power plant is provided below. In the example calculation, a fuel sulphur content of 0.05 percent (%) by weight (500 parts per million weight [ppmw]) is assumed. Supplier documentation will be used to confirm the fuel sulphur content for each reporting period.

Example: Assume the engines in a power plant consume 24,000 cubic metres (m³) of fuel per year, and that the fuel has a density of 881 kilograms per cubic metre (kg/m³) and a sulphur content of 0.05% by weight.

$$M = \rho \times V_f \times f_s \times \frac{MW_{SO_2}}{MW_s}$$

Where:

M = total emissions, (tonnes per year)

ρ = fuel density, (kg/m³)

V_f = volume of fuel used, (m³ per year)

f_S = fraction of sulphur in fuel, (unit-less)

MW_{SO₂} = molecular weight of sulphur dioxide (SO₂), (64.06 kilograms per kilomol [kg/kmol])

MW_S = molecular weight of sulphur (S), (32.07 kg/kmol)

Note: The above is a general equation designed to estimate SO₂ emissions from the combustion of fuel based on known fuel sulphur content.

Calculate the total weight of the compound released in kilograms per year (kg/year).

$$M = \frac{881\text{kg}}{\text{m}^3} \times \frac{24,000\text{m}^3}{\text{year}} \times 0.0005 \times \frac{64.06\text{kg}/\text{kgmolSO}_2}{32.07\text{kg}/\text{kgmolS}} = 21,117.63 \frac{\text{kgSO}_2}{\text{year}}$$

Convert the annual release to a yearly value in tonnes.

$$21,117.63 \frac{\text{kgSO}_2}{\text{year}} \times \frac{1\text{tonnes}}{1000\text{kg}} = 21.12 \frac{\text{tonnesSO}_2}{\text{year}}$$

SO₂ Fugitive Emissions

In addition to Mine combustion emissions, fugitive emissions should also be considered. In the case of SO₂, no fugitive emissions are expected from the Mine.

3.2.2.2 NO_x Emission Calculation Methods

NO_x Combustion Emissions

Fuel burned in combustion equipment produces NO_x emissions at the Mine. An example calculation of power plant NO_x emissions using the emission factor approach is provided below.

Example: Assume the engines in a power plant consume 24,000 m³ of fuel per year and the diesel specifications indicate that the heating value of diesel is 0.0449 gigajoules per kilogram (GJ/kg) of fuel consumed. Furthermore, the diesel has a density of 881 kg/m³ and the emission factor for NO_x is 1,376 grams per gigajoules (g/GJ).

$$M = \rho \times V_f \times HV \times E$$

Where:

M = total emissions, (tonnes per year)

ρ = fuel density, (kg/m³)

V_f = volume of fuel used, (m^3 per year)

HV = fuel heating value, (GJ/kg)

E = emission factor, (g/GJ)

Note: The above is a general equation for emissions estimation using emission factors.

Calculate the total weight of the compound released in g/year.

$$M = \frac{881kg}{m^3} \times \frac{24,000m^3}{year} \times \frac{0.0449GJ}{kg} \times \frac{1,376g}{GJ} = 1.306 \times 10^9 \frac{g}{year}$$

Convert the annual release to a yearly value in tonnes.

$$1.306 \times 10^9 \frac{g}{year} \times \frac{1tonne}{10^6g} = 1.306 \times 10^3 \frac{tonnes}{year}$$

NO_x Fugitive Emissions

In addition to Mine combustion emissions, fugitive emissions should also be considered. In the case of NO_x, no fugitive emissions are expected from the Mine.

3.2.2.3 Particulate Emission Calculation Methods

Particulate Combustion Emissions

Fuel burned in combustion equipment produces particulate emissions at the Mine. An example calculation of power plant particulate emissions using the emission factor approach is provided below.

Example: Assume the engines in a power plant consume 24,000 m³ of fuel per year and the diesel specifications indicate that the heating value of diesel is 0.0449 GJ/kg of fuel consumed. Furthermore, the diesel has a density of 881 kg/m³ and the emission factor for TSP is 42.99 g/GJ.

$$M = \rho \times V_f \times HV \times E$$

Where:

M = total emissions, (tonnes per year)

ρ = fuel density, (kg/m³)

V_f = volume of fuel used, (m^3 per year)

HV = fuel heating value, (GJ/kg)

E = emission factor, (g/GJ)

Note: The above is a general equation for emissions estimation using emission factors.

$$M = \frac{881kg}{m^3} \times \frac{24,000m^3}{year} \times \frac{0.0449GJ}{kg} \times \frac{42.99g}{GJ} = 4.081 \times 10^7 \frac{g}{year}$$

Convert the annual release to a yearly value in tonnes

$$4.081 \times 10^7 \frac{g}{year} \times \frac{1 \text{ tonne}}{10^6 g} = 40.81 \frac{\text{tonnes}}{year}$$

Particulate Fugitive Emissions

In addition to Mine combustion emissions, fugitive emissions should also be considered. Fugitive particulate emissions are expected from the Mine, particularly from vehicle traffic.

Vehicle Traffic Particulate Emissions

An example calculation of TSP emissions from vehicle traffic using the emission factor approach is provided below. The road dust emission calculation takes into consideration the following factors:

- The particle size;
- The silt content of the road surface;
- The mean vehicle weight;
- The surface material moisture content; and,
- The number of days of precipitation per year.

The calculation is used to generate a site-specific emission factor, in this case kilograms (kg) of TSP released per vehicle kilometre travelled (VKT). The site-specific emission factor is then multiplied by the number of vehicle kilometres travelled on-site over the reporting period to obtain a mass emission rate.

$$E = FVKT \times k \times \left(\frac{s}{12}\right)^a \times \left(\frac{W}{3}\right)^b \times \left(\frac{M}{1}\right)^c \times \left[\frac{365 - (p + \text{snow})}{365}\right]$$

Where:

- E = emission factor, (kg per VKT)
- k = particle size multiplier, (pound [lb] per VMT)
- s = silt content of road surface material, (%)
- W = mean vehicle weight, (tonnes)
- M = surface material moisture content, (%)
- P = number of days with at least 0.01 inches of precipitation per year (dimensionless)
- snow = number of days of snow cover per year (dimensionless)
- FVKT = conversion from (lb per VMT) to (kg per VKT)
- a, b, c = constants

The above equation can be found in the Environment and Climate Change Canada Road Dust Guidance Document (Environment and Climate Change Canada, 1998).

All of the above terms, except mean vehicle weight (W), which will be specific to the vehicle type, can be found in regulatory guidance documents (i.e., Environment and Climate Change Canada Road Dust Guidance Document (Environment and Climate Change Canada, 1998) and U.S. EPA AP-42 (USEPA, 1995)).

$$E = 0.2819 \times 5.3 \times \left(\frac{88.3}{12}\right)^{0.8} \times \left(\frac{20}{3}\right)^{0.5} \times \left(\frac{0.7}{1}\right)^{-0.4} \times \left[\frac{365 - (118 + 181)}{365}\right] = 0.599 \text{ kg/VKT}$$

Wind Erosion Particulate Emissions

Fugitive particulate emissions generated by wind erosion of open aggregate storage piles are also expected from the Mine. The wind-generated particulate emission calculation takes into consideration various factors, such as the particle size, the number of disturbances over the reporting period, amount of precipitation and the surface erosion potential. The calculated site-specific emission factor for the North Pile is 3.504×10^{-5} kilograms per square metre per day ($\text{kg}/\text{m}^2/\text{day}$), which is then multiplied by the exposed North Pile surface area over the reporting period to obtain a mass emission rate.

3.2.2.4 Greenhouse Gas Emission Calculation

GHGs are emitted from the combustion sources at the Mine. The GNWT has implemented a Greenhouse Gas Management Strategy (GNWT, 2001). Significant emitters of GHGs must report their emissions on an annual basis.

Diesel combustion at the Mine is the largest contributor to GHG emissions. The GHGs that are expected to be released as a result of the Mine include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Though the emissions of CH_4 and N_2O are expected in much smaller volumes than CO_2 , their global warming potentials are much greater than that of CO_2 . To maintain a valid comparison of the relative contribution of each compound to the overall total GHG emissions from the Mine, CH_4 and N_2O emissions are converted to CO_2 equivalent (CO_2e) units. Global warming potential factors are used to convert non- CO_2 greenhouse gases to CO_2e . The global warming potential factor for CH_4 and N_2O are 25 and 298 respectively (IPCC, 2007). An example calculation is provided below.

Example: Assume the engines in a power plant consume $24,000 \text{ m}^3$ of fuel per year. The GHG emission factors for CO_2 , CH_4 and N_2O are 2690, 0.133 and $0.4 \text{ kg}/\text{m}^3$ respectively (IPCC, 2007).

$$M = V_f \times E$$

Where:

M = total emissions, (tonnes per year)

V_f = volume of fuel used, (m^3 per year)

E = emission factor, (kg/m^3)

Calculate the total CO_2 emissions in tonnes/year.

$$M_{CO_2} = \frac{24,000m^3}{year} \times \frac{2690k}{m^3} \times \frac{1tonne}{1,000kg} = 64,560 \frac{tonnesCO_2}{year}$$

Calculate the total CH₄ emissions in tonnes/year.

$$M_{CH_4} = \frac{24,000m^3}{year} \times \frac{0.133kg}{m^3} \times \frac{1tonne}{1,000kg} = 3.182 \frac{tonnesCH_4}{year}$$

Calculate the total N₂O emissions in tonnes/year.

$$M_{N_2O} = \frac{24,000m^3}{year} \times \frac{0.4kg}{m^3} \times \frac{1tonne}{1,000kg} = 9.600 \frac{tonnesN_2O}{year}$$

Calculate the total CO_{2e} emissions in tonnes/year using the global warming potential factors for CH₄ and N₂O.

$$64,560tonnesCO_2 + (3.192tonnesCH_4 \times 25) + (9.600tonnesN_2O \times 298) = 67,500 \frac{tonnesCO_2e}{year}$$

3.2.2.5 Dioxins, Furans and Mercury Calculation Methods

Combustion of waste in the Mine incinerator has the potential to release dioxins, furans, and mercury to the atmosphere. The emissions of these compounds are regulated under the Canada-Wide Standards.

The emissions of dioxins, furans, and mercury in the Mine incinerator will be highly dependent on the quantities and types of waste that will be burned. For this reason, emission estimates based on mass balance or emission factors are difficult to calculate. The proposed approach for estimating emissions from the incinerator is to use intermittent stack sampling data for the incinerator and compare this data to the Canada-Wide Standards or any subsequent predictions in the annual reports.

In addition to Mine combustion emissions, fugitive emissions should also be considered. In the case of dioxins, furans, and mercury, no fugitive emissions are expected from the Mine.

3.3 Fuel Use Summary

Fuel usage for the primary combustion sources, identified in Section 3.2.1, will be documented monthly during the Closure phase and presented in the annual report. Table 3-3 provides an example that could be used to track fuel usage per source on a monthly basis. This table also allows for year by year comparisons of fuel usage so that trends can be identified in the annual reports. In addition to fuel usage at the site, the amount of waste burned in the incinerator will be provided in the annual report. An example of a table that could be used to track waste tonnage and liquid fuel use in the incinerator is presented as Table 3-4. During the Post-Closure phase it is anticipated that fuel usage will be limited to small volumes associated with execution of the monitoring programs.

Table 3-3 Example of Table for Tracking Monthly Fuel Usage from Major Combustion Sources (cubic metres [m³])

Month	Power Generation	Mine Heaters	Mobile Fleet	Incineration	Total	2022 Total	2023 Total
January							
February							
March							
April							
May							
June							
July							
August							
September							
October							
November							
December							
Total							

Table 3-4 Example of Table for Tracking Monthly Waste Tonnage Burned (tonnes) and Liquid Fuel Usage (cubic metres [m³])

Month	Waste Tonnage Burned	Liquid Fuel Usage	Total	2022 Total	2023 Total
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					
Total					

3.4 Emissions Mitigation Strategies

There are a number of mitigation measures that will be integrated into the operations phase of the Mine to minimize air emissions. These mitigation measures primarily focus on minimizing fugitive dust emissions. This is because fugitive dust can be effectively managed through operational strategies to a greater degree than the other air emission compounds released from the Mine.

A fugitive dust abatement program has been incorporated as Section 3.4.1 of this document. For other compounds, including combustion compounds (i.e., SO₂, NO_x, particulate, dioxins, furans, and mercury), the following mitigation measures are used during the Closure phase:

- Fuel conservation measures to reduce SO₂, NO_x and particulate emissions;
- CCME compliant equipment to reduce NO_x emissions;
- Waste diversion methods to minimize dioxins, furans, and mercury emissions from the incinerator;
- Operation of combustion equipment, particularly the incinerator, at optimal conditions (e.g., manufacturer recommended temperature, pressure, etc.); and,
- Regular maintenance of the vehicle fleet and limiting of engine idling

As the Mine enters the Post-Closure phase, there will be no permanent equipment to produce these combustion compounds; thus, the mitigation strategies will not be required Post-Closure.

3.4.1 Fugitive Dust Abatement Program

3.4.1.1 Objectives

The objective of the fugitive dust abatement program is to effectively manage dust generation from surface dust sources. The dominant fugitive dust sources during Closure are expected to include building demolition, crushing, materials handling, earthworks and contouring, capping the North Pile, ditch and spillway construction, excavation, blasting and material placement for storage pond construction (if required), scarifying roads and mine surfaces, placing organic materials for revegetation, vehicle fleet operation, heavy equipment operation, combustion of diesel fuel, and solid waste incineration, the take-off and landing of aircraft from the airstrip, and wind erosion. Wind erosion of natural landscapes is expected to be the exclusive source of fugitive dust emissions at the Mine during Post-Closure.

3.4.1.2 Methods

Section 7.4 of the Mine EAR (De Beers, 2002) presented mitigation measures to minimize dust from the drilling, blasting, ore handling, and primary crushing activities associated with the Mine. This section provides a discussion of these and other fugitive dust abatement measures. These measures may be revisited pending results of the annual Air Quality Meteorological Monitoring and Emissions Report.

3.4.1.3 Watering Surfaces

De Beers will control dust through watering surfaces that have high dust generation potential. Water controls dust in two ways:

1. The surface tension of the water present between dust particles will increase the cohesiveness of the surface material making it less susceptible to becoming suspended in the air.
2. Water droplets in the form of a spray will also knock or wash out suspended particles from the air at a more defined source such as crushers and exposed conveyor transfer points.

Dust is expected to be most significant during the warm, dry periods of the year. During these months (typically late May through late September) the application of water to dust-prone surfaces will be used to manage fugitive dust. In addition to surface watering site roads and airstrip, a water mist would also be effective for controlling dust in other dust production areas and exposed conveyor transfer points. Surface watering could additionally be implemented to reduce and manage fugitive dust emissions.

3.4.1.4 Wind Protection

Where practical during Closure, De Beers will protect surfaces that may erode along with any other potentially high dust generation areas from the wind. This action can take various forms including:

- Using fabric discharge chutes to shield conveyor drop and transfer points from the effects of the wind, thereby reducing the amount of particulate that is exposed to the effects of the wind. Enclosing high dust generation potential activities within buildings has the same effect and can considerably reduce the amount of dust that leaves the immediate area. Examples that are planned include underground ore crushing and enclosing the surface ore stockpile within a building.
- The application of coarse material on roadways and stockpiles (e.g., the North Pile) physically separates the fine material that would create dust if it were exposed to wind or traffic. In areas where high traffic activity is expected, road surfaces should be prepared to include a surface layer that does not have a high erosion potential. Plans for the reclamation of the North Pile include protecting it from the effects of the wind by placing coarse material on the completed surfaces.

3.4.1.5 Managing Activity Intensity

De Beers will also limit the intensity of certain activities that have the potential to generate significant fugitive dust. For example, speed limits will be strictly enforced to ensure that dust generation from motor vehicles is minimized. The maximum speed is 35 km/hour.

3.4.1.6 Other Measures

There are other activities that could be undertaken to reduce the potential for dust generation; however, the indirect effects of undertaking these activities can result in other less desirable environmental consequences. For example, during the winter months, when watering surfaces is impractical, other liquid chemicals could be used to control dust. Chemical dust control with salt solutions (most frequently, calcium, magnesium, or sodium chloride) may be investigated and used depending upon the environmental consequence.

4 RESPONSE PLANNING

As indicated by the GNWT and ECCC (GNWT and Environment and Climate Change Canada, 2006), one of the purposes of the AQEMMP is to identify trends in ambient air quality and to use this information to inform management decisions around emissions mitigation. This type of proactive management requires that a clear and well-documented system be established. This section provides details on how such a system would operate.

For the system to operate effectively the following parameters must be clearly defined:

- the methodology for determining trends and identifying when emissions mitigation is necessary;
- the monitoring timeframe over which emissions mitigation decisions will be made; and,
- the action levels at which emissions mitigation will be employed.

Each year the annual average concentrations of monitored parameters will be summarized in the annual report. These concentrations will be plotted on a graph, similar to the example plot shown for PM_{2.5} in Figure 4-1, such that the magnitude and trends in concentration over time can be easily observed. To evaluate the magnitude and trends in concentrations, a series of pre-determined action levels will also be shown on the figure. These action levels indicate a range or percent change (year to year) in concentrations at which emissions mitigation should be considered. A description of how the action levels should be applied to each of the compounds emitted by the Mine is provided below.

A systematic approach was taken to develop action levels for each compound based on the 2007 Air Modelling Update predictions (Golder, 2007), the applicable ambient air quality criteria and an annual percent change in measured concentrations. Revised Action Levels were adopted based on recommendations submitted in December 2014, as the criteria outlined in the AQEMMP were deemed too sensitive and overly conservative (Golder, 2014). For the Closure and/or Post-Closure phase, the action levels for PM_{2.5} are as follows:

- **Action Level I** – annual aggregate concentrations (averaged over duration of collection) are above the 2007 update prediction (Golder, 2007) but remain below 50% of the applicable ambient air quality criteria;
- **Action Level II** – annual aggregate concentrations (averaged over duration of collection) are above the 2007 Air Modelling Update prediction (Golder, 2007) but remain below 75% of the applicable ambient air quality criteria; and,
- **Action Level III** – annual aggregate (averaged over duration of collection) concentrations are within 25% of the applicable ambient air quality criteria.

Action levels for SO₂ and NO₂ are no longer used, as monitoring has been discontinued.

Action levels for dustfall were set out in the Mine's VMP to act as a trigger for additional Triggered Monitoring Programs (De Beers, 2023b) and include:

- Dustfall and/or vegetation dustfall monitoring data exceed the Alberta Ambient Air Quality Guidelines (AAAQG) (AEP, 2019) for dustfall over a three-month period within a single year. In the event that three

months of dustfall or vegetation dustfall data is not obtained in a single year, the dustfall measured over the reduced time period, over a single year, will be used in the evaluation; or,

- Visual dust observations reported during daily operations when personnel are present show a high-dust condition extending over a long enough period that visible dusting of vegetation occurs, then a dustfall effects monitoring program is triggered.

During Post-Closure, the Dustfall Monitoring Program (see Section 2.5) will be limited to the snow-free season for three consecutive years until applicable closure criteria are achieved. A single confirmatory sampling program will also be completed in year 3 to year 5 of Post-Closure. The Vegetation Dustfall Monitoring Program (see Section 2.6) will also occur once more after all earthworks have been completed for Closure.

During periods with no dustfall collection, the trigger for this program will be based on visual dust observations during other monitoring and maintenance visits. Notable visual observations of dust, which may result in a trigger for the Dustfall Effects Monitoring Program (De Beers, 2023b), will be reported in the AQEMMP annual report along with photographs of the observed dustfall. In addition to triggering the Dustfall Effects Monitoring Program, notable observations of dust may require mitigative measures be taken to limit or prevent adverse effects to the environment. Therefore, the following action level triggers are proposed to identify situations in which dustfall observations warrant a response:

- **Action Level I** – notable dustfall (i.e., visible dusting on vegetation observed with the unaided eye) is observed within 30 m of the disturbed zone or source of dust; and
- **Action Level II** – notable dustfall (i.e., visible dusting on vegetation observed with the unaided eye) is observed beyond 30 m of the disturbed zone or source of dust.

Figure 4-1 Example Plot of Action Levels for Ambient PM_{2.5} Concentrations

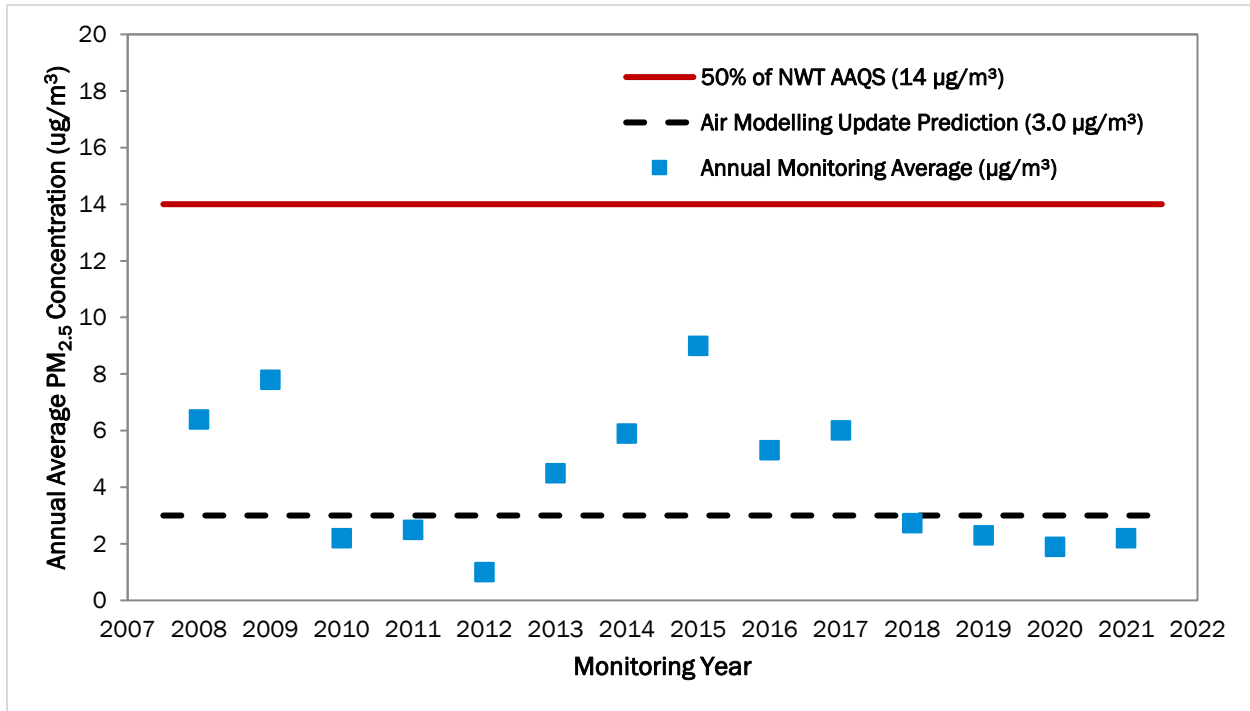


Table 4-1 shows each of the current and former criteria used to trigger the Action Levels and appropriate management action. The management action that will be implemented for each of the action levels is as follows:

- **Action Level I** – continue monitoring, no mitigation necessary;
- **Action Level II** – internal review and development and implementation of Action Plan; and,
- **Action Level III** – external review and development and implementation of Action Plan.

Table 4-1 Criteria Used to Trigger Action Levels

Parameter	Criteria	Source	Status
Maximum Annual SO ₂	30	NWT AAQS ^(a)	Discontinued
Maximum Annual NO ₂	60	NWT AAQS ^(a)	Discontinued
Maximum 24-Hour TSP	120	NWT AAQS ^(a)	Discontinued
Maximum Annual TSP	60	NWT AAQS ^(a)	Discontinued
Maximum 24-Hour PM ₁₀	50	Objective in British Columbia ^(b)	Discontinued
Maximum 24-Hour PM _{2.5}	28	NWT AAQS ^(a)	In Use
Maximum 30-Day Dustfall in Residential and Recreational Areas	53	AAAQG ^(c)	In Use

Parameter	Criteria	Source	Status
Maximum 30-Day Dustfall in Commercial and Industrial Areas	158	AAAQG ^(c)	In Use
Visible Dust Observations	Visual dust observations reported during daily operations of occupation	AQEMMP ^(e) VMP ^(d)	In Use

(a) (GNWT, 2014)

(b) (Government of British Columbia, 2020)

(c) (AEP, 2019)

(d) (De Beers, 2023b)

(e) (De Beers, 2023c)

SO₂ = sulphur dioxide; NO₂ = nitrogen dioxide; TSP = Total Suspended Particulate; PM₁₀ = particulate matter less than 10 microns diameter; PM_{2.5} = particulate matter less than 2.5 microns diameter; µg/m³ = micrograms per cubic metre, GNWT = Government of Northwest Territories, AAQS = Ambient Air Quality Standards.

This is a general approach that can be applied to any of the monitored compounds. If either an internal or external review is necessary, this will likely include a review of ambient monitoring data and Mine emissions to assess whether the elevated concentrations or trends are related to Mine equipment or operations. In this manner, any potential issues can be resolved before the ambient air quality standards are reached, which is the primary benefit of this type of proactive management system.

A dustfall “trigger” may produce a response that would include enhanced dust suppression such as some of the operational mitigations described in the Fugitive Dust Abatement Program (Section 3.4). In the event of a trigger, a Dustfall Effects Triggered Monitoring Program may also be initiated to identify if dust from the Mine has caused a significant difference in the plant species cover or composition of Ecological Land Classification (ELC) types, in the vigour of plant species, or in the depth of the active layer. The Dustfall Effects Triggered Monitoring Program is described within the Mine’s VMP (De Beers, 2023b). If studies show evidence that dustfall is the cause of significant changes in vegetation community or active layer characteristics, then the appropriate changes during Closure and/or Post-Closure would be applied.

In addition, as described in Section 9.4.2 of the FCRP V1.3 (De Beers, 2023a), a Performance Assessment Report will be completed within 5 years of completing the closure and reclamation of any specific component of the Mine and provide an evaluation of site conditions against the closure objectives and criteria. Where site conditions and closure criteria do not align, the Performance Assessment Report will include details of the corrective actions to be implemented, and proposed modifications to applicable Post-Closure monitoring programs. Examples of potential corrective actions in Post-Closure are provided in Table 9.1 of the FCRP V1.3.

5 ANNUAL REPORT

De Beers will provide an annual report that summarizes the air quality monitoring and air emissions data collected each year during Closure. Consistent with the other environmental requirements under the Water License, the annual Air Quality Meteorological Monitoring and Emissions reporting requirements will be submitted by the legislated date of March 31 of each calendar year as part of the Water License Annual Report. The Annual Air Quality Meteorological Monitoring and Emissions Report will be submitted to the signatories of the Environmental Agreement by the proposed date of June 30 of each calendar year. In addition, De Beers will report annual emission estimates to the National Pollutant Release Inventory (NPRI) and GHG emissions to the appropriate federal program.

Examples of air emissions and ambient air monitoring tracking tables that could be used in the annual reports are provided as Table 5-1 and Table 5-2 respectively.

Table 5-1 Example of Table for Tracking Emissions (litres/year) (tonnes/year)

Source	Diesel Consumption (L/yr)	Emission Rates (t/yr)				
		SO ₂	NO _x	TSP	PM ₁₀	PM _{2.5}
Power Generators						
Mine Heaters/Incinerators						
Fleet						
Furnaces						
Total						

Table 5-2 Example of Table for Tracking Monitored PM_{2.5} (micrograms per cubic metre [µg/m³])

Compound	Monitoring Sites	Applicable Guideline (µg/m ³)		2007 Operations Model (Golder, 2007) or subsequent predictions (µg/m ³)		2022 (µg/m ³)
		24-Hour	Annual	24-Hour Max	Annual	
PM _{2.5}						

Meteorological data will be summarized and presented by parameter, including seasonal and annual wind roses. Comparisons to applicable climate normals (30-year average) for Yellowknife and past site monitoring will also be included.

Data summaries for each of the ambient monitoring stations and compounds (PM_{2.5}, dustfall, SO₂, NO₂) will also be presented. Due to the configuration of the particulate, dustfall and passive monitoring programs, data will not be available for the entirety of the calendar year. Therefore, each annual report will include a listing of the monthly results since program start.

