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SUPPLIER DOCUMENT

AIR QUALITY ASSESSMENT FOR THE NEAR SURFACE DISPOSAL FACILITY

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Revision 1

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TECHNICAL SUPPORTING DOCUMENT

Canadian Nuclear Laboratories

Air Quality Assessment for the Near Surface Disposal Facility - Revision 3

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Table of Contents

TABLES

FIGURES

List of Acronyms and Abbreviations

Acronym	Definition
AAQC	Ambient Air Quality Criteria
AECL	Atomic Energy of Canada Limited
AWOS	Automated Weather Observing System
BMP	Best Management Practice
BPIP	Building Profile Input Program
BSFC	Brake-Specific Fuel Consumption
CAAQS	Canadian Ambient Air Quality Standards
CAC	Criteria Air Contaminant
CCME	Canadian Council of Ministers of the Environment
CNL	Canadian Nuclear Laboratories
CNSC	Canadian Nuclear Safety Commission
CO	Carbon Monoxide
CRL	Chalk River Laboratories
ECCC	Environment and Climate Change Canada
ECM	Engineered Containment Mound
EIS	Environmental Impact Statement
GHG	Greenhouse Gas
HVAC	Heating, Ventilation and Air Conditioning
IPCC	Intergovernmental Panel on Climate Change
ISC	Industrial Source Complex
LSA	Local Study Area
MOECC	Ministry of the Environment and Climate Change
MECP	Ministry of the Environment, Conservation and Parks
MTO	Ministry of Transportation
NAAQS	National Ambient Air Quality Objectives
NAPS	National Air Pollution Surveillance Network
NASA	National Aeronautics and Space Administration
NO	Nitrogen Oxide
NO_X	Nitrogen Oxides
NPRI	National Pollutant Release Inventory
NSDF	Near Surface Disposal Facility
REGDOC	Regulatory Document
RSA	Regional Study Area
RVP	Reid Vapour Pressure
SPM	Suspended Particulate Matter
SSA	Site Study Area

Acronym	Definition
TSD	Technical Supporting Document
TSP	Total Suspended Particles
U.S. EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VOC	Volatile Organic Compounds
WWTP	Wastewater Treatment Plant

List of Units

Unit Symbol	Definition
%	percent
°C	degrees Celsius
µg/m	microgram per metre
$\mu g/m^3$	microgram per cubic metre
µm	micrometre
am^3/s	actual cubic metre per second
cm	centimetre
F	degrees Fahrenheit
g/GJ	grams per gigajoule
g/hp-hr	grams per horse power hour
g/L	grams per litre
g/m^2	grams per square metre
g/s	grams per second
$g/s\text{-}m^2$	grams per square metre seconds
g/VKT	grams per vehicle kilometres travelled
GJ/m^3	gigajoules per cubic metre
hp	horse power
hrs/day	hours per day
k	particle size multiplier for particle size range
kg	kilogram
kg/GJ	kilogram per gigajoule
kg/ha/day	kilograms per hectare per day
kg/m^3	kilogram per cubic metre
kg/Mg	kilogram/megagram (tonne)
km	kilometre
km/h	kilometres per hour
km/hr	kilometres per hour
kPa	kilopascals
kPA	kilopascal
$kWh/m^2/d$	kilowatt hours per square metre per day
L/hp-hr	litres per horse power hour
$lb/10^6scf$	pounds per million standard cubic feet
lb/MMBTU	pounds per million British thermal units
lb/VMT	pounds per vehicle miles travelled
lbs	pounds
m	metre

Unit Symbol	Definition
m/s	metre per second
m^2	square metre
m^3	cubic metre
m^3/hr	cubic metre per hour
m^3/s	cubic metre per second
m^3/year	cubic metre per year
mm	millimetres
mm(eq)	millimetres equivalent
MMBtu/10^6 scf	million British thermal units per million square cubic feet
MMBTU/hr	million British thermal units per hour
OU/m^3	odour unit per cubic metre
OU/s	odour unit per second
ppb	parts per billion
ppm	parts per million
tonnes	tonnes (1,000 kg)
tonnes	metric tonnes
tonnes CO_2/L	tonnes of carbon dioxide per litre
tonnes/day	metric tonnes per day
tonnes/m^3	metric tonnes per cubic metre
tonnes/year	metric tonnes per year
tons	tons (Imperical, US)
VKT/hr	vehicle kilometres travelled per hour

1.0 INTRODUCTION

Canadian Nuclear Laboratories (CNL) is proposing to construct the Near Surface Disposal Facility (NSDF) Project for the long-term management of large quantities of waste from legacy waste, current operations, and decommissioning projects at Chalk River Laboratories (CRL) and its other business locations. The NSDF Project will provide a safe, permanent solution for the disposal of solid, low-level radioactive waste and other acceptable waste streams at CRL and replace the current CNL practice of placing the waste in temporary storage.

This Air Quality Assessment Technical Supporting Document (TSD) has been prepared to support the Environmental Impact Statement (EIS) for the NSDF Project. This TSD comprises four elements for a comprehensive assessment of air quality, which are presented in Sections 2.0 through 5.0:

- Section 2.0: Meteorology Assessment
- Section 3.0: Air Quality Baseline
- Section 4.0: Emissions Estimates
- Section 5.0: Dispersion Modelling

2.0 METEOROLOGY ASSESSMENT

This section summarizes the current climate conditions at the CRL site, including the NSDF Project site, and assesses the suitability of the dispersion meteorological dataset provided by the Ontario Ministry of the Environment, Conservation and Parks (MECP) for use in the non-radiological dispersion modelling for the effects assessments.

Meteorological parameters analyzed include wind speed and direction, temperature, precipitation, relative humidity, atmospheric pressure, and solar radiation, as well as the occurrence of extreme and rare meteorological phenomena, as required by the Canadian Nuclear Safety Commission (CNSC) *REGDOC-2.9.1 Environmental Principles, Assessments and Protection Measures* (CNSC 2017), for the characterization of the atmospheric baseline environment. An analysis of the mixing height as the degree of contaminant mixing (or dilution within the atmosphere) as it directly influences air dispersion, is also included.

This section also describes the methods, data, and assumptions that were used to validate the meteorological dataset used in the dispersion modelling assessment of the NSDF Project provided in Section 5. The purpose of the validation of the dispersion meteorology is to address the following questions:

- Is the 5-year MECP dataset for the Facility representative of long-term climate in the area?
- Is the 5-year MECP dataset for the Facility representative of on-site meteorological conditions?

The validation was carried out by:

- obtaining a pre-processed meteorological dataset for air dispersion modelling from the MECP for the NSDF Project in order to have a dataset ready to use for dispersion modelling and future permitting purposes;
- comparing the MECP dataset to regional climate data to demonstrate that the dataset is comparable to long-term averages at the NSDF Project site; and

- comparing the MECP dataset to on-site meteorological data to demonstrate that the dataset is appropriate for dispersion modelling at the NSDF Project site.

These steps are detailed in Sections 2.1 and 2.2.

2.1 Climate and Meteorological Data Sources

This section summarizes the data sources used in the meteorology assessment prepared for the NSDF Project EIS (see EIS Section 5.2.1 [Air Quality]).

2.1.1 Climate Normals

Climate normals are used to summarize or describe the average climatic conditions of a particular location. Climate normals, which are long-term usually averages of observed climate data from Environment and Climate Change Canada (ECCC) climate stations located near the NSDF Project are used to describe the long-term record of general meteorological conditions in the region and are used to validate the MECP dispersion meteorological dataset. Additional information on climate change and climate projection is available in the Climate Change Assessment TSD for the NSDF Project (Golder 2019).

The nearest 30-year (1981 to 2010) climate station is located on the CRL site, and is less than 1 kilometre (km) north of the NSDF Project centroid. For meteorological parameters not monitored at the Chalk River AECL station, the next closest climate normals station with the required parameters, Ottawa MacDonald-Cartier International Airport (Ottawa), was used for the assessment (ECCC 2016a). Table 2-1 presents the location of climate stations used in this assessment.

Table 2-1: Location of Climate Stations

Station Name	Climate ID	Distance from NSDF Centroid (km)	Direction from the NSDF Project	Use	Normal Period[b] (Dates)
Chalk River AECL(a)	6101335	1	North	MECP dataset validation through consistency review with NSDF Project surface data from MECP	1981 – 2010
Ottawa MacDonald-Cartier Int'l Airport[a]	6106000	158	Southeast	MECP dataset validation as additional consistency check for Chalk River data and NSDF Project surface data from MECP	1981 – 2010

Note:

[a] ECCC 2016a.

[b] Normal period as defined by ECCC. ID = Identification; NSDF = Near Surface Disposal Facility; MECP = Ontario Ministry of Environment, Conservation and Parks; km = kilometre. AECL = Atomic Energy Canada Ltd.

2.1.2 Dispersion Meteorological Dataset

A request was made to the MECP on June 15, 2016 to obtain a localized pre-processed meteorological dataset for the NSDF Project site for use in AERMOD plume model air dispersion model to support the EIS. On-site meteorological data provided by CNL (CNL 2016a) was included in the request to the MECP for inclusion in the site-specific meteorological dataset. The MECP developed an AERMOD-ready meteorological dataset for the NSDF Project and it was provided for use in the EIS on July 14, 2016. The five year (2011 to 2015) dispersion meteorology dataset was created with the aid of AERMET, a meteorological pre-processor model for AERMOD, using meteorological data from the stations identified in Table 2-2. The dataset consists of surface and upper air meteorological variables, including precipitation for the assessment of dust deposition (MECP 2016a and 2016b).

Table 2-2: Sources of Meteorological Data included in the MECP Dispersion Meteorological Dataset

Station Name	Environment Canada Station ID	Distance from the NSDF Project (km)	Direction from the NSDF Project	Data File Use	Dates
CNL(a)	—	Located on CRL site at Perch Lake	Northwest portion of the NSDF Project site	Surface data	2011 – 2015
Petawawa AWOS 2(b)	6106396	11	Southeast south	Surface data	2011 – 2015
Pembroke(b)	6106367	22	Southeast	Surface data	2011 – 2015
Ottawa MacDonald-Cartier Int'l Airport(b)	6106000	158	Southeast	Surface data	2011 – 2015
Maniwaki(b)	7034482	650	Northeast	Upper air data	2011 – 2015

Notes:

(a) CNL 2016b.

(b) ECCC 2016b. AWOS = Automated Weather Observing System.

2.2 Climate and Meteorology for the NSDF Project

This section presents the closest available climate normal and compares the MECP dispersion modelling dataset to the appropriate climate normal. The expected values of weather parameters, including temperature, relative humidity, precipitation, wind speed and direction, atmospheric pressure, and solar radiation, can be expressed in terms of normal values obtained from the long-term averages.

2.2.1 Temperature

A summary of the monthly temperature distribution for the climate normals from the Chalk River AECL station is shown in Table 2-3. The daily average temperature in the winter season is approximately -9.3 degrees Celsius (°C), while the daily average temperature in the summer season is approximately 19.1°C. The extreme minimum temperature was -39°C while the extreme maximum temperature was 36°C. Temperatures below -10°C have occurred in November through April, while temperatures above 30°C occur occasionally in May through August.

Table 2-3: Monthly Temperature Distribution for the Chalk River AECL Climate Normals

Climate Normals Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual(a)
Daily Average (°C)	-11.8	-9.2	-2.9	5.5	12.5	17.8	20.3	19.1	14.4	7.6	0.7	-6.9	5.6
Standard Deviation (°C)	3.6	2.6	2.0	1.8	1.7	1.4	1.1	1.3	1.5	1.4	1.7	3.4	0.8
Daily Maximum (°C)	-6.7	-3.5	2.7	11.2	18.7	24.0	26.2	24.8	19.6	12.0	4.2	-2.8	10.9

Table 2-3: Monthly Temperature Distribution for the Chalk River AECL Climate Normals

Climate Normals Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual[a]
Daily Minimum (°C)	-16.8	-14.9	-8.5	-0.3	6.2	11.6	14.2	13.3	9.1	3.1	-2.9	-11.0	0.3
Extreme Maximum (°C)	11.1	15.0	23.9	31.7	34.0	36.0	39.4	37.2	34.5	29.5	22.2	14.5	39.4
Extreme Minimum (°C)	-39.0	-35.6	-32.0	-19.4	-8.9	-1.7	3.3	-3.0	-2.0	-9.0	-21.0	-38.0	-39.0
Days with Maximum Temperatures Above 30°C	0	0	0	0	1	3	4	3	0	0	0	0	11
Days with Minimum Temperatures Below -10°C	23	19	12	1	0	0	0	0	0	0	3	15	72

Notes:
[a] Data are annualized and may not appear to add across columns due to rounding.

A "box-and-whisker" plot is used to show the range of temperatures obtained from the MECP dataset compared to reported climate normals from the Chalk River AECL station (Figure 2-1). The box in the graph represents the middle 50% of the observations (i.e., from the 25th to 75th percentiles). The whiskers extend up to the maximum observation and down to the minimum. The diamond represents the average of the observations in each month. The green lines on the graph represent the climate normals at the Chalk River AECL station for the extreme maximum (dotted line above the average normal), the daily maximum (dashed line above the average normal), the average (solid line), the daily minimum (dashed line below the average normal), and the extreme minimum temperatures (dotted line below the average normal) for each month. The hourly temperature data in the dataset generally falls within the extreme climate normals except in March and December, when the extreme maximum temperatures were above the climate normals, and September, when the extreme minimum temperatures were below the normals.

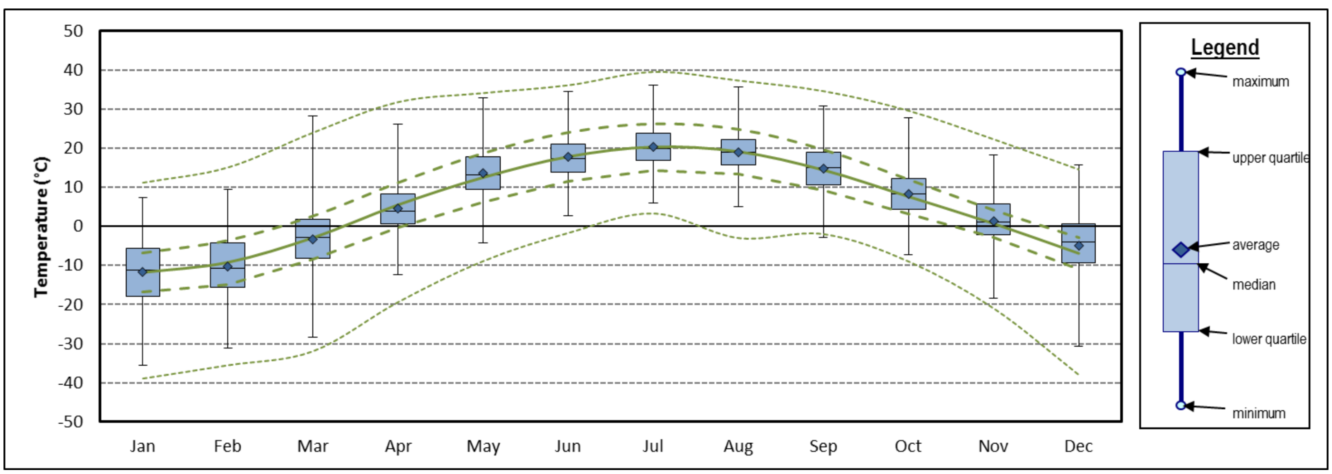


Figure 2-1: Monthly Temperature Distribution for the MECP Dispersion Meteorology Dataset Compared to Chalk River AECL Climate Normals

A more detailed breakdown of the monthly temperature distribution in the MECP meteorological dataset is shown in Table 2-4. In the MECP dataset, the average temperature in the winter season is approximately -9.0°C, while the extreme minimum temperature was -35.7°C. The average temperature in the summer season is approximately 19°C. The extreme maximum temperature was 36°C in the summer. Temperatures above 30°C can occur in June, July, and August, while temperatures below -10°C occur in December through March. Overall, the MECP dataset contained similar daily average temperatures compared to the reported climate normals; daily average temperatures were nearly the same in January and June through August, however the MECP dataset was between 0.4°C and 1.9°C higher than the climate normals in May and for the September through December period. The MECP dataset was between 0.4°C and 1.0°C lower than the climate normals for the February through April period. Temperatures in the MECP dataset generally fell within the range shown in the reported climate normals and are therefore considered representative for the region.

Table 2-4: Monthly Temperature Distribution for the MECP Dispersion Meteorology Dataset

MECP Dataset Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual[(a)]
Daily Average (°C)	-11.7	-10.2	-3.3	4.6	13.7	17.7	20.4	18.9	14.8	8.4	1.3	-5.0	5.9
Standard Deviation (°C)	8.4	7.4	7.8	5.7	6.3	5.2	5.3	4.7	6.0	5.5	6.2	7.3	12.8
Daily Maximum (°C)	-6.8	-5.4	2.0	10.0	19.9	23.4	26.6	24.5	20.6	12.9	5.3	-1.8	11.0
Daily Minimum (°C)	-18.1	-16.1	-9.4	-1.0	6.8	11.4	13.5	13.0	8.8	3.6	-3.5	-9.0	0.1
Extreme Maximum (°C)	7.2	9.3	28.2	26.0	32.7	34.3	36.0	35.6	30.6	27.7	18.2	15.6	36.0
Extreme Minimum (°C)	-35.7	-31.2	-28.4	-12.3	-4.4	2.7	6.0	4.9	-2.8	-7.3	-18.4	-30.7	-35.7
Days with Maximum Temperatures Above 30°C	0	0	0	0	1	2	6	2	0	0	0	0	11
Days with Minimum Temperatures Below -10°C	25	22	13	0	0	0	0	0	0	0	4	12	77

Notes:
(a) Data are annualized and may not appear to add across columns due to rounding.

A similar table is presented for the five years of available temperature data from the CNL on-site station in Table 2-5. Temperatures measured at the CNL on-site station are similar to the climate normals from the Chalk River AECL station, both having reported an annual daily average temperature of 5.6°C. Temperature trends between the CNL on-site station and the MECP dataset are similar and support the conclusion that the MECP dataset is representative of conditions at the NSDF Project.

Table 2-5: Monthly Temperature Distribution for the CNL On Site Meteorological Station

CNL On-Site Data Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual[(a)]
Daily Average (°C)	-11.9	-10.3	-3.1	4.5	13.9	17.5	19.8	18.3	14.2	7.9	0.6	-5.5	5.6
Standard Deviation (°C)	8.9	8.2	7.9	6.0	6.7	6.2	5.9	5.3	6.1	5.7	5.9	7.2	12.8
Daily Maximum (°C)	-6.2	-4.6	2.8	10.5	20.8	24.0	27.2	25.1	20.8	13.0	5.2	-1.9	11.5
Daily Minimum (°C)	-19.1	-17.2	-10.0	-1.4	6.8	10.5	12.8	11.8	8.1	3.2	-4.0	-9.7	-0.6
Extreme Maximum (°C)	6.9	11.4	26.3	25.3	34.0	35.5	36.0	33.9	30.9	29.3	18.3	14.7	36.0
Extreme Minimum (°C)	-36.3	-33.9	-31.7	-13.4	-4.6	2.7	0.0	0.0	-2.2	-7.2	-18.3	-31.9	-36.3
Days with Maximum Temperatures Above 30°C	0	0	0	0	2	3	8	3	0	0	0	0	16
Days with Minimum Temperatures Below -10°C	25	22	14	1	0	0	0	0	0	0	4	12	78

Notes:
(a) Data are annualized and may not appear to add across columns due to rounding.

2.2.2 Relative Humidity

Relative humidity is the ratio of the actual water vapour in the air to the maximum amount the air can hold at a given temperature (ECCC 2016a). Table 2-6 presents the monthly average relative humidity climate normals from the Ottawa Station recorded for 6:00 a.m. and 3:00 p.m. local time. Although the Ottawa station is located over 150 km from the NSDF Project, it has been used as a regional comparison as there is no closer station reporting long-term relative humidity climate normals.

Table 2-6: Monthly and Annual Average Relative Humidity from Ottawa Climate Normals

Month	Average Relative Humidity (%)	
	6:00 a.m.	3:00 p.m.
January	76.5	67.5
February	74.9	61.3
March	73.7	56.6
April	73.5	50.2
May	76.1	49.9
June	81.1	53.1
July	84.4	53.7
August	87.9	55.0
September	89.6	59.1
October	86.1	61.6
November	83.5	68.1
December	81.8	72.2
Annual	**80.8**	**59.0**

As identified in Section 2.2.3, in order to model deposition additional weather variables, including relative humidity, were included in the surface meteorological data. The relative humidity from the MECP dataset shows the expected diurnal variability, with relative humidity ranging from 25% to 100%. The average relative humidity during the daytime is 66.4%, while the average is 78.3% during the nighttime. Overall, the relative humidity data appears to be representative of what would be expected in the NSDF Project site.

Relative humidity is not measured at the on-site CNL meteorological station; therefore, no comparison between measured on-site data and regional or climate normals data is possible.

2.2.3 Precipitation

The 30-year climate normal from the Chalk River AECL station calculates an average annual precipitation of approximately 859 millimetres equivalent (mm[eq]) for the region, with the highest precipitation typically occurring in the summer at 252 mm[eq]. The greatest extreme daily precipitation also occurs in summer at 71 mm[eq]. Winter and spring have comparable precipitation amounts but approximately 70% of the precipitation in winter is attributed to snow. Winter extreme daily precipitation is typically 35.9 mm[eq].

In order to model deposition, additional weather variables including hourly precipitation rate and precipitation code were added into the surface meteorological data. A special request was made to the MECP to include these parameters into the dispersion meteorology dataset. For AERMOD, precipitation data is flagged as liquid precipitation when the temperature is equal to or above 0°C (precipitation code 11) and as solid precipitation when the temperature is below 0°C (precipitation code 22).

The comparison of the 5-year average MECP dataset with the 30-year average climatic normal for the Chalk River AECL station is illustrated in Figure 2-2. The Chalk River AECL climate normals showed somewhat greater precipitation than the MECP dispersion modelling dataset in February, March, and May, and significantly more precipitation in September, and November. This variability between the two sets of data is not unexpected given that the climate normals are based on a 30-year period while the MECP's data covers only five years, none of which are included in the existing climate normals.

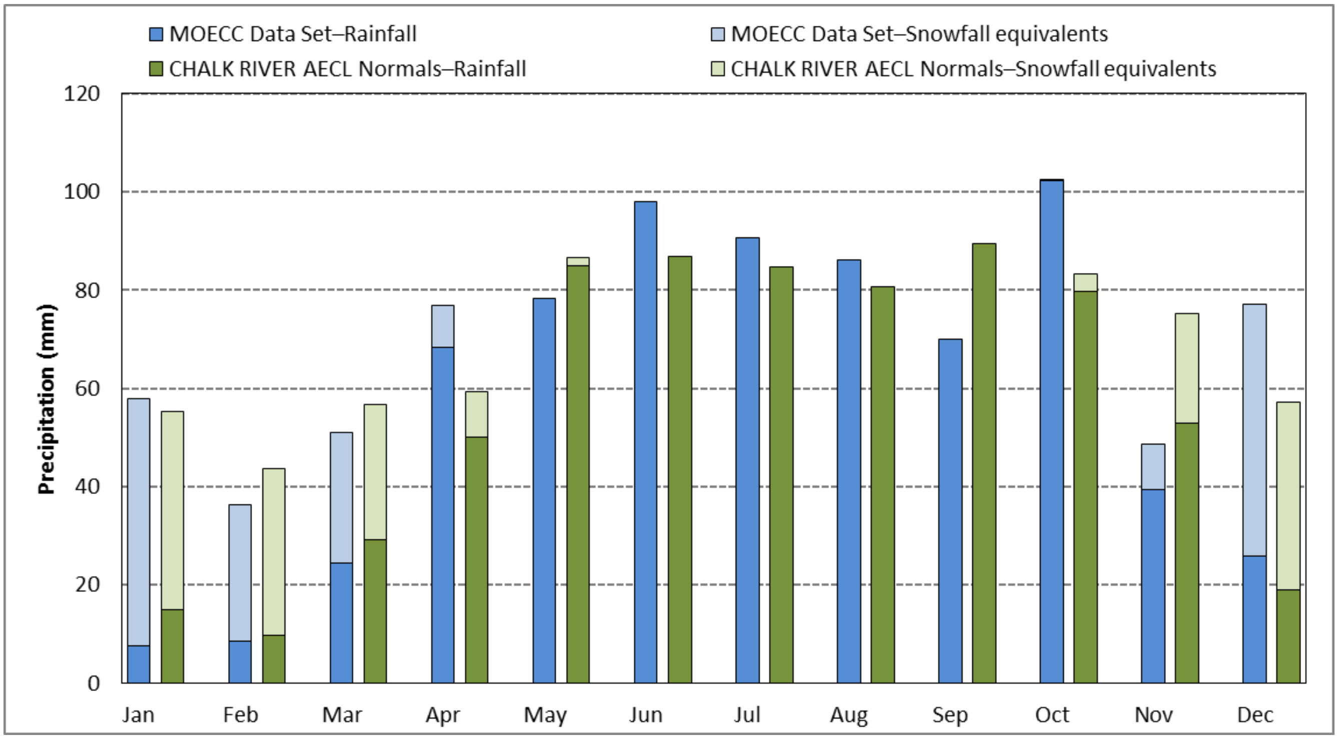


Figure 2-2: Precipitation Comparison between the MECP Dataset and Chalk River AECL Precipitation Normals

Monthly total precipitation and its yearly total for the five years for the MECP dispersion meteorology dataset is illustrated in Table 2-7. From the observed 5-year meteorology, an annual average of 874 mm[eq] of precipitation are expected. The greatest seasonal precipitation occurs during the summer months at 275 mm[eq] and the greatest extreme daily precipitation rate of 33.6 mm[eq] occurring in the winter. Winter typically has the least amount of precipitation, at 171 mm[eq], with approximately 80% occurring as snow.

Table 2-7: Precipitation Summary for the MECP Dispersion Meteorology Dataset

Month	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)	Extreme Daily Precipitation (mm)	Days with Measurable Precipitation
January	7.7	50.3	58.0	4.2	15
February	8.5	27.7	36.3	20.0	13
March	24.4	26.8	51.1	6.5	11
April	68.3	8.5	76.8	7.1	13
May	78.3	0.0	78.3	11.6	13
June	98.1	0.0	98.1	14.5	12
July	90.7	0.0	90.7	32.2	9
August	86.2	0.0	86.2	18.6	12
September	70.0	0.0	70.0	18.0	11
October	102.3	0.1	102.4	12.5	16
November	39.5	9.2	48.7	7.8	14
December	26.0	51.1	77.0	33.6	16
Annual	**699.9**	**173.7**	**873.6**	**33.6**	**154**

Notes:
mm = millimetres; cm = centimetres

Precipitation is not measured at the on-site CNL meteorological station and regional data was used to complete the MECP dataset; therefore, no comparison between measured on-site data and regional or climate normals data is possible.

2.2.4 Wind Speed and Direction

A comparison of the winds reported in the MECP dataset compared to the long-term average from the Ottawa station is provided in Table 2-8. Winds were predominantly from the west at the Ottawa station, with an annual average wind speed of 13 kilometres per hour (km/h).

Wind climate normals from the Ottawa MacDonald-Cartier International Airport (Ottawa) station were used for this comparison as there were no long-term wind data (1981 to 2010) available for stations located closer to the NSDF Project.

Table 2-8: Monthly Wind MECP Dispersion Meteorology Dataset compared to Ottawa Climate Normals

Month	Season	MECP Dataset (2011-2015)		Ottawa Climate Normals (1981-2010)	
		Average Wind Speed (km/h)	Most Frequent Direction	Average Wind Speed (km/h)	Most Frequent Direction
January	Winter	10.3	SE	14.6	W
February		10.3	NW	14.3	W
March	Spring	11.4	NW	14.4	W
April		11.9	NW	15.0	E
May		9.9	SE	13.1	W
June	Summer	9.0	SE	11.4	W
July		8.3	W	10.7	W
August		8.1	W	10.2	SW
September	Fall	8.4	SE	11.1	S
October		9.8	SE	12.7	W
November		10.3	SE	13.8	W
December	Winter	10.0	SE	14.2	W

Notes:
SE = Southeast; NW= Northwest; W = West; SE = Southeast; km/h = kilometres per hour

In the MECP dataset, annual winds are predominantly from the southeast. In the winter, winds are generally from the southeast averaging 10 km/h or more. In the spring, wind speeds are similar to the winter season, but winds are generally from the northwest. In the summer, the winds shift toward the west and wind speeds are lower. Finally, in the fall season, the winds are predominantly from the southeast, increasing in speed through October and November.

In the MECP dataset, winds were highest in early spring, and lowest (slowest) in the summer. Monthly average wind speeds were lower (slower) in all months than reported in the climate normals. The differences in reported wind speeds and directions are likely due to the difference in locations, as the regional climate station (Ottawa) is located at an airport near an urban center while the CNL on-site station, the primary source of wind data in the MECP dataset, is located in a rural area, approximately 1 km southwest of the Ottawa River and more than 150 km northwest of the Ottawa climate station.

Over the entire dispersion modelling dataset (43,824 hours), none of the wind speed hours were defined as "calm." Calm hours were defined as hours having a wind speed less than 3.6 km/h or 1 m/s to correspond with the MECP treatment of hours with wind speeds of less than 1 metre per second (m/s) in the pre-processed meteorological dataset. The annual average wind speed in the dataset was 9.8 km/h.

A wind-rose showing the annual and seasonal winds in the MECP dataset is provided on Figure 2-3. For the purposes of this and following "seasonal" figures, "Spring" is assumed to be from March 1 to May 31, "Summer" from June 1 to August 31, "Fall" from September 1 to November 30, and "Winter" from December 1 to February 28 (or February 29 in leap years).

The on-site meteorological station records wind speed and direction at ground level (1.5 m), 30 m, and 60 m (CNL 2016b). Since wind data at 10 m was not available, hourly data recorded at ground level from the CNL on-site station have been summarized for comparison purposes to the Ottawa climate normals. Figure 2-4 shows a wind-rose for the annual and seasonal winds measured on-site from January 2011 to December 2015 (excluding August 5, 2015 to September 1, 2015 which were missing from the data).

Figure 2-5 shows the diurnal (daytime vs. nighttime) wind-roses for the MECP dataset. Nighttime winds are noticeably lower in speed than those during the day, averaging 8.6 km/h during the night compared to 11 km/h during the day. This behaviour is expected as nighttime atmospheric conditions are more stable than daytime conditions when convective mixing occurs due to incoming solar radiation. Similarly, Figure 2-6 shows the diurnal wind-roses for the on-site data. Again, nighttime winds are noticeably lower in speed than those during the day, averaging 7.1 km/h during the night compared to 9.5 km/h during the day. Based on the comparisons shown, although winds in the MECP dataset differ slightly from the long-term averages for the Ottawa area, they are consistent with the on-site data for 2011 to 2015 and are appropriate for dispersion modelling for the NSDF Project.

