APPENDIX 7C

DISPERSION MODELLING APPROACH

Table of Contents

Maps

Figures

Tables

Abbreviations

Abbreviation	Definition
2D	two-dimensional
3D	three-dimensional
Ca_2^+	calcium base cation (particle)
CAMS	continuous air monitoring station
Cl^-	chlorine ions
CO	carbon monoxide
Diavik Mine	Diavik Diamond Mine
Dominion Diamond	Dominion Diamond Ekati Corporation
E	east
e.g.	for example
Ekati Mine	Ekati Diamond Mine
et al.	and more than one additional author
GNWT	Government of the Northwest Territories
H^+	hydrogen ions
HNO_3	nitric acid (gas)
i.e.	that is
ISC3	Industrial Source Complex Model Version 3
K^+	potassium base cation (particle)
Koala Station	Koala Meteorological Station
LAI	Leaf Area Index
LDG	Lac de Gras
LiDAR	light detection and ranging
LSA	local study area
Mg^+	magnesium ion
MM5	Mesoscale Model Version 5
MODIS	MODerate-resolution Imaging Spectroadiometer
N	north
Na^+	sodium ion
NAD	North America Datum
NAtChem	National Atmospheric Chemistry Precipitation Database
NH_3	ammonia
NH_4^+	ammonium ions
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NO_3^-	nitrate (ion)
NW	northwest
NWT	Northwest Territories
O_3	ozone
OLM	Ozone Limited Method

Abbreviation	Definition
PAH	polycyclic aromatic hydrocarbons
PAI	potential acid input
PG	Pasquill-Gifford
PM	particulate matter
$PM_{2.5}$	particulate matter with a mean aerodynamic diameter of 2.5 microns (μm) or smaller
PM_{10}	particulate matter with a mean aerodynamic diameter of 10 microns (μm) or smaller
Project	Jay Project
RELAD	Regional Lagrangian Acid Deposition Model
RSA	regional study area
S	south
SO_2	sulphur dioxide
SO_X	sulphur oxide
SO_4^{2-}	sulphate (particle)
SW	southwest
TSP	total suspended particulate
US	United States
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VOC	volatile organic compounds
Z_0	roughness length

Units of Measure

Unit	Definition
%	percent
<	less than
>	greater than
°	degrees
°C	degrees Celsius
$\mu g/m^3$	micrograms per cubic metre
cm	centimetre
ha	hectare
keq	kiloequivalent
keq/ha/yr	kiloequivalent per hectare per year
kg/ha/yr	kilograms per hectare per year
km	kilometre
km/hr	kilometres per hour
kmol	kilomole
m	metre
mm	millimetre
mm/year	millimetres per year
ppb	parts per billion
ppm	parts per million
W/m^2	watts per square metre

7C1 INTRODUCTION

The purpose of this appendix is to present the technical information associated with air dispersion modelling that was completed for the Jay Project (Project). The appendix provides the following:

- description of the models considered for the assessment and rationale for model selection;
- overview of the meteorological data used in the modelling;
- description of modelling domain and associated receptor locations where ground-level concentrations and deposition rates were predicted; and,
- description of dispersion modelling approaches, including assumptions and model options.

Emission information used in the dispersion modelling is presented in Air Emission Results, Appendix 7B.

7C2 REGULATORY MODEL GUIDANCE

7C2.1 Northwest Territories Air Dispersion Modelling Guidelines

Dispersion modelling guidelines have been established by several jurisdictions in Canada including Alberta and British Columbia. In the absence of a dispersion modelling guideline for the Northwest Territories (NWT), the dispersion modelling approach for this assessment is based on the Air Quality Model Guideline developed by Alberta Environment and Sustainable Resource Development (ESRD 2013). The purpose of the guideline is to provide uniform benchmarks and a structured approach to the selection and application of dispersion models, and to provide a sound scientific basis for the selection of alternatives. This approach is consistent with ongoing dialogue between Dominion Diamond and the GNWT Environment and Natural Resources regarding the Ekati site’s air monitoring programs.
The ESRD Air Quality Model Guideline considers the following issues:

- determination of model performance by comparing model predictions to air quality observations;
- meteorological data requirements, noting that a single year of meteorological data was available for consideration;
- receptor placement;
- consideration of permanent structure (e.g., building) downwash effects;
- incorporation of complex terrain; and,
- assumptions for consideration when preparing source information.

7C2.2 United States Environmental Protection Agency Guidance

The dispersion models that were considered for this Project were either developed or recommended by the United States (US) Environmental Protection Agency (US EPA 1992, 1999) to address regulatory modelling requirements. National (i.e., US) dispersion modelling guidelines used for regulatory application have a long development history and provide consistency between air quality assessments conducted in the US. These guidelines are found in Appendix W of Section 40 of the *Code of Federal Regulations* (US Government 2005), which describes each model accepted for regulatory use and provides guidance on the suitability of each model, which is dependent on the application. Dominion Diamond has used this guideline in previous Air Quality modelling programs (i.e., Rescan 2006).

7C2.3 Models Evaluated

The following models were evaluated for use in the Project air quality assessment:

- CALPUFF 3D – a Lagrangian puff model operating in dynamic three-dimensional (3D) mode (CALPUFF using CALMET three-dimensional meteorology);
- CALPUFF 2D – a Lagrangian model operating in steady-state two-dimensional (2D) mode (CALPUFF using Industrial Source Complex Model Version 3 [ISC3] single station meteorology); and,
- AERMOD - a steady–state Gaussian dispersion model designed for short-range (up to 50 kilometres [km]) dispersion of air pollutant emissions from stationary industrial sources.

A brief description of each model follows.

7C2.3.1 CALPUFF 3D

The CALPUFF modelling system is a non-steady state meteorological and air quality modelling system that has been recommended for use by the US EPA (US EPA 1999), specifically for long-range transport (i.e., greater than 50 km) of air pollutants and associated effects.

The CALPUFF model was developed with the following objectives:

- to consider time varying point, line, area, and volume sources;
- be suitable for modelling domains ranging from tens of metres to hundreds of kilometres from a source;
- predict averages ranging from one hour to one year;
- incorporate building downwash effects;
- be capable of incorporating horizontal and vertical wind shear effects;
- be applicable to inert pollutants and those subject to linear removal and chemical conversion mechanisms; and,
- applicable for complex terrain scenarios.

Suitable application of the CALPUFF modelling system may include near-field impacts associated with complex flow or drop areas (e.g., complex terrain, stagnation, calm wind conditions), long-range transport of air pollutants, visibility assessment, criteria air pollutant (e.g., nitrogen oxide [NO_X], sulphur oxide [SO_X], volatile organic compounds [VOCs]) modelling, buoyant area and line sources, and others.

In 3D mode, wind fields determined by the CALMET meteorological model can vary across the modelling domain on both horizontal and vertical scales. This variation often results in improved estimates of plume dispersion compared to non-varying wind fields. Additionally, terrain effects are incorporated into the wind field derivations to enable plumes to travel around or over terrain features, as appropriate, rather than impacting the features directly.

7C2.3.2 CALPUFF 2D

The CALPUFF model can be run in a steady-state or two-dimensional mode, which is more indicative of historical dispersion models including ISC3. Many of the CALPUFF dynamic model features are also available in two-dimensional mode. Features available include puff splitting, long-range transport estimates, and chemical transformations. However, wind field variation is not a component of the 2D model. These features are considered to be an important advantage over other models such as ISC3, but less of an advantage over AERMOD (Hanna et al. 2001).

7C2.3.3 AERMOD

The improvements of AERMOD over ISC3 include introduction of a non-Gaussian probability density function in the vertical dimension for unstable conditions. The dispersion is Gaussian in the horizontal for unstable conditions, and in the horizontal and vertical for stable conditions. The AERMOD model produces profiles of wind, temperature, and turbulence using upper air measurements (Paine 2006).

The AERMOD model uses data from only one meteorological station. Additional land use parameters like Bowen Ratio, albedo, and roughness height (Z_o) are calculated or estimated for the area surrounding the station. These parameters may be different in the area of emission sources or sensitive receptors. The model is sensitive to the choice of those parameters (especially to the roughness height).

In the US, AERMOD is considered as the model of the choice for plume travel distances less than 50 km. Because the regional study area (RSA) that was chosen for the Project is large, the AERMOD model was not considered further.

7C3 SELECTED MODEL: CALPUFF 3D

For the purposes of assessing air quality effects from the Project, CALPUFF-3D (hereafter CALPUFF) was determined to be the most appropriate model. The primary rationale for use of the CALPUFF model includes the following:

- the applicability at a range of spatial scales from a few kilometres to more than 100 km (e.g., evaluating regional and local air emission effects);
- it incorporates wet and dry removal processes (deposition);
- it includes both sulphur dioxide (SO_2) and NO_X chemistry which is required for predicting potential acid input (PAI);

- it applies three-dimensional wind speed and wind direction and time allowing for more realistic plume movement simulations;
- it is based on principles that have been explicitly documented and undergone independent peer review; and,
- the most recent version incorporates PRIME downwash algorithms.

The CALPUFF model has also undergone improvements, to make it more suitable for application at the regional level (Scire 2007). Modifications to the CALPUFF system include the following:

- new modules to treat buoyant rise and dispersion from area sources;
- buoyant line sources;
- volume sources;
- improved treatment of complex terrain;
- additional model switches to facilitate its use in regulatory applications;
- enhanced treatment of wind shear through puff splitting;
- capability to model periods shorter than 1 hour, e.g., 0.5 hour, 15 minutes (Version 6 – CALPUFF-Professional Beta 2.3.1005); and,
- capability to model plume length and frequency of fog occurrences (CALPUFF-VISTA).

The CALPUFF model was run in 3D mode for the purposes of assessing the Project using a wind field developed specifically for the Project from regional surface meteorological data and mesoscale data for northern Canada. The RIVAD/ARM3 chemistry was used for calculations of wet and dry deposition of sulphate and nitrate compounds.

Despite many advancements of the CALPUFF modelling system over other available models, CALPUFF has certain limitations. For example, predicted concentrations and deposition of airborne contaminants are known to be higher than observed near major area sources of SO_2 and NO_X, such as mine pits. This result is likely due to the RIVAD/ARM3 chemical transformation algorithms used by the model (Staniaszek et al. 2006; Staniaszek and Davies 2006).

The CALPUFF model in dynamic mode was selected to meet the assessment Terms of Reference for the Jay Project Environmental Assessment, particularly with respect to deposition. Its use in environmental impact assessments in the NWT is generally supported by regulators and regional stakeholders. CALPUFF Version 6.42 was used for this assessment.

7C4 DISPERSION METEOROLOGY

The three-dimensional wind fields used in the CALPUFF dispersion modelling assessment were created using the CALMET model pre-processor developed specifically for use with the CALPUFF model. The CALMET wind fields were simulated over an area larger than the modelling domain so that the CALPUFF model used the most representative wind fields across the entire region. One year of meteorological data covering January 1, 2002 to December 31, 2002 was generated using output from a mesoscale meteorological model in combination with local meteorological observations.

The CALMET model is composed of two main components: a wind field module and a boundary layer meteorological module. In Step 1 of the wind field development, an initial guess wind field is adjusted for the kinematic effects of terrain, slope flows, and blocking effects as appropriate. Observational data are introduced in Step 2 through an objective analysis procedure. An inverse distance squared interpolation scheme is used where observational data are weighted most heavily around the observation station.

The overland boundary layer model computes gridded fields of surface friction velocity, convective velocity scale, Monin-Obukhov length, mixing height, Pasquill-Gifford stability class, air temperature, and precipitation rate using the energy balance method of Holtslag and van Ulden (1983).

The CALMET modelling domain size is 122 km in the east-west direction and 122 km in the north-south direction. The domain lies between 473,906 metres (m) east (E) and 7,091,217 m north (N) to 595,906 m E to 7,213,217 m N Zone 12. The horizontal grid spacing is 1 km x 1 km. This combination of grid size and number of cells was chosen to minimize run time while capturing large-scale terrain feature influences on wind flow patterns.

The height of vertical layers is defined as the midpoint between two adjacent layers or interfaces (i.e., eleven interfaces for 10 layers, with the lowest layer always at ground level). The vertical interfaces used for the Project were 0, 20, 50, 100, 200, 400, 800, 1,200, 1,600, 2,200 and 3,000 m above ground level.

The initial guess wind field was determined from the National Center for Atmospheric Research Mesoscale Model Version 5 (MM5) simulation and CALMET was run in no observation mode.

7C4.1 CALMET Description

The MM5 model output was provided by Environment Canada covering January 1, 2002 to December 31, 2002. The MM5 modelling domain extends 240 km in the east-west direction and 360 km in the north-south direction. The modelling domain has a 10-km spatial resolution in the east-west direction, and a15-km spatial resolution in the north-south direction with an hourly time step of output.

7C4.1.1 Geophysical Parameters

The CALMET model requires a physical description of the ground surface to determine meteorological parameters near the surface. The geophysical parameters are land use category, terrain elevation, roughness length, albedo, Bowen ratio, soil heat flux parameter, anthropogenic heat flux, and Leaf Area Index (LAI). Values for all land use parameters except land use category and elevation were determined for the following periods:

- foliage or non-frozen period – summer (June 1, 2002 to September 30, 2002); and,
- non-foliage or frozen period – winter (January 1, 2002 to May 31, 2002 and October 1, 2002 to December 31, 2002).

7C4.1.1.1 Land Use

Land use category data were obtained from MODerate-resolution Imaging Spectroadiometer (MODIS) satellite data. MODIS measurements provide sufficient spectral information to extract land use directly at a temporal resolution of two weeks and a spatial resolution ranging from 500 m to 1 km. The MODIS data were obtained from the United States Geological Survey Land Processes Distributed Active Archive Center (USGS 2009), and included the following:

- Land Use – Land Use was derived from the MODIS Land Cover Type 1 product. The MODIS Land Cover Type 1 product contains multiple classification schemes, which describe land cover properties derived from observations spanning a year's input of Terra and Aqua satellite data. The primary land cover scheme used by the Land Cover Type 1 product identified 17 land cover classes defined by the International Geospehere Biosphere Programme, which includes 11 natural vegetation classes, three developed and mosaicked land classes, and three non-vegetated land classes.
- To begin pre-processing the data, a geographical region was created. Then, the Geobase Digital Elevation Model of Canada was spatially resampled to the desired resolution of 4 km, sub-set to the region of interest, and used as the base image for subsequent sub-setting of other MODIS geospatial layers.

The MODIS Land cover map derived from the MODIS Land Cover Type 1 Product was processed through a conversion program to obtain the equivalent CALMET land cover types. An automated process was used that simultaneously produced the land-cover and the corresponding geophysical parameters. This process was applied to the original MODIS data before any resampling to keep the integrity of the resulting physical values.

The layer stacking process applied in the geographic information system programme used the Digital Elevation Model extent as the base layer for determining the geographical projection (Universal Transverse Mercator [UTM] Zone 12, North American Datum [NAD] 83) and the data set resolution. Therefore, all geophysical parameters were resampled from physical values with a cubic convolution.

Since land use does not vary much from month to month, the land use category was defined for the year included in the assessment period. For the non-foliage and foliage periods, each land use category was assigned values of roughness length, albedo, Bowen Ratio, soil and anthropogenic flux parameters, and LAI. Unless otherwise noted, geophysical parameters were selected using the default values recommended in the CALMET manual (Scire et al. 2000). The geophysical parameters for the foliage season are summarized in Table 7C4.1-1, and the geophysical parameters for the non-foliage season are summarized in Table 7C4.1-2. The land use categories within the CALMET domain are shown in Map 7C4.1-1. Tundra covers approximately 89 percent (%) of the modelling domain, water covers approximately 11%, and barrenland covers less than 1% of the modelling domain.