Consistent with Section 6.3 item e) of the Environmental Agreement, and other commitments made by De Beers, the annual report will include the following information:

- Annual NO_x, SO₂, particulate and greenhouse gas emissions;
- Confirmation of use of low sulphur (0.05% or less) diesel fuel through supplier specification sheets;
- An annual fuel use summary apportioned by the major sources using the same methods as the Air Modelling Update (Golder, 2007);
- An assessment of the effectiveness of the emissions mitigation measures including the fugitive dust abatement program;
- Comparisons of annual emission estimates to previous years and the estimates used in the predictive air dispersion modelling;
- Comparisons of ambient air quality and deposition monitoring results to previous years, the predictions of the Air Modelling Update dispersion modelling or any subsequent predictions, and all applicable federal and territorial criteria, standards, objectives and guidelines;
- Analysis of ambient air quality trends to determine if emissions mitigation is necessary;
- Responses (either initiated and/or planned) to air quality issues (e.g., equipment failure, data loss, increasing trends or exceedances of air quality critical/dispersion modelling predictions);
- Monitoring results made available to the GNWT for the data storage system; and,
- Notable dust accumulation visually observed during site visits and maintenance, which may act as a trigger for the Dustfall Effects Monitoring Program, as per the VMP (De Beers, 2023b).

6 REGIONAL AND CUMULATIVE EFFECTS MONITORING PROGRAMS

De Beers will make available the results of the air quality monitoring programs and emissions estimates to the recognized administering agency of the yet to be developed regional cumulative effects monitoring program.

7 SUMMARY OF AIR QUALITY AND EMISSIONS MONITORING

The following table provides a summary of the air quality and emissions monitoring during the Closure and Post-Closure phases. A comparison of the monitoring completed during the operations, ECM, Closure and Post-Closure phases is presented in Appendix E.

Table 7-1 Summary of Air Quality and Emissions Monitoring at the Mine

Parameter	Reason for Monitoring	Closure Phase			Post-Closure Phase		
		Number of Stations	Yearly Number of Samples	Frequency of Monitoring	Number of Stations	Yearly Number of Samples	Frequency of Monitoring
Meteorological (various)	Monitoring of environmental conditions at the Mine.	2 meteorological stations	Continuous 52 downloads/year x 2 stations = 104	Continuously, with data downloads completed weekly.	Not monitored		
TSP	Monitoring of suspended particulate matter (dust) emissions from various Mine sources. TSP monitoring was discontinued at the end of 2015 for PM _{2.5} measurements address health considerations (Golder, 2012).	Not monitored					
PM ₁₀	There is evidence linking inhalable particles (PM ₁₀) to health concerns. PM ₁₀ monitoring was discontinued in July 2014 for PM _{2.5} measurements address health considerations (Golder, 2012).	Not monitored					
PM _{2.5}	Scientific studies have indicated that there are health effects associated with PM _{2.5} .	1 suspended particulate matter station (Communications Building)	Continuous during periods of occupancy 24 downloads/year	Continuously, with real-time measurements downloaded bi-weekly during periods of occupancy.	Not monitored		
Dustfall	To evaluate the effects of dust deposition on the surrounding vegetation.	7 dustfall stations	4 samples/year x 7 stations = 28	Dustfall canisters are exposed for a nominal period of 30 days at each station between May and September.	7 dustfall stations	2 samples/year x 7 stations = 14	Monitoring until closure criteria achieved for 3 consecutive years and confirmed once more in year 3 to year 5 of Post-Closure. Dustfall canisters are exposed for a nominal period of 30 days at each station between July and August.
Vegetation Dustfall	To evaluate the effects of dust deposition on the surrounding vegetation.	9 vegetation dustfall stations along 20 km transect	3 samples/year x 9 stations = 27	Program to be conducted once more after completion of earthworks for Closure. If confirmed that no Mine-related impacts remain or are of negligible risk, and the applicable closure criteria have been achieved, the program will be terminated. Dustfall canisters are exposed for a nominal period of 30 days at each station between July and October.	Sampling will only occur if closure criteria are not met following completion of reclamation activities (De Beers, 2023a).		
NO ₂	To demonstrate compliance with the NWT standards (GNWT, 2014) and NAAQOs (Environment and Climate Change Canada, 2011).	Not monitored					
SO ₂	NO ₂ and SO ₂ monitoring will be discontinued for Closure and Post-Closure due to reduced site activity and a record of no exceedances to ambient air benchmarks in historical monitoring data.						

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9 GLOSSARY

Ambient	Existing or present in the surrounding air.
Inhalable particles (PM ₁₀)	Fine particulate matter than can reach the lungs.
North Pile	An area for storing and containing the processed kimberlite material and potentially acid generating rock.
Relative humidity	The ratio of the amount of water vapour actually present in the air to the greatest amount possible at the same temperature.
Respirable particles (PM _{2.5})	Fine particulate matter that is able to reach the lungs, and go deeper into the respiratory tract and may have greater deleterious health impacts than the courser inhalable particles (PM ₁₀).
Total suspended particulate (TSP)	The Fraction of airborne particulates that will remain airborne after their release in the atmosphere; the average diameter is nominally of 100 µm (micrometres) and below.

APPENDIX A **CONCORDANCE TABLE SHOWING AIR MONITORING REQUIREMENTS
OUTLINED IN THE ENVIRONMENTAL AGREEMENT AND THE WATER
LICENSE AND WHERE COMMITMENTS ARE ADDRESSED IN THE AIR
QUALITY AND EMISSIONS MONITORING AND MANAGEMENT PLAN**

Table A-1 Concordance Table showing Air Monitoring Requirements Outlined in the Environmental Agreement and the Section Where Commitments are Addressed in the Air Quality and Emissions Monitoring and Management Plan

Section	Requirement/Commitment	AQEMMP Section	AQEMMP Section Heading
6.3	d) The Air Quality and Emissions Management Plan shall:	-	-
	i. Be designed in consultation with Environment Canada and the GNWT;	All	All
	ii. Be reviewed every 5 years (or sooner if a major change in infrastructure, equipment, emission quantity, quality or location occurs) with Environment Canada, the GNWT and	Section 5	Annual Report
	iii. Clearly define goals, objectives and methodologies for each of the component programs within the plan.	All	All
	e) DBCMI shall prepare and provide to the Parties and the Monitoring Agency an Air Quality and Emissions Management annual report summarizing and analyzing the emissions and ambient monitoring information, including:	Section 5	Annual Report
	i. Comparisons of annual emission estimates to previous years and the estimates used in the Environmental Assessment dispersion modelling	Section 3	Emissions Monitoring Program
	ii. Comparisons of ambient air quality and deposition monitoring results to previous years, the predictions of the Environmental Assessment Report dispersion modeling and all applicable federal and territorial ambient air quality criteria, standards, objectives and guidelines.	Section 2.4 Section 2.5 Section 2.6 Section 2.7	Total Suspended Particulate, PM ₁₀ and PM _{2.5} Monitoring Dustfall Monitoring Vegetation Dustfall Monitoring Passive Monitoring of SO ₂ and NO ₂

Section	Requirement/Commitment	AQEMMP Section	AQEMMP Section Heading
	<p>iii. Analysis of emissions and ambient air quality trends and effectiveness of strategies employed to minimize emissions.</p>	<p>Section 2.4 Section 2.5 Section 2.6 Section 2.7 Section 3</p>	<p>Total Suspended Particulate, PM₁₀ and PM_{2.5} Monitoring Dustfall Monitoring Vegetation Dustfall Monitoring Passive Monitoring of SO₂ and NO₂ Emissions Monitoring Program</p>
	<p>iv. Responses (either initiated and/or planned) to issue (e.g., equipment failure, data loss, increasing trends or exceedances of air quality critical/dispersion modeling predictions).</p>	<p>Section 4</p>	<p>Response Planning</p>
<p>7.1</p>	<p>a) DBCMI shall undertake compliance and environmental effects monitoring of the Project through the Environmental Monitoring Programs.</p> <p>b) DBCMI shall provide the Parties and the Monitoring Agency (when established) with copies of its Environmental Monitoring Programs. The Environmental Monitoring Programs contemplated by this Article shall be reviewed in accordance with Article 7.5 of this agreement. The Environmental Monitoring Programs shall be revised on an ongoing basis as necessary and where appropriate in response to changing circumstances and additional information.</p> <p>c) The Environmental Monitoring Programs shall include activities designed to:</p> <p>i. meet the monitoring requirements of all Regulatory Instruments;</p> <p>ii. verify the accuracy of the impact predictions from the Environmental Assessment Report of the Project;</p>	<p>All</p>	<p>All</p>

Section	Requirement/Commitment	AQEMMP Section	AQEMMP Section Heading
	iii. determine the effectiveness of measures taken to mitigate any adverse environmental effects of the Project;		
	iv. consider, and incorporate where possible, traditional knowledge;		
	v. establish thresholds or early warning signs;		
	vi. trigger action by adaptive mitigation measures where appropriate;		
	vii. provide opportunities for the involvement or active participation of members of each of the Aboriginal Parties in the implementation of the monitoring programs;		
	viii. provide training opportunities for members of each of the Aboriginal Parties;		
	ix. include hypothesis testing during the analysis of data to facilitate Adaptive Management where appropriate; and,		
	x. provide for appropriate monitoring during any suspension of operations.		
7.2	For each Environmental Management Plan there should be a complementary Environmental Monitoring Program to support the process of Adaptive Management. The Environmental Monitoring Program shall include	-	-
	a) The Air Quality Monitoring Program shall include but not be limited to:	-	-
	i. Monitoring of total suspended particulate (TSP), PM ₁₀ and PM _{2.5} ; ii.	Section 2.4	Total Suspended Particulate, PM ₁₀ and PM _{2.5} Monitoring
	i. Monitoring of fugitive dust to determine the effects of dust deposition on the surrounding environment;	Section 2.5 Section 2.6	Dustfall Monitoring Vegetation Dustfall Monitoring
	ii. Documentation of quality assurance and quality control (QA/QC) procedures used to ensure valid data collection; and	Section 2.8	Quality Assurance/Quality Control Procedures
	iii. Contingency plans to respond to increasing trends or exceedances of the air quality criteria/dispersion model predictions.	Section 4	Response Planning

Section	Requirement/Commitment	AQEMMP Section	AQEMMP Section Heading
	b) The Air Emissions Monitoring Program shall include, but not be limited to:	-	-
	i. Annual estimation of emissions from the facility, apportioned by major sources, using the same methodology as that used in February 2002 Environmental Assessment Report. Emissions include at a minimum:	Section 3.2	Emission Estimates
	i. Annual summary of fuel use, apportioned by major sources, and confirmation of use of low sulphur (0.05% or less) diesel fuel.	Section 3.3	Fuel Use Summary
	ii. A fugitive dust abatement program to minimize the generation of non-point source particulate (e.g., from roads, waste rock piles, quarries, etc).	Section 3.4.1	Fugitive Dust Abatement Program
	iii. Documentation of mitigation measures and pollution prevention strategies (e.g., best management /environmental plans, energy conservation strategies, best available control technology) used to ensure emissions are minimized.	Section 3.4	Emissions Mitigation Strategies
	iv. Contingency or response plans to increasing trends or exceedances of emission estimates used in the Environmental Assessment Report.	Section 4	Response Planning
7.4	a) DBCMI shall deliver monitoring data and information to the Parties and the Monitoring Agency in time- frames and in formats developed in consultation with the Monitoring Agency.	Section 5	Annual Report
b) With respect to data and information pertaining to wildlife matters within the jurisdiction of the GNWT, the time-frames and format for reporting shall be developed in consultation with the GNWT.			
c) The formats for submission of monitoring program results and analysis shall not be inconsistent with reporting requirements established under legislation, regulations, and Regulatory Instruments and the requirements of such legislation, regulations, and Regulatory Instruments shall apply to the extent of any inconsistency.			
d) Reporting dates will be established to conform with the requirements of the appropriate Regulatory			
e) DBCMI shall carry out the monitoring in a manner which will provide data consistent with any cumulative effects monitoring programs undertaken or authorized by GNWT and Canada.			

Section	Requirement/Commitment	AQEMMP Section	AQEMMP Section Heading
10.1	a) DBCMI shall prepare and submit an Annual Report to the Parties and the Monitoring Agency, for each calendar year for the term of this Agreement.	Section 5	Annual Report

Table A-2 Concordance Table Showing Air Monitoring Requirements Outlined in the Water Licence and the Section Where Commitments are Addressed in the Air Quality and Emissions Monitoring and Management Plan

Water License (MV2019L2-0004) Subsection and Requirement	AQEMMP Section	AQEMMP Heading
Schedule 1: Annual Water Licence Report		
1. i), vii. Monthly and annual estimates and/or measurements of precipitation and runoff;	Monthly and annual estimates of precipitation will be documented in the Air Quality Meteorological Monitoring and Emissions Annual Report. See Section 2.3 and Section 5 of the AQEMMP.	Hydro-Meteorological Monitoring Annual Report
Surveillance Network Program Part C		
1. The Licencee shall measure and record the following meteorological data during periods of occupancy:		
a) Precipitation, measured and recorded in hourly and daily totals;	Further to discussion with Bob Reid in June/04 – Rainfall, not total precipitation, will be measured as input to evaporation calculations. The data are presented in	Hydro-meteorological Monitoring
b) Evaporation, as calculated from the parameters listed below with hourly and daily averages:	Section 2.3	Hydro-meteorological Monitoring
c) Wind speed including daily minima and maxima;		
d) Wind direction on an hourly basis and air temperature including daily minima and maxima;		
e) Relative humidity at approximately 0.75 and 2.0 metres above the water surface;		
f) Water temperature at one (1) and two (2) meters depths below surface;		

Water License (MV2019L2-0004) Subsection and Requirement	AQEMMP Section	AQEMMP Heading
g) Net solar radiation over the water surface; and,		
h) Water level		
Weather data for evaporation calculations shall be measured and recorded at a site on Snap Lake near Mine operations and away from any manmade structures.		
2. The Licensee shall submit to the Board for approval, the location, methods and frequency for measuring and recording meteorological data identified in Part C, Condition 1(a) of this Annex.	Section 2.3	Hydro-meteorological Monitoring

**APPENDIX B AIR DISPERSION MODELLING FOR EXTENDED CARE AND
MAINTENANCE**



DE BEERS CANADA INC., SNAP LAKE MINE AIR DISPERSION MODELLING FOR EXTENDED CARE AND MAINTENANCE PHASE

February 21, 2018

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EXECUTIVE SUMMARY

ARKTIS Solutions Inc. (ARKTIS) was retained by De Beers Canada Inc. (De Beers) Snap Lake Mine (Mine) to perform an update to the air dispersion modelling for the Extended Care and Maintenance (ECM) phase. As part of the current air quality monitoring program, SHARP monitors are used to measure particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). As part of the Extended Care and Maintenance Plan (De Beers, 2016), site infrastructure will be managed to ensure environmental stability and minimize operating footprint, which involves, but not limited to: reduction in power and heating requirements; reduction of on-site personnel requirements; and reconfiguration of power requirements to maximize efficiency. As a result of these recent changes, power will no longer be supplied to the SHARP Monitors located at the airstrip and emulsion plant. De Beers has informed ARKTIS that during ECM, providing alternative power options to the current SHARP Monitors is impractical between the months of October to April when personnel are not at the Mine.

A primary objective of the Air Dispersion Modelling for ECM Phase is to provide evidence to support a modification to the Air Quality and Emissions Monitoring and Management Plan (De Beers, 2017a) that operation of the SHARP monitors be suspended while Mine personnel are not at the site (between October and April) during ECM. A primary objective of the air dispersion modelling update is to provide evidence to support this modification to the Air Quality and Emissions Monitoring and Management Plan. The air dispersion model predicts concentrations of relevant air borne particles within the effective Mine area using an integrated non-steady-state Lagrangian puff modeling system.

An air dispersion model was first used to predict Mine emissions as part of the environmental assessment report (EAR) (De Beers, 2002) using a steady-state (2D) version of the CALPUFF dispersion model. This model was updated in 2007 to reflect current technologies and Mine conditions (Golder, 2007). The air dispersion model utilized in this report uses the same dispersion modelling approach applied in the 2002 EAR (De Beers, 2002) and the 2007 re-modelling (Golder, 2007), but incorporates the current Mine configuration and usage for ECM phase as detailed in the Snap Lake Mine Extended Care and Maintenance Plan V1.1 (De Beers, 2016). CALPUFF View (WebLakes, 2017), a software capable of executing the CALPUFF Modeling System using local geophysical and meteorological datasets, was utilized to complete the air dispersion modelling.

The airborne particles of Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and $PM_{2.5}$ were modeled in the air dispersion model using various emissions rates across relevant Mine operations. Site specific emission rates from Mine operations during ECM (De Beers, 2017b; ARKTIS, 2017c; De Beers, 2017a; Golder, 2007) were applied in the model and included: the diesel fuel generator (main and auxiliary), the incinerator, the glycol boiler, the aggregate crushing plant, the surface fleet, road dust, the quarry vehicles, quarry activities, and the North Pile. Temporal variations in the emission sources were accounted for in the model to reflect anticipated on-site activity.

The ECM air dispersion model predicted the 1-hour and 24-hour, and annual concentrations of $PM_{2.5}$, NO_2 , and SO_2 and in the local study area (LSA), regional study area (RSA), and at the two SHARP monitoring stations. The LSA for the Mine includes the project footprint surrounded by a 500 metre buffer. The RSA is the area within a 48 kilometre radius of the Mine site. The 2017 ECM model predicted eleven exceedances to the NWT 24-hour $PM_{2.5}$ air quality standard during the Summer (April to September) within the LSA. No $PM_{2.5}$ exceedances occurred in the Winter (October to March). The $PM_{2.5}$ exceedances occur within a localized area within the LSA and are not reflective of the conditions across the LSA. When this area is omitted from the analysis, there is a large decrease in the predicted concentrations, resulting in no exceedances to the air quality standards. One exceedance to the NWT annual NO_2 air quality standard within the LSA occurred within a localized area adjacent to an emission source. With this emission source removed from the analysis, there is no exceedance to the air quality standards; thus, this exceedance is not representative of the LSA. No exceedance to the air quality standards for SO_2 occurred in the LSA.

SO_2 , NO_2 , and $PM_{2.5}$ were predicted to be below the applicable Northwest Territories standards and acceptable federal objectives (GNWT, 2014a; CCME, 2000; Environment and Climate Change Canada, 2013) in the RSA and the LSA which includes the locations for the SHARP monitors. The air dispersion model predicted that the SHARP monitors would not measure any exceedances from October to March to



relevant ambient air quality standards of $PM_{2.5}$, which supports the change to operate the SHARP Monitors located at the airstrip and emulsion plant exclusively during the months of April to September.

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APPENDIX E: GENERAL TERMS AND CONDITIONS

1.0 INTRODUCTION

ARKTIS Solutions Inc. (ARKTIS) was retained by De Beers Canada Inc. (De Beers) to perform an update to the air dispersion modelling for the Snap Lake Mine (Mine) Extended Care and Maintenance (ECM) phase. An air dispersion model was first used to predict Mine emissions as part of the environmental assessment report (EAR) (De Beers, 2002) using a steady-state (2D) version of the CALPUFF dispersion model. This model was updated in 2007 to reflect current technologies and Mine conditions (Golder, 2007). The purpose of the 2002 and 2007 modelling was to:

- Evaluate the various emission source types present in the region;
- Predict the concentrations of select air quality species; and,
- Generate model predictions consistent with local observations.

It was predicted that under the projected operating conditions, the Mine would comply with the applicable ambient air quality criteria (GNWT, 2014a; CCME, 2000; Environment and Climate Change Canada, 2013) outside the active Mine area for most emission sources.

The current modeling approach used in this assessment (herein referred to as the 2017 ECM model) is similar to the approach used in the Environmental Assessment (De Beers, 2002) and 2007 re-modelling (Golder, 2007), with a few exceptions:

- Inclusion of modified building and stack configurations to reflect current site conditions;
- Incorporation of new or updated emission sources that reflect the ECM phase;
- Use of PRIME¹ building downwash algorithm; and,
- Use of an updated meteorological dataset (2016).

For the 2017 ECM model, an air dispersion software, CALPUFF View (WebLakes, 2017), was used to execute an integrated non-steady-state Lagrangian puff modeling system version of CALPUFF to simulate the atmospheric dispersion of select air quality species at the Mine (local study area, LSA) and a 48 kilometre radius outwards from the Mine (regional study area, RSA).

1.1 Purpose and Scope

The purpose of the 2017 ECM model, and this report, is to complete updated predictions of air dispersion modelling for the ECM phase. The model results will be used to support the following changes to ECM air quality monitoring for the Mine:

- SHARP Monitors, which measure PM_{2.5} concentrations, located near the airstrip and emulsion plant will not operate when Mine personnel are not at site, approximately between the months of October and April. These SHARP Monitors will operate at their current locations for the remaining months of the year (approximately May to September).
- The frequency of SHARP Monitor monitoring will be as per the Air Quality and Emissions Monitoring and Management Plan (De Beers, 2017a).
- The SHARP Monitor data will be reported within the Air Quality Meteorological Monitoring and Emissions Reporting Annual Report. The measured PM_{2.5} concentrations will be compared to the NWT AAQS (GNWT, 2014) for ambient air quality compliance.

This report presents the 2017 ECM model analysis for ECM operations to compare with applicable ambient air quality criteria (GNWT, 2014a; CCME, 2000; Environment and Climate Change Canada, 2013).

The layout of this report is as follows:

- Section 1 provides an overview of the 2017 ECM model of the Mine, and the purpose and scope of the current assessment.

¹ Plume Rise Model Enhancements (PRIME) is a Gaussian dispersion model which has been developed for plume rise and building downwash. PRIME considers the position of the stack relative to the building, streamline deflection near the building, and vertical wind speed shear and velocity deficit effects on plume rise (Schulman, 2000).

- Section 2 summarizes the primary features of the 2017 ECM model.
- Section 3 details the input parameters that are applied to the 2017 ECM model.
- Section 4 presents the air quality predictions for the 2017 ECM model.
- Section 5 outlines the conclusions and recommendations from the study.

2.0 AIR DISPERSION MODEL

An overview of the 2017 ECM model is provided in the following sub-sections.

2.1 MODEL FEATURES

A numerical air dispersion model is required to predict concentrations and deposition patterns for select air emission species from the Mine. The CALPUFF dispersion model was selected for this analysis for its ability to:

- Evaluate the various emission source types present in the region such as point and area sources;
- Predict the concentrations of select air species; and,
- Employ the latest principles regarding atmospheric dispersion of contaminants.

CALPUFF was developed by the United States Environmental Protection Agency (U.S. EPA). The model has a long history of usage and has undergone rigorous testing. Additionally, the model has been applied in the Northwest Territories for permitted mines (De Beers, 2002; Golder, 2007; De Beers, 2010). The model has been previously used to establish predictions of site emissions in the EAR (De Beers, 2002), as well as, predicting that the Mine was continuing to stay within relative ambient air quality standards (Golder, 2007).

The CALPUFF dispersion model incorporates useful features such as:

- Simulation of dispersion from multiple sources;
- Simulation of the effects of buildings and structures;
- Assimilation of meteorological data from the closest suitable station;
- Ability to incorporate topographic effects; and,
- Ability to predict 1-hour, 24-hour, and model duration concentrations.

The CALPUFF system consists of the following three major components. Each are described further in the following sub-sections of this report.

- CALMET – a meteorological model that develops hourly wind and temperature fields on a three-dimensional gridded modelling domain.
- CALPUFF – a transport and dispersion model that advects “puffs” of material emitted from modelled sources, simulating dispersion and transformation processes.
- CALPOST – a program that takes the output of CALPUFF and provides usable concentrations and deposition rates.

2.2 CALMET

CALMET is a diagnostic 3D meteorological model used to create a 3D wind field that is inputted into the CALPUFF module. The software uses proximal surface and upper air meteorological station data in conjunction with geophysical terrain and land use data to develop a wind field that spans the model space. The model uses a two-step approach to create the wind field:

1. An initial guess of the wind field is adjusted for kinematic effects of terrain, slope flows, and terrain locking effects.
2. Observational data is introduced to the algorithm to produce the final wind field.

The meteorological data input into the CALMET module is discussed in Section 3.1.

2.3 CALPUFF

CALPUFF is a non-steady-state Lagrangian Gaussian puff air dispersion model. It predicts the plume dispersion of the emissions using the CALMET gridded wind field, and contains algorithms for:

- Near Source Effects
 - Building downwash
 - Transitional plume rise
 - Partial plume penetration

- Subgrid scale terrain interactions
- Long-Range Effects
 - Pollutant removal by wet scavenging and dry deposition
 - Chemical transformation
 - Vertical wind shear
 - Overwater transport
 - Coastal interaction

CALPUFF is capable of accounting for hour-by-hour and spatial variations in wind and stability. The puff model is adaptable and performs well at downwind distances ranging from a few kilometres to upwards of 300 km (Scire, 2000).

In addition to point, area, volume and line emissions sources, CALPUFF can accommodate varying source emissions and gridded area source emission (i.e., dynamic source emissions in both time and location).

2.4 CALPOST

The CALPOST module is a post-process for the CALPUFF output data. CALPOST was used to extract from the output data the maximum 1-hour, 24-hour and model duration values for PM_{2.5}, SO₂, and NO₂, as well as, the number of exceedances of each species with its respective air quality criteria.

3.0 MODEL INPUTS

A summary of the following CALPUFF model inputs is provided in this section of the report:

- Geophysical and meteorological data;
- Spatial model boundaries and domain features;
- Emission rates for, and locations of, the emission sources; and,
- Emissions receptors.

3.1 Geophysical and Meteorological Data Acquisition

The CALPUFF model uses several different datasets to depict current Mine conditions. Geophysical and meteorological datasets are required to build a 3-dimensional wind field used to predict plume dispersion. Meteorological datasets were selected based on the Mine's proximity to the closest available measuring station (discussed below). Geophysical data is composed of terrain and land use datasets. Terrain data (WebGIS, 2017a) was obtained using the SRTM3 dataset with an approximate resolution of 90 metres. Land use data (WebGIS, 2017b) was obtained using the Global Land Cover Characterization with an approximate resolution of 1 km. Both datasets span the RSA and were automatically organized in a CALMET-ready format.

Surface and upper air (weather balloon) meteorological data is a required input to the CALMET module of CALPUFF View. The Mine is located outside the region of automatically collected and formatted datasets using CALPUFF View. Therefore, hourly surface meteorological data was retrieved from onsite records, and the historical data archive of Environment and Climate Change Canada (ECCC) to develop a 2016 meteorological dataset. The 2016 meteorological data represents the most recent and complete dataset (full calendar year) that was available.

Surface station data was provided hourly from January 1st 2016 for a one year duration, collected from the Hill Station at the Mine and supplemented with data from the Yellowknife Airport surface station (WMO ID: 71936) when gaps were present. This station was selected for its proximity to the Mine, in addition to its usage in previous air dispersion models (De Beers, 2002; Golder, 2007).

Before executing the air dispersion model, CALPUFF requires a 3D vectorized wind field input which spans the model domain. This wind field is created by the CALMET module, which in turn requires hourly measurements of the following:

- Wind direction (tens of degrees);
- Wind speed (knots);
- Dry bulb temperature (Fahrenheit);
- Opaque cloud cover (tens of percent);
- Ceiling height (hundreds of metres);
- Relative humidity (percent); and,
- Surface station pressure (millibars).

Additionally, twice daily measurements of the following are required:

- Total number of levels in the original sounding²;
- Number of levels extracted from the original sounding³;
- Pressure (mb);
- Height above sea level (m);
- Temperature (K);
- Wind direction (degrees); and,
- Wind speed (m/s).

A 30% opaque cloud coverage was assumed. For comparison, in Yellowknife during the clearest part of the year, the sky is overcast or mostly cloudy 45% of the time (Weather Spark, 2017). The adopted

² The number of measurements taken during the upper air data collection.

³ The number of extracted (used) measurements from the upper air data collection.

assumption errs on the side of less cloud coverage (causing more radiation and thus more particle movement/dispersion).

Ceiling height and cloud cover measurements were not monitored at the Hill station or Yellowknife airport station. Thus, ceiling height data was calculated using Yellowknife Airport data from 2016 and Equation 1:

(1)

$$CH = \frac{(T_{avg} - T_{dew})}{2.5} \times 1000 + h_{YA}$$

where,

CH = ceiling height (m);

T_{avg} = average temperature (°C);

T_{dew} = average dew point temperature (°C); and,

h_{YA} = Yellowknife Airport station elevation above sea level (m).

Any missing data was filled by interpolating between the closest existing measurements (typically ± 1 hour).

Upper air data was provided by the Integrated Global Radiosonde Archive. The dataset consisted of twice daily upper air measurements from Fort Smith, the closest of three NWT upper air surface collection datasets to the Mine, starting January 1st, 2016 for a one-year duration (same duration as the surface station data). The required data was not provided for all morning and afternoon entries for 2016. Any missing data entries were filled using the closest previous (chronological) measurement.

