4-A: Air Quality Baseline

It should be noted that this historical baseline report (Appendix 4-A) was reviewed and received conformity approval as part of the Approved Project FEIS submission (Agnico Eagle 2016c), and then final approval under Project Certificate No. 008. This baseline report remain unchanged.

4.A-1 INTRODUCTION

This document provides detailed technical information regarding the existing long-term weather and climate in the vicinity of the Whale Tail Pit Project (the Project). Baseline meteorological data are required as inputs to the air quality model used to predict potential Project-related effects to air quality.

There is very little information regarding existing ambient air quality in the Kivalliq Region of Nunavut. This document provides detailed analysis of the available air quality data relevant to the region. By necessity, this includes data from outside the Kivalliq Region, including data from the Northwest Territories. These data are the only known data relevant to Nunavut and the Canadian Arctic available for estimating existing air quality for the Project. Baseline air quality data are needed as supplementary information to predict the potential effects of the Project on ambient air quality.

4.A-2 EXISTING WEATHER AND CLIMATE

The Project is located in Canada's Northern Arctic ecozone. This ecoregion includes most of Canada's Arctic Archipelago and northern regions of continental Nunavut and the Northwest Territories. The ecoregion is classified as a polar desert and is characterized by long cold winters and short cool summers. Extreme winter cold, low precipitation, and persistent drying winds make this one of the harshest climates in Canada (McGill University 2016; University of Guelph 2016).

Climate refers to the long-term averages of weather measured using meteorology and can be estimated by using climate normal data derived from a 30 year period of observed data. Environment Canada operates a meteorological monitoring station at Baker Lake, Nunavut, approximately 125 kiometres (km) southeast of the Whale Tail Pit. This station provides climate information and hourly meteorological data. This assessment uses the 1981 to 2010 climate normal data for the Baker Lake A station calculated by Environment Canada (Environment Canada 2016).

AERMET is the meteorological processor used to generate meteorological data files for the AERMOD model that was used to assess potential effects of the Project on air quality. An AERMET dataset dictates the transport and dispersion of atmospheric emissions from the Project, as well as the predicted ground-level concentrations of criteria air contaminants considered in this assessment. The AERMET dataset was constructed using the latest five years (2005 to 2009) of surface observations and upper air data from the Environment Canada Baker Lake A meteorology station.

There is also an on-site meteorological station at the Meadowbank Mine located approximately 62 km southeast of the Whale Tail Pit. Two years of hourly and daily meteorology data (2013 and 2014) were available for meteorological parameters including temperature, pressure, relative humidity, wind speed and direction, and precipitation. However these data were not used to derive the AERMET dataset because this station does not monitor all of the parameters required to complete an AERMET dataset.

The following sections present the meteorology data from the Baker Lake A station and a comparison between the AERMET dataset and the Meadowbank Mine on-site meteorological dataset.

4.A-2.1 Temperature

The Environment Canada climate normals provide a means to assess the long-term temperature trends at the Project. As presented in Table 4-A-1: the annual daily average air temperature recorded at the Baker Lake A

Station was -11.3 degrees Celsius (°C), and daily averages ranged from -31.3°C in January to +11.6°C in July. The "Unfrozen" period, which for the purpose of this assessment is classified as months having daily average temperatures above 0°C, occurs from June through September. During this period, the daily average temperature is approximately 7°C. The "Frozen" period, which for the purpose of this assessment is classified as months having daily average temperatures below 0°C, occurs from October through May. During this period, the average daily temperature is approximately -20.6°C.

Table 4-A-1: Temperature Normals for the Baker Lake A Station (1981 to 2010)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
daily average (°C)	-31.3	-31.1	-26.3	-17.0	-6.4	4.9	11.6	9.8	3.1	-6.5	-19.3	-26.8	-11.3
daily maximum (°C)	-27.7	-27.4	-22.0	-12.3	-3.0	9.3	17.0	14.3	6.4	-3.4	-15.5	-23.1	-7.3
daily minimum (°C)	-34.8	-34.8	-30.6	-21.5	-9.8	0.5	6.1	5.3	-0.2	-9.5	-23.1	-30.5	-15.2

°C = degrees Celsius

Table 4-A-2 summarizes the AERMET-derived monthly temperatures for the five year assessment period (2005 to 2009). The AERMET-derived daily average monthly surface temperatures in the Project area ranged from -30.6°C in February to +11.1°C in July. The annual AERMET-derived daily average air temperature was -10.7°C and is comparable to the Baker Lake A observed average of -11.3 °C.

Table 4-A-2: AERMET-derived Temperature (2005 to 2009)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
daily average (°C)	-28.9	-30.6	-26.6	-15.0	-6.4	4.5	11.1	10.1	2.6	-4.8	-18.5	-25.3	-10.7
daily maximum (°C)	-25.1	-27.7	-22.8	-11.1	-3.9	8.7	16.0	14.0	5.6	-2.6	-15.4	-21.9	-7.2
daily minimum (°C)	-32.1	-33.6	-30.7	-19.7	-9.5	0.4	6.2	6.0	-0.4	-7.7	-22.1	-28.5	-14.3

°C = degrees Celsius

Table 4-A-3 summarizes the monthly temperatures monitored at the Meadowbank Mine site station from 2013 to 2014. The daily average monthly surface temperatures were -31.5°C in February to +12.6°C in July. The daily average temperature was -11.4°C at the Meadowbank Mine compared to the long-term average of -11.3 °C observed at the Baker Lake A meteorology station.

Table 4-A-3: On-Site Temperature Monitoring (2013-2014)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
daily average (°C)	-33.1	-31.5	-26.4	-17.8	-4.3	8.0	12.6	10.1	1.4	-6.0	-21.8	-27.7	-11.4
daily maximum (°C)	-30.4	-28.5	-23.1	-14.3	-1.1	12.3	16.4	13.3	3.5	-4.2	-18.9	-24.7	-8.3
daily minimum (°C)	-35.6	-34.2	-29.8	-21.7	-7.6	3.5	8.6	7.0	-0.6	-8.3	-24.6	-30.9	-14.5

°C = degrees Celsius

Figure 4-A-1 shows a comparison of AERMET-derived temperatures and the observed temperatures at the Baker Lake station. The AERMET derived temperature profile for the Project area is similar to the average climatic conditions at the Baker Lake station and to the Meadowbank Mine meteorological data.

