Golder Associates Ltd.

10th Floor, 940 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
Telephone (403) 299-5600
Fax (403) 299-5606

TECHNICAL REFERENCE FOR THE METEOROLOGY, EMISSIONS AND AMBIENT AIR QUALITY IN THE ATHABASCA OIL SANDS REGION

Submitted to:

Suncor Energy Inc., Oil Sands

Prepared by:

Golder Associates Ltd.

and

Conor Pacific Environmental Technologies Inc.

May 1998

972-2205

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10th Floor, 940 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
Telephone (403) 299-5600
Fax (403) 299-5606

Golder Associates

May 7, 1998

Proj. No. 972-2205

Mr. Martin Holysh
Senior Environmental Specialist
Sustainable Development
Suncor Energy Inc., Oil Sands
P.O. Box 4001
Fort McMurray, AB
T3H 3E3

RE: Technical Reference for the Meteorology, Emissions and Ambient Air Quality in the Athabasca Oil Sands Region

Dear Martin:

Attached is the final version of the technical reference report that supports the Air Quality Assessment for the Project Millennium Environmental Impact Assessment. This document is the result of collaboration among Suncor, Syncrude Canada Ltd., Conor Pacific and Golder.

The report is a replacement for three air baseline documents issued in support of Suncor's Steepbank Mine EIA. This document provides an updated meteorological picture for the oil sands region (with additional years of data incorporated for modelling purposes).

The air emission sources have been characterized for both the currently approved plus planned oil sands developments. Additionally, the ambient air quality data has been updated to mid-1997 where possible.

Should you have any questions about the report, please contact me at 299-5640.

Yours very truly,

GOLDER ASSOCIATES LTD.

John R. Gulley, M.Sc., P. Biol.
Oil Sands Project Director

attachment

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EXECUTIVE SUMMARY

This document provides a detailed technical reference for the oil sands region air quality assessments. The document includes sections on meteorological conditions, air emission sources and the ambient air quality for the Athabasca Oil Sands Region.

The document has been developed collaboratively among Suncor Energy Inc., Oil Sands (Suncor), Syncrude Canada Ltd. (Syncrude), Golder Associates Ltd. and Conor Pacific Environmental Technologies Inc. The document is designed to provide some of the technical background information for air quality environmental impact assessments (EIAs) completed for Suncor and Syncrude. The document provides a consolidated update of three documents previously issued in support of oil sands EIAs. These documents included:

> Sources of Atmospheric Emissions in the Athabasca Oil Sands Region (Report 1). Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Ltd. Prepared by BOVAR Environmental. June 1996.
>
> Ambient Air Quality Observations in the Athabasca Oil Sands Region. Prepared for Suncor Inc. Prepared by Golder Associates and BOVAR Environmental. May 1996.
>
> Meteorology Observations in the Athabasca Oil Sands Region. Prepared for Suncor Inc. Prepared by Golder Associates and BOVAR Environmental. May 1996.

This report is comprised of four sections, including an overall report introduction, a review of the meteorological observations, the anthropogenic atmospheric emissions and the ambient air quality for the Oil Sands Region.

No assessments of the Oil Sands Region air quality are completed within this technical report. Neither is there any discussion on the models that might be employed to complete air quality impact assessments. Impact assessment and model discussions are provided in the EIAs prepared by, or under preparation by Suncor and Syncrude.

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1 INTRODUCTION

1.1 BACKGROUND

The objective of the air component impact analysis is to identify and analyze the potential effects associated with Project Millennium. Current and expected air quality changes associated with Suncor Energy Inc., Oil Sands (Suncor) approved (Fixed Plant Expansion Project and the Steepbank Mine) and proposed Project Millennium (the Project) operations are provided in that assessment. As the Suncor facility is located in an airshed that contains other sources, the cumulative air quality assessment includes the combined operation of these other sources; the major one being the operations of Syncrude Canada Ltd. (Syncrude).

The air quality impact analysis focuses on determining changes to the chemical composition of the air and not on the impacts these changes may have on receptors. Impacts of air quality changes to forest ecosystems and human health are discussed in the Terrestrial Resources Impact Analysis and the Human Health Impact Analysis sections, respectively. This report provides technical information on the air component in support of the above analyses.

Alberta produces a significant portion of Canada's energy requirements through the production of fossil fuels that include natural gas, conventional crude oil, synthetic crude oil and coal. The oil sands sector produces almost 25% of Canada's needs through the production of synthetic crude oil from bitumen. Both Syncrude and Suncor have plans to develop new oil sands leases and to further increase crude oil and bitumen production through existing extraction and upgrading facilities. These developments and the development of new leases by other operators (e.g., Shell, SOLV-EX) in the region will have effects on the environment. Because air quality issues are a principal concern in the assessment of these developments, this technical reference has been prepared to support the multi-stakeholder interests and analyses of the potential impacts.

Summarized in this technical reference are air quality data current to the end of 1997. In summary, this reference includes:

- The meteorological observations in the Athabasca Oil Sands region. Meteorological data which describe the transport, dispersion and deposition of emissions in the area are summarized. The focus is on the meteorological data collected by Suncor from the Lower Camp and the Mannix tower. A review of the terrain in the region and its effect on meteorology is also provided.
- The sources of anthropogenic atmospheric emissions in the Athabasca Oil Sands region. The air emissions in the Fort McMurray - Fort McKay corridor, including industrial point, fugitive, traffic and

residential sources, are identified. Emissions of interest are sulphur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), total hydrocarbons (THC) that include volatile organic compounds (VOC), total reduced sulphur species (RS), particulates (PM) and carbon dioxide (CO_2); and

- The ambient air quality observations in the Athabasca Oil Sands region. Sources include data from the Suncor, Syncrude and AEP networks, and data associated with other monitoring programs.

The information in this document is further supported through the provincial initiatives outlined in the next section.

This report summarizes air quality baseline data information to the end of 1997. It can be used to assist in the management of future developments. Furthermore, this report can also be used by Wood Buffalo Air Monitoring Zone (WBAMZ) or the Regional Air Quality Coordinating Committee (RAQCC) in support of their regional air quality related initiatives.

2 METEOROLOGICAL OBSERVATIONS

2.1 INTRODUCTION

The meteorological processes in the Athabasca oil sands region are affected by a combination of regional conditions and local topographic influences. To accurately simulate the emissions from the multiple sources in the area, it is important to develop a good understanding of the local meteorological conditions and how they can affect the dispersion and transport of airborne pollutants. This section of the report endeavours to:

- Identify the most suitable meteorological data source in the oil sands airshed for characterizing the transport of pollutants;
- Summarize the observations that describe the transport and dispersion processes;
- Identify possible diurnal and seasonal trends in the atmospheric observations; and
- Summarize the meteorological data set selected for use in the dispersion modelling analyses presented in the body of the EIA.

2.1.1 Glossary of Terms and Variables

This report is technical in nature, and therefore uses a number of terms and abbreviations. To assist understanding a listing of terms and definitions has been provided in Table 2-1.

Table 2.1 Definition of Meteorological Terms and Abbreviations in Section 2

Term or Variable	Definition
Atmospheric Boundary Layer	The vertical extent to which the daytime heating and nighttime cooling cycle influences atmospheric behaviour. This is the layer closest to the earth's surface, and within which pollutants are released and dispersed.
Atmospheric Dispersion	Gases and small particles released into the atmosphere become dispersed or separated by random eddy motions or turbulence. Turbulence results in the dilution of a plume as it is mixed with the ambient air and carried downwind from the release point.
Season	For the purposes of this report, the four seasons are defined as fixed three month periods: winter is considered to be December, January and February; spring is March, April and May; summer is June, July and August; and fall is September, October and November.
Wind Direction	The direction of the mean air flow over a given averaging period. The wind direction is expressed between 0 and 360 degrees true (not magnetic) and is the direction from which the wind is blowing. For example, a 90° wind is blowing from the east.
Wind Speed	The wind speed is frequently reported in either kilometres per hour (km/h) or metres per second (m/s) (note: 1 m/s = 3.6 km/h). Wind speeds generally increase with increasing height above the ground because of reduced frictional effects between the air motion and the surface of the earth.
Power Law Exponent	A power-law relationship used to extrapolate wind speeds from a measured level to a level at which no information is available.

Term or Variable	Definition
Surface Roughness	The surface roughness length characterizes the roughness of a surface and forms the boundary layer in dispersion models.
Horizontal Turbulence	The random turbulent motions that produce the crosswind spread of a plume as it moves downwind. The standard deviation of the wind direction provides a measure of the horizontal turbulence. The standard deviation is often expressed as $\sigma\theta$ (sigma theta) in units of degrees.
Vertical Turbulence	The random turbulent motions that produce the vertical spread of a plume as it moves downwind. Vertical spread below the plume centreline results in a plume being brought down to surface. The standard deviation of the vertical wind angle is expressed as $\sigma\phi$ (sigma phi) in units of degrees.
Stability Class	A method of classifying the level of turbulence generation (or suppression) in the atmosphere. Pasquill-Gifford (PG) stability classes range from unstable (Classes A, B and C) through neutral (Class D) to stable (Classes E and F).
Unstable Conditions	Periods when convective turbulence dominates. Unstable conditions are characterized by strong daytime heating and low wind speed conditions.
Neutral Conditions	Periods when mechanical turbulence dominates. Neutral conditions are characterized by high wind speeds.
Stable Conditions	Periods when turbulence is suppressed by the radiation cooling of the earth's surface during the night. Stable conditions are characterized by clear skies and low wind speed conditions. Mechanical turbulence dominates in a layer 5 to 100 m in depth during stable conditions.
Friction Velocity	The friction velocity is representative of turbulence fluctuations in the lowest layer of the atmospheric boundary layer.
Monin-Obukhov Length	This is a scaling parameter based on the comparison of the generation or suppression of thermal turbulence by heating or cooling to the generation of turbulence by mechanical means.
Temperature Gradient	Temperature normally decreases with increasing height above the earth's surface. Temperature gradients are defined as positive for decreasing values with increasing heights and negative for increasing values with increasing heights. The temperature gradient is expressed in units of degrees Kelvin per metre of elevation (K/m). For neutral atmospheric conditions, this rate of cooling is about 1 C° (1 K) for every 100 m in elevation increase (e.g., 0.01 K/m). During unstable conditions, the temperature gradients are greater than 0.01 K/m, (e.g., 0.03 K/m). During stable conditions, the temperature gradients are less than 0.01 K/m (e.g., -0.01 K/m).
Potential Temperature Gradient	A value of 0.01 K/m is used to "normalize" the temperature gradient. Neutral atmospheres are therefore characterized by a potential temperature gradient of 0.0 K/m. Positive potential temperature gradient values correspond to unstable conditions, while negative values correspond to stable conditions.
Net Radiation	Net radiation is defined as the difference between the incoming radiation from the sun and the outgoing radiation from the earth's surface. During the day, net radiation is positive and during the night net radiation is negative. Net radiation provides a measure of the production of convective turbulence during the day and the suppression of turbulence by cooling during the night.
Inversion	A stable atmospheric condition caused when the temperature increases with increasing height above the ground. An elevated inversion can produce a barrier that inhibits vertical dispersion and hence acts as a lid.
Mixing Height	A near-neutral or convective layer near the ground that is capped by an inversion. The mixing height can vary from typical early morning values of <100 m to daytime values of > 1000 m.
Mechanical Turbulence	Turbulence created by the action of the wind blowing over a rough irregular surface. Mechanical turbulence is greatest with a rough surface and high wind speeds.
Mechanical Mixing Height	The turbulent layer that is produced by mechanical interaction of wind with the earth's surface. The mixing height is determined by mechanical processes during the night and during the day when high wind speeds occur.
Convective Turbulence	Turbulence in the atmosphere can be created by the sun heating the earth's surface. Convective turbulence is greatest on a hot summer day.
Convective Mixing Height	The turbulent layer that is produced by convective activity resulting from

Term or Variable	Definition
	daytime surface heating. The mixing height is dominated by convective processes during the day under strong solar heating conditions.
θ or Theta	Wind direction
U	Wind speed
p	Power-law exponent
Z	Height above ground
Z_o	Surface roughness length
Z_m	Mixing height
σ_U or Sigma U	Standard deviation of hourly wind speed
$\sigma\phi$ or Sigma Phi	Standard deviation of wind elevation angle
σ_w or Sigma W	Standard deviation of vertical wind
$\sigma\theta$ or Sigma Theta	Standard deviation of wind direction
U*	Friction velocity
L	Monin-Obukhov length
ψ_m	Stability correction function for momentum
$\partial T/\partial Z$	Temperature gradient
$\partial T/\partial Z + 0.01$	Potential temperature gradient
Z_i	Mechanical mixing layer depth
ϕ or Phi	Latitude
h	Convective mixing height
c_p	Specific heat of air at constant pressure
ρ	Density of ambient air
$\gamma_d = 0.01$ K/m	Adiabatic lapse rate
$\gamma = -\partial T/\partial Z$	Lapse rate
H	Surface heat flux
R_{net}	Net radiation

2.2 MONITORING OVERVIEW

Suncor maintains two comprehensive meteorological monitoring stations that collect enhanced meteorological data in the vicinity of their plant. The stations are named Mannix and Lower Camp, and are located above the Athabasca River valley and on the valley floor, respectively. The Mannix tower is 75 m tall and is instrumented at three levels (20, 45 and 75 m). The Lower Camp station has a 167 m tall tower with instruments at four levels (20, 45, 100 and 167 m). The relative base elevations and heights of the two towers are such that the upper instruments are nearly level with each other (409 metres above sea level [masl] for the Mannix and 412 masl at Lower Camp).

Within the airshed, there are also a series of ambient monitoring stations which collect limited meteorological parameters at heights ranging from 10 to 15 m above the ground. Due to the possibility of localized terrain effects and the limited nature of the data collected at these stations, the meteorological analysis and subsequent dispersion modelling considered only those data collected from the two principal stations in the region. The locations of the monitoring stations are illustrated in Figure 2-1.

2.3 TERRAIN

The path followed by a plume and the turbulence levels that result in the dilution of the plume can be affected by terrain features such as valleys and hills. The magnitude of the terrain effect is dependent on factors such as terrain elevation, the slope of the terrain feature, the relative height of the plume with respect to the terrain and the meteorological conditions.

Step-like terrain features can cause complex recirculating flow patterns in their immediate vicinity, while a valley can generate its own air flow path independent of the regional winds above the valley. In some cases, the plume will flow either around or over dominant terrain features. In extreme cases, the plume may impinge directly on the terrain feature in its path.

Figure 2-2 shows the terrain on a regional scale. The dominant terrain features on a regional scale include:

- The Athabasca River Valley, which has a general north-south orientation in the vicinity of the oil sands plants;
- The Clearwater River Valley, which has a general east-west orientation;
- The highest elevations are associated with the Birch Mountains, which are 50 km to the northwest of the Suncor plant area. At a distance of 75 km to the northwest, these mountains reach an elevation of 820 masl;
- Muskeg Mountain is about 40 km to the east of the plant area. At a distance of 55 km, this mountain reaches an elevation of 665 masl;
- The Thickwood Hills are about 20 km to the southwest of the plant area. At a distance of 25 km, these hills rise to an elevation of 515 masl; and
- Stoney Mountain is about 60 km to the south of the plant area. At a distance of 65 km, this mountain rises to an elevation of 760 masl.

For the purposes of comparison, the base elevation of the Suncor plant stacks is about 259 masl and the base elevation of the Syncrude plant stack is about 304 masl.

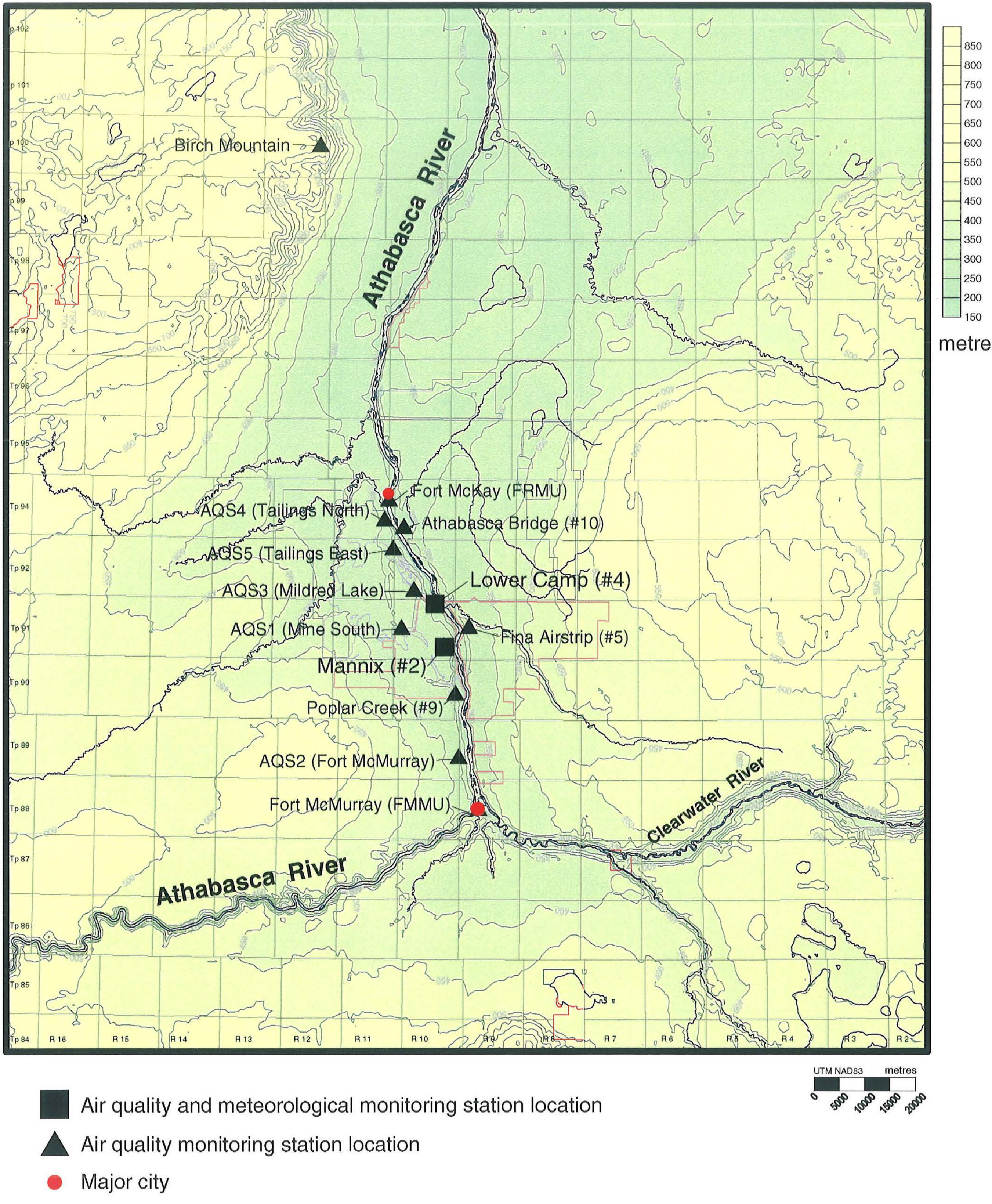


Figure 2-1 Locations of Continuous Air Quality Monitoring Stations

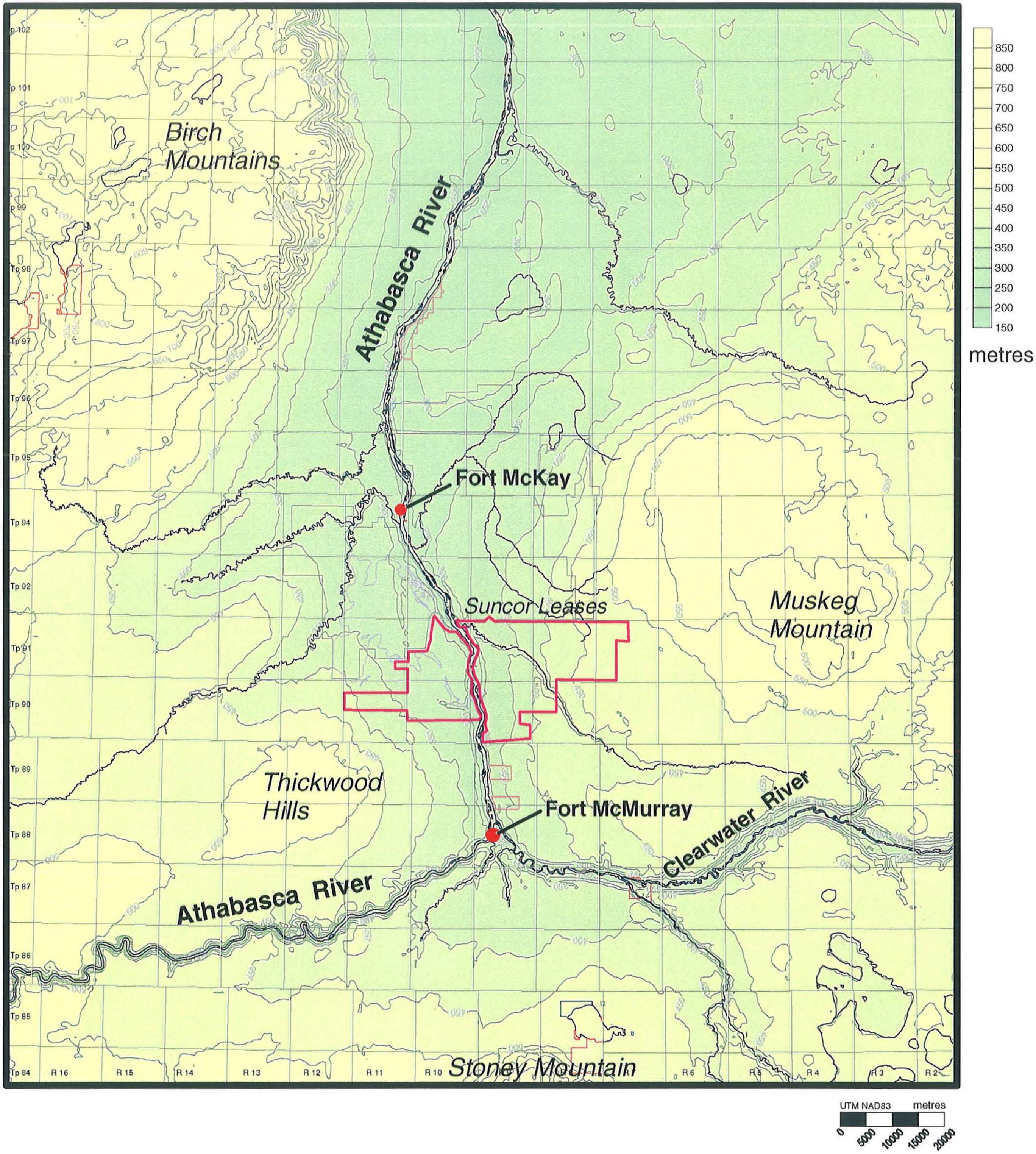


Figure 2-2 Terrain Over the RSA Used in the Air Quality Analysis

The relative roughness of a vegetation canopy affect the wind speed and turbulence profiles. The oil sands area is located in the Boreal Forest Region which supports a variety of upland and lowland vegetation. The area is characterized by forest associations of white spruce, black spruce, jack pine, balsam fir, tamarack, aspen, balsam poplar and white birch.