3.2 Study area

The model domain encompasses the LSA and RSA for the Mine, consistent with the approach used in the previous modelling (De Beers, 2002; Golder, 2007). The LSA for the Mine includes the project footprint surrounded by a 500 metre buffer. The RSA is the area within a 48 kilometre radius of the Mine site. The domain incorporates two adjusted study areas, each with its own grid resolution (Figure 1). The first study area encompasses the LSA and extends approximately 500 metres to 1,000 metres beyond the Mine footprint and has a grid resolution of 100 metres. The second study area encompasses the RSA with a 100 kilometre square centred at the Mine, and has a grid resolution of 1 kilometre. For this assessment, the smaller and larger study areas will be referred to as the LSA and RSA respectively from this point forward. The dimensions are based on the areas used in previous modelling, with the maximum extent of the RSA created using wind speed and directional data at the Mine (Golder, 2007; De Beers, 2002). Since the model predicts hourly downwind concentrations for each hour of available meteorological data, the domain needs to be larger than the distance a species can travel in a single hour. The 2017 ECM model domain encapsulates the furthest distance a species can travel in any of the sixteen cardinal directions.

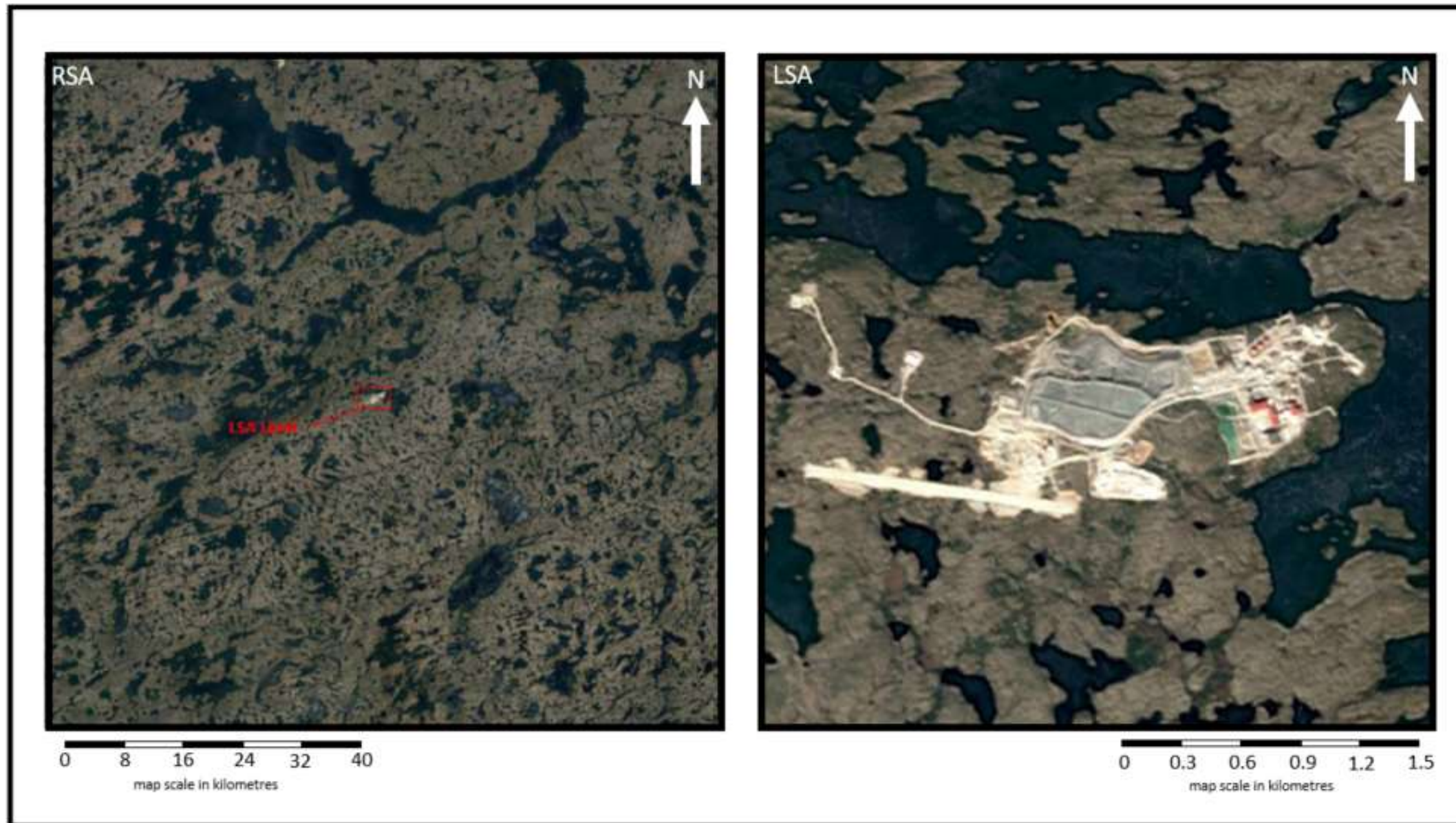


Figure 1. RSA (left) and LSA (right) used in the 2017 ECM model.

3.3 Emissions

The CALPUFF air dispersion model uses the emissions from various operations to create plume models of air borne particles of interest ($PM_{2.5}$, NO_x , and SO_2). The Mine emissions are represented in two different methods within the ECM model (Figure 2): area sources and point sources. Point sources are discrete locations – such as a power generator – which release a finite amount of air borne particles of interest. The rate at which air borne particles are released from a point source is measured in tonnes per year (t/yr). Area sources are used to represent locations at the Mine which release emissions across a known area. These are useful for representing emission generating operations which occur over a non-discrete location, including, the North Pile, Road Dust, Airstrip, Quarry Activities, and Aggregate Crushing Plant. The release of these emissions is measured in tonnes per squared metre per year ($t/m^2/yr$). Due to model software limitations, the extent of the area sources applied in the model do not precisely align with the site disturbed areas. The areas sources applied in the model do have the same surface area as the disturbed area at site. As a result, the predictions of each particle of interest will yield a reasonable species load from the source to the air, and therefore the model is considered a reasonable approximation of the site.

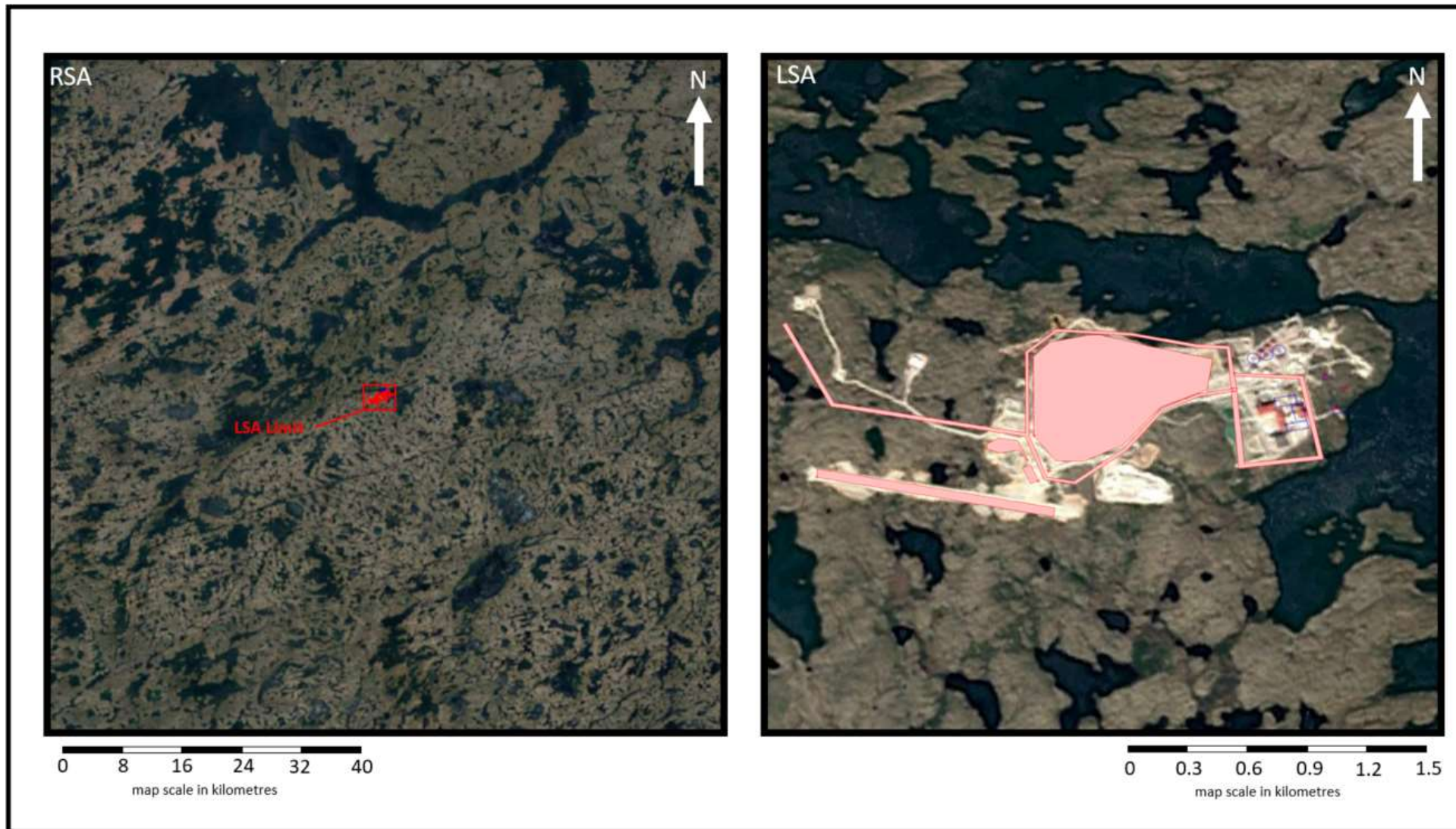


Figure 2. Buildings (blue) and emission sources (red) incorporated in the 2017 ECM model.

In addition to these rates, each emission source has a temporal variation (a scaling factor to adjust the emission rates on a monthly basis). The temporal variations are used to represent the level of operations occurring at each source. For example, the main generator only operates from April to September. The temporal variation adjusts the rate of release such that there are no emissions from the main generator point source outside of these months.

3.3.1 Emission Constituents and Rate Calculations

The combustion of diesel fuel results in the release of air borne particles, including NO_x, PM_{2.5}, and SO₂. Their emissions rates are calculated as follows: NO_x (oxides of nitrogen) and PM_{2.5} (respirable particulate matter) emissions from combustion sources were calculated using the estimated fuel usage of each source (ARKTIS, 2017b), and Equation 2.

(2)

$$M = \rho \times V_f \times HV \times E$$

where,

M = total emissions, (tonnes per year);
ρ = fuel density, (kg/m³);
V_f = volume of fuel used, (m³ per year);
HV = fuel heating value, (GJ/kg); and,
E = emission factor (g/GJ).

SO₂ (sulfur dioxide) emissions were calculated using Equation 3

(3)

$$M = \rho \times V_f \times f_s \times \frac{MW_{SO_2}}{MWS}$$

where,

M = total emissions, (tonnes per year);
ρ = fuel density, (kg/m³);
V_f = volume of fuel used, (m³ per year);
f_s = fraction of sulphur in fuel, (unit-less);
MWSO₂ = molecular weight of sulphur dioxide (SO₂); and,
MWS = emission factor (g/GJ).

3.3.2 Erosion Based Emission Sources

Emissions may result from wind induced erosion from the Mine roads, Airstrip, and the North Pile (542615 m²). The North Pile is the primary means of storing and containing the processed kimberlite (PK) and is a potential source of wind-generated particulate emissions. The PK contained within the North Pile contains as much as 50% moisture (for the finest particles that are most susceptible to wind erosion), which effectively mitigates the volumes of windblown dust that will be generated. The North Pile size applied in the model reflects current site conditions (e.g., starter and east cells constructed, select west cell perimeter features constructed). As these fine materials start to dry out, they will form a crust that will be resistant to wind erosion (U.S. EPA, 1988). The rate at which wind erosion occurs at the North Pile (3.504x10⁻⁵ kg/m²/day) (De Beers, 2017a) was applied as the emission rate for the North Pile, airstrip and Mine road dust.

Table 1. Source emissions caused primarily by erosion.

Emission Source	Emissions (t/d)			Temporal Variation		
	PM _{2.5}	SO ₂	NO ₂	Jan to Mar	Apr to Sep	Oct to Dec
Road Dust ^(a)	5.5x10 ⁻³	0	0	100%	100%	100%
North Pile ^(a)	0.019	0	0	100%	100%	100%
Airstrip ^(a)	2.5x10 ⁻³	0	0	100%	100%	100%

a) Source: De Beers, 2017a

Road dust, surface fleet and quarry vehicle emissions are combined into an area source (155744 m²) in the 2017 ECM model. This source is modelled to represent the approximate travel area of the vehicles where most emissions would be released and subsequently where road erosion is potentially concentrated. Aggregate crushing plant and quarry activities used emission rates from the 2007 re-modelling (Golder, 2007). There is no evidence water being used to reduce the PM emissions at fugitive dust emissions sources included in the model (ARKTIS, 2017c), therefore a conservative assumption was made that no dust mitigation strategies were applied.

3.3.3 Operational Emissions Sources

Air emissions of SO₂, NO_x, and PM_{2.5} were calculated based on the current ECM phase operations. Total suspended particulate (TSP) and inhalable particulate (PM₁₀) were not included in the 2017 ECM model as the instruments which monitor their activity were decommissioned in 2015 and 2014, respectively. PM_{2.5} represents the fraction of airborne particles that is nominally smaller than 2.5 µm in diameter.

Each source has a specific emission rate, variation rate and emission type associated with it (Table 2). The temporal variations for each source is presented in Table 2.

Table 2. Input emission source and temporal variation applied in 2017 ECM model.

Emission Source	Emissions (t/d)			Temporal Variation		
	PM _{2.5}	SO ₂	NO _x	Jan to Mar	Apr to Sep	Oct to Dec
Main Generator ^{(a)(c)}	0.018	6.02E-04	1.22	0%	100%	0%
Auxiliary Generator ^{(a)(c)}	5.26x10 ⁻⁵	1.70x10 ⁻⁶	0.0035	100%	0%	100%
Incinerator ^(c)	0.0018	2.46x10 ⁻⁴	0.023	0%	100%	0%
Glycol Boiler ^(b)	0.002	8.00x10 ⁻³	0.039	100% during March	100% during April	0%
Surface Fleet ^(d)	0.033	0.10	0.202	0%	100%	0%
Quarry Vehicles ^(c)	0.001	0.001	0.001	0%	100%	0%
Quarry Activities ^(b)	0.001	0	0	0%	100%	0%
Aggregate Crushing Plant ^(b)	0.002	0	0	0%	100%	0%

a) Source: ARKTIS, 2017b

b) Source: Golder, 2007

c) Source: De Beers, 2017b

d) Source: ARKTIS, 2017c

For the duration of 2017, a fuel usage of 1,388 m³/month is estimated during the months of April to September for the main generator (summer months), for a total of 8,328 m³ (ARKTIS, 2017b). The fuel

usage is derived from the monthly fuel usage in 2016 from the main generator. Emission rates for NO₂ and PM_{2.5} and SO₂ were calculated with Equation 2 and 3, respectively.

The fuel usage of the auxiliary generator is derived from the anticipated annual fuel requirements of the newly sourced diesel generator. The generator can burn 4.98 m³ of diesel fuel a month when operating at 100% of its power rating for 24 hours a day for 31 days⁴. A fuel usage of 4 m³/month (approximately 80.3% power usage) was used as a conservative estimation during the months of January to March, and October to December for the auxiliary generator, for a total of 24 m³ used (ARKTIS, 2017b). Emission rates for NO₂ and PM_{2.5} and SO₂ were calculated with Equation 2 and 3, respectively.

Incinerator emissions were calculated using Equation 2 and its 2016 fuel usage (De Beers, 2017b). Additionally, the annual tonnage of emissions from burned waste was added to this value to get a total emission output. There were no measurements for PM_{2.5} burned waste emissions, so the PM₁₀ emissions from the burned waste were used as a conservative approximation.

Emissions rates from the glycol boiler, used emission rates from the 2007 re-modelling (Golder, 2007). Emission rates from the surface fleet and quarry vehicles were calculated from the reported 2016 emissions for both fleet fuel combustion and road dust generation (ARKTIS, 2017c). Emissions from the Quarry activities and aggregate crushing plant were sourced from the 2007 re-modelling report (Golder, 2007).

In addition to emission estimates, each source has specific properties which guide the output flow (Table 3). Point sources (generator, incinerator, glycol boiler) have specified stack height, stack diameter, exhaust velocity and exhaust temperature. The parameters for the main generator, incinerator and glycol boiler were sourced from the air dispersion re-modeling (Golder, 2007). The auxiliary generator parameters were matched to the Wajax generator (Model# WDS20D6S) which was anticipated to be purchased for ECM.

Table 3. Properties of the discrete emission sources.

Emission Source	Stack Height (m)	Stack Diameter (m)	Exhaust Velocity (m/s)	Exhaust Temperature (k)
Main Generator	33	0.61	51.8	706.2
Auxiliary Generator	3	0.102	2.389	673.15
Incinerator	11.2	0.7	4.6	1273.2
Glycol Boiler	16.6	0.51	10	430.4

A comparison of source emission rates of the EA (De Beers, 2002), re-modeling (Golder, 2007) and 2017 ECM model assessments models are shown in Table 4.

⁴ Fuel consumption is based on a density of 0.84 of diesel and use of the Wajax generator 281PSL5246.

Table 4. Comparison of EAR (De Beers, 2002), re-modelling (Golder, 2007) and 2017 ECM model air dispersion model air emissions.

Emission Source	PM _{2.5}			SO ₂			NO _x			Notes
	EAR ^(a)	Re-modelling ^(b)	ECM ^(c)	EAR ^(a)	Re-modelling ^(b)	ECM ^(c)	EAR ^(a)	Re-modelling ^(b)	ECM ^(c)	
Main Generator	0.052	0.051	0.018	0.057	0.085	6.02x10 ⁻⁴	3.578	6.215	1.22	ECM main generator only runs for six months of the year at a reduced rate.
Auxiliary Generator	N/A	N/A	5.26x10 ⁻⁵	N/A	N/A	1.70x10 ⁻⁶	N/A	N/A	0.0035	The auxiliary generator is exclusively operational during the Winter months while the Mine is in ECM.
Incinerator	0.004	0.016	0.0018	0	0.127	2.46x10 ⁻⁴	0.001	0.182	0.023	
Glycol Boiler	N/A	0.004	0.002	N/A	0.016	0.008	N/A	0.078	0.039	ECM uses one glycol boiler. Two glycol boilers are used in the 2007 re-modelling ^(b) .
Aggregate Crushing Plant	0.001	0.002	0.002	0	0	0	0	0	0	
Quarry Activities	0.007	0.001	0.001	0.001	0	0	0.011	0	0	
Surface Fleet	N/A	0.015	0.033	0.037	0.01	0.1	1.56	0.202	0.202	EAR surface fleet emissions included road dust and mining fleet emissions
Quarry Vehicles	0.014	0.001	N/A	0.01	0.001	N/A	0.202	0.001	N/A	Quarry vehicle emissions are included in the surface fleet emissions for the ECM model.
Road Dust	N/A	0.007	0 ^(e)	N/A	0	0	N/A	0	0	Road Dust emissions are incorporated in the surface fleet emissions for ECM modelling.
North Pile	0.002	0.003	0.019	0	0	0	0	0	0	North Pile emissions were calculated using a release rate of 3.504x10 ⁻⁵ kg/m ² /day and current surface area at the Mine ^(d) .

a) Source: De Beers, 2002

b) Source: Golder, 2007

c) Emissions used for current modelling (ECM)

d) Source: De Beers, 2017a

e) Road dust emission from the 2017 ECM model are accounted for in the Surface Fleet emissions.

3.3.4 Seasonal Influences on Emission Rates

Mine emissions vary throughout the year depending on the current equipment usage and fuel consumptions. Emissions from each source for the ECM phase are summarized in Table 5. Two periods of operations were considered, a winter period (January to March, and October to December) and a summer period (April to September). As noted in Table 5, the majority of the emissions sources are active in the summer period when the Mine is anticipated to be in an active ECM operation compared to the winter period when the Mine is dormant. Within each period, a constant emission rate was applied.

Table 5. Emission sources during the winter and summer periods of ECM operations.

Emission Source	Winter	Summer
Main Diesel Generator	Not Operational	1 Operational
Auxiliary Power Diesel Generator	1 Operational	Not Operational
Incineration	Not Operational	Operational
Glycol Boiler	Not Operational	1 Operational ^(a)
Mine Air Heaters	Not Operational	Not Operational
Underground Fleet	Not Operational	Not Operational
Underground Material Handling	Not Operational	Not Operational
Aggregate Crushing Plant	Not Operational	Operational
Surface Fleet	Not Operational	Operational
Road Dust	Reduced Occurrence	Occurs
Quarry Vehicles	Not Operational	Operational
Quarry Activities	Not Operational	Operational
North Pile	Reduced Occurrence	Occurs

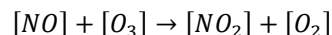
a) Glycol boiler might be operational within the light vehicle tire shop exclusively during March and April 2017. The boiler is running at 100% capacity during March and April in the 2017 ECM model as a conservative estimate.

3.4 Special Considerations

3.4.1 Ozone Limiting Method

The oxides of nitrogen (NO_x) are comprised of nitric oxide (NO) and nitrogen dioxide (NO₂). High temperature combustion processes primarily produce NO that in turn can be converted to NO₂ in the atmosphere through reactions with tropospheric ozone (O₃) as represented in Equation 4:

(4)



where,

- [NO] is the nitrogen monoxide concentration in ppm;
- [O₃] is the ambient ozone concentration in ppm;
- [NO₂] is the nitrogen dioxide concentration in ppm, and
- [O₂] is the oxygen concentration in ppm.

Currently, the NWT does not have an established protocol for determining the fraction of NO that is converted to NO₂. Environment and Climate Change Canada (ECCC) has identified that the most reasonable approach is to follow the guidance provided by Alberta Environment (AENV, 2000; De Beers, 2002). This approach, which was confirmed as being appropriate for the EAR (De Beers, 2002) involves two steps. The initial conservative step assumes that all the emitted NO_x is converted to NO₂. If the ambient ozone concentration is less than ninety percent of the present NO_x (5), then the NO_x predictions should be converted to NO₂ using the ozone limiting method (OLM). The OLM assumes that approximately 10% of

the NO_x emissions are in the form of NO₂, with the balance being in the form of NO. The NO is assumed to rapidly react with ambient levels of ozone (O₃) to form additional NO₂. The following OLM formulation is based on the work of Cole and Summerhays (1979) as represented in Equation 5:

(5)

$$[NO_2] = [O_3] + 0.1 \times [NO_x] \quad \text{and} \quad [O_3] < 0.90 \times [NO_x]$$

where,

- [NO₂] is the nitrogen dioxide concentration in ppm;
- [O₃] is the ambient ozone concentration in ppm, and
- [NO_x] is the concentration of oxides of nitrogen in ppm.

Since there is no site-specific ozone data available at the Mine, ECCC indicated that the following ambient ozone values should be used:

- 50 ppb for converting hourly NO_x concentrations;
- 40 ppb for converting daily NO_x concentrations; and,
- 35 ppb for converting annual NO_x concentrations.

3.4.2 Buildings

Buildings or other solid structures may affect the flow of air near a source and cause eddies to form on the downwind side of a building that can force air particles to the ground instead of allowing them to rise freely within the atmosphere. The inclusion of the building downwash in the 2017 ECM model addresses the influence of these wake zones on point source emissions (i.e. diesel generators, glycol boiler and incinerator). The point sources and the main buildings at the Mine are located towards the centre of the infrastructure area. Large buildings at the Mine (Table 6) (Figure 2) were incorporated into the 2017 ECM model to allow for active building downwash. Smaller buildings near the main generator were not included as they would have a negligible effect on the stack release height of 33 metres.

Table 6. Buildings incorporated into the 2017 ECM model.

Building	Height (m)	Footprint (m ²)
Fuel Tank	16	3,848
Fuel Tank	16	3,848
Fuel Tank	16	3,848
Process Complex	27.3	6,779
Service Complex	16	6,417
Utilities Complex	18	4,564
Accommodation Complex	12	5,391
Light Vehicle Tire Shop	10.5	540
Communications module	3	190

Receptors

Receptors are discrete locations within the model which measure the concentrations of specified air borne particles (PM_{2.5}, NO_x, and SO₂). The 2017 ECM model uses two discrete receptors (Figure 3) to simulate the SHARP PM_{2.5} monitors, and passive NO_x and SO₂ monitoring equipment at the emulsion plant and air strip. These receptors are used in the CALPOST module, as they record hourly measurements of the NO_x, SO₂, and PM_{2.5} at their discrete locations. The predicted emissions at each receptor can be used to evaluate occurrence of exceedances to the relevant air quality standards.

Additionally, two nested grid receptors which span the LSA and RSA were implemented to evaluate the predicted maximum concentrations within the LSA and RSA. The LSA has a receptor resolution of 100 metres and the RSA has a receptor resolution of 2 kilometres (Figure 3).

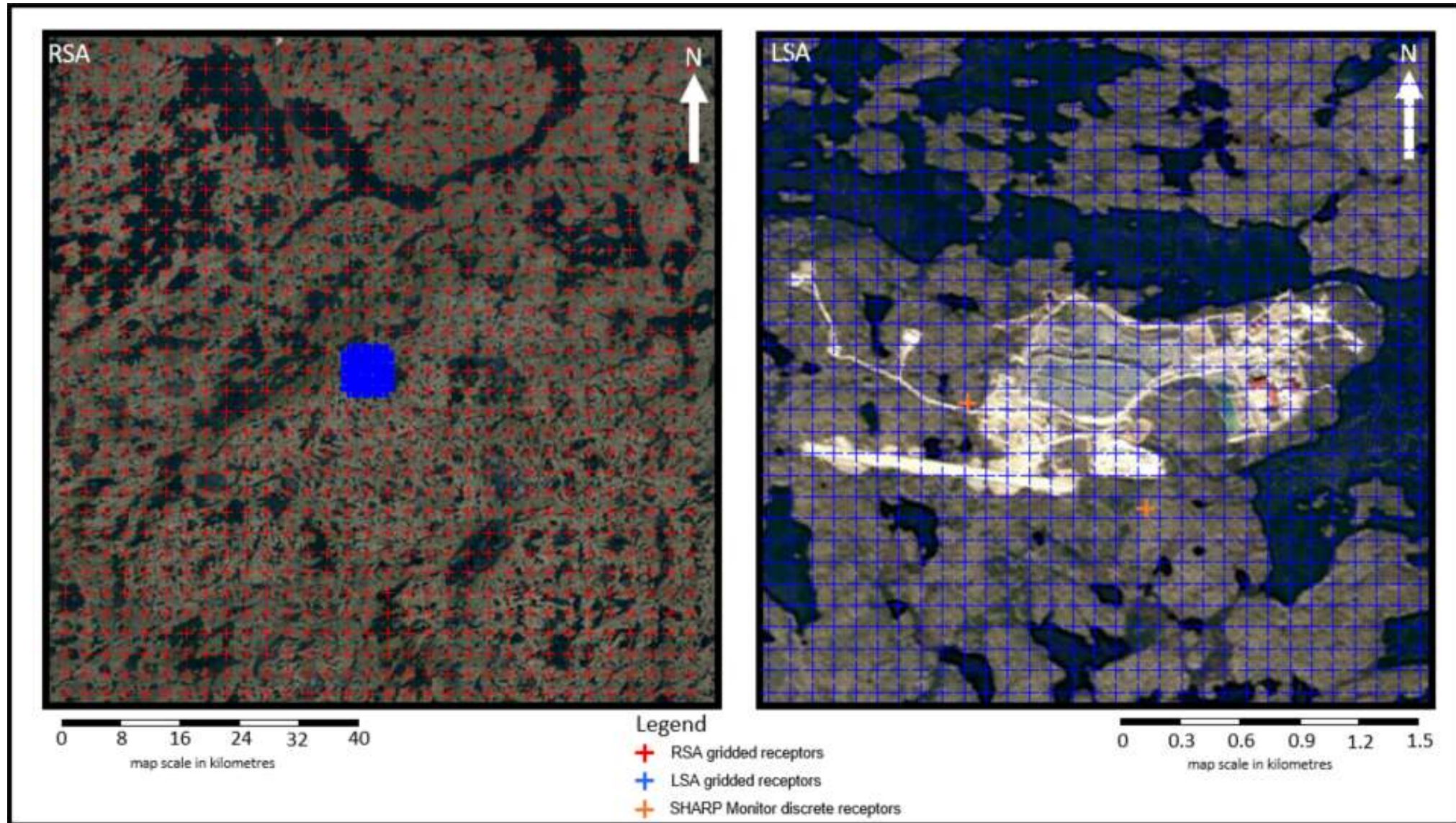


Figure 3. Discrete receptor configuration of the air dispersion model.