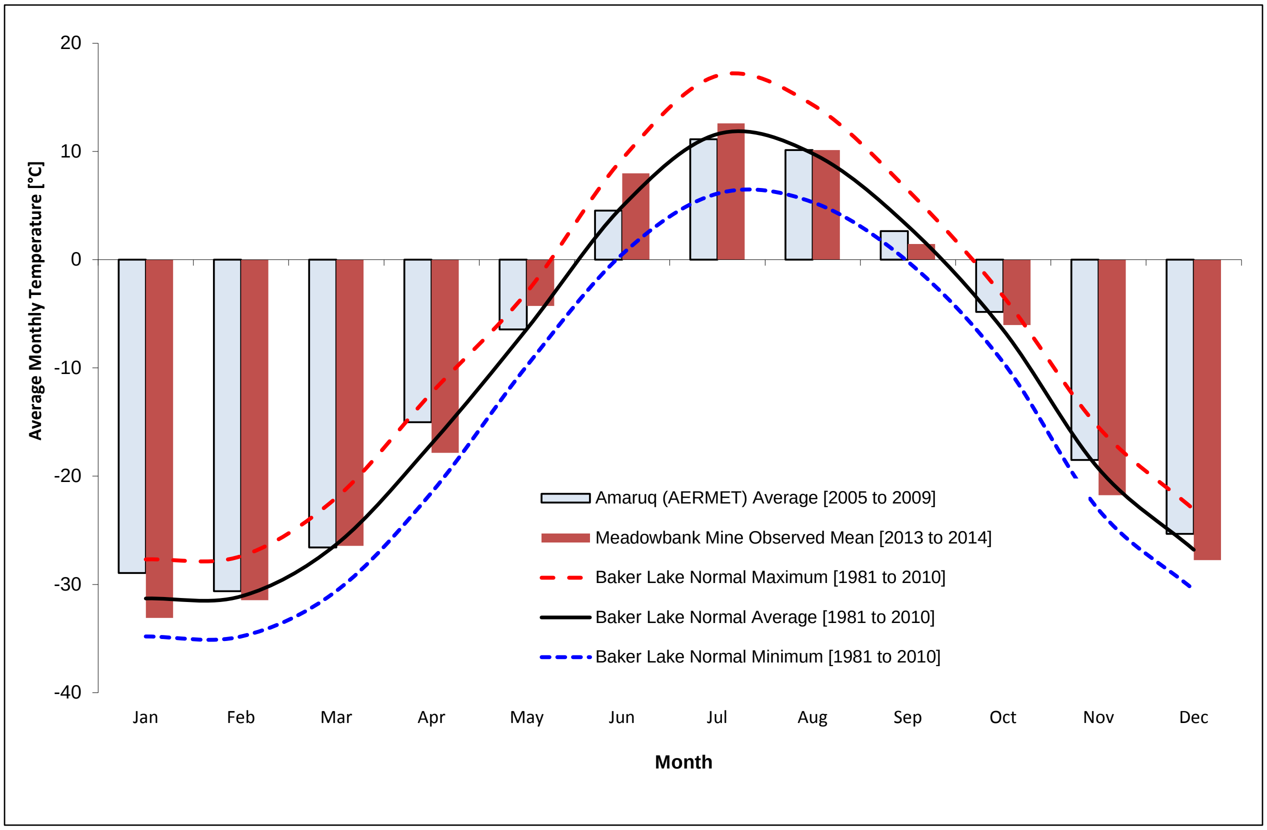

Figure 4-A-1: Comparison of AERMET-Derived and Observed Ambient Temperature

4.A-2.2 Wind

Windroses are useful for presenting wind speed, wind direction and frequency information in a single figure. A windrose consists of bars whose length indicates the frequency of winds blowing from a given direction referenced to a 16-point compass. The bars are also broken into sections, each of which defines a wind speed range. A longer section indicates that winds blow more frequently at a given speed for that compass direction.

Figure 4-A-2 presents a comparison of the windroses generated for the Project using AERMET and the data collected at the Meadowbank Mine meteorology station. The datasets are comparable and show that the winds were predominantly from the north-northwest.

For both datasets, the wind pattern is predominantly from the northwest quadrant. However, winds originating from the north-northwest and north are also common.

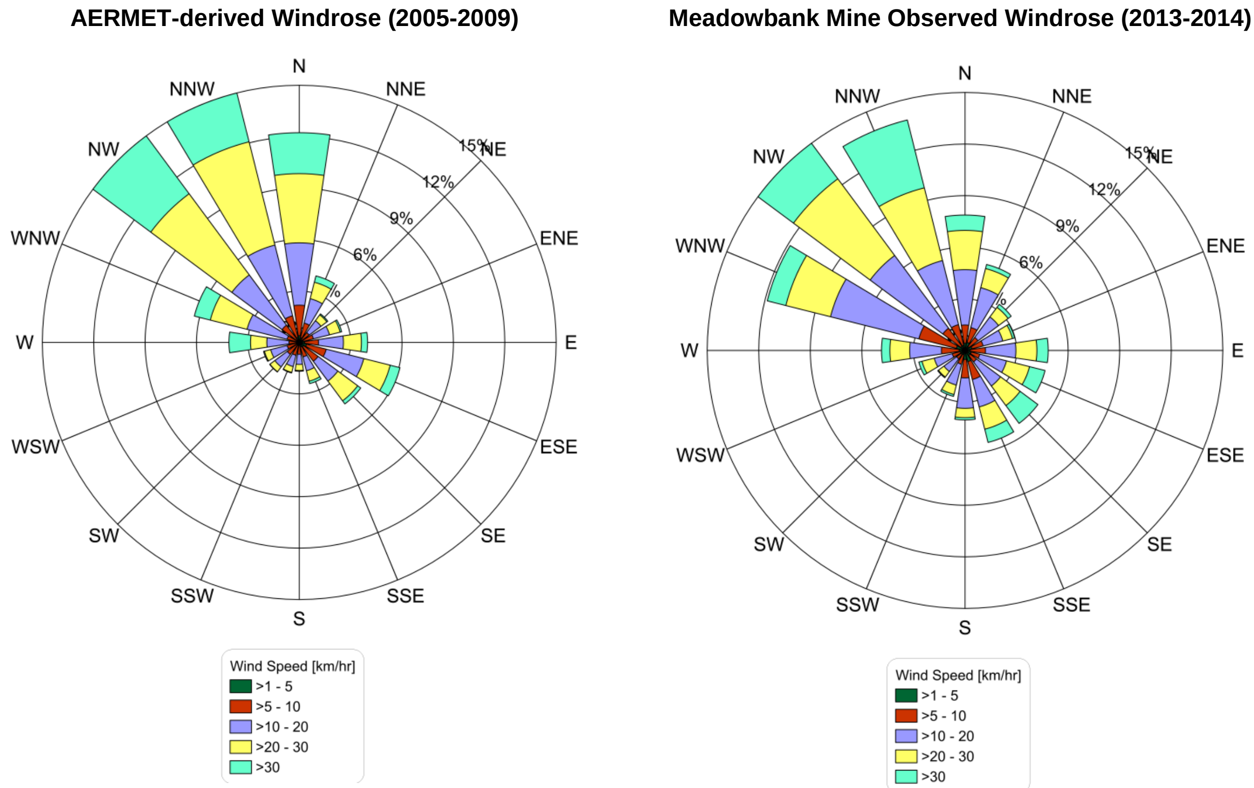

Figure 4-A-2: Comparison of AERMET-Derived (2005-2009) and Meadowbank Mine (2013-2014) Winds for the Project Area