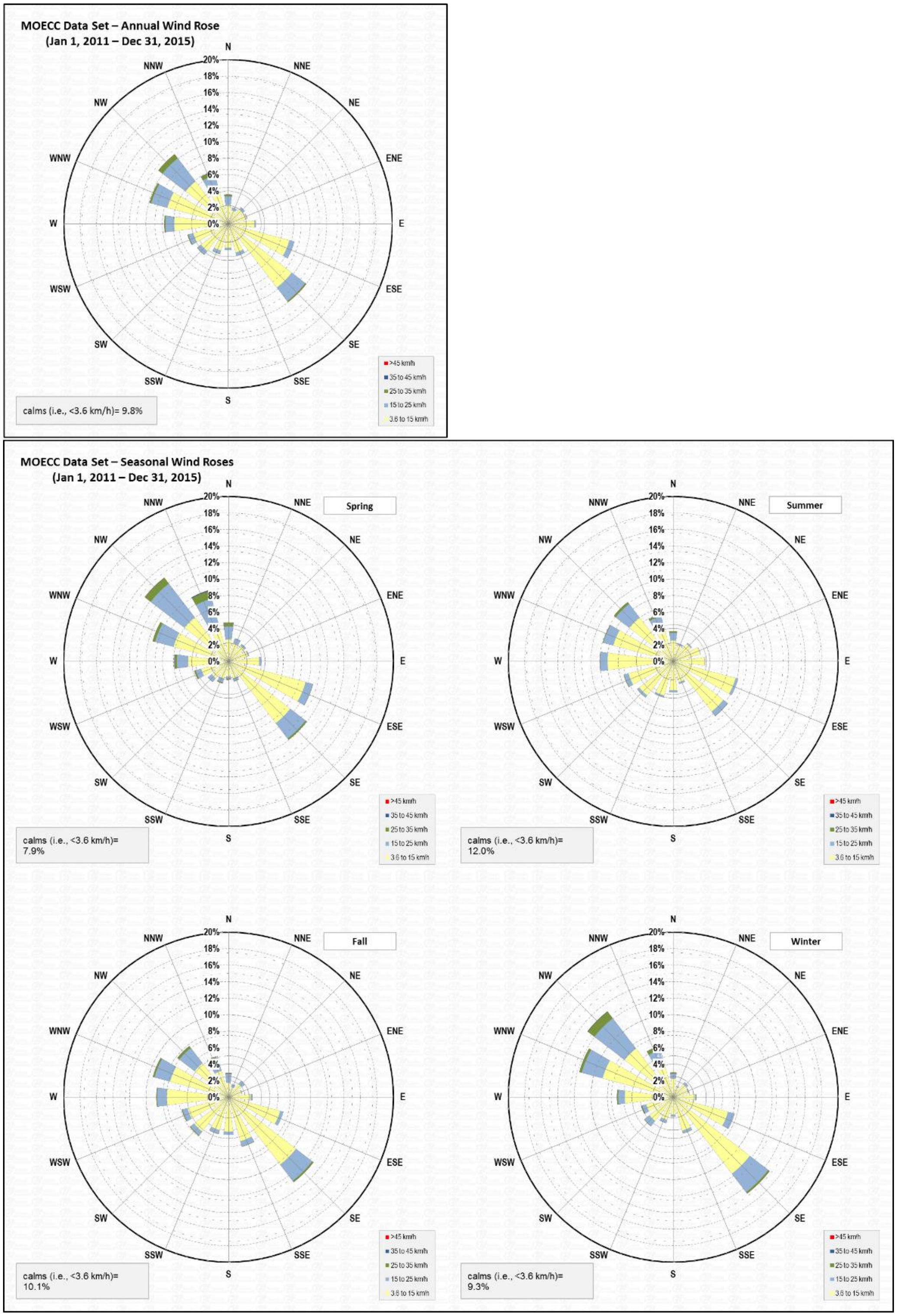


Figure 2-3: Annual and Seasonal Wind roses for the MECP Dispersion Meteorology Dataset

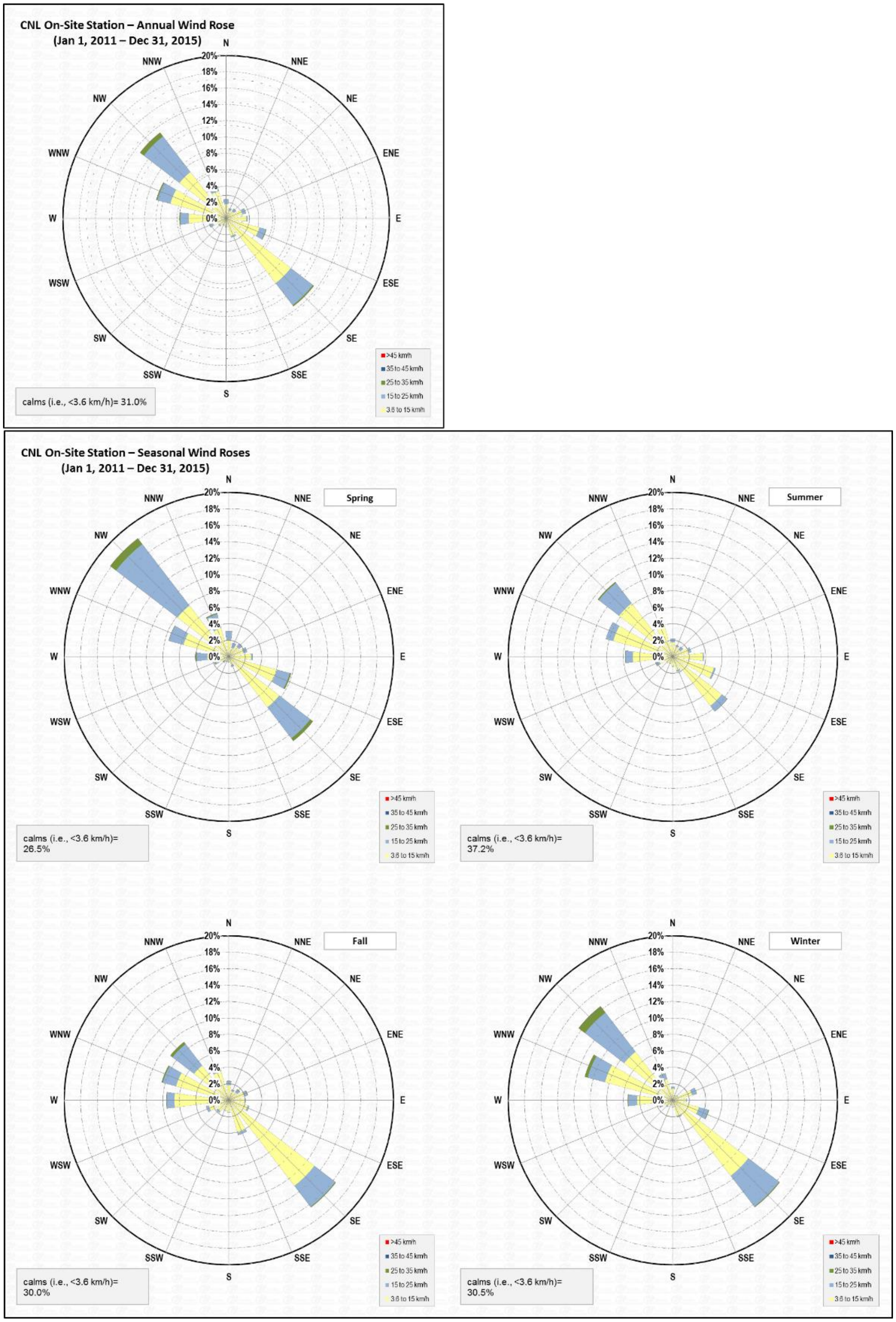


Figure 2-4: Annual and Seasonal Wind roses for the CNL On Site Station Data

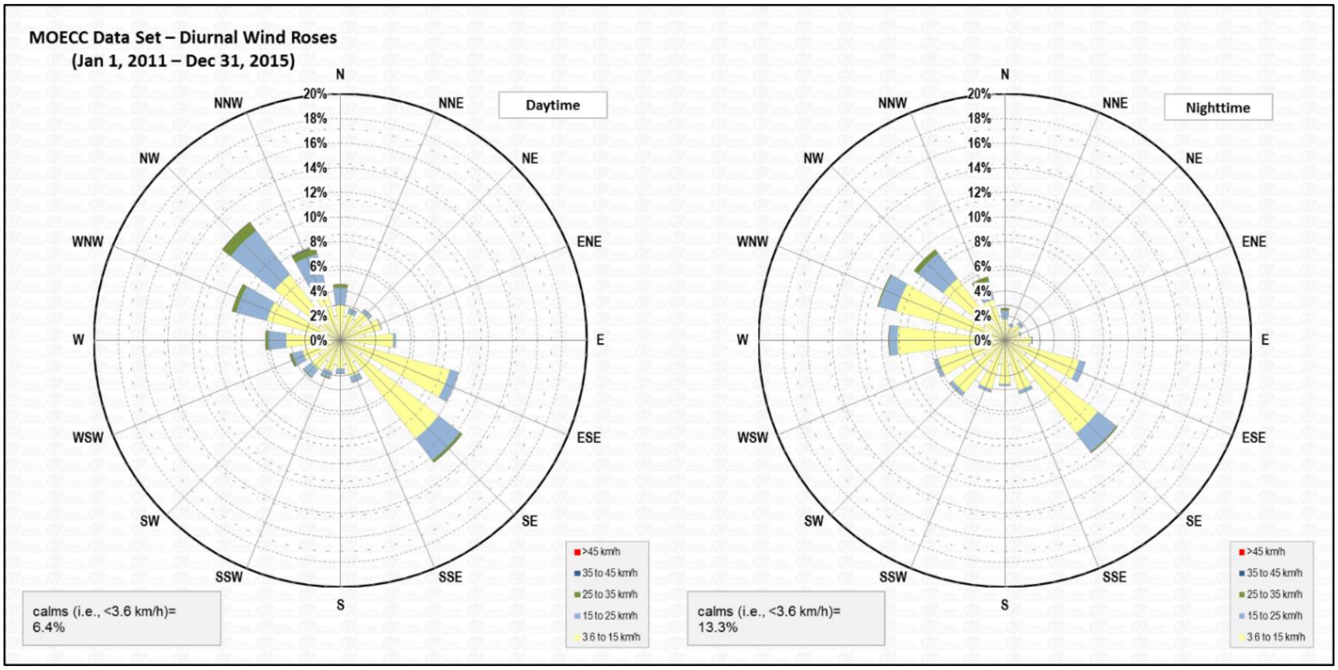


Figure 2-5: Daytime and Nighttime Wind-roses for the MECP Dispersion Meteorology Dataset

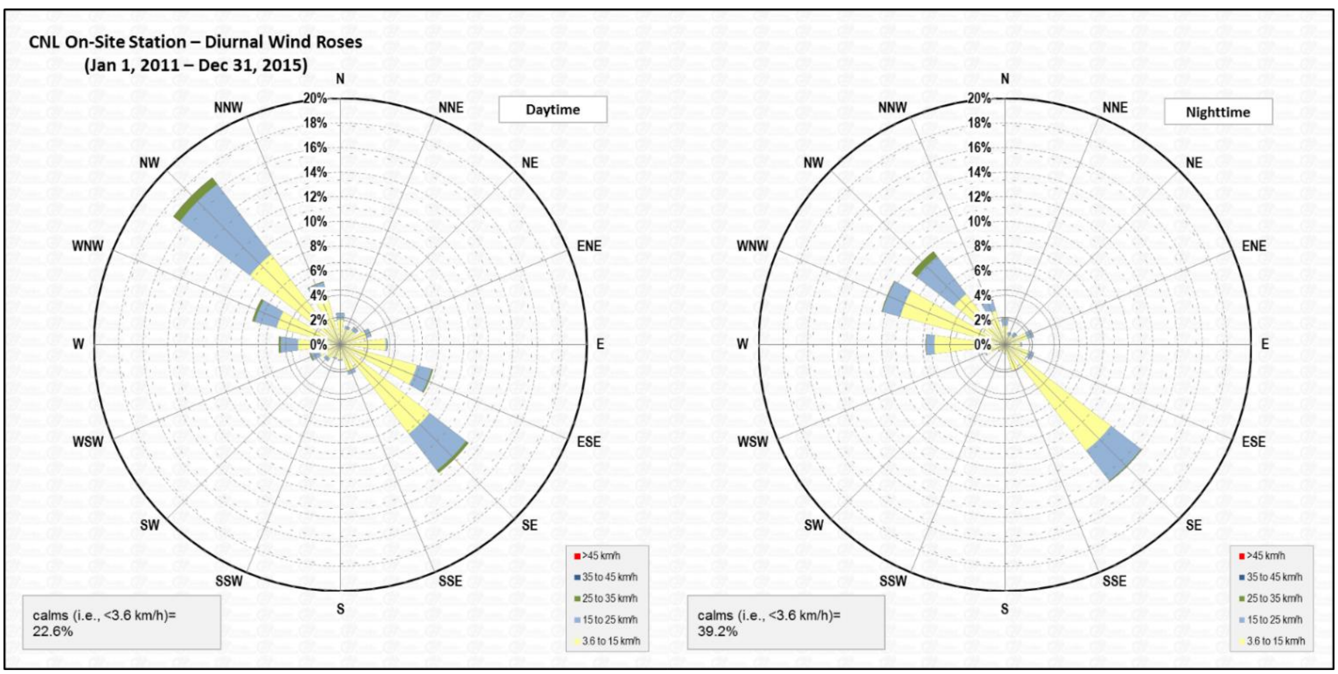


Figure 2-6: Daytime and Nighttime Wind-roses for the CNL On-Site Station Data

2.2.5 Atmospheric Pressure

Atmospheric pressure is the force in unit area exerted by the atmosphere on a surface. The higher the altitude, the lower the atmospheric pressure will be as less force will be applied on the surface. A comparison of the monthly average atmospheric pressure from the Ottawa climate normals station with the 5-year average MECP dataset with is presented in Table 2-9. Although the Ottawa station is located over 150 km from the NSDF Project, it has been used as a regional comparison, as there is no closer station reporting long-term (1981 to 2010) atmospheric pressure climate normals.

Table 2-9: Monthly and Annual Average Atmospheric Pressure MECP Dispersion Meteorology Dataset Compared to Ottawa Climate Normals

Month	Atmospheric Pressure (kPa)	
	MECP Dataset (2011 – 2015)	Ottawa Climate Normals (1981 – 2010)
January	99.9	100.2
February	99.9	100.3
March	100.0	100.2
April	99.7	100.0
May	100.0	100.1
June	99.8	99.9
July	99.7	100.0
August	99.8	100.2
September	100.1	100.3
October	99.9	100.3
November	100.2	100.3
December	100.1	100.3
Annual	**99.9**	**100.2**

Notes:
kPa = kilopascal

Overall, atmospheric pressures reported in the MECP dataset were consistently slightly lower than those reported in the Ottawa climate normals (the difference ranged from 0.1 to 0.4 kilopascals [kPa] lower). This is representative of the area as less pressure is exerted on its surface as the NSDF Project is located at a higher elevation than the Ottawa station.

2.2.6 Solar Radiation

Solar radiation data from Petawawa A is provided in Table 2-10. The solar radiation for the Ottawa International Airport station has also been provided in Table 2-10 for comparison purpose. Both stations have the same annual average daily solar radiation. Within 150 km of the NSDF Project site, there are no ECCC climate normals stations that monitor solar radiation. However, solar radiation data is available through RETScreen (Natural Resources Canada 2013). RETScreen allows the user to select an ECCC station and provides the site reference conditions for the station selected, including daily solar radiation based on data from the National Aeronautics and Space Administration (NASA). The nearest ECCC station to the NSDF Project site in RETScreen in Petawawa A (Climate ID: 6106398).

Table 2-10: Daily Solar Radiation

Daily Solar Radiation – Horizontal (kWh/m^2/d)		
Month	**Petawawa A**	**Ottawa International Airport**
January	1.62	1.54
February	2.58	2.60
March	3.79	3.68
April	4.59	4.61
May	5.17	5.41
June	5.64	5.91
July	5.74	5.90
August	4.90	4.96
September	3.74	3.60
October	2.42	2.33
November	1.49	1.29
December	1.30	1.16
Annual	**3.59**	**3.59**

Notes:
kWh/m^2/d = Kilowatt hours per square metre per day

Solar radiation is a required element for the Air Quality assessment, as indicated in Appendix B of REGDOC-2.9.1 (CNSC 2017); however; it is not one of the elements included in MECP dispersion meteorological datasets. Solar radiation is not recorded by the on-site CNL station therefore no comparison to the daily solar radiation from the NSDF Project to the Petawawa AWOS 2 station is possible. Given the proximity of the Petawawa AWOS 2 station, solar radiation from this station is considered representative for the NSDF Project.

2.2.7 Mixing Height Summary

Mixing height describes the height above ground of the atmospheric layer in which turbulent flow occurs because of the influence of surface characteristics such as albedo, Bowen ratio and surface roughness. Mixing height can be described as “convective”, resulting from solar heating (daylight hours only); or mechanical, resulting from wind flow over terrain. Mixing height is not reported in long-term climate normals. For this parameter, the MECP dataset was reviewed to assess if the data appear reasonable for the region.

Convective and mechanical mixing heights are presented below, by hour of day, for each season, and as an annual summary from MECP dispersion meteorology dataset. The convective mixing height is a result of the upward movement of an air mass driven by the temperature lapse rate as a function of surface characteristics. Convective mixing heights increase during the day as the sun rises and decrease after sunset when temperatures drop. Mechanical mixing is mostly driven by winds over the Earth’s surface and the surface roughness. Mixing height greatly influences dispersion by providing a region of turbulent flow through which emissions can mix and disperse, and through the daily growth/collapse cycle of the convective mixing layer, which greatly affects ground concentrations of emissions.

The annual and seasonal summary of mixing heights by hour of day is shown in Figure 2-7. The mixing heights from the MECP dataset show the expected seasonal variability. For example, the mixing layer begins to build at 7:00 am in the summer, but not until 10:00 am in the winter. This is consistent with the fact that sunrise is later during the winter than in the summer. Overall, the mixing layer data appears to be representative of what would be expected in the NSDF Project site.

The daytime mixing heights for both convective and mechanical mixing and the nighttime mixing heights for mechanical mixing are compared in Figure 2-8. Convective mixing heights are effectively zero from sunset until just after sunrise.

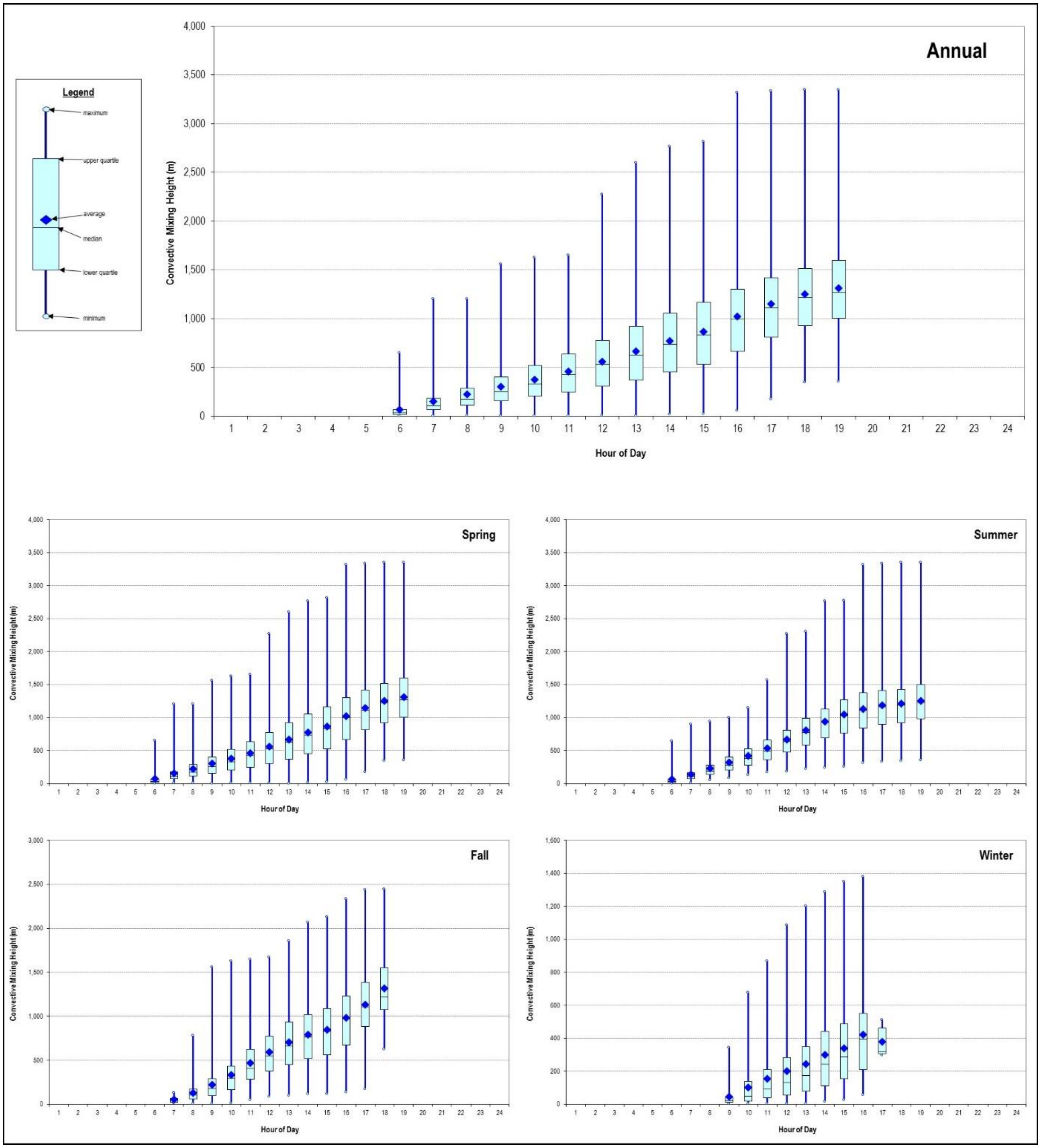


Figure 2-7: Annual and Seasonal Mixing Height Summary for the MECP Dispersion Meteorology Dataset

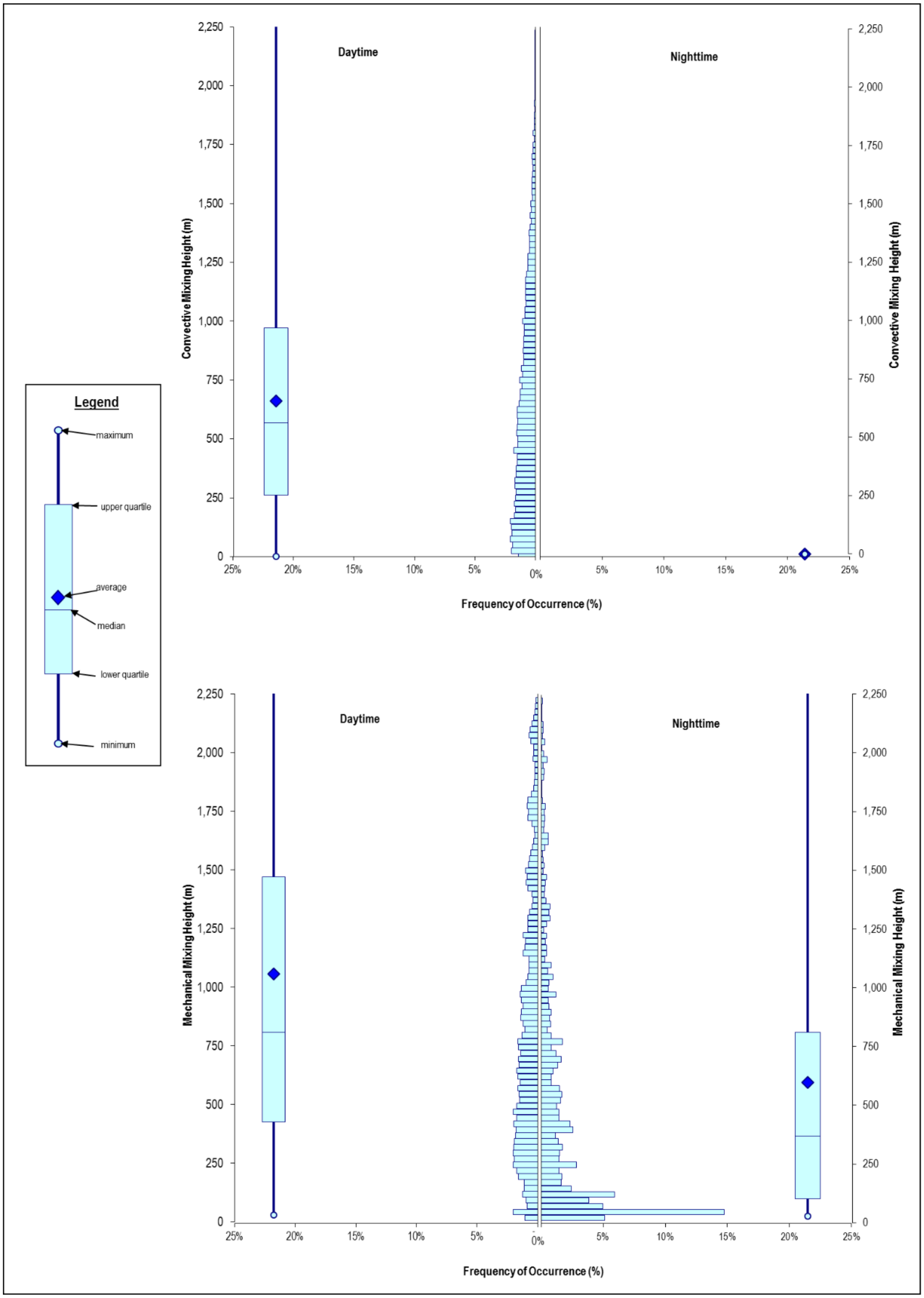


Figure 2-8: Convective and Mechanical Mixing Height Summary for the MECP Dispersion Meteorology Dataset

2.3 Extreme Weather Phenomena

Extreme weather conditions, including extreme temperature (either high or low), precipitation, and winds, have been discussed in Section 2.2. In addition, REGDOC-2.9.1 indicates that extreme weather phenomena should also be included in the air quality assessment. Thunderstorm winds and tornadoes have been identified as an extreme weather phenomenon of particular concern for the NSDF site. The CRL Site Characteristics Document (CNL 2018) identifies tornados as having a one in 100,000 year frequency, with a maximum wind speed of 225 km/h and maximum static pressure drop of 2.8 kPa.

2.4 Summary and Conclusions

Comparisons between the MECP dispersion meteorological dataset, the Chalk River AECL, the Ottawa MacDonald-Cartier International Airport climate and the on-site CNL station show that climatic conditions at the NSDF Project can be appropriately represented by the MECP dispersion modelling dataset. The 5-year dispersion meteorological dataset appears representative of long-term climate in the region, when compared to the 30-year climate normals (1981 to 2010) from the Chalk River AECL and Ottawa MacDonald-Cartier International Airport climate stations, and also appears representative of the local conditions at the NSDF Project site over the last five years (2011 to 2015), when compared to the CNL on-site meteorological station. Based on the analyses presented Section 2 of this TSD, the dataset processed by the MECP is suitable for dispersion modelling at the NSDF Project site.

3.0 AIR QUALITY BASELINE

This section summarizes the available non-radiological ambient air quality monitoring data for stations located outside of the Regional Study Area (RSA) selected for the air quality assessment for the NSDF Project (see EIS Section 5.2 [Atmospheric Environment]). These data are used to assess the existing conditions for non-radiological air quality in the NSDF Project Local Study Area (LSA) and the RSA that will be added as background to dispersion modelling results as part of the effects assessment.

3.1 Overview

As described in EIS Section 5.2.1.3.1 (Spatial Boundaries), the LSA is defined as the area within which there is potential for measurable changes to measurement indicators resulting from the proposed NSDF Project activities. The LSA includes the Site Study Area (SSA) and corresponds to the CRL site boundary. The RSA is defined as the area within which the potential effects of the NSDF Project may interact with the effects of other existing or reasonably foreseeable projects. The RSA is equivalent to a circle surrounding the LSA with an approximate radius of 7.4km.

The air quality baseline documents the methods, data, and assumptions that were used to assess the non-radiological background air quality at the NSDF Project and in the LSA and RSA. The assessment was carried out by:

- identifying the non-radiological indicator compounds expected to be emitted from the NSDF Project;
- identifying and comparing non-radiological air quality guidelines in Ontario and Canada for the indicator compounds;
- identifying existing emission sources located within 25 km of the LSA with shared indicator compounds;
- assessing air quality data sources for use in the background air quality assessment; and
- comparing air quality monitored data to the applicable air quality guidelines.

These steps are detailed in Sections 3.1.1, 3.1.2 and 3.1.3.

3.1.1 Non-Radiological Indicator Compounds

The assessment of air quality focused on predicting changes in the concentrations of selected non-radiological indicator compounds. These indicator compounds represent non-radiological compounds that are expected to be emitted from the NSDF Project, and include some of the compounds identified in the Annual Compliance Monitoring Report Effluent Verification Monitoring at Chalk River Laboratories in 2018 (CNL 2019) and other compounds based on the understanding of the NSDF Project. These compounds are generally accepted as indicative in changing air quality, and for which relevant air quality criteria exist. The selected non-radiological indicator compounds fall into the following four categories:

- **particulate matter**: suspended particulate matter (SPM), particles nominally smaller than 10 µm in diameter (PM_{10}), and particles nominally smaller than 2.5 µm in diameter ($PM_{2.5}$);
- **combustion gases**: NO_X represented by nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and acrolein (C_3H_4O);

- **decomposition of waste**: hydrogen sulfide (H_2S), vinyl chloride (C_2H_3Cl), and odour; and
- **metals**: lead (Pb) and mercury (Hg).

These compounds are associated with various NSDF Project activities as well as activities at the CRL main campus. Particulate matter is typically associated with airborne dust from vehicles travelling on on-site unpaved roads/haul routes, as well as material loading and unloading activities. Products of combustion (particulate matter, NO_2, SO_2, CO, and Pb) are associated with the exhaust from on-site vehicles and stationary combustion from the Wastewater Treatment Plant (WWTP) process and comfort heating equipment. In addition, at the request of CNSC as part of their comments on the draft EIS, C_3H_4O was included to represent Volatile Organic Compounds (VOCs) from combustion. Emissions from the decomposition of waste (H_2S, C_2H_3Cl, and odour) were not included in the CRL 2018 Effluent Verification Monitoring Report (CNL 2019), but are the result of breakdown of waste material within the NSDF Project; and therefore, included as indicator compounds. Other contaminants identified as indicator compounds that occur from the decomposition of the waste such as CO and Hg were also included from the engineered containment mound (ECM). Odour emissions from the WWTP were also included. Metals are associated with number 6 fuel oil consumption at the CRL main campus (CNL 2019), and have decreased since the conversion to Natural Gas at the powerhouse as part of the completed facility improvements. Total VOCs and halocarbon refrigerants are not considered indicator compounds; and therefore, were not retained for the air quality baseline assessment.

In addition to the compounds above, ozone (O_3) was also included in the air quality baseline assessment as it will be used to calculate the NO_2 in the effects assessment. Ozone is not emitted directly into atmosphere but is associated with the reaction of NO_X and VOCs (MECP 2018).