Mature tree heights range from 10 m for black spruce in low-lying areas to 30 m for jack pine located on sandy soils. Mature white spruce and aspen forest stands tend to be 25 and 15 m in height, respectively. Due to differing soil types and drainage patterns, the vegetation cover is non-uniform within the region.

2.4 SELECTION OF METEOROLOGICAL DATA

Prior to conducting any dispersion modelling analyses it was necessary to identify the most suitable set of data to use in simulating the transport and dispersion throughout the region. Once a data source was selected, the available data had to be subjected to extensive quality assurance and control steps to ensure that the final set of meteorological parameters used in the dispersion models were truly indicative of the observed conditions.

2.4.1 Tower Selection

Meteorological data for use in the dispersion modelling analysis were available from two possible locations in the region. The Mannix and Lower Camp monitoring stations (see Figure 2-1), which have been operated by Suncor for an extended time period, record the hourly data required in the modelling.

The Lower Camp monitoring station is situated in the Athabasca River valley, making it susceptible to local topographic effects. While a comparison of the wind directions and speeds collected at the upper levels of both stations show some agreement over time (BOVAR 1996a), the wind data from the Lower Camp is expected to be more representative of the local in-valley conditions. The Mannix station is located out of the river valley, and is likely to provide data more representative of the wind patterns over the RSA. This is highlighted more fully in Section 2.5.

2.4.2 Anemometer Level Selection

Meteorological data are gathered at three levels at the Mannix station; at elevations of 20, 45 and 75 m above the base of the tower. Discussions with U.S. EPA personnel (Bailey 1998) and review of U.S. EPA guidance documents (U.S. EPA 1995) indicate that when available, wind speeds and directions gathered at the 75 m level are most appropriate for use in simulating plume dispersion because this height is closest to the plume height for the major sources. In addition, the wind parameters measured at the lowest level (i.e., 20 m height) are expected to be influenced by the local tree canopy (Conor Pacific 1998) and, therefore, may not be representative of the winds over the entire RSA. The influence of the local tree canopy is less prevalent for winds measured at the 75 m level.

For the purposes of this assessment, the dispersion modelling analysis was conducted using wind speeds and directions gathered at the 75 m level on the Mannix tower. These winds are considered to be most appropriate for use in the dispersion modelling analysis as they are:

- generally free from the strong river valley influence evident in the data gathered at the Lower Camp station;
- free of the local tree canopy effects which effect the winds at the 20 m level at the Mannix station;
- closest to the plume heights for the major emission sources being evaluated; and
- consistent with previous modelling completed in the region.

2.4.3 Data Period Selection

For the purposes of the air quality modelling analysis, it was necessary to select an extended period of meteorological data that would provide a representative cross section of the conditions to be expected in the region. The data period used for the modelling analysis spanned from November 1993 through to the end of October 1997. This data set covers a full four years of meteorological conditions and includes the most recent data available at the time the assessment was initiated.

2.4.4 Meteorological Data Parameters Utilized

Not all of the meteorological parameters required for use in the dispersion models can be monitored directly with electronic instruments. In these cases, the values were derived from the available measurements.

The wind speeds and directions used for the dispersion modelling analyses were taken from the data collected at the 75 m level on the Mannix tower. Since the models require that the user provide wind vector values, 180° were added to each reading. The methodology used in the models in the assessment cannot deal readily with wind speeds that are less than 1 m/s. In cases where the wind speeds were below this threshold, they were set to a minimum speed of 1 m/s. In situations when the wind speeds or directions were missing at the 75 m level, winds from lower levels on the Mannix tower were used to extrapolate speeds at the 75 m level. This is consistent with U.S. EPA guidance in meteorological processing for use with the air quality models.

One of the important characteristics required by the air quality models that is not available by direct on-site measurement is the mixing height (i.e., the depth of surface layer in which atmospheric mixing of emissions occurs). The mixing height was calculated based on local observations of wind speed and was set to a minimum height of 200 m. A minimum mixing height threshold of 200 m is a reasonable characterization of the meteorology for use in the air quality models based on the ways in which the dispersion models apply the mixing height. These include:

1. Wind speeds below 1 m/s have been truncated to 1 m/s because these calm conditions are not handled by the dispersion models. Mixing heights are calculated based on the maximum of the mechanical or convective mixing heights. The mechanical mixing height is estimated by $Z_m = 200\,U$.

2. If a minimum mixing height is selected that is below the final rise height of the stack plume, increased lofting can occur for point sources. Lofting prevents the plume from reaching the ground, and therefore the model can inadvertently underpredict long-term exposures. In addition, ground level area sources (e.g., pond emissions or fleet vehicle emissions) can become entrapped, and thereby create an arbitrary fumigation (i.e., uniform mixing of the pollutant between the ground and the mixing height, generally resulting in very high concentrations due to the restricted mixing) of the entire RSA. This is an unlikely and unreasonable assumption.

3. Low mixing heights can occur early in the morning when the sun begins to warm air near the ground surface. During this time, atmospheric stability classes change from Class F (or Class E) to Class D. During the change over to Class D (i.e., break up of the stable atmosphere), short periods in time may exist where the mixing height is less than 200 m. It is not reasonable that these low mixing heights would persist in time and spatial extent, because of the boundary layer mixing which would occur with Class D stability and a minimum wind speed of 1 m/s. Whereas on a local scale the observed mixing height could be low to the ground and the wind speeds very small, such that entrapment and fumigation could occur for a short time, the air quality models are not valid during these periods. It would not be reasonable to assume that these conditions would be applicable over the entire RSA.

2.5 WIND

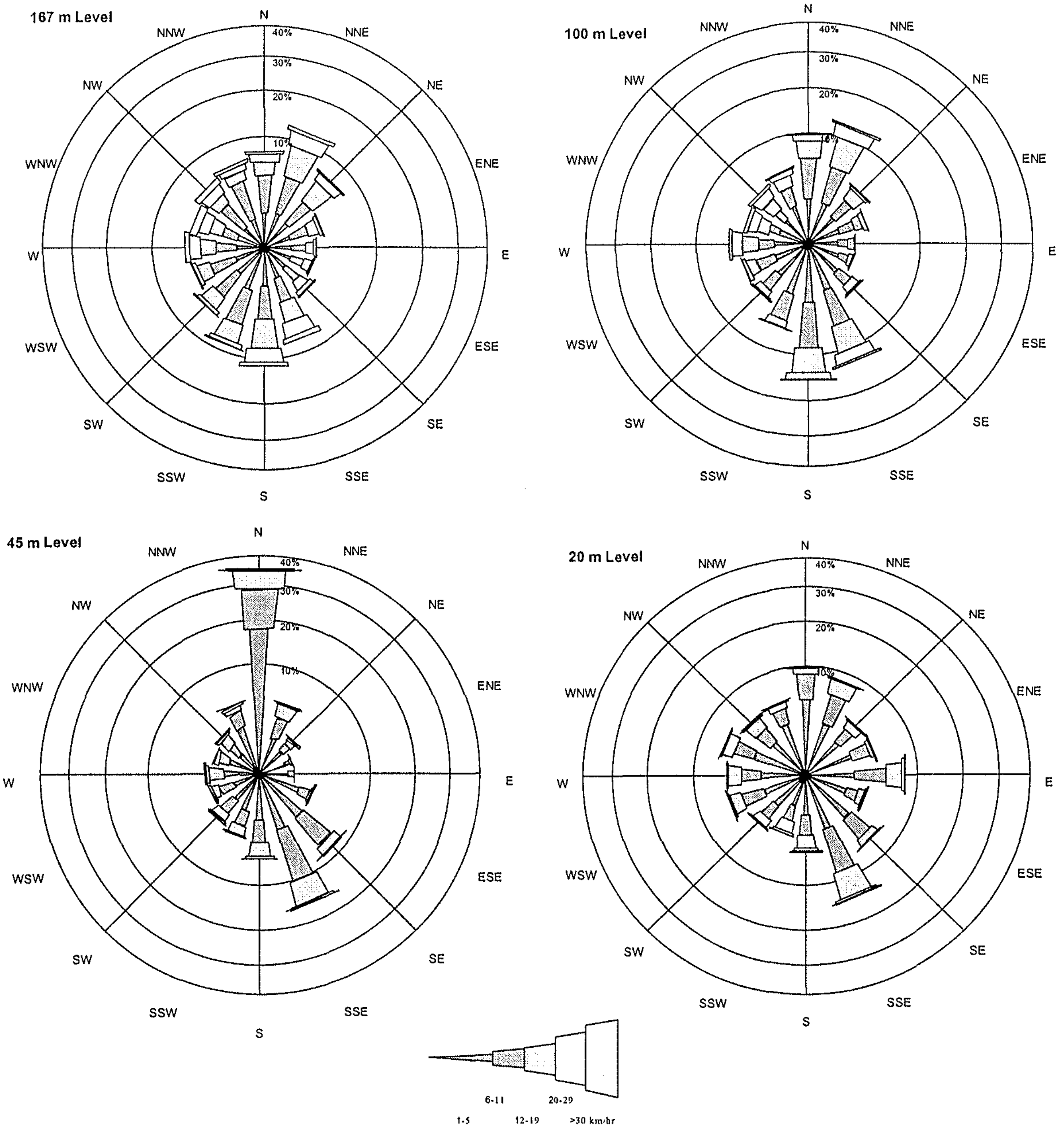
The dispersion and transport of the emissions in the region are controlled primarily by the direction and magnitude of the winds. For the purposes of dispersion modelling, only the Lower Camp and Mannix stations operated by Suncor provide adaquate data.

2.5.1 Wind Direction (θ)

Wind direction was measured at four levels at the Lower Camp monitoring station (i.e., 167, 100, 45 and 20 m) and at three levels at the Mannix monitoring station (i.e., 75, 45 and 20 m). Wind data can be compared by plotting the frequency distribution as a "windrose". Each windrose consists of 16 rays corresponding to winds from a cardinal direction. The length of each ray is broken down into wind speed categories, whose length is proportional to the frequency of time they were observed.

Figure 2-3 and 2-4 illustrate the annual windroses for each of the monitoring levels at the Lower Camp and Mannix stations, respectively. These figures are calculated on the raw monitoring data collected between November 1993 and October 1997, and are illustrative in determining possible data gaps or anomolies. The 45 m level winds at Lower Camp, for example, show a high frequency of north winds. This is anomolous compared to the other levels and may be due to the low data recovery efficiency for this level. The 20 m level winds at Lower Camp show a more even distribution of winds and have a greater frequency of across valley than those at higher elevations. The Mannix windrose diagrams, on the other hand, show a similar pattern of winds at all three levels. The wind speeds tend to increase with increasing hight, which is consistent with expectations. Overall, the Mannix wind data appear to demonstrate none of the highly localized effects which appear to affect the Lower Camp data.

Figure 2-3 Annual Windrose Diagrams for the 167, 100, 45 and 20 m Levels at the Lower Camp Monitoring Station


167 m Level

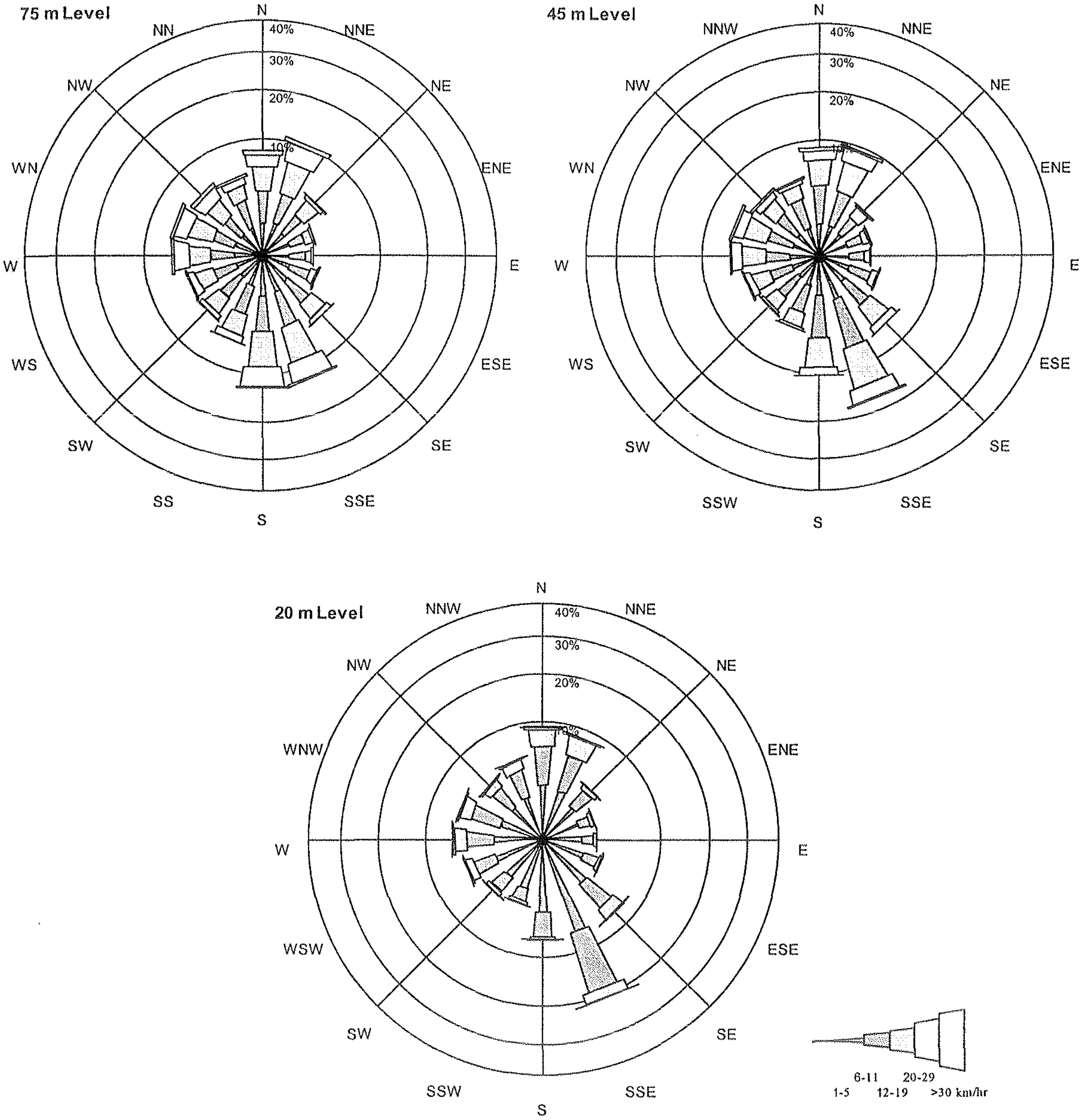
100 m Level

45 m Level

20 m Level

Note: winds blowing from

Figure 2-4 Annual Windrose Diagrams for the 75, 45 and 20 m Levels at the Mannix Monitoring Station



Note: winds blowing from

A review of the major emission sources, combined with the above comparison of Lower Camp and Mannix wind data, confirms that the winds from the upper level of Mannix station are most representative for dispersion modelling over the entire region. These raw data were subjected to rigourous QA/QC procedures to remove any gaps or missing data. This refined data set has been used in the balance of this technical report.

Figures 2-5 and 2-6 present the annual and seasonal windrose diagrams based on the Mannix 75 m level data after the QA/QC proceedures. All of the seasonal windroses show similar frequency patterns to the annual winds. However, during the summer and autumn months there are an increased number of cross valley winds.

2.5.2 Wind Speed (U)

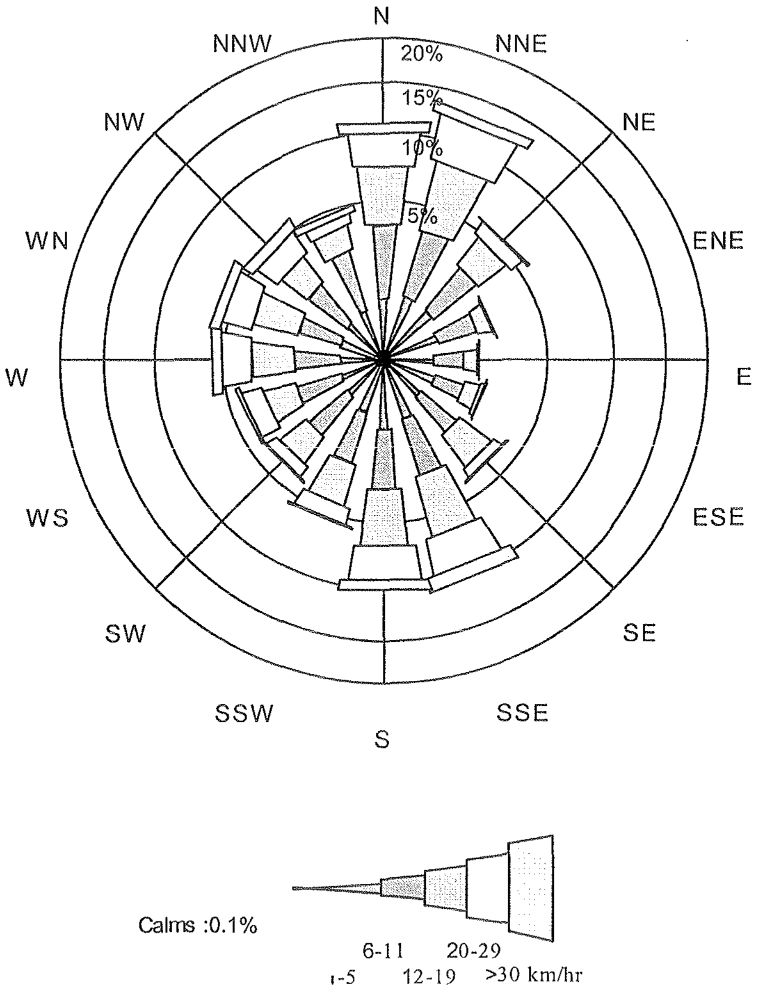
Wind speed is important with respect to plume dispersion for the following reasons:

- The along-wind dilution is proportional to the wind speed;
- The height of the plume above the ground is inversely proportional to the wind speed; and
- Wind flow interaction with surface features creates turbulence.

Figures 2-7 and 2-8 summarize the observed wind speeds at the 75 m level on the Mannix tower. There is minimal month to month variation observed in the average speeds at the 75 m level (Figure 2-7), however, slightly higher average speeds were observed in the spring and autumn months. Similarly, there is little in the way of diurnal variations in the winds at this level (Figure 2-8). Generally, the wind speeds increased gradually from the mid day low speeds to the higher observed speeds at night.

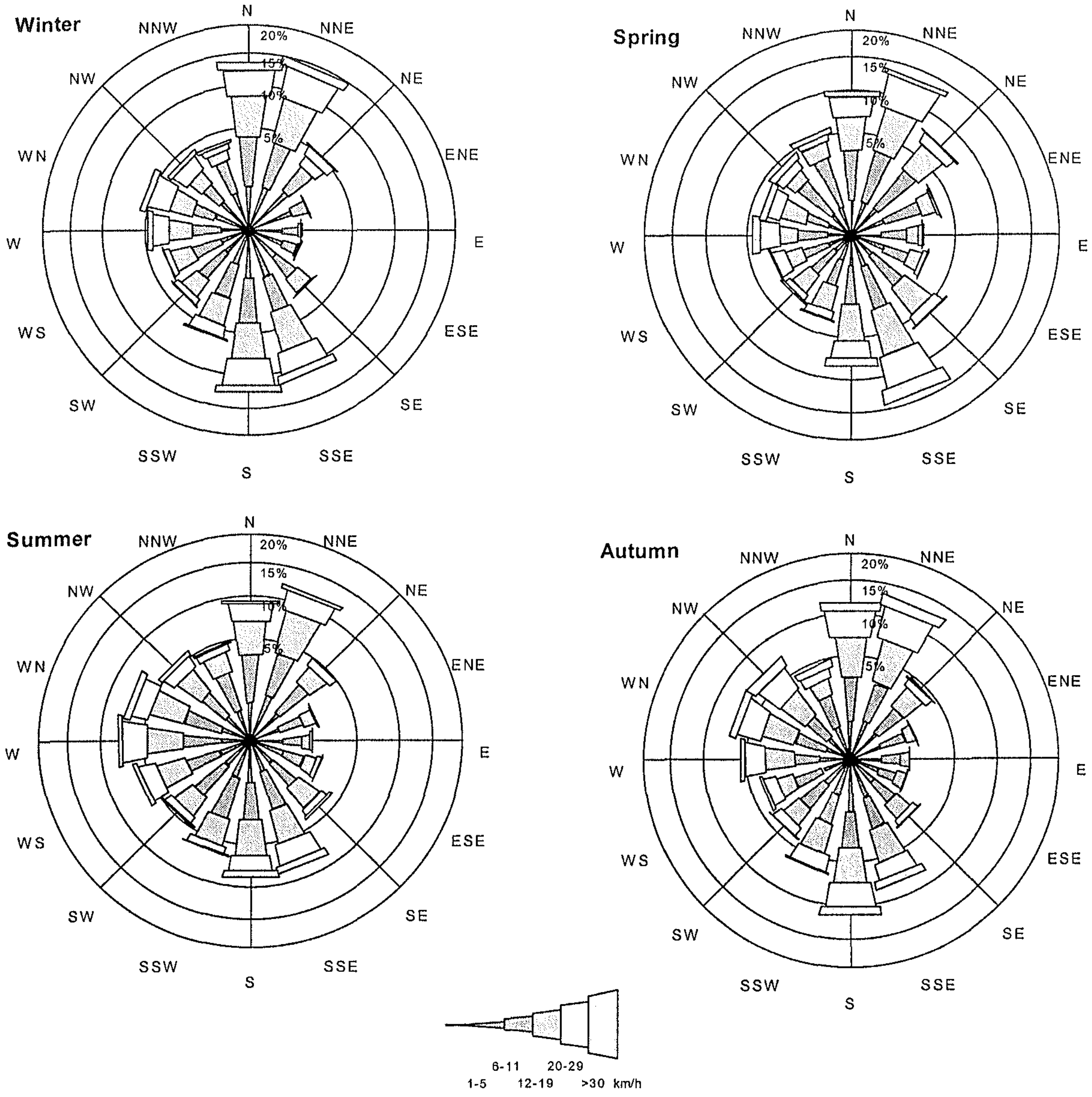
In comparison, the wind speeds at the 20 m level on the Mannix tower are summarized in Figures 2-9 and 2-10. The difference between the spring and autumn wind speeds and the lower speeds during the summer and winter are more pronounced at the 20 m level. The 20 m wind speeds also demonstrate a diurnal pattern, increasing from late morning to a high in the middle of the afternoon.