Hourly wind data are required to generate a windrose, therefore a windrose cannot be created from monthly climate normal data. However, wind normals do provide insight into long term wind data trends. Over the period from 1981-2010, the average wind speed at the Baker Lake A station was 20 km/hr. Table 4.A-4 provides a summary of climate normals for wind at the Baker Lake A station, and indicates the predominant wind direction was from the northwest.

Table 4-A-4: Normal Surface Wind at the Baker Lake A Station

Period	Speed (km/h)	Most Frequent Direction	Maximum Hourly Speed (km/h)	Direction of Maximum Hourly Speed	Maximum Gust Speed (km/h)	Direction of Maximum Gust
Jan	22.8	NW	105	N	140	N
Feb	22.1	NW	124	SE	133	NW
Mar	20.9	NW	93	W	121	W
Apr	20.1	NW	91	NW	104	NW
May	19.5	N	91	NW	106	NW
Jun	16.4	N	121	W	177	W
Jul	15.4	N	67	N	91	N
Aug	17.4	N	81	W	137	W
Sep	19.1	N	78	N	103	W
Oct	21.4	NW	106	N	109	NW
Nov	21.9	NW	97	N	121	N
Dec	22.5	NW	100	NW	128	NW
Annual	20	NW	124	SE	177	W

4.A-2.3 Precipitation

Precipitation data is recorded at the Environment Canada Baker Lake A station. On average, the Baker Lake A station receives a total annual precipitation (Rainfall + Snowfall) of approximately 272.5 millimietres (mm). The average annual rainfall is approximately 163.4 mm, with most of the rainfall occurring from May through October. The average annual snowfall is approximately 1265 mm, with most snowfall occurring from October through May. Some months experience mixed precipitation. Figure 4-A-3 provides a summary of monthly and annual precipitation normals, including extremes. AERMET data for total precipitation, which have been derived from Environment Canada surface observations between 2005 and 2009, are also presented in Figure 4-A-3. Precipitation data are not recorded at the Meadowbank Mine meteorology station.

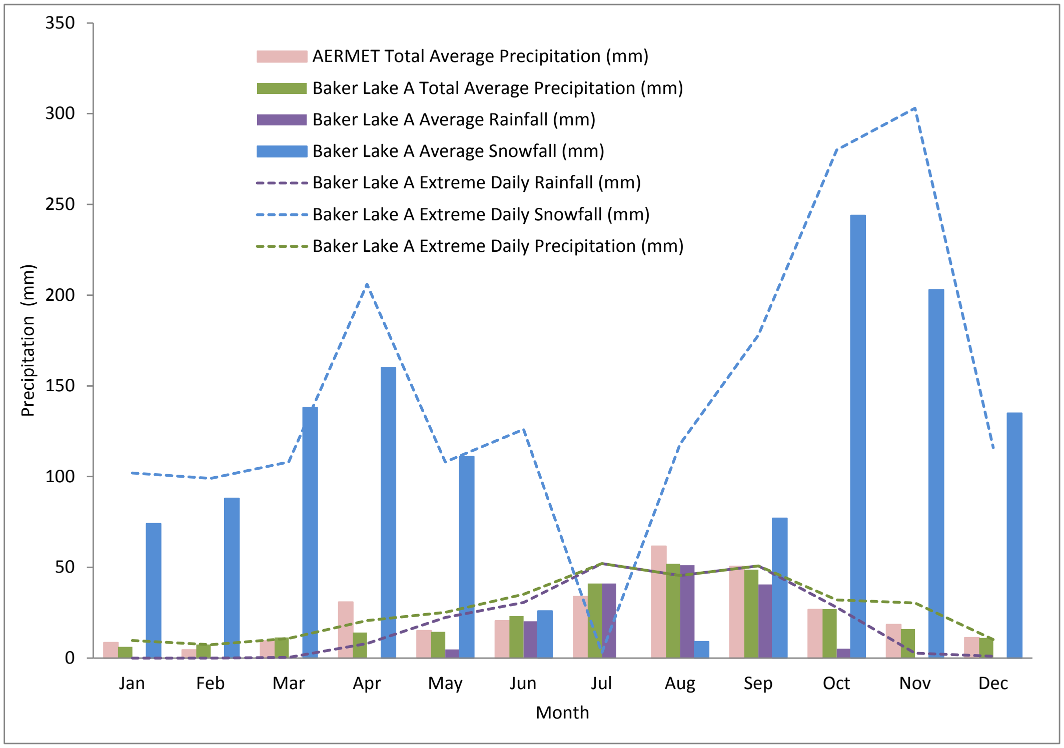

Figure 4-A-3: Precipitation at Baker Lake

4.A-3 EXISTING AIR QUALITY

This technical appendix summarizes background criteria air contaminant (CAC) concentrations that are used in the assessment to predict potential changes to regional air quality as a result of Project-related air emissions.

The Project will result in emissions to air that could change local or regional air quality. To determine whether Project-related emissions lead to air quality conditions that are consistent with existing Territorial and Federal air quality criteria, maximum predicted concentrations of CACs emitted from the Project must be added to the background concentrations of the CACs in the region. Background concentrations can be established through baseline measurements (Ontario MOE 2009; AESRD 2013), or prescribed by regulators based on regional airsheds (Saskatchewan MOE 2012). The CACs considered for the FEIS Amendement include the following:

- carbon monoxide (CO);
- oxides of nitrogen (NO, NO_2, NO_x);
- sulfur dioxide (SO_2); and
- particulate matter, including:
  - particulate smaller than 2.5 micrometres in aerodynamic diameter ($PM_{2.5}$);
  - particulate smaller than 10.0 micrometres in aerodynamic diameter (PM_{10}); and
  - total suspended particulate matter (TSP).