3.1.2 Applicable Guidelines

The relevant air quality criteria used for screening air quality effects in the region include the Ontario criteria, and federal standards and objectives where provincial guidelines are not available. The MECP has set guidelines related to ambient air concentrations and are summarized in *Ontario's Ambient Air Quality Criteria* (AAQC) document (MOE 2012). The Ontario AAQCs are characterized as desirable ambient air concentrations, and have been set at levels that are protective of human health and the environment. The Ontario AAQCs are not regulatory limits, and therefore, exceedances are permitted. The Ontario AAQCs are used for screening the air quality effects in environmental assessments, in studies using ambient air monitoring data, and as assessment of general air quality in a community or across the province (MOE 2012).

There are two sets of federal objectives and criteria: the National Ambient Air Quality Objectives (NAAQOs) and the Canadian Ambient Air Quality Standards (CAAQSs, formerly National Ambient Air Quality Standards [NAAQS]). Similar to the Ontario AAQCs, the NAAQOs are benchmarks that can be used to facilitate air quality management on a regional scale, and provide goals for outdoor air quality that protect public health, the environment, or aesthetic properties of the environment (Canadian Council of Ministers of the Environment [CCME] 1999). The federal government has established the following levels of NAAQOs (Hopper at al. 1994):

- the maximum ***Desirable*** level defines the long-term goal for air quality and provides a basis for an anti-degradation policy for unpolluted parts of the country and for the continuing development of control technology; and
- the maximum ***Acceptable*** level is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort, and well-being.

The CAAQSs have been developed under the *Canadian Environmental Protection Act, 1999*, and include standards for $PM_{2.5}$, NO_2, SO_2 and ozone that must be achieved by 2020. In 2015 the standard was phased in, with the final standard phase in date in 2020 (Government of Canada 2013). Like the Ontario AAQCs, the CAAQSs are not regulatory limits and are used as national targets for $PM_{2.5}$, NO_2, SO_2 and ozone, excluding Quebec (CCME 2014). These more stringent standards were adopted because, as stated by the CCME (emphasis added):

> Canadians living in heavily populated and industrialized areas of the country may be exposed to potentially harmful levels of outdoor air pollutants, at concentrations that exceeded established standards. (CCME 2014)
>
> However, the key aspect of "CAAQS Achievement" (i.e., compliance), as stated by the CCME, is (emphasis added):
>
> Achievement of the CAAQS means that the measured air pollutant concentration in an air zone does not exceed the CAAQS numerical value. (CCME 2014)

These values are reported based on a series of monitoring stations located in airsheds across Canada and in this context, an "air zone" refers to a local or regional sub-region of the established provincial or territorial airsheds. Currently, Southern Ontario and Southern Quebec are treated as a single Airshed (East Central) and Southern Ontario, excluding Hamilton and Sarnia, is designated as a single air zone.

A summary of the applicable Ontario, Quebec and federal objectives and criteria are listed in Table 3-1. The Quebec standards and criteria (MELCC 2018) are included for reference only and were not considered for comparison to the maximum modelled concentrations.

Table 3-1: Ontario and Canadian Regulatory Air Quality Objectives and Criteria

Substance	Averaging Period	Ontario Ambient Air Quality Guidelines[a] (µg/m³)	Canadian Ambient Air Quality Standards[b] (µg/m³)	National Ambient Air Quality Standards and Objectives[c] (µg/m³)		Quebec Atmospheric Quality Standards and Criteria (µg/m³)
				Desirable	Acceptable	
SPM[d]	24-Hour	120	—	—	120	120
	Annual	60[e]	—	60	70	—
PM_{10}	24-Hour	50[f]	—	—	—	—
$PM_{2.5}$	24-Hour	30[g]	27	—	—	30
	Annual	—	8.8	—	—	—
NO_2	1-Hour	400[h]	113 (60ppb)[i]	—	400	414
	24-Hour	200[h]	—	—	—	207
	Annual	—	32 (17ppb)	60	100	103
SO_2	4-minute	—	—	—	—	1,050
	1-Hour	690	183 (70ppb)[j]	450	900	—
	24-Hour	275	—	150	300	288
	Annual	55	13 (5ppb)	30	60	52
CO	1-Hour	36,200	—	15,000	35,000	34,000
	8-Hour	15,700	—	6,000	15,000	12,700

Table 3-1: Ontario and Canadian Regulatory Air Quality Objectives and Criteria

Substance	Averaging Period	Ontario Ambient Air Quality Guidelines[(a)] ($\mu g/m^3$)	Canadian Ambient Air Quality Standards[(b)] ($\mu g/m^3$)	National Ambient Air Quality Standards and Objectives[(c)] ($\mu g/m^3$)		Quebec Atmospheric Quality Standards and Criteria ($\mu g/m^3$)
				Desirable	Acceptable	
C_3H_4O	4-minute	—	—	—	—	8.3
	1-Hour	4.5	—	—	—	—
	24-Hour	0.4	—	—	—	—
	Annual	—	—	—	—	0.02
O_3	1-Hour	165	—	100	160	160
	8-Hour	—	122 (62 ppb)[(k)]	—	—	125
Pb	24-Hour	0.5	—	—	—	—
	30-Day	0.2[(l)]	—	—	—	—
	Annual	—	—	—	—	0.1
Hg	24-Hour	2	—	—	—	—
	Annual	—	—	—	—	0.005
H_2S	4-minute	—	—	—	—	6
	10-Minute	13	—	—	—	—
	24-Hour	7	—	—	—	—
	Annual	—	—	—	—	2
C_2H_3Cl	24-Hour	1	—	—	—	—
	Annual	0.2	—	—	—	0.05
Odour[(m)] (OU/m^3)	4-minute	—	—	—	—	1(5)[(o)]
	10-minute	1[(n)]	—	—	—	—

Note:

(a) MOE (2012).

(b) Canadian Ambient Air Quality Standards published in the Canada Gazette Volume 147, No. 21 - May 25, 2013. Final standard phase in date of 2020 used. For SO2, NO2 and O3, the reference is ppb and was converted using a pressure of 1 atmosphere and a temperature of 25 degree Celsius.

(c) CCME (1999)

(d) SPM in Ontario is defined as Suspended Particulate Matter (<44 µm diameter)

(e) Geometric mean

(f) Interim AAQC and is provided as a guide for decision making (MOE 2012)

(g) Compliance is based on the 98th percentile of the annual monitored data averaged over three years of measurements.

(h) Standard is for nitrogen oxides (NOX) but is based on the health effects of NO2.

(i) As described by the CCME, 3-year average of the annual 98th percentile of the NO2 daily-maximum 1-hour average concentrations

(j) As described by the CCME, 3-year average of the annual 99th percentile of the SO2 daily-maximum 1-hour average concentrations

(k) Ozone is not emitted directly into the atmosphere but is associated with the reaction of NOX to calculate NO2 in the effects assessment.

(l) Arithmetic mean

(m) Odour unit per cubic metre (OU/m3)

(n) The Ontario Guideline is based on the 99.5th percentile on a 10-minute averaging period, in OU/m3 (MOE 2016)

(o) Odour concentration must be 1 odour unit or less 98% of the time and 5 units or less 99.5% of the time. Predicted concentrations above the 1 odour unit criteria are permitted up to 175 hours per year and predicted concentrations above the 5 odour unit criteria are permitted up to 44 hours per year.

(p) MELCC 2018.

— = No guideline available; $\mu g/m^3$ = microgram per cubic metre; ppb = parts per billion.

3.1.3 Existing Emissions Sources

There are two industrial facilities that report Criteria Air Contaminant (CAC) and pollutant releases, disposals, and transfers for recycling under Part 1A to the National Pollutant Release Inventory (NPRI) within 25 km of the LSA (ECCC 2018). The only facility within the LSA is CNL. These emissions contribute to the local air quality and the consideration of cumulative effects. Reporting facilities and emission totals are summarized in Table 3-2. These sources are minor contributors of the non-radiological indicator compounds, with the exception of the lead emissions from the Department of National Defence. CNL baseline emissions of indicator compounds (SO_2, SPM, PM_{10}, Pb and Hg) have decreased appreciably starting in 2017. The reduction of these emissions and greenhouse gas emissions is the direct result of the full switch over to natural gas from #6 fuel oil for the CRL Powerhouse, the facility providing most of the heating for building on the CRL Site. The switchover was a CNL initiative to reduce emissions from the CRL site.

Table 3-2: Air Emission Totals for Industry within 25 km of the Local Study Area

Company Name	Distance to the NSDF Project[a] (km)	Direction from the NSDF Project	Emissions						
			Contaminant	Units	2014	2015	2016	2017	2018[b]
Canadian Nuclear Laboratories	1	North	NO_x	tonnes	65.124	62.421	58.478	67.955	52.350
			SO_2	tonnes	223.901	200.373	240.393	182.076	10.000
			CO[c]	tonnes	8.463	8.386	8.250	11.048	9.920
			SPM	tonnes	33.098	29.067	49.148	38.980	14.760
			PM_{10}	tonnes	19.220	17.248	23.684	19.268	5.300
			$PM_{2.5}$	tonnes	10.523	9.627	11.260	9.736	2.220
			Hg	kg	0.145	0.132	0.122	0.104(d)	0.053
			Pb	kg	2.042	1.963	1.778	1.222	0.148
Department of National Defence	16	Southeast	NO_x	tonnes	37.537	37.983	24.020	24.463	—
			SO_2	tonnes	—	—	—	—	—
			CO	tonnes	35.391	34.523	35.869	38.701	—
			SPM	tonnes	—	—	—	—	—
			PM_{10}	tonnes	2.200	4.374	3.610	9.972	—
			$PM_{2.5}$	tonnes	1.459	2.579	2.350	5.806	—
			Hg	kg	—	—	—	—	—
			Pb	kg	20.404	19.517	21.200	24.500	—

Notes:

All emissions taken from ECCC 2018a unless otherwise noted

(a) Distance from the NSDF centroid.

(b) NPRI database is current up to 2017 reporting year. CNL Emissions for 2018 taken from CNL 2019. No available data for DND emissions in 2018

(c) CO emissions provided by CNL

(d) CNL did not report Hg emissions to NPRI in 2017. Emissions taken from CNL 2019

— = Not available. km = kilometre; tonnes = metric tonnes; kg = kilograms.

3.2 Data Sources

Although air quality data is provided in the CRL 2018 Effluent Verification Monitoring Report (CNL 2019), the data is based on emission estimates (emission factors), rather than measured data, and represents emissions solely from the CRL main campus. Other industries outside the LSA are not considered in the baseline and therefore data from monitored data sources was used and is considered to be more representative of background air quality. Site-specific air quality monitoring was not carried out as part of this assessment. Data from the Canadian Air and Precipitation Monitoring Network (CAPMoN) network was received from ECCC for the station located at the CRL site (CAPMCAON1CHA); however due to limited data availability at the time of the assessment (only 2009 to 2011 and only certain indicator compounds) the data was not considered for the air quality baseline assessment.

Therefore the background air quality was assessed using observations from the Environment and Climate Change Canada (ECCC) National Air Pollution Surveillance Network (NAPS) air quality monitoring stations (ECCC 2013) at locations outside the RSA. The monitoring data considered ranged from 2009 through 2013, which was the latest data available at the time of the baseline assessment in 2015 and is still considered representative of the baseline air quality for the NSDF Project site. It is understood that there is an ECCC Canadian Air and Precipitation Monitoring Network (CAPMoN) air quality monitoring location at the CRL site. Data from the CAPMoN network was received from ECCC for the station located at the CRL site (CAPMCAON1CHA); however due to limited data availability (only 2009 to 2011 and only certain indicator compounds) the data was not considered for the air quality baseline assessment. The closest air quality monitoring station otherwise is located in Petawawa, however not all indicator compounds are monitored at the Petawawa station. The next closest air quality monitoring station with additional indicator compounds is the Ottawa Downtown monitoring station. Some indicator compounds (C_3H_4O, Hg, H_2S, C_2H_3Cl, and odour) were not monitored at either monitoring station. The relative locations of each of the air monitoring stations selected to describe the background air quality is summarized in Table 3-3 and presented on Figure 3-1.

Table 3-3: Location of Air Monitoring Stations

City	NAPS Station ID	Location	Latitude and Longitude	Distance to the NSDF Project[a] (km)	Location with Respect to the NSDF Project
Petawawa	66201	Outside Regional Study Area	45.996722, -77.441194	7	Southwest, generally downwind
Ottawa Downtown	60104	Outside Regional Study Area	45.43433, -75.676	148	Southeast, generally upwind

Notes:
[a] Distance from the NSDF Centroid. ID = Identification; km = kilometre.

The air flow into the Chalk River area is predominantly from the southeast. The air quality monitoring station in Ottawa Downtown (NAPS ID 60104) captures this air flow into Chalk River; however, the station is located approximately 150 km from the NSDF Project. The results can be considered to provide conservative air quality estimates (likely to be greater than the existing conditions in the RSA) given its urban location and proximity to the Canada-United States' border. The Petawawa station (NAPS ID 66201), located approximately 2km south of the Village of Chalk River, is generally downwind of the NSDF Project and is considered to be the most representative station of the RSA, due to proximity and similarity in geographic siting (rural location and distance from the Ottawa River). The majority of the stations located outside the 100 km radius only monitor $PM_{2.5}$ and O_3. As mentioned above, the closest station which monitors some of the remaining indicator compounds is the Ottawa Downtown station.

Table 3-4 provides a summary of the monitoring data available from each of these stations for the period from 2000 through 2013. At the time of this assessment, complete datasets were available up until 2013, with only partial information being available for 2014 and 2015. Not all compounds have the same data availability period for a given station, as additional compounds are added to the station at different dates as required by the ECCC (i.e., SO_2 and CO were only monitored starting in 2006).

Table 3-4: Availability of Ambient Air Quality Data

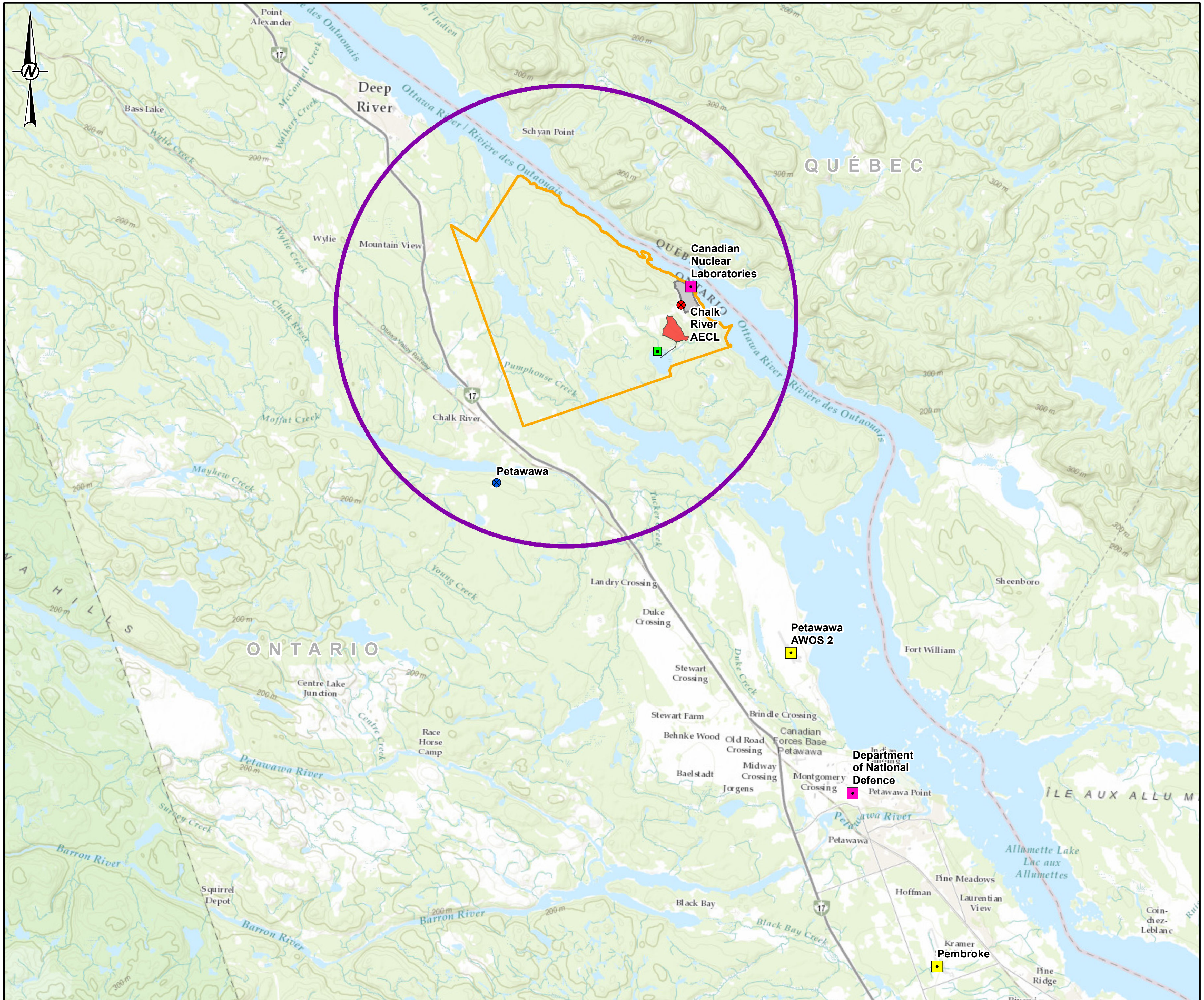
Compound	Petawawa	Ottawa Downtown
SPM	—	—
PM_{10}	—	2000 - 2013
$PM_{2.5}$	2007 - 2013	2000 - 2013
NO_2	—	2000 - 2013
NO	—	2000 - 2013
SO_2	—	2006 - 2012
CO	—	2006 - 2013
C_3H_4O	—	—
O_3	2007 - 2013	2000 - 2013
Pb	—	2006 - 2013
Hg	—	—
H_2S	—	—
C_2H_3Cl	—	—
Odour[(a)]	—	—

Notes:

"—" indicates that data for the parameter were not available at that station.

[(a)] Responses to odour are based on short-term exposure and presence, which is based on olfactory perception of the individual to which the odour is exposed. Background odour can be estimated through a community odour survey; however, this type of sampling has not been conducted in the area; therefore background odour values are not available.

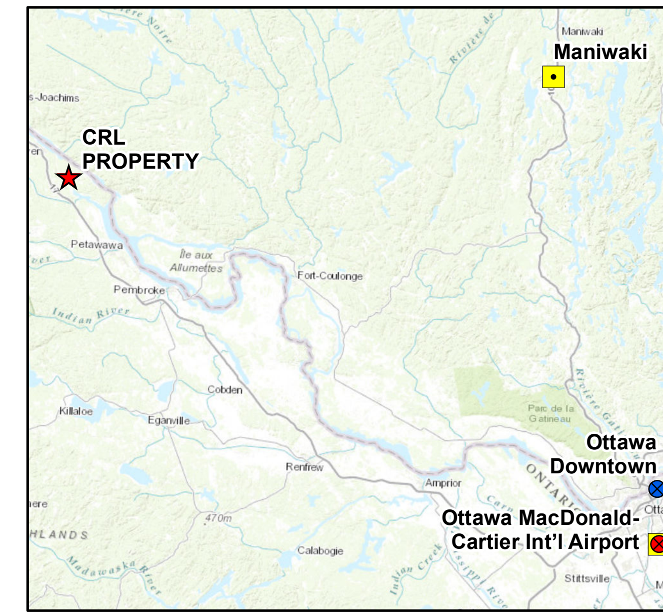
There is no monitoring data available for SPM and PM_{10} at the Petawawa station, however, an estimate of the background SPM and PM_{10} concentrations can be estimated from the available $PM_{2.5}$ monitoring results. $PM_{2.5}$ is a subset of PM_{10}, and PM_{10} is a subset of SPM. Therefore, it is reasonable to assume that the ambient concentrations of SPM will be greater than corresponding PM_{10} levels, and PM_{10} concentrations will be greater than the corresponding levels of $PM_{2.5}$. The mean levels of $PM_{2.5}$ in Canadian locations are found to be about 50% of the PM_{10} concentrations and about 25% of the SPM concentrations (Brook et al. 1997). By applying this ratio it is possible to estimate the background SPM and PM_{10} concentrations for the RSA.



LEGEND

- CRL ENVIRONMENTAL MONITORING STATION
- AMBIENT AIR QUALITY MONITORING STATION
- NPRI REPORTING FACILITY
- CLIMATE NORMALS STATION
- METEOROLOGICAL STATION
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- LOCAL STUDY AREA (CRL PROPERTY)
- REGIONAL STUDY AREA

REGIONAL AMBIANT AIR MONITORING STATION



5 0 5

1:125,000 KILOMETRES

REFERENCE(S)
1. BASEMAP:SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND MAY 2017)
3. HIGHWAYS AND FIRST NATION RESERVES MNRF 2016
4 PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT
NEAR SURFACE DISPOSAL FACILITY, AIR QUALITY ASSESSMENT TECHNICAL SUPPORTING DOCUMENT, CHALK RIVER, ONTARIO

TITLE
AMBIENT AIR QUALITY MONITORING STATIONS AND NPRI REPORTING FACILITIES

CONSULTANT
GOLDER

YYYY-MM-DD	NOVEMBER 2020
DESIGNED	SO
PREPARED	SO
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APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
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3.3 Assessment of Background Air Quality

The continuous monitoring stations listed in Table 3-3 were used to reflect the existing conditions in the RSA. The existing air quality levels, based on background air concentrations from available monitoring stations are summarized in the following sections. The available air monitoring data represents the combined effect of emissions from sources near to each of the monitoring stations, as well as the effect of the emissions transported into the region. The emissions transported into the region could be considered to be the “background air quality”, which would be added to dispersion modelling results as part of the effects assessment.

Although gaseous monitoring equipment records concentrations in units of parts per million parts (ppm) or parts per billion parts (ppb), regulatory criteria are established on the basis of micrograms per cubic metre (µg/m³). In this section, monitoring results for gaseous compounds are presented in the units of µg/m³, to facilitate the comparison of monitoring to criteria. The conversion from ppm to µg/m³ is unique to each compound, based on the molecular weight of the compound and standard atmospheric conditions (1 atmosphere of pressure and 25°C). In contrast, particulate and metals monitoring equipment records concentrations in units of µg/m³, allowing for direct comparison to the regulatory criteria.

3.3.1 Comparison of Monitored Data by Indicator Compound

Figures 3-2 to 3-7 present simplified box-and-whisker plots showing the available concentration data. The box on the figures represents the bounds of the middle 50% of the data points. The top of the box represents the 75th percentile concentration, while the bottom of the box represented the 25th percentile concentration. The line through the middle of the box represents the median, or 50th percentile concentration. The orange diamond represents the average concentration and the green circle represents the 90th percentile. On these figures, the whiskers extend up to the maximum, and down to the minimum concentration.

The 90th percentile of the 1-hour, 8-hour and 24-hour measurements are typically used to represent the background air quality value when conducting an impact assessment as this value is exceeded only 10% of the time. The annual average concentration is used for annual background levels (Alberta Environment and Sustainable Resource Development 2013) and based on the limited measurement data. The average concentration for the shorter time periods provides an indication of what air quality would typically be at the location. The 75th percentile provides an indication of the concentration below which the vast majority of the existing air quality readings occurred. Significant differences between the average and 75th percentile readings provide an indication that the background air quality is dominated by infrequent, but extreme events.

Fine Particulate Matter ($PM_{2.5}$)

Particulate emissions occur due to anthropogenic activities (such as industrial, transportation, and residential sources) and natural sources. Suspended particulate matter is classified based on its aerodynamic particle size, primarily due to the different health effects that can be associated with the particles of different diameters. In Ontario, $PM_{2.5}$ emissions have been demonstrating a steady decline over time, decreasing by approximately 22% from 2004 to 2013 (MOECC 2016).

While the maximum annual value of $PM_{2.5}$ at the Ottawa Downtown (Ottawa_D) station may exceed the Ontario AAQC (based on the Canada-wide Standard) and the CAAQS, as shown on Figure 3-2, the standards are calculated as the 98th percentile of the annual monitored data averaged over three years of measurements. Table 3-5 lists the 24-Hour $PM_{2.5}$ ambient monitoring results calculated according to this methodology. The Ontario AAQC and the CAAQS have not been exceeded at either station.

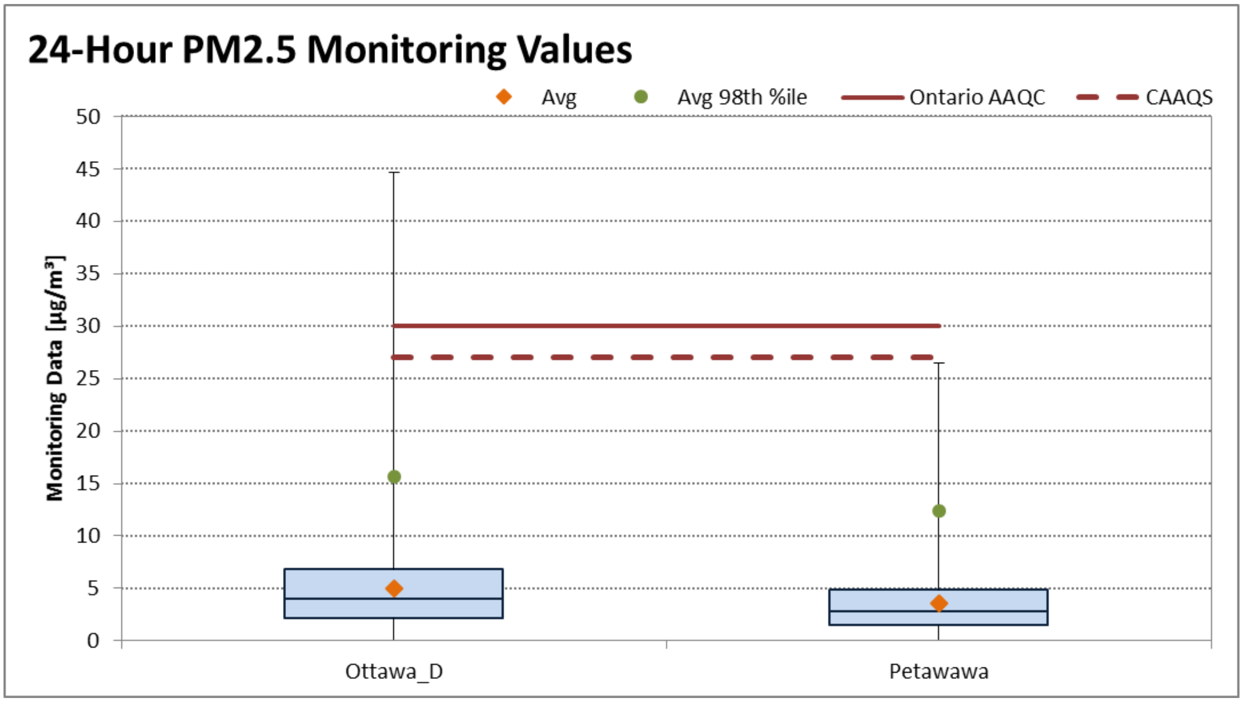


Figure 3-2: $PM_{2.5}$ Monitoring Data for 2009 through 2013

Table 3-5: Summary of 24-Hour $PM_{2.5}$ Monitoring Results for Comparison to the Canada-wide Standard (Ontario AAQC)[(a)]

Years	24-Hour $PM_{2.5}$ [µg/m³]	
	Ottawa_D	Petawawa
2007–2011	20.17	17.07
2008–2012	16.92	14.24
2009–2011	13.32	9.56
2010–2012	15.90	12.59

Notes:

µg/m³ = microgram per cubic metre. [(a)] Ontario AAQC for $PM_{2.5}$ is the Canada-wide Standard (CWS) for $PM_{2.5}$ which is based on the 98th percentile of the annual monitored data averaged over three years of measurements.

NO_x and NO_2 Concentrations

NO_x is emitted in two primary forms: nitric oxide (NO) and nitrogen dioxide (NO_2). NO reacts with ozone in the atmosphere to create NO_2. The primary source of oxides of nitrogen (NO_x) in the region is the combustion of fossil fuels. Emissions of NO_X result from the operation of stationary sources such as incinerators, boilers, and generators, as well as the operation of mobile sources such as vehicles, haul trucks, and other equipment.

The annual mean concentrations of NO_2 in Ontario have decreased by 42% from 2005 to 2014 (MOECC 2016). While NO_2 monitoring was not available at the Petawawa station, no exceedances of the 1-hour or 24-hour AAQC for NO_2 were recorded at the Ottawa Downtown station between 2009 and 2013 (Figure 3-3).