4.0 2017 ECM MODEL RESULTS

The 2017 ECM model predictions of PM_{2.5}, SO₂, and NO₂ concentrations are presented within this section. The predicted concentrations are separated into three study areas: SHARP Monitors, LSA and RSA. The predicted plume extents are presented in Appendix A.

The 2017 ECM model predictions for PM_{2.5} concentrations (Table 7) do not exceed the annual NWT standard during ECM operations in any of the modelled regions. The PM_{2.5} concentration within the LSA is predicted to exceed the 24-hour air quality criteria eleven times during Summer ECM operations (April to September). Predictions for PM_{2.5} concentrations at the location of the two SHARP Monitors at the Mine do not exceed the relevant air quality criteria. Relative to the ambient air quality criteria, the model predictions for PM_{2.5} concentrations within the RSA are very low, with no exceedances.

Table 7. PM_{2.5} 2017 ECM annual model predictions.

Monitoring area	1-hour Maximum	24-hour Maximum	Annual Maximum
SHARP Monitors (Discrete Receptors)			
Maximum PM _{2.5} Concentration (µg/m ³)	85.0	7.8	0.96
Occurrences Above the NWT Standard	-	0	0
LSA (Gridded Receptors)			
Maximum PM _{2.5} Concentration (µg/m ³)	275.2 ^a	53.4 ^a	7.4 ^a
Occurrences Above the NWT Standard	-	11	0
RSA (Gridded Receptors)			
Maximum PM _{2.5} Concentration (µg/m ³)	5.8	1.2	0.04
Occurrences Above the NWT Standard	-	0	0
Relevant PM_{2.5} Criteria (µg/m³)	-	28	10

^a Maximum occurs at two receptors (ID#361 and ID#360) which represent an isolated area within the LSA and is not representative of the entire LSA.

The maximum annual ambient air quality predictions of PM_{2.5} that exceed NWT standards occurred at model receptors (ID#361 and ID#360) located near the North Pile, Aggregate Crushing Plant, Incinerator, Quarry, and Mine road. The elevated predicted concentrations at these two receptors is a result of their proximity to several PM_{2.5} emitting sources and is not reflective of the remainder of the LSA. With these two receptors removed from the analysis, the maximum 1 hr, 24 hr and annual concentrations for PM_{2.5} within the LSA are 226.3, 25.6, and 4.2 µg/m³, respectively, which are below the NWT standards. The Mine's existing dust mitigation strategies (De Beers, 2017a) are considered appropriate to reduce the PM_{2.5} emissions within the LSA.

The 2017 ECM model predictions for SO₂ concentrations (Table 8. SO₂ 2017 ECM model predictions. Table 8) do not exceed the NWT standard during ECM operations in any of the modelled regions. The 2017 ECM model predictions for NO₂ concentrations (Table 9) is predicted to exceed the annual air quality criteria within the LSA. The maximum annual ambient air quality prediction of NO₂/NO_x that exceeds criteria occurred at a model receptor (ID#461) located approximately 10 to 20 metres from the main diesel generator. The elevated predicted concentration at this receptor is due to its proximity to the main diesel generator and is not reflective of the conditions across the LSA. Removing this receptor from the analysis, the maximum 1hr, 24hr, and annual concentrations for NO₂ within the LSA are 183.4, 109.49, and 22.0 µg/m³ respectively (a 70.9% decrease in the annual concentration).

Table 8. SO₂ 2017 ECM model predictions.

Monitoring area	1-hour max	24-hour max	Annual max
SHARP Monitors (Discrete Receptors)			
Maximum SO ₂ Concentration (µg/m ³)	2.97	0.34	0.008
Occurrences Above the NWT Standard	0	0	0
LSA (Gridded Receptors)			
Maximum SO ₂ Concentration (µg/m ³)	28.3	10.0	0.32
Occurrences Above the NWT Standard	0	0	0
RSA (Gridded Receptors)			
Maximum SO ₂ Concentration (µg/m ³)	1.22	0.16	0.002
Occurrences Above the NWT Standard	0	0	0
Relevant SO₂ Criteria (µg/m³)	450	150	30

Table 9. NO₂ and NO_x 2017 ECM model predictions.

Monitoring area	1-hour max	24-hour max	Annual max
SHARP Monitors (Discrete Receptors)			
Maximum NO ₂ Concentration (µg/m ³)	149.56	38.2	3.63
Maximum NO _x Concentration (µg/m ³)	555.2	38.2	3.63
Occurrences Above the NWT Standard	0	0	0
LSA (Gridded Receptors)			
Maximum NO ₂ Concentration (µg/m ³)	232.1	173.9	75.6 ^a
Maximum NO _x Concentration (µg/m ³)	1380.5	986.7	97.6 ^a
Occurrences Above the NWT Standard	0	0	1
RSA (Gridded Receptors)			
Maximum NO ₂ Concentration (µg/m ³)	105.3	20.6	9.38
Maximum NO _x Concentration (µg/m ³)	113.0	20.6	9.38
Occurrences Above the NWT Standard	0	0	0
Relevant NO₂ Criteria (µg/m³)	400	200	60

^a Maximum occurs at a receptor (ID#461) which is approximately 10 to 20 metres from the main diesel generator. The receptor does not accurately reflect the conditions across the LSA.

5.0 CONCLUSIONS

The results of the 2017 ECM model were produced using the best available meteorological, geophysical and emissions data for the Snap Lake Mine. Mine emissions were based on 2016 consumption and release data (ARKTIS, 2017b; ARKTIS, 2017c; De Beers, 2017b) as well as parameters from the 2007 air re-modelling (Golder, 2007). These emissions should be considered conservative estimates of actual 2017 emissions.

The primary objective of this report was to predict the $PM_{2.5}$ to support the decision to not operate the SHARP Monitoring stations during the Winter months (October to March, inclusive). With reduced operations during the Winter, the 2017 ECM model predicted zero exceedances of ambient air quality criteria during the Winter. These results suggest that not operating the SHARP Monitoring stations during the Winter months (October to March, inclusive) is an appropriate response.

Predictions of $PM_{2.5}$, SO_2 and NO_2 emission across the RSA, LSA and SHARP Monitoring locations were completed. The main conclusions of 2017 ECM model predictions are summarized below.

- At the SHARP Monitoring stations:
 - Maximum 1-hour, 24-hour, and annual concentration predictions of $PM_{2.5}$ are less than the applicable NWT standards and acceptable federal objectives.
 - The predictions indicate that not operating the SHARP Monitors located at the emulsion plant and airstrip during ECM Winter operations (October to March, inclusive) at the Mine is an appropriate response.
- Within the LSA:
 - Maximum 1-hour and annual concentration predictions of $PM_{2.5}$ are less than the applicable NWT standards and acceptable federal objectives. There are eleven exceedances to the 24-hour $PM_{2.5}$ NWT air quality standard. All exceedances are measured by receptors (ID#360 and ID#361) which do not accurately reflect the conditions across the LSA as indicated by a 52.1% decrease in the maximum 24-hour $PM_{2.5}$ prediction when the suspect receptors are removed.
 - Maximum 1-hour and 24-hour concentration predictions of NO_2 are less than the applicable NWT standards and acceptable federal objectives. There is an exceedance to the annual NO_2 NWT air quality standard. The exceedance occurs at a receptor (ID#461) which is located approximately ten to twenty metres from the main diesel generator. The receptor does not accurately reflect the conditions across the LSA as indicated by a 70.9% decrease in the maximum annual NO_2 emissions when this receptor is removed from the model.
 - Maximum 1-hour, 24-hour, and annual concentration predictions of SO_2 are less than the applicable NWT standards and acceptable federal objectives.
- Within the RSA (excluding the LSA)
 - Maximum 1-hour, 24-hour, and annual concentration predictions of $PM_{2.5}$, NO_2 , and SO_2 are less than the applicable NWT standards and acceptable federal objectives. Plume dispersion from the Mine sources are contained within the RSA.

6.0 CLOSING

This report has been prepared exclusively for the use of De Beers Canada for the specific application described within this report. The details provided in this report are for general information purposes only. The information and recommendations contained in this report should not be used for any other purpose, at another location, or by any other parties. Any use of, or reliance on this report by any third party is at that party's sole risk. ARKTIS assumes no responsibility for inappropriate use of the contents of this report, and disclaims all liability arising from negligence or otherwise. General terms and conditions are provided in Appendix E.

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APPENDIX A: PLUME DISPERSION OF MODELLED SPECIES AT MAXIMUM 1-HOUR CONCENTRATIONS

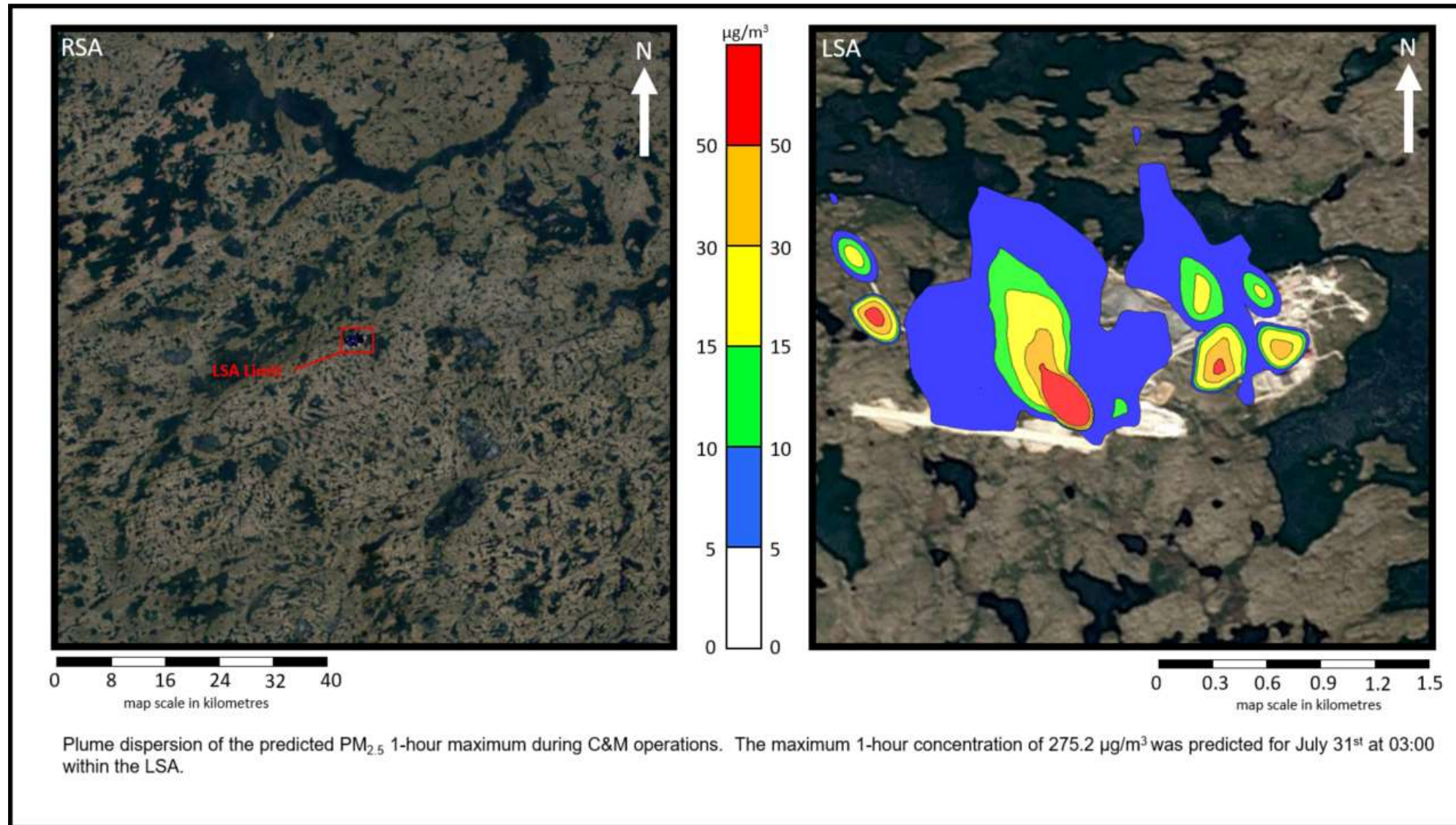


Figure A - 1. Predicted plume dispersion of the 1-hour maximum concentration of PM_{2.5} in the 2017 ECM as seen from the RSA (left) and LSA (right).

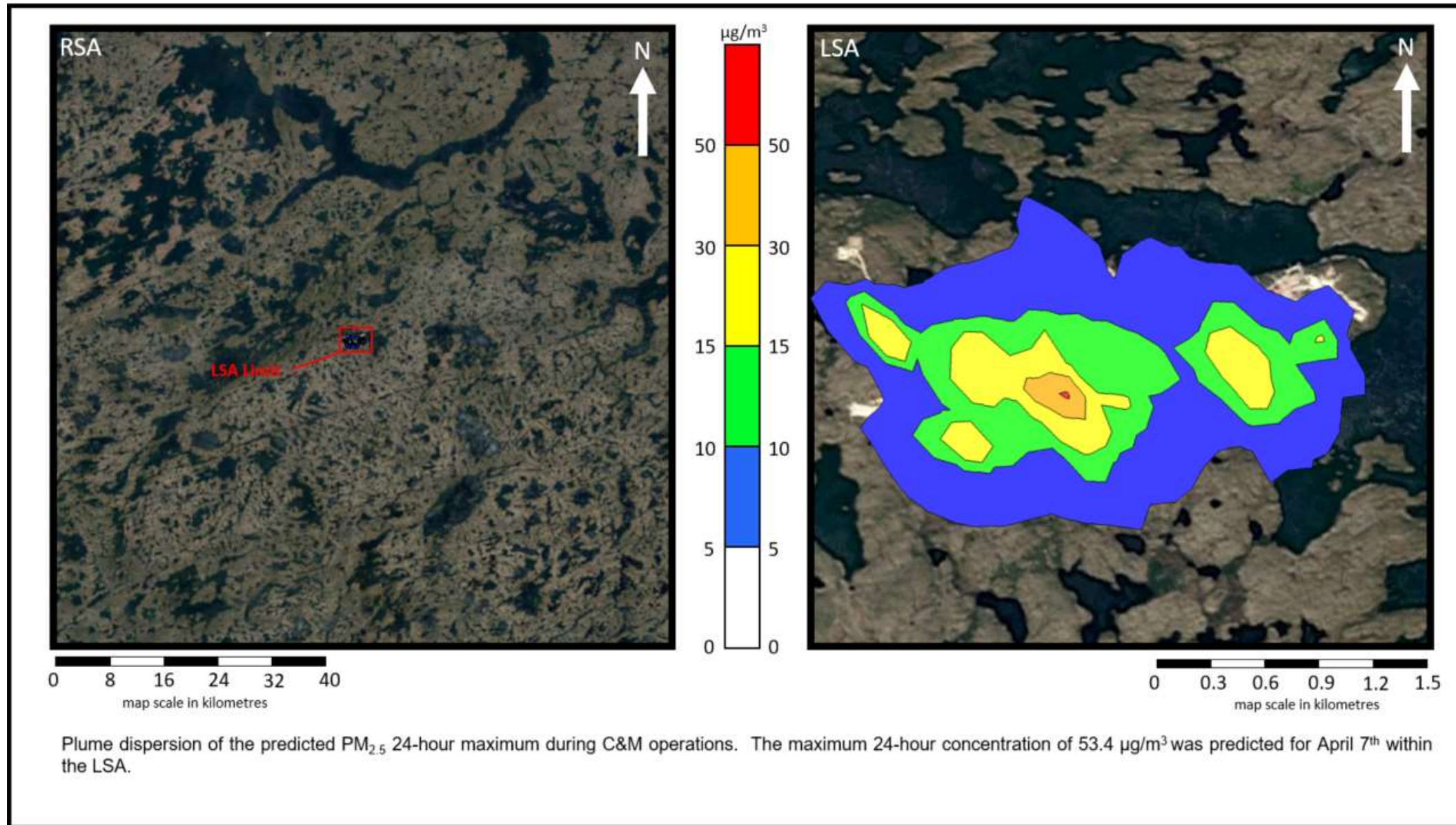


Figure A - 2. Predicted plume dispersion of the 24-hour maximum concentration of PM_{2.5} in the 2017 ECM as seen from the RSA (left) and LSA (right).

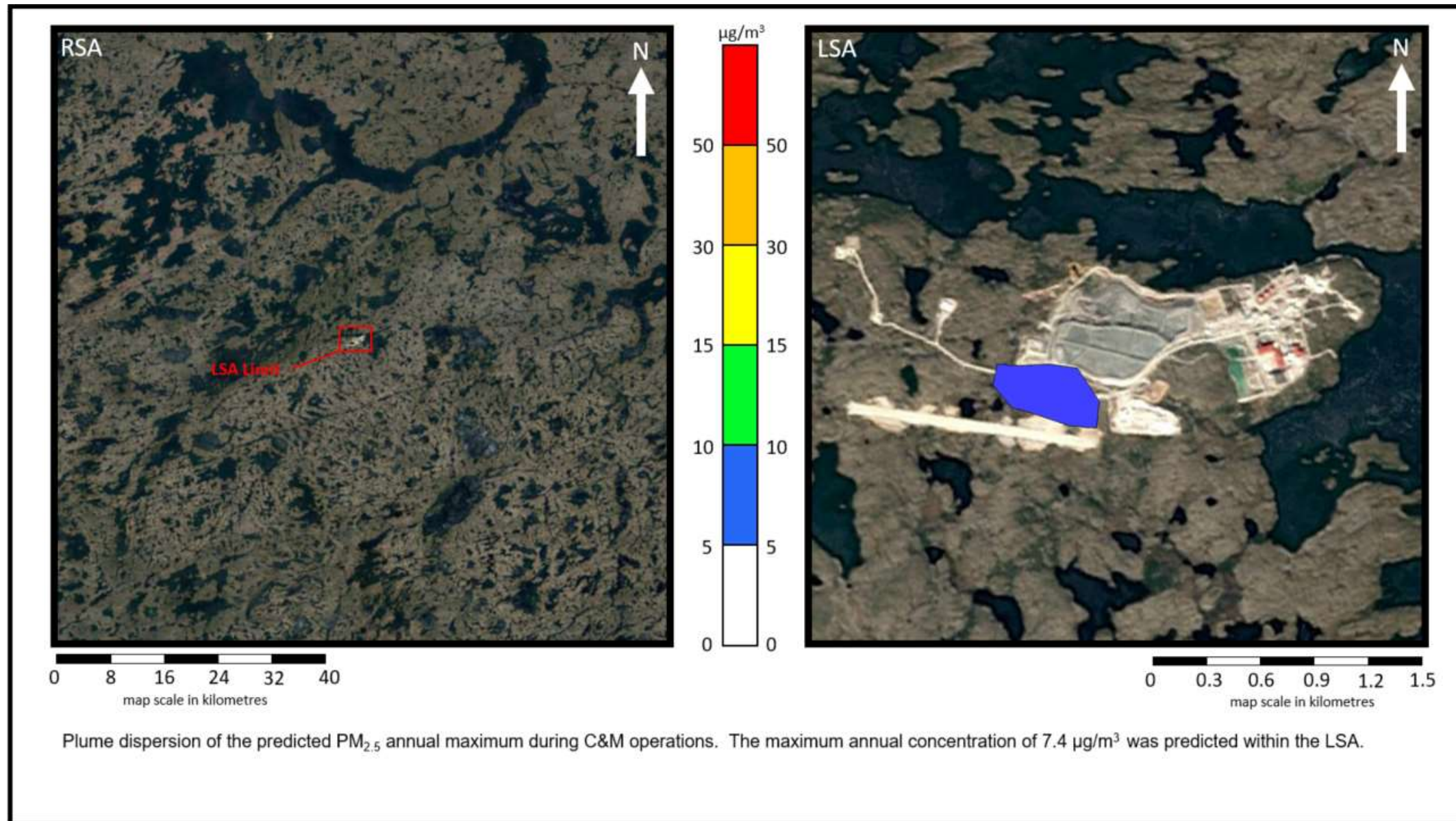


Figure A - 3. Predicted plume dispersion of the annual concentration of PM_{2.5} in the 2017 ECM as seen from the RSA (left) and LSA (right).

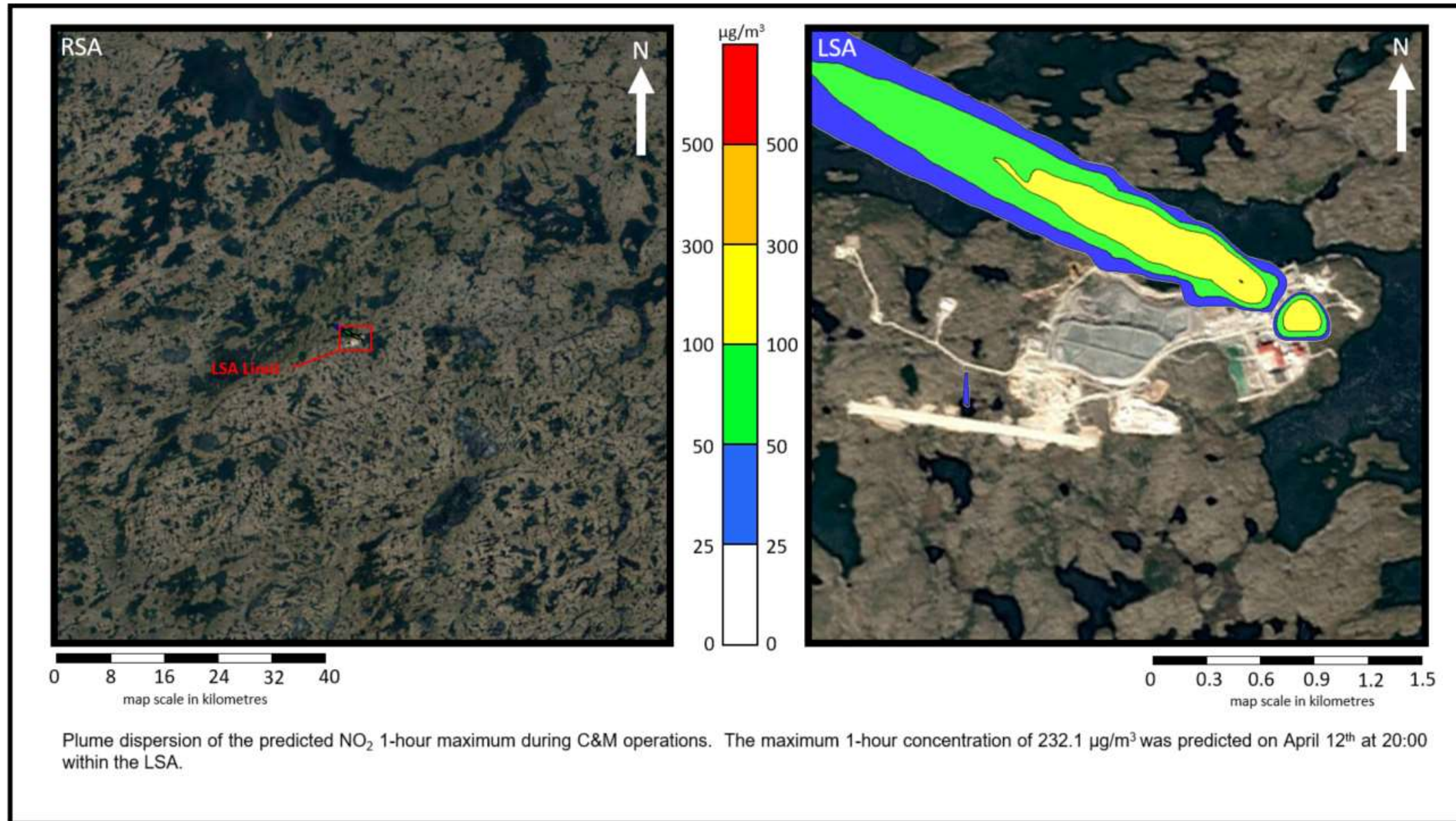


Figure A - 4. Predicted plume dispersion of the 1-hour maximum concentration of NO_2 in the 2017 ECM as seen from the RSA (left) and LSA (right).

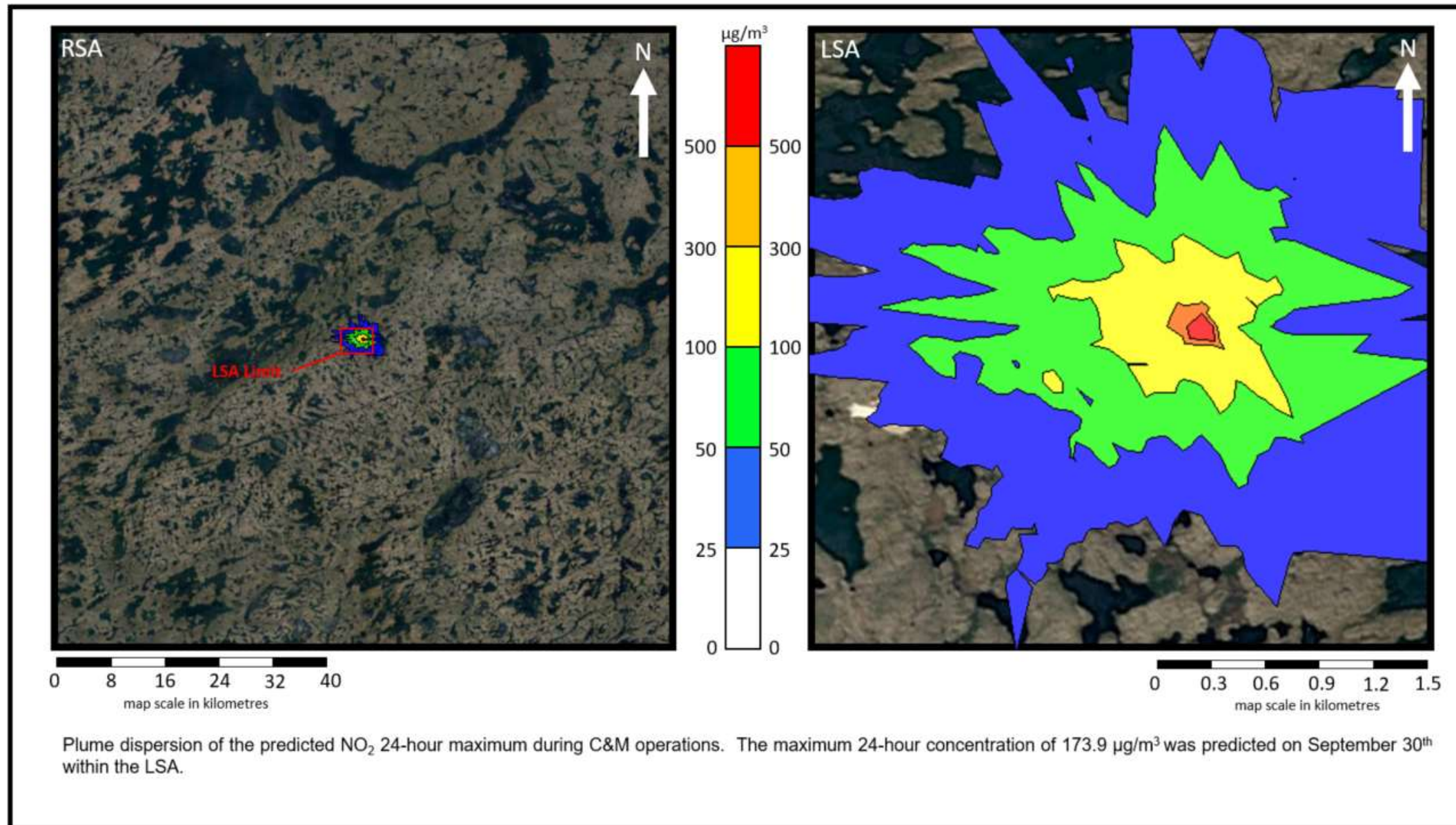


Figure A - 5. Predicted plume dispersion of the 24-hour maximum concentration of NO₂ in the 2017 ECM as seen from the RSA (left) and LSA (right).