Figure 2-5 Annual Windrose for the Mannix 75 m Level



Note: winds blowing from

Figure 2-6 Seasonal Windroses for the 75 m Level Winds at Mannix



Note: Winds blowing from

Figure 2-7 75 m Wind Speeds Observed at the Mannix Monitoring Station as a Function of Month

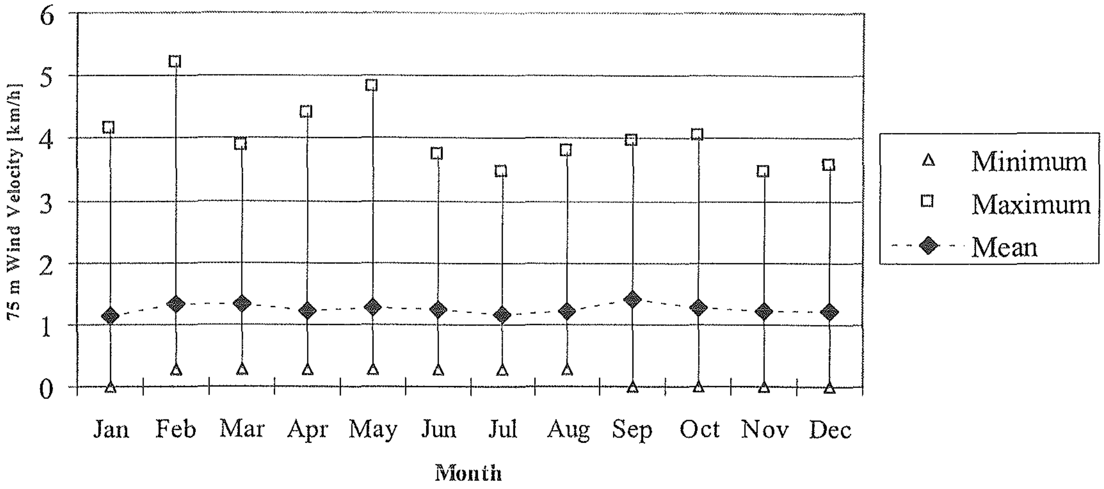


Figure 2-8 75 m Wind Speeds Observed at the Mannix Monitoring Station as a Function of Hour

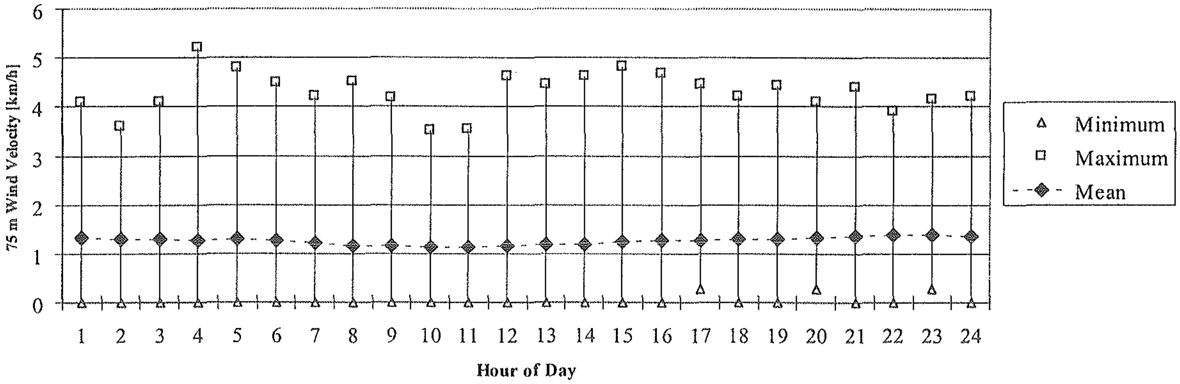


Figure 2-9 **20 m Wind Speeds Observed at the Mannix Monitoring Station as a Function of Month**

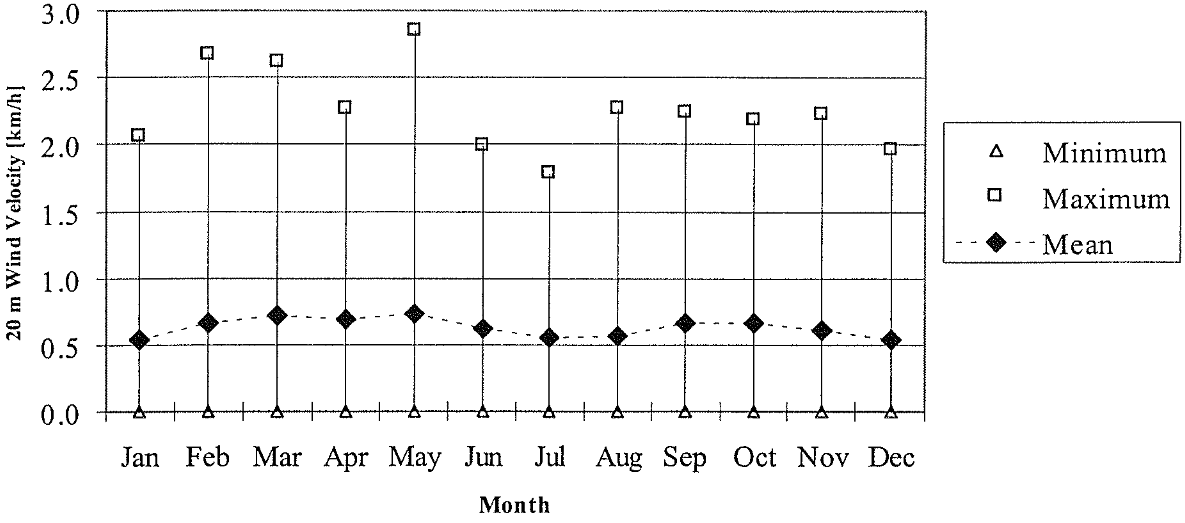
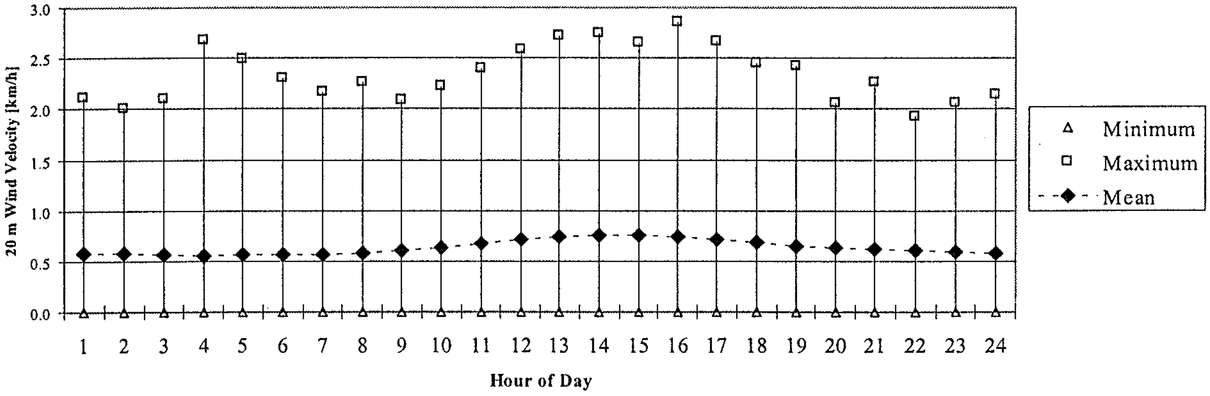


Figure 2-10 **20 m Wind Speeds Observed at the Mannix Monitoring Station as a Function of Hour**



2.5.3 Power Law Exponent (p)

A power-law relationship is frequently used to extrapolate wind speeds from a measured level to a level at which no measurement is available. This relationship may be approximated using the following formula:

$$U_Z = U_R \left(\frac{Z}{Z_R} \right)^p$$

where: U_Z = the wind speed at an arbitrary height (Z)

U_R = the wind speed at a reference height (Z_R)

p = the power-law exponent.

The power-law exponent (p) is a best fit value and is dependent on atmospheric stability, surface roughness and height above the ground. The value of p typically ranges from 0.1 on a sunny afternoon to 0.6 during a cloudless night (U.S. EPA 1987).

Rearranging the preceding equation to solve for p gives the following formulation:

$$p = \frac{\ln(U_h) - \ln(U_l)}{\ln(Z_h) - \ln(Z_l)}$$

where:

- the subscript $_h$ refers to the higher of the two levels
- the subscript $_l$ refers to the lower of the two levels.

The preceding relationship was used to calculate power-law exponents for the Mannix data. The calculations were performed using wind speeds ≥ 1 m/s (3.6 km/h) at the Mannix 75 and 20 m levels. The wind profiles vary from hour to hour throughout the year, however, overall average values were derived and used as inputs into the dispersion models. The range of wind profiles determined from the observed wind speeds at 20 and 75 m are presented graphically in Figures 2-11 and 2-12.

Figure 2-11 **Wind Speed Profiles Derived From Observations at the Mannix Monitoring Station as a Function of Month**

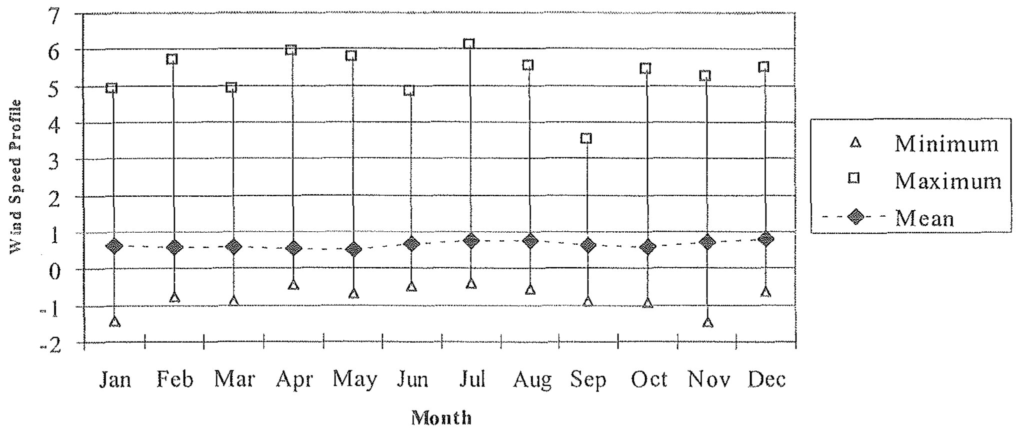
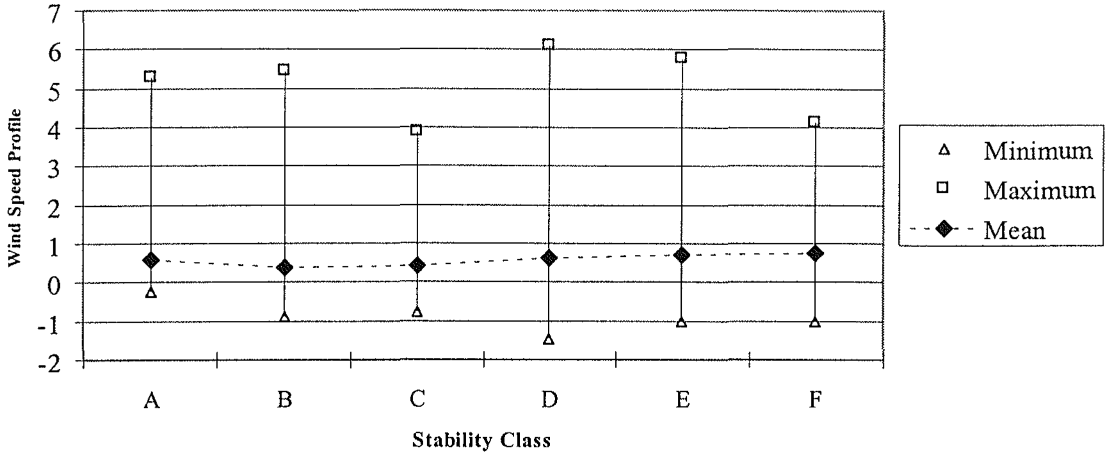


Figure 2-12 Wind Speed Profiles Derived From Observations at the Mannix Monitoring Station as a Function of Stability



The on-site p values generated from the hourly data have been compared to the default values used in regulatory models (U.S. EPA 1987, Alberta Environment 1992) for each PG stability class in Table 2-2.

Table 2-2 Wind Profile Exponents Derived from the Mannix Tower Data

Stability Class	Calculated Values Mannix 20 to 75 m	Default Model Ranges
A	0.28	0.05 to 0.17
B	0.28	0.06 to 0.17
C	0.30	0.06 to 0.20
D	0.44	0.12 to 0.27
E	0.59	0.30 to 0.38
F	0.46	0.30 to 0.61

Although the on-site p values fall within the typical range mentioned earlier (0.1 to 0.6), some values tend to be higher than those used in regulatory models. This may be due to the following:

- The model default p values were derived based on tower data over flat terrain with a lower surface roughness than at Lower Camp and Mannix; and
- Tree canopy and/or terrain effects at Mannix could cause a steeper wind speed gradient than at Lower Camp.

2.5.4 Surface Roughness Length

The aerodynamic surface roughness length (Z_0) characterizes the roughness of a surface and forms the lower boundary in dispersion models. In theory, the roughness length is the height at which the wind speed is zero. The effective roughness length may be determined using the gustiness, which is calculated as the ratio of variations in wind speed divided by the average wind speed (U.S. EPA 1987). The relationship between gustiness and the surface roughness is set out in the following formula:

$$Z_0 = Z_R \exp\left(-\frac{\overline{U}}{\sigma_U}\right)^p$$

where:

Z_o = surface roughness length
Z_R = reference height
σ_U = standard deviation of the wind speed at Z_R
$\overline{U}$ = mean wind speed at Z_R

For the purposes of the dispersion modelling assessment, Z_o was calculated for neutral conditions (i.e., D stability class), using the wind speeds close to the surface (i.e., 20 m). The overall resultant surface roughness length was calculated to be 1.2 m.

2.6 TURBULENCE

2.6.1 Horizontal Turbulence

Horizontal turbulence is responsible for the cross-wind spreading of a plume released into the atmosphere. A measure of the horizontal turbulence is the standard deviation of the wind direction (sigma theta or σ_θ). When collected close to the surface (i.e., 20 m) the σ_θ value provides a reasonable measure of the turbulence.

Figures 2-13 and 2-14 illustrate the variation of the measured horizontal turbulence as a function of stability class and wind speed, respectively. The figures illustrate that the horizontal turbulence is greatest during the unstable classes and diminishes with increasing stability. In a similar manner, the greatest variation in the horizontal wind direction corresponds with low wind speeds.

Figure 2-13 Variation of Horizontal Wind Direction (σ_θ) Observed at the Mannix Monitoring Station as a Function of Stability Class

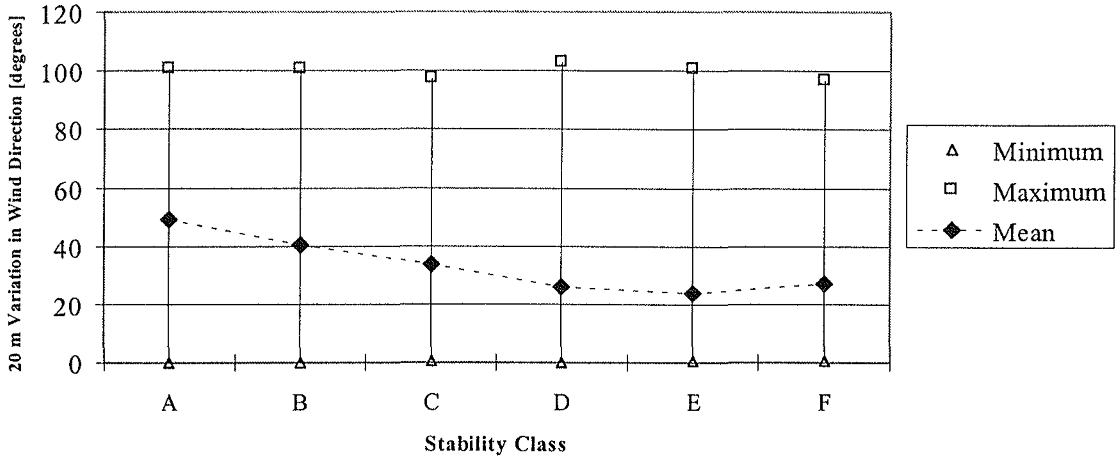
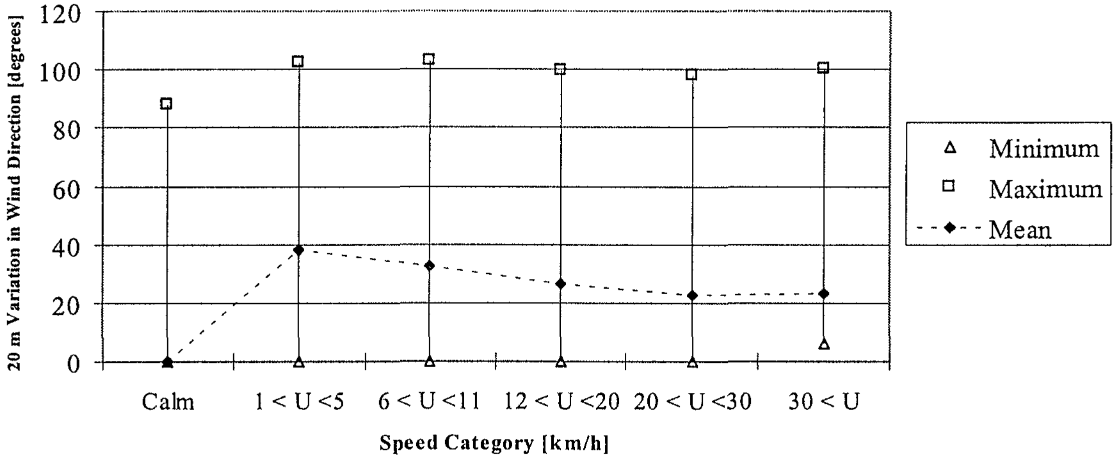


Figure 2-14 Variation of Horizontal Wind Direction (σ_θ) Observed at the Mannix Monitoring Station as a Function of Wind Speed Class



2.6.2 Vertical Turbulence

Vertical turbulence is responsible for the vertical spreading of a plume released into the atmosphere. One measure of the vertical turbulence is the standard deviation of the wind angle, or wind declination (sigma phi or $\sigma\phi$). The $\sigma\phi$ values can be calculated using the following simple relationship:

$$\sigma_\phi = \left(\frac{180}{\pi}\right)\tan^{-1}\left(\frac{\sigma_W}{U}\right)$$

where:

σ_w = the standard deviation of the vertical wind speed;

U = the horizontal wind speed; and

$180/\pi$ = converts values from radians to degrees.

Figures 2-15 and 2-16 illustrate the variation of $\sigma\phi$ with respect to stability class and wind speed for the Mannix stations, respectively. The diagrams show that the highest $\sigma\phi$ values tend to be associated with unstable conditions and low wind speeds.