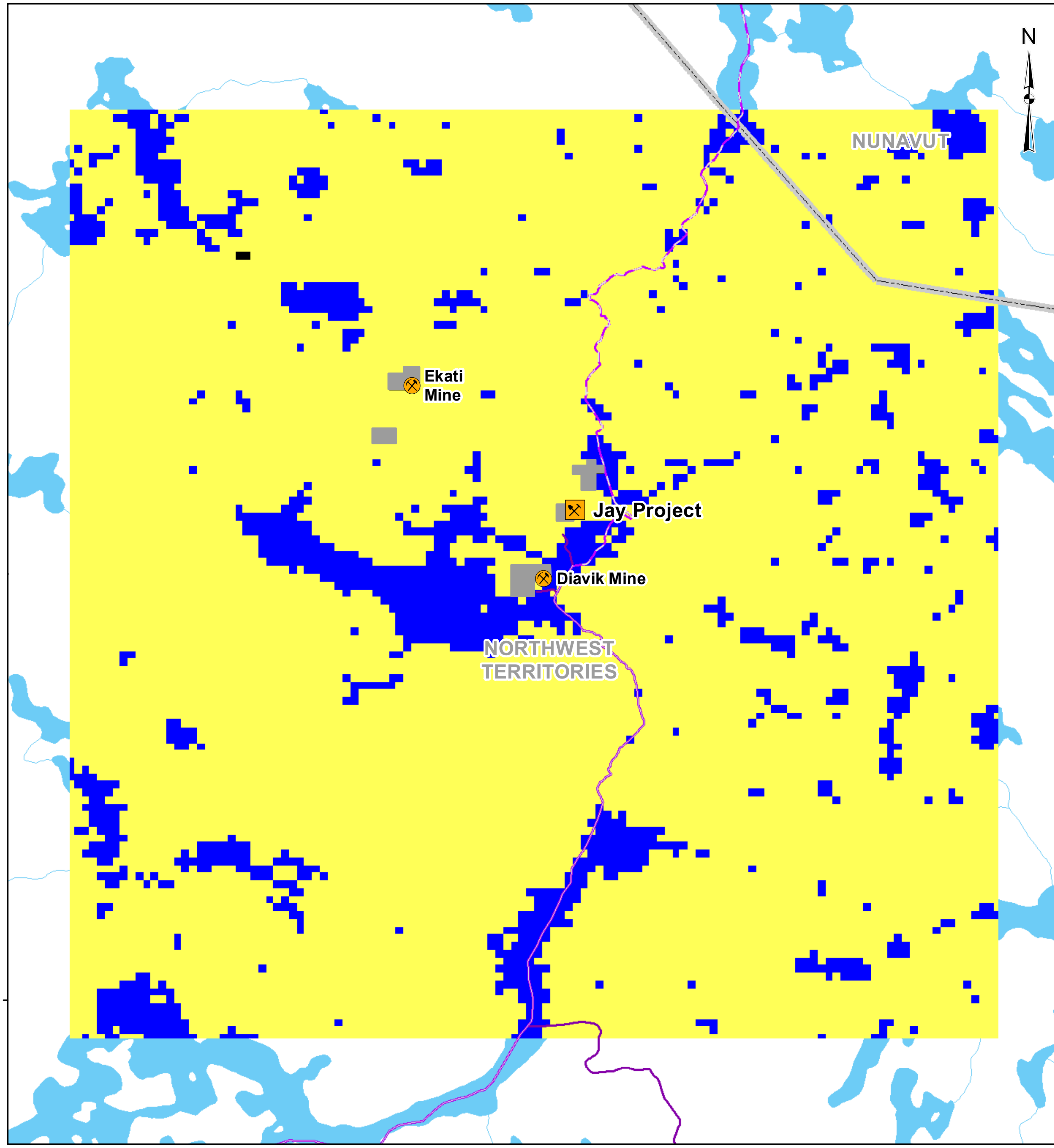
Table 7C4.1-1 Geophysical Parameters for the Foliage or Non-Frozen Season

Land Use Category	Description	Roughness Length (m)	Albedo	Bowen Ratio	Soil Heat Flux (W/m²)	Leaf Area Index	Anthropogenic Heat Flux (W/m²)
52	Lakes	0.0001	0.1	0.1	1.0	0.0	0.0
70	Barrenland	0.05	0.3	1.0	0.15	0.05	0.0
80	Tundra	0.2	0.3	0.5	0.15	0.0	0.0

Table 7C4.1-2 Geophysical Parameters for the Non-Foliage or Frozen Season

Land Use Category	Description	Roughness Length (m)	Albedo	Bowen Ratio	Soil Heat Flux (W/m²)	Leaf Area Index	Anthropogenic Heat Flux (W/m²)
52	Lakes	0.2	0.7	0.5	0.15	0.0	0.0
70	Barrenland	0.05	0.3	1.0	0.15	0.05	0.0
80	Tundra	0.2	0.7	0.5	0.15	0.0	0.0

m = metre; W/m² = watts per square metre.



LEGEND

- JAY PROJECT
- EXISTING MINE OR PROJECT
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- WATERCOURSE
- WATERBODY

LAND USE CATEGORIES

- LAKE
- TUNDRA
- BARREN LAND

15 0 15

SCALE 1:750,000 KILOMETRES

REFERENCE

WATER OBTAINED FROM ATLAS OF CANADA
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
LAND USE DATA FROM CALMET, 2014
PROJECTION: NAD 83 UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

LAND USE CATEGORIES IN THE MODELLING DOMAIN

Golder Associates

PROJECT		13-1328-0041	FILE No. DAR_Air_019_GIS
DESIGN	DC	05/09/14	SCALE AS SHOWN REV. 0
GIS	SBM/JR	25/09/14	MAP 7C4.1-1
CHECK	ACP	16/10/14	
REVIEW	CDM	16/10/14	

G:\CLIENTS\DOMINION\DDEC Jay and Lynx Projects\13-1328-0041 Jay & Lynx EA\Air\DAR\DAR_Air_019_GIS.mxd

7C4.1.1.2 Terrain

The terrain elevations for the modelling domain were obtained from the Geobase and from light detection and ranging (LiDAR) data that were available around the Project site. The data was interpolated to 1 km spacing, and incorporated into CALMET via the geo.dat file as ascii data.

7C4.1.1.3 Roughness Length

Roughness length (Z_0) is the height at which the vertical wind profile is extrapolated to zero wind speed. It is a measure of the aerodynamic roughness of a surface and is related to the height, shape, and density of the surface, and wind speed.

The CALMET model default values were used according to the assigned land use categories for the Project (Tables 7C4.1-1 and 7C4.1-2).

7C4.1.1.4 Albedo

Albedo is defined as the ratio of the reflected solar radiation to the total incoming solar radiation received at the surface. The lowest albedo values are recorded for oceans (0.035) and the highest for snow (0.90).

7C4.1.1.5 Bowen Ratio

The Bowen Ratio is defined as the ratio of sensible heat flux to latent heat flux. Bowen Ratio values range from below 0.1 (tropical ocean) to above 10 (deserts).

The Bowen Ratio values used in the assessment (Tables 7C4.1-1 and 7C4.1-2) were taken from CALMET defaults (Scire et al. 2000).

7C4.1.1.6 Soil Heat Flux Parameter

The soil heat flux parameter is a function of the surface properties and is used to compute the rate of energy transfer from the soil into the atmosphere. The values recommended by CALMET were used in the assessment (Tables 7C4.1-1 and 7C4.1-2).

For modelling purposes, the anthropogenic heat flux is usually considered to be zero due to lack of local measurements. For the Project, the anthropogenic heat is considered zero due to lack of human settlements in the study areas.

Small industrial facilities, like the Project or the nearby Diavik Diamond Mine (Diavik Mine), do not generate enough heat to be considered “urban heat islands”. The urban heat island effect is a result of the interaction of several factors, including the absorption of heat during the day by surfaces such as asphalt roads, concrete pavements, and roofs, which is then radiated out into the atmosphere at night.

7C4.1.1.7 Leaf Area Index

The Leaf Area Index (LAI) is defined as the ratio of leaf area to soil surface area. A non-uniform forest canopy was assumed for the modelling domain for the purpose of evaluating dry deposition. The values recommended by CALMET for the LAI were used in the assessment (Tables 7C4.1-1 and 7C4.1-2).

7C4.1.2 Precipitation

The annual MM5 model total precipitation was considered to be too high based on a comparison to climate normals from Yellowknife A and Fort Reliance stations, and comparison to the Diavik on-site meteorological station. The annual MM5 model total precipitation for the year 2002 was found to be 1,569 millimetres per year (mm/year), whereas climate normals from Yellowknife A and Fort Reliance indicate annual precipitation of 281 and 272 mm/year respectively. A comparison of precipitation data for the non-frozen months (June through September) between the MM5 data and the Diavik on-site meteorological station is provided in Table 7C4.1-3. The month of June was excluded from the comparison because the data completeness for the Diavik on-site meteorological station, which is the nearest station to the Project, was low at 50%.

Table 7C4.1-3 Comparison of Precipitation Data – MM5 Model Results and Diavik On-Site Meteorological Station

Month	MM5 Model Results (2002)	Diavik On-Site Meteorological Station (2002)	
	Precipitation (mm)	Precipitation (mm)	Data Completeness (%)
July	196.9	76.1	100
August	304.8	78.1	100
September	189.1	26.8	100

mm = millimetre;% = percent.

Use of the MM5 precipitation values in the modelling, without adjustment, could potentially result in erroneous predicted deposition and ambient concentrations.

The MM5 total precipitation values were adjusted to closer match precipitation values observed at the on-site meteorological station. Diavik on-site precipitation data was used to derive a ratio, which was then applied to the MM5 precipitation events to adjust the MM5 precipitation data to lower values. The temporal pattern of precipitation events within the on-site data did not necessarily coincide with the pattern within the MM5 data; therefore, a ratio of on-site precipitation to model precipitation data daily would not be appropriate. A ratio that was re-calculated every seventeen days was found to be the most appropriate. This method resulted in an adjusted MM5 total precipitation of 350 mm/year. The temporal pattern of precipitation events within the MM5 data was unmodified. The approach of adjusting the MM5 precipitation data has previously been discussed with Environment Canada and the Government of the Northwest Territories (GNWT) for other modelling in the region.

7C4.1.3 CALMET Model Options

The model input options that were used for the CALMET model are provided in Table 7C4.1-4. The CALMET model contains several options for calculating the domain wind field. Surface winds are extrapolated to upper layers using the similarity theory.

Table 7C4.1-4 CALMET Model Input Options

Input Group	Parameter	Default	Project	Description
Input Group 1 – General Run Control Parameters	IBYR	-	2002	starting year
	IBMO	-	3	starting month
	IBDY	-	31	starting day
	IBHR	-	0	starting hour
	IBSEC	-	0	starting second
	IEYR	-	2002	ending year
	IEMO	-	5	ending month
	IEDY	-	1	ending day
	IEHR	-	23	ending hour
	IESEC	-	3600	ending second
	ABTZ	-	UTC-0700	UTC time zone (Mountain Standard Time)
	NSECDT	3600	3600	length of modelling timestep (seconds)
	IRTYPE	1	1	run type – computes wind fields and micrometeorological variables
	LCALGRD	T	T	do not compute special data fields required by CALGRID
	ITEST	2	2	continues with execution of computational phase after setup
	MREG	-	0	no checks for conformance with US EPA guidance
Input Group 2 – Map Projection and Grid Control Parameters	PMAP	UTM	UTM	map projection = Universal Transverse Mercator (UTM)
	FEAST	0	0	false easting at the projection origin - not used when PMAP = UTM
	FNORTH	0	0	false northing at the projection origin - not used when PMAP = UTM
	IUTMZN	-	12	UTM zone
	UTMHEM	N	N	northern hemisphere projection
	RLAT0	-	40N	latitude of projection origin – not used when PMAP = UTM
	RLON0	-	90W	longitude of projection origin – not used when PMAP = UTM
	XLAT1	-	30N	matching parallel(s) of latitude for projection – not used when PMAP = UTM
	XLAT2	-	60N	matching parallel(s) of latitude for projection – not used when PMAP = UTM
	DATUM	WGS-84	NAR-C	datum region for output coordinates = NAR-C North American 1983 GRS 80 Spheroid
Input Group 3 – Output Options	NX	-	122	number of X grid cells
	NY	-	122	number of Y grid cells
	DGRIDKM	-	1.0	grid spacing (km)
	XORIGKM	-	473.906	X coordinate of southwest corner of domain (km)
	YORIGKM	-	5981.814	Y coordinate of southwest corner of domain (km)
	NZ	-	10	number of vertical layers
	ZFACE	-	0.,20.,50.,100., 200.,400.,800., 1200.,1600.,2200.,3000.	cell face heights in vertical grid (m)

Table 7C4.1-4 CALMET Model Input Options

Input Group	Parameter	Default	Project	Description
Input Group 3 continued	LSAVE	T	T	save meteorological fields in an unformatted output file
	IFORMO	1	1	CALPUFF/CALGRID type of unformatted output file
	LPRINT	F	F	do not print meteorological fields
	IPRINF	1	1	print interval (hours)
	IUVOUT	NZ*0	NZ*0	layers of U, V wind component to print (0=no, 1=yes)
	IWOUT	NZ*0	NZ*0	levels of W wind component to print (0=no, 1=yes)
	ITOUT	NZ*0	NZ*0	I (0 = no, 1 = yes)
	STABILITY	0	0	Do not print PGT stability class
	USTAR	0	0	do not print friction velocity
	MONIN	0	0	do not print Monin-Obukhov length
	MIXHT	0	0	do not print mixing height
	WSTAR	0	0	do not print convective velocity scale
	PRECIP	0	0	do not print precipitation rate
	SENSHEAT	0	0	do not print sensible heat flux
	CONVZI	0	0	do not print convective mixing height
	LDB	F	F	do not print input meteorological data and internal variables
	NN1	1	1	first time step for which debug data are printed
	NN2	1	1	last time step for which debug data are printed
	LDBCST	F	F	do not print distance to land internal variables
	IOUTD	0	0	control variable for writing the test/debug wind fields to disk files
	NZPRN2	1	1	number of levels to print
	IPR0 to IPR8	0	0	do not print wind field components after each adjustment
Input Group 4 – Meteorological Data Options	NOOBS	0	2	No surface, overwater, or upper air observations. Use MM4/MM5/M3D for surface, overwater, and upper air data
	NSSTA	-	0	number of surface stations
	NPSTA	-	1	number of precipitation stations
	ICLOUD	0	4	Gridded cloud cover from Prognostic Rel. Humidity at all levels (MM5toGrads algorithm)
	IFORMS	2	2	free-formatted user input for surface meteorological data file format
	IFORMP	2	2	free-formatted user input for precipitation data file format
	IFORMC	2	2	free-formatted CALMET output user input for cloud data file format
	IWFCOD	1	1	diagnostic wind module
	IFRADJ	1	1	compute Froude number adjustment effects
	IKINE	0	0	do not compute kinematic effects
	IOBR	0	0	do not use O'Brien procedure for adjustment of the vertical velocity
	ISLOPE	1	1	compute slope flows
	IEXTRP	-4	-1	no extrapolation is done, layer 1 data at upper air stations are ignored
	ICALM	0	0	do not extrapolate surface winds if calm
	BIAS	NZ*0	-1, 0, 0, 0, 0, 0, 0, 0, 0, 0	layer-dependant biases for modifying the weights of surface and upper air stations

Table 7C4.1-4 CALMET Model Input Options

Input Group	Parameter	Default	Project	Description
Input Group 5 – Wind Field Options and Parameters	RMIN2	4	10	minimum distance from nearest upper air station to surface station for which extrapolation of surface winds at surface station will be allowed. Set to -1 when all surface stations should be extrapolated
	IPROG	0	14	winds from MM5/M3D.dat used as initial guess field
	ISTEPPG	3600	3600	timestep of the prognostic model input data (seconds)
	IGFMET	0	0	do not use CALMET fields as initial guess fields
	LVARY	F	F	use varying radius of influence
	RMAX1	-	50	maximum radius of influence over land in the surface layer (km)
	RMAX2	-	100	maximum radius of influence over land aloft (km)
	RMAX3	-	300	maximum radius of influence over water
	RMIN	0.1	0.1	minimum radius of influence used in the wind field interpolation (km)
	TERRAD	-	20	radius of influence of terrain features
	R1	-	25	relative weighting of the first guess field and observations in the surface layer (km)
	R2	-	50	relative weighting of the first guess field observations in the layers aloft (km)
	RPROG	-	54	relative weighting parameter of the prognostic wind field data (km). Used only if IPROG=1.
	DIVLIM	0.000005	0.000005	maximum acceptable divergence in the divergence minimization procedure
	NITER	50	50	maximum number of iterations in the divergence minimization procedure
	NSMTH	2, (mxnz-1)*4	2,4,4,4,4,4,4,4	number of passes in the smoothing procedure
	NINTR2	99	99, 99, 99, 99, 99, 99, 99, 99, 99, 99	maximum number of stations used in each layer for the interpolation of data to a grid point
	CRITFN	1	1	critical Froude number
	ALPHA	0.1	0.1	empirical factor controlling the influence of kinematic effects
	FEXTR2	NZ*0	NZ*0	multiplicative scaling factor for extrapolation of surface observations to upper layers. Used only if IEXTRP = 3 or -3.
	NBAR	0	0	number of barriers to interpolation of the wind fields
	KBAR	NZ	9	Level (1 to NZ) up to which barriers apply
	XBBAR	-	0	X coordinate of BEGINNING of each barrier
	YBBAR	-	0	Y coordinate of BEGINNING of each barrier
	XEBAR	-	0	X coordinate of ENDING of each barrier
	YEBAR	-	0	Y coordinate of ENDING of each barrier
	IDIOPT1	0	0	compute surface temperature internally from hourly surface observations
	ISURFT	-1	-1	surface meteorological station to use for the surface temperature
	IDIOPT2	0	0	compute domain-averaged temperature lapse rate internally from twice-daily upper air observations
	IUPT	-1	-1	use 2-D spatially varying lapse rate