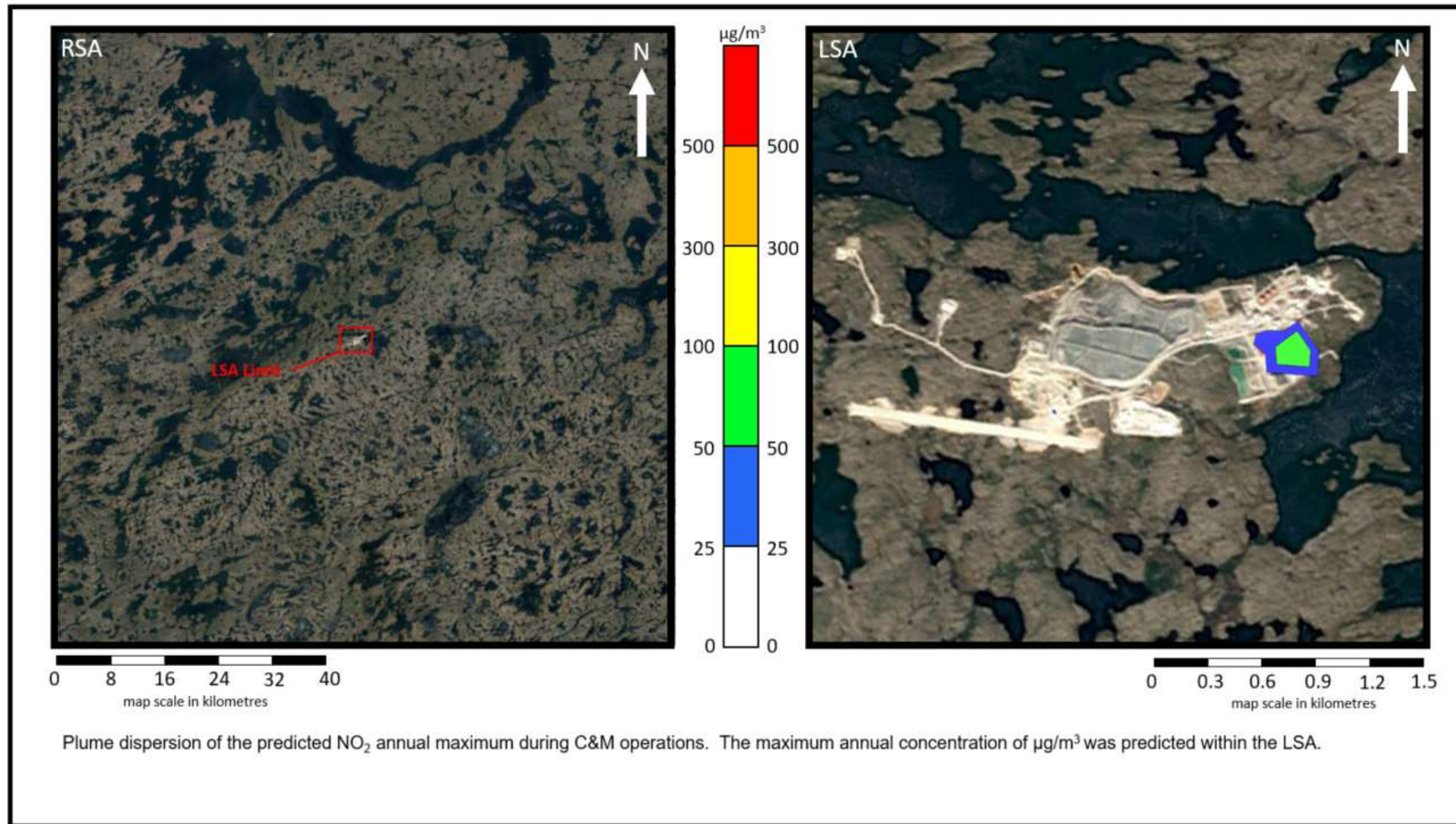


Figure A - 6. Predicted plume dispersion of the annual concentration of NO₂ in the 2017 ECM as seen from the RSA (left) and LSA (right).

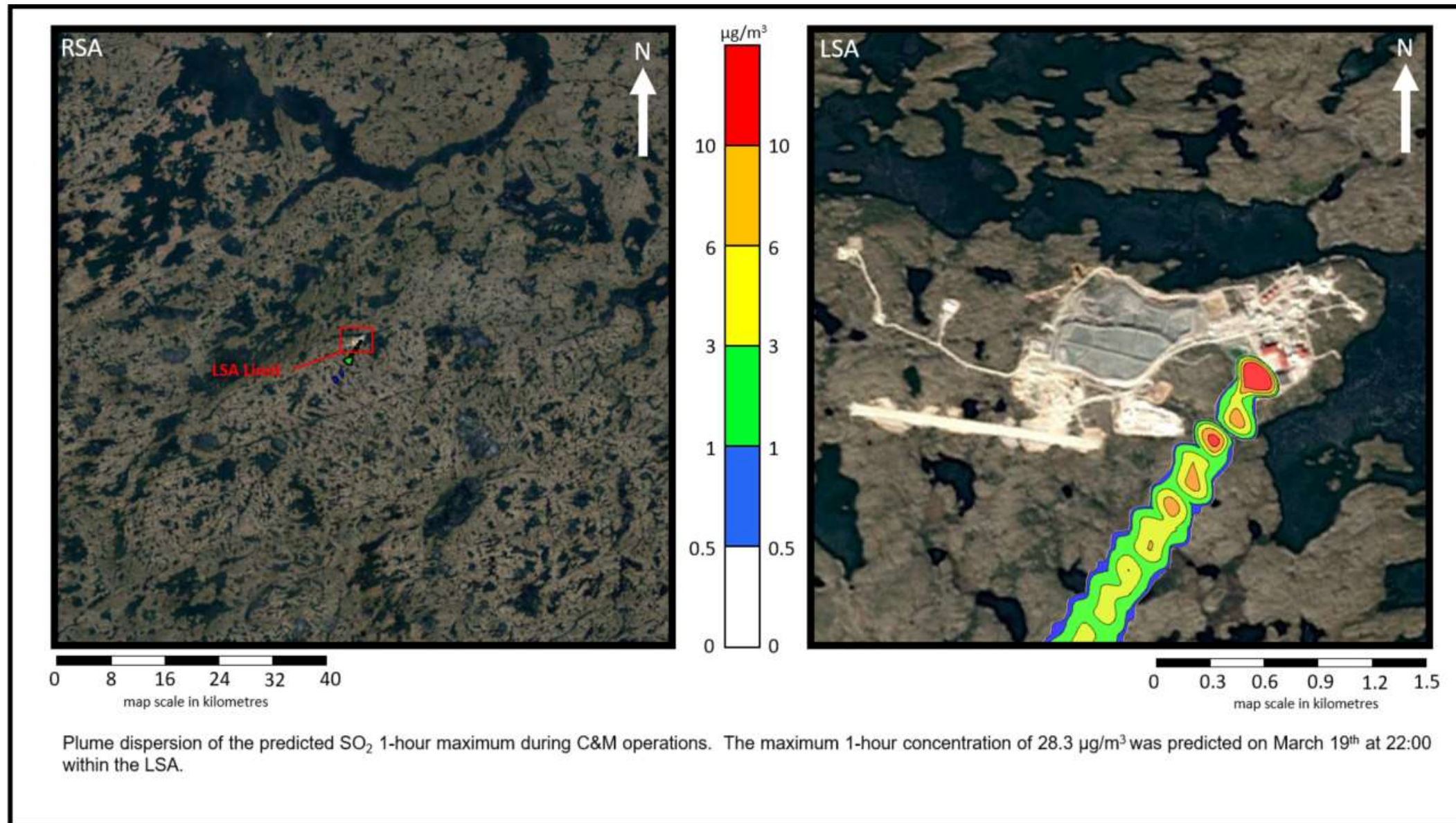


Figure A - 7. Predicted plume dispersion of the 1-hour maximum concentration of SO₂ in the 2017 ECM as seen from the RSA (left) and LSA (right).

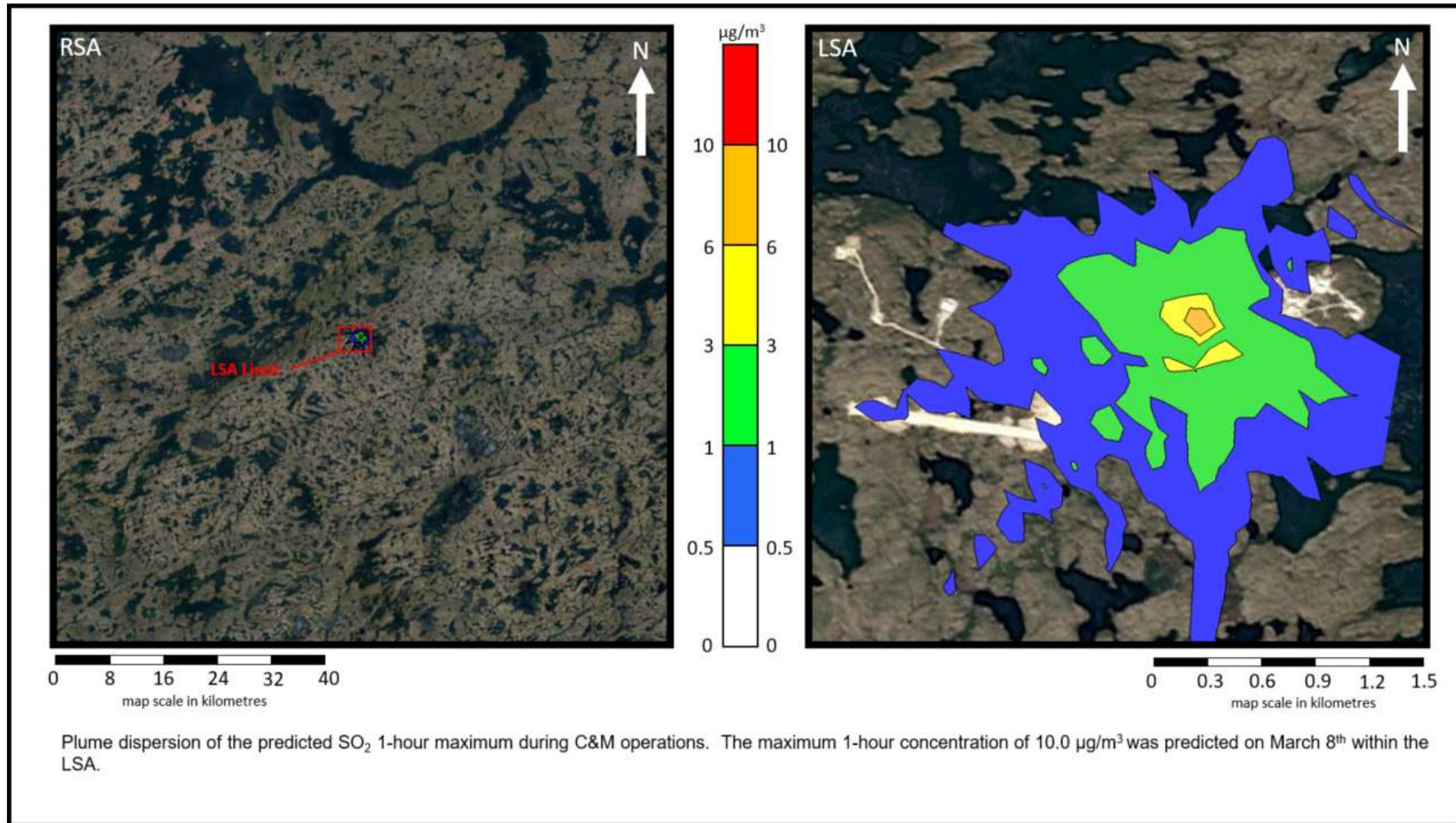


Figure A - 8. Predicted plume dispersion of the 24-hour maximum concentration of SO_2 in the 2017 ECM as seen from the RSA (left) and LSA (right).

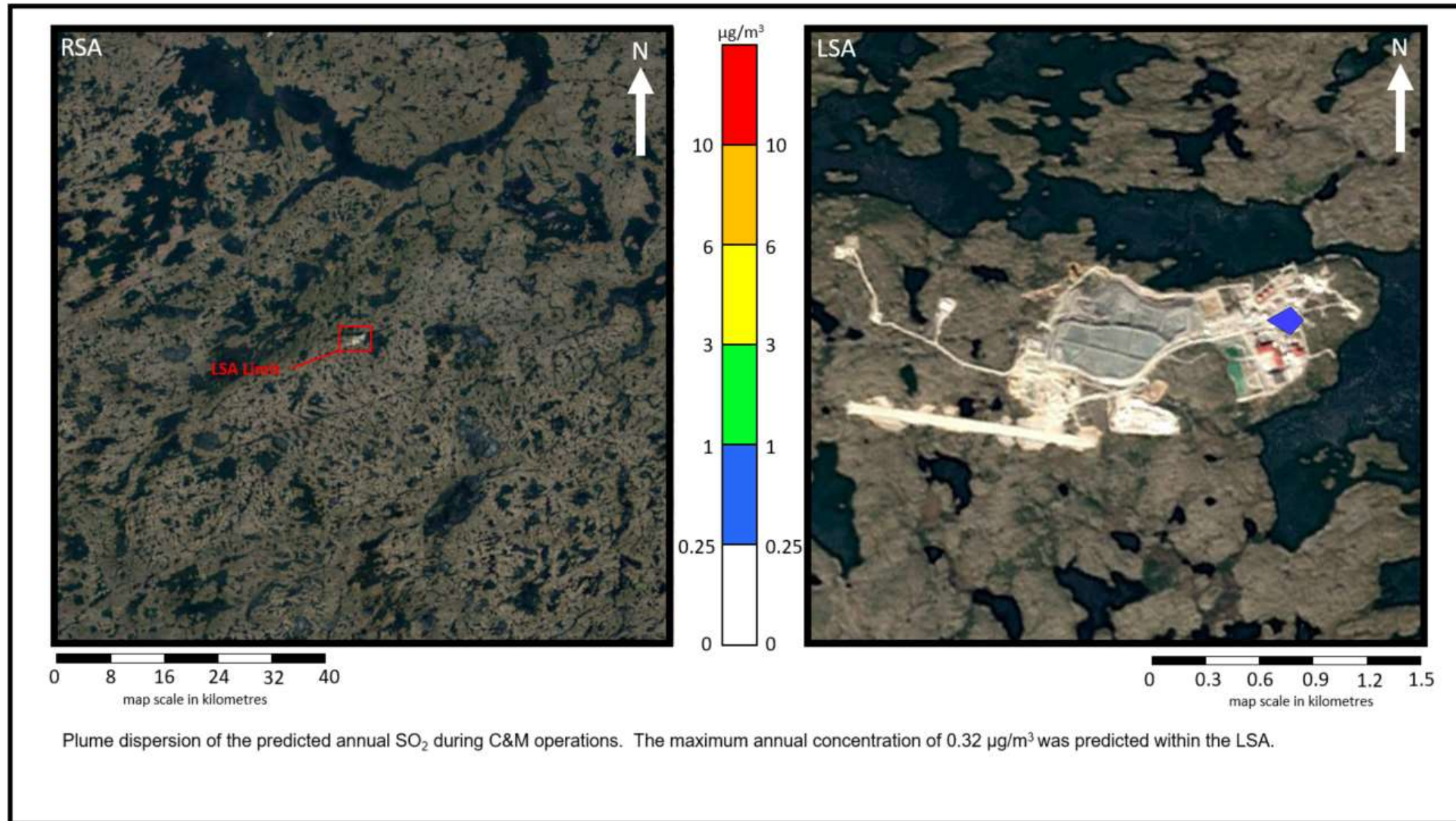


Figure A - 9. Predicted plume dispersion of the annual concentration of SO₂ in the 2017 ECM as seen from the RSA (left) and LSA (right).

APPENDIX B: TERMS AND DEFINITIONS

Term	Definition
AENV	Albert Environment
CALMET	Air dispersion module for creating wind fields
CALPUFF	Air dispersion software for plume dispersion predictions
EA	Environmental assessment
EAR	Environmental assessment report
ECCC	Environment and Climate Change Canada
ECM	Extended Care and Maintenance
K	Degrees Kelvin
LSA	Local study area
m	Metres
m ²	Squared metres
m ³	Cubic metres
m/s	Metres per second
NWT	Northwest Territories
NO	Nitrogen monoxide
[NO]	Concentration of nitrogen monoxide
NO ₂	Nitrogen dioxide
NO _x	Oxides of nitrogen
[NO _x]	Concentration of oxides of nitrogen
[O ₂]	Concentration of oxygen molecule
O ₃	Ozone molecule
[O ₃]	Concentration of ozone
OLM	Ozone limiting method
PM _{2.5}	Particulate matter smaller than 2.5 µg aerodynamic diameter
PM ₁₀	Particulate matter smaller than 10 µg aerodynamic diameter
ppb	Parts per billion
ppm	Parts per million
RSA	Regional study area
SO ₂	Sulphur dioxide
t/d	Metric tonnes per day
t/m ² /yr	Tonnes per square metre per year
t/yr	Tones per year
TSP	Total suspended particulate
µg	Micrograms
µg/m ³	Micrograms per cubic metre

APPENDIX C: CALMET INPUT PARAMETERS

Parameter	Description	Value
INPUT GROUP: 0 -- Input and Output File Names		
GEODAT	Input file of geophysical data (GEO.DAT)	GEO.DAT
SRFDAT	Input file of hourly surface meteorological data (SURF.DAT)	SURF.DAT
METLST	Output file name of CALMET list file (CALMET.LST)	CALMET.LST
METDAT	Output file name of generated gridded met files (CALMET.DAT)	CALMET.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NUSTA	Number of upper air stations	1
NOWSTA	Number of overwater stations	0
NM3D	Number of prognostic meteorological data files (3D.DAT)	0
NIGF	Number of IGF-CALMET.DAT files used as initial guess	0
UPDATE	Input file of upper air sounding data (UPn.DAT)	UP_26118.DAT
INPUT GROUP: 1 -- General Run Control Parameters		
IBYR	Starting year	2016
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBSEC	Starting second	0
IEYR	Ending year	2016
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC-0600
NSECDT	Length of modeling time-step (seconds)	3600
IRTYPE	Output run type (0 = wind fields only, 1 = CALPUFF/CALGRID)	1
LCALGRD	Compute CALGRID data fields (T = true, F = false)	T
ITEST	Flag to stop run after setup phase (1 = stop, 2 = run)	2
MREG	Regulatory checks (- = no checks, 1 = US EPA LRT checks)	0
INPUT GROUP: 2 -- Map Projection and Grid Control Parameters		
IUTMZN	UTM zone (1 to 60)	12
UTMHEM	Hemisphere of UTM projection (N = northern, S = southern)	N
XLAT1	1st standard parallel latitude (decimal degrees)	30N
XLAT2	2nd standard parallel latitude (decimal degrees)	60N
DATUM	Datum-Region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	100
NY	Meteorological grid - number of Y grid cells	100
DGRIDKM	Meteorological grid spacing (km)	1
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	456.6134
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	7003.0682
NZ	Meteorological grid - number of vertical layers	10

Parameter	Description	Value
ZFACE	Meteorological grid - vertical cell face heights (m)	0, 20, 40, 80, 100, 250, 500, 900, 1300, 1750, 2300
INPUT GROUP: 3 -- Output Options		
LSAVE	Save met fields in unformatted output file (T = true, F = false)	T
IFORMO	Type of output file (1 = CALPUFF/GALGRID, 2 = MESOPUFF II)	1
LPRINT	Print met fields (F = false, T = true)	F
IPRINF	Print interval for output wind fields (hours)	1
STABILITY	Print gridded PGT stability classes? (0 = no, 1 = yes)	0
USTAR	Print gridded friction velocities (0 = no, 1 = yes)	0
MONIN	Print gridded Monin-Obukhov lengths? (0 = no, 1 = yes)	0
MIXHT	Print gridded mixing heights? (0 = no, 1 = yes)	0
WSTAR	Print gridded convective velocity scales (0 = no, 1 = yes)	0
PRECIP	Print gridded hourly precipitation rates? (0 = no, 1 = yes)	0
SENSHEAT	Print gridded sensible heat fluxes? (0 = no, 1 = yes)	0
CONVZI	Print gridded convective mixing heights? (0 = no, 1 = yes)	0
LDB	Test/debug option: print input met data and internal variables (F = false, T = true)	T
NM1	Test/debug option: first time step to print	1
NM2	Test/debug option: last time step to print	3
LDBCST	Test/debug option: print distance to land internal variables (F = false, T = true)	F
IOUTD	Test/debug option: print control variables for writing winds? (0 = no, 1 = yes)	0
NZPRN2	Test/debug option: number of levels to print starting at the surface	1
IPR0	Test/debug option: print interpolated winds? (0 = no, 1 = yes)	0
IPR1	Test/debug option: print terrain adjusted surface wind? (0 = no, 1 = yes)	0
IPR2	Test/debug option: print smoothed wind and initial divergence fields? (0 = no, 1 = yes)	0
IPR3	Test/debug option: print final wind speed and direction? (0 = no, 1 = yes)	0
IPR4	Test/debug option: print final divergence fields? (0 = no, 1 = yes)	0
IPR5	Test/debug option: print winds after kinematic effects? (0 = no, 1 = yes)	0
IPR6	Test/debug option: print winds after Froude number adjustment? (0 = no, 1 = yes)	0
IPR7	Test/debug option: print winds after slope flow? (0 = no, 1 = yes)	0
IPR8	Test/debug option: print final winds? (0 = no, 1 = yes)	0
INPUT GROUP: 4 -- Meteorological Data Options		
NOOBS	Observation mode (0 = stations only, 1 = surface/overwater stations with prognostic upper air, 2 = prognostic data only)	0
NSSTA	Number of surface stations	2
NPSTA	Number of precipitation stations	0

Parameter	Description	Value
ICLOUD	Output the CLOUD.DAT file? (0 = no, 1 = yes)	0
MICLOUD	Method to compute cloud fields (1 = from surface obs, 2 = from CLOUD.DAT, 3 = from prognostic (Teixera), 4 = from prognostic (MM5toGrads))	3
IFORMS	Surface met data file format (1 = unformatted, 2 = formatted)	2
IFORMP	Precipitation data file format (1 = unformatted, 2 = formatted)	2
IFORMC	Cloud data file format (1 = unformatted, 2 = formatted)	1
INPUT GROUP: 5 -- Wind Field Options and Parameters		
IWFCOD	Wind field model option (1 = objective analysis, 2 = diagnostic)	1
IFRADJ	Adjust winds using Froude number effects? (0 = no, 1 = yes)	1
IKINE	Adjust winds using kinematic effects? (0 = no, 1 = yes)	0
IOBR	Adjust winds using O'Brien velocity procedure? (0=no, 1 = yes)	0
ISLOPE	Compute slope flow effects? (0 = no, 1 = yes)	1
IEXTRP	Extrapolation of surface winds to upper layers method (1 = none, 2 = power law, 3 = user input, 4 = similar theory, - = same except layer 1 data at upper air stations are ignored)	-4
ICALM	Extrapolate surface winds even if calm? (0 = no, 1 = yes)	0
BIAS	Weighting factors for surface and upper air stations (NZ values)	0, 0, 0, 0, 0, 0, 0, 0, 0, 0
RMIN2	Minimum upper air station radius of influence for surface extrapolation exclusion (km)	4
IIPROG	Use prognostic winds as input to diagnostic wind model (0 = no, 13 = use winds from 3D.Dat as Step 1 field, 14 = use winds from 3D.Dat as initial guess field, 15 = use winds from 3DDat file as observations)	0
ISTEPPGS	Prognostic data time step (seconds)	3600
IGFMET	Use coarse CALMET fields as initial guess? (0 = no, 1 = yes)	0
LVARY	Use varying radius of influence (F = false, T = true)	F
RMAX1	Maximum radius of influence in the surface layer (km)	50
RMAX2	Maximum radius of influence over land aloft (km)	100
RMAX3	Maximum radius of influence over water (km)	0
RMIN	Minimum radius of influence used in wind field interpolation (km)	0.1
TERRAD	Radius of influence of terrain features (km)	7
R1	Relative weight at surface of step 1 fields and observations (km)	30
R2	Relative weight aloft of step 1 field and observations (km)	30
RPROG	Weighting factors of prognostic wind field data (km)	0
DIVLIM	Maximum acceptable divergence	5x10 ⁻⁶
NITER	Maximum number of iterations in the divergence minimization procedure	50
NSMTH	Number of passes in the smoothing procedure (NZ values)	2, 9*4
NINTR2	Maximum number of stations used in each layer for interpolation (NZ values)	10*99
CRITFN	Critical Froude number	1
APHA	Empirical factor triggering kinematic effects	0.1

Parameter	Description	Value
NBAR	Number of barriers to interpolation of the wind fields	0
KBAR	Barrier - level up to which barriers apply (1 to NZ)	10
IDIOPT1	Surface temperature (0 = computer from obs/prognostic, 1 = read from DIAG.DAT)	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	-1
IDIOPT2	Temperature lapse rate used in the computation of terrain-induced circulations (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPT	Upper air station to use for the domain-scale lapse rate (between 1 and NUSTA)	-1
ZUPT	Depth through which the domain-scale lapse rate is computer (m)	200
IDIOPT3	Initial guess field winds (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPWND	Upper air station to use for domain-scale winds	-1
ZUPWND	Bottom and top of layer through which the domain-scale winds are computed (m)	1,1
IDIOPT4	Read observed surface wind components (0 = from SURF.DAT, 1 = from DIAG.DAT)	0
IDIOPT5	Read observed upped wind components (0 = from Upn.DAT, 1 = from DIAG.DAT)	0
LLBREZE	Use Lake Breeze module (T = true F = false)	F
NBOX	Lake Breeze - number of regions	0
INPUT GROUP: 6 -- Mixing Height, Temperature, and Precipitation Parameters		
CONSTB	Mixing height constant: neutral, mechanical equation	1.41
CONSTE	Mixing height constant: convective equation	0.15
CONSTN	Mixing height constant: stable equation	2400
CONSTW	Mixing height constant: overwater equation	0.16
FCORIOI	Absolute value of Coriolis parameter (1/s)	0.0001
IAVEZI	Spatial mixing height averaging? (0 = no, 1 = yes)	1
MNMDAV	Maximum search radius in averaging process (grid cells)	1
HAFANG	Half-angle of upwind looking cone for averaging (degrees)	30
ILEVZI	Layer of winds used in upwind averaging (between 1 and NZ)	1
IMIXH	Convective mixing height method (1 = Maul-Carson, 2 = Batchvarova-Gryning, - for land cells only, + for land and water cells)	1
THRESHL	Overland threshold boundary flux (W/m ³)	0.05
THRESHW	Overwater threshold boundary flux(W/m ³)	0.05
ITWPROG	Overwater lapse rate and deltaT options (0 = from SEA.DAT, 1 = use prognostic lapse rates and SEA.DAT deltaT, 2 = from prognostic)	0
ILUOC3D	Land use category in 3D.Dat	16
DPTMIN	Minimum potential temperature lapse rate (K/m)	0.001
DZZI	Depth of computing capping lapse rate (m)	200
ZIMIN	Minimum overland mixing height (m)	50
ZIMAX	Maximum overland mixing height (m)	3000
ZIMINW	Minimum overwater mixing height (m)	50
ZIMAXW	Maximum overwater mixing height (m)	3000

Parameter	Description	Value
ICOARE	Overwater surface fluxes method	10
DSHELF	Coastal/shallow water length scale (km)	0
IWARM	COARE warm layer computation (0 = off, 1 = on)	0
ICOOL	COARE cool skin layer computation (0 = off, 1 = on)	0
IRHPROG	Relative humidity read option (0 = from SURF.DAT, 1 = from 3D.DAT)	0
ITPROG	3D temperature read option (0 = station, 1 = surface from station and upper air from prognostic, 2 = prognostic)	0
IRAD	Temperature interpolation type (1 = 1/R, 2 = 1/R ²)	1
TRADKM	Temperature interpolation radius of influence (km)	500
NUMTS	Maximum number of stations to include in temperature interpolation	5
IAVET	Conduct spatial averaging of temperatures? (0 = no, 1 = yes)	1
TGDEFB	Default overwater mixed layer lapse rate (K/m)	-0.0098
TGDEFA	Default overwater capping lapse rate (K/m)	-0.0045
JWAT1	Beginning land use category for temperature interpolation over water	999
JWAT2	Ending land use category for temperature interpolation over water	999
NFLAGP	Precipitation interpolation method (1 = 1/R, 2 = 1/R ² , 3 = EXP/R ²)	2
SIGMAP	Precipitation interpolation radius of influence (km)	100
CUTP	Minimum precipitation rate cut-off (mm/hr)	0.01