Project emissions of NO and NO_2 are combined as NO_x, with the photochemical conversion of NO to NO_2 being simulated by the air quality model. The conversion of NO to NO_2 requires information regarding the ambient concentrations of ozone (O_3), which have also been evaluated as part of this baseline air quality assessment (see Section 4.A-3.1). Model results are assessed against the relevant ambient air quality standards for NO_2. Since NO is relatively short-lived, only the background concentration of NO_2 needs to be added to the results of the model simulation to estimate potential Project-related effects.

Elevated ambient $PM_{2.5}$ concentrations have been linked to public health concerns, while TSP is relevant to aerial deposition of CAC's to terrestrial and aquatic ecosystems. National Air Pollution Surveillance (NAPS) stations and National Aeronautics and Space Administration (NASA) aircraft have both measured $PM_{2.5}$ concentrations in the region; however, there are no relevant air quality monitoring data for PM_{10} or TSP in the Arctic. As a result, ambient concentrations of PM_{10} and TSP have been assigned a value equal to that of $PM_{2.5}$ in this assessment.

In Nunavut, there are no prescribed background concentrations for CACs when performing air quality predictions for proposed developments. This technical appendix includes a statistical analysis of publicly available air quality monitoring data in the Western Arctic, and summarizes background CAC values that were used to predict the changes to regional air quality that may arise from Project-related air emissions.

4.A-3.1 Methods

Table 4-A-5 summarizes publicly available air quality data that are relevant to this study, including sampling locations, compounds measured, and dates that the compounds were measured.

Table 4-A-5: Available NAPS Station Data and NASA ARCTAS Data

Name	Territory	Compounds	Data Available	Notes
Sir John Franklin High School	NWT	CO, SO_2, NO/NO_2/NO_x, $PM_{2.5}$	2009-2013	Publicly available NAPS data.
Norman Wells NW Regional Office	NWT	SO_2, NO/NO_2/NO_x, $PM_{2.5}$	2009-2013	Publicly available NAPS data.
Fort Liard	NWT	SO_2, NO/NO_2/NO_x, $PM_{2.5}$	2009-2012	Publicly available NAPS data.
Samueal Hearne School	NWT	SO_2, NO/NO_2/NO_x, $PM_{2.5}$	2009-2011	Publicly available NAPS data.
Snare Rapids	NWT	Not available		
WildLife Services Garage Iqaluit	NU	NO/NO_2/NO_x, $PM_{2.5}$, O_3	2014 – 2015	One year of data obtained from Government of NU.
Water Quality Lab Iqaluit	NU	NO/NO_2/NO_x, $PM_{2.5}$, O_3	2012 – 2013	One year of data obtained from Government of NU.
Alert	NU	O_3	1992-2003	Special Studies Data - Ozone at ALERT
		Aerosols Chemistry (Chloride, Bromide, Nitrate, Sulfate, Sodium, Ammonium, Lead, Cooper, Aluminum, Iron, etc.)	1980-2006	Quality Controlled Weekly Data
		Black Carbon Data	1989-2012	Quality Controlled Hourly Data
NASA ARCTAS	AK, YT, NWT, NU	CO, SO_2, NO/NO_2/NO_x, $PM_{2.5}$	2008 (April/May)	NASA Airborne Science Mission

NWT = Northwest Territory; NU = Nunavut; AK = Alaska; YT = Yukon Territory; CO = carbon monoxide; SO_2 = sulphur dioxide; NO, NO_2, NO_x = oxides of nitrogen; $PM_{2.5}$ = particulate smaller than 2.5 micrometers in aerodynamic diameter; O_3 = ozone

The goal of the NAPS program is to provide accurate long-term air quality data of a uniform standard across Canada (EC 2015a). The NAPS program was established in 1969 to monitor and assess the quality of ambient (outdoor) air in the populated regions of Canada. The NAPS program is managed using a cooperative agreement among the provinces, territories and some municipal governments. Today there are 286 NAPS sites in 203 communities located in every province and territory. However, NAPS geographic coverage in the Canadian Territories is sparse, and NAPS stations in the Arctic do not measure all CAC's emitted by the Project.

For example, data collected at the Alert, Nunavut air quality monitoring station are not available from Canada's National Air Pollution Survey (NAPS; EC 2015a) database, but are archived separately under the Canadian Aerosol Baseline Measurements data (EC 2015b). Canadian Aerosol Baseline Measurements files for Alert did not contain trace gas concentrations or total aerosol mass. Instead the files include only specialized aerosol chemistry data and ozone data; data not relevant for this assessment. The Alert data are therefore excluded from this analysis. There were also no relevant, publicly available data for the NAPS locations at Snare Rapids in the Northwest Territories.

Data for the two NAPS stations located in Iqaluit, Nunavut are not publicly available via the NAPS web portal. To inform this assessment, Golder Associates Ltd. (Golder), on behalf of Agnico Eagle, signed a data sharing agreement with the Government of Nunavut. The Government of Nunavut then provided Golder with two years of air quality monitoring data from the Iqaluit NAPS stations to support this assessment.

In April and May of 2008, NASA conducted the *Arctic Research of the Composition of the Troposphere from Aircraft and Satellites* mission (ARCTAS; Jacob et al. 2010). ARCTAS was part of a larger interagency International Polar Year effort collectively identified as POLARCAT. While the aircraft data were only collected for a 2-month period, the data include atmospheric soundings from 100 metres (m) up to 12 km over most of the Western Arctic using state-of-the-art in-situ airborne instruments (McNaughton et al. 2011).

Publicly available NAPS data were quality assured (QA) and quality controlled (QC) by Environment Canada prior to publication on the Internet. Raw air quality monitoring data ($NO/NO_2/NOx$, $PM_{2.5}$ and O_3) from the Iqaluit NAPS stations were quality controlled by air quality experts at Golder prior to their use in this assessment.

To generate appropriate background estimates of CAC concentrations in the Kivalliq Region, the data must be screened to eliminate known event-based biases. Specifically, boreal forest fire smoke is seasonally transported into the Arctic where it episodically can affect air quality (Forster et al. 2001; Warneke et al 2009). Ambient 1-hour average concentrations of $PM_{2.5}$ during these events can exceed 200 or even 300 micrograms per cubic metre ($\mu g/m^3$). These concentrations are more than 10 times the 24-hr average $PM_{2.5}$ Canadian Ambient Air Quality Standard (CAAQS) of 28 $\mu g/m^3$. Including these events in background datasets results in 24-hr 90th percentile $PM_{2.5}$ concentrations and annual average $PM_{2.5}$ concentrations that exceed, or are a significant fraction of the CAAQS. To remove these events, concentrations that exceeded the 97.6th percentile of all data were removed from the dataset prior to generating statistics for background concentrations of $PM_{2.5}$. The 97.6th percentile was selected for $PM_{2.5}$ as this excludes only 1-hr concentrations greater than two standard deviations from the sample mean (i.e., greater than $\bar{u} + 2\sigma$) from a pooled dataset with more than 43,000 independent observations.