Table 7C4.1-4 CALMET Model Input Options

Input Group	Parameter	Default	Project	Description
Input Group 5 – Wind Field Options and Parameters (continued)	ZUPT	200	200	depth through which the domain-scale lapse rate is computed
	IDIOPT3	0	0	Compute internally from observations or prognostic wind fields
	IUPWIND	-1	-1	upper air station to use 3-D initial guess field
	ZUPWND	1, 1000	1, 3000	bottom and top of layer through which the domain-scale winds are computed
	IDIOPT4	0	0	read wind speed and wind direction from a surface data file for observed surface wind components for wind field module
	IDIOPT5	0	0	read WS and WD from an upper air data file for observed upper air wind components for wind field module
	LLBREZE	F	F	do not use lake breeze module
Input Group 6 – Mixing Height, Temperature and Precipitation Parameters	CONSTB	1.41	1.41	constant for neutral mechanical equation
	CONSTE	0.15	0.15	constant for convective mixing height equation
	CONSTN	2400	2,400	constant for stable mixing height equation
	CONSTW	0.16	0.16	constant for overwater mixing height equation
	FCORIOL	0.0001	0.00012	absolute value of Coriolis parameter
	IAVEZI	1	1	conduct spatial averaging of mixing heights
	MNMDAV	1	10	maximum search radius in averaging process (grid cells)
	HAFANG	30	30	half-angle of upwind looking cone for averaging
	ILEVZI	1	1	layer of winds used in upwind averaging
	IMIXH	1	1	convective mixing height option = Maul-Carson for land and water cells
	THRESHL	0	0	threshold buoyancy flux required to sustain convective mixing height growth overland (expressed as a heat flux per metre of boundary layer W/m³)
	THRESHW	0.05	0.05	threshold buoyancy flux required to sustain convective mixing height growth overwater (expressed as a heat flux per metre of boundary layer W/m³)
	ITWPROG	0	1	use prognostic lapse rates (only if IPROGis greater than 2) and SEA.DAT deltaT (or neutral if missing)
	ILUOC3D	16	16	land use category ocean in 3D.dat datasets
	DPTMIN	0.001	0.001	minimum potential temperature lapse rate in the stable layer above the current convective mixing height (K/m)
	DZZI	200	200	depth of layer above current convective mixing height through which lapse rate is computed
	ZIMIN	50	50	minimum overland mixing height (m)
	ZIMAX	3,000	3,000	maximum overland mixing height (m)
	ZIMINW	50	50	minimum overwater mixing height (m)
	ZIMAXW	3,000	3,000	maximum overwater mixing height (m)
	ICOARE	10	10	use COARE with no wave parameterization for overwater surface fluxes
	DSHELF	0	0	coastal/shallow water length scale (km) (COARE fluxes only)
	IWARM	0	0	COARE warm layer computation off
	ICOOL	0	0	COARE cool skin layer computation off
	IRHPROG	0	1	3D relative humidity from prognostic RH
	ITPROG	0	2	No surface or upper air observations, use MM5/M3D for surface and upper air data

Table 7C4.1-4 CALMET Model Input Options

Input Group	Parameter	Default	Project	Description
Input Group 6 (continued)	IRAD	1	1	use 1/R for temperature interpolation
	TRADKM	500	500	radius of influence for temperature interpolation (km)
	NUMTS	5	5	maximum number of stations to include in temperature interpolation
	IAVET	1	1	conduct spatial averaging of temperatures
	TGDEFB	-0.0098	-0.0098	default temperature gradient below the mixing height over water (K/m)
	TGDEFA	-0.0045	-0.0045	default temperature gradient above the mixing height over water (K/m)
	JWAT1, JWAT2	-	99,99	beginning and ending land use categories for temperature interpolation over water
	NFLAGP	2	2	use 1/R2 for precipitation interpolation
	SIGMAP	100	100	radius of influence (km)
	CUTP	0.01	0.01	minimum precipitation rate cut-off (mm/hr)
Input Group 7 – Surface Meteorological Station Parameters	-	-	No observation mode	surface meteorological station parameters
Input Group 8 – Upper Air Meteorological Station Parameters	-	-	No observation mode	upper air meteorological station parameters
Input Group 9 – Precipitation Station Parameters	-	-	No observation mode	precipitation station parameters

- = Not applicable; km = kilometre; m = metre; 2D = two dimensional; 3D = three dimensional; W/m³ = watts per cubic metre; K/m = degrees Kelvin per metre; mm/hr = millimetres per hour.

7C4.2 CALMET Evaluation

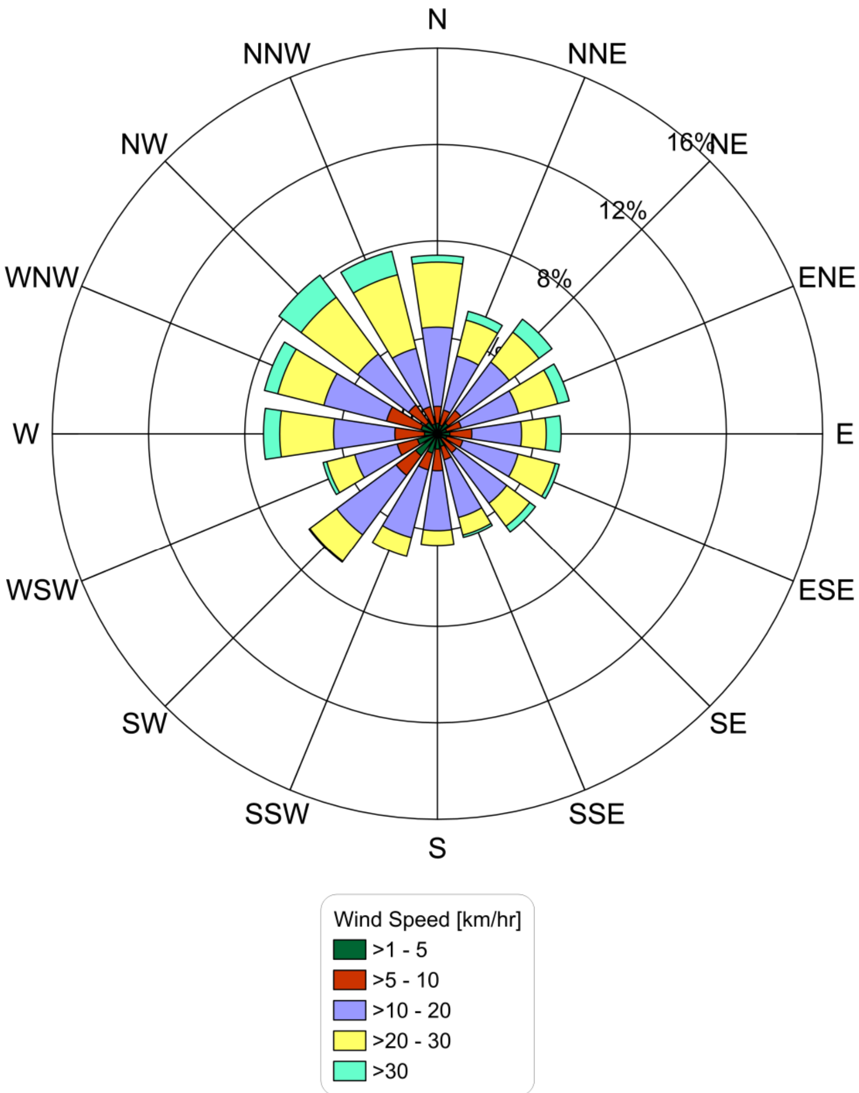
The meteorological parameters generated by CALMET, including wind, temperature, mixing height, and stability class, are summarized in the following sections.

7C4.2.1 Wind

The dispersion and transport of atmospheric emissions are driven primarily by the wind. A windrose is often used to illustrate the frequency of wind direction and the magnitude of wind velocity. The lengths of the bars on the windrose indicate the frequency and speed of wind, and the direction from which the wind blows is illustrated by the orientation of the bar in one of 16 directions.

The CALMET-derived winds for the Project site are presented in Figure 7C4.2-1. The predominant winds at the Project site are from the northeast. The CALMET winds for the 1 km by 1 km grid cell containing the Project indicate that the predominant winds are from the northwest and north-northwest.

Figure 7C4.2-1 CALMET-Derived Windrose for the Project Site



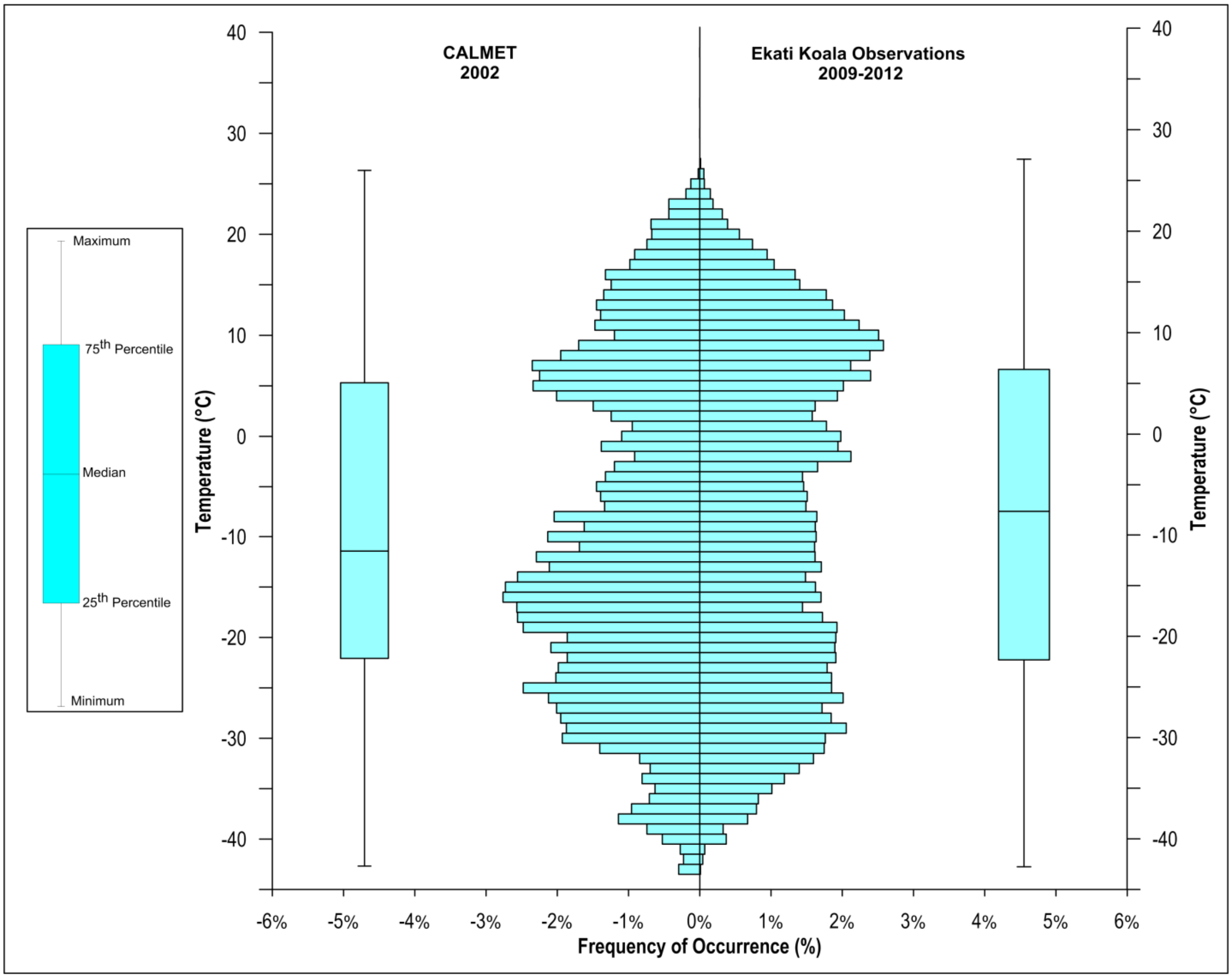
km/hr = kilometres per hour; >= greater than; N = north; E = east; S = south; W = west.

7C4.2.2 Temperature

A comparison of observed and CALMET-derived temperatures for the Ekati Koala meteorological station and the Ekati Diamond Mine (Ekati Mine) site is provided in Figure 7C4.2-2. The figure includes a box-whisker plot which shows the minimum and maximum temperatures, the 25th and 75th percentiles and the median temperature. The frequency distribution of temperatures is also shown. This comparison indicates that the CALMET-derived temperatures are similar to the observed temperatures.

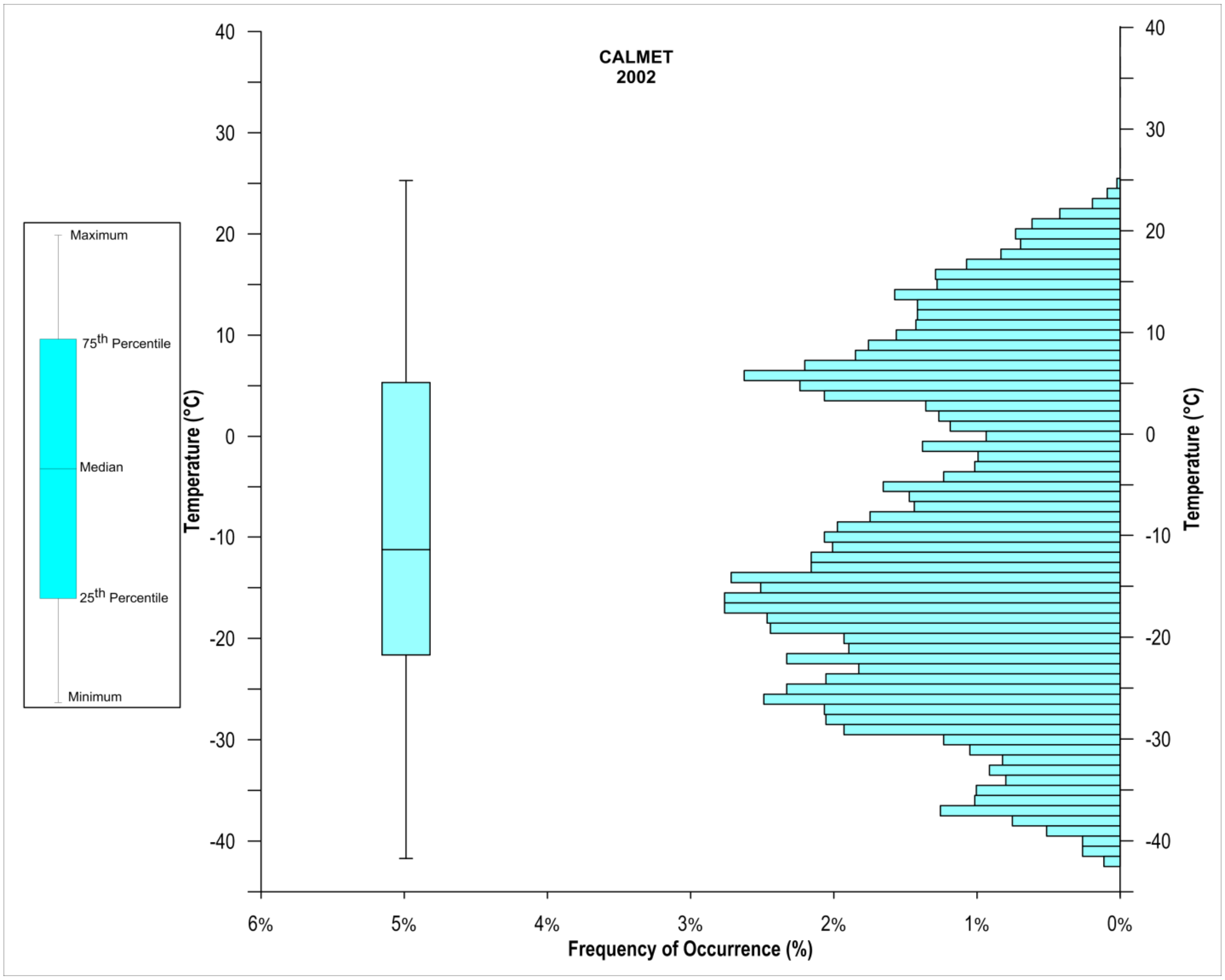
The CALMET-derived temperatures for the Project area are shown in Figure 7C4.2-3.

Figure 7C4.2-2 Comparison of Observed and CALMET-Derived Temperatures for the Koala Station



ºC = degrees Celsius;% = percent.

Figure 7C4.2-3 CALMET-Derived Temperatures for the Project Area



ºC = degrees Celsius;% = percent.