Figure 2-15 **Variation of Sigma Phi (σ_ϕ) With Respect to Stability Class for the Mannix Station**

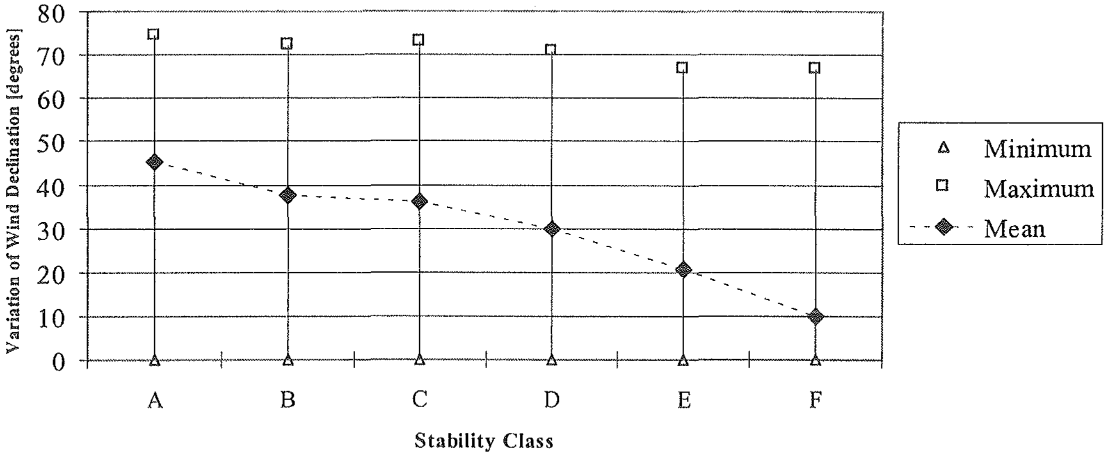
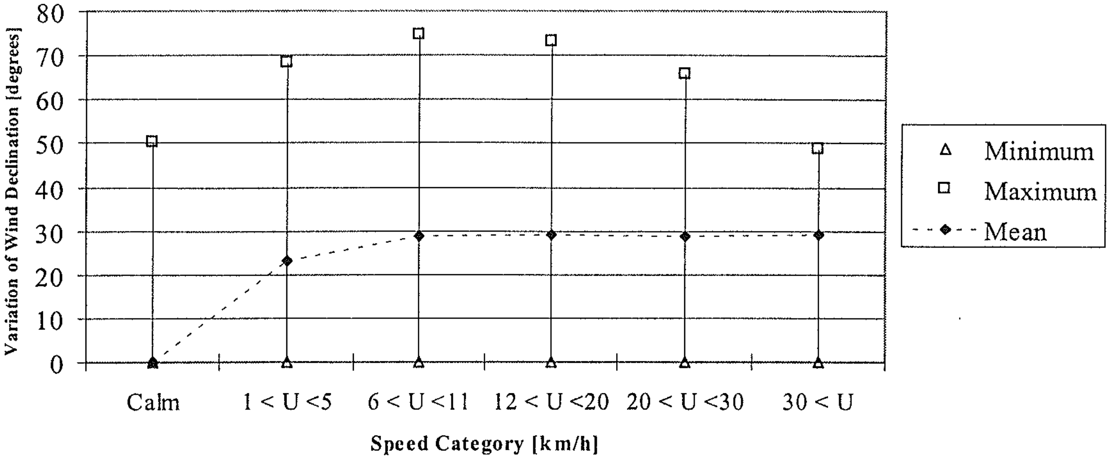


Figure 2-16 Variation of Sigma Phi (σ_ϕ) With Respect to Wind Speed Class at the Mannix Station



2.6.3 Stability Class

A series of simplified schemes have been widely adopted for describing the amount of turbulence present in the atmosphere. The most common of these are the Pasquill-Gifford (PG) stability classes which range from Unstable (Stability Classes A, B and C) through Neutral (Stability Class D) to Stable (Stability Classes E and F). Unstable conditions are primarily associated with sunny daytime hours when surface heating results in enhanced turbulence near the surface. Stable conditions typically occur during the night-time when cooling which results in suppressed turbulence levels. The neutral conditions are typically associated with cloudy conditions when heating or cooling is restricted. These hours also correspond to conditions with relatively high wind speeds.

A number of methodologies have been put forward to relate meteorological observations to the Pasquill-Gifford stability classes. The schemes recommended by the U.S. EPA (1987) include the following:

- The Turner (1964) scheme which uses routine airport observations of wind speed and cloud cover;
- The solar radiation and delta temperature (SRDT) method. This is a derivation of the solar radiation and wind speed method proposed by Bowen et al. (1983);
- The standard deviation of the vertical wind angle (σ_ϕ); and
- The standard deviation of the wind direction (σ_θ).

Although not recommended by the U.S. EPA, the temperature gradient method ($\delta T/\delta Z$), based on temperature measurements from the upper and lower tower observations (U.S. NRC 1972) is also available for classifying stability. This method is useful for determining whether the conditions are stable or unstable, but cannot be readily applied for determining individual Pasquill-Gifford classes (Coulter 1994).

For the modelling assessment, the stability classes were determined using the standard deviation of the vertical wind angle ($\sigma\phi$) methodology. The method made use of the surface winds at Mannix (i.e., 20 m level) and a day/ night determination was made using the local sunrise and sunset times.

Tables 2-3 and 2-4 present the criteria used for the $\sigma\phi$ method. Adjustments were made to the stability class schemes to account for the actual observation height (20 m) and local surface roughness (1.2 m) in accordance with U.S. EPA guidance (1987).

Table 2-3 Initial Criteria Used to Determine Pasquill-Gifford Stability Classes Based on Observed $\sigma\phi$ (degrees)

Observation Height (m) Surface Roughness (m)	10[a] 0.15	20[b] 1.2
A	> 11.5	> 17.7
B	10.0 to 11.5	15.6 to 17.7
C	7.8 to 10.0	11.9 to 15.6
D	5.0 to 7.8	6.9 to 11.9
E	2.4 to 5.0	2.9 to 6.9
F	< 2.4	< 2.9

[a] Criteria recommended by U.S. EPA for an observation height of 10 m and a surface roughness of 0.15 m.

[b] Criteria adjusted for a 20 m observation height and a 1.2 m surface roughness. These criteria were applied to the Suncor Mannix observations.

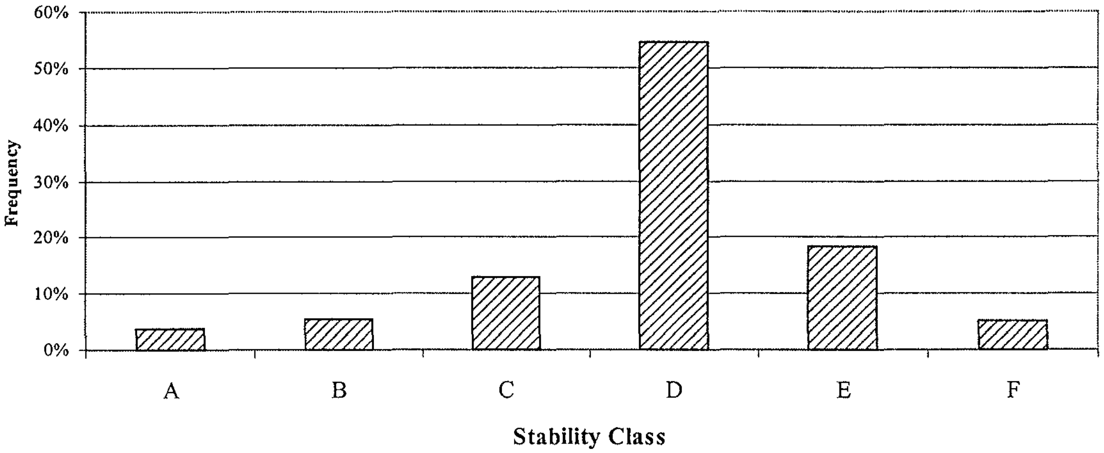
Figure 2-17 illustrates the variation of Pasquill-Gifford stability classes derived from the observations at the Mannix tower.

Table 2-4 **Wind Speed Adjustment to the Initial Pasquill-Gifford Stability Classes Based on Observed σ_ϕ (degrees)**

Observation Height (m)	Initial P-G Stability Class Estimate	Wind Speed	Final P-G Stability Class[a]
Daytime	A	$U < 3$	A
	A	$3 \le U < 4$	B
	A	$4 \le U < 6$	C
	A	$6 \le U$	D
	B	$U < 4$	B
	B	$4 \le U < 6$	C
	B	$6 \le U$	D
	C	$U < 6$	C
	C	$6 \le U$	D
	D, E and F	ANY	D
Nighttime	A	ANY	D
	B	ANY	D
	C	ANY	D
	D	ANY	D
	E	$U < 5$	E
	E	$5 \le U$	D
	F	$U < 3$	F
	F	$5 \le U < 5$	E
	F	$5 \le U$	D

[a] Stability classes cannot vary by more than 1 stability class from one hour to the next.

Figure 2-17 **Frequency of Pasquill-Gifford Stablity Classes Observed at the Mannix Monitoring Station**



2.6.4 Similarity Parameters (U*, L)

Some dispersion models require additional similarity parameters to assist in characterizing the velocity fluxes and turbulence. The two most frequent of these similarity parameters are the friction velocity (U*), and the Monin-

Obukhov length (L). These parameters are discussed below, along with a description of the methodologies used to determine them from the observations made at the Mannix station.

With characteristic velocity based on surface stress, the value U* is representative of the turbulent fluctuations in the lowest layer of the atmospheric boundary layer. Other models require the Monin-Obukhov length (L) as a measure of stability.

2.6.4.1 Monin-Obukhov Length

The Monin-Obukhov length (L) is a scaling length which compares the amount of thermal turbulence to the turbulence generated by mechanical means. Negative values of L are associated with unstable atmospheres and positive values are associated with stable atmospheres. Large values of (L) (greater than 100 m) are associated with atmospheres in which almost all of the ground-level turbulence is generated by mechanical means.

The Monin-Obukhov lengths (L) used for the modelling assessment were calculated in accordance with the method outlined in the Alberta Environment ADEPT2 Users' Guide (Alberta Environment 1992). In this method, the Monin-Obukhov length is determined as a function of turbulence and roughness length as indicated in the following equation:

$$L = \frac{1}{aZ_0^b}$$

where:

L = Monin-Obukhov length
Z_0 = Surface roughness length

The "a" and "b" constants were derived by Liu and Durran (1977) and vary as a function of stability class. The median surface roughness length estimated for the Mannix station was 1.2 m. The following table presents the "a" and "b" constants in conjunction with the Monin-Obukhov lengths (L) calculated for the Suncor data.

Table 2-5 Calculated Monin Obukhov Lengths, Based on Local Surface Roughness Characteristics

Stability Class	a	b	L
A	-0.1135	-0.1025	-9
B	-0.0385	-0.1710	-27
C	-0.0081	-0.3045	-131
D	0	-0.5030	±∞
E	0.0081	-0.3045	131
F	0.0385	-0.1710	27

2.6.4.2 Friction Velocity

The friction velocities (U*) were calculated according to the following equation (Alberta Environment 1992):

$$U^* = \frac{k \times U}{\ln\left(\frac{Z_R}{Z_o}\right) - \Psi m}$$

where:

U* = Friction velocity
k = Von Karman's constant (k = 0.4)
U = Wind speed (m/s) at reference height Z_R (Z_R = 20 m)
Z_o = Surface roughness (Z_o = 1.2 m)
ψ_m = Correction function for momentum
L = Monin-Obukhov length

The stability correction functions for momentum (ψ_m) were calculated using the equations listed in Table 2-6.

Table 2-6 Stability Correction Term (Ψm) Used in the Determination of Monin Obukhov Lengths

Stability Class	ψ_m
Unstable (A, B, C)	$\exp\left\{0.032 + 0.448 \times \ln\left(\frac{-Z_R}{L}\right) - 0.132 \times \left[\ln\left(\frac{-Z_R}{L}\right)\right]^2\right\}$
Neutral (D)	0
Stable (E, F)	$\frac{-5Z_R}{L}$

For this assessment, the preceding U* equation may be simplified to the following:

$$U^* = c \times U$$

where:

$$c = \frac{0.4}{\ln(20) - \psi_m}$$

2.7 TEMPERATURE

2.7.1 Ambient Temperature

The temperature in the oil sands region area is typical of that found in a northern continental region and is characterized by cool summers and long cold winters, with short spring and fall transition periods.

Temperatures observed from November 1, 1993 through October 31, 1997 compare well with the ambient temperature normals collected at Fort McMurray between 1961 and 1990 (Atmospheric Environment Service 1995). The mean monthly temperature ranges from -19.7°C in January to 18.0°C in July. At the Fort McMurray Airport, the mean monthly temperature ranges from -19.8°C in January to 16.6°C in July.

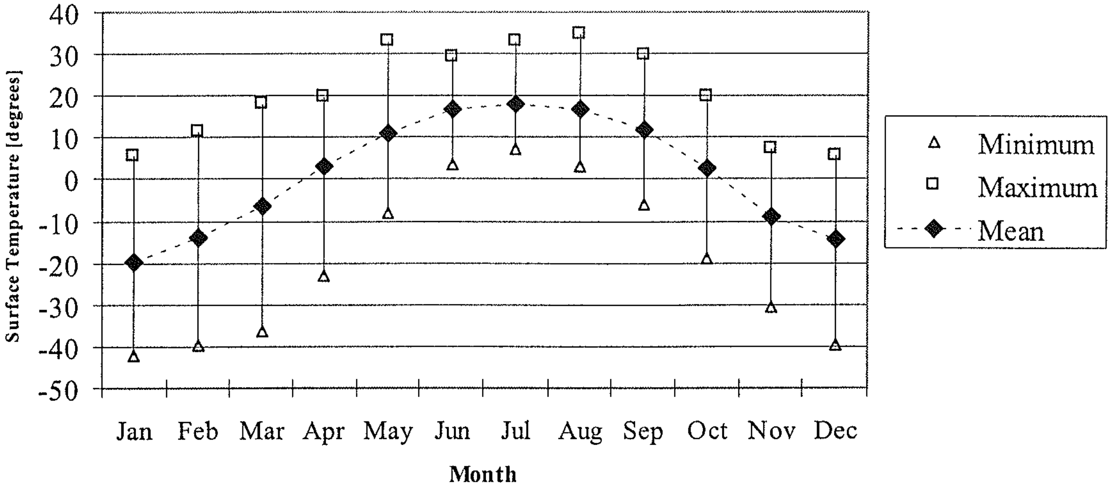
Table 2-7 compares the mean seasonal and annual temperature observed at Mannix and the Fort McMurray Airport during the monitoring periods outlined previously:

Table 2-7 **Comparison of Seasonal Temperatures Observed at the Mannix Monitoring Station and Fort McMurray Airport**

Season	Temperature °C	
	Mannix	Fort McMurray Airport
Winter	-15.3	-17.3
Spring	2.5	1.7
Summer	17.1	15.5
Fall	1.1	1.1
Annual	1.3	0.2

Figure 2-18 presents the mean and extreme temperatures observed at the Mannix monitoring stations from November 1, 1993 to October 31, 1997.

Figure 2-18 **Mean and Extreme Temperatures (°C) Observed at the Mannix Monitoring Station From November 1, 1993 to October 31, 1997**



2.7.2 Potential Temperature Gradient (∂T/∂Z + 0.01 K/m)

The temperature gradient indicates the change in temperature with respect to the difference in monitoring height above ground. The potential temperature gradient is equivalent to the temperature gradient (∂T/∂Z) plus the adiabatic lapse rate (0.01 K/m).

The temperature gradient or the potential temperature gradient can be related to the stability of the atmosphere. The relationship between these gradients and stability is dependent on the height and vertical spacing of the temperature sensors. For the purposes of display, potential temperature gradients less than -0.01 K/m were arbitrarily assumed to be associated with unstable atmospheric conditions. Similarly, values greater than +0.01 K/m were assumed to be associated with stable conditions. Potential temperature gradient values nearly equal to 0 K/m (i.e., ≥ -0.01 K/m and ≤ 0.01 K/m) were assumed to be associated with neutral atmospheric conditions.

Figures 2-19 and 2-20 illustrate the seasonal potential temperature gradients for the Mannix station for $\Delta T_{75\ \text{to}\ 20\ \text{m}}$. For the most part, the temperature gradients indicate a trend for stable conditions (i.e., positive values) at night moving to less stable conditions during the day. The information presented, however, tends6 to suggest a bias towards stable conditions.

Figure 2-19 **Seasonal Variation of Potential Temperature Gradients (K/m) Observed at the Mannix Monitoring Station for $\Delta T_{75\text{ to }20\text{ m}}$**

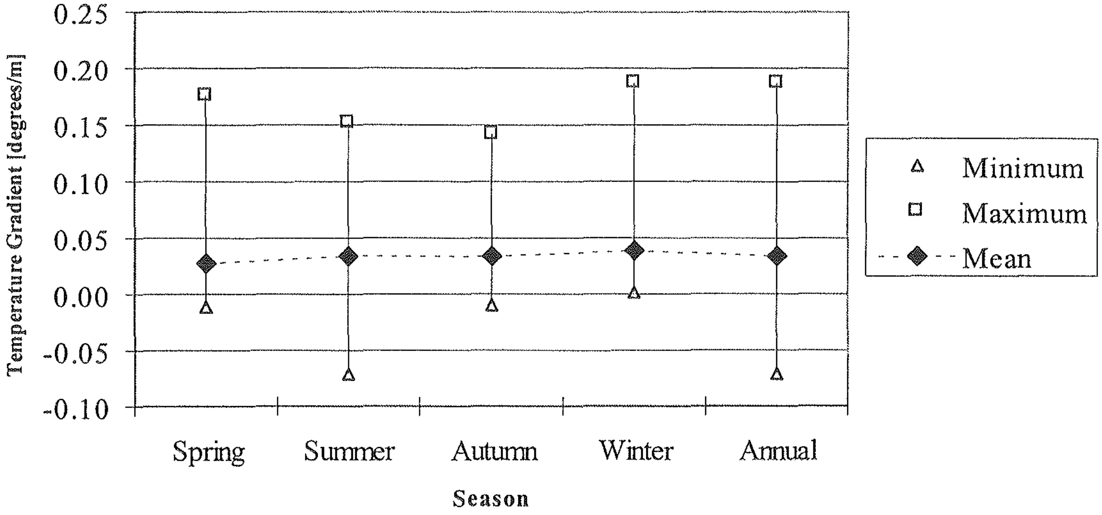
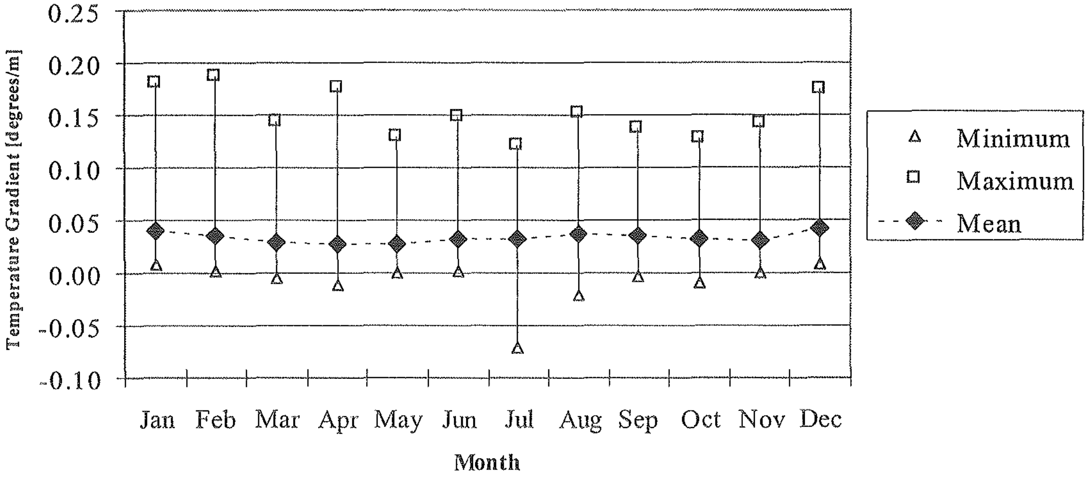


Figure 2-20 **Monthly Variation of Potential Temperature Gradients (K/m) Observed at the Mannix Monitoring Station for $\Delta T_{75\text{ to }20\text{ m}}$**



2.8 NET RADIATION AND MIXING HEIGHT

2.8.1 Incoming Solar Radiation

The stability of the atmosphere is driven by the heating and cooling of the surface. Solar radiation is the primary means of energy input, however, this parameter was not measured directly at the Mannix station. The monitoring program did include the collection of the net radiation which is the incoming solar radiation less the reflected radiation. The dispersion models used in the assessment to calculate the chemical transformations require the incoming solar radiation, not the net radiation. Therefore, this parameter had to be calculated. The formulation used for this calculation followed the procedures specified in the PCRAMMET model (U.S. EPA 1993). The methodology combined the observed cloud cover at Fort McMurray airport with the solar elevation angle.

Figures 2-21 and 2-22 summarize the seasonal and monthly values of incoming solar radiation derived from observations at the Fort McMurray airport.

Figure 2-21 Seasonal Variation of Incoming Solar Radiation (W/m^2)

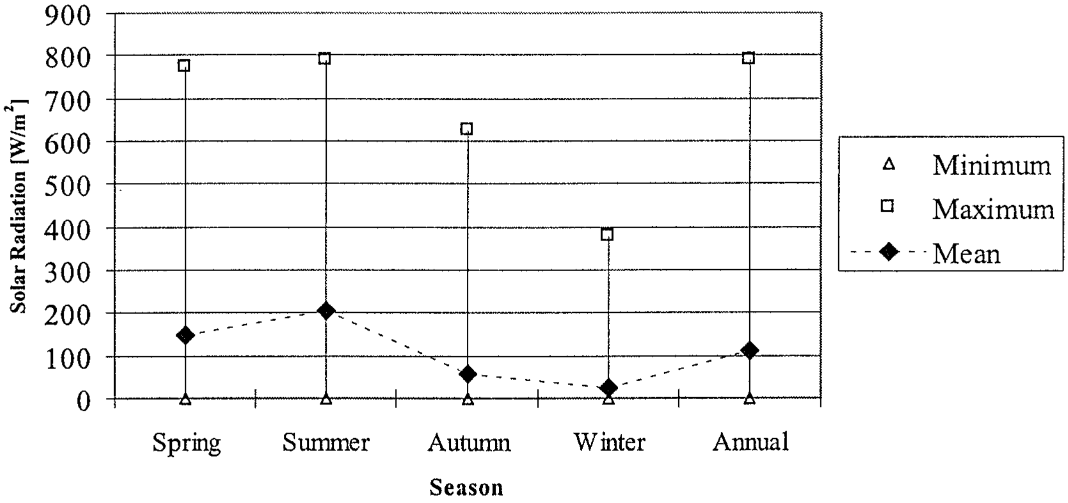
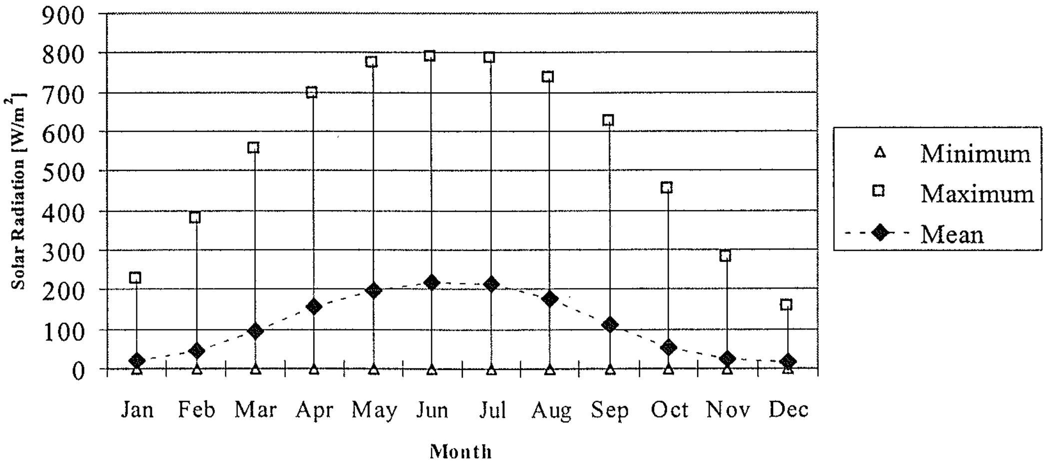


Figure 2-22 Monthly Variation of Incoming Solar Radiation (W/m^2)



2.8.2 Mixing Height

When the lapse rate changes at some height above the ground from the positive to negative, an artificial ceiling is created which is known as an inversion. An inverstion creates a two-layered atmosphere. The lower layer is well-mixed and is characterized by neutral or unstable conditions. The depth of this lower layer is referred to as the mixing height. The upper layer tends to be characterized by stable conditions. The vertical transfer of mass between these two layers is typically minimal.