Appropriate 8-hour, 24-hour, and annual averages for each of the other CACs were generated by arithmetically averaging the 1-hr data. Background concentrations for 1-hour, 8-hour, and 24-hour averaging periods were assigned a value equal to the 90th percentile value from the available period of observations. Background concentrations for the annual averages were assigned the median (50th percentile) value of the available period of observations.

The background annual $PM_{2.5}$ concentration was not assigned the median annual average from the available period of observations. Instead, the annual average background $PM_{2.5}$ concentration was calculated as the geometric mean (50th percentile) of the available 24-hr average observations. This approach is required to eliminate bias associated with arithmetically averaging (rather than geometrically averaging) the variable ambient aerosol concentrations. This bias can result in elevated background concentration estimates (6.2 $\mu g/m^3$) that are a significant percentage (>70%) of the Canadian Ambient Air Quality Standard (8.8 $\mu g/m^3$).

NASA ARCTAS data were QA/QC'd by the NASA Principal Investigators prior to data submission to the NASA airborne science archive. These data have not been screened for any event-based biases. The available NASA ARCTAS data are 1-minute in-flight averages. Due to the speed of the airborne platform, the effective averaging time compared to a ground-based measurement is much longer than 1 minute.

True airspeeds of approximately 120 (NASA P-3B aircraft) to 150 metres per second (m/s) (NASA DC-8 aircraft) correspond to spatial averages of 7 to 9 km over a 1-minute sampling period. For an average surface wind speeds of 5.5 m/s, this corresponds to an effective sample integration time of 21 to 27 minutes for each data point (N). The two NASA aircraft recorded more than 132 hours of 1-minute average data over the Western Arctic in April and May of 2008. However, the statistics summarized in this assessment consider only the CAC concentrations measured below 1 km altitude. Airborne trace gas measurements obtained aboard the NASA aircraft are accurate and precise. Airborne particulate matter measurements are considered comparable to ground-based measurements of $PM_{2.5}$ (McNaughton et al. 2007).

To generate summary statistics relevant for comparison to the NAPS station data, no separate averaging of the aircraft data was applied to the 1-hr versus the 24-hr averages. Instead, the 1-hr and 24-hr averages were computed from the 90th percentile of the 1-minute flight average values, and the annual average was calculated based on the median (50th percentile) value.

4.A-3.2 Results

Figure 4-A-4 is a Google Earth image depicting the locations of the NAPS and Alert air quality monitoring stations in Arctic Canada. NASA P-3B and DC-8 aircraft ground tracks are also plotted, with data collected below 1-km shaded red and blue, respectively.

Table 4-A-6 summarizes the NAPS data completeness (hourly data) between January, 2009 and December, 2014 for the Norman Wells, Sir John Franklin High School, Fort Laird, and Samuel Hearne NAPS stations. For the Iqaluit data, the data completeness is calculated over the approximate 1-year of data provided by the Government of Nunavut. Table 4-A-6 also includes the number of valid 1-minute average ARCTAS data points used to generate the summary statistics. Table 4-A-7 provides summary statistics for the NAPS and ARCTAS data, a set of recommended background concentrations of CACs for the Kivalliq Region of the Western Arctic, and relevant Canadian ambient air quality standards for these CACs. Note that the monthly average concentrations of ozone are required as input to the air quality model and are not simulated by the model for comparison to the CAAQS. The background concentrations summarized in Table 4-A-7 are the ground-level CAC concentrations used to inform the air quality portion of the FEIS Amendment.