APPENDIX D: CALPUFF INPUT PARAMETERS

Parameter	Description	Value
PRFDAT	CTDM/AERMET-type meteorological profile data file	PROFILE.DAT
PUFLST	CALPUFF output list file (CALPUFF.LST)	CALPUFF.LST
CONDAT	CALPUFF output concentration file (CONC.DAT)	CONC.DAT
DFDAT	CALPUFF output dry deposition flux file (DFLX.DAT)	DFLX.DAT
WFDAT	CALPUFF output wet deposition flux file (WFLX.DAT)	WFLX.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NMETDOM	Number of CALMET.DAT domains	2
NMETDAT	Number of CALMET.DAT input files	2
NPPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
DOMAIN1	CALMET Domain #n (if NMETDOM > 1)	Outermost or Single Domain
DOMAIN2	CALMET Domain #n (if NMETDOM > 1)	Mine
METDAT1	CALMET gridded meteorological data file	CALMET.DAT
METDAT2	CALMET gridded meteorological data file	CALMET.DAT
INPUT GROUP: 1 -- General Run Control Parameters		
METRUN	Run all periods in met data file? (0 = no, 1 = yes)	0
IBYR	Starting year	2016
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBSEC	Starting second	0
IEYR	Ending year	2016
IEMO	Ending month	12
IEDY	Ending day	30
IEHR	Ending hour	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC-0600
NSECDT	Length of modeling time-step (seconds)	3600
NSPEC	Number of chemical species to be modeled	4
NSECDT	Number of chemical species to be emitted	3
ITEST	top run after SETUP phase (1 = stop, 2 = run)	2
MRESTART	Control option to read and/or write model restart data	0
NRESPD	Number of periods in restart cycle	0
METFM	Meteorological data format (1 = CALMET, 2 = ISC, 3 = AUSPLUME, 4 = CTDM, 5 = AERMET)	1

Parameter	Description	Value
MPRFFM	Meteorological profile data format (1 = CTDM, 2 = AERMENT)	1
AVET	Averaging time (minutes)	60
PGTIME	PG Averaging time (minutes)	60
IOUTU	Output units for binary output files (1 = mass, 2 = odour, 3 = radiation)	1
INPUT GROUP: 2 -- Technical Options		
MGAUSS	Near field vertical distribution (0 = uniform, 1 = Gaussian)	1
MCTADJ	Terrain adjustment method (0 = none, 1 = ISC-type, 2 = CALPUFF-type, 3 = partial plume path)	3
MCTSG	Model subgrid-scale complex terrain? (0 = no, 1 = yes)	0
MSLUG	Near-field puffs modeled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	2
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modeled, 1 = MESOPUFF II, 2 = User-specified, 3 = RIVAD/ARM3, 4 = MESOPUFF II for OH, 5 = half-life, 6 = RIVAD w/ISORROPIA, 7 = RIVA w/ISORROPIA CalTech SOA)	0
MAQCHEM	Model aqueous phase transformation? (0 = no, 1 = yes)	0
MLWC	Liquid water content flag	1
MWET	Model wet removal? (0 = no, 1 = yes)	0
MDRY	Model dry deposition? (0 = no, 1 = yes)	0
MTILT	Model gravitational settling (plume tilt)? (0 = no, 1 = yes)	0
MDISP	Dispersion coefficient calculation method (1= PROFILE.DAT, 2 = Internally, 3 = PG/MP, 4 = MESOPUFF II, 5 = CTDM)	3
MTURBVW	Turbulence characterization method (only if MDISP = 1 or 5)	3
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	0
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	0
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0

Parameter	Description	Value
MBCON	Boundary conditions modeled? (0 = no, 1 = use BCON.DAT, 2 = use CONC.DAT)	0
MSOURCE	Save individual source contribution? (0 = no, 1 = yes)	0
MFOG	Enable FOG model output? (0 = no, 1 = yes - PLUME mode, 2 = yes - RECEPTOR mode)	0
MREG	Regulatory checks (0 = no checks, 1 = USE PA LRT checks)	0
INPUT GROUP: 3 -- Species list		
CSPEC	Species included in model run	PM2.5
CSPEC	Species included in model run	PM10
CSPEC	Species included in model run	SO2
CSPEC	Species included in model run	NOX
INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
PMAP	Map projection system	UTM
FEAST	False easting at projection origin (km)	0
FNORTH	False northing at projection origin (km)	0
IUTMZN	UTM zone (1 to 60)	12
UTMHEM	Hemisphere (N = northern, S = southern)	N
RLAT0	Latitude of projection origin (decimal degrees)	0.00N
RLON0	Longitude of projection origin (decimal degrees)	0.00E
XLAT1	1st standard parallel latitude (decimal degrees)	30N
XLAT2	2nd standard parallel latitude (decimal degrees)	60N
DATUM	Datum-region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	100
NY	Meteorological grid - number of Y grid cells	100
NZ	Meteorological grid - number of vertical layers	10
DGRIDKM	Meteorological grid spacing (km)	1
ZFACE	Meteorological grid - vertical cell face heights (m)	0, 20, 40, 80, 100, 250, 500, 900, 1300, 1750, 2300
XORIGKM	Meteorological grid - X coordinate for SW corner	456.6134
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	7003.0682
IBCOMP	Computational grid - X index of lower left corner	1
JBCOMP	Computational grid - Y index of lower left corner	1
IECOMP	Computational grid - X index of upper right corner	100
JECOMP	Computational grid - Y index of upper right corner	100
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	T
IBSAMP	Sampling grid - X index of lower left corner	1
JBSAMP	Sampling grid - Y index of lower left corner	1
IESAMP	Sampling grid - X index of upper right corner	100
JESAMP	Sampling grid - Y index of upper right corner	100
MESHDN	Sampling grid - nesting factor	1
INPUT GROUP: 5 -- Output Options		

Parameter	Description	Value
ICON	Output concentrations to CONC.DAT? (0 = no, 1 = yes)	1
IDRY	Output dry deposition fluxes to DFLX.DAT? (0 = no, 1 = yes)	0
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	0
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
LCOMPRS	Use data compression in output file (T = true, F = false)	T
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	0
IPRFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2= yes use sampling step)	0
IMFLX	output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g., 3 = $\mu\text{g}/\text{m}^3$ - $\mu\text{g}/\text{m}^2$, 5 = odor units)	3
IMESG	Message tracking run progress on screen (0 = no, 1 and 2 = yes)	2
LDEBUG	Enable debug output? (0 = no, 1= yes)	F
IPFDEB	First puff to track in debug output	1
NPFDEB	Number of puffs to track in debug output	1000
NN1	Starting meteorological period in debug output	1
NN2	Ending meteorological period in debug output	10
INPUT GROUP: 6 -- Subgrid Scale Complex Terrain Inputs		
NHILL	Number of terrain features	0
NCTREC	Number of special complex terrain receptors	0
MHILL	Terrain and CTSG receptor data format (1 = CTDM, 2 = OPTHILL)	2
XHILL2M	Horizontal dimension conversion factor to metres	1
ZHILL2M	Vertical dimension of conversion factor to metres	1
XCTDMKM	X origin of CTDM system relative to CALPUFF system (km)	0
YCTDMKM	Y origin of CTDM system relative to CALPUFF system (km)	0
INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
RCUTR	Reference cuticle resistance (s/cm)	30
RGR	Reference ground resistance (s/cm)	10
REACTR	Reference pollutant reactivity	8
NINT	Number of particle size intervals for effective particle deposition velocity	9
IVEG	Vegetation state in unirrigated areas (1 = active and unstressed, 2 = active and stressed, 3= inactive)	1
INPUT GROUP: 11 -- Chemistry Parameters		

Parameter	Description	Value
MOZ	Ozone background input option (0 = monthly, 1 = hourly from OZONE.DAT)	1
BCKO3	Monthly ozone concentrations (ppb)	80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80
MNH3	Ammonia background input option (0 = monthly, 1 = from NH3Z.DAT)	0
MAVGNH3	Ammonia vertical averaging option (0 = no averaging, 1 = average over vertical extend of puff)	1
BCKNH3	Monthly ammonia concentrations (ppb)	10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10
RNITE1	Nighttime SO ₂ loss rate (%/hr)	0.2
RNITE2	Nighttime NO _x loss rate (%/hr)	2
RNITE3	Nighttime HNO ₃ loss rate (%/hr)	2
MH202	H ₂ O ₂ background input option (0 = monthly, 1 = hourly from H ₂ O ₂ .DAT)	1
BCKH202	Monthly H ₂ O ₂ concentrations (ppb)	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
RH_ISRP	Minimum relative humidity for ISORROPIA	50
SO4_SIRP	Minimum SO ₄ for ISORROPIA	0.4
BCKPMF	SOA background fine particulate (µg/m ³)	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
OFRAC	SOA organic fine particulate fraction	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15
VCNX	SOA VOC/NO _x ratio	50, 50, 50, 50, 50, 50, 50, 50, 50, 50, 50, 50, 50, 50
NDECAY	Half-life decay blocks	0
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
SYTDEP	Horizontal puff size for time-dependent sigma equations (m)	550
MHFTSZ	Use Heffter equation for sigma-z? (0 = no, 1 = yes)	0
JSUP	PG stability class above mixed layer	5
CONK1	Vertical dispersion constant - stable conditions	0.01
CONK2	Vertical dispersion constant - neutral/unstable conditions	0.1
TBD	Downwash scheme transition point option (<0 = Huber-Snyder, 1.5 = Schulman-Scire, 0.5 = ISC)	0.5
IURB1	Beginning land use category for which urban dispersion is assumed	10
IURB2	Ending land use category for which urban dispersion is assumed	19
ILANDUIN	Land uses cateogry for modeling domain	20
ZOIN	Roughness length for modeling domain (m)	0.25

Parameter	Description	Value
XLAIIN	Leaf area index for modeling domain	3
ELEVIN	Elevation above sea level (m)	0
XLATIN	Meteorological station latitude (deg)	-999
XLONIN	Meteorological station longitude (deg)	-999
ANEMHT	Anemometer height (m)	10
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XMMLLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs released from one source during on time step	99
MXSAM	Maximum number of sampling steps for one puff/slug during on time step	99
NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise	2
SYMIN	Minimum sigma-y for a new puff/slug (m)	1
SZMIN	Minimum sigma-z for a new puff/slug (m)	1
SZCAP_M	maximum sigma-z allowed to avoid numerical problem in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factors temperature categories (K)	265, 270, 275, 280, 285, 290, 295, 300, 205, 310, 315
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PLG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
IRESPLIT	Hour for puff re-split	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0

Parameter	Description	Value
ZISPLIT	Minimum mixing height for splitting (m)	100
ROLDMAX	Mixing height ratio for splitting	0.25
NSPLITH	Number of puffs created from horizontal splitting	5
SYSPLITH	Minimum sigma- (met grid cells)	1
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr)	2
CNSPLITH	Minimum concentration (g/m ³)	0
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1x10 ⁻⁶
DSRISE	Trajectory step-length for numerical rise integration (m)	1
HTMINBC	Minimum boundary condition puff height (m)	500
RESAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1
INPUT GROUP: 13 -- Point Source Parameters		
NPT1	Number of point sources	4
IPTU	Units used for point source emissions (e.g., 1 = g/s)	7
NSPT1	Number of source-species combinations with variable emission scaling factors	12
NSPT2	Number of pointsources in PTEMARB.DAT files(s)	0
INPUT GROUP: 14 -- Area Source Parameters		
NAR1	Number of polygon area sources	32
IARU	Units used for area source emission (e.g., 1 = g/m ² /s)	7
NSAR1	Number of source-species combinations with variable emission scaling factors	67
NAR2	Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0
INPUT GROUP: 15 -- Line Source Parameters		
NLN2	Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Number of buoyant line sources in LNEMARB.DAT file	0
ILNU	Units used for line source emissions (e.g., 1 = g/s)	1
NSLN1	Number of source-species combinations with variable emissions scaling factors	0
NLRISE	Number of distances at which transitional rise is computed	6
INPUT GROUP: 16 -- Volume Source Parameters		
NVL1	Number of volume sources	0
IVLU	Units used for volume source emissions (e.g., 1 = g/s)	1
NSVL1	Number of source-species combinations with variable emissions scaling factors	0
NVL2	Number of volume sources in VOLEMARB.DAT file(s)	0
INPUT GROUP: 17 -- FLARE Source Control Parameters (variable emissions file)		
NFL2	Number of flare sources defined in FLEMARB.DAT file(s)	0
INPUT GROUP: 18 -- Road Emissions Parameters		
NRD1	Number of road-links sources	0
NRD2	Number of road-links in RDEMARB.DAT file	0



Parameter	Description	Value
NSFRDS	Number of road-links and species combinations with variable emission-rate scale-factors	0
INPUT GROUP: 19 -- Emission Rate Scale-Factor Tables		
NSFTAB	Number of emissions scale-factor tables	7
INPUT GROUP: 20 -- Non-gridded (Discrete) Receptor Information		
NREC	Number of discrete receptors (non-gridded receptors)	2043
NRGRP	Number of receptor group names	0

APPENDIX E: GENERAL TERMS AND CONDITIONS

USE OF REPORT

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained in it are intended for the sole use of ARKTIS Solutions Inc.'s (ARKTIS) client. ARKTIS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than ARKTIS' client unless otherwise authorized in writing by ARKTIS. Any unauthorized use of the report is at the sole risk of the user.

LIMITATIONS OF REPORT

This report is based solely on the conditions which existed on site at the time of ARKTIS' investigation. The client, and any other parties using this report with the express written consent of the clients and ARKTIS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive.

The client, and any other party using this report with the express written consent of the client and ARKTIS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made.

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APPENDIX C AIR DISPERSION MODELLING FOR FINAL CLOSURE



DE BEERS CANADA INC., SNAP LAKE MINE AIR DISPERSION MODELLING FOR FINAL MINE CLOSURE

May 28, 2018

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EXECUTIVE SUMMARY

Air dispersion modelling was completed for the De Beers Canada Inc. (De Beers) Snap Lake Mine's (Mine) post-reclamation period of final Closure. A primary objective of the air dispersion modelling for Closure is to predict the concentrations of air borne particles of interest at the Mine after the active reclamation phase of the Mine has been completed. The air dispersion model will be used to predict Mine emissions to inform the air quality monitoring program during the post-reclamation period,

An air dispersion model was first used to predict Mine emissions as part of the environmental assessment report (EAR) (De Beers, 2002) using a steady-state (2D) version of the CALPUFF dispersion model. This model was updated in 2007 to reflect current technologies and Mine conditions (Golder, 2007). The model was updated further when the Mine went into Extended Care and Maintenance (ECM) to reflect the operations at the Mine at that time (ARKTIS, 2018). The air dispersion model utilized in this report uses the same dispersion modelling approach applied in the previously mentioned models, but incorporates the current Mine configuration and site activities that reflect the post-reclamation phase of the Mine. CALPUFF View (WebLakes, 2017), a software capable of executing the CALPUFF Modeling System using local geophysical and meteorological datasets, was utilized to complete the air dispersion modelling.

The air dispersion model predicted the maximum 1-hour, 24-hour, and annual concentrations of Sulphur Dioxide (SO₂), Nitrogen Dioxide (NO₂) and particulate matter less than 2.5 microns in diameter (PM_{2.5}) in the local study area (LSA) and regional study area (RSA). The LSA for the Mine included the Mine footprint surrounded by a 500 metre buffer. The RSA is the area within a 48 kilometre radius of the Mine. The concentrations of SO₂, NO₂, and PM_{2.5} were predicted to be below the applicable Northwest Territories standards and acceptable federal objectives (GNWT, 2014a; CCME, 2000; Environment and Climate Change Canada, 2013) in the RSA and the LSA.



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1.0 INTRODUCTION

ARKTIS Solutions Inc. (ARKTIS) was retained by De Beers Canada Inc. (De Beers) to complete an air dispersion model for the Snap Lake Mine (Mine) for the post-reclamation period of final Closure. The post-reclamation phase represents the time after active reclamation of the Mine components are complete. The air dispersion model will be used to predict Mine emissions to inform the air quality monitoring program during the post-reclamation period. The Post Closure phase air quality monitoring is outside the scope of this report and will be presented separately.

An air dispersion model was first used to predict Mine emissions during the environmental assessment process (De Beers, 2002) using a steady-state (2D) version of the CALPUFF dispersion model. This model was updated in 2007 to reflect current technologies and Mine conditions (Golder, 2007). The purpose of the 2002 and 2007 modelling was to:

- Evaluate the various emission source types present in the region;
- Predict the concentrations of select air quality species; and,
- Generate model predictions consistent with local observations.

It was predicted that during Mine operations, the Mine would comply with the applicable ambient air quality criteria (GNWT, 2014a; CCME, 2000; Environment and Climate Change Canada, 2013) outside the active Mine area for most emission sources.

The current modeling approach used in this assessment (herein referred to as the 2018 Closure model) is similar to the approach used during the Environmental Assessment (De Beers, 2002) and 2007 re-modelling (Golder, 2007), with a few exceptions:

- Removed buildings to represent post-reclamation Mine conditions;
- New or updated emission sources that reflect the post-reclamation period of final Closure;
- PRIME¹ building downwash algorithm; and,
- Updated meteorological dataset (2016).

The 2018 Closure model used the same air dispersion software (WebLakes, 2017), meteorological data, terrain data, and geophysical as the 2017 Extended Care and Maintenance (ECM) model (ARKTIS, 2018), which evaluated the ECM phase of the Mine. The 2018 Closure model simulates the atmospheric dispersion of select air quality species at the Mine (local study area, LSA) and a 48 kilometre radius outwards from the Mine (regional study area, RSA).

The layout of this report is as follows:

- Section 1 summarizes the purpose and scope of the current assessment;
- Section 2 details the input parameters that are applied to the 2018 Closure model;
- Section 3 presents the air quality predictions for the 2018 Closure model; and,
- Section 4 outlines the conclusions and recommendations from the study

2.0 MODEL INPUTS

CALMET and CALPUFF inputs for the 2018 Closure model were identical to the 2017 ECM model (ARKTIS, 2018) with the following exceptions:

- Omission of combustion emission sources because they are not present after active reclamation is completed;
- Fugitive dust emission rates; and,
- Seasonal emission rates.

Adjustments and alterations made from the 2017 ECM model (ARKTIS, 2018) are discussed below. For complete description of all model inputs, refer to the 2017 ECM model report (ARKTIS, 2018). Appendix C

¹ Plume Rise Model Enhancements (PRIME) is a Gaussian dispersion model which has been developed for plume rise and building downwash. PRIME considers the position of the stack relative to the building, streamline deflection near the building, and vertical wind speed shear and velocity deficit effects on plume rise (Schulman, 2000).

and Appendix D provide a summary of the CALMET and CALPUFF model inputs for the 2018 Closure model respectively.

2.1 Emissions

The CALPUFF air dispersion model uses emissions from various activities to create plume models of air borne particles of interest: particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), oxides of Nitrogen (NO_x), and Sulphur Dioxide (SO_2). The Mine emissions at final Closure are exclusively come from fugitive dust emissions. These are represented by an area source within the 2018 Closure model (Figure 1). Area sources are used to represent locations at the Mine which release emissions across a known area and are useful for representing natural erosion which occurs over a non-discrete location. The 2018 Closure model uses one area source to represent natural erosion that occurs across the disturbed footprint of the Mine for the post-reclamation period. The release of these emissions is measured in metric tonnes per square metre per year ($t/m^2/yr$). Due to model software limitations, the extent of the area sources applied in the model do not precisely align with the Mine disturbed areas. The area source in the 2018 Closure model is a conservative estimate of the sum of the disturbed areas at the Mine. As a result, the predictions of each particle of interest will yield a reasonable species load from the source to the air, and therefore the model is considered a reasonable approximation of the Mine.

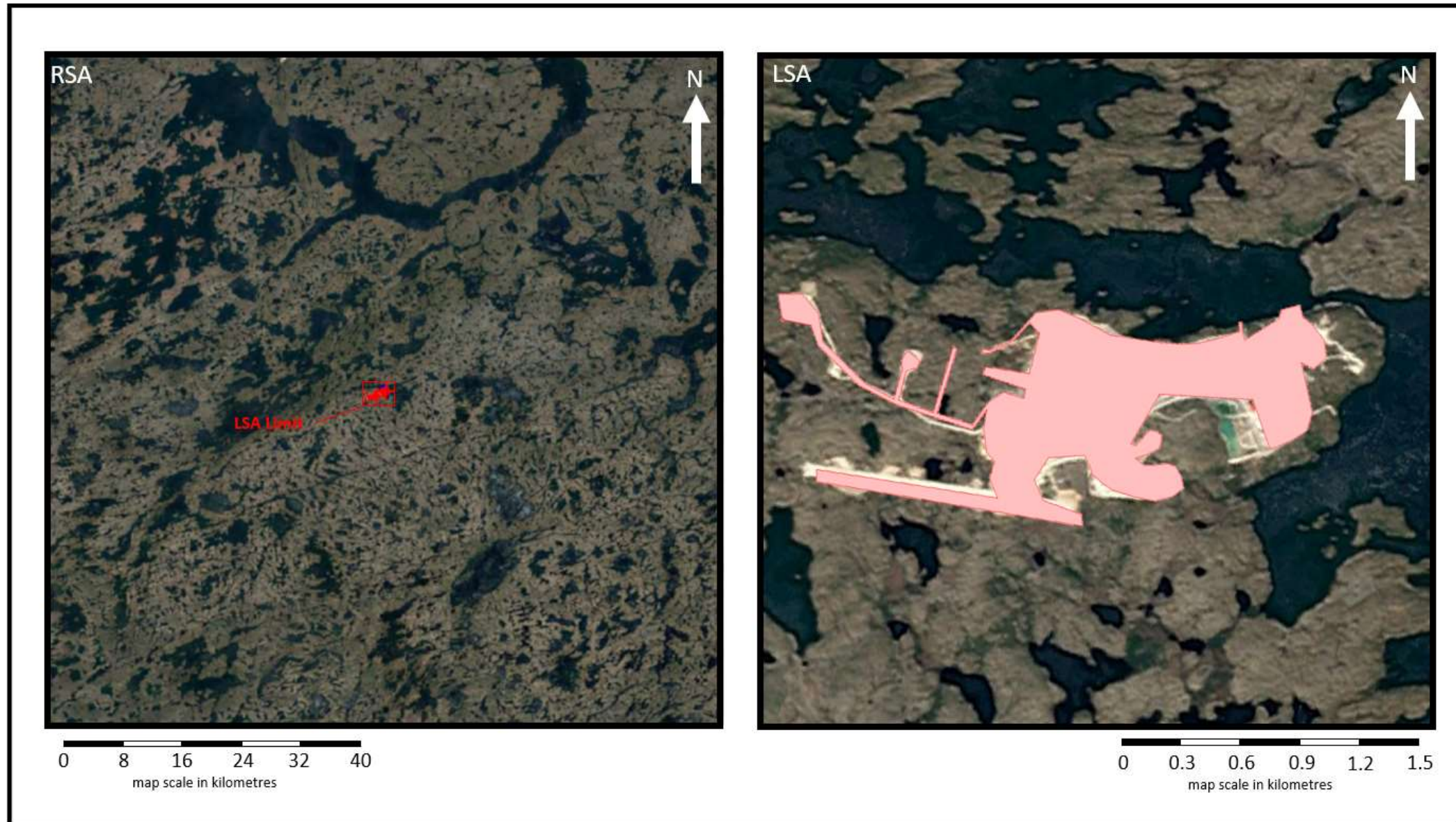


Figure 1. Emissions source implemented in the 2018 Closure model.

2.1.1 Emission Constituents and Rate Calculations

During the post-reclamation period, fugitive emissions are predicted to occur across the disturbed land at the Mine. Primary contributors to fugitive emissions at the Mine site post-reclamation include:

- North Pile;
- Infrastructure areas, such as the locations where buildings were located;
- Laydowns; and,
- Site roads.

To be conservative, the 2018 Closure model applied the same erosion rate (3.504×10^{-5} kg/m²/day) to all disturbed areas at the Mine. The selected erosion rate is the same as that applied to the North Pile in the 2017 ECM model (ARKTIS, 2018) and the 2007 updated air quality modelling (Golder, 2007) which represented fugitive emissions from exposed processed kimberlite (PK). The closure plan for the North Pile is to apply a rock cover to the surface; therefore, PK will not be exposed to wind erosion during the post-reclamation period. Additionally, infrastructure areas, laydowns and site roads are planned to either be covered with rock or will naturally revegetate. The existing surface materials for these areas are granular in size, not sand/PK size. Due to the larger grain size anticipated post-reclamation on the disturbed areas, it is conservative to apply erosion rate that is based on PK wind erosion. Further, no reduction in erosion rate for snow cover periods was applied to the model, thereby adding additional conservatism to the predictions.

Emission sources in the CALPUFF air dispersion model are defined using a series of properties unique to each source. The properties which define the rate and means of released emissions from the area source in the 2018 Closure model are summarized in Table 1. The 2018 Closure model also conservatively assumes no dust mitigations will occur in the Post Closure phase.

Table 1. Area source properties in the 2018 Closure model.

Source	Area Source Properties			Emission Rate (t/d)		
	Release Height (m)	Sigma (m)	Surface Area (ha)	PM _{2.5}	SO ₂	NO ₂
Mine Footprint	10 ^(a)	1	175.4 ^(b)	0.061	0	0

a) A release height of 10m was chosen as a conservative estimate to represent the effective height of the North Pile. This approach increases the range of dispersion that will occur in the 2018 Closure model.

b) Surface area of the area source is representative of the land altered at the Mine (163 ha) displayed in figure 1-4 of the 2014 Vegetation Monitoring Program Annual Report (Golder, 2015). The additional area is representative of the development that occurred for the West Cell post 2014.

A comparison of source emission rates applied within the EA air quality modelling (De Beers, 2002), 2007 updated air quality modelling (Golder, 2007), the 2017 ECM model (ARKTIS, 2018) and the 2018 Closure model is provided in Table 2. The SO₂ and NO₂ species were not included in the post-reclamation predictive modelling for their loadings were considered negligible for the anticipated activities that would occur at the Mine. In previous closure models (De Beers, 2002; Golder, 2007; ARKTIS, 2018), SO₂ and Nitrogen Dioxide (NO₂) emissions were generated combustion sources. The 2018 Closure model has no emission sources for SO₂ or NO₂ within the LSA or RSA. The post-reclamation activities are anticipated to be lower in magnitude than that experienced during the ECM phase. For example, the calculated mass of SO₂ and NO₂ generated in December 2017 (during ECM) was 0.003 and 8.53 tonnes, respectively. For a one month presence at the Mine during the post-reclamation phase, the SO₂ and NO₂ emissions are anticipated to be less than in December 2017, and thus, less than the National Pollutant Release Inventory reporting thresholds.

Table 2. Comparison of EAR (De Beers, 2002), re-modelling (Golder, 2007), 2017 ECM model (ARKTIS, 2018), and 2018 Closure model air dispersion model air emissions.

Emission Source	PM _{2.5} (t/d)				SO ₂ (t/d)				NO _x (t/d)			
	EA ^(a)	Updated Modelling ^(b)	ECM ^(c)	Closure ^(d)	EA ^(a)	Updated Modelling ^(b)	ECM ^(c)	Closure ^(d)	EA ^(a)	Updated Modelling ^(b)	ECM ^(c)	Closure ^(d)
Main Generator	0.052	0.051	0.018	0	0.057	0.085	6.0x10 ⁻⁴	0	3.58	6.215	1.22	0
Auxiliary Generator	N/A	N/A	5.3x10 ⁻⁵	0	N/A	N/A	1.7x10 ⁻⁶	0	N/A	N/A	0.004	0
Incinerator	0.004	0.016	0.002	0	0	0.127	2.5x10 ⁻⁴	0	0.001	0.182	0.023	0
Glycol Boiler	N/A	0.004	0.002	0	N/A	0.016	0.008	0	N/A	0.078	0.039	0
Aggregate Crushing Plant	0.001	0.002	0.002	0	0	0	0	0	0	0	0	0
Quarry Activities	0.007	0.001	0.001	0	0.001	0	0	0	0.011	0	0	0
Surface Fleet	N/A	0.015	0.033	0	0.037	0.01	0.1	0	1.56	0.20	0.20	0
Quarry Vehicles	0.014	0.001	N/A	0	0.01	0.001	N/A	0	0.20	0.001	N/A	0
Airstrip	N/A	N/A	2.5x10 ⁻³	0	N/A	N/A	0	0	N/A	N/A	0	0
Road Dust	N/A	0.007	0 ^(e)	0	N/A	0	0	0	N/A	0	0	0
North Pile	0.002	0.003	0.019	0	0	0	0	0	0	0	0	0
Disturbed Footprint	0	0	0	0.061 (f)	0	0	0	0	0	0	0	0

a) Source: De Beers, 2002

b) Source: Golder, 2007

c) Source: ARKTIS, 2018

d) Emissions of 2018 Closure model

e) Road Dust emissions from the 2017 ECM model are accounted for in the Surface Fleet emissions.

f) Closure emissions are represented by a single area source which represents natural erosion across the disturbed footprint at the Mine.