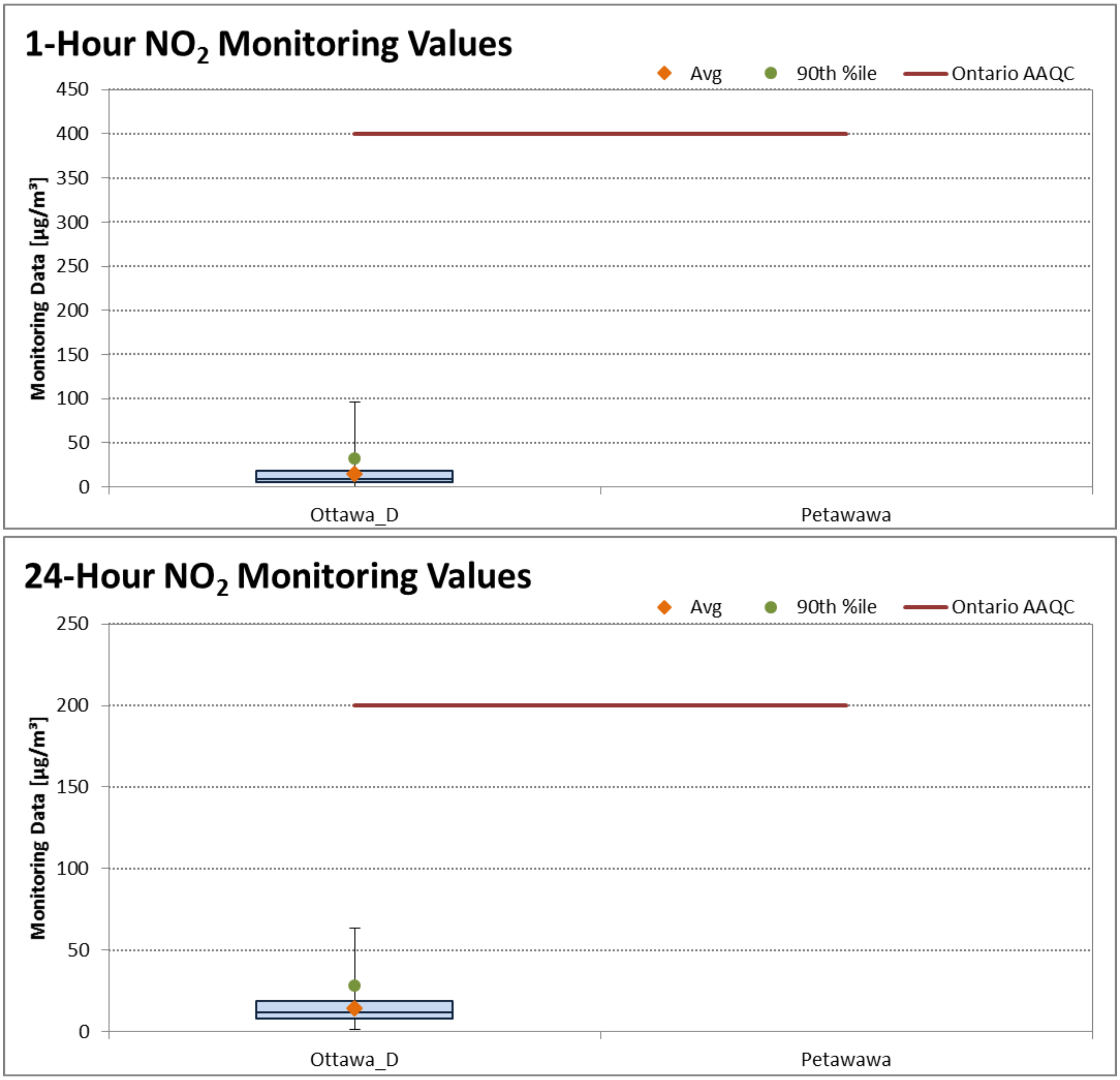
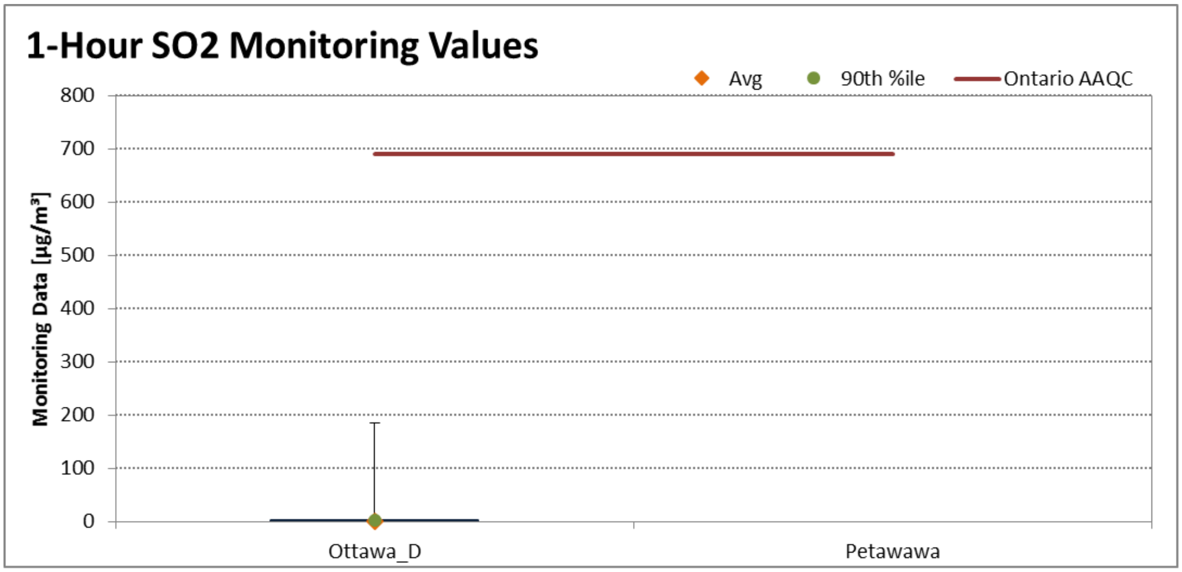


Figure 3-3: NO_2 Monitoring Data for 2009 through 2013

SO_2 Concentrations

The primary source of sulphur dioxide (SO_2) in Ontario is the combustion of fossil fuels in the electricity and smelter sectors. Emissions have decreased significantly due to the phase out of coal-fired generating stations in the province. A summary of the monitored SO_2 concentrations are summarized on Figure 3-4. While SO_2 monitoring was not available at the Petawawa station, no exceedances of the 1-hour or 24-hour AAQC for SO_2 were recorded at the Ottawa Downtown station between 2009 and 2013.



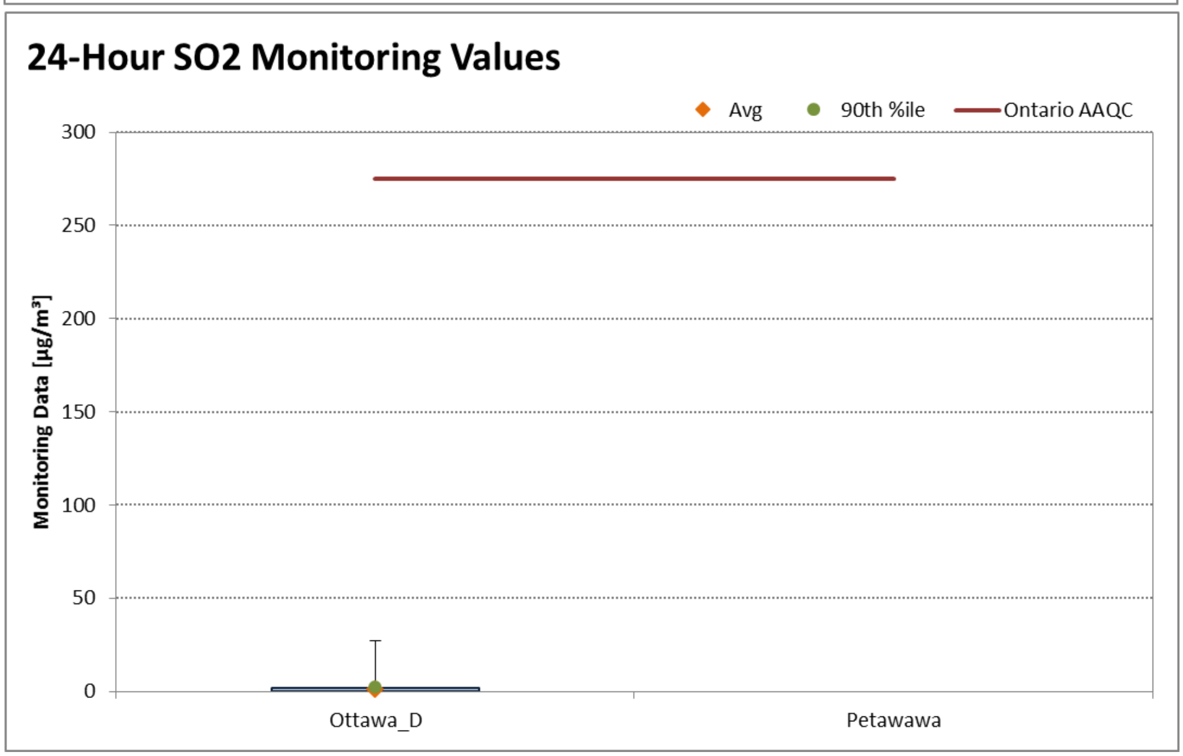


Figure 3-4: SO_2 Monitoring Data for 2009 through 2013

Carbon Monoxide (CO)

Carbon Monoxide is a colourless, odourless, tasteless, and, at high concentrations, toxic gas. It is produced primarily from the incomplete combustion of fossil fuels, as well as natural sources, with approximately 70% of emissions arising from the transportation sector in Ontario (MOECC 2016). While CO monitoring was not available at the Petawawa station, no exceedances of the 1-hour or 8-hour AAQC for CO were recorded at the Ottawa Downtown station between 2009 and 2013 (Figure 3-5).

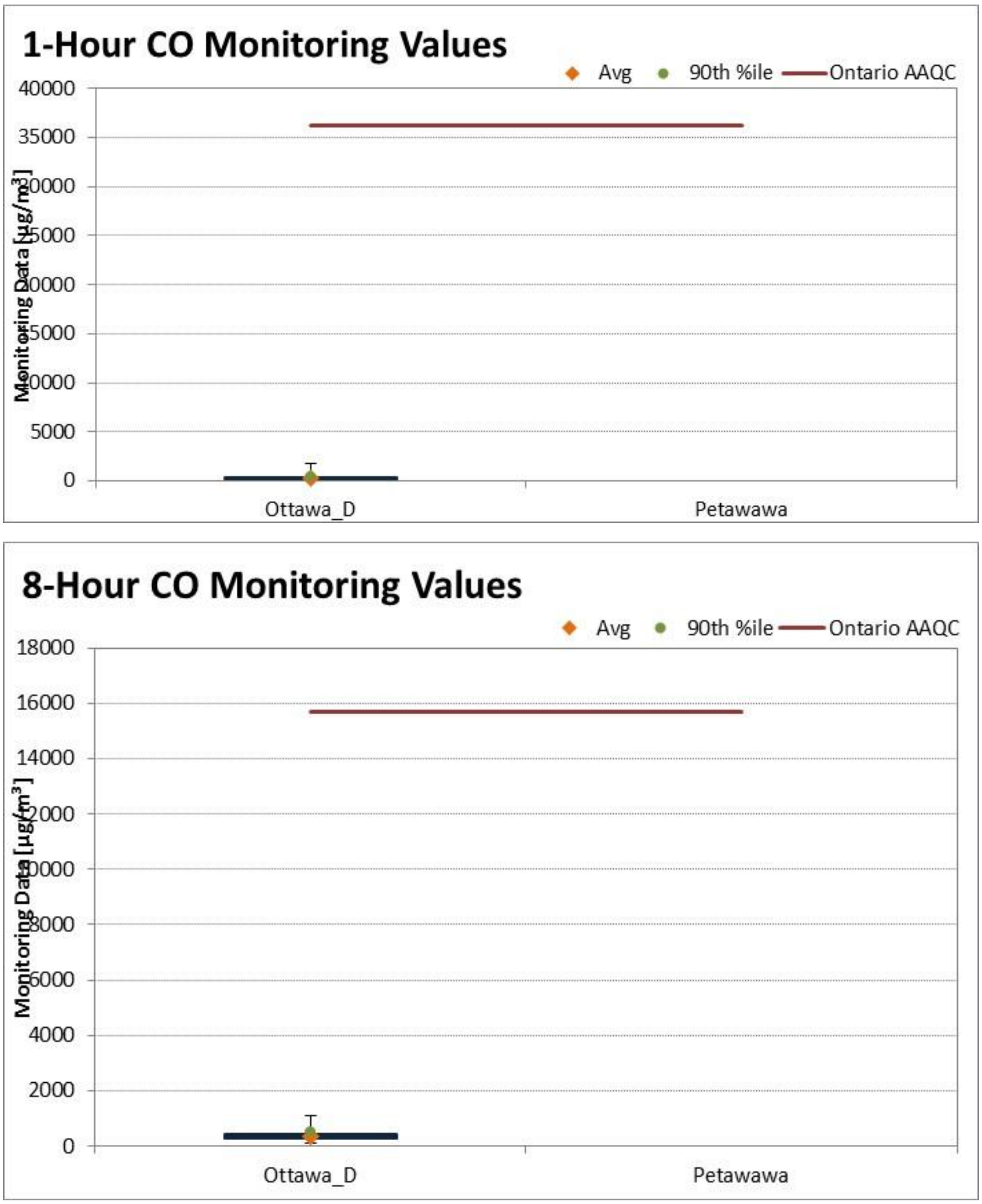


Figure 3-5: CO Monitoring Data for 2009 through 2013

Ozone (O_3)

Ground-level ozone is formed when NO_x and VOCs react in the presence of sunlight. Ground-level ozone exceeded the 1-hour AAQC at 8 stations in Ontario in 2014 (MOECC 2016). A summary of the monitored O_3 concentrations are summarized on Figure 3-6. The maximum 1-hour concentration of O_3 was just below the Ontario AAQC. Currently there is no 8-hour AAQC for O_3, but there is a Canada-wide Standard which has been used for comparison to the data. While the maximum 8-hour concentration of O_3 may exceed the standard at both stations, compliance with the Canada-wide Standard is based on the fourth highest 8-hour value annually, averaged over a 3-year period. Table 3-6 presents a summary of the 3-year averaging methodology using 8-hour O_3 ambient monitoring results. The Canada-wide Standard has not been exceeded at either station.

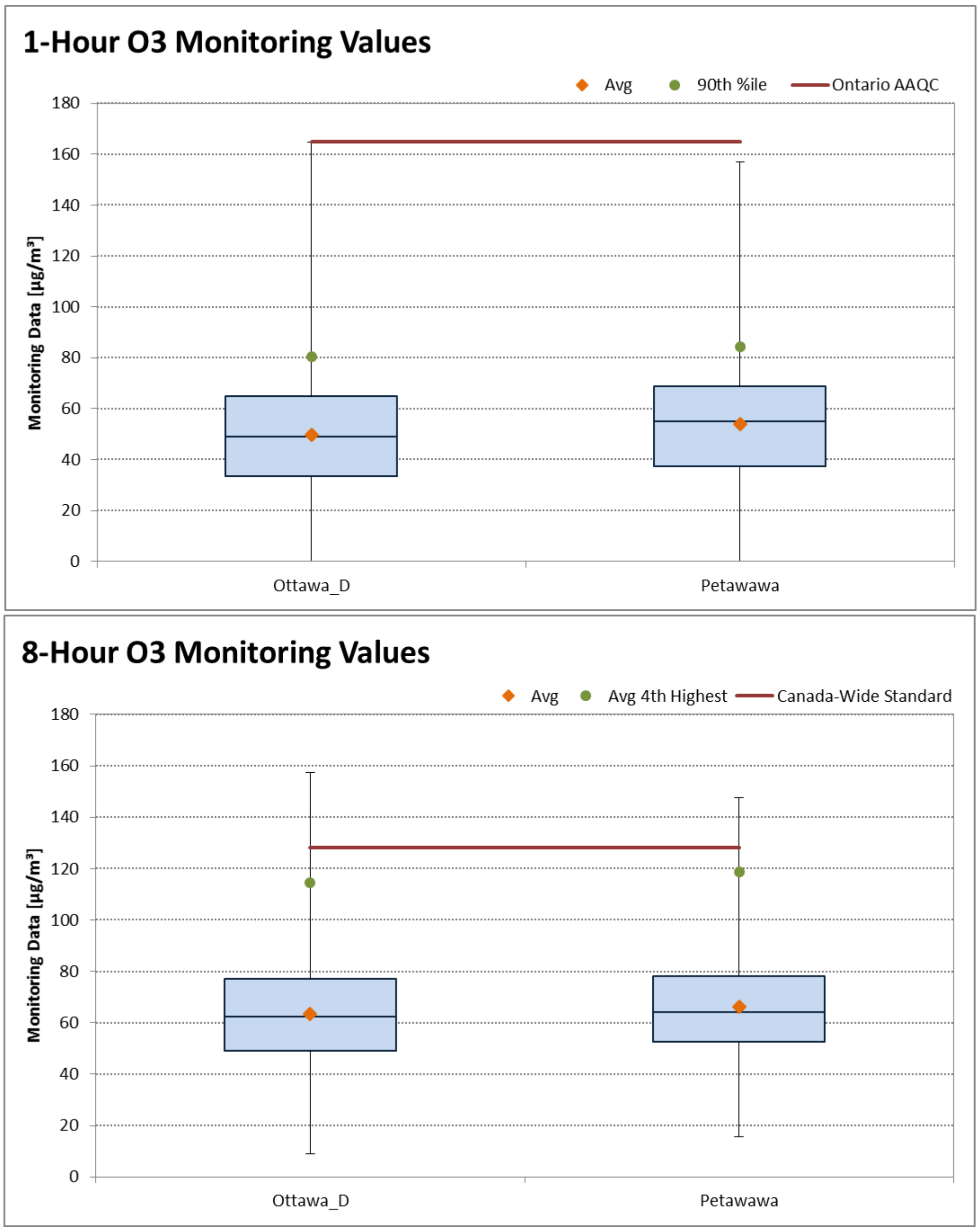


Figure 3-6: O_3 Monitoring Data for 2009 through 2013

Table 3-6: Summary of 3-year average 8-Hour O_3 Monitoring Results for Comparison to the Canada wide Standard

Years	8-Hour Ozone (µg/m³)	
	Ottawa_D	Petawawa
2007–2011	118.83	2007–2011
2008–2012	116.67	2008–2012
2009–2011	111.37	2009–2011
2010–2012	116.69	2010–2012
2011–2013	114.40	2011–2013

Notes:
µg/m³ = microgram per cubic metre

Lead (Pb)

Ambient lead (Pb) concentrations in air have declined significantly in Canada since the removal of leaded gasoline, by approximately 99% from 1984 – 2008 (ECCC 2013). While lead monitoring was not available at the Petawawa station, no exceedances of the 24-hour AAQC for Pb were recorded at the Ottawa Downtown station between 2009 and 2013 (Figure 3-7).

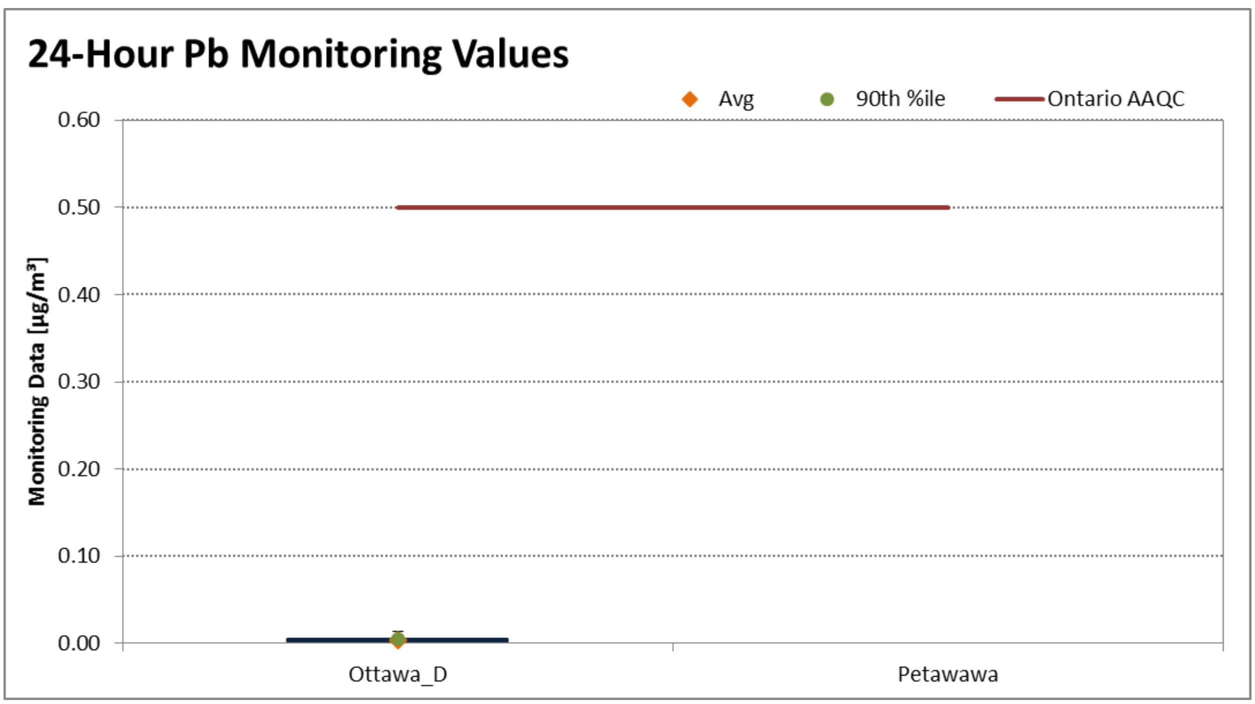


Figure 3-7: Pb Monitoring Data for 2009 through 2013

3.3.2 Summary of Monitored Data by Station

For each of the Petawawa and Ottawa Downtown stations, monitoring data for the years 2009 through 2013 were summarized by indicator compound for the averaging period relevant to the AAQC. To provide an understanding of the variability of the monitoring data, the average, 75th percentile, 90th percentile, and maximum values are summarized in Table 3-7 and Table 3-8. As discussed Section 3.3.1, the 90th percentile of the 1-hour, 8-hour, and 24-hour measurements are typically used to represent the background air quality value when conducting an impact assessment and the annual average concentration is used for annual background levels (Alberta Environment and Sustainable Resource Development 2013). The average concentration for the shorter time periods provides an indication of what air quality would typically be at the location. The 75th percentile provides an indication of the concentration below which the vast majority of the existing air quality readings occurred.

Table 3-7: Summary of Background Air Quality in Petawawa, Ontario (2009 – 2013) in µg/m³(a)

Indicator	Averaging Period	Average	75th	90th	Max
SPM	24-hour	15.03	20.30	30.95	97.83
	Annual	14.53	—	—	19.43
PM_{10}	24-hour	7.51	10.15	15.48	48.92
$PM_{2.5}$	24-hour	3.76	5.08	7.74	24.46
	Annual	3.63	—	—	4.86
NO_2	1-Hour	—	—	—	—
	24-Hour	—	—	—	—
	Annual	—	—	—	—
SO_2	1-Hour	—	—	—	—
	24-Hour	—	—	—	—
	Annual	—	—	—	—
CO	1-Hour	—	—	—	—
	8-Hour	—	—	—	—
C_3H_4O	1-Hour	—	—	—	—
	24-Hour	—	—	—	—
O_3	1-Hour	53.89	68.69	84.39	157.00
	8-Hour	66.28	78.25	93.93	147.68
Pb	24-Hour	—	—	—	—
	30-Day	—	—	—	—
Hg	24-Hour	—	—	—	—
H_2S	10-Minute	—	—	—	—
	1-Hour	—	—	—	—
C_2H_3Cl	24-Hour	—	—	—	—
	Annual	—	—	—	—
Odour(b)	10-Minute	—	—	—	—

Notes:

(a) Data measured in parts per billion (ppb) or parts per million (ppm), were converted to µg/m³ assuming standard temperature and pressure (25°C and one atmosphere of pressure).

(b) Values are in odour units per cubic metre (OU/m³). µg/m³ = microgram per cubic metre.

Table 3-8: Summary of Background Air Quality in Ottawa Downtown, Ontario (2009 – 2013) in µg/m³[(a)]

Indicator	Averaging Period	Average	75th	90th	Max
SPM	24-hour	20.64	28.00	41.50	178.50
	Annual	20.68	—	—	27.99
PM_{10}	24-hour	10.32	14.00	20.75	89.25
$PM_{2.5}$	24-hour	5.16	7.00	10.38	44.63
	Annual	5.17	—	—	7.00
NO_2	1-Hour	14.86	18.81	31.98	95.93
	24-Hour	14.88	19.30	28.61	63.25
	Annual	14.86	—	—	16.15
SO_2	1-Hour	1.05	2.62	2.62	185.98
	24-Hour	1.05	1.95	2.62	27.29
	Annual	1.05	—	—	2.23
CO	1-Hour	298.69	343.57	458.10	1717.86
	8-Hour	347.39	415.15	486.73	1096.16
C_3H_4O	1-Hour	—	—	—	—
	24-Hour	—	—	—	—
O_3	1-Hour	49.05	64.76	78.50	164.85
	8-Hour	62.48	76.05	89.95	157.24
Pb	24-Hour	0.0034	0.0045	0.0046	0.0092
	30-Day	—	—	—	—
Hg	24-Hour	—	—	—	—
H_2S	10-Minute	—	—	—	—
	1-Hour	—	—	—	—
C_2H_3Cl	24-Hour	—	—	—	—
	Annual	—	—	—	—
Odour[(b)]	10-Minute	—	—	—	—

Notes:

[(a)] Data measured in parts per billion (ppb) or parts per million (ppm), were converted to µg/m³ assuming standard temperature and pressure (25°C and one atmosphere of pressure).

[(b)] Values are in odour units per cubic metre (OU/m³).

µg/m³ = microgram per cubic metre.

3.4 Summary of Background Air Quality

This section presents the existing air quality for the RSA to be added as background to the dispersion modelling results as part of the effects assessment. Due to proximity and similarity in geographic siting (rural location and distance from the Ottawa River), the Petawawa station is considered to be the most representative station of the RSA, and therefore represents the background for indicator compounds monitored at that station. For some of the remaining indicator compounds, monitored data from the Ottawa Downtown have been used in the background although the station is located approximately 150 km from the NSDF Project. The results from the Ottawa Downtown station can be considered to provide conservative air quality estimates (likely to be greater than the existing conditions in the RSA) given its urban location and proximity to the Canada-United States' border. Table 3-9 provides the background air quality values, based on Petawawa station and the Ottawa Downtown stations.

Table 3-9: Background Air Quality Values (90th Percentile, Average for Annual Only)

Indicator	Averaging Period	Background	Petawawa (7 km SSW)	Ottawa Downtown (148 km SE)
SPM	24-hour	**30.95**	**30.95**	41.50
	Annual	**14.53**	**14.53**	20.68
PM_{10}	24-hour	**15.48**	**15.48**	20.75
$PM_{2.5}$	24-hour	**7.74**	**7.74**	10.38
	Annual	**3.63**	**3.63**	5.17
NO_2	1-Hour	**31.98**	—	**31.98**
	24-Hour	**28.61**	—	**28.61**
	Annual	**14.86**	—	**14.86**
SO_2	1-Hour	**2.62**	—	**2.62**
	24-Hour	**2.62**	—	**2.62**
	Annual	**1.05**	—	**1.05**
CO	1-Hour	**458.10**	—	**458.10**
	8-Hour	**486.73**	—	**486.73**
C_3H_4O	1-Hour	—	—	—
	24-Hour	—	—	—
O_3	1-Hour	**84.39**	**84.39**	78.50
	8-Hour	**93.93**	**93.93**	89.95
Pb	24-Hour	**0.0046**	—	**0.0046**
	30-Day	—	—	—
Hg	24-Hour	—	—	—
H_2S	10-Minute	—	—	—
	1-Hour	—	—	—
C_2H_3Cl	24-Hour	—	—	—
	Annual	—	—	—
Odour[(a)]	10-Minute	—	—	—

Notes:

SSW = South southwest; SE = Southeast. **Bolded** values represent the background air quality.

[(a)] Values are in odour unit per cubic metre (OU/m^3).

$\mu g/m^3$ = microgram per cubic metre.

4.0 EMISSIONS ESTIMATES

This section summarizes the emission calculations methods followed to quantify the air quality and greenhouse gas (GHG) emissions for use in the non-radiological dispersion modelling and the GHG assessment for the NSDF Project. This section also documents the methods, input parameters, and assumptions that were used to estimate the emission rates for the non-radiological indicator compounds and GHG emissions for the NSDF Project.

The emission estimation methods described in this section follow generally accepted practices for conducting Environmental Assessments and, where appropriate, guidance in Appendix C of REGDOC-2.9.1 (CNSC 2017), and the MECP document *Procedure for Preparing an Emission Summary and Dispersion Modelling Report, Version 4.1* dated March 2018 (ESDM Procedure Document; MOECC 2018).

4.1 Assessment of Compounds and Activities

The assessment of air quality focused on predicting changes in the concentrations of selected non-radiological indicator compounds, as well as a GHG assessment that focused on predicting the emissions of GHGs expressed as carbon dioxide equivalent (CO_2e) and comparing them to provincial and federal emissions.

4.1.1 Air Quality – Indicator Compounds

The selected non-radiological indicator compounds fall into four categories:

- **particulate matter**: SPM, particles nominally smaller than 10 micrometres (µm) in diameter (PM_{10}), and particles nominally smaller than 2.5 µm in diameter ($PM_{2.5}$);
- **combustion gases**: NO_X represented by nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and acrolein (C_3H_4O);
- **decomposition of waste**: hydrogen sulfide (H_2S), vinyl chloride (C_2H_3Cl), and odour; and
- **metals**: lead (Pb) and mercury (Hg).

Emissions were assessed for the NSDF Project activities during the construction and operations phases. Scientifically accepted and well-documented emission factors, such as AP-42 from the United States Environmental Protection Agency (U.S. EPA 1995) were also used.

Compounds that will be emitted from the NSDF Project in negligible amounts and/or activities that discharge a compound in a negligible amount were excluded from further analysis. The rationale for these exclusions is provided in Section 4.1.2. Table 4-1 and Table 4-2 provide a summary of the activities for which emissions were calculated in the air quality assessment, as well as a summary of the compounds expected to be released for the construction and operations phases, respectively.

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Table 4-1: Activities and Non Radiological Indicator Compounds Released/Expected During Construction

NSDF Project Activity(a)	Source	Source Description	Non-Radiological Indicator Compounds											
			SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H_2S	C_2H_3Cl	Odour
—	Engineered Containment Mound (ECM)	ECM cover[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		ECM passive vents[c]	—	—	—	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (material handling)	X	X	X	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (vehicle exhaust)	X	X	X	X	X	X	X	—[d]	—[d]	—	—	—
All construction activities[b]	Unpaved Roads	Vehicle exhaust and fugitive road dust	X	X	X	X	X	X	X	—[d]	—[d]	—	—	—
All construction activities[b]	Stockpile	Stockpile	X	X	X	—	—	—	—	—	—	—	—	—
—	Wastewater Treatment Plant (WWTP)	Wastewater treatment activities[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		WWTP natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—	Support Activities	Vehicle decontamination facility natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		Administration office natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		Operations support centre natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—

Notes:
X = applicable indicator compound for source activity
— = not applicable.
(a) As described in the air quality pathway analysis of the NSDF Project EIS (see EIS Section 5.2.1.5).
(b) Construction activities include site preparation, construction of the ECM, development of the surface water management structures, construction of the WWTP and other support facilities, and on-site road access development.
(c) These sources are not operational while they are constructed resulting in no emissions during the Construction Phase
(d) Hg and Pb occur as trace elements from the combustion of diesel fuel and are excluded from the diesel combustion sources emissions and were therefore not assessed.

Table 4-2: Activities and Non Radiological Indicator Compounds Released/Expected During Operations

NSDF Project Activity[a]	Source	Source Description	Non-Radiological Indicator Compounds											
			SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H_2S	C_2H_3Cl	Odour
—	Engineered Containment Mound (ECM)	ECM cover	—	—	—	—	—	X	—	X	—	X	X	X
—		ECM passive vents	—	—	—	—	—	X	—	X	—	X	X	X
Staged development of the ECM disposal cells, placement of waste in the ECM, and progressive closure of disposal cells and installation of cover		ECM operations (material handling)	X	X	X	—	—	—	—	—	—	—	—	—
Staged development of the ECM disposal cells, placement of waste in the ECM, and progressive closure of disposal cells and installation of cover		ECM operations (vehicle exhaust)	X	X	X	X	X	X	X	—[b]	—[b]	—	—	—
On-site transportation of waste	Unpaved Roads	Vehicle exhaust and fugitive road dust	X	X	X	X	X	X	X	—[b]	—[b]	—	—	—
Staged development of the ECM disposal cells	Stockpile	Stockpile	X	X	X	—	—	—	—	—	—	—	—	—
Operation of WWTP	Wastewater Treatment Plant (WWTP)	Wastewater treatment activities	—	—	—	—	—	—	—	—	—	—	—	X
Operation of WWTP		WWTP natural gas combustion	X[c]	X[c]	X[c]	X[c]	X[c]	X[c]	—	—[d]	X	—	—	—
—	Support Activities	Vehicle decontamination facility natural gas combustion	X[c]	X[c]	X[c]	X[c]	X[c]	X[c]	—	—[d]	X	—	—	—
—		Administration office natural gas combustion	X[c]	X[c]	X[c]	X[c]	X[c]	X[c]	—	—[d]	X	—	—	—
—		Operations support centre natural gas combustion	X[c]	X[c]	X[c]	X[c]	X[c]	X[c]	—	—[d]	X	—	—	—

Notes:

X = applicable indicator compound for source activity

— = not applicable

(a) As described in the air quality pathway analysis of the NSDF Project EIS (see EIS Section 5.2.1.5).

(b) Hg and Pb occur as trace elements from the combustion of diesel fuel and are excluded from the diesel combustion sources emissions and were therefore not assessed.