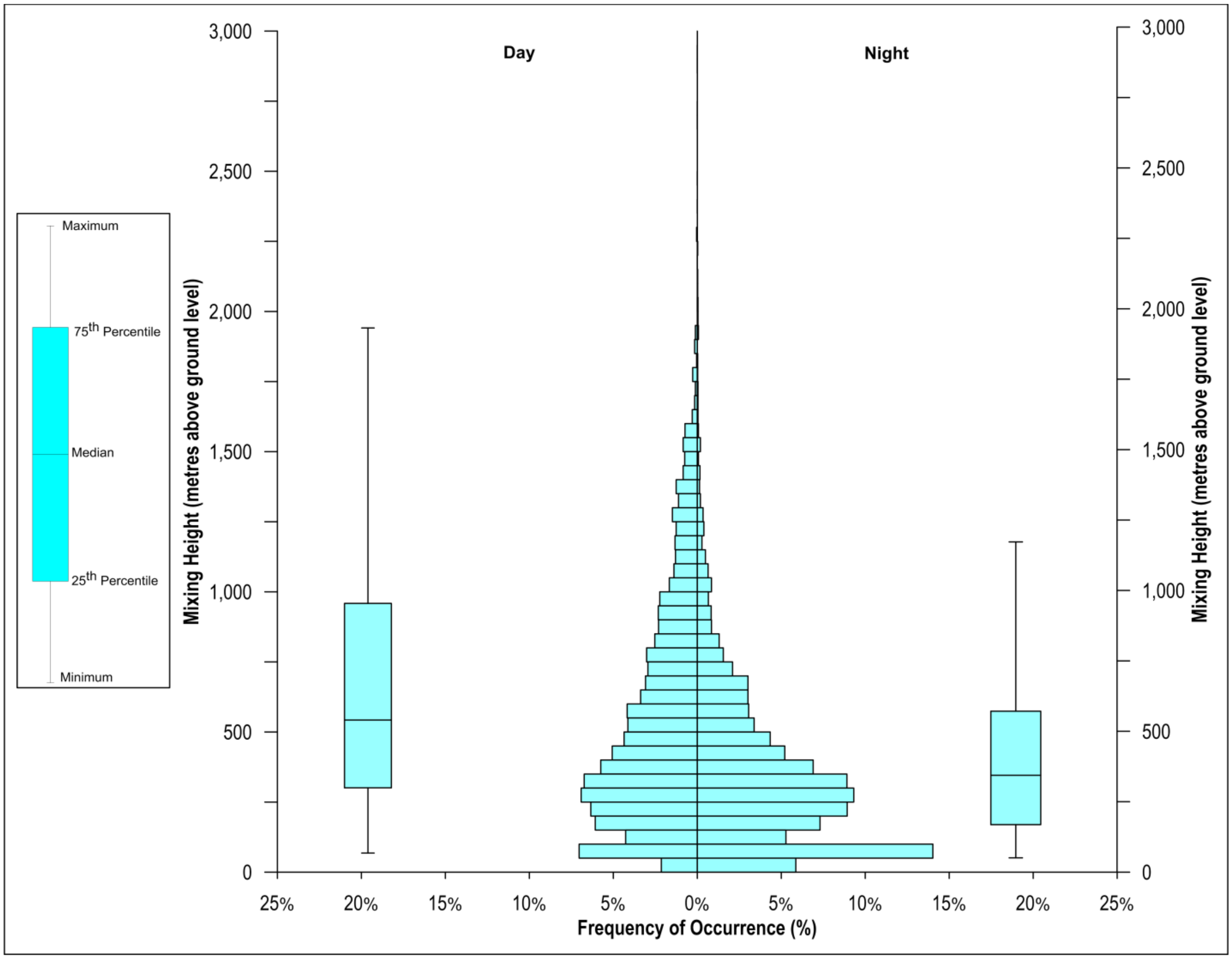
7C4.2.3 Mixing Height

Mixing height is a measure of the depth of the atmosphere through which mixing of emissions can occur. Mixing heights often exhibit a strong diurnal and seasonal variation: they are lower during the night and higher during the day. Seasonally, mixing heights are typically lower in the winter and higher in the late spring and early summer.

CALMET calculates an hourly convective mixing height for each grid cell from hourly surface heat fluxes and vertical temperature profiles from twice-daily soundings. Mechanical mixing heights are calculated using an empirical relationship that is a function of friction velocity. To incorporate advective effects, mixing height fields are smoothed by incorporating values from upwind grid cells. The higher of the two mixing heights (convective or mechanical) in a given hour is used. A more detailed description of this method is given in the CALMET User's Manual Version 5.0 (Earth Tech 2000).

The frequency of diurnal mixing heights derived by CALMET for the Project site for the assessment period is shown in Figure 7C4.2-4. Mixing heights are typically lower at night than during the day. The average nighttime mixing height is 360 m, and the average daytime mixing height is 554 m. The minimum and maximum mixing heights were set to 50 and 3,000 m, respectively.

Figure 7C4.2-4 CALMET-Derived Mixing Heights for the Project Site



% = percent.

7C4.2.4 Stability Class

Atmospheric stability can be viewed as a measure of the atmosphere's capability to disperse emissions. The amount of turbulence plays an important role in the dilution of a plume as it is transported by the wind. Turbulence can be generated by either thermal or mechanical mechanisms. Surface heating or cooling by radiation contributes to the generation or suppression of thermal turbulence, while high wind speeds contribute to the generation of mechanical turbulence.

The Pasquill-Gifford (PG) stability classification scheme is one classification of the atmosphere. The classification ranges from Unstable (Stability Classes A, B, and C), Neutral (Stability Class D), to Stable (Stability Classes E and F). Unstable conditions are primarily associated with daytime heating conditions which result in enhanced turbulence levels (enhanced dispersion). Stable conditions are associated primarily with nighttime cooling conditions, which result in suppressed turbulence levels (poorer dispersion). Neutral conditions are primarily associated with higher wind speeds or overcast conditions.

The results for stability class in the Project area were as follows:

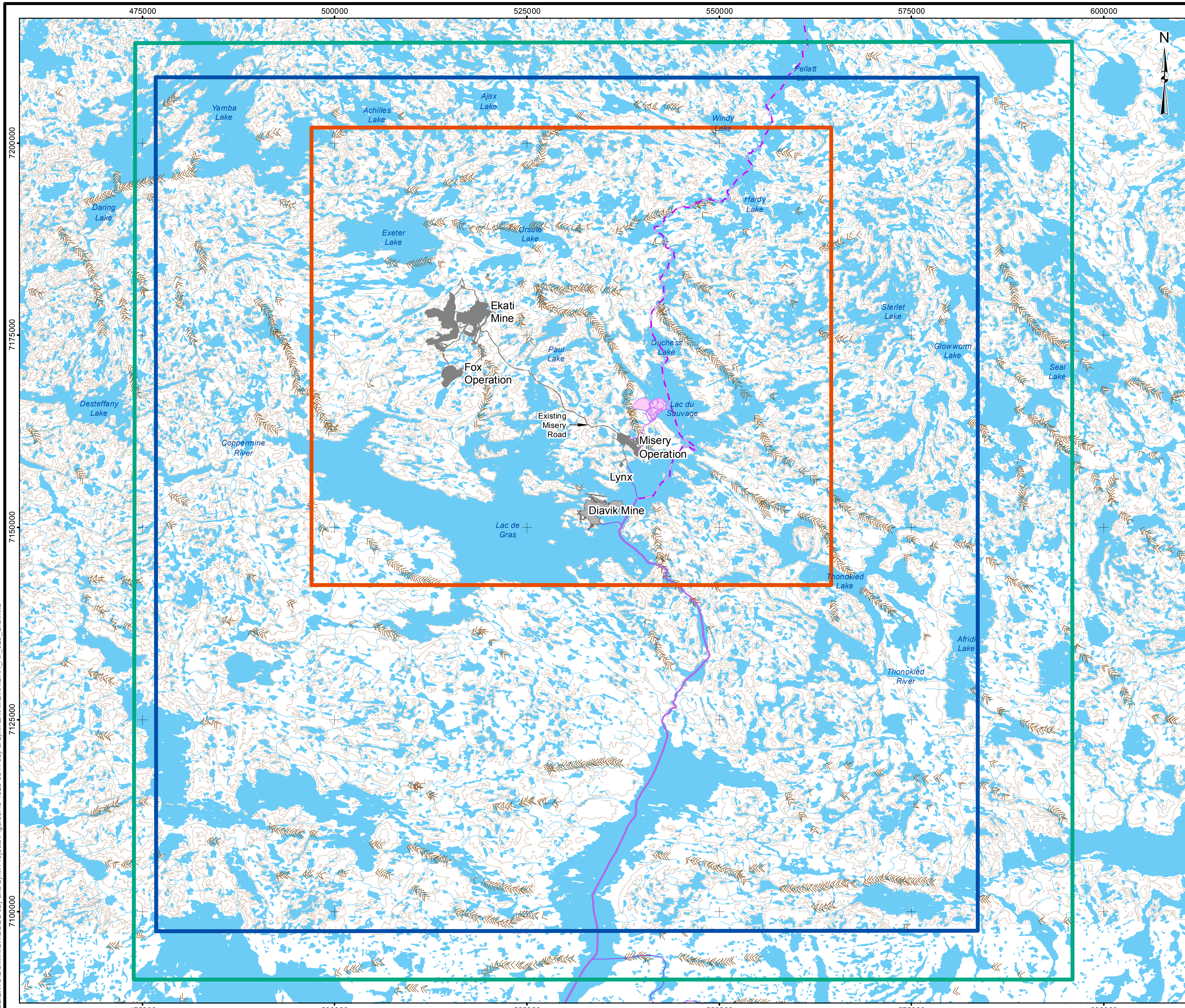
- The CALMET model estimated that unstable (A, B and C) conditions would occur 16% of the time.
- Neutral conditions were estimated to occur 61% of the time.
- Stable (E and F) conditions were estimated to occur 23% of the time.

7C5 DISPERSION MODELLING APPROACH

7C5.1 Modelling Domain

The Air Quality Assessment of the Project was based on the following regions:

- The air quality modelling domain defines the region over which air quality predictions were performed. Emission sources located within the modelling domain were quantified and used in the air quality predictions. The modelling domain chosen for the Air Quality Assessment of the Project is presented in Map 7C5.1-1. It is large enough to encompass the effects related to air emissions from other developments in the region.
- The air quality regional study area (RSA) defines the region over which modelling results are presented and is typically smaller than the modelling domain. The RSA for the Project is defined by a 107 km by 110 km area (Map 7C5.1-1). The RSA is also large enough to capture the air quality cumulative effects associated with emissions from existing and approved industrial sources within the region in combination with the proposed Project.
- The air quality local study area (LSA) defines the area in the immediate vicinity of the Project where the majority of air quality effects are expected to occur. The LSA represents a subset of the RSA and allows a more focused assessment of the effects associated with the Project. The LSA (Map 7C5.1-1) is defined by an area of approximately 68 km by 60 km, encompassing the Project footprint.
- The Project footprint represents the areas that will be physically disturbed due to the construction, operation, and reclamation of the Project (Map 7C5.1-1).
- The development area is an area approximately outlined by the Project footprint that is only used in the air quality assessment to determine compliance with applicable ambient air quality standards (Map 7C5.1-1). The NWT Standards (GNWT-ENR 2014) are applicable outside this boundary. The developed area enveloped all major emission sources associated with the activities at the Project.



LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (20 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA
- MODELLING DOMAIN

REFERENCE

NATIONAL TOPOGRAPHIC BASE DATA (NTDB) 1:250,000
CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

10 0 10

SCALE 1:500,000 KILOMETRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

AIR QUALITY MODELLING DOMAIN AND STUDY AREAS

Golder Associates

PROJECT	13-1328-0041		FILE No. DAR_Air_020_GIS	
DESIGN	DC	11/08/14	SCALE AS SHOWN	REV 0
GIS	SBM	25/09/14	MAP 7C5.1-1	
CHECK	ACP	16/10/14		
REVIEW	CDM	16/10/14		

G:\CLIENTS\DOMINION\DDEC Jay and Lynx Projects\Figures\13-1328-0041 Jay & Lynx EA\Air\DAR\DAR_Air_020_GIS.mxd

7C5.2 Receptors

7C5.2.1 Regional Receptors

Ground-level concentrations and deposition rates were modelled at selected locations (referred to as receptors) within the modelling domain. In the absence of NWT specific air quality modelling guidelines, the receptor locations are based primarily on Alberta *Air Quality Model Guideline* (ESRD 2013).
The receptor placements are as follows:

- spacing of 50 m within 1 km of the sources of interest;
- spacing of 250 m within 2 km of the sources of interest;
- spacing of 500 m within 5 km of the sources of interest;
- spacing of 1,000 m between 5 and 10 km from the sources of interest;
- spacing of 5 km beyond 10 km from the sources of interest; and,
- spacing of 100 m along the Project footprint boundary, and at 100 m and 200 m outside of the Project footprint boundary.

The receptor scheme is shown in Map 7C5.2-1.

7C5.2.2 Discrete Receptors

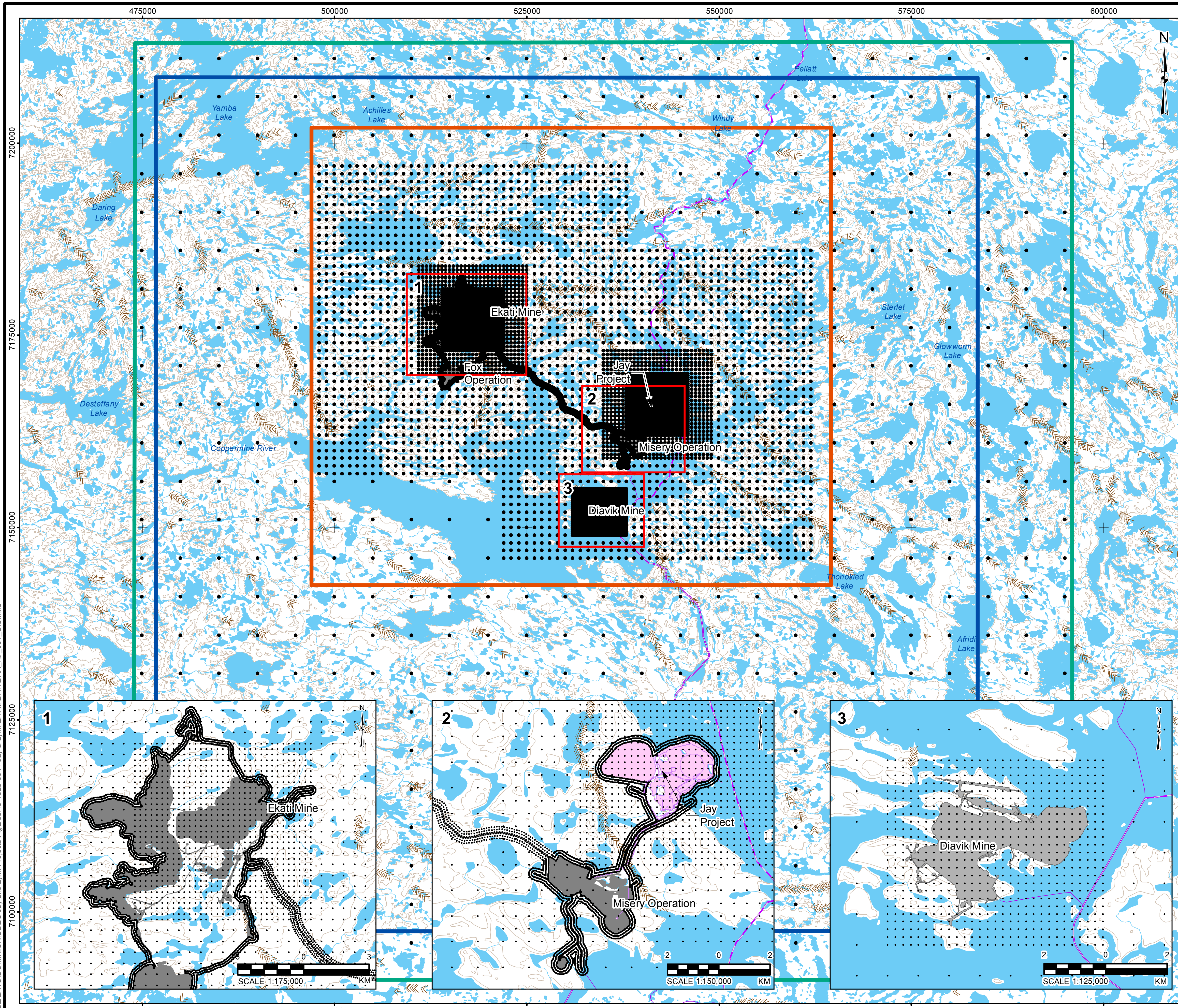
One of the objectives of this air quality assessment is to put the potential air concentrations into perspective for regional stakeholders and regulatory authorities.

To facilitate this objective, maximum air quality concentrations were also predicted at discrete receptor locations near the Project. These discrete receptors can be nominally categorized as health receptors, station receptors, and lake receptors. The discrete receptors are listed in Table 7C5.2-1 and graphically shown in Map 7C5.2-2.

A total of ten health receptor locations were assessed. The list includes: five recreational areas and cabins; the camp locations for Ekati Mine, Misery Pit, and Diavik Mine; the winter road rest stop nearest to the Project; and the traditional knowledge camp near Diavik Mine.

Air quality and meteorological stations located at the Ekati Mine and the Project were also included as station receptors, because data from these stations were utilized for the Air Quality and Meteorological Baseline Report (Annex I) and for the air dispersion model. Six air quality stations and three meteorological stations were included.

Discrete lake receptors were included to predict potential air concentrations and deposition rates at specific lakes within the RSA. The predictions from these receptors are utilized in the water quality models, in Section 8. A total of 101 lake receptors were assessed.