2.8.2.1 Mechanical Mixing

During the night or under overcast conditions, the mixing layer is determined by mechanical interactions of wind with surface features. The mixing layer depth is related to wind speed through the following theoretical relationship:

$$Z_i = \frac{a\,U^*}{f}$$

where:

Z_i = mechanical mixing layer height
a = constant that has been reported to range from 0.15 to 0.30
U^* = friction velocity
f = Coriolis force, $2\,\Omega \sin \phi$
Ω = $7.29 \times 10^{-5}\ s^{-1}$
ϕ = latitude (57°)

For neutral conditions U^* is given by:

$$U^* = \frac{0.4\,U_z}{\ln\left(Z/Z_o\right)}$$

where:

U_z = wind speed at height Z
Z_o = surface roughness length

These two relationships can be combined to produce a single expression for Z_i:

$$Z_i = \frac{a\,0.4}{2\,\Omega \sin \ \ln\left(Z/Z_o\right)} U_z$$

$$= \frac{3271\,a}{\ln\left(Z/Z_o\right)} U_z$$

For this assessment, the 20 m level wind speeds from Mannix were used in the analysis (i.e., Z = 20 m) with a surface roughness length of 1 m. The equation therefore reduces to the following:

$$Z_i = 1092\ a\ U_{20}$$

where: U_{20}= the three hour centre average 20 m level wind speed (m/s) at Mannix.

The multiplier "1092 a" ranges from 164 to 327, depending on the value of "a" selected. Benkley and Schulman (1979) specifically recommend a value for "a" of 0.185 which corresponds to a multiplier of 202. Therefore, for this assessment, the following relationship was used to estimate mechanical mixing heights:

$$Z_i = 200\ U_{20}$$

2.8.2.2 Convective Mixing

During summer conditions, surface heating will produce a well-mixed layer. A simplified expression for predicting the convective mixing height is as follows:

$$h = \left[\frac{2}{c_p\ \rho\left(\gamma_d - \gamma\right)} \int_{t_o}^{t} H\ dt \right]^{1/2}$$

where:

h = convective mixing height (m)
c_p = specific heat of air at constant pressure (1005 J/kg K)
ρ = ambient density of air (kg/m^3)
γ_d = adiabatic lapse rate
γ = lapse rate at sunrise
H = surface heat flux (W/m^2)

From a simplified perspective, the surface heat flux can be assumed to be directly proportional to the net radiation. This assumption ignores latent heat and ground effects. An empirical relationship was used to relate the mean afternoon mixing height values to net radiation. Table 2-8 shows the mixing height values and accumulated net radiation values for Stony Plain, Norman Wells and Whitehorse. The best mathematical fit between these two parameters as described by the following:

$$Z_i = 512\,(R_{net})^{0.527}$$

Given the assumed equivalency between R_{net} and $\int_{t_0}^{t} H\,dt$, it is comforting that the empirical exponent is approximately equal to 0.5.

Table 2-8 Data Used in the Estimation of Convective Mixing Heights for Accumulated Net Radiation

	Mixing Heights (m)[a]			Accumulated Net Radiation (MJ/m^3)[b]		
Month	**Edmonton Stony Plain**	**Norman Wells**	**Whitehorse**	**Edmonton Stony Plain**	**Norman Wells**	**Whitehorse**
January	227	155	182	-	-	-
February	295	247	329	0.635	-	-
March	696	474	936	2.231	-	-
April	1578	812	1588	8.516	-	5.211
May	2396	1237	2019	11.020	10.279	9.936
June	2185	1555	2366	11.891	11.592	10.893
July	1954	1448	1841	11.926	10.666	9.957
August	1563	1117	1761	9.993	7.404	7.861
September	1322	758	1205	6.234	3.646	4.500
October	998	355	760	3.140	0.497	1.301
November	420	180	290	0.641	-	-
December	208	135	190	-	-	-

(a) Mean maximum afternoon mixing height. From Table B1 in Portelli (1977).

(b) Only positive values are accumulated. From Pages 1-38, 44 and 48 in Phillips and Aston (1980).

2.8.2.3 Summary

The mechanical mixing height can be estimated from the relationship:

$$Z_i = 200\,U_{20}$$

where: U_{20} = the three hour centre average 20 m level wind speed (m/s) at Mannix.

The convective mixing height can be estimated from the relationship:

$$Z_i = 512\,(R_{net})^{0.527}$$

where: R_{net} is the net accumulated value of positive radiation since sunrise.

For an individual hour, the mixing height is taken as the maximum of the mechanical and convective values.

2.8.2.4 Calculated Mixing Heights

The mixing heights based on the Mannix 20 m level wind speed and the net radiation observations were calculated using the methods described in the previous sections. Figures 2-23 and 2-24 shows the monthly and diurnal variation of the calculated mixing heights. The largest average mixing heights are associated with afternoon, spring and summer hours. These values are in the 1,600 to 2,000 m range. During the night and in the winter, the average mixing height values tend to be in the 400 to 500 m range.

Figure 2-23 Monthly Variation in Mixing Heights for Mannix Monitoring Station

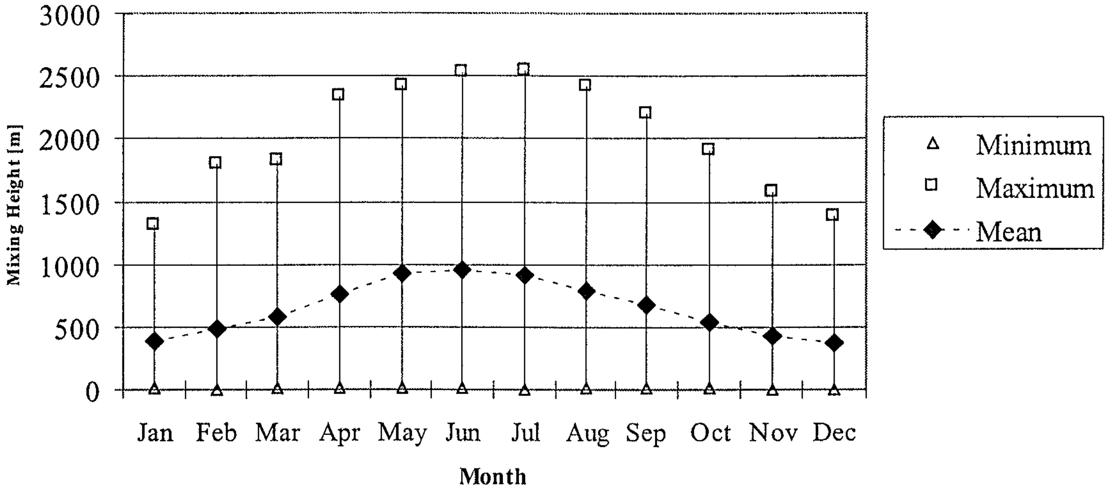
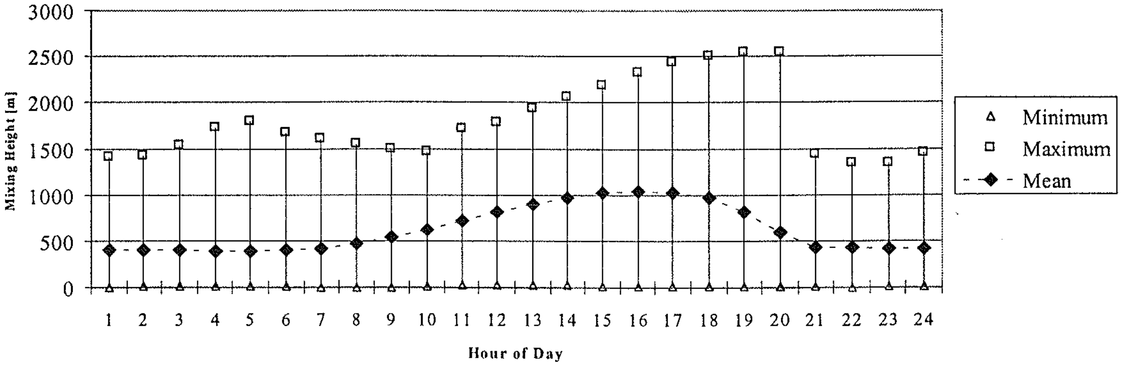


Figure 2-24 Hourly Variation in Mixing Heights for Mannix Monitoring Station

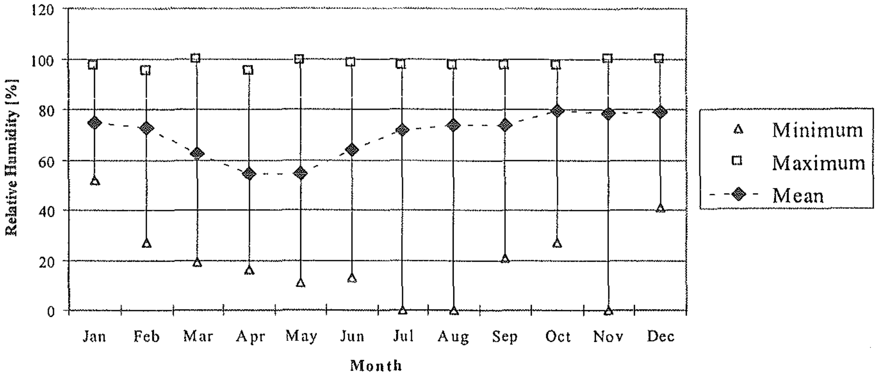


2.9 RELATIVE HUMIDITY AND PRECIPITATION

2.9.1 Relative Humidity

Relative humidity was monitored at the Mannix monitoring station from November 1, 1993 to October 31, 1997. Figure 2-25 presents the average and extreme relative humidity observations made at the Mannix station as a function of time of day. As indicated in the figure, the relative humidities are at a minimum during the early spring months.

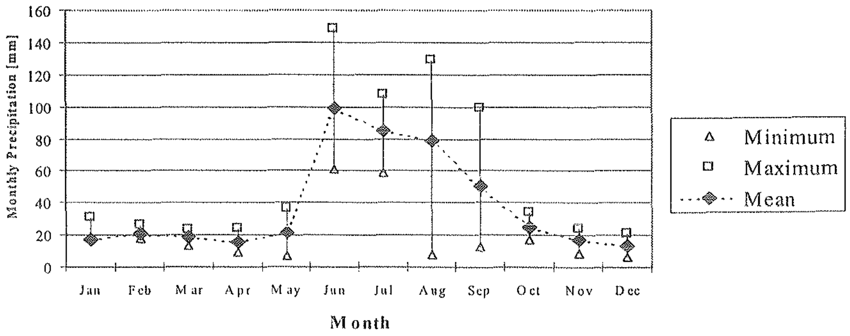
Figure 2-25 Monthly Variation in Observed Relative Humidity for the Mannix Monitoring Station



2.9.2 Precipitation

Precipitation data were not collected at the Mannix station. However, these data were available from the Atmospheric Environment Service station operated at Fort McMurray Airport. Figure 2-26 summarizes the monthly mean precipitation, as equivalent rainfall (mm), at the Fort McMurray Airport.

Figure 2-26 Observed Monthly Precipitation at Fort McMurray Airport



3 EMISSIONS

3.1 INTRODUCTION

The operation of oil sands mining, extraction and upgrading facilities result in controlled and fugitive, gaseous and particulate matter (PM) emissions to the atmosphere. The emissions from oil sands sources can be broadly classified as:

- Combustion emissions result from burning fossil fuel (e.g., natural gas, diesel oil or coke). The end products from the ideal combustion of these fuels are water (H_2O) and carbon dioxide (CO_2). The combustion products, however, also include trace amounts of oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons (HC) and particulate matter (PM). Depending on the fuel, PM may be accompanied by metals and polycyclic aromatic hydrocarbons (PAH).
- Fugitive emissions, for the purposes of this assessment, result from non-stationary combustion sources (e.g., mine fleet) and non-combustion sources (e.g., tailings pond). The sources include volatilization of HC and reduced sulphur (RS) compounds from the mines, plant sites and settling basins. Fugitive PM sources can result from mining activities as well as from disturbed and exposed surfaces (e.g., mine area, tailings dykes).

The emissions from the oil sands mining operations can also be grouped according to the source of emissions. In general, there are three principal emission sources, that are discussed in the following sub-sections.

Extraction, Upgrading and Energy Services Plant Operations

- Stationary combustion sources are comprised of natural gas fired process heaters, furnaces and boilers. Products of combustion include NO_x, CO and HC. The combustion of coke and other process gas streams can also result in RS and PM emissions.
- Fugitive plant site emissions include leaks from flanges, couplings, valves, rotating equipment seals, process vents and storage tank vents. These fugitive emissions include HC and RS compounds.

Mining Operations

- Mine fleet exhausts. The truck and shovel operations are diesel fuelled. Products of combustion include NO_x, CO, HC, PM and PAH. The truck and shovel mining operations are on a continuous basis (a nominal 24 hours per day, 7 days a week).

- Fugitive mine emission of HC and RS are associated with exposed mine surfaces and are expected to be greatest during warm summer periods.

PM emissions also result from tire/haul road surface abrasion and the resulting entrainment of dust into the atmosphere (which has not been estimated in this assessment).

Fugitive Tailings Pond Emissions

- Settling basin surfaces: VOC and RS emissions result from the volatilization of residual amounts of diluent contained in the tailings discharged to settling basins. The emission magnitude depends on the temperature of the pond surface, the nature of the VOC and the exposed area of the surface.
- Consolidated tailings surfaces: Initially the consolidated tailings (CT) will be capped with water and any VOC and RS in the capping layer can potentially volatilize from the water surface. The CT will then form a solid surface and residual VOC/RS may potentially volatilize from the exposed surface.

Table 3-1 provides a summary source/emission matrix for oil sands production operations. All combustion sources result in SO_2, NO_x, CO, PM, VOC and RS emissions due to the sulphur or small mercaptan content in combustion fuels. PM emissions associated with mine activities and tailings pond dykes are crustal in origin and will reflect the composition of the parent surface material. These PM emissions are largely manageable through dust suppression or reclamation practices. Because these emissions can be controlled and minimized, they have not been included in this assessment. Included in this assessment are PM emissions resulting from by-products of combustion which have potential health effects. The assessment of VOCs includes all C_2+ (two or more carbon atoms) hydrocarbons.

Table 3-1 Summary of Source/Emission Matrix for Oil Sands Production Operations

Source	Emission					
	SO_2	NO_x	CO	PM[a]	VOC	RS
Mining						
Fleet (Combustion) exhausts	✓	✓	✓	✓	✓	
Fugitive exposed surface sources				✓	✓	✓
Extraction, Upgrading and Energy Serices						
Combustion sources	✓	✓	✓	✓	✓	✓
Fugitive plant sources					✓	✓
Tailings Management						
Settling basin				✓	✓	✓
Consolidated tailings				✓	✓	✓

[a] Combustion based PM will be associated with PAH and metals. Non-combustion PM will reflect the nature of the parent surface material.

Within each section the emissions and associated emission characteristics due to regional facilities and the information are listed based on operating status of each lease operator or facility.

- The Existing emission scenario is based on a blend of 1996 and 1997 operating information. These emissions are due to the existing base mine, extraction, upgrading, energy services and tailings operations. The Syncrude SCO production rates associated with the existing emission scenario are 74 MMbbl/y (or 200,000 bbl/d) for 1996 and 76 MMbbl/y (or 210,000 bbl/d) for 1997. The emissions from the existing Syncrude operations overlap with those from Suncor's existing operations. The existing Suncor emissions are associated with a SCO production of 29 MMbbl/y (79,400 bbl/d).
- The Baseline emission scenario for Syncrude is based on a SCO production of 94 MMbbl/y (or 260 000 bbl/d) and one train of bitumen production at the Aurora North Mine. This Baseline emission scenario will also overlap with Suncor's approved fixed plant expansion and Steepbank Mine operation. The Suncor Baseline emissions are associated with an SCO production of 39 MMbbl/y (107,000 bbl/d). The Suncor Baseline emission scenario is expected to occur in 2001.
- The Cumulative Effects Assessment (CEA) emission scenario includes currently operating, currently approved and publicly disclosed operations in the Athabasca oil sands region. The projects included for the CEA are identified in Table 3-2. The CEA assessment includes a Syncrude application emission scenario based on a SCO production of 173 MMbbl/y (or 480,000 bbl/d) and a Suncor application emissions scenario based on a SCO production of 77 MMbbl/y (or 210,000 bbl/d). Suncor's application is called Project Millennium. This emission scenario is expected to occur in 2007.

The emissions in this reference report represent estimates based on engineering designs and forecasts of production rates, at a particular point in time. The engineering design process, however, is not a one time estimate but a continuing refinement of processes, efficiencies and problem solving. As such, the emission estimates are not exact and may be subject to variation within the approval limits. Further, the emission estimates reflect the average (nominal) emission rates from the processing equipment. Many pieces of equipment have varying emissions which may depend on weather, production rates or operating efficiencies. The estimates can therefore overpredict or underpredict emissions at a given instant but represent the best estimate of emissions at the time of the assessment.

Basic details on the regional emission sources, base elevations and UTM grids is provided in Appendix I.

Table 3-2 **Operating, Baseline and Disclosed Oil Sands Developments for the RSA**

Facility	Type	Operating	Baseline	Disclosed
Syncrude Mildred Lake	Mining, extraction and upgrading	✓		
Syncrude Mildred Lake DBII	Upgrader Debottlenecking Phase II		✓	
Syncrude Mildred Lake SCL Upgrader	Upgrader expansion			✓
Suncor Lease 86/17	Mining, extraction and upgrading	✓		
Suncor Steepbank	Mining		✓	
Suncor Project Millennium	Mining, extraction and upgrading			✓
Syncrude Aurora North	Mining and extraction		✓	
Syncrude Aurora South	Mining and extraction		✓	
Shell Muskeg River	Mining and extraction			✓
Shell Lease 13 East	Mining and extraction			✓
Mobil Kearl Lake	Mining, extraction and upgrading			✓
Petro-Canada Muskeg River	Steam assist, gravity drainage (SAGD)			✓
Solv-Ex	Mining and metal extraction		✓	
Northstar UTF	In-situ bitumen extraction	✓		
Gulf Surmont	SAGD			✓
JACOS Hangingstone	SAGD			✓

3.1.2 Section Organization

The source and emission inventory information is presented according to the following outline:

- Section 3.2: Syncrude Mildred Lake extraction and upgrading plant site sources;
- Section 3.3: Suncor extraction, upgrading and energy services plant site sources;
- Section 3.4: Other extraction, upgrading and production plant site sources;
- Section 3.5: Mine fleet sources from Existing, Baseline and Disclosed oil sands mines;
- Section 3.6: Fugitive emissions from Existing, Baseline and Disclosed oil sands mines; and
- Section 3.7: Fugitive emissions from Existing, Baseline and Disclosed tailings areas.

3.1.3 Source Identification

The objective of this source and emission inventory is to identify, quantify and characterize emissions so air quality changes can be calculated using dispersion models. Each subsection is comprised of text followed by tables relating to the specific section. Emission values are expressed as either 't/d' or 'kg/d', depending on the magnitude of the emission.

3.1.4 Definition of Terms

Given the technical nature of this report, it is useful to confirm some of the terminology used to facilitate a common understanding. Table 3-3 provides definitions of technical terms used in the report.

Table 3-3 Definition of Commonly Used Terms

Term	Definition
Airshed	A geographical region that shares one or more of the following: similar terrain, similar meteorology, similar sources, similar receptors. For the purposes of this report, the Athabasca oil sands region airshed was selected as the area located within 60 km of the Suncor and Syncrude oil sands operations.
Receptor	A biological or physical entity that is exposed to air emissions. Vegetation and humans are examples of biological receptors. Soils and water are examples of physical receptors.
Point Sources	An emission source that is described as a conventional stack, a flare stack or a process vent. Stacks and vents can range in height from a few metres to more than 100 m.
Line Sources	An emission source that can be described as single or multiple emissions that occur along a line. Dust emissions from a conveyer belt is an example of a single line source. A highway is an example of a line source that is comprised of multiple sources (i.e., vehicles).
Area Sources	An emission source that is described as occurring over a defined area. Evaporation from a pond surface is an example of a single area source. Emissions from residential heating units and mine vehicle traffic are examples of area sources that are comprised of multiple small emissions.
Stack Surveys	A periodic measurement taken to characterize and quantify stack emissions. Measurements for large stacks are typically taken halfway up the stack using probes. Alberta Environmental Protection and the U.S. EPA have rigourously prescribed procedures for conducting stack surveys.
CSEM	Continuous Stack Emission Monitors (CSEM) measure stack gas temperatures, exit velocities and contaminant flow rates on a continuous basis. Stack surveys are conducted to confirm satisfactory CSEM operation.
Fugitive Sources	Fugitive emissions are defined as contaminants emitted from any source except those from stacks or vents. Typical sources include gaseous leakages from valves, flanges, drains, volatilization from ponds and lagoons, and open doors and windows. Typical particulate sources include bulk storage areas, open conveyers, construction areas or plant roads.
Upset Emissions	During plant start-up, shut-down and abnormal operating conditions, gas streams can be vented directly into the atmosphere prior to usual treatment. Petrochemical (gas plants, refineries) frequently use a flare stack to dispose of gas streams under these conditions. Prudent stewardship ensures both infrequent and short duration upset emissions.
Emission Factor	In the absence of measurements, industry standard emission factors can be used to estimate emissions from a wide range of sources. An emission factor is a conversion factor and can be expressed as a contaminant release rate per amount of fuel consumed.
Emission Inventory	A database identifying, characterizing and quantifying emission sources. The database can provide spatial and temporal variation.
Stream day / Calendar day	Emissions of a pollutant are often expressed on a mass per unit time basis, for example, tonnes per day which can be abbreviated as t/d. Process engineers often distinguish between tonnes per stream day (t/sd) which is the emission rate based on the period when the facility is operating and tonnes per calendar day, which is the average over the full period (e.g., a full 365 day year). The emission rate expressed on a t/sd basis will usually be larger than that expressed on a t/cd basis.
Julian Day	A designation that identifies the day of the year by using a number between 1 and 365 (366 for leap years). For example, Julian day 1 = January 1, Julian day 365 = December 31.