(c) Contaminants are presented for completeness however they have not been carried through for the dispersion modelling assessment as they were identified as negligible as identified in Table 4-3.

(d) Hg occurs as a trace element in the combustion of natural gas and is excluded from the natural gas combustion sources and were therefore not assessed.

4.1.2 Activities Not Considered in the Air Quality Assessment

There are many activities associated with the NSDF Project that produce emissions; however, not all activities produce emissions for any or all compounds that are relevant to the overall emissions assessment. All activities that potentially produce emissions were evaluated to assess their relevance, however only activities that were considered to be relevant were included in the assessment.

The following lists rationale as to why certain activities and/or emissions of certain compounds can be excluded from the assessment:

- the emission rates of certain compounds are minor relative to the overall emissions at the NSDF Project;
- the emissions of certain sources are known to not be relevant due to the type of operations in the assessment; and
- the location of the source relative to the rest of the sources on-site (i.e., the source is located far away from any potential receptors).

Table 4-3 lists the activities that were not assessed and the accompanying rationale.

Table 4-3: Emission Sources or Contaminants Not Included in the Air Quality Assessment

Activity/Compound	Rationale for Excluding from the Air Quality Assessment
Natural gas combustion for WWTP process, Vehicle Decontamination Facility, Administration Office and Operations Support Centre	CO, SO2, SPM, PM_{10}, and $PM_{2.5}$ emissions from these sources are not required to be assessed (MOE 2018) and NO_x/NO_2 are negligible (<1%) compared to emissions from the mobile combustion sources. Only Pb emissions were included in the dispersion modelling in response a comment received during the review process.
WWTP and associated equipment (i.e., collection tanks)	The treatment of wastewater may result in the release of hydrogen sulfide, mercaptans, chlorine and various other chemicals, to a smaller extent. With the exception of odour, the emissions from the WWTP have been excluded from the assessment as they are expected to have a negligible effect on the overall air quality.
Contact water ponds	Water from precipitation that has not infiltrated into the waste but is treated as suspect of contamination is collected in contact water ponds or equivalent structures on a lined portion of the cell floor. The contact ponds are temporary, and therefore, potential odorous emissions have been excluded from the assessment as they are expected to have a negligible effect on the overall air quality.
Natural gas emergency power generator	The emergency power equipment only operates periodically during monthly routine maintenance testing and for very short duration (20 minutes; rather than continuously). Additionally, the emergency power generator will only be used to supply electricity during power outage when other equipment is not operation; and therefore, is not included in the representative scenario and the modelling is meant to represent normal operations for the NSDF Project.
Diesel pumps, air compressors, and lighting equipment at all Near Surface Disposal Facility (NSDF) buildings	This equipment is part of miscellaneous equipment and only operates periodically and for short durations. Emissions rates from these sources are minor compared to emissions from the other diesel equipment on-site, and therefore, are not included in the representative scenarios.
Snow removal equipment	Emissions from this equipment occur seasonally and are infrequent (i.e., only during the winter following a snowfall), and therefore, are not included in the representative scenario.

Table 4-3: Emission Sources or Contaminants Not Included in the Air Quality Assessment

Activity/Compound	Rationale for Excluding from the Air Quality Assessment
Operations support activities, such as maintenance activities	Emissions from these sources are infrequent, relatively minor, and do not occur at all times compared to the other activities that are occurring regularly and/or continuously. For example, these activities may include minor vehicles maintenance.

Note:

Halocarbon emissions are not considered a source of emissions for the NSDF Project. However, if a spill or leak occurs from equipment (e.g., air conditioners) it is reported to the CNL Environmental Protection Program and included in the annual reporting.

4.1.3 GHG Compounds

For the purposes of the GHG assessment, only the construction and operation phases have been considered. The GHG emissions from operations include the first year after closure, which represents the year where emissions from the decomposition of the waste within the ECM are expected to be at their highest as demonstrated in the Radon and Other Landfill Gas Modelling and Evaluation (AECOM 2018a). Only direct GHG emissions within the LSA have been considered in this assessment. Direct emissions include emissions that are owned or controlled by CNL such as fuel use and GHG emitted from the decomposition of the waste within the ECM. Indirect GHG emissions, such as electricity, are emissions that are a consequence of the CNL activities but occur at sources owned or controlled by another entity and therefore are excluded from the assessment.

The GHG indicator compounds included the following:

- carbon dioxide (CO_2);
- methane (CH_4); and
- nitrous Oxide (N_2O).

There are no NSDF Project activities which are expected to emit Sulphur hexafluoride (SF_6), Perfluorocarbons (PFCs) or Hydrofluorocarbons (HFCs); therefore, these compounds are not included in the GHG assessment.

The GHG emissions were calculated from the decomposition of the waste through the ECM cover and for stationary combustion sources and mobile equipment based on the equipment/vehicle information provided by CNL for both the construction and operations phases. In addition, GHG emissions associated with land clearing were also considered. The GHG emission estimation assumptions are documented in Section 4.2 and were calculated using methods described in the guidance documents for the following legislative GHG reporting programs (the GHG Reporting Programs):

- Ontario's GHG Emissions Reporting Regulation (O. Reg. 390/18); and
- Environment and Climate Change Canada GHG Emissions Reporting Program (the GHGRP).

4.1.4 Activities Not Considered in the GHG Emissions Assessment

There are many activities associated with the NSDF Project that produce GHG emissions; however, not all activities produce emissions for any or all compounds that are relevant to the overall emissions assessment. All activities that potentially produce emissions were evaluated to assess their relevance, however only activities that were considered to be relevant were included in the assessment.

The activities that were not assessed and the accompanying rationale are listed in Table 4-4.

Table 4-4: Emission Sources and Contaminants Not Included in the GHG Assessment

Activity/Compound	Rationale for Excluding from the GHG Assessment
WWTP and associated equipment (i.e., collection tanks)	The process of treatment of wastewater may result in a minor release of greenhouse gases. These emissions have been excluded from the assessment as they are negligible in comparison to the other GHG emissions from the NSDF Project relative to other present sources. At approximately, 29 tonnes CO_2e per year, GHG emissions from the WWTP process are less than 1% of the total GHG emissions and therefore have not been carried through the assessment.
Natural gas emergency power generator	The emergency natural gas generator only operates periodically during monthly routine maintenance testing and for very short duration (20 minutes) (rather than continuously). Additionally, the emergency power generator will only be used to supply electricity during power outage when other equipment is not in operation, and therefore, is not included in the representative scenario. These emissions have been excluded from the assessment as they are expected to be negligible in comparison to the other GHG emissions from the NSDF Project relative to other present sources.
Diesel pumps, air compressors, and lighting equipment at all NSDF buildings	This equipment is part of miscellaneous equipment and only operates periodically and for short durations. Emissions rates from these sources are minor compared to emissions from the other diesel equipment on-site, and therefore, are not included in the representative scenarios.
Snow removal equipment	Emissions from this equipment occur seasonally and are infrequent (i.e., only during the winter following a snowfall), and therefore, are not included in the representative scenario. These emissions have been excluded from the assessment as they are expected to be negligible in comparison to the other GHG emissions from the NSDF Project relative to other present sources.
Upstream GHG emissions	A March 19, 2016 Notice in the Canada Gazette presented ECCC's proposed methodology for estimating the upstream GHG emissions associated with projects undergoing federal environmental assessments. Upstream GHG emissions are those resulting from all industrial activities from the point of resource extraction to the NSDF Project. The specific processes will vary by resource but generally include extraction, processing, handling, and transportation. The NSDF Project is not planned to enable new soil or clay extraction or cement production facilities. Rather, the NSDF Project will be a customer for existing soil or clay supply and cement facilities and is unlikely to impact the Provincial supply and demand for these materials. While grouting will occur during waste placement, it is expected to be minor as it will primarily be used to reduce void space in waste packages and is not anticipated to require a mobile cement facility. Therefore, these emissions have been excluded from the assessment as they are expected to be negligible in comparison to the other GHG emissions from the NSDF Project.

Notes:

WWTP = Wastewater Treatment Plant; GHG = greenhouse gas; NSDF = Near Surface Disposal Facility; CO2e = carbon dioxide equivalent

4.2 Assumptions

The assumptions made as part of the estimation of non-radiological indicator compounds and GHG emission rates are documented in Table 4-5.

Table 4-5: Air Quality and GHG Emissions Assessment Assumptions List

Activity	Data Sources / Assumptions			
	Parameter	Value	Unit	Source / Assumption
Engineered Containment Mound (ECM) operations	Modelled Site	EMR Site	—	Preferred Site as identified in the CNL Site Selection Report (CNL 2016b)
	ECM footprint	172,882	m^2	AERMOD plot over the ECM Shapefile Landfill Development/Sequencing Plan (AECOM 2018b)
	ECM actual height	35	m	Final Cover Geosynthetics Plan (AECOM 2016a) DWG No. 1550-106120-101-01-GA-D (192.9 m - 158 m = 35 m)
	ECM modelled height	17.5	m	Actual height of ECM divided by 2
	Number of passive vents	8	—	Landfill Gas Management Plan (AECOM 2018c) Assumed based on spacing requirements of 186m
	Passive vent height	3	m	Landfill Gas Management Plan (AECOM 2018c) 3m above final cover surface
	Passive vent diameter	160	mm	Landfill Gas Management Plan, Figure 1 (AECOM 2018c)
	Decomposition of Waste Emissions	252,000	m^3/year	Landfill Gas Management Plan (AECOM 2018c) Based on parameters of Lo = 19 m3/Mg and k = 0.0051 1/year Assumed 50% methane and 50% carbon dioxide by volume
	Odour concentration	10,000	OU/m^3	Based on the 'upper range' estimate of odour concentration from the MECP's Interim Guide to Estimate and Assess Landfill Air Impacts
	Surface area of daily tipping face	50	m^2	Estimated based on similar facilities
	Daily waste receipt	81	tonnes/day	Estimated based on ECM designed for 525,000 m^3 waste volume over a 25 year period which yields 21,000 m^3 of waste per year. Assuming the facility operates 5 days/week, 52 weeks/year, the volume of waste transferred to the facility is 81 m3/day or 81 tonnes/day assuming a density of 1 tonne/m^3.
	Depth of daily cover applied	0.15	m	Waste Placement and Compaction Plan (AECOM 2018d) 150 mm-thick soil layer
	Density of daily cover	0.80	tonnes/m3	Estimated based on similar facilities
	Non-road equipment data	See Equipment List	—	List provided by CNL (Request for Information #143)
	Equipment Tier	Tier 2	—	Assumed that all equipment will comply with U.S. EPA Tier 2 emissions standards at a minimum, since Tier 2 standards were completed phased-in by 2006, and more stringent Tier 4 emissions standards now apply for new equipment
	Hours of operation for each non-road equipment	Daytime only	—	Assumed 7:00 - 19:00 for construction and operation phases
Unpaved Roads	Silt content	6.4	%	U.S. EPA AP-42 Section 13.2.2, mean silt loading for municipal solid waste landfills
	Dust Control Efficiency	85%	%	Assumed based on combination of mitigation controls (i.e., application of water, speed limit) identified in Dust Management Plan (AECOM 2018e) and WRAP Fugitive Dust Handbook (Countess Environmental 2006)
	Natural mitigation	Not included	—	Includes precipitation days for which there is over 25 mm of precipitation
	Average vehicle height	3.50	m	Typical height of waste hauling trucks
	Vehicle Data	See Equipment List	—	List provided by CNL (Request for Information #143)
	Vehicle weights	Various	—	Vehicle weights were estimated based similar projects and vehicle websites.
	Road width	6	M	Landfill Development/ Sequencing Plan (AECOM 2018b) with 1 m shoulders
	All roads	Unpaved	—	Assume that all roads within the NSDF Boundary will be granular
Vehicle Exhaust - Road	Vehicle Tier	Tier 2	—	Assumed that all equipment will comply with at a minimum U.S. EPA Tier 2 emissions standards. Tier 2 standards are vehicle emission standards that were phased-in between 2004 and 2009. More stringent standards, Tier 3 standards will replace the Tier 2 standards starting in 2017.

Table 4-5: Air Quality and GHG Emissions Assessment Assumptions List

Activity	Data Sources / Assumptions			
	Parameter	Value	Unit	Source / Assumption
	Annual hours of operations of each vehicle	See Equipment List - Op phase tab	—	Assume each truck remains at the facility for 1 hour while it drops off its waste, 260 days per year
	Load factor	Various	—	The loader factor for road vehicles was conservatively estimated to be 0.9.
Storage Piles	Area	21,650	m^2	Landfill Development/Sequencing Plan (AECOM 2018b)
Wastewater Treatment Plant (WWTP)	Hours of operation	24	hrs/day	Conservative worst case assumption
	Days of operation	365	days/year	Conservative worst case assumption
	Design Flow	11.36	m^3/hr	WWTP Material and Energy Report (AECOM 2018f)
	Odour concentration from WWTP	1000	OU/m^3	Tricking filter, Odor Threshold Emission Factors for Common WWTP Processes (St. Croix Sensory Inc. 2008) based on a similar facility
	Pre-treatment Area stack flow rate	24,780	Cfm	Single Line HVAC Diagrams (AECOM 2016b) Drawing B1551-73000-602-01-ED-D
	Residue Management Area stack flow rate	17,522	Cfm	Single Line HVAC Diagrams (AECOM 2016b) Drawing B1551-73000-601-01-ED-D
	Fuel Type	Natural gas	—	Building Services Summary Report (AECOM 2018g)
	Natural gas equipment thermal heat input	2969	kW	Building Services Summary Report (AECOM 2018g)
Emergency Power Generators	Number of generators	1	—	Emergency power required for the WWTP and lighting along fence line.
	Number of generators tested at one time	1	—	Maintenance testing occurs once a month for 20 minutes.
	Fuel Type	Natural gas	—	Building Services Summary Report (AECOM 2018g)
	Generator thermal heat input	690	kW	Building Services Summary Report (AECOM 2018g)
Natural Gas Heating Equipment	Fuel Type	Natural gas	—	Building Services Summary Report (AECOM 2018g)
	Natural gas equipment total maximum thermal heat input	4287.3	kW	Building Services Summary Report (AECOM 2018g)
Land Clearing	Area	33.45	Ha	Area size extracted from the dispersion modelling software
	Project lifetime	50.00	years	Section 1 of the EIS
	Land type	—	—	Assumed the entire area is forested; Natural Temperate Continental Forest, North America (IPCC 2006)

Notes:

— denotes not applicable.

4.3 Calculations

The emission calculations during the construction and operations phases of the NSDF Project are described in Sections 4.3.1 and 4.3.2. Sample calculations are provided to demonstrate how the emission estimates were developed. The emission rates for the non-radiological indicator compounds are all in units of grams per seconds (g/s), which are required for the dispersion models, with the exception of odour, which is in odour units per second (OU/s), and GHG which are expressed in tonnes per year. The dispersion model assumes the emission rate is constant over an hourly period, which is the smallest time-step within the models used for predictions. The emission rates for GHG emissions are in tonnes of equivalent CO_2e per year, as required under the assessment methods discussed in Section 4.3.2.5.

4.3.1 Indicator Compounds – Emission Calculations

Non-radiological indicator compounds emissions for particulates (SPM, PM_{10}, $PM_{2.5}$), NOx, SO_2, CO, C_3H_4O, H_2S, C_2H_3Cl, odour and metals (Pb and Hg), were calculated for activities described in the NSDF Project description for the construction and operations phases. These included the emissions from the ECM cover and passive vents, material handling at the ECM, vehicles exhaust (non-road and on-road vehicles), fugitive dust from unpaved roads, wind erosion from the stockpile, odour from the WWTP and lead from stationary combustion sources.

The assessment follows scientifically accepted and well documented calculation methods and emission factors, such as AP-42 from the United States Environmental Protection Agency (U.S. EPA 1995) and the MECP ESDM Procedure Document.

4.3.1.1 Engineered Containment Mound Cover and Passive Vents

Potential emissions from the ECM cover and passive vents from the decomposition of the waste within the ECM were estimated using landfill gas generation rates from Landfill Gas Management Plan (AECOM 2018c). The landfill gas generation rates were estimated using the LandGEM model (1991) developed by the U.S. EPA (AECOM 2018c).

The key input parameters for the model are the projected annual tonnages of waste disposed in the landfill footprint, the landfill gas production potential (L_o) and the landfill gas generation factor (k). L_o is a measure of the ultimate methane yield in cubic metres of methane per tonne of waste (m^3/tonne) and k is the methane generation rate constant in year^{-1}. AECOM used a value of L_o of 19 m^3/tonne and a k value of 0.0051 year^{-1}and assumed to comprise of 50% methane and 50% carbon dioxide by volume (AECOM 2018c). The projected annual tonnages of waste were based on a waste capacity of 1,000,000 m^3 and an expected operations period of 50 years.

The resulting theoretical LFG generation rate estimates obtained from the LandGEM model are considered conservative estimates due to the projected waste composition differing from a typical municipal solid waste composition (AECOM 2018c). The maximum landfill gas emission per year from the LandGEM Simulation No. 1 included in the Landfill Gas Management Plan was used in the emission estimates for the indicators compounds, odour, and greenhouse gas emissions. It is assumed the majority of emissions generated from the decomposition of waste will emit via the passive vents with the remaining amount through the ECM cover. However, for conservatism in the modelling assessment, it was assumed that all emissions generated from the decomposition of waste are solely emitted through the ECM cover. This is a conservative assessment as emissions through the passive vents (as point sources) would have better dispersion than through the area source used to represent the ECM cover. Given the limited information about the amount of gas that will be emitted through each individual passive vent, Golder decided to retain the more conservative approach that modeled the emissions through the

ECM cover. Mercury, hydrogen sulphide, and vinyl chloride were calculated from their estimated respective concentrations in the LFG obtained from the U.S. EPA AP-42 Chapter 2.4 (Table 2.4-1) – Draft Version (U.S. EPA 2008).

The following is a sample calculation for the emission rate of carbon monoxide from the ECM cover:

$$\mathrm{ER} = \mathrm{conc.}\frac{\mu\mathrm{g}}{\mathrm{m}^3} \times \mathrm{LFG}\,\frac{\mathrm{m}^3}{\mathrm{yr}} \times \frac{1\ \mathrm{yr}}{365\ \mathrm{days}} \times \frac{1\ \mathrm{day}}{24\ \mathrm{hrs}} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}} \times \frac{1\ \mathrm{g}}{1{,}000{,}000\ \mu\mathrm{g}}$$

Where:

ER .... = emission rate (m^3/s),
conc. .... = concentration of the contaminant in the landfill gas (µg/m^3) obtained from U.S. EPA AP-42 Chapter 2.4
LFG .... = average landfill gas emissions per yr (m^3/yr) (obtained from LandGEM).

$$\mathrm{ER} = 27{,}935\ \frac{\mu\mathrm{g}}{\mathrm{m}^3} \times 252{,}000\,\frac{\mathrm{m}^3}{\mathrm{yr}} \times \frac{1\ \mathrm{yr}}{365\ \mathrm{days}} \times \frac{1\ \mathrm{day}}{24\ \mathrm{hrs}} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}} \times \frac{1\ \mathrm{g}}{1{,}000{,}000\ \mu\mathrm{g}}$$

$$\mathrm{ER} = 2.23\mathrm{E}-4\,\frac{\mathrm{g}}{\mathrm{s}}$$

Emissions from the remaining indicator compounds that are LFG constituents were calculated in the same manner presented above.

4.3.1.2 NSDF Material Handling

Material handling activities are expected to occur during both the construction and operations phase of the NSDF Project. These are characterized during construction by the movement of material during the preparation of the NSDF Project site, including excavation for the ECM. During the operations phase of the NSDF Project the following activities will take place at the ECM: depositing of waste and application of daily cover. Potential emissions from these activities include particulate matter as a result of the disturbance of material during handling. It was assumed that material handling operations will occur throughout the typical operating hours for the NSDF Project during both the construction and operations phases (refer to the Table 5 for hours of operation).

Predictive emission factors for particulate emissions were developed using equations from the U.S. EPA document entitled *Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources* (AP-42), which is published on-line at http://www.epa.gov/ttn/chief/ap42/index.html. Equations documented in AP-42 Section 13.2.4, dated 11/06 were used. The following predictive emissions equation was used in determining the emission factors for material handling:

$$\mathrm{EF} = \mathrm{k} \times 0.0016\ \times \frac{\left(\frac{\mathrm{U}}{2.2}\right)^{1.3}}{\left(\frac{\mathrm{M}}{2}\right)^{1.4}}$$

Where:

EF .... = particulate emission factor (kg/Mg)
k .... = particle size multiplier for particle size range (see Table 6)
U .... = mean wind speed (m/s)
M .... = moisture content of material (percent) (%).

Table 4-6: Particle Size Assumptions Material Transfer

Size Range	k
SPM	0.74
PM_{10}	0.35
$PM_{2.5}$	0.053

Notes:
k = particle size multiplier for particle size range

The following is a sample calculation for the SPM emission factor from the material handling of waste at the NSDF Project during the operations phase. A mean wind speed of 2.93 metres per second (m/s) obtained from the MECP pre-processed meteorological data (2011 to 2015) was used for the calculation. A moisture content of 12% for miscellaneous fill material was used, which was obtained from Table 13.2.4.1 of the U.S. EPA AP-42.

$$\mathrm{EF} = 0.74 \times 0.0016 \times \frac{\left(\frac{2.93}{2.2}\right)^{1.3}}{\left(\frac{12}{2}\right)^{1.4}}$$

$$\mathrm{EF} = 0.0001 \frac{\mathrm{kg}}{\mathrm{Mg}}$$

The following is a sample calculation for the SPM emission rate for a waste handling rate of 81 tonnes/day and application of daily cover of 9 tonnes/day.

$$\mathrm{ER\ waste\ handling} = \frac{0.0001\ \mathrm{kg}}{\mathrm{Mg}} \times \frac{81\ \mathrm{Mg}}{\mathrm{day}} \times \frac{1\ \mathrm{day}}{12\ \mathrm{hr}} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}} \times \frac{1{,}000\ \mathrm{g}}{1\ \mathrm{kg}}$$

$$\mathrm{ER\ waste\ handling} = 2.61\ \mathrm{E} - 04\ \frac{\mathrm{g}}{\mathrm{s}}$$

$$\mathrm{ER\ daily\ cover} = \frac{0.0001\ \mathrm{kg}}{\mathrm{Mg}} \times \frac{9\ \mathrm{Mg}}{\mathrm{day}} \times \frac{1\ \mathrm{day}}{12\ \mathrm{hr}} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}} \times \frac{1{,}000\ \mathrm{g}}{1\ \mathrm{kg}}$$

$$\mathrm{ER\ daily\ cover} = 3.03\ \mathrm{E} - 05\ \frac{\mathrm{g}}{\mathrm{s}}$$

The emission rates of PM_{10} and $PM_{2.5}$ were calculated as presented above. The emission rates from the construction phase were calculated as presented above, assuming the quantity of fill excavated per day is equivalent to the daily waste receipt rate and no application of daily cover.

4.3.1.3 Non-Road Vehicles – Exhaust Emissions

Crank case emission factors and load factors for non-road Engine Modelling (Compression Ignition) – U.S. EPA 009d (July 2010, U.S. EPA 2010a) (Crank case document) were used to calculate the exhaust (tailpipe) emissions from on-Site vehicles during construction and operations phases. A load factor of 1.0 was assumed for equipment that did not have an explicitly defined a load factor or a representative load factor to use in the pieces of equipment identified in the Crank case document. For conservatism, it was assumed that all on-Site vehicles comply with Tier 2 emission standards.

The following predictive emissions equation was used to calculate the combustion emission rates for on-Site vehicles:

$$\mathrm{ER} = \mathrm{EF} \times \text{engine horsepower rating} \times \text{load factor} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}}$$

Where:

ER = ... emission rate (g/s)
EF = ... emission factor (g/hp-hr).

The following is a sample calculation for the SPM emissions for the compactor to be located at the NSDF Project:

$$\mathrm{ER} = \frac{0.1316\ \mathrm{g}}{\mathrm{hp} - \mathrm{hr}} \times 565\ \mathrm{hp} \times 1.00 \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}}$$

$$\mathrm{ER} = 2.07\mathrm{E} - 02\ \mathrm{g/s}$$

The emissions rates for SPM, PM_{10} and $PM_{2.5}$, NOx, SO_2, and CO were calculated using the same equation. The emission rate for C_3H_4O was calculated by first converting the hydrocarbon emission factor from the Crank case document to an emission factor for total volatile organic compounds (VOCs) (U.S. EPA 2010b) and then by applying the estimated percent weight of acrolein to the VOC emission factor (University of California 2004).
The emission rates for non-road vehicles were calculated for both the NSDF Project construction and operations phases based on the type and number of equipment present (e.g., dozers, excavators, and trucks). Emission calculations for both phases assume all equipment is operating at the same time and all are located at the NSDF Project. The emissions calculated were then modelled at the locations where they are anticipated to occur (i.e., on cell 1 for the construction of the NSDF Project and over the entire surface area during the operations phase). Additional information on the modelling sources is provided in Section 5.

4.3.1.4 On-Road Vehicles – Exhaust Emissions

Emission factors for the vehicle exhaust for on-road vehicles for the construction and operations phases were obtained using the U.S. EPA's mobile source emission factor model MOBILE6.2. The Canadian version of MOBILE 6.2, which integrates the Canadian climate and fuel compositions emission model, was used for this assessment (MOBILE6.2C, Version 6.2.3).

The following inputs to MOBILE6.2C were created by following the Ministry of Transportation's *Environmental Guide for Assessing and Mitigating the Air Quality Impacts and Greenhouse Gas Emissions of Provincial Transportation Projects* (MTO 2012).

- The month of evaluation was July which is the preferred month by the MTO.
- The diurnal patterns in temperature were derived using the measured data (2011 to 2015) from the CNL on-site station (see Section 2 for more details on the meteorology assessment).
- The diurnal patterns in relative humidity were derived using measured data (2011 – 2015) from the MECP dispersion meteorology dataset (see Section 2 for more details on the meteorology assessment).
- The vehicle characteristics parameters including the vehicle miles travel (VMT) fraction, age distribution, annual mileage accumulation rates, and diesel fractions for the 16 vehicle classes, were based on the default input data built into the MOBILE6.2C.
- Ontario's drive clean program requires the diesel sulphur content of 15 parts per million (ppm) which was used. The emission reductions due to Ontario's Emissions Inspection and Maintenance (I/M) Program have not been considered as a conservative approach.
- Local was used as the road type and the speed of 20 kilometres per hour (km/hr) were used.
- Fuel composition and properties was representative of Ontario.

The main inputs to the MOBILE 6.2C for this assessment are summarized in Table 4-7.

Table 4-7: MOBILE 6.2C Inputs

External Conditions	Input
Calendar year of evaluation	2020
Month	July
Altitude	Low
Temperature	Hourly temperature at the CNL on-site station
Humidity	Hourly relative humidity from the MECP meteorological dataset
Pressure	29.5 in Hg based on the annual average pressure from the MECP meteorological dataset
Fuel Options	
RVP (PSI)	8.9 psi
Diesel sulphur content	15 ppm (Ontario Drive Clean)
Gasoline sulphur content	25 ppm
Air Toxics	
Gasoline aromatics (%)	28.4
Gasoline olefin (%)	10.3
Gasoline benzene (%)	0.8
Vapor percentage of gasoline at 200 F (%)	47.3
Vapor percentage of gasoline at 300 F (%)	83.3
Oxygenate volume% of Ethanol or Ethyl Alcohol (Ethanol)	10% volume and 20% market share
Vehicle Fleet Characteristic	
Distribution of Vehicle Registrations	default
Diesel fractions	default
Annual mileage accumulation rates	default
Vehicle Miles Travelled (VMT) fraction	default
Natural gas vehicles (NGVs) fraction	default
Alternate emission factors for NGVs	default
Activity Commands	
Fractions of Vehicle Miles Traveled (VMT)	default
VMT by facility, hour and speed	default
Starts per day	default
Distribution of vehicle starts during the day	default
Soak distribution	default
hot soak activity	default
Diurnal soak activity	default
Weekday trip length distribution	default
Weekend trip length distribution	default
Use weekend vehicle activity	default
Facility type	Local

Notes:

psi = Pounds per Square Inch; RVP = Reid Vapour Pressure; ppm = parts per million; % = percent; F = Degrees Fahrenheit.

The emission factors developed for the trucks are provided in Table 4-8. These emission factors were converted from VMT to vehicle kilometres travelled (VKT) and used for estimating emissions from on-road vehicles in both the construction and operations phases.

Table 4-8: Emission Factors for Fleet Trucks Calculated Using MOBILE6

Compound	Emission Factor (g/VKT)
SPM	4.25E-02
PM_{10}	4.25E-02
$PM_{2.5}$	2.45E-02
NO_X	1.09E+00
SO_2	8.14E-03
CO	5.89E-01
Total VOC*	3.09E-01

Notes:
g/VKT = grams per vehicle kilometres travelled

C_3H_4O emissions were estimated using the total VOC emission factor from MOBILE6 and by applying a 0.059% factor based on the document "Chemical Composition of Vehicle-Related Volatile Organic Compound Emissions in Central California" (University of California 2004).

The following equation was used to calculate the vehicle kilometres travelled per hour (VKT/hr):

$$\frac{VKT}{hr} = \frac{\#\ of\ Trucks}{Hour} \times Road\ Length\ Travelled\ (km)$$

The following is a sample calculation for VKT/hr on one segment (UP1) of the unpaved roads:

$$\frac{VKT}{hr} = \frac{6\ Trucks}{Hour} \times 0.251\ km$$

VKT/hr = 1.51

Each of the road segments UP1 to UP7 were calculated using the equation above. The road segments for the construction and operation phases are presented in Section 5, Figures 5-5 and 5-6, respectively. The length of the segments were estimated based on the Landfill Development/Sequencing Plan (AECOM 2018b). The value of 85.69 VKT/hr represents total vehicle kilometres travelled per hour on all road segments during the construction phase and the value of 12.75 VKT/hr represents total vehicle kilometres travelled per hour on all segments during the operations phase. The value for roads operations phase is used in the sample calculation for suspended particulate matter (SPM).

The following predictive emissions equation was used to calculate the tailpipe emission rates for on-site vehicles travelling on roads:

$$\mathrm{ER} = \mathrm{EF} \times \mathrm{VKT} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}}$$

Where:

ER = ... emission rate (g/s)
EF = ... emission factor (g/VKT)
VKT = ... 12.75 VKT (calculated VKT for all road segments).

The following is a sample calculation for SPM emissions for on-site vehicles tailpipe emissions on road segments during the operations phase.

$$E\mathrm{R} = \frac{0.0425\ \mathrm{g}}{\mathrm{VKT}} \times \frac{12.75\ \mathrm{VKT}}{\mathrm{hr}} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}}$$

$$\mathrm{ER} = 1.50\mathrm{E} - 04\ \mathrm{g/s}$$

Suspended particulate matter, PM_{10} and $PM_{2.5}$, SO_2, CO, and C_3H_4O were calculated using the same equation.