LEGEND

- EKATI MINE FOOTPRINT
- DIAVIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (20 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY
- REGIONAL RECEPTOR LOCATION
- LOCAL STUDY AREA
- REGIONAL STUDY AREA
- MODELLING DOMAIN

REFERENCE

NATIONAL TOPOGRAPHIC BASE DATA (NTDB) 1:250,000
CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

DEVELOPER'S ASSESSMENT REPORT

10 0 10
SCALE 1:500,000 KILOMETRES

PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

REGIONAL RECEPTORS INCLUDED IN THE AIR QUALITY ASSESSMENT

Golder Associates

PROJECT	13-1328-0041	FILE No. DAR_Air_004_GIS
DESIGN	DC	11/08/14
GIS	SM/JR	30/09/14
CHECK	ACP	16/10/14
REVIEW	CDM	16/10/14

SCALE AS SHOWN REV 0

MAP 7C5.2-1

G:\CLIENTS\DOMINION\DDEC Jay and Lynx Projects\Figures\13-1328-0041 Jay & Lynx EA\Air\DAR\DAR_Air_004_GIS.mxd

Table 7C5.2-1 Discrete Receptors Included in the Air Quality Assessment

Receptor	Receptor Type	Coordinates[(a)]	
		Northing (m)	Easting (m)
Courageous Lake Lodge	Health Receptor	477,486	7,114,030
Diavik Camp	Health Receptor	534,285	7,150,820
Diavik Traditional Knowledge Camp	Health Receptor	541,143	7,152,262
Ekati Camp/Administration	Health Receptor	518,138	7,176,305
Lac de Gras Winter Road Rest Stop	Health Receptor	542,862	7,144,018
Lac De Gras Hunting Camp	Health Receptor	549,002	7,157,167
Misery Camp	Health Receptor	539,804	7,161,108
Pellatt Lake Cabin	Health Receptor	560,000	7,211,000
Salmita Airstrip	Health Receptor	492,136	7,105,248
Treeline Lodge	Health Receptor	488,113	7,105,679
13DDJPA	Air Quality Station	543,253	7,165,551
13DDJPB	Air Quality Station	541,267	7,166,089
CAMS Polar Explosives	Air Quality Station	516,438	7,176,428
TSP1	Air Quality Station	518,101	7,176,292
TSP2	Air Quality Station	521,031	7,177,782
TSP3	Air Quality Station	515,812	7,178,835
Ekati Airport Station	Meteorological Station	518,573	7,175,862
Koala Station	Meteorological Station	518,743	7,173,772
Polar Lake Station	Meteorological Station	520,796	7,178,714
AA-1	Lake Receptor	552,282	7,165,025
AA-2	Lake Receptor	552,773	7,165,665
AB-1	Lake Receptor	547,766	7,162,266
AB-2	Lake Receptor	548,215	7,161,177
AC-1	Lake Receptor	543,339	7,165,138
AC-2	Lake Receptor	545,832	7,165,447
AC-4	Lake Receptor	543,695	7,162,938
AC-5	Lake Receptor	543,149	7,163,287
AC-7	Lake Receptor	544,247	7,165,068
AC-8	Lake Receptor	544,777	7,165,855
AD-1	Lake Receptor	539,898	7,168,781
AD-2	Lake Receptor	539,868	7,168,991
AE-1	Lake Receptor	542,494	7,170,252
AE-2	Lake Receptor	542,589	7,170,675
AF-1	Lake Receptor	542,155	7,173,731
AF-10	Lake Receptor	538,299	7,176,361
AF-2	Lake Receptor	542,074	7,173,542
AF-4	Lake Receptor	544,360	7,173,181
AF-7	Lake Receptor	541,367	7,174,902
CL-1	Lake Receptor	539,465	7,163,731
C-L1	Lake Receptor	537,612	7,167,085
Counts	Lake Receptor	533,815	7,169,863
Cujo	Lake Receptor	538,730	7,162,008
D-L3	Lake Receptor	534,303	7,169,862
E-L1-1	Lake Receptor	535,065	7,174,657
E-L1-2	Lake Receptor	535,292	7,174,406

DOMINION DIAMOND

Table 7C5.2-1 Discrete Receptors Included in the Air Quality Assessment

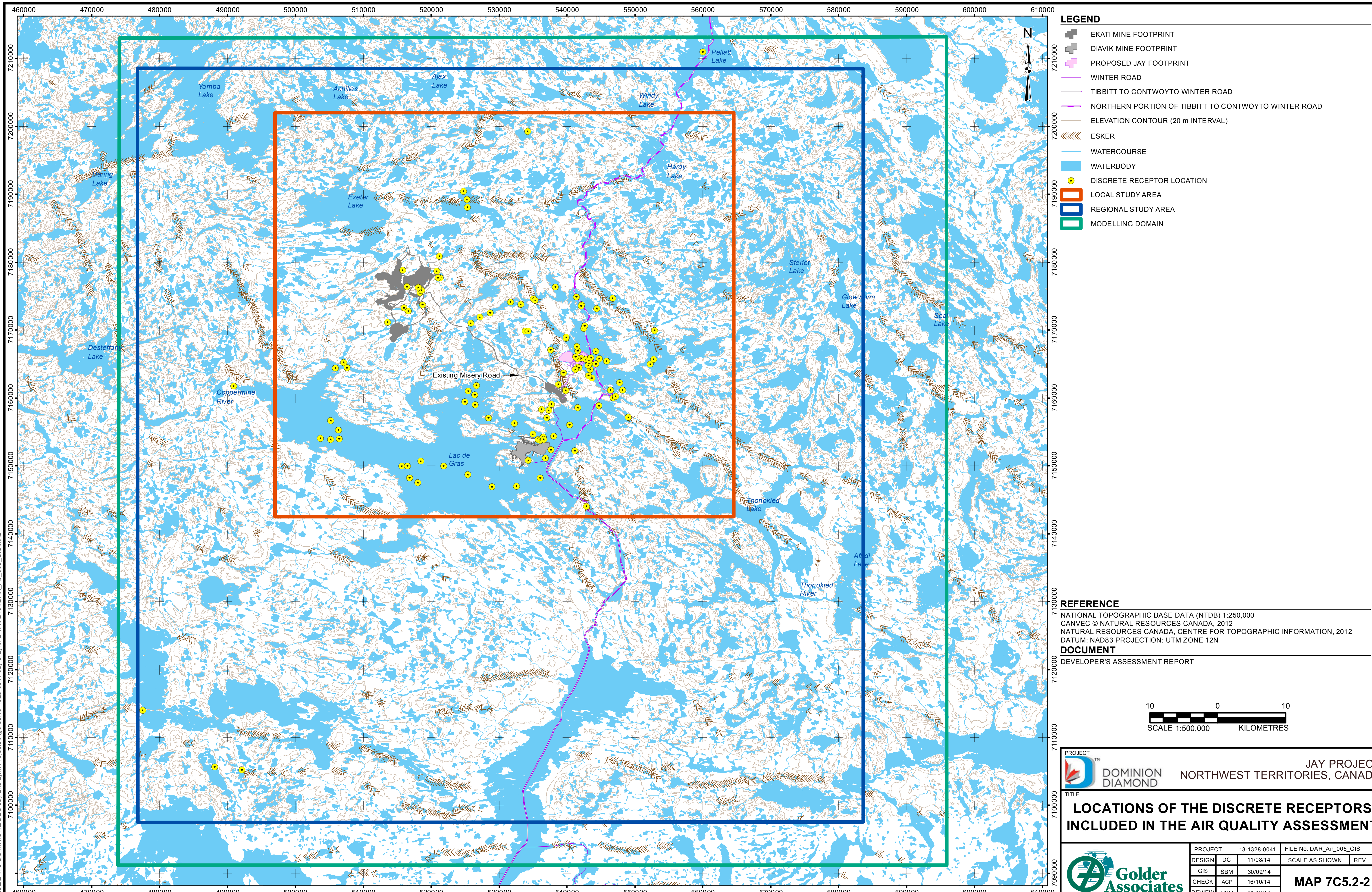
Receptor	Receptor Type	Coordinates[a]	
		Northing (m)	Easting (m)
F1	Lake Receptor	537,042	7,157,119
FF1-1	Lake Receptor	525,430	7,161,043
FF1-2	Lake Receptor	524,932	7,159,476
FF1-3	Lake Receptor	526,407	7,160,492
FF1-4	Lake Receptor	526,493	7,159,058
FF1-5	Lake Receptor	526,683	7,161,824
FF2-2	Lake Receptor	541,588	7,158,561
FF2-5	Lake Receptor	544,724	7,158,879
FFA-1	Lake Receptor	506,453	7,154,021
FFA-2	Lake Receptor	506,315	7,155,271
FFA-3	Lake Receptor	505,207	7,153,887
FFA-4	Lake Receptor	503,703	7,154,081
FFA-5	Lake Receptor	505,216	7,156,657
FFB-1	Lake Receptor	516,831	7,148,207
FFB-2	Lake Receptor	518,473	7,150,712
FFB-3	Lake Receptor	518,048	7,147,557
FFB-4	Lake Receptor	515,687	7,150,036
FFB-5	Lake Receptor	516,533	7,150,032
Fisher	Lake Receptor	536,271	7,158,344
G-L2	Lake Receptor	546,706	7,174,698
Grizzly	Lake Receptor	521,305	7,177,725
H-L1	Lake Receptor	552,899	7,169,950
Kodiak	Lake Receptor	518,328	7,175,525
LDG-48	Lake Receptor	490,900	7,161,750
LdS1	Lake Receptor	541,620	7,164,525
LdS1	Lake Receptor	541,789	7,164,516
LDS-1	Lake Receptor	546,398	7,161,179
LdS10	Lake Receptor	544,254	7,166,873
LdS11	Lake Receptor	543,451	7,164,236
LdS2	Lake Receptor	541,241	7,164,233
LdS2	Lake Receptor	541,211	7,164,250
LDS-2	Lake Receptor	546,807	7,160,027
LdS3	Lake Receptor	542,070	7,165,905
LDS-3	Lake Receptor	547,191	7,160,256
LdS4	Lake Receptor	541,535	7,165,807
LdS5	Lake Receptor	542,789	7,165,666
LdS6	Lake Receptor	541,563	7,166,957
LdS7	Lake Receptor	543,465	7,165,961
LdS8	Lake Receptor	543,085	7,164,811
LdS9	Lake Receptor	541,436	7,167,616
Leslie	Lake Receptor	515,984	7,173,296
Lynx	Lake Receptor	537,336	7,158,230
MF1-1	Lake Receptor	535,008	7,154,699
MF1-3	Lake Receptor	532,236	7,156,276
MF1-5	Lake Receptor	528,432	7,157,066

Table 7C5.2-1 Discrete Receptors Included in the Air Quality Assessment

Receptor	Receptor Type	Coordinates[a]	
		Northing (m)	Easting (m)
MF2-1	Lake Receptor	538,033	7,154,371
MF2-3	Lake Receptor	540,365	7,156,045
MF3-1	Lake Receptor	537,645	7,152,432
MF3-2	Lake Receptor	536,816	7,151,126
MF3-3	Lake Receptor	536,094	7,148,215
MF3-4	Lake Receptor	532,545	7,147,011
MF3-5	Lake Receptor	528,956	7,146,972
MF3-6	Lake Receptor	525,427	7,148,765
MF3-7	Lake Receptor	521,859	7,150,039
Moose	Lake Receptor	516,642	7,172,796
Nanuq	Lake Receptor	534,194	7,199,310
Nema	Lake Receptor	513,580	7,171,127
NF1	Lake Receptor	535,740	7,153,854
NF2	Lake Receptor	536,095	7,153,784
NF3	Lake Receptor	536,369	7,154,092
NF4	Lake Receptor	536,512	7,154,240
NF5	Lake Receptor	536,600	7,153,864
Phantom	Lake Receptor	537,741	7,159,089
PL-05	Lake Receptor	525,859	7,171,047
PL-1	Lake Receptor	533,179	7,173,835
PL-2	Lake Receptor	531,655	7,174,122
PL-3	Lake Receptor	528,681	7,172,550
PL-4	Lake Receptor	527,145	7,171,895
S2	Lake Receptor	507,635	7,164,482
S3	Lake Receptor	505,898	7,164,448
Slipper	Lake Receptor	507,106	7,165,281
UL1	Lake Receptor	524,766	7,190,484
UL2	Lake Receptor	525,264	7,189,286
UL3	Lake Receptor	525,355	7,188,141
Vulture	Lake Receptor	521,183	7,180,886

a) Universal Transverse Mercator (UTM) North American Datum (NAD) 83 Zone 12.

m = metre; CAMS = continuous air monitoring station.



Yamba Lake
Achilles Lake
Ajax Lake
Pellatt Lake
Windy Lake
Hardy Lake
Daring Lake
Exeter Lake
Sterlet Lake
Glowworm Lake
Sea Lake
Desteffany Lake
Coppermine River
Existing Misery Road
Lac de Gras
Thonokied Lake
Afridi Lake
Thonokied River
N
LEGEND
EKATI MINE FOOTPRINT
DIAVIK MINE FOOTPRINT
PROPOSED JAY FOOTPRINT
WINTER ROAD
TIBBITT TO CONTWOYTO WINTER ROAD
NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
ELEVATION CONTOUR (20 m INTERVAL)
ESKER
WATERCOURSE
WATERBODY
DISCRETE RECEPTOR LOCATION
LOCAL STUDY AREA
REGIONAL STUDY AREA
MODELLING DOMAIN
REFERENCE
NATIONAL TOPOGRAPHIC BASE DATA (NTDB) 1:250,000
CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N
DOCUMENT
DEVELOPER'S ASSESSMENT REPORT
10 0 10
SCALE 1:500,000 KILOMETRES
PROJECT
DOMINION DIAMOND
JAY PROJECT
NORTHWEST TERRITORIES, CANADA
TITLE
LOCATIONS OF THE DISCRETE RECEPTORS INCLUDED IN THE AIR QUALITY ASSESSMENT
Golder Associates
PROJECT 13-1328-0041 FILE No. DAR_Air_005_GIS
DESIGN DC 11/08/14 SCALE AS SHOWN REV 0
GIS SBM 30/09/14
CHECK ACP 16/10/14
REVIEW CDM 16/10/14
MAP 7C5.2-2
G:\CLIENTS\DOMINION\DDEC Jay and Lynx Projects\Figures\13-1328-0041 Jay & Lynx EA\Air\DAR\DAR_Air_005_GIS.mxd

7C5.3 Model Options

The CALPUFF dispersion model is a sophisticated tool that uses numerous user-specified options. The selection of options used in the analysis requires great care and understanding of the underlying model algorithms. Most of the modelling options used in the model followed Alberta Air Quality Model Guideline (ESRD 2013) recommendations or US EPA default CALPUFF model options. However, a few of the model options are not the default options and each is discussed in detail here.

7C5.3.1 MBDW – (Building Downwash)

Buildings or other solid structures may affect the flow of air in the vicinity of a source and cause eddies to form on the downwind side of a building. Building downwash algorithms only apply to point sources. The point sources and the main buildings at the Project are located towards the centre of the development area, far from the development area boundary. Therefore, the effects of building downwash on the ground-level concentrations or deposition rates outside the development area would be minimal. Therefore, building downwash was not included in this assessment.

7C5.3.2 MREG – (Regulatory Check)

Test options specified to see if they conform to regulatory values. The MREG is an optional check and it was turned off (MREG=0).

7C5.3.3 DATUM – (Geographic Coordinate System)

The DATUM option was set to NAR-C (DATUM=NAR C) because the coordinates used in the assessment are in NAD83 (North American 1983 GRS 80 Spheroid) datum. The NAD83 uses the same GRS 80 spheroid as WGS 84.

7C5.3.4 IVEG – (Vegetation State in Unirrigated Areas)

The IVEG option was set to 2 (IVEG=2) to represent the unirrigated land as stressed.

The model input options that were used in the modelling completed for the Project are summarized in detail in Table 7C5.3-1.