3.2 SYNCRUDE MILDRED LAKE EMISSIONS

The emission inventories for the Existing, Baseline and Application scenarios are presented on a source by source basis as follows:

- Section 3.2.1: Continuous point sources

  - Main stack
  - 8-3 stack
  - Secondary stacks

- Section 3.2.2: Intermittent point sources
  - Diverter stack
  - Flaring
  - FGD bypass

- Section 3.2.3: Fugitive plant sources

The emission information for the Existing case is based on a blend of 1996 and 1997 operating data and the information from the Baseline and Application cases are based on engineering estimates. For the purposes of presentation, the existing emissions are referred to as "1996/1997" emissions and are associated with the respective annual synthetic crude oil (SCO) production of "74/76" MMb. In contrast, the Baseline emissions are associated with 94 MMbbl/y SCO production and the year 2001, and the Application emissions are associated with 173 MMbbl/y SCO production and the year 2007.

3.2.1 Continuous Point Sources

3.2.1.1 Main Stack

The Main Stack is the major source of SO_2 emissions at the Syncrude Mildred Lake plant. Tail gas from the sulphur recovery plants, ammonia vapours from the sour water treatment plant and coke burner overhead gas (CBOG) from the fluid cokers are incinerated in the CO boilers. Supplemental natural gas is added to ensure complete combustion. Fly ash and coke fines that have not been removed by the upstream cyclone separators are entrained into the CO stream from the fluid cokers. An electrostatic precipitator is used to remove most of the particulates that result during the combustion of these streams.

Manual stack surveys are conducted several times per year and the stack is equipped with a continuous stack emission monitor (CSEM). The CSEM and stack surveys provide data on the gross flow characteristics as well as the emission rates of selected compounds.

Gaseous and PM Emissions

Table 3-4 summarizes the stack and emission parameters for the Existing, Baseline and Application emission scenarios. The total flow parameters were based on stack surveys from 1997. The average SO_2 emission for the Existing scenario is based on 1996 continuous stack emission monitoring.

Table 3-4 Summary of Stack and Emission Parameters Associated With the Syncrude Main Stack

Emission Scenario		Existing	Baseline	Application
SCO Production (MMbbl/y)		74/76	94	173
Year		1996/97	2001	2007
UTM location North		6,322,111	6,322,111	6,322,111
UTM location East		462,632	462,632	462,632
Stack Height	[m]	183.0	183.0	183.0
Stack Diameter	[m]	7.90	7.90	7.90
Total Flow Rate	[m^3/s]	736	650	784
Exit Velocity	[m/s]	26.8	23.9	28.8
Exit Temperature	[°C]	240	240	240
Approved hourly SO_2 emission	[t/h]	16.4	16.4	-
Approved daily SO_2 emission	[t/d]	292	292	-
Approved 90 rolling average	[t/d]	260	260	-
Average SO_2 Emission Rate	[t/d]	197	208	188
Approved hourly NO_x emission	[t/h]	1.5	1.5	-
Average NO_x Emission Rate	[t/d]	13.2	10.9	14.8
Average CO Emission Rate	[t/d]	51.0	45.0	55.2
Approved PM Emission Rate	[t/h]	0.6	0.6	-
Average PM Emission Rate	[t/d]	8.0	7.1	8.5
Average PM_{10} Emission Rate	[t/d]	4.0	3.6	4.3
Average $PM_{2.5}$ Emission Rate	[t/d]	2.9	2.6	3.1
Average $(NH_4)_2SO_4$ Emission Rate	[t/d]	4.4	3.9	4.7

Volumetric flows are referenced to 25°C and 101.3 kPa. The PM emission rate excludes ammonium sulphate contribution.

The particle size distribution associated with PM emissions from the main stack was measured in 1984 (Concord Scientific 1984). Table 3-5 lists the size distribution for particulates based on three tests conducted on three days (June 14, June 18 and June 19).

Table 3-5 Particulate distribution associated with the Syncrude Main Stack

Diameter (μm)	Weight %
> 6.1	55.4
2.5 to 6.1	7.9
1.9 to 2.5	3.0
0.7 to 1.9	1.5
0.4 to 0.7	0.8
< 0.4	31.4

The PM size distribution is bimodal, with the bulk of the PM being either less than 0.4 μm in diameter or larger than 6.1 μm in diameter. Based on this distribution, about 50% and 36% of the total PM emissions are in the PM_{10} and $PM_{2.5}$ size fractions, respectively. A fly ash specific gravity of 2.31 has been assumed (Theodore and Buonicore, 1988). Wet deposition scavenging coefficients of 0.66×10^{-3} h $s^{-1}mm^{-1}$ liquid and 0.22×10^{-3} h $s^{-1}mm^{-1}$ ice have been assumed based on BOVAR (1996d).

The Baseline values represent maximum limits and apply not only to normal operating conditions, but also to start-up and shut-down operations. On an annual basis, the SO_2 emissions are less than the Baseline values.

Metal Emissions

A stack survey was conducted in 1994 to characterize heavy metal emissions associated with the main stack particulate emissions (Concord Scientific 1984). A more recent stack survey was conducted in December 1997 to update the metal emission profile (Conor Pacific 1997). The metal concentrations and associated emissions for the existing case, based on the 1997 survey are provided in Table 3-6. This table also provides the projected metal emissions for the Baseline and Application cases. These projected values are scaled according to total PM emission rate.

Table 3-6 Metal Emissions Associated With the Syncrude Main Stack Based on 1997 Stack Survey Measurements

Emission Scenario	Existing	Baseline	Application
SCO Production (MMbbl/y)	74/76	94	173
Year	1996/1997	2001	2007
Metal	kg/d	kg/d	kg/d
Aluminum	18.5	16.321	19.7
Antimony	< 0.072	< 0.064	< 0.077
Arsenic	0.11	0.098	0.12
Barium	1.0	0.897	1.1
Beryllium	< 0.014	< 0.013	< 0.015
Cadmium	0.046	0.041	0.049
Chromium	7.4	6.535	7.9
Cobalt	0.43	0.377	0.46
Copper	0.73	0.643	0.78
Iron	92.0	81.250	98.0
Lead	0.65	0.572	0.69
Manganese	2.4	2.084	2.5
Mercury	< 0.018	< 0.016	< 0.019
Molybdenum	1.3	1.166	1.4
Nickel	13.0	11.446	13.8
Selenium	0.22	0.194	0.23
Silver	< 0.21	< 0.187	< 0.22
Tin	< 0.72	< 0.636	< 0.77
Titanium	1.7	1.526	1.8
Vanadium	5.0	4.380	5.3
Zirconium	< 0.72	< 0.63	< 0.77
Zinc	65.6	57.9	69.9
Total	**212**	**188**	**225**

Note: Existing values are based on 1997 stack survey results; Baseline and Application values were estimated according to projected PM emissions

PAH Emissions

Concurrent with the December 1997 stack survey, PAH emission information was obtained for the main stack. The concentrations and emission measurements for the Existing case are provided in Table 3-7. The projected values for the Baseline and Application cases are scaled according to total PM emission rate.

Table 3-7 PAH Emissions Associated With the Syncrude Main Stack Based on 1997 Stack Survey Measurements

Emission Scenario SCO Production (MMbbl/y) Year	Existing 74/76 1996/1997		Baseline 94 2001	Application 173 2007
PAH	**μg/m^3**	**kg/d**	**kg/d**	**kg/d**
Acenaphthene	< 0.010	< 0.007	< 0.0006	< 0.0008
Acenaphylene	1.9	0.11	0.099	0.12
Anthracene	0.017	0.0010	0.0009	0.0011
1,2-Benzathracene	0.023	0.0015	0.0013	0.0016
Benzo(b & j)fluoranthene	0.070	0.0042	0.0037	0.0044
Benzo(k)fluoranthene	0.033	0.0019	0.0017	0.0020
Benzo(a)fluorene	< 0.010	< 0.0007	< 0.0006	< 0.0008
Benzo(b)fluorene	< 0.010	< 0.0007	< 0.0006	< 0.0008
Benzo(g, h, i)perylene	0.033	0.0021	0.0019	0.0023
Benzo(a)pyrene	< 0.017	< 0.0011	< 0.0010	< 0.0012
Benzo(e)pyrene	< 0.010	< 0.0007	< 0.0006	< 0.0008
Camphene	< 0.010	< 0.0007	< 0.0006	< 0.0008
Carbazole	<0.010	< 0.0007	< 0.0006	< 0.0008
1-Chloronaphthalene	< 0.013	< 0.0008	< 0.0007	< 0.0009
2-Chloronaphthalene	< 0.040	< 0.0026	< 0.0023	< 0.0027
Chrysene	0.070	0.0045	0.0040	0.0048
Dibenz(a, j)acridine	< 0.023	< 0.0014	< 0.0013	< 0.0015
Dibenz(a, h)acridine	< 0.010	< 0.0007	< 0.0006	< 0.0008
Dibenz(a, h anthracene	< 0.013	< 0.0008	< 0.0007	< 0.0009
Dibenzothiophene	7.3	0.44	0.39	0.47
7,12-dimethylbenz(a)anthracene	< 0.010	< 0.0007	< 0.0006	< 0.0008
1, 6-Dinitropyrene	< 0.010	< 0.0007	< 0.0006	< 0.0008
1, 8-Dinitropyrene	< 0.010	< 0.0007	< 0.0006	< 0.0008
Fluoranthene	< 0.11	< 0.0070	< 0.0061	< 0.0074
Fluorene	< 0.010	< 0.0007	< 0.0006	< 0.0008
Ideno(1, 2, 3-cd)pyrene	0.040	0.0023	0.0020	0.0025
Indole	< 0.010	< 0.0007	< 0.0006	< 0.0008
1-Methylnaphthalene	1.8	0.11	0.097	0.12
2-Methylnaphthalene	1.5	0.092	0.082	0.098
Naphthalene	26.7	1.6	1.4	1.7
Nitro-pyrene	< 0.010	< 0.0007	< 0.0006	< 0.0008
Perylene	< 0.010	< 0.0007	< 0.0006	< 0.0008
Phenanthrene	2.5	0.15	0.13	0.16
Pyrene	0.27	0.016	0.0139	0.017
Retene	0.14	0.0086	0.0077	0.0092
Total		2.56	2.27	2.72

3.2.1.2 8-3 Stack

The Application case will require the addition of a third fluid coker. This coker will be serviced by a flue gas desulphurization (FGD) system that will recover a nominal 90% of the sulphur prior to venting combustion products to the atmosphere. The coker and FGD plant will be serviced by a new stack (referred to as the 8-3 Stack).

Gaseous and PM Emissions

Table 3-8 presents the stack and emission parameters for the proposed 8-3 Stack associated with the Application case. The FGD system reduces the exhaust gas stream temperature to 75°C. An SO_2 emission of 10 t/sd is a stream day average when the FGD is operational. An approximate emission rate of 12 t/cd accounts for periods when the FGD system may be bypassed during unplanned outages (eight days a year). The PM size fraction for the main stack is assumed to be applicable to the 8-3 stack.

Table 3-8 **Summary of Stack and Emission Parameters Associated With the New 8-3 Stack**

Emission Scenario SCO Production (MMbbl/y) Year		Application 173 2007
Operation		Normal
Days per annum		357
UTM location North		6,322,880
UTM location East		462,807
Stack Height	[m]	76.2
Stack Diameter	[m]	6.60
Total Flow Rate	[m^3/s]	293
Exit Velocity	[m/s]	10.5
Exit Temperature	[°C]	75
Average SO_2 Emission Rate [(a)]	[t/sd]	10
Average NO_x Emission Rate	[t/sd]	3.5
Average CO Emission Rate	[t/sd]	13.5
Average PM Emission Rate	[t/sd]	5.8
Average PM_{10} Emission Rates	[t/sd]	2.9
Average $PM_{2.5}$ Emission Rates	[t/sd]	2.1
Average $2(NH_4)SO_4$ Emission Rate	[t/sd]	1.4

Volumetric flows at 25°C and 101.3 kPa.

[(a)] The annualized SO_2 emission rate based on combined Normal and Bypass modes is 12 t/d.

Metal and PAH Emissions

The metal and PAH emissions for the 8-3 Stack were scaled from the Main Stack values on the basis of PM emission rates. Table 3-9 summarizes the metal and PAH emissions expected from the 8-3 Stack.

3.2.1.3 Secondary Stacks

For this assessment, the non-sulphur compound emitting stacks are collectively classified as secondary stacks (e.g., stacks servicing turbines, furnaces and boilers). The primary fuel for the GTG turbines and the bitumen heater stacks is natural gas (NG). Other combustion sources are fired with plant refinery gas (RG). The trace sulphur compound content in the natural gas and refinery gas are estimated as zero and 10 ppm, respectively. Compared to the Main and 8-3 stacks, the SO_2 emissions from the secondary stacks are negligible, and have not been included in the SO_2 inventory.

Table 3-9 Metal and PAH Emissions Associated With the Proposed 8-3 Stack (normal operation)

Emission Scenario		Application	
SCO Production (MMbbl/y)		173	
Year		2007	
Metal	**kg/d**	**PAH**	**kg/d**
Aluminum	13.4	Acenaphthene	0.0005
Antimony	<0.05	Acenaphylene	0.0806
Arsenic	0.08	Anthracene	0.0007
Barium	0.74	1,2-Benzathracene	0.0011
Beryllium	<0.01	Benzo(b & j)fluoranthene	0.0030
Cadmium	0.034	Benzo(k)fluoranthene	0.0014
Chromium	5.37	Benzo(a)fluorene	0.0005
Cobalt	0.31	Benzo(b)fluorene	0.0005
Copper	0.53	Benzo(g, h, i)perylene	0.0015
Iron	66.7	Benzo(a)pyrene	0.0008
Lead	0.47	Benzo(e)pyrene	0.0005
Manganese	1.71	Camphene	0.0005
Mercury	<0.01	Carbazole	0.0005
Molybdenum	0.96	1-Chloronaphthalene	0.0006
Nickel	9.4	2-Chloronaphthalene	0.0019
Selenium	0.16	Chrysene	0.0033
Silver	<0.15	Dibenz(a, j)acridine	0.0010
Tin	<0.52	Dibenz(a, h)acridine	0.0005
Titanium	1.25	Dibenz(a, h)anthracene	0.0006
Vanadium	3.60	Dibenzothiophene	0.3190
Zirconium	<0.52	7,12-dimethylbenz(a)anthracene	0.0005
Zinc	47.6	1, 6-Dinitropyrene	0.0005
		1, 8-Dinitropyrene	0.0005
		Fluoranthene	0.0050
		Fluorene	0.0005
		Ideno(1, 2, 3-cd)pyrene	0.0017
		Indole	0.0005
		1-Methylnaphthalene	0.0795
		2-Methylnaphthalene	0.0669
		Naphthalene	1.1542
		Nitro-pyrene	0.0005
		Perylene	0.0005
		Phenanthrene	0.1073
		Pyrene	0.0114
		Retene	0.0063
Total Metal	**154**	**Total PAH**	**1.86**

NO_x emission estimates for the secondary stacks are based on Syncrude specific emission factors. CO, VOC and PM emission estimates are based on the emission factors provided in Table 3-10 that were obtained from U.S. EPA AP-42 emission factors (U.S. EPA 1995). For external combustion sources (e.g., boilers, heaters, furnaces), the emission factor is dependent on the unit size. The VOC emission factor refers to non-methane hydrocarbon compounds.

Table 3-10 Emission Factors Used to Calculate CO, VOC and PM Emission Rates Associated With Secondary Stack Emissions

Compound	Unit Type (Size)	U.S. EPA Table	Emission Factor ($kg/10^6$ m^3)
CO	Boiler (>100 MMBTU/h)	1.4-2	640
	Boiler (10 to 100 MMBTU/h)	1.4-2	560
	Boiler (0.3 to 10 MMBTU/h)	1.4-2	330
	Turbine	3.2-1	1,569
VOC	Boiler (>100 MMBTU/h)	1.4-3	23
	Boiler (10 to 100 MMBTU/h)	1.4-3	44
	Boiler (0.3 to 10 MMBTU/h)	1.4-3	84
	Turbine	3.2-1	31
PM_{10}	Boiler (>100 MMBTU/h)	1.4-1	200
	Boiler (10 to 100 MMBTU/h)	1.4-1	219
	Boiler (0.3 to 10 MMBTU/h)	1.4-1	192
	Turbine	3.1-1	614

U.S. EPA tables are from U.S. EPA (1995) AP-42 emission factor document. Turbine values are based on 71, 0.9 and 18 ng/J for CO, VOC and PM_{10}, respectively.

Table 3-11, Table 3-12 and Table 3-13 provide secondary stack and emission parameters for the Existing, Baseline and Application emission cases, respectively. The following provides a summary for each emission case:

- Existing case (Table 3-11): A total of 32 secondary stacks result in 12.3 t/d of NO_x emission;
- Baseline case (Table 3-12): One additional source is associated with this case. A total of 33 stacks result in 14.0 t/d of NO_x emission; and
- Application case (Table 3-13): An additional 14 sources are associated with this case. A total of 47 stacks result in 26.4 t/d of NO_x emission.

The increases in total NO_x emissions result from the new stacks as well as changes with the existing stacks. The CO emissions are typically 23% (on a mass basis) of the NO_x emissions. The VOC emissions are typically 2% (on a mass basis) of the NO_x emissions. The PM_{10} emissions are typically 9% (on a mass basis) of the NO_x emissions.

Table 3-11a Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Existing; 74/76 MMbbl/y)

Stack Description	**Gas Turbine**	**Gas Turbine**	**Bitumen Column Feed Heater Stacks**				**Steam Super Heater Stacks**			
Stack Number	**31 GTG 201**	**31 GTG 202**	**7-1F-1A**	**7-1F-1B**	**7-2F-1A**	**7-2F-1B**	**8-1F-6A**	**8-1F-6B**	**8-2F-6A**	**8-2F-6B**
Heat Duty (MMBTU/h)	109.2	109.2	246.0	246.0	246.0	246.0	62.6	19.2	62.6	19.2
(MW)	32.0	32.0	72.1	72.1	72.1	72.1	18.3	5.6	18.3	5.6
(GJ/h)	115.2	115.2	259.5	259.5	259.5	259.5	66.0	20.3	66.0	20.3
Fuel Type	RG	RG	RG	RG	RG	RG	RG	RG	RG	RG
Fuel Consumption (MMscfd)	7.19	7.19	6.90	6.90	6.90	6.90	1.82	0.56	1.82	0.56
(10^3 m^3/d)	204	204	195	195	195	195	52	16	52	16
Efficiency (%)	45	45	86	86	86	86	83	83	83	83
Assumed Excess Air (%)	200	200	25	25	25	25	25	25	25	25
UTM location (N)	6,322,003	6,322,012	6,322,427	6,322,434	6,322,476	6,322,485	6,322,261	6,322,268	6,322,231	6,322,237
UTM location (E)	462,693	462,721	462,596	462,617	462,578	462,605	462,662	462,683	462,570	462,588
Stack Height (m)	34.0	34.0	51.8	51.8	51.8	51.8	39.6	44.7	39.6	44.7
(ft)	111.5	111.5	169.9	169.9	169.9	169.9	129.9	146.7	129.9	146.7
Stack Diameter (m)	2.4	2.4	3.2	3.2	3.2	3.2	2.1	1.1	2.1	1.1
(ft)	7.9	7.9	10.5	10.5	10.5	10.5	7.0	3.5	7.0	3.5
Exit Velocity (m/s)	46.4	46.4	7.7	7.7	7.7	7.7	5.2	6.1	5.2	6.1
Exit Temperature (°C)	490	490	283	283	283	283	343	343	343	343
(°F)	914	914	541	541	541	541	649	649	649	649
(K)	763	763	556	556	556	556	616	616	616	616
Stack Gas Flow (10^3 m^3/d)	6291	6291	2756	2756	2756	2756	727	223	727	223
NO_x (t/d)	2.13	2.13	0.36	0.36	0.36	0.36	0.11	0.03	0.11	0.03
CO (t/d)	0.32	0.32	0.13	0.13	0.13	0.13	0.03	0.01	0.03	0.01
VOC (t/d)	0.006	0.006	0.004	0.004	0.004	0.004	0.002	0.001	0.002	0.001
PM_{10} (t/d)	0.125	0.125	0.039	0.039	0.039	0.039	0.011	0.004	0.011	0.004

Table 3-11b Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Existing; 74/76 MMbbl/y)

Stack Description	Reformer Furnace Stacks			Hydrogen Heater Stacks				Fractionator Reboiler Stacks				Sulfreen Regeneration Furnace
Stack Number	**9-1F -1**	**9-2F-1**	**9-3F-1**	**15-1F-1**	**15-2F-1**	**18-1F-1**	**22-1F-2**	**15-1F-2**	**15-2F-2**	**18F-2**	**22-1F-3**	**12-0F-101**
Heat Duty (MMBTU/h)	630.0	630.0	820.0	81.0	81.0	61.0	60.0	50.0	50.0	61.0	20.0	21.0
(MW)	184.6	184.6	240.3	23.7	23.7	17.9	17.6	14.7	14.7	17.9	5.9	6.2
(GJ/h)	664.7	664.7	865.1	85.5	85.5	64.4	63.3	52.8	52.8	64.4	21.1	22.2
Fuel Type	RG	RG	RG/TG	RG	RG	RG	RG	RG	RG	RG	RG	RG
Fuel Consumption (MMscfd)	17.51	17.51	61.8	2.11	2.11	1.60	1.70	1.49	1.49	1.60	0.57	0.61
$(10^3\ m^3/d)$	496	496	1751	60	60	45	48	42	42	45	16	17
Efficiency (%)	87	87	93	93	93	93	86	81	81	93	85	83
Assumed Excess Air (%)	25	25	25	25	25	25	25	25	25	25	25	25
UTM location (N)	6,322,453	6,322,612	6,322,474	6,322,400	6,322,408	6,322,485	6,322,657	6,322,545	6,322,555	6,322,494	6,322,644	6,322,333
UTM location (E)	463,084	462,947	463,167	462,879	462,904	463,221	463,028	462,820	462,850	463,247	463,032	462,741
Stack Height (m)	23.5	23.5	22.9	41.8	41.8	42.7	45.7	45.7	45.7	42.7	45.7	15.4
(ft)	77.0	77.0	75.1	137.0	137.0	140.0	150.0	150.0	150.0	140.0	150.0	5.0
Stack Diameter (m)	4.1	4.1	3.7	1.7	1.7	1.8	1.7	1.9	1.9	1.8	1.1	0.5
(ft)	13.5	13.5	12.0	5.6	5.6	6.0	5.5	6.4	6.4	6.0	3.5	1.5
Exit Velocity (m/s)	11.6	11.6	18.5	6.3	6.3	4.3	7.2	5.3	5.3	4.3	6.1	37.2
Exit Temperature (°C)	267	267	160	153	153	160	296	380	380	160	312	343
(°F)	513	513	320	307	307	320	565	716	716	320	594	649
(K)	540	540	433	426	426	433	569	653	653	433	585	616
Stack Gas Flow $(10^3\ m^3/d)$	6993	6993	11 318	844	844	638	678	595	595	638	228	244
NO_x (t/d)	1.60	1.60	1.72	0.19	0.19	0.10	0.11	0.11	0.11	0.10	0.04	0.04
CO (t/d)	0.32	0. 32	1.12	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.01	0.01
VOC (t/d)	0.011	0.011	0.040	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.001
PM_{10} (t/d)	0.099	0.099	0.350	0.013	0.013	0.010	0.011	0.009	0.009	0.010	0.004	0.004