4.3.1.5 On-Road Vehicles – Unpaved Road Dust

The predictive equation in U.S. EPA AP-42 Chapter 13.2.2 – Unpaved Roads (November 2006) was used to calculate the fugitive dust emissions from unpaved roadways. The equation accounts for a control efficiency for the implementation of dust control measures. The equation is as follows:

$$\mathrm{EF} = \left(\mathrm{k}\left(\frac{\mathrm{s}}{12}\right)^{\mathrm{a}} \times \left(\frac{\mathrm{W}}{3}\right)^{\mathrm{b}} \times 281.9\right)(1 - \text{control efficiency})$$

Where:

EF .... = particulate emission factor (g/VKT)
k .... = empirical constant for particle size range (pounds (lbs) per vehicle mile travelled (VMT)) (see Table 9)
s .... = road surface silt content (%) assumed to be 6.4% (as per U.S. EPA AP-42 Section 13.2.2 for Municipal Solid Waste [MSW] landfills)
W .... = average weight (tons) of the vehicles traveling the road,
a .... = empirical constant for particle size range (dimensionless) (see Table 9)
b .... = empirical constant for particle size range (dimensionless) (see Table 9)
281.9 .... = conversion from pounds per vehicle miles travelled to grams per vehicle kilometres travelled
control efficiency ... = reduction of fugitive dust emissions of 85% due to implementation of a water truck and on-site speed limit.

Particle size assumptions for unpaved road dust are provided in Table 4-9.

Table 4-9: Particle Size Assumptions for Unpaved Road Dust

Size Range	k (lb/VMT)	a	b
SPM	4.9	0.7	0.45
PM_{10}	1.5	0.9	0.45
$PM_{2.5}$	0.15	0.9	0.45

Notes:

lb/VMT = pounds per vehicle miles travelled.

The following is a sample calculation for SPM for the emission factor for vehicles that will travel along unpaved segment 1 (UP1), along the perimeter of the NSDF Project to the vehicle decontamination facility. It was estimated that the fleet vehicles will have an average weight of 28.5 tons. A control efficiency of 85% was selected to represent the implementation of the Dust Management Plan (DMP) for the NSDF Project, which will include road watering and a speed limit.

$$\mathrm{EF} = \left(4.9\left(\frac{6.4}{12}\right)^{0.7} \times \left(\frac{28.5}{3}\right)^{0.45} \times 281.9\right)(1 - 85\%)$$

$$\mathrm{EF} = 367.4\ \mathrm{g/VKT}$$

The following is a sample calculation for the SPM emission rate for vehicles travelling along the same unpaved road segment:

$$\mathrm{ER} = \frac{367.4\ \mathrm{g}}{\mathrm{VKT}} \times \frac{1.51\ \mathrm{VKT}}{\mathrm{hr}} \times \frac{1\ \mathrm{hr}}{3600\ \mathrm{s}}$$

$$\mathrm{ER} = 1.54\mathrm{E} - 01\ \mathrm{g/s}$$

The emission rates of PM_{10} and $PM_{2.5}$ were calculated as presented above.

4.3.1.6 Stockpiles Fugitive Dust

The U.S. EPA AP-42 emission factors from U.S. EPA Control of Open Fugitive Dust Source (EPA-45/3-88-008), September 1988, Page 4-17 were used to calculate the fugitive dust emissions associated with the stockpile. The following predictive emissions equation was used in determining the emission factors for material handling:

$$\mathrm{EF} = 1.9 \times \left(\frac{\mathrm{s}}{1.5}\right) \times \left(\frac{\mathrm{f}}{15}\right) \times scaling\ factor \times (1 - control\ efficiency)$$

Where:

EF .... = particulate emission factor (kg/ha/day),
s .... = silt loading (%)
f .... = percent of time the wind speed is greater than 5.4 m/s (%),
Scaling factor .... = a scaling factor for particulate (see Table 4-10), and
Control efficiency .. = reduction of fugitive dust emissions due to implementation of a BMP (best management practice) for fugitive dust.

Table 4-10: Scaling Factor

Size Range	k
SPM	1
PM_{10}	0.5
$PM_{2.5}$	0.075

Notes:
k = particle size multiplier for particle size range.

The percent of time the wind speed is greater than 5.4 m/s was obtained from the MECP pre-processed meteorological data (2011 to 2015) used for the dispersion modelling assessment. Refer to Section 5 for further detail on the dispersion meteorological data.

The following is a sample calculation for the SPM emission factor for emissions that will occur from the soil stockpile. The silt content for clay/dirt mix of 9.2% from Table 13.2.4-1 of the U.S. EPA AP-42 Section 13.2.4 was conservatively used for soil.

$$\mathrm{EF} = 1.9 \times \left(\frac{9.2}{1.5}\right) \times \left(\frac{7.5}{15}\right) \times 1$$
$$\mathrm{EF} = 5.845\ \frac{kg}{\mathrm{ha-day}}$$

The silt content for cover of 9.0% from Table 13.2.4-1 in the U.S. EPA AP-42 Section 13.2.4 was used for the fill stockpile.

The following is a sample calculation for the SPM emission rate for the fill stockpile. A control efficiency of 75% was selected to represent the implementation of a fugitive dust DMP.

$$\mathrm{ER} = \mathrm{EF} \times \mathrm{A} \times \frac{1\ \mathrm{ha}}{10{,}000\ \mathrm{m}^2} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}} \times \frac{1{,}000\ \mathrm{g}}{1\ \mathrm{kg}} \times \frac{1\ \mathrm{day}}{24\ \mathrm{hr}}\ \mathrm{x}\ (1 - \mathrm{control\ efficiency})$$

Where:

EF .... = particulate emission factor (kg/ha/day)
A .... = Exposed area (m^2)
Control efficiency =reduction of fugitive dust emissions due to implementation of a DMP for fugitive dust

$$\mathrm{ER} = 5.718\frac{\mathrm{kg}}{\mathrm{ha-day}}\ \mathrm{x}\ 16{,}000\ \mathrm{m}^2 \times \frac{1\ \mathrm{ha}}{10{,}000\ \mathrm{m}^2} \times \frac{1\ \mathrm{hr}}{3{,}600\ \mathrm{s}} \times \frac{1{,}000\ \mathrm{g}}{1\ \mathrm{kg}} \times \frac{1\ \mathrm{day}}{24\ \mathrm{hr}} \times (1 - 75\%)$$

$$\mathrm{ER} = 2.65\mathrm{E} - 02\ \mathrm{g/\ s}$$

The emission rates of PM_{10} and $PM_{2.5}$ were calculated as presented above.

4.3.1.7 General Stationary Combustion

The NSDF Project includes four buildings that will be heating by natural gas: the WWTP, the vehicle decontamination facility, the administration office, and the operations support centre. In addition to heating requirements, the WWTP will require natural gas for the treatment process.

Annual natural gas consumption for the WWTP and the other support buildings was obtained from the 100% Energy Model Analysis (AECOM 2017). The natural gas consumption for each individual support building (i.e., the vehicle decontamination facility, administration office, and operations support centre) was scaled based on the maximum thermal input provided in the Building Services and Summary Report (AECOM 2018g).

All emission factors, with the exception of SPM, were obtained from U.S. EPA AP-42 Section 1.4 - Natural Gas Combustion (9/98) from uncontrolled small boilers (less than 100). As a conservative measure the uncontrolled emission factor was used in estimating the emissions. The SPM emission factor was obtained from the Canadian Energy Partnership for Environmental Innovation (CEPEI) Natural Gas Combustion Emissions Calculator. The emission factors in lb/ 10^6 standard cubic feet (scf) were converted to kg/10^6 cubic metres based on a conversion factor of 16 provided in the U.S. EPA AP-42 Section 1.4.

The following is a sample calculation for the wastewater treatment building for the emission rate of NOx:

$$\mathrm{ER} = \text{Annual natural gas consumption}\ \frac{m^3}{\mathrm{yr}} \times \text{ emission factor NOx}\frac{\mathrm{kg}}{10^6 m^3} \times \frac{1\ \mathrm{yr}}{365\ \mathrm{days}} \times \frac{1\ \mathrm{day}}{24\ \mathrm{hrs}} \times \frac{1\ \mathrm{hr}}{3600\ \mathrm{s}} \times \frac{1000\ \mathrm{g}}{1\ \mathrm{kg}}$$

$$\mathrm{ER} = 456{,}841\frac{m^3}{\mathrm{yr}} \times 1{,}600\frac{\mathrm{kg}}{10^6 m^3} \times \frac{1\ \mathrm{yr}}{365\ \mathrm{days}} \times \frac{1\ \mathrm{day}}{24\ \mathrm{hrs}} \times \frac{1\ \mathrm{hr}}{3600\ \mathrm{s}} \times \frac{1000\ \mathrm{g}}{1\ \mathrm{kg}}$$

$$\mathrm{ER} = 2.32\mathrm{E} - 02\frac{g}{s}$$

As identified in Section 4.1.2, emissions from natural gas comfort heating sources occur seasonally (i.e., do not occur at all times during a year) and are minor compared to emissions from the mobile combustion sources, with the exception of Pb emissions.

4.3.1.8 Wastewater Treatment Plant - Odour

Potential odour emissions from the WWTP were estimated based on a conservative detection threshold (i.e., emission factor) of 1000 OU for a trickling filter from the published paper titled 'Odor Threshold Emission Factors for Common WWTP Processes' (St. Croix Sensory Inc. 2008). This represents a WWTP where emissions are collected and emitted through a stack equipped with emission control. Given that the WWTP will be treating primarily contact water from the NSDF, since leachate is produced in relatively low rates (AECOM 2018f), and there is no odour in contact water, the odour threshold was scaled to reflect the estimated breakdown of WWTP influent. The stack flow rate was obtained from the Single Line HVAC Diagrams (AECOM 2016b).

The following is a sample calculation for the emission rate of odour from the Wastewater Treatment Plant pre-treatment area:

$$\mathrm{ER} = \text{odour concentration}\ \frac{\mathrm{OU}}{\mathrm{m}^3} \times \text{ flow rate}\,\frac{\mathrm{m}^3}{s}$$

$$\mathrm{ER} = 18\ \frac{\mathrm{OU}}{\mathrm{m}^3} \times\ 11.69\ \frac{\mathrm{m}^3}{\mathrm{s}}\ \ \mathrm{ER} = 216\ \mathrm{OU/s}$$

4.3.2 GHG – Emission Calculations

The GHG emissions, including carbon dioxide (CO_2), methane (CH_4) and nitrous Oxide (N_2O), were calculated for the ECM cover (decomposition of waste), stationary combustion sources, and mobile equipment (vehicle exhaust). Emissions for the operations phase of the NSDF Project were calculated using the maximum annual landfill gas generation rate estimated using the U.S. EPA LandGEM model (refer to Section 4.3.1.1) and equipment/vehicle information provided by CNL for both the construction and operations phases.

The assessment generally followed the calculation methods in the Ontario MECP Publication entitled *Guideline for Quantification, Reporting and Verification of Greenhouse Gas Emissions* (MECP 2018), as set out under O. Reg. 390/18 under the Ontario *Environmental Protection Act*, as well as the ISO (International Organization of Standardization) 14064-1 standard entitled *Specification with Guidance at the Organizational Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals* (ISO 2006).

4.3.2.1 Engineered Containment Mound Cover – Operations Phase only

The GHG emissions from the ECM cover were estimated using the LandGEM model developed by the U.S. EPA. LandGEM predicts the maximum CO_2 and CH_4 annual emission rates. The LandGEM model inputs are discussed in Section 4.3.1.1. Additional details on the maximum landfill gas generated is provided in the Radon and Other Landfill Gas Modelling and Evaluation (AECOM 2018a).

The GHG emissions from the ECM cover are based on the maximum annual LFG emissions from LandGEM results and a composition by volume of 50% methane and 50% carbon dioxide. CH_4 density was assumed as 0.656 kilogram per cubic metre (kg/m^3) at 25°C and 101.3 kilopascal (kPa) and CO_2 density was assumed as 1.808 kg/m^3 at 25°C and 101.3 kPa.

The following is a sample calculation for the CH_4 emissions through the ECM cover:

$$E_{CH_4} = \mathrm{CH_4\ LFG\ emissions}\ \left(\frac{m^3}{yr}\right) \times \mathrm{density}\,\frac{\mathrm{kg}}{\mathrm{m^3}} \times \frac{\mathrm{1\ tonnes}}{\mathrm{1000kg}}$$

$$E_{CH_4} = 126{,}000\,\frac{m^3}{yr} \times 0.656\,\frac{\mathrm{kg}}{\mathrm{m^3}} \times \frac{\mathrm{1\ tonnes}}{\mathrm{1000kg}}$$

$$E_{CH_4} = 82.66\ \frac{\mathrm{tonnes}}{\mathrm{yr}}$$

Carbon dioxide emissions were calculated in the same manner as presented above. There are no nitrous oxide emissions emitted from the decomposition of waste emitted from the cover.

4.3.2.2 On-Road and Non-Road Equipment (Mobile Equipment) – Operations and Construction Phase

The GHG emissions from mobile equipment from the NSDF Project were calculated based on fuel consumption and fuel-specific emission factors on an energy basis as presented in Appendix 19 of the O. Reg. 390/18 Guideline for calculating CO_2, CH_4 and N_2O emissions. For the purposes of this assessment, Calculation Methodology 2 (Equations 280-2 and 280-5) from the O. Reg. 390/18 Guideline was used. This method is based on equipment rating, load factor, and the default fuel specific emission factor (kilogram per gigajoule [kg/GJ] or gram per gigajoule [g/GJ]) from Table 20-2, Table 20-3, and Table 20-4 of ON.20 (General Stationary Combustion).

The equations below present the methods for calculating CO_2, CH_4 and N_2O emissions from mobile equipment:

Total CO_2 emissions from mobile equipment:

$$E_{CO_2} = \mathrm{h_{i,k}} \times \mathrm{h_{pi,k}} \times \mathrm{LF_{i,k}} \times \mathrm{BSFC_{i,k}} \times \mathrm{EF_{i,CO2}}$$

Where:

- E_{CO2} .... = Annual CO_2 emissions from combustion of fuel in mobile equipment sources (tonnes CO_2)
- $h_{i,k}$ .... = total annual hours of operation for the mobile equipment sources (hr)
- $h_{pi,k}$ .... = rated equipment horsepower for mobile equipment (hp)
- $LF_{i,k}$ .... = load factor for mobile equipment, between 0 and 1
- $BSFC_{i,k}$ .... = brake-specific fuel consumption for mobile equipment (L/hp-hr)
- EF .... = Fuel-specific default CO_2 emission factor, from section ON.20 (tonnes CO_2/L)

Total CH_4 and N_2O emissions from mobile equipment operation:

$$E_{CH_4/N_2O} = h_{i,k} \times h_{pi,k} \times LF_{i,k} \times BSFC_{i,k} \times EF_{i,g} \times 0.000001$$

Where:

$E_{CH4/N2O}$ .... = Annual CH_4 or N_2O emissions from combustion of fuel in mobile equipment sources (tonnes CH_4 or N_2O)
$h_{i,k}$ .... = total annual hours of operation for the mobile equipment sources (hr)
$h_{pi,k}$ .... = rated equipment horsepower for mobile equipment (hp)
$LF_{i,k}$ .... = load factor for mobile equipment, between 0 and 1
$BSFC_{i,k}$ .... = brake-specific fuel consumption for mobile equipment (L/hp-hr)
$EF_{i,g}$ .... = Fuel-specific default CH_4 or N_2O emission factor, from section ON.20 (g/L)
0.000001 = Conversion factor from g to tonnes

It was assumed that all mobile equipment is fueled by diesel. The annual fuel consumption for each vehicle type was calculated based on an assumed vehicle horsepower, brake specific fuel consumption and load factors from the Crank case document (U.S. EPA 2010a).

The following is a sample calculation for the emission rate of CO_2 from the compactor:

$$E_{CO_2} = \left(h_{i,k} \times h_{pi,k} \times LF_{i,k} \times BSFC_{i,k}\right) \times EF_{i,CO2} \times \#\ \text{of equipment}$$

$$E_{CO_2} = (3{,}120\frac{hr}{yr} \times 565\ hp\ \times 1.0 \times 0.367\frac{lb}{hp - hr} \times 0.45359\frac{kg}{lb} \times \frac{1\ L}{0.845\ kg}) \times 2663\frac{g}{L} \times \frac{1\ tonne}{1{,}000{,}000g} \times 1\ compactor$$

$$E_{CO_2} = (347{,}277\frac{L}{year}) \times 2663\frac{g}{L} \times \frac{1\ tonne}{1{,}000{,}000g} \times 1\ compactor$$

$$E_{CO_2} = 925\frac{tonnes\ CO_2}{year}$$

4.3.2.3 General Stationary Combustion – Operations Phase Only

Stationary combustion sources for the NSDF Project includes natural gas used in the WWTP process and for comfort heating. Stationary combustion methods from Appendix 10 of the O. Reg. 390/18 Guideline have been used to calculate the GHG emissions from the construction and operations phases.

For the purposes of this assessment, Calculation Methodology 1 (Equation 20-1) and Calculation Methodology 5 (Equation 2010) from the O. Reg. 390/18- Guideline were used. This method is based on fuel consumption, default high heat values (HHV), and the default fuel specific emission factors (kg/GJ or g/GJ) from Table 20-2, Table 20-3, and Table 20-4.

The equations below present the method for calculating CO_2, CH_4 and N_2O emissions from general stationary combustion:

Total CO_2 emissions from stationary fuel combustion:

$$E_{CO_2} = \text{Fuel} \times \text{HHV} \times \text{EF} \times 0.001$$

Where:

E_{CO2} .... = Annual CO_2 emissions from combustion of fuel in stationary sources (tonnes CO_2)
Fuel .... = Volume of the fuel combusted in the calendar year (m^3)
HHV .... = Default high heat value of the fuel from Table 20-1 or 20-1a (GJ/m^3)
EF .... = Fuel-specific default CO_2 emission factor, from Tables 20-2 and 20-3 of ON.20 (General Stationary Combustion) (kg/GJ)
0.001 = Conversion factor from kilograms (kg) to tonnes

Total CH_4 and N_2O emissions from stationary fuel combustion:

$$\mathrm{E}_{\mathrm{CH_4/N_2O}} = \text{Fuel} \times \text{HHV} \times \text{EF} \times 0.000001$$

Where:

$E_{CH4/N2O}$ .... = Annual CH_4 or N_2O emissions from combustion of fuel in stationary sources (tonnes CH_4 or N_2O)
Fuel .... = Volume of the fuel combusted in the calendar year (m^3)
HHV .... = Default high heat value of the fuel from Table 20-1 or 20-1a (GJ/m^3)
EF .... = Fuel-specific default CH_4 or N_2O emission factor, from Tables 20-2 and 20-4 of ON.20 (General Stationary Combustion) (g/GJ)
0.000001 = Conversion factor from g to tonnes

Fuel consumption for the natural gas combustion equipment was based on the Baseline Design presented in the 100% Energy Model Analysis (AECOM 2017).

The following is a sample calculation for the emission rate of CO_2 from the WWTP:

$$E_{CO_2} = \text{Fuel} \times \text{HHV} \times \text{EF} \times 0.001$$

$$E_{CO_2} = 456{,}841 \ \frac{m^3}{yr} \times 0.038 \ \frac{GJ}{m^3} \times 49.03 \ \frac{kg}{GJ} \times 0.001$$

$$E_{CO_2} = 851.16 \frac{\text{tonnes } CO_2}{\text{yr}}$$

4.3.2.4 Land Clearing

Land clearing for the NSDF Project results in GHG emissions. These emissions take into account both the loss of a carbon sink (i.e., the vegetative cover) in future years as well as the one-time loss of carbon stored in the biomass from the cleared area.

One-Time Loss of Carbon Stored in Biomass

CO_2 emissions will also result from a one-time release of carbon currently stored in the biomass after land clearing but are dependent on the disposal method and as this is unknown the emissions have been amortized over the lifetime of the NSDF Project. These emissions are calculated as follows:

$$Ldisturb = A * BW * (1 + R) * CF * fd$$

Where:

A= the total area of forested land (ha);

BW = the average above-ground biomass (tonnes dry matter ha^{-1})

R = the ratio of below to above-ground biomass

CF = the carbon fraction of dry matter (tonnes C tonnes dry $matter^{-1}$)

fd = the fraction of biomass, assumed to be 1.

All required biomass and carbon fraction data was obtained from the IPCC guidelines chapter 4, as shown in Table 4-11.

Table 4-11: Land Disturbance Factors

Parameter	Value used	Reference	Note
BW	95 tonne dm ha-1	IPCC Volume 4 Chapter 4, Table 4.7	Natural Temperate Continental Forest, North America. Assumed to be the average of 60 for forests <20 years old and 130 for forests >20 years old.
R	0.46	IPCC Volume 4 Chapter 4, Table 4.4	Temperate forests, higher value between other broadleaf and conifer forest with <50 tonnes ha-1
CF	0.47	IPCC Volume 4 Chapter 4, Table 4.3	All temperate and boreal forests

$$Ldisturb = 33.45\ ha * 95\ tonnes\ dm\ ha^{-1} * (1 + 0.46) * 0.47 * 1$$

$$Ldisturb = 2{,}181\ tonnes\ C$$

Using the molecular weights, the annual amount of carbon dioxide emitted was calculated.

$$CO_2 = 2{,}181\ tonnes\ C * \frac{44}{12}$$

$$CO_2 = 7{,}995.43\ tonnes\ CO_2$$

The emissions presented as annual emissions over the lifetime of the NSDF Project (50 years):

$$CO_2 = \frac{7{,}995\ tonnes\ CO_2}{50\ years}$$

$$CO_2 = 159.91\ \frac{tonnes\ CO_2}{year}$$

Loss of Carbon Sink Potential

Emissions from the loss of a carbon sink represents the amount of carbon which could have been removed from the atmosphere by the vegetative cover in the area had the land not been cleared, it represents lost carbon removal potential in the years after land clearing. The equation below present the method for calculating the annual increase in biomass carbon stored due to biomass growth ***(C_G)*** (tonne C yr^{-1}). This annual carbon storage is considered a loss for the NSDF Project since this carbon storage will be removed when the land is cleared.

$$C_G = A * GW * (1 + R) * CF$$

Where:

A= the total area of forested land (ha)

GW = the average annual above-ground biomass growth (tonnes dry matter ha^{-1} yr^{-1})

R = the ratio of below to above-ground biomass

CF = the carbon fraction of dry matter (tonnes C tonnes dry $matter^{-1}$)

The total area is of land is the total area that will be cleared for the NSDF Project, which is 33.45 ha. In the interest of conservatism, the entire area is assumed to be temperate forest.

All required biomass and carbon fraction data was obtained from the IPCC guidelines chapter 4, as shown in Table 4-12.

Table 4-12: Biomass Growth Factors

Parameter	Value used	Reference	Note
GW	4 tonne dm ha-1 yr-1	IPCC Volume 4 Chapter 4, Table 4.9	Natural Temperate Continental Forest, North America
R	0.46	IPCC Volume 4 Chapter 4, Table 4.4	Temperate forests, higher value between other broadleaf and conifer forest with <50 tonnes ha-1
CF	0.47	IPCC Volume 4 Chapter 4, Table 4.3	All temperate and boreal forests

$$C_G = 33.45\ ha * 4\ tonnes\ dm\ ha^{-1} yr^{-1} * (1 + 0.46) * 0.47$$

$$C_G = 92\ \frac{tonnes\ C}{year}$$

Using the molecular weight of carbon (12 g/mol) and carbon dioxide (44 g/mol), the annual amount of carbon dioxide that would be stored in the area was calculated.

$$CO_2\ storage\ loss = 92\ \frac{tonnes\ C}{year} * \frac{44}{12}$$

$$CO_2\ storage\ loss = 337\ \frac{tonnes\ CO_2}{year}$$

Therefore the annual amount of carbon dioxide storage that will be lost from clearing the land is 337 tonnes CO_2/year. Since this is a loss of a carbon sink, we are including this as annual emissions of CO_2. These annual emissions are associated with the construction phase of the NSDF Project since the sink is removed during construction.

Therefore the total CO_2 emission rate from this source is:

$$Total\ CO_2 Emissions\ = 337\ \frac{tonnes\ CO_2}{year} + 159.91\ \frac{tonnes\ CO_2}{year}$$

$$Total\ CO_2 Emissions\ = 496.56\ \frac{tonnes\ CO_2}{year}$$

4.3.2.5 Global Warming Potentials

Emissions from CO_2, CH_4 and N_2O were converted to CO_2e. The GHG emissions are expressed as tonnes of equivalent CO_2, by multiplying the annual emissions of each GHG by its 100-year global warming potential (GWP). The GWP of each gas represents the gas's ability to trap heat in the atmosphere in comparison to CO_2. The federal and provincial GWPs that are used to calculate the GHG emissions from the NSDF Project are listed in Table 4-13. Federal GWPs were used to compare against the Canada-wide GHG emissions and provincial GWPs were used to calculate reportable emissions and compare against the Ontario GHG emissions.

Table 4-13: Federal and Provincial Global Warming Potentials

GHG Compound	GHGRP GWP	O. Reg. 390/18 GWP
CO_2	1	1
CH_4	25	21
N_2O	298	310

4.3.2.6 Methods Summary

Table 4-14 presents a summary of the emission's methods and the references for the sources included in this GHG assessment for the NSDF Project.

Table 4-14: GHG Assessment Methodology Summary

NSDF Project Activity[a]	Source	Source Category	Methods
Construction Phase			
Site preparation, construction of the ECM, development of surface water management structures, construction of the WWTP and other support facilities, and on-site road and access development	Mobile Equipment (non-road and road vehicle exhaust emissions)	Mobile Combustion	ON-280 Mobile Equipment Operation
Site Preparation	Land Clearing Loss of Carbon Sink	Site Preparation	IPCC 2006 Vol 4, Chapter 4
Operations Phase			
Operation of the WWTP	Stationary Combustion (WWTP natural gas combustion and natural gas heating)	Stationary Combustion	ON-20 General Stationary Combustion
Staged development of disposal cells, on-site transportation of waste and placement of the waste in the ECM, progressive closure of disposal cells and installation of cover	Mobile Equipment (non-road and road vehicle exhaust emissions)	Mobile Combustion	ON-280 Mobile Equipment Operation
ECM (decomposition of waste)	ECM Cover and Passive Vents	Waste Emissions	Estimated using LandGEM model.
Site Preparation	Loss of Carbon Sink	Site Preparation	IPCC 2006 Vol 4, Chapter 4

Notes:
[a] As described in the pathway analysis of the EIS (Section 5.2.2.5). NSDF = Near Surface Disposal Facility; WWTP = Wastewater Treatment Plant; ECM = engineered containment mound.

4.4 Emission Rates

This section outlines the emission rates to be used in the Air Quality Assessment, in g/s, which were calculated for each activity as described in Section 4.3.

4.4.1 Air Quality Assessment

Table 4-15 and Table 4-16 summarize the emission rates for each activity at the NSDF Project and the percentage that each source contributes to the overall emissions from the NSDF Project during the construction phase. Table 4-17 and Table 4-18 summarize the emission rates for each activity at the NSDF Project and the percentage that each source contributes to the overall emissions from the NSDF Project during the operations phase.

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Table 4-15: Summary of Emission Rates during the Construction Phase

NSDF Project Activity[a]	Source	Source Description	Non-Radiological Indicator Compound Emission Rate (g/s)											
			SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H_2S	C_2H_3Cl	Odour (OU/s)
—	Engineered Containment Mound (ECM)	ECM cap[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		ECM passive vents[c]	—	—	—	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (material handling)	2.61E-04	1.24E-04	1.87E-05	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (vehicle exhaust)	2.86E-01	2.86E-01	2.86E-01	9.21E+00	1.07E-02	1.79E+00	2.43E-04	—	—	—	—	—
All construction activities[b]	Unpaved Roads	Vehicle exhaust and fugitive road dust	9.75E+00	2.63E+00	2.64E-01	2.59E-02	1.94E-04	1.40E-02	4.35E-06	—	—	—	—	—
All construction activities[b]	Storage Piles	Stockpile	3.60E-02	1.80E-02	2.70E-03	—	—	—	—	—	—	—	—	—
—	Wastewater Treatment Plant (WWTP)	Wastewater treatment activities[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		WWTP natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—	Support Activities	Vehicle Decontamination Facility natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		Administration Office natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		Operations Support Centre natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—

Notes:

(a) As described in the air quality pathway analysis of the EIS (Section 5.2.1.5).

(b) Construction activities include site preparation, construction of the ECM, development of the surface water management structures, construction of the WWTP and other support facilities, and on-site road access development.

(c) These sources are not operational while they are constructed resulting in no emissions during the Construction Phase

% = percent; OU/s = Odour Unit per second.

Table 4-16: Summary of Percentage Contributions of Emissions during the Construction Phase

NSDF Project Activity[a]	Source	Source Description	Percentages											
			SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H_2S	C_2H_3Cl	Odour (OU/s)
—	Engineered Containment Mound (ECM)	ECM cap[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		ECM passive vents[c]	—	—	—	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (material handling)	0.003%	0.004%	0.003%	—	—	—	—	—	—	—	—	—
All construction activities[b]		ECM construction (vehicle exhaust)	2.84%	9.75%	51.81%	99.72%	98.22%	99.22%	98.24%	—	—	—	—	—
All construction activities[b]	Unpaved Roads	Vehicle exhaust and fugitive road dust	96.80%	89.63%	47.70%	0.28%	1.78%	0.78%	1.76%	—	—	—	—	—
All construction activities[b]	Storage Piles	Stockpile	0.36%	0.61%	0.49%	—	—	—	—	—	—	—	—	—
—	Wastewater Treatment Plant (WWTP)	Wastewater treatment activities[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		WWTP natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—	Support Activities	Vehicle Decontamination Facility natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		Administration Office natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—
—		Operations Support Centre natural gas combustion[c]	—	—	—	—	—	—	—	—	—	—	—	—

Notes:
(a) As described in the air quality pathway analysis of the EIS (Section 5.2.1.5).
(b) Construction activities include site preparation, construction of the ECM, development of the surface water management structures, construction of the WWTP and other support facilities, and on-site road access development.
(c) These sources are not operational while they are constructed resulting in no emissions during the Construction Phase
% = percent; OU/s = Odour Unit per second.

Table 4-17: Summary of Emission Rates during the Operations Phase

Source Description	Non-Radiological Indicator Compound Emission Rate (g/s)											
	SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H2S	C_2H_3Cl	Odour (OU/s)
ECM cap	—	—	—	—	—	2.23E-05	—	7.99E-10	—	3.56E-05	2.90E-06	7.99E+00
ECM passive vents	—	—	—	—	—	2.01E-04	—	7.19E-09	—	3.21E-04	2.61E-05	7.19E+01
ECM operation (material handling)	2.92E-04	1.38E-04	2.09E-05	—	—	—	—	—	—	—	—	—
ECM operation (vehicle exhaust)	8.33E-02	8.33E-02	8.33E-02	2.62E+00	3.04E-03	5.21E-01	7.28E-05	—[(b)]	—[(b)]	—	—	—
Vehicle exhaust and fugitive road dust	1.27E+00	3.42E-01	3.43E-02	3.85E-03	2.88E-05	2.09E-03	6.46E-07	—[(b)]	—[(b)]	—	—	—
Stockpile	3.60E-02	1.80E-02	2.70E-03	—	—	—	—	—	—	—	—	—
Wastewater treatment activities	—	—	—	—	—	—	—	—	—	—	—	3.69E+02
WWTP natural gas combustion [(c)]	6.95E-05	6.95E-05	6.95E-05	2.32E-02	1.39E-04	1.95E-02	—	—[(d)]	1.16E-07	—	—	—
Vehicle Decontamination Facility natural gas combustion [(c)]	1.25E-05	1.25E-05	1.25E-05	4.16E-03	2.49E-05	3.49E-03	—	—[(d)]	2.08E-08	—	—	—
Administration Office natural gas combustion [(c)]	1.28E-06	1.28E-06	1.28E-06	4.26E-04	2.56E-06	3.58E-04	—	—[(d)]	2.13E-09	—	—	—
Operations Support Centre natural gas combustion [(c)]	4.23E-06	4.23E-06	4.23E-06	1.41E-03	8.46E-06	1.18E-03	—	—[(d)]	7.05E-09	—	—	—

Notes:

(a) As described in the air quality pathway analysis of the EIS (Section 5.2.1.5).