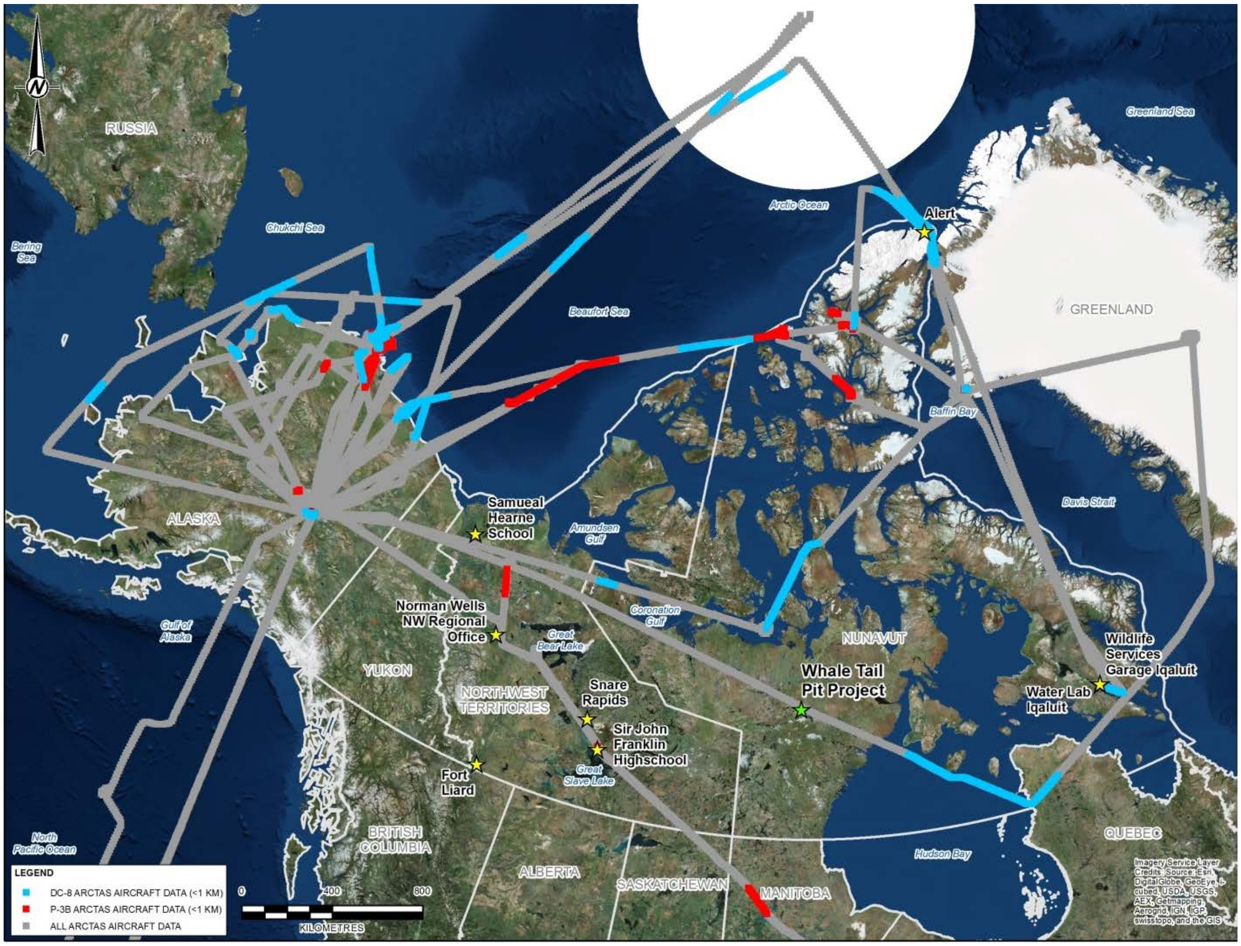

Figure 4-A-4: Location of NAPS stations and ARCTAS aircraft measurements in the Canadian Arctic

Table 4-A-6: Data Completeness Summary

Compound (units)	Normal Wells (NWT)	Sir John Franklin High School (NWT)	Fort Laird (NWT)	Samuel Hearne Station (NWT)	Iqaluit Water Services Garage (NU)	Iqaluit Water Quality Lab (NU)	NASA ARCTAS
CO (ppbv)	N/A	97%	N/A	N/A	N/A	N/A	N = 1206
NO_2 (ppbv)	90%	96%	46%	40%	76%	97%	N = 1183
SO_2 (ppbv)	88%	94%	76%	48%	N/A	N/A	N = 922
$PM_{2.5}$ (µg/m^3)	85%	92%	65%	42%	93%	81%	N = 2916

N/A = not available; NWT = Northwest Territories; CO = carbon monoxide; NO_2 = nitrogen dioxide; SO_2 = sulfur dioxide; $PM_{2.5}$ = particulate matter smaller than 2.5 micrometers in aerodynamic diameter; ppbv = parts per billion, volumetric; µg/m^3 = micrograms per cubic metre

Table 4-A-7: Summary Statistics for Criteria Air Contaminants

Compound (units)	Averaging Period	Percentile	Norman Wells (NWT)	Sir John Franklin High School (NWT)	Fort Laird (NWT)	Samuel Hearne Station (NWT)	Iqaluit Water Services Garage (NU)	Iqaluit Water Lab (NU)	NASA ARCTAS	Background Concentra-tions used in the FEIS	Air Quality Standard
CO (ppmv)	1-hr	90th	N/A	0.5	N/A	N/A	N/A	N/A	0.2	**0.3**	13
	8-hr	90th	N/A	0.5	N/A	N/A	N/A	N/A	0.2	**0.3**	5
NO_2 (ppbv)	1-hr	90th	4.0	7.0	6.0	8.0	4.7	16.4	0.11	**5.0**	159
	24-hr	90th	3.5	7.0	4.9	6.9	6.2	13.0	0.11	**4.5**	106
	Annual	50th	1.4	3.0	1.2	4.1	2.7	5.8	0.008	**1.9**	24
O_3 (ppbv)	1-hr	90th	35.0	36.0	38.0	N/A	32.5	39.9	49.2	**17.3 – 30.6**[b]	82
	8-hr	90th	34.1	35.4	37.9	N/A	24.6	39.3	34.2		63
SO_2 (ppbv)	1-hr	90th	1.0	1.0	1.0	1.0	N/A	N/A	0.2	**1.0**	172
	24-hr	90th	1.0	1.0	1.2	1.2	N/A	N/A	0.2	**1.0**	48
	Annual	50th	<1.0	<1.0	<1.0	<1.0	N/A	N/A	0.1	**0.1**	8
$PM_{2.5}$ (µg/m³)	24-hr	90th	6.8	7.7	6.4	8.0	6.8	7.2	3.9	**6.6**	28
	Annual	50th	3.5[a]	4.5[a]	3.4[a]	4.3[a]	3.3	3.9	2.0	**3.6**	8.8

[a] Geometric average (median or 50th percentile) of 5-years of 24-hr average concentrations after removing zeros and hourly concentrations above the 97.6th percentile.

[b] Indicated values are the range in monthly average concentrations used as input for the conversion of NO_2 to NO in the air quality model.

N/A = not available; NWT = Northwest Territories; CO = carbon monoxide; NO_2 = nitrogen dioxide; SO_2 = sulfur dioxide; $PM_{2.5}$ = particulate matter smaller than 2.5 micrometers in aerodynamic diameter; ppbv = parts per billion, volumetric; µg/m³ = micrograms per cubic metre

The most complete baseline air quality data are those from the Sir John Franklin High School NAPS station and the ARCTAS airborne data. The Sir John Franklin High School station is also the closest to the Project, located at approximately the same latitude, but some 1,200 km due west of the Project. The available data from the Norman Wells NAPS station is also robust, but lacks measurements of CO. Measurements from the Fort Laird and Samuel Hearne Station NAPS stations contain large data gaps and lack CO data. The Iqaluit NAPS station data include NO_2, $PM_{2.5}$ and O_3 data and are short in duration (approximately one year each), but the available data are relatively complete and of high quality.

NAPS and ARCTAS CO data are consistent and indicate a background concentration of 0.2 parts per million volumetric (ppmv); a value less than 10% of the relevant 1-hr and 8-hr ambient air quality standards.

The ARCTAS measurements of NO_2 and SO_2 are more precise (approximately +/-0.001 ppbv) than the corresponding ground-based measurements (approximately +/-0.5 ppbv). However, airborne sampling below 300 m was infrequent aboard the DC-8 aircraft (only aircraft with NO_2 and SO_2 instruments) used during ARCTAS. Since Arctic atmosphere concentrations of these gases are often <0.5 ppbv, this results in ARCTAS background concentrations appearing much lower than concentrations observed at the surface NAPS stations. NAPS stations are also closer to the surface-based combustion emissions sources of these compounds.

Figure 4-A-5 shows the NO_2 time series data from the Sir John Franklin High School and the Norman Wells NAPS stations. These stations are presented as they contain the longest, most complete, publicly available records of ambient ground level NO_2 and $PM_{2.5}$ concentrations in Arctic Canada. However, all available station data were used to compute the statistics in Table 4-A-7.