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 1 – General Run Control Parameter	METRUN	-	0	run period explicitly defined below
	IBYR	-	2001	starting year for run if METRUN = 0
	IBMO	-	12	starting month for run if METRUN = 0
	IBDY	-	31	starting day for run if METRUN = 0
	IBHR	-	4	starting hour for run if METRUN = 0
	IBSEC	-	0	starting second for run if METRUN = 0
	IEYR	-	2002	ending year for run if METRUN = 0
	IEMO	-	12	ending month for run if METRUN = 0
	IEDY	-	31	ending day for run if METRUN = 0
	IEHR	-	23	ending hour for run if METRUN = 0
	IEMIN	-	0	ending minute for run if METRUN = 0
	IESEC	-	3,600	ending second for run if METRUN = 0
	ABTZ	-	7	base time zone (PST = 8, MST = 7, CST = 6, EST = 5)
	NSECDT	3,600	3,600	Length of modeling time-step (seconds)
	NSPEC	5	7	number of chemical species for the example file
	NSE	3	4	number of chemical species to be emitted
	ITEST	2	2	program is executed after SETUP phase
	MRESTART	0	0	do not read or write a restart file
	NRESPD	0	0	restart file written only at last period
	METFM	1	1	CALMET binary file (CALMET.MET)
	MPRFFM	1	1	meteorological profile data format (CTDM plus tower file)
	AVET	60	60	Averaging time (minutes)
	PGTIME	60	60	PG Averaging Time (minutes)
	IOUTU	1	1	Output units for binary concentration and flux files written in Dataset v2.2 or later formats (1 = mass - g/m3 (conc) or g/m^2/s (dep)
	IOVERS	2	2	Output Dataset format for binary concentration and flux files (2 = Dataset Version 2.2)

DOMINION DIAMOND

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 2 – Technical Options	MGAUSS	1	1	Gaussian distribution used in near field
	MCTADJ	3	3	partial plume path terrain adjustment
	MCTSG	0	0	subgrid-scale complex terrain not modelled
	MSLUG	0	0	near-field puffs not modelled as elongated
	MTRANS	1	1	transitional plume rise modelled
	MTIP	1	1	stack tip downwash used
	MBDW	1	2	method to simulate building downwash (PRIME method)
	MRISE	1	1	Briggs plume rise used
	MSHEAR	0	0	vertical wind shear not modelled
	MSPLIT	0	0	puffs are not split
	MCHEM	1	3	transformation rates computed internally using RIVAD/ARM3 scheme
	MAQCHEM	0	0	aqueous phase transformation rates not modelled
	MLWC	1	1	Liquid Water Content flag (Used only if MAQCHEM = 1)
	MWET	1	1	wet removal modelled
	MDRY	1	1	dry deposition modelled
	MTILT	0	0	Gravitational settling not modelled
	MDISP	3	2	dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (e.g., u*, w*, L)
	MTURBVW	3	3	use both sigma-(v/theta) and sigma-w from PROFILE.DAT to compute sigma-y and sigma-z (valid for METFM = 1,2,3,4)
	MDISP2	3	3	PG dispersion coefficients for RURAL areas (computed using the ISCST multi-segment approximation) and MP coefficients in urban areas
	MTAULY	0	0	Method used for Lagrangian timescale for Sigma-y (Draxler default 617.284 (s))
	MTAUADV	0	0	Method used for Advective-Decay timescale for Turbulence (used only if MDISP=2 or MDISP2=2) (No turbulence advection)
	MCTURB	1	1	Method used to compute turbulence sigma-v & sigma-w using micrometeorological variables (Standard CALPUFF subroutines)
	MROUGH	0	0	PG sigma-y and sigma-z not adjusted for roughness

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 2 – Technical Options (continued)	MPARTL	1	1	partial plume penetration of elevated inversion
	MPARTLBA	1	1	Partial plume penetration of elevated inversion modeled for buoyant area sources
	MTINV	0	0	strength of temperature inversion not computed from measured/default gradients
	MPDF	0	1	PDF used for dispersion under convective conditions
	MSGTIBL	0	0	sub-grid TIBL module not used for shoreline
	MBCON	0	0	boundary conditions not modelled
	MSOURCE	0	0	Individual source contributions are not saved
	MFOG	0	0	do not configure for FOG Model output
	MREG	1	0	do not test options specified to see if they conform to regulatory values
Group 3 – Species List	CSPEC	-	SO_2, SO_4 , NO, NO_2, HNO_3, NO_3, CO	list of chemical species
		-	1,1,1,1,1,1,1	is SO_2, SO_4, NO, NO_2, HNO_3, NO_3 modelled? (0=no, 1=yes)
		-	1,0,1,1,0,0,1	is SO_2, SO_4, NO, NO_2, HNO_3, NO_3 emitted? (0=no, 1=yes)
		-	1,2,1,1,1,2,1	SO_2, SO_4, NO, NO_2, HNO_3, NO_3 dry deposition method (1=computed-gas, 2=computed-particle)
		-	0,0,0,0,0,0,0	SO_2, SO_4, NO, NO_2, HNO_3, NO_3 output group number
Group 4 – Map Projection and Grid Control Parameters	PMAP	UTM	UTM	map projection
	FEAST	0	0	false Easting (km) at the projection origin
	FNORTH	0	0	false Northing (km) at the projection origin
	IUTMZN	-	12	UTM zone
	UTMHEM	N	N	hemisphere for UTM projection
				(N = north, S = south)
	RLAT0	-	40N	latitude of projection origin
				(not used if PMAP = UTM)
	RLON0	-	90W	longitude of projection origin
				(not used if PMAP = UTM)

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 4 – Map Projection and Grid Control Parameters (continued)	XLAT1	-	30N	matching parallel(s) of latitude (decimal degrees) for projection (used only if PMAP = LCC or PS)
	XLAT2	-	60N	matching parallel(s) of latitude (decimal degrees) for projection (used only if PMAP = LCC or PS)
	DATUM	WGS-84	NAR-C	datum-region for output coordinates
	NX	-	122	number of X grid cells in meteorological grid
	NY	-	122	number of Y grid cells in meteorological grid
	NZ	-	10	number of vertical layers in meteorological grid
	DGRIDKM	-	1.0	grid spacing in kilometres
	ZFACE	-	0.,20.,50.,100.,200.,400.,800.,1200.,1600.,2200.,300.	cell face heights in meteorological grid (m)
	XORIGKM	-	473.906	reference X coordinate for south-west corner of grid cell (1,1) of meteorological grid (km)
	YORIGKM	-	7091.217	reference Y coordinate for south-west corner of grid cell (1,1) of meteorological grid (kilometres)
	IBCOMP	-	1	X index of lower left corner of the computational grid
	JBCOMP	-	1	Y index of lower left corner of the computational grid
	IECOMP	-	122	X index of upper right corner of the computational grid
	JECOMP	-	122	Y index of upper right corner of the computational grid
	LSAMP	T	F	sampling grid is not used
	IBSAMP	-	1	X index of lower left corner of the sampling grid
	JBSAMP	-	1	Y index of lower left corner of the sampling grid
	IESAMP	-	17	X index of upper right corner of the sampling grid
	JESAMP	-	17	Y index of upper right corner of the sampling grid
	MESHDN	1	1	nesting factor of the sampling grid

DOMINION DIAMOND

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 5 – Output Options	ICON	1	1	output file CONC.DAT containing concentration fields is created
	IDRY	1	1	output file DFLX.DAT containing dry flux fields is created
	IWET	1	1	output file WFLX.DAT containing wet flux fields is created
	IT2D	0	0	2D Temperature (IT2D)
	IRHO	0	0	2D Density (IRHO)
	IVIS	0	0	output file containing relative humidity data is not created
	LCOMPRS	T	T	use data compression in output files
	IQAPLOT	1	0	standard series of output files not created for plotting
	IPFTRAK	0	0	puff locations and properties not reported to PFTRAK.DAT file for post-processing
	IMFLX	0	0	mass flux across specified boundaries for selected species not reported hourly
	IMBAL	0	0	mass balance for each species not reported hourly
	INRISE	0	0	file for plume properties for each rise increment, for each model timestep not created
	ICPRT	0	0	do not print concentration fields to the output list file
	IDPRT	0	0	do not print dry flux fields to the output list file
	IWPRT	0	0	do not print wet flux fields to the output list file
	ICFRQ	1	1	concentration fields are printed to output list file every 1 hour
	IDFRQ	1	1	dry flux fields are printed to output list file every 1 hour
	IWFRQ	1	1	wet flux fields are printed to output list file every 1 hour
	IPRTU	1	3	units for line printer output are in µg/m^3 for concentration and µg/m^2/s for deposition
	IMESG	2	2	messages tracking the progress of run are written on screen

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 5 – Output Options (continued)	SO_2, SO_4 , NO, NO_2, HNO_3, NO_3, CO	-	0,0,0,0,0,0,0	concentrations printed to output list file (0 = no, 1 = yes)
		-	1,1,1,1,1,1,1	concentrations saved to disk (0=no, 1=yes)
		-	0,0,0,0,0,0,0	dry fluxes printed to output list file (0=no, 1=yes)
		-	1,1,1,1,1,1,1	dry fluxes saved to disk (0=no, 1=yes)
		-	0,0,0,0,0,0,0	wet fluxes printed to output list file (0=no, 1=yes)
		-	1,1,1,1,1,1,1	wet fluxes saved to disk (0=no, 1=yes)
		-	0,0,0,0,0,0,0	mass fluxes saved to disk (0=no, 1=yes)
	LDEBUG	F	F	logical value for debug output
	IPFDEB	1	1	first puff to track
	NPFDEB	1	1	number of puffs to track
	NN1	1	1	meteorological period to start output
	NN2	10	10	meteorological period to end output
Group 6 – Subgrid Scale Complex Terrain Inputs	NHILL	0	0	number of terrain features
	NCTREC	0	0	number of special complex terrain receptors
	MHILL	-	0	input terrain and receptor data for CTSG hills input in CTDM format not used
	XHILL2M	1	1	conversion factor for changing horizontal dimensions to metres
	ZHILL2M	1	1	conversion factor for changing vertical dimensions to metres
	XCTDMKM	-	0	X origin of CTDM system relative to CALPUFF coordinate system in kilometres
	YCTDMKM	-	0	Y origin of CTDM system relative to CALPUFF coordinate system in kilometres

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 7 – Chemical Parameters for Dry Deposition of Gases		-	0.1509	diffusivity for SO_2 (cm^2/s)
		-	1,000.00	alpha star for SO_2
		-	8	reactivity for SO_2
		-	0	mesophyll resistance for SO_2 (s/cm)
		-	0.04	Henry's Law coefficient for SO_2
		-	0.1345	diffusivity for NO (cm^2/s)
		-	1	alpha star for NO
		-	2	reactivity for NO
		-	25	mesophyll resistance for NO (s/cm)
		-	18	Henry's Law coefficient for NO
		-	0.1656	diffusivity for NO_2 (cm^2/s)
		-	1	alpha star for NO_2
		-	8	reactivity for NO_2
		-	5	mesophyll resistance for NO_2 (s/cm)
		-	3.5	Henry's Law coefficient for NO_2
		-	0.1628	diffusivity for HNO_3 (cm^2/s)
		-	1	alpha star for HNO_3
		-	18	reactivity for HNO_3
		-	0	mesophyll resistance for HNO_3 (s/cm)
		-	0.00000008	Henry's Law coefficient for HNO_3
		-	0.1860	diffusivity for CO(cm^2/s)
		-	1.0	alpha star for CO
		-	2.0	reactivity for CO
		-	61	mesophyll resistance for CO (s/cm)
		-	44.	Henry's Law coefficient for CO
Group 8 – Size Parameters for Dry Deposition of Particles		0.48	0.48	geometric mass mean diameter of SO_4 (µm)
		2	2	geometric standard deviation of SO_4 (µm)
		0.48	0.48	geometric mass mean diameter of NO_3 (µm)
		2	2	geometric standard deviation of NO_3 (µm)

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 9 - Miscellaneous Dry Deposition Parameters	RCUTR	30	30	reference cuticle resistance in seconds/centimetre (s/cm)
	RGR	10	10	reference ground resistance in s/cm
	REACTR	8	8	reference pollutant reactivity
	NINT	9	9	number of particle size intervals used to evaluate effective particle deposition velocity
	IVEG	1	1	Vegetation state in unirrigated areas for active and unstressed vegetation
Group 10 – Wet Deposition Parameters		0.00003	0.00003	the SO_2 scavenging coefficient for liquid precipitation (1/second [1/s])
		0	0	the SO_2 scavenging coefficient for frozen precipitation (1/s)
		0.0001	0.0001	the SO_4^{2-} scavenging coefficient for liquid precipitation (1/s)
		0.00003	0.00003	the SO_4^{2-} scavenging coefficient for frozen precipitation (1/s)
		0.00006	0.00006	the HNO_3 scavenging coefficient for liquid precipitation (1/s)
		0	0	the HNO_3 scavenging coefficient for frozen precipitation (1/s)
		0.0001	0.0001	the NO_3^- scavenging coefficient for liquid precipitation (1/s)
		0.00003	0.00003	the NO_3^- scavenging coefficient for frozen precipitation (1/s)
Group 11 – Chemistry Parameters	MOZ	1	1	Ozone data input : read hourly ozone concentrations from the OZONE.DAT data file
	MNH_3	0	0	use monthly background ammonia values ($BCKNH_3$) - no vertical variation
	$MAVGNH_3$	1	1	average NH_3 values over vertical extent of puff
	$BCKNH_3$	12*10	12*0.22	Monthly ammonia concentrations in ppb
	RNITE1	0.2	0.2	nighttime SO_2 loss rate in percent/hour
	RNITE2	2	2	nighttime NO_X loss rate in percent/hour

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 11 – Chemistry Parameters (continued)	RNITE3	2	2	nighttime HNO_3 formation rate in percent/hour
	MH2O2	1	1	read hourly H_2O_2 concentrations from the H2O2.DAT
	BCKH2O2	12*1	12*1	monthly H_2O_2 concentrations in ppb
	BCKPMF	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00	Clean Continental - characterize the air mass when computing the formation of Secondary Organic Aerosols (SOA) from VOC emissions
	OFRAC	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15	
	VCNX	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00	
	NDECAY	0	0	Number of half-life decay specification blocks
Group 12 – Miscellaneous Dispersion and Computational Parameters	SYTDEP	550	550	horizontal size of a puff in metres beyond which the time dependant Heffter dispersion equation is used
	MHFTSZ	0	0	do not use Heffter formulas for sigma z
	JSUP	5	5	stability class used to determine dispersion rates for puffs above boundary layer
	CONK1	0.01	0.01	vertical dispersion constant for stable conditions
	CONK2	0.1	0.1	vertical dispersion constant for neutral/unstable conditions
	TBD	0.5	0.5	Use Industrial Source Complex (ISC) transition point for determining the transition point between the Schulman-Scire to Huber-Snyder Building Downwash scheme
	IURB1	10	10	lower range of land use categories for which urban dispersion is assumed
	IURB2	19	19	upper range of land use categories for which urban dispersion is assumed
	ILANDUIN	20	20	land use category for modelling domain
	Z0IN	0.25	0.25	roughness length in metres for modelling domain
	XLAIIN	3	3	leaf area index for modelling domain

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 12 – Miscellaneous Dispersion and Computational Parameters (continued)	ELEVIN	0	0	elevation above sea level in (m)
	XLATIN	–999	–999	latitude of station in degrees (°)
	XLONIN	–999	–999	longitude of station in degrees (°)
	ANEMHT	10	10	anemometer height in (m)
	ISIGMAV	1	1	sigma-v is read for lateral turbulence data
	IMIXCTDM	0	0	predicted mixing heights are used
	XMXLEN	1	1	maximum length of emitted slug in meteorological grid units
	XSAMLEN	1	1	maximum travel distance of slug or puff in meteorological grid units during one sampling unit
	MXNEW	99	99	maximum number of puffs or slugs released from one source during one time step
	MXSAM	99	99	maximum number of sampling steps during one time step for a puff or slug
	NCOUNT	2	2	number of iterations used when computing the transport wind for a sampling step that includes gradual rise
	SYMIN	1	1	minimum sigma y in metres for a new puff or slug
	SZMIN	1	1	minimum sigma z in metres for a new puff or slug
	SZCAP_M	5.0e06	5.0e06	Maximum sigma z (m) allowed to avoid numerical problem in calculating virtual time or distance.
	SVMIN LAND	0.5	0.5	minimum turbulence (σ_v) velocity for stability class A (m/s)
		0.5	0.5	minimum turbulence (σ_v) velocity for stability class B (m/s)
		0.5	0.5	minimum turbulence (σ_v) velocity for stability class C (m/s)
		0.5	0.5	minimum turbulence (σ_v) velocity for stability class D (m/s)
		0.5	0.5	minimum turbulence (σ_v) velocity for stability class E (m/s)
		0.5	0.5	minimum turbulence (σ_v) velocity for stability class F (m/s)

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 12 – Miscellaneous Dispersion and Computational Parameters (continued)	SVMIN WATER	0.37	0.37	minimum turbulence (σ_v) velocity for stability class A (m/s)
		0.37	0.37	minimum turbulence (σ_v) velocity for stability class B (m/s)
		0.37	0.37	minimum turbulence (σ_v) velocity for stability class C (m/s)
		0.37	0.37	minimum turbulence (σ_v) velocity for stability class D (m/s)
		0.37	0.37	minimum turbulence (σ_v) velocity for stability class E (m/s)
		0.37	0.37	minimum turbulence (σ_v) velocity for stability class F (m/s)
	SWMIN LAND	0.2	0.2	minimum turbulence (σ_w) velocity for stability class A (m/s)
		0.12	0.12	minimum turbulence (σ_w) velocity for stability class B (m/s)
		0.08	0.08	minimum turbulence (σ_w) velocity for stability class C (m/s)
		0.06	0.06	minimum turbulence (σ_w) velocity for stability class D (m/s)
		0.03	0.03	minimum turbulence (σ_w) velocity for stability class E (m/s)
		0.016	0.016	minimum turbulence (σ_w) velocity for stability class F (m/s)
	SWMIN WATER	0.2	0.2	minimum turbulence (σ_w) velocity for stability class A (m/s)
		0.12	0.12	minimum turbulence (σ_w) velocity for stability class B (m/s)
		0.08	0.08	minimum turbulence (σ_w) velocity for stability class C (m/s)
		0.06	0.06	minimum turbulence (σ_w) velocity for stability class D (m/s)
		0.03	0.03	minimum turbulence (σ_w) velocity for stability class E (m/s)
		0.016	0.016	minimum turbulence (σ_w) velocity for stability class F (m/s)
	CDIV	0.0, 0.0	0.0, 0.0	divergence criteria for dw/dz in met cells
	NLUTIBL	4	4	Search radius (number of cells) for nearest land and water cells used in the subgrid TIBL module
	WSCALM	0.5	0.5	minimum wind speed allowed for non-calm conditions (m/s)
	XMAXZI	3,000	3,000	maximum mixing height (m)
	XMINZI	50	50	minimum mixing height (m)