(b) Hg and Pb occur as trace elements from the combustion of diesel fuel and are excluded from the combustion sources emissions.

(c) Contaminants are presented for completeness however they have not been carried through for the dispersion modelling assessment as they were identified as negligible as identified in Table 3 with the exception of Pb.

(d) Hg occurs as trace element from the combustion of natural gas and is excluded from the natural gas combustion sources emissions.

% = percent; OU/s = Odour Unit per second.

Table 4-18: Summary of Percentage Contributions of Emissions during the Operations Phase

Source Description	Percentages											
	SPM	PM_{10}	$PM_{2.5}$	NO_x/NO_2	SO_2	CO	C_3H_4O	Hg	Pb	H2S	C_2H_3Cl	Odour (OU/s)
ECM cap	—	—	—	—	—	0.00%	—	10%	—	10%	10%	1.78%
ECM passive vents	—	—	—	—	—	0.04%	—	90%	—	90%	90%	16.02%
ECM operation (material handling)	0.02%	0.03%	0.02%	—	—	—	—	—	—	—	—	—
ECM operation (vehicle exhaust)	6.00%	18.76%	69.17%	98.75%	93.72%	95.10%	99.12%	—(b)	—(b)	—	—	—
Vehicle exhaust and fugitive road dust	91.37%	77.13%	28.49%	0.15%	0.89%	0.38%	0.88%	—(b)	—(b)	—	—	—
Stockpile	2.60%	4.06%	2.24%	—	—	—	—	—	—	—	—	—
Wastewater treatment activities	—	—	—	—	—	—	—	—	—	—	—	82.20%
WWTP natural gas combustion (c)	0.01%	0.02%	0.06%	0.87%	4.28%	3.56%	—	—(d)	79.45%	—	—	—
Vehicle Decontamination Facility natural gas combustion (c)	0.00%	0.00%	0.01%	0.16%	0.77%	0.64%	—	—(d)	14.25%	—	—	—
Administration Office natural gas combustion (c)	0.00%	0.00%	0.00%	0.02%	0.08%	0.07%	—	—(d)	1.46%	—	—	—
Operations Support Centre natural gas combustion (c)	0.00%	0.00%	0.00%	0.05%	0.26%	0.22%	—	—(d)	4.84%	—	—	—

Notes:

(a) As described in the air quality pathway analysis of the EIS (Section 5.2.1.5).

(b) Hg and Pb occur as trace elements from the combustion of diesel fuel and are excluded from the diesel combustion sources emissions.

(c) Contaminants are presented for completeness however they have not been carried through for the dispersion modelling assessment as they were identified as negligible as identified in Table 3 with the exception of Pb.

(d) Hg occurs as trace element from the combustion of natural gas and is excluded from the natural gas combustion sources emissions.

g/s = grams per second; OU/s = Odour Unit per second.

4.4.2 Greenhouse Gas Assessment

The GHG emissions were estimated for the construction and operations phases of the NSDF Project. For the construction phase, the emissions consist of road and non-road vehicles and equipment. For the operations phase, emissions represent mobile and stationary fuel combustion sources and emissions from the ECM cover. Table 4-19 and Table 4-20 present the emissions from the construction and operations phases, respectively. Tonnes of CO_2e were calculated using the provincial GWPs from the O.Reg. 390/18 Guideline.

Table 4-19: Summary of GHG Emissions during the Construction Phase

NSDF Project Activity[a]	Source	GHG Annual Emissions (tonnes)			tonnes of CO_2e	% NSDF Project
		CO_2	CH_4	N_2O		
Construction of the ECM, development of surface water management structures, construction of the WWTP and other support facilities, and on-site road and access development	Mobile Combustion (road and non-road vehicles)	26,986	1.3	4.1	28,271	98.3%
Site preparation	Land Clearing - Loss of Carbon Stored in Biomass	160	—	—	160	0.6%
Site preparation	Land Clearing - Loss of Carbon Sink Potential	337	—	—	337	1.2%
Total		**27,483**	**1.3**	**4.1**	**28,768**	**100.0%**

Notes:
[a] As described in the GHG pathway analysis of the EIS (Section 5.2.2.5). tonnes = metric tonne; % = percent.

Table 4-20: Summary of GHG Emissions during the Operations Phase

NSDF Project Activity[a]	Source	GHG Annual Emissions (tonnes)			tonnes of CO_2e	% NSDF Project
		CO_2	CH_4	N_2O		
Engineered Containment Mound (ECM) (waste decomposition)	ECM Cover	228	83	—	1,964	21.3%
Operation of the Wastewater Treatment Plant (WWTP)	Stationary Fuel Combustion	1,071	0.02	0.02	1,078	11.7%
Staged development of disposal cells, on-site transportation of waste and placement of the waste in the ECM, progressive closure of disposal cells and installation of cover	Mobile Combustion (road and non-road vehicles)	5,589	0.3	0.8	5,855	63.4%
Operations – Cleared Land	Land Clearing - Loss of Carbon Sink Potential	337	—	—	337	3.6%
Total		7,224	83	0.9	9,232	100.0%

Notes:
[a] As described in the GHG pathway analysis of the EIS (Section 5.2.2.5). tonnes = metric tonne; % = percent.

4.5 Conservatism in Emission Calculations

Table 4-21 outlines the areas where conservatism was assumed in the emission rate calculations for air quality and GHG emissions which results in an assessment that is not likely to under-predict the emissions associated with the NSDF Project.

Table 4-21: Areas of Conservatism in the Emission Rate Calculations

Project Activity	NSDF Project Phase	Conservatism
ECM Cover and Passive Vents (Operations)	Operations	The odour and greenhouse emission rates are based on the maximum waste capacity of 1,000,000 m^3. The gas from the ECM was estimated to comprise of 50% methane and 50% CO_2, which will lead to overestimating the GHG emissions from this source.
ECM Construction and Operations	Construction and Operations	Assumes the ECM that 81 tonnes of material will be handled on a daily basis. Assumes the ECM that 9 tonnes of material will be handled for daily cover on a daily basis during operations. Assumes that all non-road vehicles will be in operations at the same time and at maximum firing rate.
Vehicles Emissions (on-road and non-road)	Construction and Operations	Assumed that all equipment will comply with U.S. EPA Tier 2 emissions standards, Tier 2 standards are currently being phased-out and new equipment is required to comply with Tier 3 emissions standards since 2017
Fugitive Dust from Unpaved Roads	Construction and Operations	See discussion in Section 4.5.1.
Natural gas combustion	Operations	An uncontrolled emission factor for small boilers <100 MMBtu from U.S. EPA AP-42 Section 1.4 was used for the calculations Based on annual natural gas consumption for the Baseline Design (AECOM 2017)
Land Clearing	Construction	Conservatively assumes that the entire area to be cleared is temperate forest which results in the GHG emissions from land clearing.

Notes:

NSDF = Near Surface Disposal Facility; ECM = engineered containment pond; U.S. EPA = United States Environmental Protection Agency; GHG = greenhouse gases; m^3 = cubic metres.

4.5.1 Fugitive Dust from Unpaved Roads

Roadway segments at the NSDF Project were assessed assuming that all on-Site road segments are unpaved and using their respective anticipated traffic. Emission estimation equations from Chapter 13.2.2 of the AP-42 Emission Factor (U.S. EPA 2006) were used to calculate fugitive road dust from unpaved roads. These emission estimates are conservative and will overestimate emissions from facility roadways for the following reasons:

- The U.S. EPA AP-42 equations were developed from measured emissions from public roadways and as a result will tend to over-estimate low speed vehicle traffic from construction and industrial sites.
- All roadways at the NSDF Project were modelled assuming simultaneous and continuous use; however, it is unlikely that this situation will occur in reality.
- As the dust best management practices are revised through continuous improvements, the emissions from the on-Site roadways are likely to decrease.
- Seasonal variability for fugitive dust emissions was not considered in the assessment.

5.0 DISPERSION MODELLING

This section describes the dispersion model and modelling approach used to conduct the non-radiological air dispersion modelling as part of the impacts assessment. More specifically, this section documents the methods, inputs, and assumptions that were used to prepare and complete the dispersion modelling to predict ground-level concentrations of non-radiological indicator compounds and deposition rates resulting from the NSDF Project. The modelling approach follows generally accepted practices for conducting environmental assessments and, where appropriate, follows guidance in the MECP document *Guideline A-11: Air Dispersion Modelling Guideline for Ontario, Version 3.0*, dated July 2016 (ADMGO) PIBS 5165e02 (MECP 2017a).

5.1 Air Dispersion Model

The likely environmental effects for the air quality indicators were evaluated with the aid of the AERMOD dispersion model (Version 16216r) developed by the United States Environmental Protection Agency (U.S. EPA).

The selection of this model was based on the following capabilities:

- has a technical basis that is scientifically sound, and is in keeping with the current understanding of dispersion in the atmosphere;
- applies formulations that are clearly delineated and are subjected to rigorous independent scrutiny;
- makes predictions that are consistent with observations;
- is recognized by federal and provincial regulators as one suitable for use;
- evaluates the various source configurations and indicator compounds associated with the NSDF Project;
- the terrain surrounding the NSDF Project is relatively simple and can be addressed by the terrain features of the model;
- allows for the use of localised meteorological data;

- incorporates building downwash effects; and
- long range transport of compounds is not anticipated.

More specifically, AERMOD is recognized by federal and Ontario regulators as one of the regulatory default dispersion models and is suitable to model construction activities, waste disposal operations, and fugitives. The same model was used for predicting concentrations and deposition rates of non-radiological compounds (those compounds used by other disciplines in assessing the indirect effects of air quality).

AERMOD consists of the model and two pre-processors; the AERMET meteorological pre-processor and the AERMAP terrain pre-processor (Figure 5-1). The following approved dispersion model and pre-processors were used in the assessment:

- AERMOD dispersion model (v. 16216r);
- AERMAP surface pre-processor (v. 11103); and
- Building Profile Input Program (BPIP) building downwash pre-processor (v. 42104).

Building heights are required inputs to assess building downwash using the BPIP pre-processor. However, for conservatism and because most sources in this assessment would not be subject to building downwash, building downwash has not been included in this assessment. AERMET was used by the MECP to prepare a 5-year meteorological dataset for the NSDF Project site. The meteorological dataset incorporated data from the CNL on-site station. Additional information on meteorology is presented in Section 2.

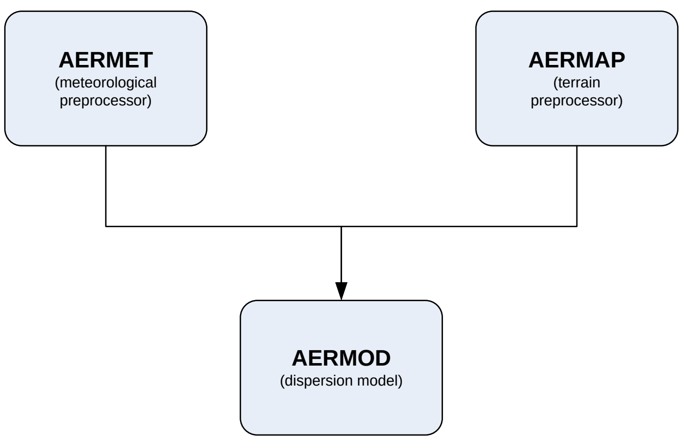


Figure 5-1: AERMOD Model System

5.1.1 Model Development

The AERMOD dispersion modelling system was developed by the U.S. EPA as a replacement to the long-standing Industrial Source Complex (ISC) model, as the model recommended by the U.S. EPA for regulatory applications in the United States. This model has also been adopted in Ontario as the regulatory model recommended for permitting and regulatory applications (MECP 2017a). The model is generally based on Gaussian plume dispersion theory (U.S. EPA 2004), but also incorporates a series of specific algorithms to reflect current understanding of dispersion theory (U.S. EPA 2004).

5.1.2 Model Calibration

Regulatory dispersion models do not readily lend themselves to modification to incorporate site-specific characteristics in the equations themselves. However, the model does require site-specific meteorological data to operate. Digital terrain data for the site and surrounding area are also required inputs to the AERMAP pre-processor and used to characterize how the local topography could affect the dispersion of air contaminants.

5.1.3 Model Validation

Part of the rigorous process used by the U.S. EPA prior to adopting AERMOD as a regulatory model (U.S. EPA 2004) was a significant peer review process to confirm that the model could accurately predict ground-level concentrations when compared to monitoring data (U.S. EPA 2003, 2004).

5.1.4 Model Uncertainty and Sensitivity

Dispersion models employ assumptions that simplify the random processes associated with atmospheric motions and turbulence. While this simplification limits the model's ability to replicate individual events, the strength of the model lies in the ability to predict overall values for a given set of meteorological conditions. The process undertaken by the U.S. EPA ensured that the model predictions can be relied on as reasonable estimate of the likely concentrations. AERMOD is based on known theory, and proven to reliably produce repeatable results. To limit the uncertainty associated with emissions input to the model, conservative assumptions were made where practical (Table 5-1). Finally, five years of meteorological data are used as an input to the model to ensure the full range of possible meteorological conditions is evaluated.

Table 5-1: Reliability Summary for the AERMOD Dispersion Model

Model Name	Developer	Use in Assessment	Development	Calibration	Validation	Uncertainty and Sensitivity
AERMOD (Version 16216r)	United States Environmental Protection Agency	Predict air quality concentrations and deposition	▪ AERMOD was developed to replace the long-standing ISC model as the model recommended by the U.S. EPA. ▪ AERMOD is based on Gaussian plume dispersion theory (U.S. EPA 2004) that has been used for more than 30 years. ▪ The application of specific algorithms has been updated to reflect current understanding of dispersion theory (U.S. EPA 2004).	▪ Site-specific meteorological data were used in the modelling (Section 3.1). ▪ Digital terrain data for the site and surrounding area input to the model (Section 3.2.1).	AERMOD has been adopted by the U.S. EPA as it is preferred and recommended dispersion model (U.S. EPA 2005). Prior to adoption, the U.S. EPA completed a rigorous review of the model performance (U.S. EPA 2003, 2005).	▪ AERMOD is based on known theory, and proven to reliably produce repeatable results. ▪ Uncertainty associated with emissions is managed by making conservative assumptions. ▪ Model predictions are sensitive to fluctuations in the meteorology, which can be managed by using a five-year dataset. ▪ Five years of data should include the full range of possible meteorological conditions.

5.2 Model Inputs

To predict ambient air concentrations with the aid of AERMOD, a series of inputs are required that parameterize the sources of emissions as well as their transport. These inputs can be grouped into categories:

- Dispersion meteorological data.
- Terrain and receptors.
- Building downwash.
- Emissions and source configurations.

Each of these input categories are discussed separately in Sections 5.2.1 to 5.2.3

5.2.1 Dispersion Meteorological Data

The MECP, as well as other agencies, recommends that five years of hourly data be used in the model to cover a wide range of potential meteorological conditions (MECP 2017a). A localized pre-processed meteorological dataset for the NSDF Project was requested directly from the MECP on June 15, 2016 and obtained on July 14, 2016. The dataset was created with the aid of AERMET using meteorological data from the CNL on-site station (CNL 2016a) and from the Petawawa AWOS 2, Pembroke, and Ottawa MacDonald-Cartier International Airport Environment and Climate Change Canada stations (ECCC 2017). Upper air data was used from the Maniwaki, Quebec station. The dataset covers the period of January 2011 to December 2015. Details regarding the dispersion meteorology and the suitability of the MECP pre-processed dataset for modelling the NSDF Project are provided in the EIS Appendix 5.2-1 (Meteorology Assessment).

The wind rose for the MECP meteorological dataset showing the direction as “blowing from” is provided in Figure 5-2.

The meteorological input files used by the AERMOD dispersion model are generated using the AERMET pre-processor, which is designed to be run in three stages:

1) Extracts the data and assesses data quality.
2) Merges the available data for 24-hour periods and writes these data to an intermediate file.
3) Reads the merged data file and develops the necessary boundary layer parameters for dispersion calculations by AERMOD.

The AERMET pre-processor produces two meteorological data files. The first file contains boundary layer scaling parameters (e.g., surface friction velocity, mixing height, and Monin-Obukhov length) as well as wind speeds, wind directions and temperature at a reference-height (i.e., 10 m). The second file contains one or more levels (a profile) of winds, temperature, and the standard deviation of the fluctuating components of the wind. These files are used as inputs to AERMOD.

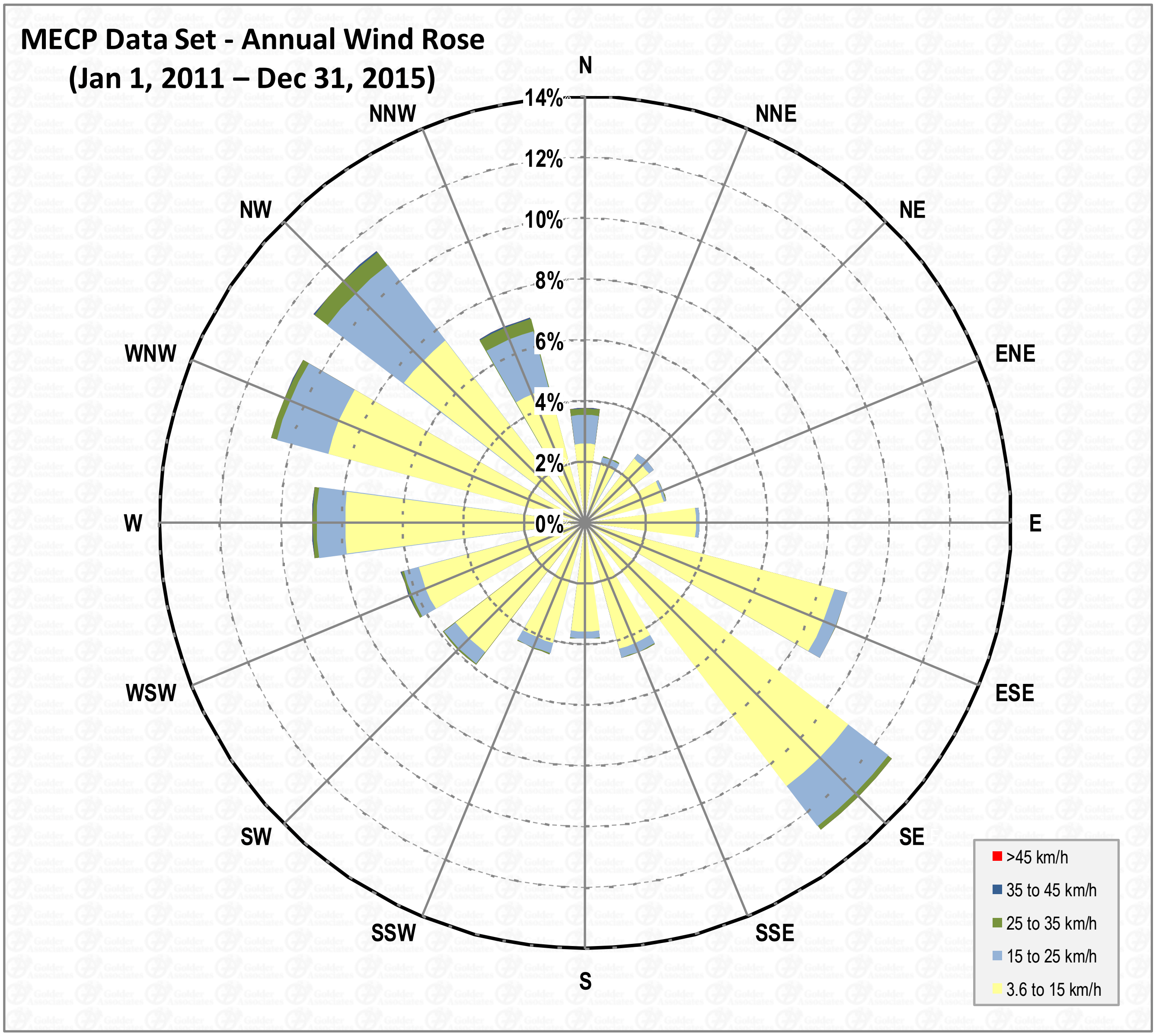


Figure 5-2: MECP Dispersion Meteorology Dataset Wind Rose

5.2.2 Terrain and Modelling Receptors

Terrain elevations have the potential to influence air quality and odour concentrations at individual receptors, therefore surrounding terrain data is required when using regulatory dispersion models in both simple and complex terrain situations (U.S. EPA 2004). Digital terrain data is used in the AERMAP pre-processor to determine the base elevations of receptors, sources and buildings. AERMAP then searches the terrain height and location that has the greatest influence on dispersion for each receptor (U.S. EPA 2004). This is referred to as the hill height scale. The base elevation and hill height scale produced by AERMAP are directly inserted into the AERMOD input file.

5.2.2.1 Digital Terrain Data

Digital terrain data was obtained from the MECP (7.5 minute format) (MECP 2017b). The Digital Elevation Model (DEM) files used in the modelling for the NSDF Project are as follows:

- 1463_3.DEM;
- 1463_4.DEM;
- 1464_3.DEM;
- 1464_4.DEM;
- 1465_3.DEM; and
- 1465_4.DEM.

5.2.2.2 Modelling Domain

The modelling domain was set to be 20 kilometres (km) by 20 km in size to encompass the site, local, regional study areas for the NSDF Project (SSA, LSA, and RSA, see Figure 5-3). This domain is large enough to capture the potential air quality effects of the NSDF Project on the surrounding area.

5.2.2.3 Model Receptors

Two modelling grids were developed to assess the air quality concentration and deposition rates from the NSDF Project.

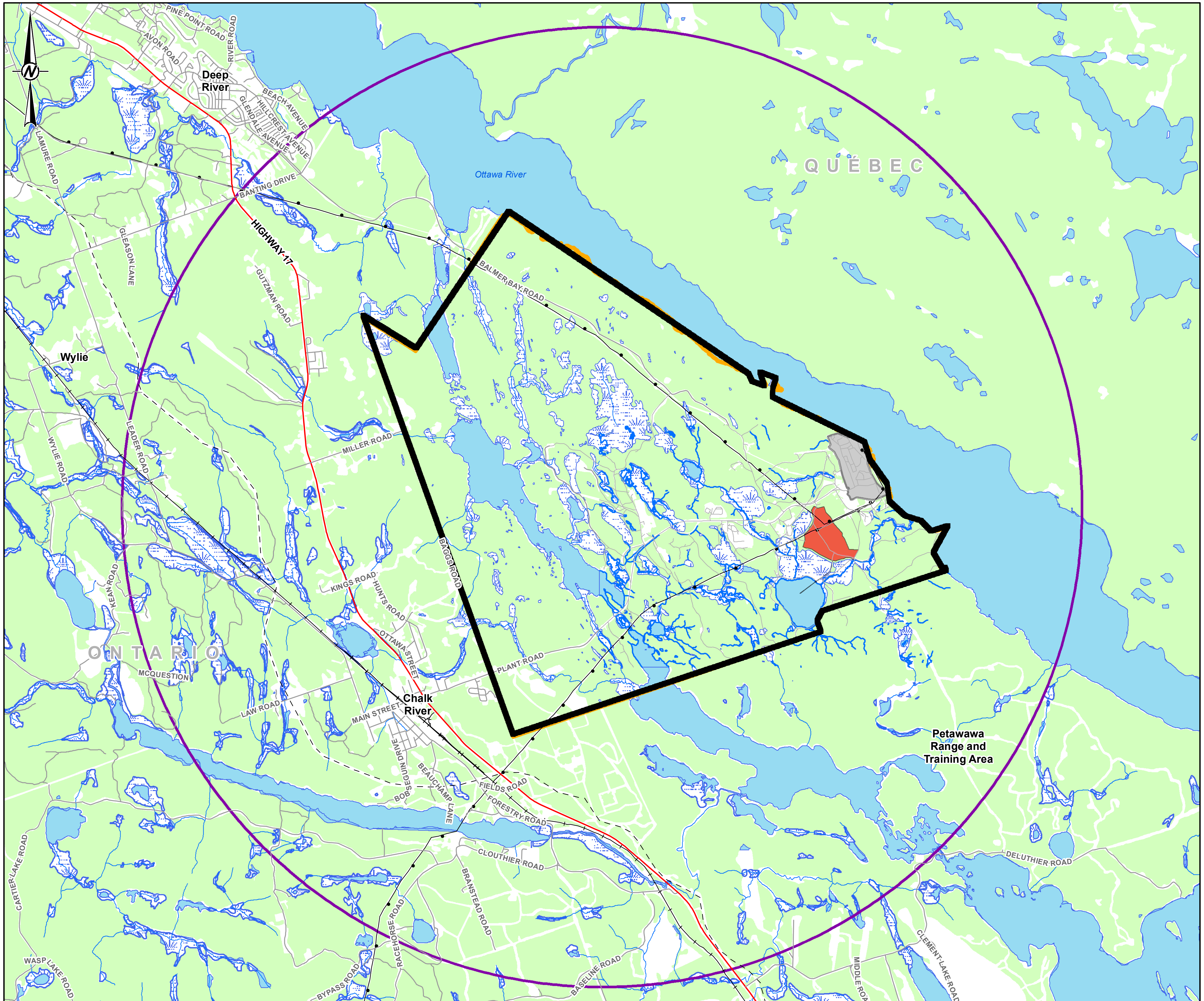
5.2.2.3.1 Air Quality Receptor Grid

Air quality concentrations were predicted at selected groups of receptors which include a grid of receptors covering the entire modelling domain. This grid includes approximately 3,000 receptor locations. The receptor locations were positioned inside the modelling domain with a spacing of 10 metres (m) along the LSA and a uniform polar grid with 36 receptors along the RSA.

This positioning allows for more receptors closer to the emission sources. All receptors within the LSA boundary were removed for the air quality assessment. The air quality receptor grid is illustrated on Figure 5-3.

5.2.2.3.2 Deposition Receptor Grid

A uniform modelling grid shown with spacing of 100 m was placed within the RSA and LSA to capture the maximum deposition rates to be used for the Terrestrial and Aquatics Biodiversity, Socio-Economics and Non-Radiological Risk Assessments components of the Environmental Assessment. All receptors within the SSA boundary were removed for the deposition assessment. The deposition receptor grid for other valued components is illustrated on Figure 5-4.



LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- LSA RECEPTOR
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- LOCAL STUDY AREA (CRL PROPERTY)
- REGIONAL STUDY AREA

2.5 0 2.5

1:60,000 KILOMETRES

REFERENCE(S)

1. BASEMAP:SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND MAY 2017)
3. HIGHWAYS AND FIRST NATION RESERVES MNRF 2016
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

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NEAR SURFACE DISPOSAL FACILITY, AIR QUALITY ASSESSMENT TECHNICAL SUPPORTING DOCUMENT, CHALK RIVER, ONTARIO

TITLE
AIR QUALITY MODELLING RECEPTOR GRID

CONSULTANT

GOLDER

YYYY-MM-DD	NOVEMBER 2020
DESIGNED	SO
PREPARED	SO
REVIEWED	EM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	FINAL 2	5-3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

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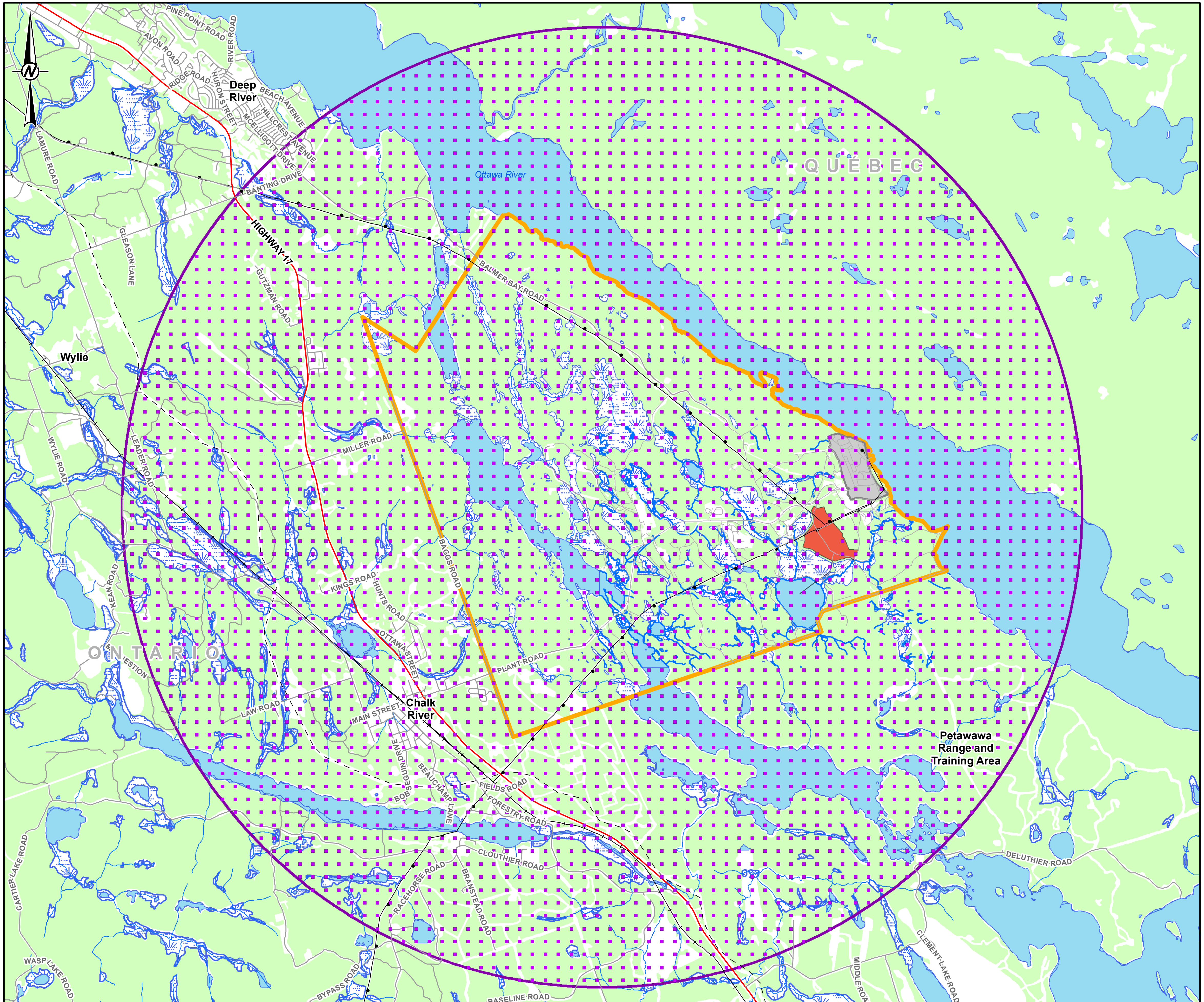

LEGEND

- HIGHWAY
- ROAD
- RAILWAY
- TRANSMISSION LINE
- NATURAL GAS PIPELINE
- RIVER/STREAM
- WATERBODY
- WETLAND
- WOODED AREA
- RSA RECEPTOR
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- LOCAL STUDY AREA (CRL PROPERTY)
- REGIONAL STUDY AREA

2.5 0 2.5

1:60,000 KILOMETRES

REFERENCE(S)

1. BASEMAP:SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND MAY 2017)
3. HIGHWAYS AND FIRST NATION RESERVES MNRF 2016
4 PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT

CANADIAN NUCLEAR LABORATORIES LTD.