Note the seasonal peak in spring associated with Arctic Haze events, and the photochemical destruction of NO_2 in the polar summer. When averaged, the NAPS and ARCTAS background concentrations for NO_2 and SO_2 are less than 10% of the relevant 1-hr, 24-hr, and annual average ambient air quality standards.

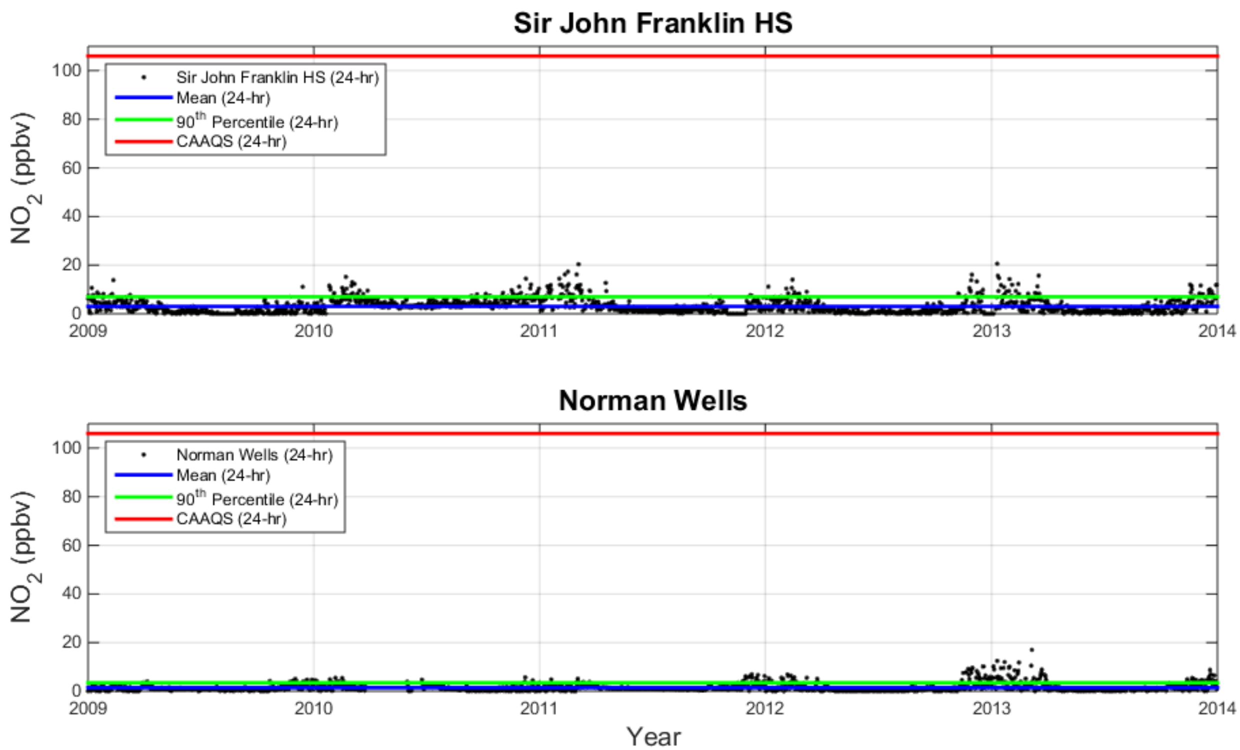

Figure 4-A-5: Time Series of NO2 Concentrations at Sir John Franklin High School (top) and Norman Wells (bottom) Stations

Particulate matter concentrations are highly variable and have been screened to eliminate bias introduced by $PM_{2.5}$ emissions from seasonal boreal forest fires. Figure 4-A-6 plots time series of the screened $PM_{2.5}$ data from the Sir John Franklin High School and Normal Wells NAPS stations. The 90th percentile for the 24-hr averages, the geometric mean (median or 50th percentile) and the relevant 24-hr ambient air quality standard are also indicated.

Results for the 90th and 50th percentile are consistent among the NAPS stations and with the ARCTAS data from April and May of 2008. Values from the NAPS stations and ARCTAS have been averaged to produce 24-hr and annual average background concentrations of 6.7 and 3.6 $\mu g/m^3$, respectively. These background concentrations represent 23% and 41% of the relevant ambient air quality standards (28 and 8.8 $\mu g/m^3$).