Table 3-11c Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Existing; 74/76 MMbbl/y)

Stack Description	Bitumen Feed Heater	Diluent Reboiler	Bitumen Heater Stacks (North)				Bitumen Heater Stacks (East)				
Stack Number	**22-1F-1**	**14F-1**	**21F-7**	**21F-8**	**21F-9**	**21F-10**	**21F-50**	**21F-51**	**21F-52**	**21F-53**	**Total**
Heat Duty (MMBTU/h)	57.0	24.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(MW)	16.7	7.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(GJ/h)	60.1	25.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
Fuel Type	RG	RG	NG	NG	NG	NG	NG	NG	NG	NG	-
Fuel Consumption (MMscfd)	1.70	0.70	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(10^3 m^3/d)	48	20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
Efficiency (%)	81	83	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
Assumed Excess Air (%)	25	25	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
UTM location (N)	6,322,626	6,322,475	6,323,038	6,323,049	6,322,830	6,322,841	6,322,778	6,322,590	6,322,477	6,322,675	-
UTM location (E)	463,038	462,647	462,865	462,898	462,933	462,966	463,964	464,025	464,062	463,997	-
Stack Height (m)	45.7	30.5	6.1	6.1	6.1	6.1	7.6	7.6	7.6	7.6	-
(ft)	150.0	100.0	20.0	20.0	20.0	20.0	24.9	24.9	24.9	24.9	-
Stack Diameter (m)	1.7	1.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-
(ft)	5.5	3.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-
Exit Velocity (m/s)	8.2	7.8	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	-
Exit Temperature (°C)	379	345	566	566	566	566	566	566	566	566	-
(°F)	714	653	1050	1050	1050	1050	1050	1050	1050	1050	-
(K)	652	618	839	839	839	839	839	839	839	839	-
Stack Gas Flow (10^3 m^3/d)	678	279	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
NO_x (t/d)	0.11	0.04	0.03	0.03(f)	0.03	0.03	0.03	0.03	0.03	0.03	12.28
CO (t/d)	0.03	0.01	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	3.28
VOC (t/d)	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.13
PM_{10} (t/d)	0.011	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	1.11

Table 3-12a Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Baseline; 94 MMbbl/y)

Stack Description	Gas Turbine	Gas Turbine	Bitumen Column Feed Heater Stacks				Steam Super Heater Stacks			
Stack Number	**31 GTG 201**	**31 GTG 202**	**7-1F-1A**	**7-1F-1B**	**7-2F-1A**	**7-2F-1B**	**8-1F-6A**	**8-1F-6B**	**8-2F-6A**	**8-2F-6B**
Status	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**
Heat Duty (MMBTU/h)	109.2 / 172	109.2 / 172	246.0	246.0	246.0	246.0	62.6	19.2	62.6	19.2
(MW)	32.0 / 50.4	32.0 / 50.4	72.1	72.1	72.1	72.1	18.3	5.6	18.3	5.6
(GJ/h)	115.2 / 181.4	115.2 / 181.4	259.5	259.5	259.5	259.5	66.0	20.3	66.0	20.3
Fuel Type	NG / RG	NG / RG	RG	RG	RG	RG	RG	RG	RG	RG
Fuel Consumption (MMscfd)	6.5 / 3.83	6.5 / 3.83	6.46	6.46	6.46	6.46	1.82	0.56	1.82	0.56
(10^3 m^3/d)	184 / 109	184 / 109	183	183	183	183	52	16	52	16
Efficiency (%)	45 / 90	45 / 90	90	90	90	90	83	83	83	83
Assumed Excess Air (%)	200 / 25	200 / 25	25	25	25	25	25	25	25	25
UTM location (N)	6,322,003	6,322,012	6,322,427	6,322,434	6,322,476	6,322,485	6,322,261	6,322,268	6,322,231	6,322,237
UTM location (E)	462,693	462,721	462,596	462,617	462,578	462,605	462,662	462,683	462,570	462,588
Stack Height (m)	45.7	45.7	51.8	51.8	51.8	51.8	39.6	44.7	39.6	44.7
(ft)	150	150	190	190	190	190	129.9	146.7	129.9	146.7
Stack Diameter (m)	3.3	3.3	3.2	3.2	3.2	3.2	2.1	1.1	2.1	1.1
(ft)	10.8	10.8	10.5	10.5	10.5	10.5	7.0	3.5	7.0	3.5
Exit Velocity (m/s)	15.8	15.8	5.7	5.7	5.7	5.7	5.2	6.1	5.2	6.1
Exit Temperature (°C)	150	150	149	149	149	149	343	343	343	343
(°F)	303	303	300	300	300	300	649	649	649	649
(K)	423	423	422	422	422	422	616	616	616	616
Stack Gas Flow (10^3 m^3/d)	7856	7856	2697	2697	2697	2697	727	223	727	223
NO_x (t/d)	2.28	2.28	0.43	0.43	0.43	0.43	0.08	0.03	0.08	0.03
CO (t/d)	0.36	0.36	0.12	0.12	0.12	0.12	0.03	0.01	0.03	0.01
VOC (t/d)	0.009	0.009	0.004	0.004	0.004	0.004	0.002	0.001	0.002	0.001
PM_{10} (t/d)	0.135	0.135	0.037	0.037	0.037	0.037	0.011	0.004	0.011	0.004

New Once Through Steam generation(OTSG) emissions are vented through the existing GTG stacks.

Table 3-12b Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Baseline; 94 MMbbl/y)

Stack Description	Reformer Furnace Stacks			Hydrogen Heater Stacks				Fractionator Reboiler Stacks				Sulfreen Regeneration Furnace
Stack Number	**9-1F-1**	**9-2F-1**	**9-3F-1**	**15-1F-1**	**15-2F-1**	**18-1F-1**	**22-1F-2**	**15-1F-2**	**15-2F-2**	**18F-2**	**22-1F-3**	**12-0F-101**
Status	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**
Heat Duty (MMBTU/h)	630.0	630.0	820.0	95	95	61	60.0	70	70	61	20	21
(MW)	184.6	184.6	240.3	27.8	27.8	17.9	17.6	20.5	20.5	17.9	5.9	6.2
(GJ/h)	664.7	664.7	865.1	100.2	100.2	64.4	63.3	73.8	73.8	64.4	21.1	22.2
Fuel Type	RG	RG	RG/TG	RG	RG	RG	RG	RG	RG	RG	RG	RG
Fuel Consumption (MMscfd)	17.51	17.51	61.8	2.41	2.41	1.6	1.70	2.04	2.04	1.6	0.57	0.61
(10^3 m^3/d)	496	496	1751	68	68	45	48	58	58	45	16	17
Efficiency (%)	87	87	93	93	93	93	86	81	81	93	85	83
Assumed Excess Air (%)	25	25	25	25	25	25	25	25	25	25	25	25
UTM location (N)	6,322,453	6,322,612	6,322,474	6,322,400	6,322,408	6,322,485	6,322,657	6,322,545	6,322,555	6,322,494	6,322,644	6,322,333
UTM location (E)	463,084	462,947	463,167	462,879	462,904	463,221	463,028	462,820	462,850	463,247	463,032	462,741
Stack Height (m)	23.5	23.5	22.9	41.8	41.8	42.7	45.7	45.7	45.7	42.7	45.7	15.4
(ft)	77.0	77.0	75.1	137.0	137.0	140.0	150.0	150.0	150.0	140.0	150.0	5.0
Stack Diameter (m)	4.1	4.1	3.7	1.7	1.7	1.8	1.7	1.9	1.9	1.8	1.1	0.5
(ft)	13.5	13.5	12.0	5.6	5.6	6.0	5.5	6.4	6.4	6.0	3.5	1.5
Exit Velocity (m/s)	11.6	11.6	18.5	7.7	7.7	4.3	7.2	8.0	8.0	4.3	6.1	37.2
Exit Temperature (°C)	267	267	160	153	153	160	296	380	380	160	312	343
(°F)	513	513	320	307	307	320	565	716	716	320	594	649
(K)	540	540	433	426	426	433	569	653	653	433	585	616
Stack Gas Flow (10^3 m^3/d)	6993	6993	11318	1008	1008	638	678	853	853	638	228	244
NO_x (t/d)	2.10	2.10	1.79	0.15	0.15	0.08	0.09	0.13	0.13	0.08	0.03	0.05
CO (t/d)	0.32	0.32	1.12	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.01	0.01
VOC (t/d)	0.011	0.011	0.040	0.003	0.003	0.002	0.002	0.003	0.003	0.002	0.001	0.001
PM_{10} (t/d)	0.099	0.099	0.350	0.015	0.015	0.010	0.011	0.013	0.013	0.010	0.004	0.004

Table 3-12c Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Baseline; 94 MMbbl/y)

Stack Description	Bitumen Feed Heater	Diluent Reboiler	VDU Heater	Bitumen Heater Stacks (North)				Bitumen Heater Stacks (East)				Total
Stack Number	22-1F-1	14F-1	37-F1A	21F-7	21F-8	21F-9	21F-10	21F-50	21F-51	21F-52	21F-53	
Status	Existing	Existing	New	Existing	Existing	Existing	Existing	Existing	Existing	Existing	Existing	
Heat Duty (MMBTU/h)	57.0	24.0	190	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(MW)	16.7	7.0	55.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(GJ/h)	60.1	25.3	200.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
Fuel Type	RG	RG	RG	NG	NG	NG	NG	NG	NG	NG	NG	-
Fuel Consumption (MMscfd)	1.70	0.70	4.93	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(10^3 m^3/d)	48	20	140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
Efficiency (%)	81	83	91	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
Assumed Excess Air (%)	25	25	10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
UTM location (N)	6,322,626	6,322,475	6,322,525	6,323,038	6,323,049	6,322,830	6,322,841	6,322,778	6,322,590	6,322,477	6,322,675	-
UTM location (E)	463,038	462,647	462,578	462,865	462,898	462,933	462,966	463,964	464,025	464,062	463,997	-
Stack Height (m)	45.7	30.5	54.3	6.1	6.1	6.1	6.1	7.6	7.6	7.6	7.6	-
(ft)	150.0	100.0	178	20.0	20.0	20.0	20.0	24.9	24.9	24.9	24.9	-
Stack Diameter (m)	1.7	1.1	3.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-
(ft)	5.5	3.5	10.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-
Exit Velocity (m/s)	8.2	7.8	3.8	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	-
Exit Temperature (°C)	379	345	162	566	566	566	566	566	566	566	566	-
(°F)	714	653	324	1050	1050	1050	1050	1050	1050	1050	1050	-
(K)	652	618	435	839	839	839	839	839	839	839	839	-
Stack Gas Flow (10^3 m^3/d)	678	279	1830	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
NO_x (t/d)	0.09	0.16	0.20	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	14.03
CO (t/d)	0.03	0.01	0.09	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	3.44
VOC (t/d)	0.002	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.14
PM_{10} (t/d)	0.011	0.004	0.028	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	1.15

Table 3-13a Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Syncrude Application)

Stack Description		**Gas Turbines**			**Bitumen Column Feed Heater Stacks**					
Stack Number		**31 GTG 201**	**31 GTG 202**	**31 GTG 203**	**7-1F-1A**	**7-1F-1B**	**7-2F-1A**	**7-2F-1B**	**7-3F-1A**	**7-3F-1B**
Status		**Existing**	**Existing**	**New**	**Existing**	**Existing**	**Existing**	**Existing**	**New**	**New**
Heat Duty	(MMBTU/h)	109.2 / 172	109.2 / 172	266.7	246.0	246.0	246.0	246.0	361	361
	(MW)	32.0 / 50.4	32.0 / 50.4	78.1	72.1	72.1	72.1	72.1	105.8	105.8
	(GJ/h)	115.2 / 181.4	115.2 / 181.4	281.3	259.5	259.5	259.5	259.5	380.8	380.8
Fuel Type		NG / RG	NG / RG	RG	RG	RG	RG	RG	RG	RG
Fuel Consumption	(MMscfd)	6.5 / 3.83	6.5 / 3.83	14.0	6.46	6.46	6.46	6.46	9.48	9.48
	(10^3 m^3/d)	184 / 109	184 / 109	396	183	183	183	183	268	268
Efficiency	(%)	45 / 90	45 / 90	45	90	90	90	90	90	90
Assumed Excess Air	(%)	200 / 25	200 / 25	200	25	25	25	25	25	25
UTM location (N)		6,322,003	6,322,012	6,322,330	6,322,427	6,322,434	6,322,476	6,322,485	6,322,688	6,322,702
UTM location (E)		462,693	462,721	463,555	462,596	462,617	462,578	462,605	462,782	462,777
Stack Height	(m)	45.7	45.7	45.7	51.8	51.8	51.8	51.8	51.8	51.8
	(ft)	150	150	150	190	190	190	190	190	190
Stack Diameter	(m)	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2
	(ft)	10.8	10.8	10.8	10.5	10.5	10.5	10.5	10.5	10.5
Exit Velocity	(m/s)	15.8	15.8	48.8	5.7	5.7	5.7	5.7	8.4	8.4
Exit Temperature	(°C)	150	150	490	149	149	149	149	149	149
	(°F)	303	303	914	300	300	300	300	300	300
	(K)	423	423	763	422	422	422	422	422	422
Stack Gas Flow	(10^3 m^3/d)	7856	7856	13479	2697	2697	2697	2697	3957	3957
NO_x	(t/d)	2.28	2.28	2.62	0.43	0.43	0.43	0.43	0.65	0.65
CO	(t/d)	0.36	0.36	0.62	0.12	0.12	0.12	0.12	0.15	0.15
VOC	(t/d)	0.009	0.009	0.012	0.004	0.004	0.004	0.004	0.012	0.012
PM_{10}	(t/d)	0.135	0.135	0.243	0.037	0.037	0.037	0.037	0.059	0.059

Table 3-13b Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Syncrude Application)

Stack Description		**Steam Super Heater Stacks**						**Reformer Furnace Stacks**				
Stack Number		**8-1F-6A**	**8-1F-6B**	**8-2F-6A**	**8-2F-6B**	**8-3F-6A**	**8-3F-6B**	**9-1F-1**	**9-2F-1**	**9-3F-1**	**9-4F-1**	**9-5F-1**
Status		**Existing**	**Existing**	**Existing**	**Existing**	**New**	**New**	**Existing**	**Existing**	**Existing**	**New**	**New**
Heat Duty	(MMBTU/h)	62.6	19.2	62.6	19.2	62.6	19.2	630.0	630.0	820.0	1225	1025
	(MW)	18.3	5.6	18.3	5.6	18.3	5.6	184.6	184.6	240.3	240.3	240.3
	(GJ/h)	66.0	20.3	66.0	20.3	66.0	20.3	664.7	664.7	865.1	865.1	865.1
Fuel Type		RG	RG	RG	RG	RG	RG	RG	RG	RG/TG	RG/TG	RG/TG
Fuel Consumption	(MMscfd)	1.82	0.56	1.82	0.56	1.82	0.56	17.51	17.51	61.8	92.4	77.3
	(10^3 m^3/d)	52	16	52	16	52	16	496	496	1751	2616	2189
Efficiency	(%)	83	83	83	83	83	83	87	87	93	93	93
Assumed Excess Air	(%)	25	25	25	25	25	25	25	25	25	25	25
UTM location (N)		6,322,261	6,322,268	6,322,231	6,322,237	6,322,749	6,322,764	6,322,453	6,322,612	6,322,474	6,322,650	6,322,658
UTM location (E)		462,662	462,683	462,570	462,588	462,970	462,965	463,084	462,947	463,167	463,355	463,528
Stack Height	(m)	39.6	44.7	39.6	44.7	39.6	44.7	23.5	23.5	22.9	22.9	22.9
	(ft)	129.9	146.7	129.9	146.7	129.9	146.7	77.0	77.0	75.1	75.1	75.1
Stack Diameter	(m)	2.1	1.1	2.1	1.1	2.1	1.1	4.1	4.1	3.7	5.5	5.5
	(ft)	7.0	3.5	7.0	3.5	7.0	3.5	13.5	13.5	12.0	16.0	16.0
Exit Velocity	(m/s)	5.2	6.1	5.2	6.1	5.2	6.1	11.6	11.6	18.5	12.5	10.5
Exit Temperature	(°C)	343	343	343	343	343	343	267	267	160	160	160
	(°F)	649	649	649	649	649	649	513	513	320	320	320
	(K)	616	616	616	616	616	616	540	540	433	433	433
Stack Gas Flow	(10^3 m^3/d)	727	223	727	223	727	223	6993	6993	11318	16908	14148
NO_x	(t/d)	0.08	0.03	0.08	0.03	0.08	0.03	2.10	2.10	1.79	4.29	3.37
CO	(t/d)	0.03	0.01	0.03	0.01	0.03	0.01	0.32	0.32	1.12	1.67	1.40
VOC	(t/d)	0.002	0.001	0.002	0.001	0.002	0.001	0.011	0.011	0.040	0.060	0.050
PM_{10}	(t/d)	0.011	0.004	0.011	0.004	0.011	0.004	0.099	0.099	0.350	0.523	0.438

Table 3-13c Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Syncrude Application)

		Hydrogen Heater Stacks								Fractionator Reboiler Stacks					
Stack Number		15-1F-1	15-2F-1	15-3F-1	18-1F-1	18-2F-1	18-1F-3	18-2F-3	22-1F-2	15-1F-2	15-2F-2	15-3F-2	18-1F-2	18-2F-2	22-1F-3
Status		Existing	Existing	New	Existing	New	New	New	Existing	Existing	Existing	New	Existing	New	Existing
Heat Duty	(MMBTU/h)	95	95	95	51.6	51.6	94.5	94.5	60.0	70	70	70	56.1	56.1	20
	(MW)	27.8	27.8	27.8	15.1	15.1	27.7	27.7	17.6	20.5	20.5	20.5	16.4	16.4	5.9
	(GJ/h)	100.2	100.2	100.2	54.4	54.4	99.7	99.7	63.3	73.8	73.8	73.8	59.2	59.2	21.1
Fuel Type		RG	RG	RG	RG	RG	RG	RG	RG	RG	RG	RG	RG	RG	RG
Fuel Consumption	(MMscfd)	2.41	2.41	2.41	1.31	1.31	2.40	2.40	1.70	2.04	2.04	2.04	1.42	1.42	0.57
	(10^3 m^3/d)	68	68	68	37	37	68	68	48	58	58	58	40	40	16
Efficiency	(%)	93	93	93	93	93	93	93	86	81	81	81	93	93	85
Assumed Excess Air	(%)	25	25	25	25	25	25	25	25	25	25	25	25	25	25
UTM location (N)		6,322,400	6,322,408	6,322,668	6,322,485	6,322,630	6,322,539	6,322,635	6,322,657	6,322,545	6,322,555	6,322,663	6,322,494	6,322,640	6 322 644
UTM location (E)		462,879	462,904	463,509	463,221	463,393	463,311	463,408	463,028	462,820	462,850	463,495	463,247	463,422	463 032
Stack Height	(m)	41.8	41.8	41.8	42.7	42.7	42.7	42.7	45.7	45.7	45.7	45.7	42.7	42.7	45.7
	(ft)	137.0	137.0	137.0	140.0	140.0	140	140	150.0	150.0	150.0	150.0	140.0	140.0	150.0
Stack Diameter	(m)	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.7	1.9	1.9	1.9	1.8	1.8	1.1
	(ft)	5.6	5.6	5.6	6.0	6.0	6.0	6.0	5.5	6.4	6.4	6.4	6.0	6.0	3.5
Exit Velocity	(m/s)	7.7	7.7	7.7	3.8	3.8	6.9	6.9	7.2	8.0	8.0	8.0	4.1	4.1	6.1
Exit Temperature	(°C)	153	153	153	160	160	160	160	296	380	380	380	160	160	312
	(°F)	307	307	307	320	320	320	320	565	716	716	716	320	320	594
	(K)	426	426	426	433	433	433	433	569	653	653	653	433	433	585
Stack Gas Flow	(10^3 m^3/d)	1008	1008	1008	547	547	1003	1003	678	853	853	853	595	595	228
NO_x	(t/d)	0.15	0.15	0.15	0.04	0.04	0.08	0.08	0.09	0.13	0.13	0.13	0.05	0.05	0.03
CO	(t/d)	0.04	0.04	0.04	0.02	0.02	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.01
VOC	(t/d)	0.003	0.003	0.003	0.002	0.002	0.003	0.003	0.002	0.003	0.003	0.003	0.002	0.002	0.001
PM_{10}	(t/d)	0.015	0.015	0.015	0.008	0.008	0.015	0.015	0.011	0.013	0.013	0.013	0.009	0.009	0.004

Table 3-13d Summary of the Stack and Emission Parameters Associated With the Syncrude Secondary Stacks (Syncrude Application)

Stack Description	Sulfreen Regeneration	Bitumen Feed	Diluent Reboiler	VDU Bitumen Feed Heater		Bitumen Heater Stacks (North)				Bitumen Heater Stacks (East)				
Stack Number	**12-0F-101**	**22-1F-1**	**14F-1**	**37-1F-1A**	**37-1F-2A**	**21F-7**	**21F-8**	**21F-9**	**21F-10**	**21F-50**	**21F-51**	**21F-52**	**21F-53**	**Total**
Status	**Existing**	**Existing**	**Existing**	**Existing**	**New**	**Existing**	**Existing**	**Relocated**	**Existing**	**Existing**	**Existing**	**Existing**	**Existing**	
Heat Duty (MMBTU/h)	21	57.0	24.0	201	201	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(MW)	6.2	16.7	7.0	58.9	58.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(GJ/h)	22.2	60.1	25.3	212.0	212.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
Fuel Type	RG	RG	RG	RG	RG	NG	NG	NG	NG	NG	NG	NG	NG	-
Fuel Consumption (MMscfd)	0.61	1.70	0.70	5.22	5.22	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
(10^3 m^3/d)	17	48	20	148	148	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	--
Efficiency (%)	83	81	83	91	91	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
Assumed Excess Air (%)	25	25	25	10	10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
UTM location (N)	6,322,333	6,322,626	6,322,475	6,322,525	6,322,535	6,323,038	6,323,049	6,322,830	6,322,841	6,322,778	6,322,590	6,322,477	6,322,675	-
UTM location (E)	462,741	463,038	462,647	462,578	462,607	462,865	462,898	462,933	462,966	463,964	464,025	464,062	463,997	-
Stack Height (m)	15.4	45.7	30.5	54.3	54.3	6.1	6.1	6.1	6.1	7.6	7.6	7.6	7.6	-
(ft)	5.0	150.0	100.0	178	178	20.0	20.0	20.0	20.0	24.9	24.9	24.9	24.9	-
Stack Diameter (m)	0.5	1.7	1.1	3.3	3.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-
(ft)	1.5	5.5	3.5	10.8	10.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-
Exit Velocity (m/s)	37.2	8.2	7.8	4.0	4.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	-
Exit Temperature (°C)	343	379	345	162	162	566	566	566	566	566	566	566	566	-
(°F)	649	714	653	324	324	1050	1050	1050	1050	1050	1050	1050	1050	-
(K)	616	652	618	435	435	839	839	839	839	839	839	839	839	-
Stack Gas Flow (10^3 m^3/d)	244	678	279	1935	1935	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-
NO_x (t/d)	0.06	0.09	0.15	0.20	0.20	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	26.39
CO (t/d)	0.01	0.03	0.01	0.10	0.10	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	7.76
VOC (t/d)	0.001	0.002	0.001	0.003	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.30
PM_{10} (t/d)	0.004	0.011	0.004	0.030	0.030	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	2.59

The 21F-7 heater will be relocated.