PROJECT

NEAR SURFACE DISPOSAL FACILITY, AIR QUALITY ASSESSMENT TECHNICAL SUPPORTING DOCUMENT, CHALK RIVER, ONTARIO

TITLE

MODELLING RECEPTOR GRID FOR VALUED COMPONENTS

CONSULTANT

GOLDER

YYYY-MM-DD	NOVEMBER 2020
DESIGNED	SO
PREPARED	SO
REVIEWED	EM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0001	FINAL 2	5-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

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5.2.3 Building Downwash

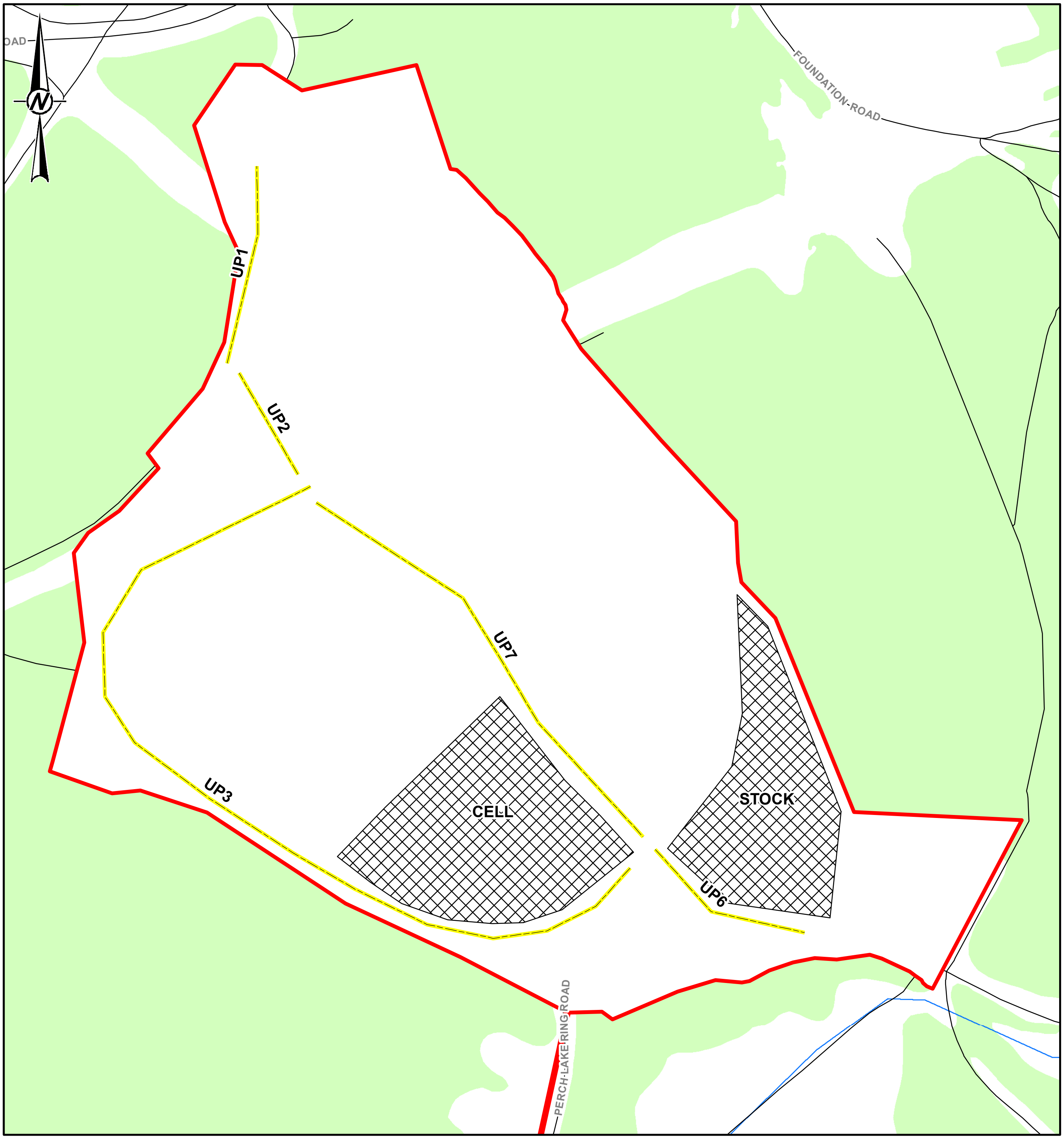
For point sources, AERMOD relies on the PRIME (Plume Rise Model Enhancement) downwash algorithm. The PRIME algorithm is designed to incorporate the two fundamental features associated with building downwash: enhanced plume dispersion coefficients due to the turbulent wake, and reduced plume rise caused by a combination of the descending streamlines in the lee of the building and the increased entrainment in the wake.

Building downwash occurs when the aerodynamic turbulence induced by a nearby building causes a contaminant emitted from an elevated source to be mixed rapidly toward the ground (downwash), resulting in higher ground-level concentrations. As previously mentioned, for this assessment, building downwash was not included in the assessment.

5.2.4 Emissions and Source Configurations

Air emission rates were estimated for the NSDF Project works and activities for which a measurable change from existing conditions is anticipated and may occur. These emission rates were then used as inputs for the dispersion modelling that provided estimates of maximum ground-level concentrations resulting from the NSDF Project emissions. Section 4 provides a detailed description of the methods, inputs, and assumption used to estimate emission rates.

The model source types used in this assessment include: point, area, and volume sources. Figure 5-5 and Figure 5-6 illustrates the model source locations used in this assessment for the construction and operations phases, respectively. In Figure 5-5, the “Cell” area source was chosen as a conservative and representative area for modelling construction activities.



LEGEND
- EXISTING ROAD
- RIVER/STREAM
- LINE VOLUME SOURCE
- AREA SOURCE
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- WOODED AREA

100 0 100
1:5,000 METRES

REFERENCE(S)
1. BASEDATA CNL 2016
2. 2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND MAY 2017)
3 PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, AIR QUALITY ASSESSMENT TECHNICAL SUPPORTING DOCUMENT, CHALK RIVER, ONTARIO

TITLE
CONSTRUCTION PHASE DISPERSION MODELLING PLAN

CONSULTANT
GOLDER

YYYY-MM-DD	NOVMEBER 2020
DESIGNED	SO
PREPARED	SO
REVIEWED	EM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	FINAL 2	5-5

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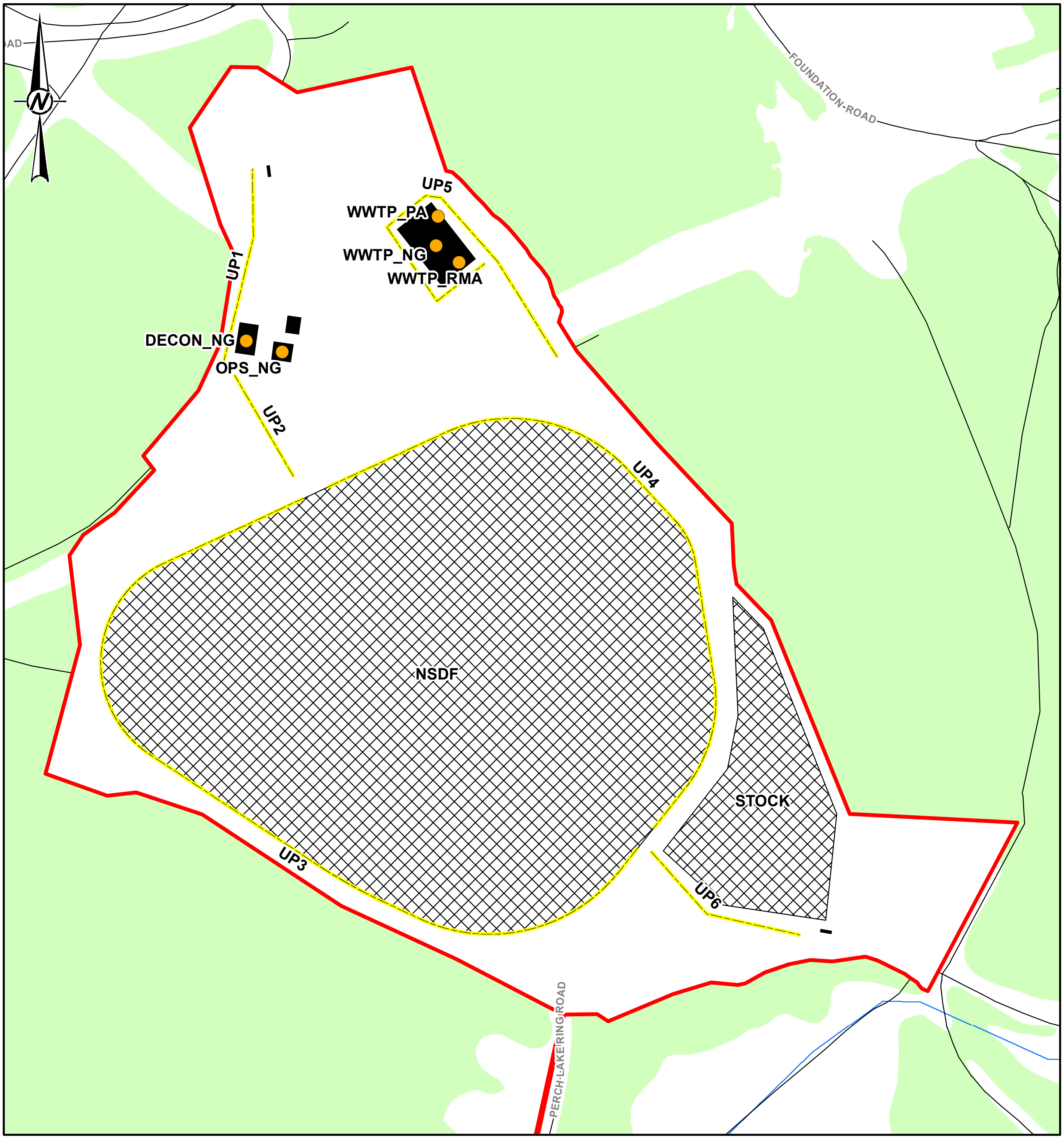
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm



LEGEND

- POINT SOURCE
- EXISTING ROAD
- LINE VOLUME SOURCE
- RIVER/STREAM
- BUILDING
- AREA SOURCE
- SITE STUDY AREA (NSDF PROJECT SITE)
- CRL MAIN CAMPUS
- WOODED AREA

100 0 100

1:5,000 METRES

REFERENCE(S)

1. BASEDATA CNL 2016
2. 2. PROPERTY BOUNDARY AND NSDF LOCATION PROVIDED BY CNL (MAY 2016 AND MAY 2017)
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CANADIAN NUCLEAR LABORATORIES

PROJECT
NEAR SURFACE DISPOSAL FACILITY, AIR QUALITY ASSESSMENT TECHNICAL SUPPORTING DOCUMENT, CHALK RIVER, ONTARIO

TITLE
OPERATION PHASE DISPERSION MODELLING PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	NOVEMBER 2020
DESIGNED	SO
PREPARED	SO
REVIEWED	EM
APPROVED	AB

PROJECT NO.	CONTROL	REV.	FIGURE
1547525	0009	FINAL 2	5-6

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 25mm

5.2.4.1 Point Sources

Point sources are typically stacks or vents. For the NSDF Project, the WWTP pre-treatment area process stack, the WWTP residue management area process stack, and the natural gas combustion equipment at the NSDF buildings were modelled as point sources. Point sources associated with the buildings were only modelled in the operation phase as they are being built during the construction phase.

It should be noted that the eight passive vents on the ECM would typically be modelled as point sources. However, as previously discussed in Section 4(Emissions Estimates), for modelling purposes emissions from the ECM were modeled as being emitted from the ECM cover area source and included the emissions that would be released from the passive vents.

The WWTP pre-treatment and residue management area process source were modelled using stack parameters obtained from the Single Line HVAC Diagrams (AECOM 2016b). The stack exit diameter and temperature were confirmed by CNL through an information request (CNL 2017).

The lead emissions from the natural gas combustion equipment located at the NSDF buildings were modelled as a single point source at each building, with the exception of the administration building, which represents less than 1.5% of total lead emissions and was therefore were not modeled. Rationale for excluding other contaminants from natural gas combustion modelling is provided in Section 4. The location of the natural gas combustion equipment stacks were assumed to be located in the centre of each building. The stack parameters were conservatively estimated based on typical combustion equipment stack parameters and adjusted to be conservative.

The point source model input parameters used in the model are presented in Table 5-2.

Table 5-2: Point Source Summary

Source Description (and ID #)	Stack Height Above Grade (m)	Stack Volumetric Flow Rate (Am^3/s)	Stack Inner Diameter (m)	Stack Exit Gas Temp (°C)	UTM Northing (m)	UTM Easting (m)	Indicator Compound	Emission Rate During Construction (g/s)	Emission Rate During Operation (g/s)
WWTP Pre-Treatment Area (S4) *Operations Phase Only*	16.5	11.69	0.2	20	316649.38	5101827.97	Odour[(a)]	—	2.16E+02
WWTP Residue Management Area (S4) *Operations Phase Only*	16.5	8.27	0.2	20	316668.31	5101786.40	Odour[(a)]	—	1.53E+02
WWTP Natural Gas Combustion (S4) *Operations Phase Only*	14.5	0.0785	1	20	316647.92	5101801.27	Lead	—	1.16E-07
Vehicle Decontamination Facility Natural Gas Combustion (S4) *Operations Phase Only*	8	0.0785	1	20	316480.09	5101717.19	Lead	—	2.08E-08
Operations Support Centre Natural Gas Combustion (S4) *Operations Phase Only*	4.2	0.0785	1	20	316511.75	5101707.35	Lead	—	7.05E-09

Notes:

[(a)] Emission rates are in odour units per second (OU/s). m = metres; am^3/s = actual cubic metre per second; °C = Degrees Celsius; g/s = grams per second.

5.2.4.2 Area Sources

Area sources are used to model low-level or ground releases. In general, area sources result in much higher ground level concentrations than those of volume or point sources. The ECM and stockpiles were modelled as an area source. The emissions from the ECM area source include the non-road vehicle activities (tailpipe exhaust and material transfers), occurring in the ECM and the total emissions generated from the decomposition of waste that would, in reality, be released through both the passive vents and the ECM cover. The area sources parameters used in the model are presented in Table 5-3. The ECM area source release height above grade was estimated to be 50% the height of the ECM, which is considered to be a conservative approach accepted by MECP.

Table 5-3: Area Source Summary

Source Description (and ID #)	Release Height Above Grade (m)	Area (m^2)	UTM Northing (m)	UTM Easting (m)	Indicator Compound	Emission Rate During Construction (g/s)	Emission Rate During Operation (g/s)
Cell (S1) *Construction Phase Only*	4	28,767	316599.05 316700.33 316758.03 316789.05 316818.58 316755.19 316721.15 316693.56 316654.28 316613.29 316585.50 316556.72	5101301.96 5101399.94 5101325.86 5101294.17 5101262.30 5101211.46 5101199.74 5101199.21 5101202.28 5101217.02 5101236.06 5101258.15	CO	1.79E+00	—
					SPM	2.87E-01	—
					PM_{10}	2.87E-01	—
					$PM_{2.5}$	2.86E-01	—
					NO_x	9.21E+00	—
					SO_2	1.07E-02	—
					C_3H_4O	2.43E-04	—
ECM (S1) *Operations Phase Only*	17.45	172,882	Various	Various	CO	—	5.21E-01
					H_2S	—	3.56E-04
					Hg	—	7.99E-09
					C_2H_3Cl	—	2.90E-05
					Odour	—	7.99E+01
					SPM	—	8.36E-02
					PM_{10}	—	8.34E-02
					$PM_{2.5}$	—	8.33E-02
					NO_x	—	2.62E+00
					SO_2	—	3.04E-03
					C_3H_4O	—	7.28E-05

Table 5-3: Area Source Summary

Source Description (and ID #)	Release Height Above Grade (m)	Area (m^2)	UTM Northing (m)	UTM Easting (m)	Indicator Compound	Emission Rate During Construction (g/s)	Emission Rate During Operation (g/s)
Stockpile (S3)	4	21,650	316936.92 316909.84 316914.60 316905.12 316848.40 316901.17 316992.18 317001.66	5101461.98 5101489.85 5101384.85 5101337.96 5101265.50 5101217.42 5101204.05 5101298.01	SPM	3.60E-02	3.60E-02
					PM_{10}	1.80E-02	1.80E-02
					$PM_{2.5}$	2.70E-03	2.70E-03

Notes:

m = metres; m^2 = square metres g/s-m^2 = grams per square metre seconds. CO = carbon monoxide; SPM = suspended particulate matter; PM_{10} = particulate matter less than 10 microns in diameter $PM_{2.5}$ = particulate matter less than 2.5 microns in diameter; SO_2 = sulphur dioxide H_2S = hydrogen sulfide Hg = mercury = C_2H_3Cl = vinyl chloride.

5.2.4.3 Volume Sources

Volume sources are used to model releases from a variety of industrial sources that cannot be classified as a point or area source. The MECP has suggested that roads should be modelled as a series of individual volume sources creating a line that follows the road (MECP 2017a). The roads in the assessment were modelled using this volume source approach. The roads were divided into contiguous volume sources with a release height of 3.5 m which is assumed to be the height of the haul truck (National Stone, Sand and Gravel Association 2004). The roads at the NSDF site are all unpaved and are 6 m wide (AECOM 2018b). The emission rate for the entire road segment was divided amongst the total volume sources for the entire segment. There are six unpaved road segments considered in the operations phase and five unpaved road segment considered in the construction phase.

The volume sources for roads are summarized in Table 5-4.

Table 5-4: Volume Source Summary

Source Description (and ID #)	Release Height Above Grade (m)	Initial Lateral Dimension of Volume[a] (m)	Initial Vertical Dimension of Volume[b] (m)	Indicator Compound	# of Model Sources Comprising Segment	Emission Rate per Model Source During Construction (g/s)	Emission Rate per Model Source During Operation (g/s)
Unpaved Roads (S2) - UP1	3.5	3.66	1.63	SPM	32	5.90E-02	4.80E-03
				PM_{10}		1.59E-02	1.30E-03
				$PM_{2.5}$		1.59E-03	1.30E-04
				NO_x		1.56E-04	1.42E-05
				SO_2		1.17E-06	1.06E-07
				CO		8.47E-05	7.70E-06
				C_3H_4O		2.63E-08	2.39E-09
Unpaved Roads (S2) - UP2	3.5	3.66	1.63	SPM	14	5.71E-02	4.65E-03
				PM_{10}		1.54E-02	1.26E-03
				$PM_{2.5}$		1.55E-03	1.26E-04
				NO_x		1.51E-04	1.38E-05
				SO_2		1.13E-06	1.03E-07
				CO		8.21E-05	7.46E-06
				C_3H_4O		2.54E-08	2.31E-09
Unpaved Roads (S2) - UP3	3.5	3.66	1.63	SPM	108	3.86E-02	3.88E-03
				PM_{10}		1.04E-02	1.05E-03
				$PM_{2.5}$		1.04E-03	1.05E-04
				NO_x		1.01E-04	1.20E-05
				SO_2		7.54E-07	8.97E-08
				CO		5.45E-05	6.49E-06
				C_3H_4O		1.69E-08	2.01E-09

Table 5-4: Volume Source Summary

Source Description (and ID #)	Release Height Above Grade (m)	Initial Lateral Dimension of Volume(a) (m)	Initial Vertical Dimension of Volume(b) (m)	Indicator Compound	# of Model Sources Comprising Segment	Emission Rate per Model Source During Construction (g/s)	Emission Rate per Model Source During Operation (g/s)
Unpaved Roads (S2) - UP4	3.5	3.66	1.63	SPM	89	—	3.84E-03
				PM_{10}		—	1.04E-03
				$PM_{2.5}$		—	1.04E-04
				NO_x		—	1.18E-05
				SO_2		—	8.88E-08
				CO		—	6.43E-06
				C_3H_4O		—	1.99E-09
Unpaved Roads (S2) - UP5	3.5	3.66	1.63	SPM	50	—	2.40E-03
				PM_{10}		—	6.47E-04
				$PM_{2.5}$		—	6.48E-05
				NO_x		—	7.08E-06
				SO_2		—	5.31E-08
				CO		—	3.84E-06
				C_3H_4O		—	1.19E-09
Unpaved Roads (S2) - UP6	3.5	3.66	1.63	SPM	35	4.20E-02	4.81E-03
				PM_{10}		1.13E-02	1.30E-03
				$PM_{2.5}$		1.14E-03	1.30E-04
				NO_x		1.09E-04	1.42E-05
				SO_2		8.17E-07	1.07E-07
				CO		5.91E-05	7.71E-06
				C_3H_4O		1.83E-08	2.39E-09
Unpaved Roads (S2) - UP7	3.5	3.66	1.63	SPM	54	2.64E-02	—
				PM_{10}		7.14E-03	—
				$PM_{2.5}$		7.15E-04	—
				NO_x		7.52E-05	—
				SO_2		5.64E-07	—
				CO		4.08E-05	—
				C_3H_4O		1.26E-08	—

Notes:
(a) Initial lateral dimension = (Haul Route Width + 9.75 m)/4.3. (b) Initial vertical dimension = (2 x height of haul truck in m)/4.3. m = metres; g/s= grams per second.

5.3 Model Options

This section describes the modelling parameters used in the modelling assessment.

5.3.1 Options Used in the AERMOD Model

The options used in the AERMOD model are summarized in Table 5-5.

Table 5-5: Options Used in the AERMOD Model

Modelling Parameter	Description	Used in Concentration Modelling?	Used in Deposition Modelling?
DFAULT	Specifies that regulatory default options will be used.	Yes	No, using Method 2 for deposition which is a non-default option
CONC	Specifies that concentration values will be calculated.	Yes	No
DEPOS	Total deposition flux values will be calculated	No, concentration values are therefore greater than if this parameter was selected	Yes, this parameter is necessary to obtain the deposition rates
OLM	Specifies that the non-default Ozone Limiting Method for NO_2 conversion will be used.	No, NO2 will be converted post processing, as described in Section 5.2	No, not included in deposition modelling
DDEP	Specifies that dry deposition will be calculated.	No, concentration values are therefore greater than if this parameter was selected	Yes, this parameter is necessary to obtain the deposition rates
WDEP	Specifies that wet deposition will be calculated.	No, concentration values are therefore greater than if this parameter was selected	Yes, this parameter is necessary to obtain the deposition rates
FLAT	Specifies that the non-default option of assuming flat terrain will be used.	No, the model will use elevated terrain as detailed in the AERMAP output.	No, the model will use elevated terrain as detailed in the AERMAP output.
NOSTD	Specifies that the non-default option of no stack-tip downwash will be used.	No	No
AVERTIME	Time averaging periods calculated.	1-hr, 8-hr, 24-hr, monthly, annual	Annual
URBANOPT	Allows the model to incorporate the effects of increased surface heating from an urban area on pollutant dispersion under stable atmospheric conditions.	No	No
URBANROUGHNESS	Specifies the urban roughness length (m).	No	No
FLAGPOLE	Specifies that receptor heights above local ground level are allowed on the receptors.	No	No

Notes:

NO_2 = nitrogen dioxide

5.3.2 Particle Deposition

AERMOD has the ability to model both wet and dry deposition; however, modelling deposition results in plume depletion, which reduces predicted ground level concentrations. To be conservative, deposition and plume depletion were not included in the predictions of ground level concentrations for the effects assessment but deposition was included for values provided to other disciplines. Daily and annual wet and dry depositions were modelled in separate model runs and the resulting deposition data was calculated at each receptor.

AERMOD provides estimates for both dry and wet deposition of particulates using either a well-defined particle size distribution (Method 1) or by applying an assumption that the compounds of interest are predominantly emitted as particles that are smaller than 10 microns (Method 2). Although it is estimated that more than 10% of the particulate matter is greater than 10 microns in size, Method 2 has been applied to the dispersion modelling as a well-known particle size distribution in not available for the NSDF Project (U.S. EPA 2016). In Method 2, the deposition velocity of the particles is calculated as the weighted average of the deposition velocity for particles in the fine mode (i.e., less than 2.5 µm in diameter) and the deposition velocity for the coarse mode (i.e., greater than 2.5 µm in diameter). Method 2 is a non-default option in AERMOD.

The parameters for Method 2 are entered for each source which emits particulate in the deposition modelling. For each source, the fraction of particles less than 2.5 µm in diameter (between 0 and 1) and the representative mass mean aerodynamic particle diameter in micrometers are entered. The particle fractions for road dust are based on the particle size multipliers from the U.S. EPA AP-42 Chapter 13.2.1 and Chapter 13.2.2 (U.S. EPA 1995). The mass mean diameters for deposition were calculated on the estimated emission rates per particulate size and are outlined in the Table 5-6.

Table 5-6: Deposition Parameters for $PM_{2.5}$

Source	Arithmetic Mass Mean Diameter	Mass Fraction Distribution
Paved Roads	1.9	0.023[(a)]
Unpaved Roads	1.9	0.038[(b)]

5.4 Post-Processing

Most air quality concentration results are output directly from the model, however there are certain parameters, including averaging periods less than 1 hour and conversion of nitrogen dioxide (NO_2) using existing regional ozone concentrations that require post-processing. These post-processing methods are described in Sections 5.4.1 and 5.4.2.

5.4.1 Time Average Conversions

The smallest time scale that AERMOD predicts is a 1-hour average value. There are instances when criteria are based on different averaging times, and in these cases the following conversion factor, recommended by the MECP for conversion from a 1-hour averaging period to the applicable averaging period less than 1-hour could be used (MECP 2017a). An example is given below for converting from a 1-hour averaging period to a 10-minute averaging period:

$$F = \left(\frac{t_1}{t_0}\right)^n$$

$$= \left(\frac{60}{10}\right)^{0.28}$$

$$= 1.65$$

Where:

F.......= the factor to convert from the averaging period t_1 output from the model (MECP assumes AERMOD predicts true 60 minute averages) to the desired averaging period t_0 (assumed to be 10-minutes in the example above), and

N ......= the exponent variable; in this case the MECP value of n = 0.28 is used for conversion.

For averaging periods greater than 1-hour, the AERMOD output was used directly.

Modelling of odour based compounds (whole odour and H_2S) was completed in accordance to the MECP Technical Bulletin titled *Methodology for Modelling Assessments of Contaminants with 10-minute Average Standards and Guidelines* (MECP 2017c).

5.4.2 Conversions of NOx to NO_2

Emissions of oxides of nitrogen (NO_X) were used as inputs to the AERMOD model. Ambient predictions of NO_2, one of the indicator compounds, can be calculated from modelled NO_X values using the Ozone Limiting Method (OLM). The OLM consists of comparing the maximum modelled NOx concentration to the background ozone (O_3) concentration to assess the limiting factor to NO_2 (Cole and Summerhays 1979). The following equations present the methodology:

$$\text{If background } [O_3] > 0.90\ [NO_x]\text{, total conversion: } [NO_2] = [NO_x]$$

$$\text{If background } [O_3] < 0.90\ [NO_x]\text{, } NO_2 \text{ is limited by } O_3\text{: } [NO_2] = [O_3] + 0.10\ [NO_x]$$

For the air quality assessment, the 24-hour and annual NO_2 concentrations were calculated assuming total conversion of NOx since no background ozone values were available for those periods. The 1-hour NO_2 concentrations were calculated using the 90th percentile of the ground-level ozone concentration from the Petawawa, Ontario station for the years 2009 to 2013. A sample calculation is presented below for 1-hour NO_2:

Background $[O_3] = 84.39\ \mu g/m^3$ *(Petawawa Station, 2009-2013)*

Modelled maximum $[NO_x] = 144.8\ \mu g/m^3$

$0.90\ [NO_x] = 130.32\ \mu g/m^3$

$[O_3] < 0.90\ [NO_x]$, therefore $[NO_2] = [O_3] + 0.10\ [NO_x]$ applies:

$[NO_2] = 84.39\ \mu g/m^3 + 0.10\ (144.8\ \mu g/m^3)$

$[NO_2] = 98.87\ \mu g/m^3$

Additional information on the background air quality assessment is presented in Section 3 (Air Quality Baseline).

5.5 Conservatism In Modelling Approach

Table 5-7 outlines the areas where conservatism was assumed in the modelling approach which results in an assessment that is not likely to under-predict the air quality associated with the NSDF Project.

Table 5-7: Areas of Conservatism in the Modelling Approach

Area	Conservatism
All operations for the NSDF Project were modelled to be occurring simultaneously during their respective assessment phases (i.e., construction and operations) including the material handling activities, waste receipts, and operating vehicles.	The modelling assessment includes all operations occurring simultaneously and continuous for each individual source's modelling period.
Waste receipt for the maximum capacity of 1,000,000 m^3 was modelled	All emission rate calculations were completed for the maximum amount of waste received during the entire life of the NSDF Project.
The ECM cap was modelled as an area source.	Modelling the ECM emissions as an area source assumes that emissions are being released from the entire area, however in reality emissions will only be emitted from discrete areas on the source.
Wet and dry depletion and deposition were not included in the model for concentration modelling.	The modelling will likely yield higher concentrations since contaminants will be deposited from the air by dry or wet depletion and deposition processes.

It is assumed that the conservative emission rates, when combined with the conservative operating conditions and conservative dispersion modelling assumptions description herein, are not likely to under predict the modelled concentrations at each of the identified receptors.

5.5.1 Fugitive Dust Modelling

The parameters that were required for fugitive dust modelling from unpaved roads include the locations of the roadway segments, base elevations, effective heights of the emissions, and the initial plume size in the lateral and vertical directions.

It is recognized that this modelling approach will result in higher predicted concentrations close to the roadways than actual values for the following reasons:

- There has been extensive research on the estimation of the “transportable fraction” of fugitive dust from roadways. Studies completed by the Desert Research Institute in Nevada and in the San Joaquin Valley, CA (Watson et al. 1996) showed a large (i.e., greater than 90%) decrease in dust concentration within 100 m of an unpaved road (Watson et al. 1996; Watson and Chow 2000). A value of 75% reduction has been suggested beyond 50 m for unpaved roadway emissions. This value would increase at greater distances. This adjustment was not be made to the dispersion modelling concentration results.
- When the roads are wet or snow-covered, the emissions will be reduced or eliminated. AERMOD has the capacity to have a variable emission rate that could account for actual meteorological emissions; however variable emission rates were not used in this assessment for conservatism.

Despite the limitations of the emission rate estimates and dispersion modelling, these are the best estimates available. The above-noted biases in the emission estimates are cumulative.

In addition, the best management practices will further reduce emissions; specifically, watering was assumed to be used on unpaved roads to decrease emissions from roads and a truck-wheel wash station will be used to reduce track out.

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