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 12 – Miscellaneous Dispersion and Computational Parameters (continued)	WSCAT	1.54	1.54	wind speed category 1 (m/s)
		3.09	3.09	wind speed category 2 (m/s)
		5.14	5.14	wind speed category 3 (m/s)
		8.23	8.23	wind speed category 4 (m/s)
		10.8	10.8	wind speed category 5 (m/s)
	PLX0	0.07	0.07	wind speed profile exponent for A stability
		0.07	0.07	wind speed profile exponent for B stability
		0.1	0.1	wind speed profile exponent for C stability
		0.15	0.15	wind speed profile exponent for D stability
		0.35	0.35	wind speed profile exponent for E stability
		0.55	0.55	wind speed profile exponent for F stability
	PTG0	0.02	0.02	potential temperature gradient for E stability (K/m)
		0.035	0.035	potential temperature gradient for F stability (K/m)
	PPC	0.5	0.5	plume path coefficient for A stability
		0.5	0.5	plume path coefficient for B stability
		0.5	0.5	plume path coefficient for C stability
		0.5	0.5	plume path coefficient for D stability
		0.35	0.35	plume path coefficient for E stability
		0.35	0.35	plume path coefficient for F stability
	SL2PF	10	10	slug-to-puff transition criterion factor equal to sigma y/length of slug
	NSPLIT	3	3	number of puffs that result every time a puff is split (not used since NSPLIT=0)
	IRESPLIT	0,0,0,0,0,0,0,0,0,0,0,0,0,0, 0,0,0,0,1,0,0,0,0,0,0	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 ,0,0,1,0,0,0,0,0,0	time(s) of day when split puffs are eligible to be split once again
	ZISPLIT	100	100	minimum allowable last hour's mixing height for puff splitting (m)
	ROLDMAX	0.25	0.25	maximum allowable ratio of last hour's mixing height and maximum mixing height experienced by the puff for puff splitting
	NSPLITH	5	5	number of puffs that result every time a puff is split
	SYSPLITH	1	1	minimum sigma-y (grid cells units) of puff before it may be split

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 12 – Miscellaneous Dispersion and Computational Parameters (continued)	SHSPLITH	2	2	minimum puff elongation rate (SYSPLITH/hr) due to wind shear before it may be split
	CNSPLITH	1.0E–07	1.0E–07	minimum concentration (g/m^3) of each species in puff before it may be split
	EPSSLUG	1.00E–04	1.00E–04	fractional convergence criterion for numerical SLUG sampling integration
	EPSAREA	1.00E–06	1.00E–06	fractional convergence criterion for numerical AREA source integration
	DSRISE	1	1	trajectory step-length (m) used for numerical rise integration
	HTMINBC	500.	500.	Minimum height (m) to which BC puffs are mixed as they are emitted
	RSAMPBC	10.	10.	Search radius (km) from a receptor for sampling nearest BC puff.
	MDEPBC	1	1	Near-Surface depletion adjustment to concentration profile Adjust Concentration for depletion
Group 13 – Point Source Parameters	NPT1	-	Vary depending on the specific modelling run	number of point sources
	IPTU	1	1	units for point source emission rates is grams per second (g/s)
	NSPT1	0	0	number of source-species combinations with variable emissions scaling factors
	NPT2	-	0	number of point sources with variable emission parameters provided in external file
Group 14 – Area Source Parameters	NAR1	-	Vary depending on the specific modelling run	number of polygon area sources
	IARU	1	1	area source emission rates ($g/m^2/s$)
	NSAR1	0	Vary depending on the specific modelling run	number of source-species combinations with variable emissions scaling factors
	NAR2	-	0	number of buoyant polygon area sources with variable location and emission parameters

DOMINION DIAMOND

Table 7C5.3-1 CALPUFF Model Input Options

Input Group	Parameter	US EPA Default	Project	Description
Group 15 – Line Source Parameters	NLN2	-	0	number of buoyant line sources with variable location and emission parameters
	NLINES	-	0	number of buoyant line sources
	ILNU	1	1	line source emission rates (g/s)
	NSLN1	0	0	number of source-species combinations with variable emissions scaling factors
	MXNSEG	7	7	maximum number of segments used to model each line
	NLRISE	6	6	number of distances at which transitional rise is computed
	XL	-	0	average line source length (m)
	HBL	-	0	average height of line source height (m)
	WBL	-	0	average building width (m)
	WML	-	0	average line source width (m)
	DXL	-	0	average separation between buildings (m)
	FPRIMEL	-	0	average buoyancy parameter
Group 16 – Volume Source Parameters	NVL1	-	0	number of volume sources
	IVLU	1	1	volume source emission rates (g/s)
	NSVL1	0	0	number of source-species combinations with variable emissions scaling factors
	NSVL2	-	0	number of volume sources with variable location and emission parameters
Group 17 – Non-Gridded Receptor Information	NREC	-	Vary depending on the specific modelling run	number of non-gridded receptors
	NRGRP	0	0	Number of receptor group names

– = Not applicable; US EPA = United States Environmental Protection Agency; g/s = grams per second; m = metre; $g/m^2/s$ = grams per square metre per second; km = kilometre; m = metre; g/m^3 = grams per cubic metre; K/m = degrees Kelvin per metre; m/s = metres per second; VOC = volatile organic carbons; H_2O_2 = hydrogen peroxide; ppb – parts per billion; NO_3^- = nitrate (ion); SO_2 = sulphur dioxide; $\mu g/m^2/s$ = micrograms per square meter per second; $\mu g/m^3$ = micrograms per cubic metre; s/cm = seconds per centimetre; SO_4 = sulphate; µm = microns; cm^2/s = square centimetres per second; CO = carbon monoxide; NO_2 = nitrogen dioxide; NO -= nitric oxide (gas).

7C5.4 NO_X to NO_2 Conversion

Oxides of nitrogen (NO_X) are comprised of nitric oxide (NO) and nitrogen dioxide (NO_2). High temperature combustion processes primarily produce NO that in turn can be converted to NO_2 in the atmosphere through reactions with tropospheric ozone (O_3):

$$\mathrm{NO} + \mathrm{O_3} \rightarrow \mathrm{NO_2} + \mathrm{O_2}$$

For the purposes of estimating potential acid input (PAI), CALPUFF uses a modified version of the RIVAD/ARM3 SO_x and NO_x chemistry scheme that was adopted to allow NO and NO_2 chemistry to be addressed explicitly. However, the CALPUFF model chemistry scheme has been shown to overestimate ambient NO_2 concentrations, especially close to emission sources (Staniaszek and Davies 2006). For that reason the NO_x obtained from the modelling was converted to NO_2 using the Ozone Limited Method (OLM). The OLM assumes that the conversion of NO to NO_2 in the atmosphere is limited by the ambient O_3 concentration in the atmosphere. If the ozone concentration is greater than 90% of the predicted NO_x, the method assumes all NO_x is converted to NO_2. Otherwise, the NO_2 concentration in parts per million (ppm) is equal to the sum of the ozone and 10% of the predicted NO_x concentration:

$$\mathrm{NO_2} = \mathrm{O_3} + 0.1 \times \mathrm{NO_x}$$

The OLM method is recommended by Alberta Environment and Sustainable Resource Development as one of the preferred NO_X to NO_2 conversion methods. Although onsite hourly ozone data that is concurrent with the meteorological data used in the air dispersion model is preferable, an ozone monitoring station located at the Project and concurrent with the dispersion meteorological data did not exist. Therefore, a dataset of hourly ozone values was built from the Snare Rapids air quality monitoring station data from years 2010 to 2012, because this station was relatively uninfluenced by anthropogenic sources and is located in a similar northern setting. A full description on how the hourly ozone data set was developed was provided in Section 7.2.3.4. The average hourly ozone concentrations determined for OLM from the Snare Rapids station for each month are listed in Table 7C5.4-1.

Table 7C5.4-1 Average Hourly Ozone Concentrations (ppb) Used in the Air Quality Assessment

Month	Hour of Day																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
January	30.8	30.8	30.7	30.8	30.9	30.9	30.5	31.0	30.9	30.8	30.9	31.1	31.2	31.4	31.4	31.4	31.3	31.2	31.3	31.2	31.1	31.0	30.9	31.0
February	33.2	33.1	32.9	32.9	32.8	32.6	32.1	32.4	32.2	32.3	32.6	32.9	33.2	33.6	33.9	34.3	34.1	34.0	33.8	33.5	33.3	33.3	33.4	33.3
March	35.4	35.0	34.7	34.3	33.9	33.6	33.5	33.2	33.4	33.8	34.6	35.3	35.8	36.3	36.7	37.0	37.3	37.2	37.2	37.0	36.5	36.2	35.9	35.7
April	35.3	34.7	34.1	33.7	33.1	32.5	32.7	33.0	33.6	34.6	35.6	36.3	37.1	37.9	38.7	39.2	39.4	39.5	39.2	38.9	38.3	37.7	37.1	36.2
May	34.2	33.3	32.6	31.8	30.9	30.6	30.8	32.7	33.7	34.7	35.6	36.4	37.3	38.2	38.8	38.9	39.2	39.6	39.6	39.1	37.9	36.8	36.0	35.0
June	29.0	27.9	26.6	26.1	25.3	25.7	26.5	27.5	28.4	29.1	30.2	31.3	32.4	33.1	33.7	34.4	35.0	35.2	35.1	34.6	33.7	32.4	31.0	29.8
July	22.2	21.2	20.5	20.1	19.3	19.1	20.4	22.0	22.9	24.0	25.4	26.1	26.8	27.4	27.7	27.7	28.2	28.1	27.9	27.3	26.3	25.1	24.1	23.1
August	18.1	17.4	16.7	16.4	16.0	16.0	15.7	17.3	18.9	20.2	21.4	22.5	23.3	23.8	24.2	24.5	24.4	24.3	23.7	23.0	22.1	20.9	19.5	18.8
September	17.9	17.2	16.8	16.5	16.3	15.9	16.0	15.7	17.0	18.4	19.8	20.9	21.6	22.1	22.4	22.6	22.5	22.1	21.1	20.3	19.7	19.3	19.0	18.3
October	23.0	22.7	22.6	22.5	22.4	22.1	22.1	22.3	22.4	23.1	23.7	24.3	24.7	25.1	25.6	25.7	25.4	25.1	24.8	24.4	24.2	24.0	23.8	23.5
November	28.3	28.3	28.5	28.5	28.7	28.8	28.7	29.0	29.0	29.1	29.2	29.4	29.7	29.9	29.8	29.6	29.4	29.4	29.1	28.9	28.7	28.7	28.4	28.3
December	29.9	30.0	30.2	30.2	30.1	30.1	29.8	29.9	29.9	29.8	29.7	30.0	30.0	30.2	30.1	30.2	30.1	30.1	30.0	29.9	29.9	29.9	30.0	29.9

ppb = parts per billion.

7C5.5 Acid Deposition Calculations

Deposition includes both wet and dry processes, and can result in the long-term accumulation of compounds in aquatic and terrestrial ecosystems. Wet processes involve the removal of emissions vented into the atmosphere by precipitation. Dry processes involve the removal of emissions by direct contact with surface features (e.g., vegetation). Wet and dry deposition values are expressed as a flux in units of mass per area per time (e.g., kilograms per hectare per year [kg/ha/yr]).

Because several chemical species of nitrogen, sulphur, and base cations are considered in the estimate of deposition, the flux is expressed in “kiloequivalent per hectare per year [keq/ha/yr]”, where “keq” refers to the number of equivalent hydrogen ions (1 keq = 1 kmol H+). For sulphur species, each molecule is equivalent to two hydrogen ions. Each molecule of nitrogen species is equivalent to one hydrogen ion. The deposition of sulphur and nitrogen compounds to these systems has been associated with changes in water and soil chemistry, and with the acidification of water and soil.

The calculation of PAI is based on the wet and dry deposition of sulphur compounds (e.g., SO_2 gas, SO_4^{2-} particle), nitrogen compounds (e.g., NO gas, NO_2 gas, HNO_3 gas, NO_3^- particle), chlorine ions (Cl^- gas), ammonium ions (NH_4^+ particle) and base cations (e.g., Ca_2^+ particle, Mg^+ particle, K^+ particle and Na^+ particle). Because PAI combines sulphur and nitrogen, the individual deposition rates need to be converted to a common measure, namely “keq/ha/yr” (kilomoles of equivalent hydrogen ions [H^+] per hectare per year), given these molecules have different equivalences to hydrogen ions as discussed above. The steps for completing the calculations are as follows:

- The PAI resulting from sulphur species is calculated from the annual sulphur deposition rates (expressed as kg/ha/yr). These rates are converted to keq/ha/yr by dividing the predicted deposition by the molecular weight and multiplying by the hydrogen ion equivalents, according to the following equation:

$$\boldsymbol{PAI_{sulphur}} = \frac{\left([\mathrm{SO_2}]_{dep,wet} + [\mathrm{SO_2}]_{dep,dry}\right) \times 2}{64} + \frac{\left([\mathrm{SO_4^{2-}}]_{dep,wet} + [\mathrm{SO_4^{2-}}]_{dep,dry}\right) \times 2}{96}$$

- The PAI resulting from nitrogen species is calculated from the annual nitrogen deposition rates (expressed as kg/ha/yr). These rates are converted to keq/ha/yr by dividing the predicted deposition by the molecular weight and multiplying by the hydrogen ion equivalents, as follows:

$$\boldsymbol{PAI}_{\mathrm{nitrogen}} = \frac{\left([\mathrm{NO}]_{\boldsymbol{dep},wet} + [\mathrm{NO}]_{\boldsymbol{dep},dry}\right)}{30} + \frac{\left([\mathrm{NO_2}]_{\boldsymbol{dep},wet} + [\mathrm{NO_2}]_{\boldsymbol{dep},dry}\right)}{46} + \frac{\left([\mathrm{HNO_3}]_{\boldsymbol{dep},wet} + [\mathrm{HNO_3}]_{\boldsymbol{dep},dry}\right)}{63} + \frac{\left([\mathrm{NO_3^-}]_{\boldsymbol{dep},wet} + [\mathrm{NO_3^-}]_{\boldsymbol{dep},dry}\right)}{62}$$

The total PAI is calculated as the sum of the sulphur and nitrogen deposition rates from sources within the study area together with the background PAI for the region.

$$PAI = PAI_{sulphur} + PAI_{nitrogen} + PAI_{background}$$

In this equation, the PAIbackground accounts for the background sulphur, nitrogen, Cl^-, NH_4^+ and base cations. Background PAI levels for the modelling domain were determined using the National Atmospheric Chemistry Precipitation Database (NAtChem) for Snare Rapids, NWT (NAtChem 2003, 2004, 2005, 2006, 2007) and through the Regional Lagrangian Acid Deposition (RELAD) modelling completed by AENV (Cheng 2009). A detailed discussion of background PAI is provided in Section 1.4.I.5.8.

7C5.6 Background Concentration and Acid Deposition

7C5.6.1 Background Concentrations

As part of the cumulative air quality assessment, background concentrations were added to predicted ground-level concentrations due to the Project, and existing and approved industrial sources in the Project region. Background concentrations include the contributions of natural sources, nearby sources, and unidentified distant sources.

The background SO_2, NO_X, total suspended particulate (TSP), particulate matter with a mean aerodynamic diameter of 10 microns (µm) or smaller (PM_{10}), and particulate matter with a mean aerodynamic diameter of 2.5 microns (µm) or smaller ($PM_{2.5}$) concentrations that were used in the air quality assessment are summarized in Table 7C5.6-1. The methodology used to determine the background concentrations is presented in Section 7.2.3.

Table 7C5.6-1 Background Concentrations Used in the Air Quality Assessment

Averaging Period	Background Concentrations [µg/m³]					
	SO_2	NO_X	CO	$PM_{2.5}$	PM_{10}	TSP
1-hour	0.0	0.0	0.0	—	—	—
8-hour	—	—	0.0	—	—	—
24-hour	0.0	0.0	—	1.9	0.0	0.0
annual	0.0	0.0	—	—	0.0	0.0

SO_2 = sulphur dioxide; NO_x = nitrogen oxides; CO = carbon monoxide; $PM_{2.5}$ = particulate matter with a mean aerodynamic diameter of 2.5 microns (µm) or smaller; PM_{10} = particulate matter with a mean aerodynamic diameter of 10 microns (µm) or smaller; TSP = total suspended particulate.

The concentrations of metals, VOCs, and polycyclic aromatic hydrocarbons (PAHs) were assumed to be primarily from industrial sources and their background concentrations were assumed to be negligible.

DOMINION DIAMOND

7C5.6.2 Background Acid Deposition

Selecting the background PAI that best represents the background conditions is important. Ideally this background value should not include the influence of industrial activities within the region of the proposed project. The background PAI for the region was determined using a combination of two data sources:

- the NAtChem precipitation data for wet deposition; and,
- the RELAD data for dry deposition.

The NAtChem/Precipitation Chemistry Database system is a Canadian central database and analysis facility set up to accommodate and maintain diverse and variable network data and combine them together into one database. The purpose of the system is to determine the chemistry of regional scale precipitation in Canada and the US Snare Rapids is the only location in the NWT for which NAtChem precipitation data are available, and therefore was used to determine the background PAI for the assessment. The NAtChem data provides wet deposition values for sulphur, nitrogen, Cl^-, NH_4^+, and base cations.

The RELAD model data was used to determine the dry deposition values of sulphur and nitrogen. Alberta Environment has used the RELAD model (Cheng and Angle 1993, 1996; Cheng et al. 1995, 1997; McDonald et al. 1996) to determine background sulphur, nitrogen, PAI, and base cation values for the Alberta Oil Sands Region.