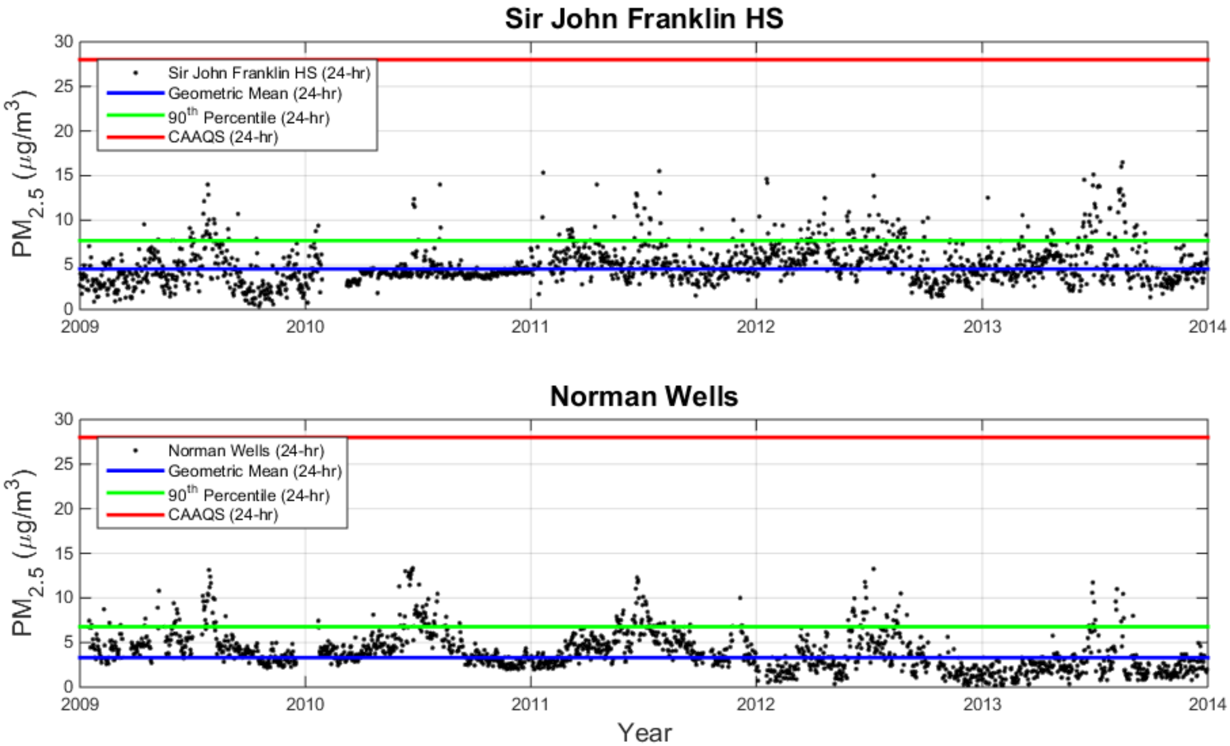

Figure 4-A-6: Time Series of $PM_{2.5}$ Concentrations at Sir John Franklin High School (top) and Norman Wells (bottom) Stations

4.A-3.3 Air Quality Summary

Publicly available Canadian Arctic air quality monitoring data were analyzed using statistics to estimate background concentrations of criteria air contaminants for the proposed Project. These background concentrations are needed as inputs to air quality models used to assess potential changes in air quality from the proposed Project. Background concentrations of particulate matter were 25 to 40% of the Canadian Ambient Air Quality Standards. Background concentrations for gases including carbon monoxide, nitrogen dioxide, and sulfur dioxide were less than 10% of the Canadian Ambient Air Quality Standards.

4.A-4 REFERENCES

AESRD (Alberta Environment and Sustainable Resource Development. 2013. Air Quality Modelling Guideline. Alberta Environment and Parks website: http://aep.alberta.ca/air/modelling/documents/AirQualityModelGuideline-Oct1-2013.pdf (accessed October 22, 2015.

EC (Environment Canada). 2015a. Natoinal Air Pollution Surveillance (NAPS) program. Environment Canada website: http://www.ec.gc.ca/rnspa-naps/Default.asp?lang=En&n=5C0D33CF-1 (accessed October 12, 2015).

EC. 2015b. Canadian Aerosol Baseline Measurements (CABM) data. Environment Canada website: http://www.ec.gc.ca/donneesnatchem-natchemdata/default.asp?lang=En&n=22F5B2D4-1 (accessed October 12, 2015).

Environment Canada. 2016. Canadian Climate Normals 1981-2010 Station data. Available at: http://climate.weather.gc.ca/climate_normals/index_e.html. Accessed on March 2016.

Forster, C., U. Wandinger, G. Wotawa, P. James, I. Mattis, D. Althausen, P. Simmonds, S. O'Doherty, S. G. Jennings, C. Kleefeld, J. Schneider, T. Trickl, S. Kreipl, H. Jager and A. Stohl. Transport of boreal forest fire emissions from Canada to Europe, Journal of Geophysical Research – Atmospheres, 106(D19), pp. 22,887-22,906, doi: 10.1029/2001JD900115, 2001.

Jacob, D. J., Crawford, J. H., Maring, H., Clarke, A. D., Dibb, J. E., Emmons, L. K., Ferrare, R. A., Hostetler, C. A., Russell, P. B., Singh, H. B., Thompson, A. M., Shaw, G. E., McCauley, E., Pederson, J. R., and Fisher, J. A. 2010. The Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) mission: design, execution, and first results, Atmos. Chem. Phys., 10, 5191-5212, doi:10.5194/acp-10-5191-2010.

McGill University (2016). Northern Arctic website: http://canadianbiodiversity.mcgill.ca/english/ecozones/northernarctic/northernarctic.htm. accessed March, 2016.

McNaughton, C. S., Clarke, A. D., Howell, S. G., Pinkerton, M, Anderson,B., Thornhill, L., Hudgins, C., Winstead, E., Dibb, J. E., Scheuer, E., and H. Maring. 2007. Results from the DC-8 Inlet Characterization Experiment (DICE): Airborne Versus Surface Sampling of Mineral Dust and Sea Salt Aerosols, Aerosol Science and Technology, 41(2), 136-159, DOI:10.1080/02786820601118406.

McNaughton, C. S., Clarke, A. D., Freitag, S., Kapustin, V. N., Kondo, Y., Moteki, N., Sahu, L., Takegawa, N., Schwarz, J. P., Spackman, J. R., Watts, L., Diskin, G., Podolske, J., Holloway, J. S., Wisthaler, A., Mikoviny, T., de Gouw, J., Warneke, C., Jimenez, J., Cubison, M., Howell, S. G., Middlebrook, A., Bahreini, R., Anderson, B. E., Winstead, E., Thornhill, K. L., Lack, D., Cozic, J., and Brock, C. A. 2011. Absorbing aerosol in the troposphere of the Western Arctic during the 2008 ARCTAS/ARCPAC airborne field campaigns, Atmos. Chem. Phys., 11, 7561-7582, doi:10.5194/acp-11-7561-2011.

Ontario MOE (Ontario Ministry of the Environment). 2009. Air Dispersion Modelling Guideline for Ontario Ontario Ministry of Environment website: https://dr6j45jk9xcmk.cloudfront.net/documents/1444/3-7-21-air-dispersion-modelling-en.pdf (accessed October 22, 2015).

Saskatchewan MOE (Saskatchewan Ministry of the Environment). 2012. Saskatchewan Air Quality Modelling Guideline. Saskatchewan Ministry of Environment website: http://www.environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=55efb669-d96a-4722-b0bc-bd3173208616&MediaID=c8a3dcd8-c42c-4445-ad91-9d6800edb26a&Filename=Saskatchewan+Air+Quality+Modelling+Guideline.pdf&l=English (accessed October 22, 2015).

University of Guelph (2016). Northern Arctic Ecozone website: http://www.arctic.uoguelph.ca/cpe/environments/land/northarctic/north_arctic.htm. Accessed March, 2016.

Warneke, C., Bahreini, R., Brioude, J., Brock, C. A., De Gouw, J. A., Fahey, D. W., Froyd, K. D., Holloway, J. S., Middlebrook, A., Miller, L., Montzka, S., Murphy, D. M., Peischl, J., Ryerson, T. B., Schwarz, J. P., Spackman, J. R. and Veres, P.: Biomass burning in Siberia and Kazakhstan as an important source for haze over the Alaskan Arctic in April 2008, Geophys. Res. Lett., 36, L02813, doi:10.1029/2008GL036194, 2009.