3.0 2018 CLOSURE MODEL RESULTS

The 2018 Closure model predicted the PM_{2.5}, NO₂ and SO₂ concentrations within the LSA and RSA. The predicted plume extents are presented in Appendix A. A comparison of the predicted concentrations to applicable criteria are presented in Tables 3 to 5, overall conclusions from the analysis are as follows:

- The 2018 Closure model predictions (Table 3) for PM_{2.5} concentrations do not exceed the applicable NWT standards during the Post Closure phase.
- The 2018 Closure model predictions for NO₂ (Table 4) and SO₂ (Table 5) do not exceed the applicable NWT standards during closure operations.

Table 3. PM_{2.5} 2018 Closure model predictions.

Monitoring Area	1-hour max	24-hour max	Annual max
LSA (Gridded Receptors)			
Maximum PM _{2.5} Concentration (µg/m ³)	57.3	23.3	2.82
Occurrences Above the NWT Standard	-	0	0
RSA Excluding LSA (Gridded Receptors)			
Maximum PM _{2.5} Concentration (µg/m ³)	14.5	4.6	0.073
Occurrences Above the NWT Standard	-	0	0
Relevant PM_{2.5} Criteria (µg/m³)	-	28	10

Table 4. NO₂ 2018 Closure model predictions.

Monitoring Area	1-hour max	24-hour max	Annual max
LSA (Gridded Receptors)			
Maximum NO ₂ Concentration (µg/m ³)	0	0	0
Maximum NO _x Concentration (µg/m ³)	0	0	0
Occurrences Above the NWT Standard	0	0	0
RSA Excluding LSA (Gridded Receptors)			
Maximum NO ₂ Concentration (µg/m ³)	0	0	0
Maximum NO _x Concentration (µg/m ³)	0	0	0
Occurrences Above the NWT Standard	0	0	0
Relevant NO₂ Criteria (µg/m³)	400	200	60

Table 5. SO₂ 2018 Closure model predictions.

Monitoring Area	1-hour max	24-hour max	Annual max
LSA (Gridded Receptors)			
Maximum SO ₂ Concentration (µg/m ³)	0	0	0
Occurrences Above the NWT Standard	0	0	0
RSA Excluding LSA (Gridded Receptors)			
Maximum SO ₂ Concentration (µg/m ³)	0	0	0
Occurrences Above the NWT Standard	0	0	0
Relevant SO₂ Criteria (µg/m³)	450	150	30

4.0 CONCLUSIONS

The results of the 2018 Closure model were produced using the best available meteorological, geophysical and emissions data for the Snap Lake Mine. Emissions applied to the North Pile, Quarry, Road Dust, and Airstrip were conservatively selected to represent a worst case scenario and therefore over-predict the closure emissions. The findings from the 2018 Closure model will be used to inform the Post Closure air quality monitoring at the Mine.

The air quality model predicted the PM_{2.5}, NO₂, and SO₂ emissions in the LSA and RSA. The main conclusions of 2018 Closure model predictions were:

1. Maximum 1-hour, 24-hour and annual concentrations of SO₂, NO₂, and PM_{2.5} are less than the applicable NWT standards and acceptable federal objectives in the RSA, and LSA; and,
2. Plume dispersion at the Mine is contained within the RSA.

5.0 CLOSING

This report has been prepared exclusively for the use of De Beers Canada for the specific application described within this report. The details provided in this report are for general information purposes only. The information and recommendations contained in this report should not be used for any other purpose, at another location, or by any other parties. Any use of, or reliance on this report by any third party is at that party's sole risk. ARKTIS assumes no responsibility for inappropriate use of the contents of this report, and disclaims all liability arising from negligence or otherwise. General terms and conditions are provided in Appendix E.

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APPENDIX A: PLUME DISPERSION OF MODELLED SPECIES

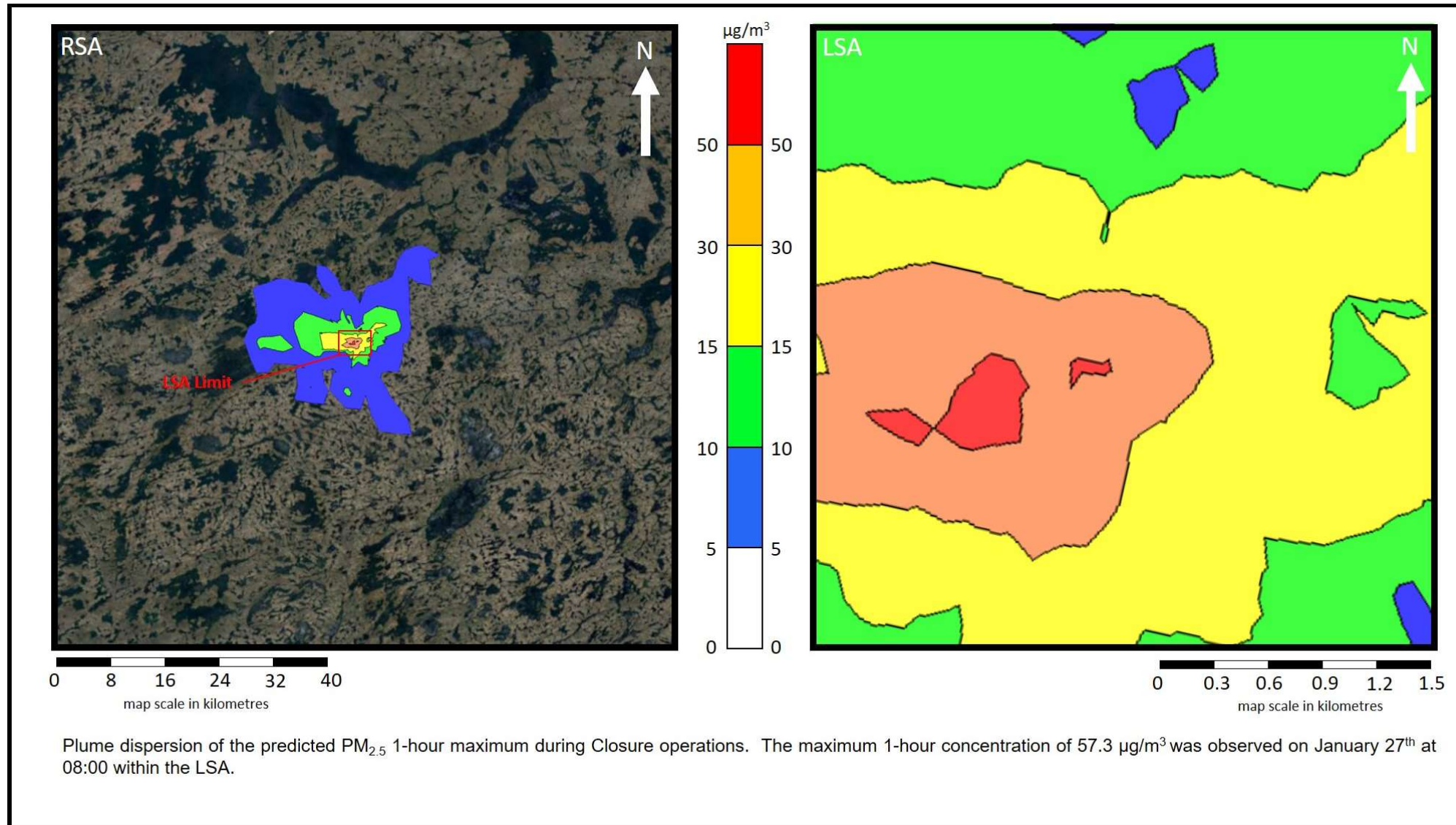


Figure A - 1. Predicted plume dispersion of the 1-hour maximum concentration of $\text{PM}_{2.5}$ in the 2018 Closure model as seen from the RSA (left) and LSA (right).

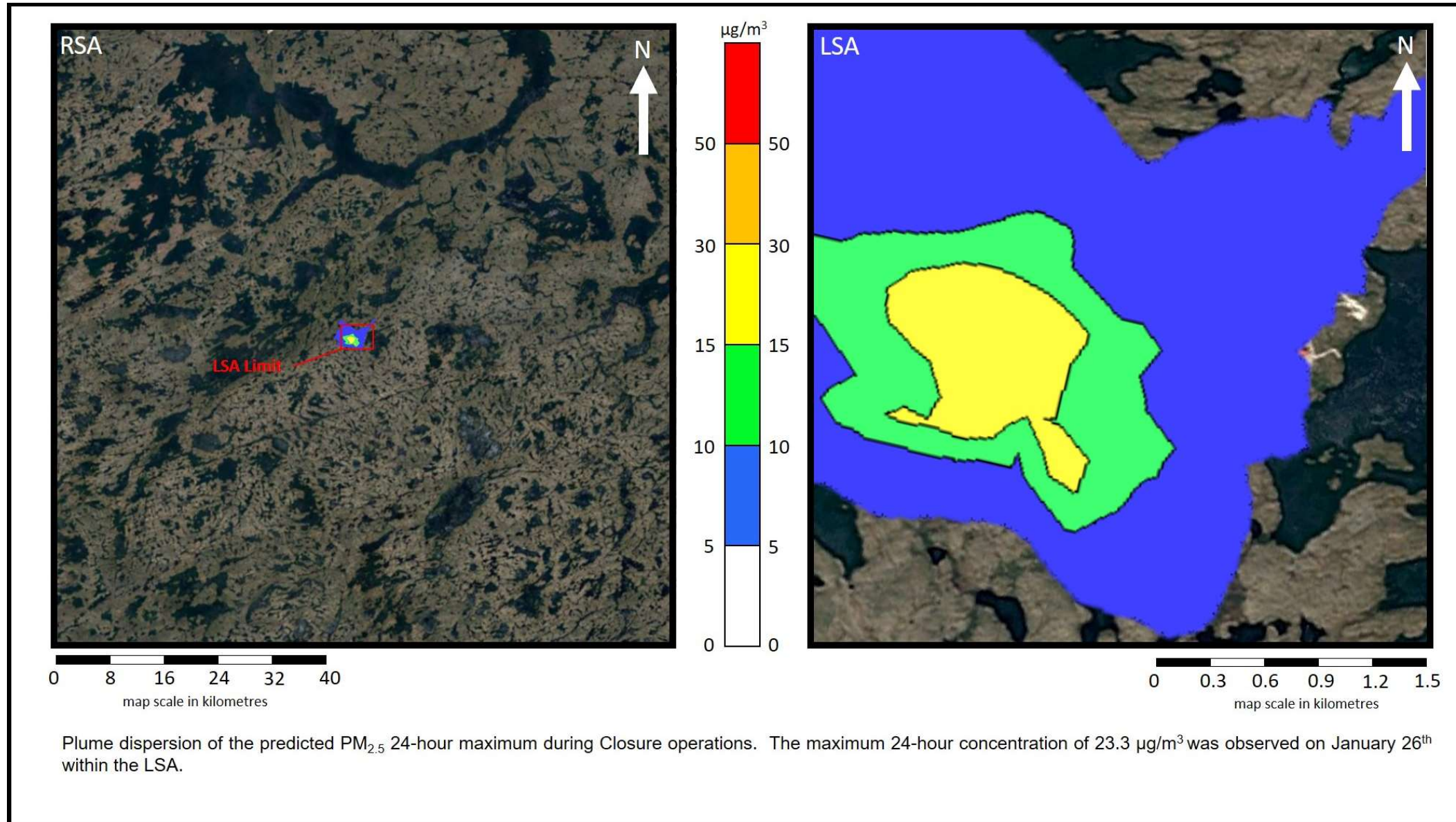


Figure A - 2. Predicted plume dispersion of the 24-hour maximum concentration of $\text{PM}_{2.5}$ in the 2018 Closure model as seen from the RSA (left) and LSA (right).

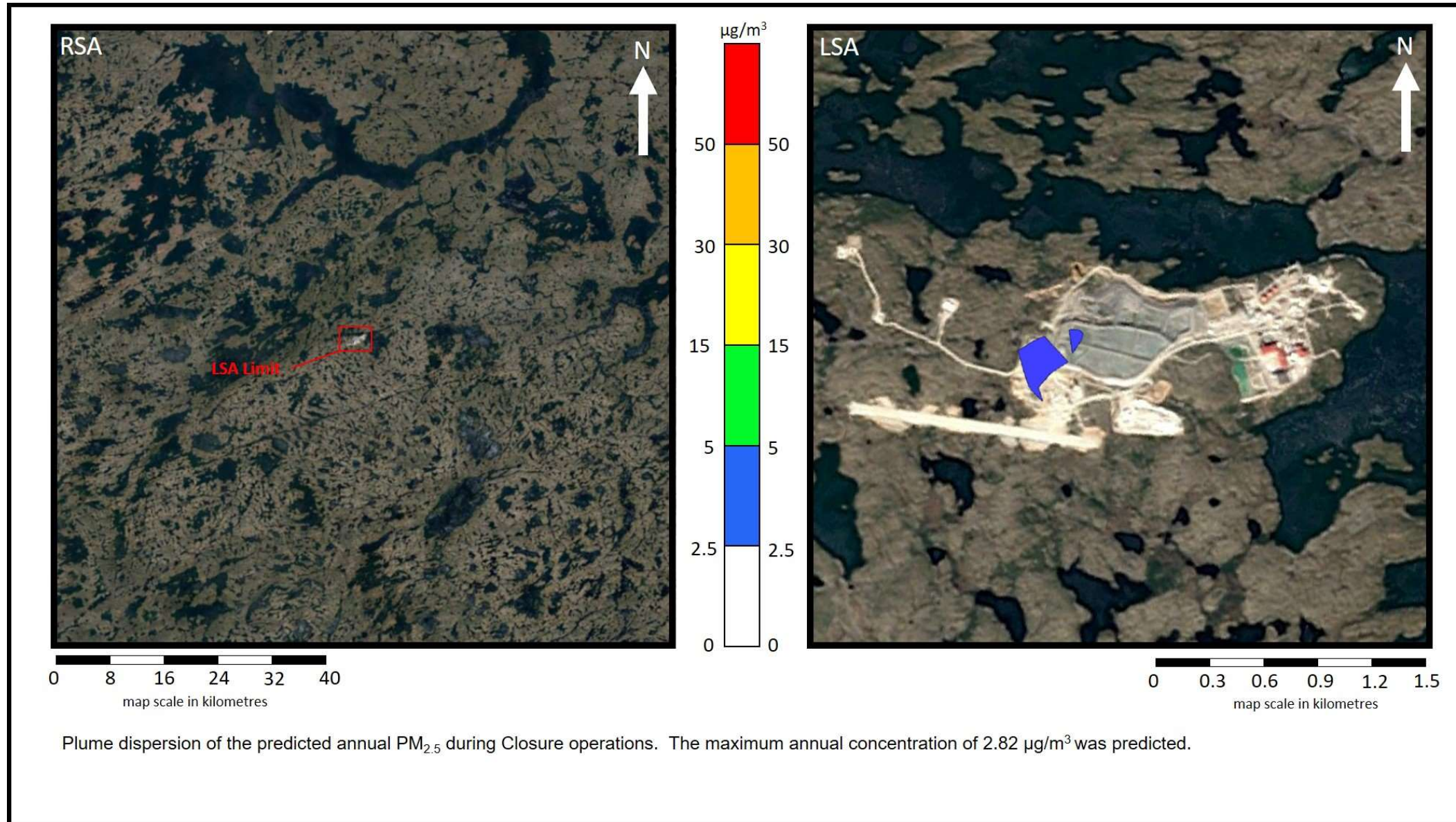


Figure A - 3. Predicted plume dispersion of the annual concentration of PM_{2.5} in the 2018 Closure model as seen from the RSA (left) and LSA (right).

APPENDIX B: TERMS AND DEFINITIONS

Term	Definition
CALMET	Air dispersion module for creating wind fields
CALPUFF	Air dispersion software for plume dispersion predictions
EA	Environmental assessment
EAR	Environmental assessment report
ECCC	Environment and Climate Change Canada
ECM	Extended Care and Maintenance
K	Degrees Kelvin
LSA	Local study area
m	Metres
m ²	Squared metres
m ³	Cubic metres
m/s	Metres per second
NWT	Northwest Territories
NO	Nitrogen monoxide
[NO]	Concentration of nitrogen monoxide
NO ₂	Nitrogen dioxide
NO _x	Oxides of nitrogen
[NO _x]	Concentration of oxides of nitrogen
[O ₂]	Concentration of oxygen molecule
O ₃	Ozone molecule
[O ₃]	Concentration of ozone
OLM	Ozone limiting method
PM _{2.5}	Particulate matter smaller than 2.5 µg aerodynamic diameter
PM ₁₀	Particulate matter smaller than 10 µg aerodynamic diameter
ppb	Parts per billion
ppm	Parts per million
RSA	Regional study area
SO ₂	Sulphur dioxide
t/d	Metric tonnes per day
t/m ² /yr	Tonnes per square metre per year
t/yr	Tones per year
TSP	Total suspended particulate
µg	Micrograms
µg/m ³	Micrograms per cubic metre

APPENDIX C: CALMET INPUT PARAMETERS

Parameter	Description	Value
INPUT GROUP: 0 -- Input and Output File Names		
GEODAT	Input file of geophysical data (GEO.DAT)	GEO.DAT
SRFDAT	Input file of hourly surface meteorological data (SURF.DAT)	SURF.DAT
METLST	Output file name of CALMET list file (CALMET.LST)	CALMET.LST
METDAT	Output file name of generated gridded met files (CALMET.DAT)	CALMET.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NUSTA	Number of upper air stations	1
NOWSTA	Number of overwater stations	0
NM3D	Number of prognostic meteorological data files (3D.DAT)	0
NIGF	Number of IGF-CALMET.DAT files used as initial guess	0
UPDATE	Input file of upper air sounding data (UPn.DAT)	UP_26118.DAT
INPUT GROUP: 1 -- General Run Control Parameters		
IBYR	Starting year	2016
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBSEC	Starting second	0
IEYR	Ending year	2016
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC-0600
NSECDT	Length of modeling time-step (seconds)	3600
IRTYPE	Output run type (0 = wind fields only, 1 = CALPUFF/CALGRID)	1
LCALGRD	Compute CALGRID data fields (T = true, F = false)	T
ITEST	Flag to stop run after setup phase (1 = stop, 2 = run)	2
MREG	Regulatory checks (- = no checks, 1 = US EPA LRT checks)	0
INPUT GROUP: 2 -- Map Projection and Grid Control Parameters		
IUTMZN	UTM zone (1 to 60)	12
UTMHEM	Hemisphere of UTM projection (N = northern, S = southern)	N
XLAT1	1st standard parallel latitude (decimal degrees)	30N
XLAT2	2nd standard parallel latitude (decimal degrees)	60N
DATUM	Datum-Region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	100
NY	Meteorological grid - number of Y grid cells	100
DGRIDKM	Meteorological grid spacing (km)	1
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	456.6134
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	7003.0682
NZ	Meteorological grid - number of vertical layers	10

Parameter	Description	Value
ZFACE	Meteorological grid - vertical cell face heights (m)	0, 20, 40, 80, 100, 250, 500, 900, 1300, 1750, 2300
INPUT GROUP: 3 -- Output Options		
LSAVE	Save met fields in unformatted output file (T = true, F = false)	T
IFORMO	Type of output file (1 = CALPUFF/GALGRID, 2 = MESOPUFF II)	1
LPRINT	Print met fields (F = false, T = true)	F
IPRINF	Print interval for output wind fields (hours)	1
STABILITY	Print gridded PGT stability classes? (0 = no, 1 = yes)	0
USTAR	Print gridded friction velocities (0 = no, 1 = yes)	0
MONIN	Print gridded Monin-Obukhov lengths? (0 = no, 1 = yes)	0
MIXHT	Print gridded mixing heights? (0 = no, 1 = yes)	0
WSTAR	Print gridded convective velocity scales (0 = no, 1 = yes)	0
PRECIP	Print gridded hourly precipitation rates? (0 = no, 1 = yes)	0
SENSHEAT	Print gridded sensible heat fluxes? (0 = no, 1 = yes)	0
CONVZI	Print gridded convective mixing heights? (0 = no, 1 = yes)	0
LDB	Test/debug option: print input met data and internal variables (F = false, T = true)	T
NM1	Test/debug option: first time step to print	1
NM2	Test/debug option: last time step to print	3
LDBCST	Test/debug option: print distance to land internal variables (F = false, T = true)	F
IOUTD	Test/debug option: print control variables for writing winds? (0 = no, 1 = yes)	0
NZPRN2	Test/debug option: number of levels to print starting at the surface	1
IPR0	Test/debug option: print interpolated winds? (0 = no, 1 = yes)	0
IPR1	Test/debug option: print terrain adjusted surface wind? (0 = no, 1 = yes)	0
IPR2	Test/debug option: print smoothed wind and initial divergence fields? (0 = no, 1 = yes)	0
IPR3	Test/debug option: print final wind speed and direction? (0 = no, 1 = yes)	0
IPR4	Test/debug option: print final divergence fields? (0 = no, 1 = yes)	0
IPR5	Test/debug option: print winds after kinematic effects? (0 = no, 1 = yes)	0
IPR6	Test/debug option: print winds after Froude number adjustment? (0 = no, 1 = yes)	0
IPR7	Test/debug option: print winds after slope flow? (0 = no, 1 = yes)	0
IPR8	Test/debug option: print final winds? (0 = no, 1 = yes)	0
INPUT GROUP: 4 -- Meteorological Data Options		
NOOBS	Observation mode (0 = stations only, 1 = surface/overwater stations with prognostic upper air, 2 = prognostic data only)	0
NSSTA	Number of surface stations	2
NPSTA	Number of precipitation stations	0

Parameter	Description	Value
ICLDOUT	Output the CLOUD.DAT file? (0 = no, 1 = yes)	0
MICLOUD	Method to compute cloud fields (1 = from surface obs, 2 = from CLOUD.DAT, 3 = from prognostic (Teixera), 4 = from prognostic (MM5toGrads)	3
IFORMS	Surface met data file format (1 = unformatted, 2 = formatted)	2
IFORMP	Precipitation data file format (1 = unformatted, 2 = formatted)	2
IFORMC	Cloud data file format (1 = unformatted, 2 = formatted)	1
INPUT GROUP: 5 -- Wind Field Options and Parameters		
IWFCOND	Wind field model option (1 = objective analysis, 2 = diagnostic)	1
IFRADJ	Adjust winds using Froude number effects? (0 = no, 1 = yes)	1
IKINE	Adjust winds using kinematic effects? (0 = no, 1 = yes)	0
IOBR	Adjust winds using O'Brien velocity procedure? (0=no, 1 = yes)	0
ISLOPE	Compute slope flow effects? (0 = no, 1 = yes)	1
IEXTRP	Extrapolation of surface winds to upper layers method (1 = none, 2 = power law, 3 = user input, 4 = similar theory, - = same except layer 1 data at upper air stations are ignored)	-4
ICALM	Extrapolate surface winds even if calm? (0 = no, 1 = yes)	0
BIAS	Weighting factors for surface and upper air stations (NZ values)	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
RMIN2	Minimum upper air station radius of influence for surface extrapolation exclusion (km)	4
IIPROG	Use prognostic winds as input to diagnostic wind model (0 = no, 13 = use winds from 3D.Dat as Step 1 field, 14 = use winds from 3D.Dat as initial guess field, 15 = use winds from 3DDat file as observations)	0
ISTEPPGS	Prognostic data time step (seconds)	3600
IGFMET	Use coarse CALMET fields as initial guess? (0 = no, 1 = yes)	0
LVARY	Use varying radius of influence (F = false, T = true)	F
RMAX1	Maximum radius of influence in the surface layer (km)	50
RMAX2	Maximum radius of influence over land aloft (km)	100
RMAX3	Maximum radius of influence over water (km)	0
RMIN	Minimum radius of influence used in wind field interpolation (km)	0.1
TERRAD	Radius of influence of terrain features (km)	7
R1	Relative weight at surface of step 1 fields and observations (km)	30
R2	Relative weight aloft of step 1 field and observations (km)	30
RPROG	Weighting factors of prognostic wind field data (km)	0
DIVLIM	Maximum acceptable divergence	5x10 ⁻⁶
NITER	Maximum number of iterations in the divergence minimization procedure	50
NSMTH	Number of passes in the smoothing procedure (NZ values)	2, 9*4
NINTR2	Maximum number of stations used in each layer for interpolation (NZ values)	10*99
CRITFN	Critical Froude number	1
APHA	Empirical factor triggering kinematic effects	0.1

Parameter	Description	Value
NBAR	Number of barriers to interpolation of the wind fields	0
KBAR	Barrier - level up to which barriers apply (1 to NZ)	10
IDIOPT1	Surface temperature (0 = computer from obs/prognostic, 1 = read from DIAG.DAT)	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	-1
IDIOPT2	Temperature lapse rate used in the computation of terrain-induced circulations (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPT	Upper air station to use for the domain-scale lapse rate (between 1 and NUSTA)	-1
ZUPT	Depth through which the domain-scale lapse rate is computer (m)	200
IDIOPT3	Initial guess field winds (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPWND	Upper air station to use for domain-scale winds	-1
ZUPWND	Bottom and top of layer through which the domain-scale winds are computed (m)	1,1
IDIOPT4	Read observed surface wind components (0 = from SURF.DAT, 1 = from DIAG.DAT)	0
IDIOPT5	Read observed upped wind components (0 = from Upn.DAT, 1 = from DIAG.DAT)	0
LLBREZE	Use Lake Breeze module (T = true F = false)	F
NBOX	Lake Breeze - number of regions	0
INPUT GROUP: 6 -- Mixing Height, Temperature, and Precipitation Parameters		
CONSTB	Mixing height constant: neutral, mechanical equation	1.41
CONSTE	Mixing height constant: convective equation	0.15
CONSTN	Mixing height constant: stable equation	2400
CONSTW	Mixing height constant: overwater equation	0.16
FCORIOL	Absolute value of Coriolis parameter (1/s)	0.0001
IAVEZI	Spatial mixing height averaging? (0 = no, 1 = yes)	1
MNMDAV	Maximum search radius in averaging process (grid cells)	1
HAFANG	Half-angle of upwind looking cone for averaging (degrees)	30
ILEVZI	Layer of winds used in upwind averaging (between 1 and NZ)	1
IMIXH	Convective mixing height method (1 = Maul-Carson, 2 = Batchvarova-Gryning, - for land cells only, + for land and water cells)	1
THRESHL	Overland threshold boundary flux (W/m ³)	0.05
THRESHW	Overwater threshold boundary flux(W/m ³)	0.05
ITWPROG	Overwater lapse rate and deltaT options (0 = from SEA.DAT, 1 = use prognostic lapse rates and SEA.DAT deltaT, 2 = from prognostic)	0
ILUOC3D	Land use category in 3D.Dat	16
DPTMIN	Minimum potential temperature lapse rate (K/m)	0.001
DZZI	Depth of computing capping lapse rate (m)	200
ZIMIN	Minimum overland mixing height (m)	50
ZIMAX	Maximum overland mixing height (m)	3000
ZIMINW	Minimum overwater mixing height (m)	50
ZIMAXW	Maximum overwater mixing height (m)	3000