To find the background values that would occur in the absence of oil sands activities, all of the Oil Sands Region emission sources were excluded from the modelling. The resulting data considered in this assessment were provided by Alberta Environment (Cheng 2009). These data were considered suitable for determining background for the Project modelling domain because the contribution of Oil Sands sources in the Project modelling domain can be expected to be minimal. The following equations demonstrate the background PAI calculation:

$$PAI_{background} = PAI_{acidifying\ substances} + PAI_{base\ cations}$$

The PAI from acidifying substances can be expressed as:

$$PAI_{acidifying\ substances} = \frac{\left([SO_4^{2-}]_{dep,wet} + [SO_4^{2-}]_{dep,dry}\right) \times 2}{96} + \frac{[NO_3^-]_{dep,wet} + [NO_3^-]_{dep,dry}}{62} + \frac{[NH_4^+]_{dep,wet}}{18} + \frac{[Cl^-]_{dep,wet}}{35.5}$$

The buffering capacity of base cations would be calculated according to the following equation:

$$PAI_{base\ cation} = -\left(\frac{[Ca^{2+}]_{dep,back} \times 2}{40} + \frac{[Mg^{2+}]_{dep,back} \times 2}{24} + \frac{[K^+]_{dep,back}}{39} + \frac{[Na^+]_{dep,back}}{23}\right)$$

The RELAD model is an appropriate tool for assessing acid deposition on a territorial or continental scale. The data generated by the model is at a resolution of 1 degrees (°) of latitude by 1° of longitude, and covered between 53º and 60º in latitude and 109º and 114° in longitude. Cells 60° x 109° to 60° x 114° compass the border between Alberta and NWT. It is reasonable to assume that the contribution of industrial emissions to background PAI in these cells will be negligible and similar to background PAI within the modelling domain. Because RELAD data are not available for the NWT, the average background deposition values in these cells were used as surrogates for the dry and wet deposition rations in the modelling domain.

The NAtChem data only provides wet deposition values. To determine dry deposition values for the modelling domain, it was assumed that on average the ratio of dry deposition to wet deposition for nitrogen and sulphur in the cells 60° x 109° through 60° x 114° will be applicable for the region of the proposed Project. This dry to wet deposition ratio for nitrogen and sulphur was then applied to NAtChem wet nitrogen and sulphur deposition values to determine the dry nitrogen and sulphur deposition values for the modelling domain. A background PAI value of 0.064 keq/ha/yr was used in the assessment.

7C6 SCIENTIFIC UNCERTAINTY

7C6.1 Predicted Concentrations

The evaluation of changes in air quality depends primarily on the use of air dispersion models to estimate future ambient levels. As with any form of prediction, there are uncertainties associated with the model's capability to predict concentrations accurately. An accepted dispersion model (i.e., CALPUFF) was selected for the analysis to minimize these uncertainties.

The air dispersion model relies upon using existing meteorological data to model the dispersion of emissions in a future context. The assumption is that the future meteorology in the Project domain during the years of operation of the Project will be similar to the meteorological data used in the dispersion model. While the meteorology from the 2002 MM5 meteorological data with input from local meteorological stations will not be identical to future meteorology in the Project domain, data were appropriate for use in preparing the 3D meteorological data set, and were corroborated by comparing with the local meteorological station data.

All years of the construction and operation lifecycle of the Project were not assessed in the dispersion model. Rather, scenarios were assessed which accounted for expected peak emissions for specified cases, namely: Base Case, Application Case, and Construction Case. These cases were each developed with conservative estimations to account for the uncertainty of emissions in each scenario. For instance, the Application Case accounted for what was considered the worst-case emission year during the timeframe of the operation phase of the Project lifetime. Actual operating years are expected to have emission rates that are lower than the scenario assessed in the Application Case. Therefore, the modelling results shown in this Developer's Assessment Report are the maximum concentration and deposition values that are estimated to result from the Project. The conservatisms that were applied to the scenarios assessed are discussed in Section 7.5.

Another uncertainty associated with air quality predictions is tied to the predicted emissions within the region. Emissions associated with industrial activities from the Project, the Ekati Mine, and the Diavik Mine were either developed with input from Dominion Diamond Ekati Corporation (Dominion Diamond) or taken from recent applications such as the1995 *NWT Diamonds Project Environmental Impact Statement* (BHP 1995), 2006 Ekati Mine air dispersion model (Rescan 2006), and Diavik Mine air dispersion model (Golder 2012).

Emission sources such as point sources were reasonably well defined, but emissions from area sources are difficult to estimate and simulate in dispersion models. The Project area emission sources include pits, roads, dikes, mine rock piles, processed kimberlite storage areas, and dried lake beds.

Characterization of emissions near pits and other sources of mechanically generated particulate are uncertain. Most estimates of particulate emissions for mining activities are based on US EPA emission factors. Many of these factors have limited applicability outside of the area in which they were developed (typically southwestern US coal mines).

Emission sources which are mitigated have mitigation factors applied to the emission rate, such as for the application of water on haul roads, or via the natural mitigation of dust on roads during winter periods.

The time frame of concentration averages are also affected by uncertainties in the release of emissions from sources which do not continually emit substances into the airshed. For example, certain processes modelled in the Project may emit at peak rate intermittently, such as generators, but they are conservatively modelled as emitting continually at peak rate due to the uncertainty in actual operations. This conservative approach will likely lead to higher predictions over 24-hour or annual concentration periods than would be expected if the source was not emitting at peak continually.

In cold weather conditions, such as those experienced at the Project, the conversion of NO concentrations to NO_2 will occur at a slower rate than in warmer conditions. Models assume the conversion is instantaneous, introducing uncertainty into the location and magnitude of predicted NO_2 concentrations.

There is uncertainty associated with capturing all emission sources relevant to the Project.
Because industrial emission sources outside of those quantified from the Project, the Ekati Mine, and the Diavik Mine are not expected to be present in the Project region during the modelled Project scenarios, an analysis of existing conditions to allow for a quantification of background concentrations was performed in the assessment to capture potential emissions from other sources. The contribution of certain compounds (e.g., NO_X, SO_2, CO, metals, VOCs, and PAHs) was considered negligible when compared to industrial sources. Particulate matter with naturally occurring background concentrations from representative monitoring data were added to model predictions. This approach was adopted for $PM_{2.5}$. The contribution of TSP and PM_{10} were considered to be negligible from sources not included in the Project, the Ekati Mine, or the Diavik Mine.

7C6.2 Predicted Deposition Rates

In general, the uncertainties that apply to predicted concentrations apply to predicted deposition rates. The evaluation of changes in the deposition of acid-forming compounds and particulate matter depends on the use of air dispersion models to estimate future ambient levels. As with any form of prediction, there are uncertainties associated with the model's capability to predict deposition rates accurately. To minimize these uncertainties, an accepted dispersion model (i.e., CALPUFF) was selected for the analysis.

A measured background PAI value is difficult to determine accurately for any region and no long-term monitoring program was performed at the Project location to determine a local background PAI value. To address this uncertainty, the Canadian National Atmospheric Chemistry Precipitation Database and RELAD data were used to determine the background PAI values for the region of the proposed Project. The background PAI value used in the Project Air Quality Assessment is presented in Section 7C5.6.2.

Another area of uncertainty associated with PAI levels is related to effects of acidifying emissions on the receiving environment. Acid deposition will affect different elements of the ecosystem in different ways. A complete evaluation of the effects of acidifying emissions on the local and regional ecosystems is presented in Section 8.5 and Section 9.3.

7C7 REFERENCES

BHP (Broken Hill Proprietary Company). 1995. NWT Diamonds Project Environmental Impact Statement, Volume IV, Impacts and Mitigation – Part 2. Available at: http://www.monitoringagency.net/ResourceCentre/EnvironmentalImpactStatement/tabid/111/Default.aspx. Accessed: September 2014.

Cheng L, Angle RP. 1996. Model Calculated Interannual Variability of Concentration, Deposition and Transboundary Transport of Anthropogenic Sulphur and Nitrogen in Alberta. Atmos Environ, 30(23): 4,021-4,030.

Cheng L, Angle RP. 1993. Development of a Coupled Simple Chemical Mechanism of SO_2-NO_X-NH4 System for Predicting Soil Effective Acidity. Prepared by Standards and Approvals Division, Alberta Environment for Acid Deposition Program, Alberta Environment. Edmonton, AB, Canada. November 1993. 79 pp.

Cheng L, Angle RP, Peake E, Sandhu HS. 1995. Effective acidity modelling to establish deposition objectives and manage emissions. Atmos Environ29(3):383-392.

Cheng L, McDonald K, Fox D, Angle RP. 1997. Total Potential Acid Input in Alberta. Report for the Target Loading Subgroup, SO_2 Management Project Team, Alberta Clean Air Strategic Alliance. May 1997.

Cheng L. 2009. Alberta Environment. Spreadsheet sent by e-mail to Koray Onder of Golder Associates Ltd.

Earth Tech (Earth Tech Inc.). 2000. User's Guide for the CALMET Meteorological Model (Version 5.0). Concord, MA, USA.

ESRD (Alberta Environment and Sustainable Resources Development). 2013. Air Quality Model Guideline. Available at: http://environment.alberta.ca/01004.html.

GNWT-ENR (Environment and Natural Resources, Government of the Northwest Territories). 2014. Guideline for Ambient Air Quality Standards in the Northwest Territories. Yellowknife, NWT, Canada, 5 pp.

Golder (Golder Associates Ltd.). 2012. Diavik Diamond Mine Air Dispersion Modelling Assessment, March 2012.

Hanna SR, Egan BA, Purdum J, Wagler J. 2001. Evaluation of the ADMS, AERMOD, and ISC3 dispersion models with the OPTEX, Duke Forest, Kincaid, Indianapolis and Lovett field datasets. Int. J. Environ. Pollut. vol. 16, no1-6: 301-314.

Holtslag AAM, van Ulden AP. 1983. A Simple Scheme for Daytime Estimates of Surface Fluxes from Routine Weather Data. J Clim Appl Meteorol, 22: 517-529.

McDonald KM, Cheng L, Olsen MP, Angle RP. 1996. A Comparison of Box and Plume Model Calculations for Sulphur Deposition and Flux in Alberta, Canada. Atmos Environ. 30(11):2969-2980.

NAtChem (National Atmospheric Chemistry Precipitation Database). 2003. Environment Canada, Science and Technology Branch, 4905 Dufferin Street, Toronto, ON, Canada.

NAtChem. 2004. Environment Canada, Science and Technology Branch, 4905 Dufferin Street, Toronto, ON, Canada.

NAtChem. 2005. Environment Canada, Science and Technology Branch, 4905 Dufferin Street, Toronto, ON, Canada.

NAtChem. 2006. Environment Canada, Science and Technology Branch, 4905 Dufferin Street, Toronto, ON, Canada.

NAtChem. 2007. Environment Canada, Science and Technology Branch, 4905 Dufferin Street, Toronto, ON, Canada.

Paine RJR. 2006. Guidelines on Air Quality Models – Introduction to AERMOD, AIR-297, course at Air & Waste Management Association Speciality Conference, April 25, 2006, Denver, Colorado, USA.

Rescan (Rescan Environmental Services Ltd). 2006. Ekati Diamond Mine CALPUFF Air Dispersion Modelling Assessment, October 2006.

Scire JS, Strimaitis DG, Yamartino RJ. 2000. A User's Guide for the CALPUFF Model (Version 5.0). Concord, MA: Earth Technologies Inc.

Scire JS. 2007. CALPUFF Training Course, Canadian Prairie and Northern Section of the Air and Waste Management Association. February 12 to 16, 2007, Calgary, AB, Canada.

Staniaszek P, Davies M. 2006. The Ambient Ratio Method for NO to NO_2 Conversion Based on Measurements in Alberta's Oil Sands Region. Proceedings of 99th Annual Conference and Exhibition. Air & Waste Management Association. New Orleans, LA, USA. June 19 to 23, 2006.

Staniaszek P, Rudolph R, Wong Y. 2006. Comparison of CALMET/CALPUFF Predictions to Observations in the Oil Sands Region of Alberta. Proceedings of Air & Waste Management Association's Speciality Conference: Guideline on Air Quality Models: Applications and FLAG Developments, Denver, CO, USA. April 26 to 28, 2006.

US EPA (US Environmental Protection Agency). 1992. Protocol for Determining the Best Performance Model. US Environmental Protection Agency. Research Triangle Park, NC, USA. EPA-454/R-92-025.

US EPA. 1999. Guideline on Air Quality Models. US Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.

US Government. 2005. Code of Federal Regulations, 40 CFR 51, Appendix W to Part 51 – Guideline on Air Quality Models.

USGS (United States Geological Survey). 2009. Land Processes Distributed Active Archive Center. Available at: https://pdaac.usgs.gov. Accessed in: June 2009.

7C8 GLOSSARY

Term	Definition
Acid Deposition	Combination of chemical and atmospheric phenomenon that occurs when gases containing sulfur (sulphur) dioxide and nitrogen oxides form acidic compounds. These compounds are deposited on ground far away from the point of their origin as acid rain, acid snow, acid fog or dry fine acidic dust.
Acidification	The decrease of acid neutralizing capacity in water, or base saturation in soil, caused by natural or anthropogenic processes. Acidification is exhibited as the lowering of pH.
Airshed	A geographic boundary for air quality standards.
Ambient air	Outdoor or open air beyond the developed industrial footprint.
Ammonia (NH_3)	A pungent, colourless, gaseous, alkaline compound of nitrogen and hydrogen that is soluble in water, lighter than air, and can easily be condensed to a liquid by cold and pressure.
Anthropogenic	Human-related, often referring to an activity, development or disturbance on the landscape.
Background concentration	The concentration of a chemical in a defined control area during a fixed period before, during or after data gathering.
Barrenland	sparsely inhabited region of tundra in N Canada, especially in the area W of Hudson Bay.
Carbon monoxide (CO)	A colourless, odourless, toxic gas at standard conditions that is a product of incomplete combustion of fossil fuels.
Diurnal	Active in the daytime.
Emission	The act of releasing or discharging air contaminants into the ambient air from any source.
Mean	Arithmetic average value in a distribution.
Median	A single statistical value used to characterize a series of data values. Half of the data values are larger than the median value, and half of the data values are less than the median value.
Mitigation	To moderate (a quality or condition) in force or intensity; alleviate.
Nitrogen dioxide (NO_2)	One of the component gases of oxides of nitrogen which also includes nitric oxide. In burning natural gas, coal, oil and gasoline, atmospheric nitrogen may combine with molecular oxygen to form nitric oxide, an ingredient in the brown haze observed near large cities. Nitric oxide is converted to nitrogen dioxide in the atmosphere. Cars, trucks, trains and planes are the major source of oxides of nitrogen in Alberta. Other major sources include oil and gas industries and power plants.
Nitrogen oxides (NO_X)	Consist of nitric oxide (NO) and nitrogen dioxide (NO_2) and are reported as equivalent NO_2.
Ozone (O_3)	A gas that occurs both in the Earth's upper atmosphere and at ground level. Ozone in the upper atmosphere protects living organisms by preventing damaging ultraviolet light from reaching the Earth’s surface. Ground-level ozone is an air pollutant with harmful effects on the respiratory systems of animals.
Particulate matter	Any aerosol that is released to the atmosphere in either solid or liquid form.
$PM_{2.5}$	Particulate matter with particle diameter nominally smaller than 2.5 micrometres (µm).
PM_{10}	Particulate matter with particle diameter nominally smaller than 10 micrometres (µm).

Term	Definition
Polycyclic Aromatic Hydrocarbons	A large group of organic compounds comprised of two or more aromatic rings and by-products of combustion. They are found in crude oil and a variety of products such as bitumen, asphalt, coal tar pitch volatiles, and unrefined or mildly refined mineral oils. Polycyclic aromatic hydrocarbons (PAHs) are emitted into the Canadian environment from both natural and anthropogenic sources. Forest fires, which release approximately 2,000 tonnes of PAHs per year, are the single most important natural source of PAHs in Canada. However, since releases from that source are generally widely separated in time and space across the country, they do not result in continuous exposure in any specific area. Anthropogenic sources are numerous and result in emissions of PAHs into all environmental compartments.
Potential Acid Input	A composite measure of acidification determined from the relative quantities of deposition from background and industrial emissions of sulphur, nitrogen and base cations.
Receptor	The person or organism subjected to exposure to chemicals or physical agents.
Relative humidity	The ratio of the amount of water vapour in the atmosphere to the amount necessary for saturation at the same temperature. Relative humidity is expressed in terms of percent and measures the percentage of saturation.
Solar radiation	The principal portion of the solar spectrum that spans from approximately 300 nanometres (nm) to 4,000 nm in the electromagnetic spectrum. It is measured in watts per square metre (W/m^2), which is radiation energy per second per unit area.
Sulphur dioxide (SO_2)	A colourless gas with a pungent odour.
Total suspended particulate (TSP)	A term used to collectively describe tiny airborne particles or aerosols that are less than 100 micrometres in size.
Tundra	A treeless area between the icecap and the tree line of Arctic regions, having a permanently frozen subsoil and supporting low-growing vegetation such as lichens, mosses, and stunted shrubs.
Volatile Organic Compounds	A group of organic chemical compounds with high vapour pressures and low boiling points that evaporate readily.
Windrose	Graphic pie-type representation of frequencies of wind directions and speeds over a period of time (e.g., one year) for a meteorological station.
Winter road	Roads which are built over frozen lakes and tundra. Compacted snow and/or ice is used for embankment construction.