Parameter	Description	Value
ICOARE	Overwater surface fluxes method	10
DSHELF	Coastal/shallow water length scale (km)	0
IWARM	COARE warm layer computation (0 = off, 1 = on)	0
ICOOL	COARE cool skin layer computation (0 = off, 1 = on)	0
IRHPROG	Relative humidity read option (0 = from SURF.DAT, 1 = from 3D.DAT)	0
ITPROG	3D temperature read option (0 = station, 1 = surface from station and upper air from prognostic, 2 = prognostic)	0
IRAD	Temperature interpolation type (1 = 1/R, 2 = 1/R ²)	1
TRADKM	Temperature interpolation radius of influence (km)	500
NUMTS	Maximum number of stations to include in temperature interpolation	5
IAVET	Conduct spatial averaging of temperatures? (0 = no, 1 = yes)	1
TGDEFB	Default overwater mixed layer lapse rate (K/m)	-0.0098
TGDEFA	Default overwater capping lapse rate (K/m)	-0.0045
JWAT1	Beginning land use category for temperature interpolation over water	999
JWAT2	Ending land use category for temperature interpolation over water	999
NFLAGP	Precipitation interpolation method (1 = 1/R, 2 = 1/R ² , 3 = EXP/R ²)	2
SIGMAP	Precipitation interpolation radius of influence (km)	100
CUTP	Minimum precipitation rate cut-off (mm/hr)	0.01

APPENDIX D: CALPUFF INPUT PARAMETERS

Parameter	Description	Value
INPUT GROUP: 0 -- Input and Output File Names		
PRFDAT	CTDM/AERMET-type meteorological profile data file	PROFILE.DAT
PUFLST	CALPUFF output list file (CALPUFF.LST)	CALPUFF.LST
CONDAT	CALPUFF output concentration file (CONC.DAT)	CONC.DAT
DFDAT	CALPUFF output dry deposition flux file (DFLX.DAT)	DFLX.DAT
WFDAT	CALPUFF output wet deposition flux file (WFLX.DAT)	WFLX.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NMETDOM	Number of CALMET.DAT domains	2
NMETDAT	Number of CALMET.DAT input files	2
NPPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
DOMAIN1	CALMET Domain #n (if NMETDOM > 1)	Outermost or Single Domain
DOMAIN2	CALMET Domain #n (if NMETDOM > 1)	Mine
METDAT1	CALMET gridded meteorological data file	CALMET.DAT
METDAT2	CALMET gridded meteorological data file	CALMET.DAT
INPUT GROUP: 1 -- General Run Control Parameters		
METRUN	Run all periods in met data file? (0 = no, 1 = yes)	0
IBYR	Starting year	2016
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBSEC	Starting second	0
IEYR	Ending year	2016
IEMO	Ending month	12
IEDY	Ending day	30
IEHR	Ending hour	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC-0600
NSECDT	Length of modeling time-step (seconds)	3600
NSPEC	Number of chemical species to be modeled	4
NSECDT	Number of chemical species to be emitted	1
ITEST	top run after SETUP phase (1 = stop, 2 = run)	2
MRESTART	Control option to read and/or write model restart data	0
NRESPD	Number of periods in restart cycle	0
METFM	Meteorological data format (1 = CALMET, 2 = ISC, 3 = AUSPLUME, 4 = CTDM, 5 = AERMET)	1

Parameter	Description	Value
MPRFFM	Meteorological profile data format (1 = CTDM, 2 = AERMENT)	1
AVET	Averaging time (minutes)	60
PGTIME	PG Averaging time (minutes)	60
IOUTU	Output units for binary output files (1 = mass, 2 = odour, 3 = radiation)	1
INPUT GROUP: 2 -- Technical Options		
MGAUSS	Near field vertical distribution (0 = uniform, 1 = Gaussian)	1
MCTADJ	Terrain adjustment method (0 = none, 1 = ISC-type, 2 = CALPUFF-type, 3 = partial plume path)	3
MCTSG	Model subgrid-scale complex terrain? (0 = no, 1 = yes)	0
MSLUG	Near-field puffs modeled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	2
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modeled, 1 = MESOPUFF II, 2 = User-specified, 3 = RIVAD/ARM3, 4 = MESOPUFF II for OH, 5 = half-life, 6 = RIVAD w/ISORROPIA, 7 = RIVA w/ISORROPIA CalTech SOA)	0
MAQCHEM	Model aqueous phase transformation? (0 = no, 1 = yes)	0
MLWC	Liquid water content flag	1
MWET	Model wet removal? (0 = no, 1 = yes)	0
MDRY	Model dry deposition? (0 = no, 1 = yes)	0
MTILT	Model gravitational settling (plume tilt)? (0 = no, 1 = yes)	0
MDISP	Dispersion coefficient calculation method (1= PROFILE.DAT, 2 = Internally, 3 = PG/MP, 4 = MESOPUFF II, 5 = CTDM)	3
MTURBVW	Turbulence characterization method (only if MDISP = 1 or 5)	3
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	Advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	0
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	0
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0
MBCON	Boundary conditions modeled? (0 = no, 1 = use BCON.DAT, 2 = use CONC.DAT)	0

Parameter	Description	Value
MSOURCE	Save individual source contribution? (0 = no, 1 = yes)	0
MFOG	Enable FOG model output? (0 = no, 1 = yes - PLUME mode, 2 = yes - RECEPTOR mode)	0
MREG	Regulatory checks (0 = no checks, 1 = USE PA LRT checks)	0
INPUT GROUP: 3 -- Species list		
CSPEC	Species included in model run	PM2.5
CSPEC	Species included in model run	PM10
CSPEC	Species included in model run	SO2
CSPEC	Species included in model run	NOX
INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
PMAP	Map projection system	UTM
FEAST	False easting at projection origin (km)	0
FNORTH	False northing at projection origin (km)	0
IUTMZN	UTM zone (1 to 60)	12
UTMHEM	Hemisphere (N = northern, S = southern)	N
RLAT0	Latitude of projection origin (decimal degrees)	0.00N
RLON0	Longitude of projection origin (decimal degrees)	0.00E
XLAT1	1st standard parallel latitude (decimal degrees)	30N
XLAT2	2nd standard parallel latitude (decimal degrees)	60N
DATUM	Datum-region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	100
NY	Meteorological grid - number of Y grid cells	100
NZ	Meteorological grid - number of vertical layers	10
DGRIDKM	Meteorological grid spacing (km)	1
ZFACE	Meteorological grid - vertical cell face heights (m)	0, 20, 40, 80, 100, 250, 500, 900, 1300, 1750, 2300
XORIGKM	Meteorological grid - X coordinate for SW corner	456.6134
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	7003.0682
IBCOMP	Computational grid - X index of lower left corner	1
JBCOMP	Computational grid - Y index of lower left corner	1
IECOMP	Computational grid - X index of upper right corner	100
JECOMP	Computational grid - Y index of upper right corner	100
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	T
IBSAMP	Sampling grid - X index of lower left corner	1
JBSAMP	Sampling grid - Y index of lower left corner	1
IESAMP	Sampling grid - X index of upper right corner	100
JESAMP	Sampling grid - Y index of upper right corner	100
MESHDN	Sampling grid - nesting factor	1
INPUT GROUP: 5 -- Output Options		
ICON	Output concentrations to CONC.DAT? (0 = no, 1 = yes)	1
IDRY	Output dry deposition fluxes to DFLX.DAT? (0 = no, 1 = yes)	0
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	0

Parameter	Description	Value
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
LCOMPRS	Use data compression in output file (T = true, F = false)	T
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	0
IPRFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2= yes use sampling step)	0
IMFLX	output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g., 3 = $\mu\text{g}/\text{m}^3$ - $\mu\text{g}/\text{m}^2$, 5 = odor units)	3
IMESG	Message tracking run progress on screen (0 = no, 1 and 2 = yes)	2
LDEBUG	Enable debug output? (0 = no, 1= yes)	F
IPFDEB	First puff to track in debug output	1
NPFDEB	Number of puffs to track in debug output	1000
NN1	Starting meteorological period in debug output	1
NN2	Ending meteorological period in debug output	10
INPUT GROUP: 6 -- Subgrid Scale Complex Terrain Inputs		
NHILL	Number of terrain features	0
NCTREC	Number of special complex terrain receptors	0
MHILL	Terrain and CTSG receptor data format (1 = CTDM, 2 = OPTHILL)	2
XHILL2M	Horizontal dimension conversion factor to metres	1
ZHILL2M	Vertical dimension of conversion factor to metres	1
XCTDMKM	X origin of CTDM system relative to CALPUFF system (km)	0
YCTDMKM	Y origin of CTDM system relative to CALPUFF system (km)	0
INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
RCUTR	Reference cuticle resistance (s/cm)	30
RGR	Reference ground resistance (s/cm)	10
REACTR	Reference pollutant reactivity	8
NINT	Number of particle size intervals for effective particle deposition velocity	9
IVEG	Vegetation state in unirrigated areas (1 = active and unstressed, 2 = active and stressed, 3= inactive)	1
INPUT GROUP: 11 -- Chemistry Parameters		
MOZ	Ozone background input option (0 = monthly, 1 = hourly from OZONE.DAT)	1

Parameter	Description	Value
BCKO3	Monthly ozone concentrations (ppb)	80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80
MNH3	Ammonia background input option (0 = monthly, 1 = from NH3Z.DAT)	0
MAVGNH3	Ammonia vertical averaging option (0 = no averaging, 1 = average over vertical extend of puff)	1
BCKNH3	Monthly ammonia concentrations (ppb)	10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10
RNITE1	Nighttime SO ₂ loss rate (%/hr)	0.2
RNITE2	Nighttime NO _x loss rate (%/hr)	2
RNITE3	Nighttime HNO ₃ loss rate (%/hr)	2
MH202	H ₂ O ₂ background input option (0 = monthly, 1 = hourly from H ₂ O ₂ .DAT)	1
BCKH202	Monthly H ₂ O ₂ concentrations (ppb)	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
RH_ISRP	Minimum relative humidity for ISORROPIA	50
SO4_SIRP	Minimum SO ₄ for ISORROPIA	0.4
BCKPMF	SOA background fine particulate (µg/m ³)	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
OFRAC	SOA organic fine particulate fraction	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15
VCNX	SOA VOC/NO _x ratio	50, 50, 50, 50, 50, 50, 50, 50, 50, 50, 50, 50
NDECAY	Half-life decay blocks	0
INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
SYTDEP	Horizontal puff size for time-dependent sigma equations (m)	550
MHFTSZ	Use Heffter equation for sigma-z? (0 = no, 1 = yes)	0
JSUP	PG stability class above mixed layer	5
CONK1	Vertical dispersion constant - stable conditions	0.01
CONK2	Vertical dispersion constant - neutral/unstable conditions	0.1
TBD	Downwash scheme transition point option (<0 = Huber-Snyder, 1.5 = Schulman-Scire, 0.5 = ISC)	0.5
IURB1	Beginning land use category for which urban dispersion is assumed	10
IURB2	Ending land use category for which urban dispersion is assumed	19
ILANDUIN	Land use category for modeling domain	20
Z0IN	Roughness length for modeling domain (m)	0.25
XLAIIN	Leaf area index for modeling domain	3
ELEVIN	Elevation above sea level (m)	0
XLATIN	Meteorological station latitude (deg)	-999
XLONIN	Meteorological station longitude (deg)	-999
ANEMHT	Anemometer height (m)	10
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1

Parameter	Description	Value
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XXLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs released from one source during on time step	99
MXSAM	Maximum number of sampling steps for one puff/slug during on time step	99
NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise	2
SYMIN	Minimum sigma-y for a new puff/slug (m)	1
SZMIN	Minimum sigma-z for a new puff/slug (m)	1
SZCAP_M	maximum sigma-z allowed to avoid numerical problem in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factors temperature categories (K)	265, 270, 275, 280, 285, 290, 295, 300, 205, 310, 315
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PLG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
IRESPLIT	Hour for puff re-split	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0
ZISPLIT	Minimum mixing height for splitting (m)	100
ROLDMAX	Mixing height ratio for splitting	0.25
NSPLITH	Number of puffs created from horizontal splitting	5
SYSPLITH	Minimum sigma- (met grid cells)	1
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr)	2
CNSPLITH	Minimum concentration (g/m ³)	0
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001

Parameter	Description	Value
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1x10 ⁻⁶
DSRISE	Trajectory step-length for numerical rise integration (m)	1
HTMINBC	Minimum boundary condition puff height (m)	500
RESAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1
INPUT GROUP: 13 -- Point Source Parameters		
NPT1	Number of point sources	0
IPTU	Units used for point source emissions (e.g., 1 = g/s)	7
NSPT1	Number of source-species combinations with variable emission scaling factors	0
NSPT2	Number of point sources in PTEMARB.DAT files(s)	0
INPUT GROUP: 14 -- Area Source Parameters		
NAR1	Number of polygon area sources	31
IARU	Units used for area source emission (e.g., 1 = g/m ² /s)	7
NSAR1	Number of source-species combinations with variable emission scaling factors	0
NAR2	Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0
INPUT GROUP: 15 -- Line Source Parameters		
NLN2	Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Number of buoyant line sources in LNEMARB.DAT file	0
ILNU	Units used for line source emissions (e.g., 1 = g/s)	1
NSLN1	Number of source-species combinations with variable emissions scaling factors	0
NLRISE	Number of distances at which transitional rise is computed	6
INPUT GROUP: 16 -- Volume Source Parameters		
NVL1	Number of volume sources	0
IVLU	Units used for volume source emissions (e.g., 1 = g/s)	1
NSVL1	Number of source-species combinations with variable emissions scaling factors	0
NVL2	Number of volume sources in VOLEMARB.DAT file(s)	0
INPUT GROUP: 17 -- FLARE Source Control Parameters (variable emissions file)		
NFL2	Number of flare sources defined in FLEMARB.DAT file(s)	0
INPUT GROUP: 18 -- Road Emissions Parameters		
NRD1	Number of road-links sources	0
NRD2	Number of road-links in RDEMARB.DAT file	0
NSFRDS	Number of road-links and species combinations with variable emission-rate scale-factors	0
INPUT GROUP: 19 -- Emission Rate Scale-Factor Tables		
NSFTAB	Number of emissions scale-factor tables	0
INPUT GROUP: 20 -- Non-gridded (Discrete) Receptor Information		
NREC	Number of discrete receptors (non-gridded receptors)	2043
NRGRP	Number of receptor group names	0

APPENDIX E: GENERAL TERMS AND CONDITIONS

USE OF REPORT

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained in it are intended for the sole use of ARKTIS Solutions Inc.'s (ARKTIS) client. ARKTIS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than ARKTIS' client unless otherwise authorized in writing by ARKTIS. Any unauthorized use of the report is at the sole risk of the user.

LIMITATIONS OF REPORT

This report is based solely on the conditions which existed on site at the time of ARKTIS' investigation. The client, and any other parties using this report with the express written consent of the clients and ARKTIS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive.

The client, and any other party using this report with the express written consent of the client and ARKTIS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made.

The client acknowledges that ARKTIS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

During the performance of the work and the preparation of this report, ARKTIS may have relied on the information provided by persons other than the client. While ARKTIS endeavors to verify the accuracy of such information when instructed to do so by the client, ARKTIS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

STANDARD OF CARE

Services performed by ARKTIS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and financial and physical constraints applicable to the services. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

ALTERNATE REPORT FORMAT

Where ARKTIS submits both electronic file and hard copy versions of reports, drawings and other project related documents and deliverables (collectively termed instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by ARKTIS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by ARKTIS shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of instruments of professional services shall not, under any circumstances, no matter who owns or uses them, be altered by any party except ARKTIS. The Client warrants that instruments of professional services will be used only and exactly as submitted by ARKTIS.

APPENDIX D EVALUATION OF AIR QUALITY PREDICTIONS FOR FINAL CLOSURE

MEMORANDUM	
File:	2022-De Beers
To:	De Beers Canada Inc.
Attention:	Lisa Tran, Regulatory Specialist
Subject:	Snap Lake Mine Air Quality Modelling – Assessment of the Post-Closure Air Quality Model Predictions
Author:	Jamie VanGulck, Ph.D., P.Eng., Principal Drew Stavinga, M.Sc., P.Geo., Environmental Geoscientist
Page Total:	6 + Appendix
Revision:	0
Date:	May 12, 2022

1.0 INTRODUCTION

In 2018, De Beers Canada Inc. (De Beers) completed air dispersion modelling (ARKTIS, 2018) to inform the post-closure air quality monitoring program at the Snap Lake Mine (Mine). The air dispersion model predicted Mine emissions for the period after active closure. In 2022, the Mine's Final Closure and Reclamation Plan (FCRP) Version 2 (De Beers, 2022) was submitted to the Mackenzie Valley Land and Water Board (MVLWB). The 2022 FCRP provides an updated description of the final closure conditions of the Mine site, which may differ from the inputs/assumptions applied in the 2018 air dispersion model.

This memorandum provides a comparison of the inputs/assumptions used in the 2018 air dispersion model to the site conditions presented in the 2022 FCRP to qualitatively assess if the model remains conservative.

2.0 COMPARISON OF MODEL INPUTS/ASSUMPTIONS TO FINAL CLOSURE CONDITIONS

The following table outlines the inputs/assumptions used in the 2018 air dispersion model with comparison to the site conditions outlined in the 2022 FCRP. For each primary model input group an opinion of the model validity or conservatism is provided.

Table 1. Comparison of air dispersion model inputs/assumptions for final Closure to FCRP final site conditions.

Input	2018 Air Dispersion Model Input / Assumption	2022 FCRP Condition	Comparison Comments	Conclusion
Geophysical and Meteorological Data	Data compiled from 2016 records from: <ul style="list-style-type: none"> • On-site Hill Station records • Yellowknife A Station records • Fort Smith records • SRTM3 terrain dataset • Global Land Cover Characterization land use dataset • Assumed 30% cloud cover 	Post-closure to commence after active closure phase which is anticipated to be up to 4 years in duration.	The 2018 model used conservative inputs based on the 2016 dataset. For example, the adopted cloud cover errs on the side of less cloud coverage (45% in Yellowknife), causing more radiation and thus more particle movement / dispersion. 2016 dataset is considered a “typical” year. Although post-closure is anticipated to occur in a different year, the near future climate is not anticipated to change at a rate where 2016 climate is no longer valid.	Model inputs remain valid. Updating the air dispersion model to utilize a different year of climate data is not considered warranted. Current analysis applied conservative assumption.
Study area	<ul style="list-style-type: none"> • RSA = 10,000 km² 	<ul style="list-style-type: none"> • RSA = 7,238 km² 	The 2018 model domain encapsulates the furthest distance a species can travel, which is larger than the RSA specified by the FCRP.	Model inputs are conservative.
Combustion Emissions (e.g. generators, incinerators, boilers, vehicles)	Combustion emission sources omitted as they are not present post-	No source of combustion emissions except during brief periods of monitoring and maintenance.	The anticipated activities that would occur post-closure would contribute only negligible loadings	Model assumptions remain valid.

Input	2018 Air Dispersion Model Input / Assumption	2022 FCRP Condition	Comparison Comments	Conclusion
	closure or are expected to be negligible.		<p>due to their very limited use (if any).</p> <p>The 2018 air model assumptions are consistent with 2022 documented post-closure condition.</p>	
Wind Erosion Emissions	<ul style="list-style-type: none"> • Disturbed area = 175.4 ha • No rock cover on North Pile • No rock cover or revegetation of infrastructure areas, laydowns and roads. • Surface materials are sand/PK size. • No erosion reduction for snow cover periods. 	<ul style="list-style-type: none"> • Disturbed area = 188 ha • Rock cover on North Pile • Revegetated infrastructure areas, laydowns and roads. • Surface materials are granular in size. • Snow cover during winter will reduce erosion. 	<p>The disturbed area used in the 2018 air model is less than the 2022 documented final closure condition. Generally, the greater the area, the greater potential for wind erosion.</p> <p>The 2018 air model was based on a 2014 satellite image of the Mine. The 2022 FCRP was based on 2018 satellite image. Minor changes to site had occurred between 2014 and 2018.</p> <p>The 2018 air model applied an extremely conservative rate of erosion which assumed that the surface of all disturbed areas is sand size. Generally, the smaller the size of the surface material, the</p>	Model results are considered highly conservative.

Input	2018 Air Dispersion Model Input / Assumption	2022 FCRP Condition	Comparison Comments	Conclusion
			<p>greater potential for wind erosion.</p> <p>The 2022 documented closure conditions show that sand size particles are not anticipated at surface post-closure. Existing surface materials at infrastructure areas, laydowns and roads are granular. Select infrastructure areas are to be revegetated which will mitigate against wind erosion. The North Pile is to be capped with a granular cover.</p> <p>The 2018 air model also does not account for erosion reduction during periods of snow cover, which will naturally occur in the region.</p>	
Vehicle Generated Road Dust Emissions	Vehicle emission sources omitted as they are not present post-closure or are expected to be negligible.	No source of vehicle generated dust except during brief periods of monitoring and maintenance.	The anticipated activities that would occur at the Mine post-reclamation would contribute only negligible temporary loadings, thus the conservativeness of the model is not considered to be impacted.	Model assumptions remain valid.

Input	2018 Air Dispersion Model Input / Assumption	2022 FCRP Condition	Comparison Comments	Conclusion
			The 2018 air model assumptions are consistent with 2022 documented post-closure condition.	
Quarry and Crushing Plant Activity Emissions	None.	None.	The 2018 air model assumptions are consistent with 2022 documented post-closure condition.	Model assumptions remain valid.
Buildings	No buildings assumed to be at the Mine post-closure and therefore no building downwash considerations.	No building will be present post-closure.	The 2018 air model assumptions are consistent with 2022 documented post-closure condition.	Model assumptions remain valid.

3.0 CONCLUSION

A comparison of the Snap Lake Mine's post-closure 2018 air dispersion model assumptions and inputs to the conditions presented in the 2022 FCRP was completed to assess whether the model remains valid or warrants update. Based on the qualitative review completed, the 2018 air dispersion model is considered to remain valid and no updates or revisions to the model are required. The 2018 air dispersion model is considered to provide a conservative prediction of the air quality at the Mine during post-closure.

4.0 CLOSING

ARKTIS Solutions Inc. assumes no responsibility for inappropriate use of the contents of this report, and disclaims all liability arising from negligence or otherwise in respect of such information and recommendations presented in this report. General terms and conditions are available in Appendix A.

ARKTIS SOLUTIONS INC.

Jamie Van Gulck, Ph.D., P.Eng.
Principal

Drew Stavinga, M.Sc., P.Geo.
Environmental Geoscientist

5.0 REFERENCES

De Beers, 2022. Snap Lake Mine, Final Closure and Reclamation Plan V2. May.

APPENDIX A – GENERAL TERMS AND CONDITIONS

This report has been prepared for the specific site, design objective, development and purpose described to ARKTIS Solutions Inc. (ARKTIS) by the Client. The factual data, interpretations and recommendations pertain to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation of site conditions, purpose, and development plans may alter the validity of the report. ARKTIS cannot be responsible for use of this report, or portions thereof, unless ARKTIS is requested to review, and if necessary, revise the report.

This report and the assessments and recommendations contained in it are intended for the sole benefit of ARKTIS' Client. No other party may use or rely on this report or any portion thereof without ARKTIS' expressed written consent.

The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any party without the express written consent of ARKTIS. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client cannot rely upon the electronic media versions of ARKTIS' report or other work products. ARKTIS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than ARKTIS' Client or Authorized User unless otherwise authorized in writing by ARKTIS.

LIMITATIONS OF REPORT

The report is of a summary nature and is not intended to stand alone without the reference to the instructions given to ARKTIS by the Client, communications between ARKTIS and the Client, and to any other reports prepared by ARKTIS for the Client relative to the specific site described in the report. In order to properly understand suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. ARKTIS cannot be responsible for use of portions of the report without reference to the entire report.

LIMITATIONS OF LIABILITY

The client, and any other parties using this report with the express written consent of the clients and ARKTIS, acknowledge that conditions affecting the financial liability of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive.

During the performance of the work and the preparation of this report, ARKTIS may have relied on the information provided by persons other than the client. While ARKTIS endeavors to verify the accuracy of such information when instructed to do so by the client, ARKTIS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

The client acknowledges that ARKTIS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

STANDARD OF CARE

Services performed by ARKTIS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and financial and physical constraints applicable to the services. Engineering judgment has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

ALTERNATE REPORT FORMAT

Where ARKTIS submits both electronic file and hard copy versions of reports, drawings and other project related documents and deliverables (collectively termed instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding.

**APPENDIX E COMPARISON OF MONITORING DURING OPERATIONS, EXTENDED
CARE AND MAINTENANCE, CLOSURE AND POST-CLOSURE**

Table E-1 Comparison of Monitoring Programs between Operations, Extended Care and Maintenance, Closure and Post-Closure Phases

Parameter	Reason for Monitoring	Operations Phase			Extended Care and Maintenance Phase			Closure Phase			Post-Closure Phase		
		Number of Stations	Yearly Number of Samples	Frequency of Monitoring	Number of Stations	Yearly Number of Samples	Frequency of Monitoring	Number of Stations	Yearly Number of Samples	Frequency of Monitoring	Number of Stations	Yearly Number of Samples	Frequency of Monitoring
Meteorological (various)	Monitoring of environmental conditions at the Mine.	2 meteorologic al stations	Continuous 24 downloads/year x 2 stations = 48	Continuously, with data downloads completed bi- weekly.	2 meteorological stations	Continuous 24 downloads/year x 2 stations = 48	Continuously, with data downloads completed bi- weekly.	2 meteorological stations	Continuous 52 downloads/year x 2 stations = 104	Continuously, with data downloads completed weekly.	Not monitored		
TSP	Monitoring of suspended particulate matter (dust) emissions from various Mine sources. TSP monitoring was discontinued at the end of 2015 for PM _{2.5} measurements address health considerations (Golder, 2012).	Not monitored											
PM ₁₀	There is evidence linking inhalable particles (PM ₁₀) to health concerns. PM ₁₀ monitoring was discontinued in July 2014 for PM _{2.5} measurements address health considerations (Golder, 2012).	Not monitored											
PM _{2.5}	Scientific studies have indicated that there are health effects associated with PM _{2.5} .	2 suspended particulate matter stations (Airstrip and Emulsion Plant)	Continuous throughout the year 24 downloads/year	Continuously, with real-time measurements downloaded bi- weekly year- round.	1 suspended particulate matter station (Communications Building)	Continuous during periods of occupancy 12 downloads/year	Continuously, with real-time measurements downloaded bi- weekly during periods of occupancy.	1 suspended particulate matter station (Communications Building)	Continuous during periods of occupancy 24 downloads/year	Continuously, with real-time measurements downloaded bi- weekly during periods of occupancy.	Not monitored		
Dustfall	To evaluate the effects of dust deposition on the surrounding vegetation.	7 dustfall stations	12 samples/year x 7 stations = 84	Dustfall canisters are exposed for a nominal period of 30 days at each station year-round.	7 dustfall stations	6 samples/year x 7 stations = 42	Dustfall canisters are exposed for a nominal period of 30 days at each station during periods of occupancy.	7 dustfall stations	4 samples/year x 7 stations = 28	Dustfall canisters are exposed for a nominal period of 30 days at each station between May and September.	7 dustfall stations	2 samples /year x 7 stations = 14	Monitoring until closure criteria achieved for 3 consecutive years and confirmed once more in year 3 to year 5 of Post-Closure. Dustfall canisters are exposed for a nominal period

Parameter	Reason for Monitoring	Operations Phase			Extended Care and Maintenance Phase			Closure Phase			Post-Closure Phase		
		Number of Stations	Yearly Number of Samples	Frequency of Monitoring	Number of Stations	Yearly Number of Samples	Frequency of Monitoring	Number of Stations	Yearly Number of Samples	Frequency of Monitoring	Number of Stations	Yearly Number of Samples	Frequency of Monitoring
													of 30 days at each station between July and August.
Vegetation Dustfall	To evaluate the effects of dust deposition on the surrounding vegetation.	9 vegetation dustfall stations along 20 km transect	3 samples/year x 9 stations = 27	Every 5 years. Dustfall canisters are exposed for a nominal period of 30 days at each station between July and October.	9 vegetation dustfall stations along 20 km transect	3 samples/year x 9 stations = 27	Every 5 years. Dustfall canisters are exposed for a nominal period of 30 days at each station between July and October.	Program to be conducted once more after completion of earthworks for Closure. If confirmed that no Mine-related impacts remain or are of negligible risk, and the applicable closure criteria have been achieved, the program will be terminated.			Sampling will only occur if closure criteria are not met following completion of reclamation activities (De Beers, 2023a).		
NO ₂	To demonstrate compliance with the NWT standards (GNWT, 2014) and NAAQOs (Environment and Climate Change Canada, 2011). NO ₂ and SO ₂ monitoring will be discontinued for Closure and Post-Closure due to reduced site activity and a record of no exceedances to ambient air benchmarks in historical monitoring data.	7 passive stations	12 samples/year x 7 stations = 84	Passive samplers are exposed for a nominal period of 30 days at each station year-round.	7 passive stations	12 samples/year x 7 stations = 84	Passive samplers are exposed for a nominal period of 30 days at each station during periods of occupancy.	Not monitored					
SO ₂													