3.2.2 Intermittent Point Sources

Intermittent sources of emissions have not been characterized in detail. A brief description of the Syncrude intermittent emissions sources is given below.

3.2.2.1 Diverter Stack

Each of the existing fluid cokers is serviced by an individual diverter stack. These stacks act as an emergency bypass venting system used in the event of a plant failure. The diverter stacks can vent coker burner overhead gas (CBOG); tail gas from the sulphur plant and ammonia from the sour water plant; and a combination of all three sources. During an upset condition, tail gas and ammonia gas streams are normally directed to the on-line CO boiler to minimize the occurrence of the combined gas case.

3.2.2.2 8-3 Diverter Stack

The new 8-3 coker will also be serviced by a diverter stack whose dimensions will be the same as those associated with the existing diverter stacks. Unlike the present diverter stacks, however, the 8-3 diverter stack will only vent CBOG under upset conditions. The diverter stack emissions associated with the new 8-3 coker are expected to have intermittent emissions similar to the existing CBOG case.

The diverter stack will also be used when the FGD unit is down. A nominal downtime of eight days a year reflects unscheduled upset conditions as routine FGD maintenance will be scheduled when the 8-3 Stack coker is off-line. When the FGD is down, the 8-3 Stack coker gas will be vented to the atmosphere without the benefit of sulphur removal. For these periods, the SO_2 emission will increase to approximately 100 t/sd and the stack top temperature increases to 260°C. SO_2 and PM emissions are assumed to increase when in bypass mode. As the FGD is not assumed to remove either NO_x or CO, these emissions remain unchanged under bypass conditions.

3.2.2.3 Flaring Emissions

The Syncrude flaring system is comprised of the following:

- One acid gas flare stack that is used when there are upsets within the amine plant, the sulphur recovery or the sour water plants. The heating values of these gases during upset conditions are in the 9.4 to 11.2 MJ/m^3 range.
- One hydrocarbon flare that is equipped with steam injection to ensure smokeless operation and is the primary hydrocarbon flare stack (low pressure). When this flare is used, the heating values of the gases are in the 10.8 to 39.4 MJ/m^3 range.

- A secondary hydrocarbon or high pressure flare that is used when the capacity of the primary hydrocarbon system is exceeded.

The Application case will result in two additional flares:

- One new acid gas flare that will service the new amine, sulphur recovery and sour water systems.
- One new low pressure hydrocarbon flare that will be used to service the new processing facility.

Flaring events by their nature are infrequent and have widely varying characteristics. Flaring events associated with the Baseline and Application production scenarios are assumed to be intermittent and similar to those associated with the existing case.

3.2.3 Fugitive Plant Sources

3.2.3.1 Background

Fugitive HC and RS emissions can originate from mine areas, plant process areas and tailings disposal areas. Syncrude has conducted several studies to identify and quantify fugitive emissions from their operations:

- A plant site study of H_2S emissions conducted in 1981 (Concord Scientific 1981);
- A facility wide study of HC and RS emissions conducted in 1987 (Concord Scientific 1988);
- Updated settling basin studies conducted in 1992 and 1994 (Concord Environmental 1992 and BOVAR-CONCORD Environmental 1994a); and
- A facility wide study conducted 14 July to 2 August 1997 (Clearstone Engineering 1997).

The emission estimates presented in this report reflect the results from the most recent study. The primary sources of HC emissions and RS for the Syncrude Mildred Lake overall operations are summarized in Table 3-14. The primary sources of HC and RS emissions, listed as percentage contribution to total emissions, are shown in Table 3-14. The general plant area (comprised of the process area, effluent pond and storage tanks) contributes about 12% of the total HC emissions. The general plant area (comprised of the process area and storage tanks) contributes about 85% of the total RS emissions.

The most recent study (Clearstone Engineering 1997) was characterized by extremely warm conditions (warmer than 30°C). In general, pond fugitive emissions will correlate to a combination of ambient temperature and wind speed. Mean monthly temperatures and wind speeds were used to test the sensitivity of fugitive emissions (see Section 3.7.1). The sensitivity results indicate that fugitive emissions can vary +60% to -35% from the values observed due to changes in temperature and wind speed. Emissions from the plant however, are expected to be less dependent on ambient conditions as the emission rates are expected to be driven more by plant process parameters (e.g., plant process temperatures, process rates and pressures). The plant fugitive emissions would therefore be expected to be much more uniform over the year.

Table 3-14 Distribution of Syncrude Mildred Lake Fixed Plant Fugitive Source Emissions of HC and RS

Plant Area	HC Emissions	RS Emissions
Mildred lake Settling Basin	53%	5%
Mine Surfaces	22	5
Southwest Sand Storage Area	10	4
Plant Process Area	5	82
Effluent Pond	4	--
Storage Tanks	3	3
Other	3	1
Total	**100%**	**100%**

The study identified 584 distinct HC and RS compounds. Only some of these compounds are of interest from a potential human health exposure perspective whereas others are potential precursors of photochemical ozone production. The VOC and RS emissions were reviewed and grouped to assess these potential effects, for the purposes of this assessment.

Section 3.6 and Section 3.7 summarize the fugitive emissions from the mine surfaces and from the tailings areas, respectively.

3.2.3.2 Plant Area Fugitive Emissions

Table 3-15 summarizes the HC and RS emissions from the three areas for the Existing, Baseline and Application emission scenarios. These emissions include the three main plant area sources (i.e., plant processing area, effluent pond and storage tanks) as well as minor plant sources (for the purposes of this assessment, all non-mine and non-tailings related fugitive emissions were included as "minor plant sources"). The existing plant area results in a HC emission of about 12.9 t/d of which, 8.0 t/d is methane. In contrast, RS emissions are about 1.8 t/d.

The Existing emissions based on the monitoring program were extrapolated to estimate emissions associated with the Baseline and Application operating scenarios. For the three main plant area sources emissions are based on the following:

Table 3-15 Fugitive HC and RS Emissions From the Mildred Lake Plant Area

Emission Scenario SCO Production (MMbbl/y) Year	Existing 74/76 1996/97	Baseline 94 2001	Application 173 2007
General, [kg/d]			
Total hydrocarbon (C1+)	12,733	14,110	23,612
Methane (C1)	8,148	8675	14,020
C2+	4,586	5,435	9,592
Human Health, [kg/d]			
C2 to C4 alkanes and alkenes	404	485	938
C5 to C8 Alkanes and alkenes	2,156	1,762	4,136
C9 to C12 alkanes and alkenes (a)	1,273	869	2,923
Cyclohexane	0.13	0.24	0.30
Benzene	107	117	195
C6 to C8 non-benzene aromatics	456	547	973
Total aldehydes	0	0	0
Total ketones	0	0	0
Total RS	1,838	1,912	3,125
Photochemical, [kg/d]			
Methane (C1)	8,148	8,675	14,020
Ethane (C2)	33	41	76
C3 to C4 alkanes	306	385	709
C5 to C8 alkanes (b)	2,976	3,482	6,082
C9 to C12 alkanes	317	392	711
C13+ alkanes	31	40	74
Ethylene (C2)	7.8	10	18
C3 to C4 alkenes	57	73	135
C5 to C8 alkenes	52	61	105
C9 to C12 alkenes	83	94	160
C13+ alkenes	0.36	0.45	0.84
Benzene (C6)	107	117	195
C6 to C8 non-benzene aromatics	456	547	973
C9 to C12 aromatics	159	195	353

(a) Unknown is placed in C9 to C12 category for the health assessment.
(b) Unknown is placed in C5 to C8 category for the photochemical assessment.

- Plant process area emissions were scaled according to the number of new major process units;
- Storage tanks emissions were scaled according to production; and
- Effluent pond emissions were scaled according to production rates.

For the Baseline emission scenario, the VOC emissions increase from 4.6 to 5.4 t/d. Similarly, the RS emissions increase from 1.8 to 1.9 t/d. For the Application emission scenario, the VOC emissions are expected to increase from the Baseline estimate of 5.4 to 9.6 t/d. Similarly, the RS emissions increase from the Baseline estimate of 1.9 to 3.1 t/d.

3.2.4 Summary of Mildred Lake Plant Emissions

Table 3-16 compares the emissions associated with continuous sources at the Mildred Lake site for the Existing, Baseline and Application scenarios.

The following are noted about the Syncrude Mildred Lake plant emissions (estimates are approximate):

- The Main Stack is, and will continue to be, the main source of SO_2 emissions. Total SO_2 emissions are expected to continue to remain in the 200 t/d range;
- NO_x emissions are expected to increase from the current 25 to 45 t/d due to the Application emission scenario;
- The Main Stack is, and will continue to be, the main source of CO emissions. Total CO emissions are expected to increase from 50 to about 77 t/d;
- Combustion PM_{10} and $PM_{2.5}$ emissions are expected to essentially double (from 5 to 10 t/d for PM_{10} and from 4 t/d to 8 t/d for $PM_{2.5}$);
- Metals and PAH emissions are also expected to essentially double (from 0.21 to 0.38 t/d for metals and from 0.0025 t/d to 0.005 t/d for $PM_{2.5}$);
- Fugitive sources are the dominant sources of VOC emissions and are expected to essentially double (from 5 to 10 t/d). Note that this does not include the ponds or mine face emissions; and
- Fugitive sources are also the dominant sources of RS emissions and are expected to nearly double (from 1.8 to 3.1 t/d).

Under upset conditions, the operation of the diverter stacks or the flare stacks can result in significant SO_2, CO, PM, HC and RS emissions on a short term basis (a few hours to a few days depending on the nature of the abnormal release).

Table 3-16 Summary of Syncrude Mildred Lake Emissions

Unit	SO_2 t/sd	NO_x t/sd	CO t/sd	PM_{10} t/sd	$PM_{2.5}$ t/sd	Metals t/sd	PAH kg/d	VOC t/sd	RS t/sd
Existing 74/76 MMbbl/y Year 1996/97 Scenario									
Main Stack	197	13.2	51	4.0	2.9	0.21	2.6	0	0
8–3 Stack	-	--	--	--	--	--	--	--	--
Secondary Stacks	0	12.3	3.3	1.1	1.1	0	0	0.1	0
Fugitive	0	0	0	0	0	0	0	4.6	1.8
Total	**197**	**25.5**	**54.3**	**5.1**	**4.0**	**0.21**	**2.6**	**4.7**	**1.8**
Baseline 94 MMbbl/y Year 2001 Scenario									
Main Stack	208	10.9	45.0	3.6	2.6	0.19	2.3	0	0
8–3 Stack	--	--	--	--	--	--	--	--	--
Secondary Stacks	0	14.0	3.4	1.2	1.2	0	0	0.1	0
Fugitive	0	0	0	0	0	0	0	5.4	1.9
Total	**208**	**24.9**	**48.4**	**4.8**	**3.8**	**0.19**	**2.3**	**5.5**	**1.9**
Application 173 MMbbl/y Year 2007 Scenario									
Main Stack	188	14.8	55.2	4.3	3.1	0.23	2.7	0	0
8–3 Stack	12	3.5	13.5	2.9	2.1	0.15	1.9	0	0
Secondary Stacks	0	26.4	7.8	2.6	2.6	0	0	0.3	0
Fugitive	0	0	0	0	0	0	0	9.6	3.1
Total	**200**	**44.7**	**76.5**	**9.8**	**7.8**	**0.38**	**4.6**	**10.9**	**3.1**

3.3 SUNCOR PLANT EMISSIONS

The emission inventory for the Existing, Baseline and CEA scenarios are presented on a source by source basis as follows:

- Section 3.3.1: Continuous emission sources
    - FGD stack
    - Powerhouse stack
    - Incinerator stack
    - Tail Gas Treatment Unit
    - Gas Turbine Generators
    - Secondary stacks
    - Flaring
- Section 3.3.2: Fugitive plant sources

The existing case is based on 1997 data and represents the first full year following FGD start-up when the FGD was operating. The Existing case is based on an SCO production rate of 79,400 bbl/d (29 MMbbl/y). Suncor Baseline SCO production rate is 107,000 bbl/d (39 MMbbl/y). Suncor has submitted an application for Project Millennium which will achieve a production rate of 210,000 bbl/d (77 MMbbl/y). The emission values presented for Suncor are based on engineering design estimates and are presented on a calendar day basis, except where noted. The anticipated annual down-time for FGD is 18 days per year.

The emissions in each scenario may reflect existing or proposed sources. Changes in total emissions may also reflect changes in emissions rates of existing sources between different scenarios.

3.3.1 Continuous Point Sources

The fixed physical parameters of the Existing, Baseline and Project Millennium emissions sources are listed in Table 3-17. The table provides the stack height, stack exit inside diameter, and base elevation of each stack as well it's location in UTM NAD 83 units. These parameters remain the same for each of the assessment scenarios.

3.3.1.1 FGD Stack

The FGD stack (37F-01) services up to three coke-fired boilers. An electrostatic precipitator (ESP) removes a nominal 98% of PM from the flue gases. Subsequently, a flue gas desulphurization (FGD) system removes a nominal 90% of the SO_2 from the flue gases and quantities of particulates prior to atmospheric venting.

Table 3-17 Continuous Emissions Fixed Physical Source Characteristics

Source ID	Description		Height [m]	Diameter [m]	Elevation [m]	Easting UTM [m]	Northing UTM [m]
31F-7A/B	Powerhouse		106.68	5.79	259	470,865	6,317,883
37F-01	FGD Stack		137.20	7.01	259	470,910	6,317,928
5F-1A	Diluent Tower Feed Heater		48.77	1.91	258	470,914	6,318,046
5F-1B	Diluent heater		48.77	1.91	258	470,914	6,318,040
5F-2	Coker Feed Heater		41.15	2.29	258	470,933	6,318,027
5F-3	Coker Feed Heater		41.15	2.29	258	470,933	6,318,003
5F-4	Coker Feed Heater		41.15	2.29	258	470,933	6,317,979
5F-5	Diluent Tower Feed Heater		50.29	1.91	258	470,910	6,318,015
5F-6	Coker Feed Heater		41.15	2.59	258	470,933	6,317,959
7F-1	Naphtha Charge Heater		41.15	1.37	258	470,889	6,318,036
7F-2	Naphtha Depropanizer Reboiler		45.0	1.50	258	470,895	6,318,036
7F-10	Kerosene Charge Heater		41.15	1.37	258	470,889	6,318,027
7F-11	Kerosene Stripper Reboiler		45.72	1.60	258	470,892	6,318,000
7F-20A	Gas Oil Charge Heater		41.15	1.63	258	470,889	6,317,983
7F-20B	Gas Oil Charge Heater		41.15	1.63	258	470,893	6,317,983
7F-20C	Gas Oil Charge Heater		41.15	1.63	258	470,899	6,317,983
6F-2	Hydrogen Reforming Furnace		60.96	2.13	258	470,786	6,318,097
6F-5	Hydrogenation Preheat Furnace		33.53	1.37	258	470,818	6,318,104
6F-3	H2 Flare Pilots and Ignitors		100.00	0.18	258	470,828	6,318,109
8F-10	Final Stage Incinerator(SUNI)		106.70	1.80	258	470,973	6,317,792
19F-1	Hydrocarbon Flare(Continuous)		100.5	0.28	258	471,190	6,318,149
19F-2	H2S Flare Stack		100.5	0.28	258	471,190	6,318,088
19F-3	Hydrocarbon Flare		100.5	0.28	258	471,249	6,318,179
25F-1	Charge Heater		59.13	2.44	258	470,796	6,318,298
25F-2	Vacuum Heater		71.63	3.33	258	470,793	6,318,317
59F-0001	Flare Stack	new	99	0.28	249	471,297	6,318,362
SWS	SWS Flare Stack	new	99	0.28	258	471,015	6,318,405
GTG 1	Gas Turbine Generators Unit 1	new	36.58	3.96	268	470,596	6,317,841
GTG 1/Bypass	Gas Turbine Generators Unit 1	new	18.29	3.96	268	470,553	6,317,841
GTG 2	Gas Turbine Generators Unit 2	new	36.58	3.96	268	470,610	6,317,841
GTG 2/Bypass	Gas Turbine Generators Unit 2	new	18.29	3.96	268	470,653	6,317,841
5F1	New Diluent Heater	new	49	1.91	258	470,910	6,318,003
52F0101A	Diluent Tower Fired Heater	new	97.54	1.98	258	470,971	6,318,554
52F0101B	Diluent Tower Fired Heater	new	97.54	1.98	258	470,971	6,318,545
52F0300	Coker Charge Heaters	new	90.22	3.02	258	471,081	6,318,554
52F0301	Coker Charge Heaters	new	90.22	3.02	258	471,081	6,318,524
SUNNHT	NHT Plant	new	30.48	1.55	259	471,011	6,318,687
SUNDHT	DHT Plant	new	30.48	2.08	260	470,785	6,318,724
SUNGOHT	GOHT	new	30.48	1.68	259	470,954	6,318,829
SUNHRF	Hydrogen Reforming Furnace	new	60.96	3.00	260	470,864	6,318,798
SUNH2FP	H2 Flare Pilots and Igniters	new	100.60	0.30	260	470,873	6,318,813
SUNHPF	Hydrogenation Preheat Furnace	new	30.48	0.79	260	470,879	6,318,763
SUNPWG	H2 Plant Waste Gas	new	60.96	0.30	260	470,852	6,318,817
53F-0610	Tail Gas Treatment Unit	new	106.7	1.83	258	470,952	6,318,483
SUNMIL	Millennium Mine 250,000 lb Boiler	new	18.29	1.37	260	602,420	6,549,762

Notes:

new: the stack is a proposed stack for Project Millennium.

GTG/Bypass: the Gas Turbine Generators will each have separate bypass stacks which would be operated intermittently.

Gases and PM Emissions

Table 3-18 summarizes the stack and emission parameters for the Existing, Baseline and Project Millennium emission scenarios. The existing rates reflect the achieved rates during the commissioning period of the FGD. During this period only one or two of the coke fired boilers were in operation. The emissions for the Baseline and Project Millennium are based on all three boilers being in operation.

Table 3-18 Summary of Stack and Emission Parameters Associated With the Suncor FGD Stack

Emission Scenario		Existing	Baseline	Millennium
Exit Velocity	[m/s]	6.88	12.5	13.12
Exit Temperature	[°C]	59	49	49
SO_2 Emission	[t/cd] ([t/sd])	4.5 (10) (a)	18. (18.9)	18.7 (19.7)
NO_x Emission (b)	[t/cd]	17.8	29.9	29.8
CO Emission (c)	[t/cd]	15.3	25.7	25.6
VOC Emission (d)	[t/cd]	0.102	0.152	0.152
PM Emission (e)	[t/cd]	2.6	2.8	2.6

(a) CSEM, based on 95 percentile which approximated nominal 2 coke fired boilers during 1997.

(b) Existing rate was based on stack survey data; Baseline and Millennium rates are based on engineering projections.

(c) Estimate based on BOVAR (1996a).

(d) AP42 (U.S. EPA 1995) estimate for coke fired boilers, Table 1.1-12, 0.055 kg/t coke burned.

(e) Conor (1998) preliminary stack test results; Suncor estimate of 1.0 t/d was used in the Suncor EIA PM_{10} assessment.

Metals and PAH Emissions

Metal emissions for the Powerhouse (PH) operating without the FGD were previously estimated by prorating the results of a 1984 study (Gnyp et al. 1984) when the total PM emission rate was 12.1 t/d. Forecasted PM emission rates from the FGD were approximately 1 t/d. Preliminary stack test results (Conor Pacific 1998) of the FGD emissions indicate that the emission rate of PM is 2.6 t/d and that approximately 98% of the emissions are $PM_{2.5}$. Table 3-19 shows the estimated metal emission rates for the Existing, Baseline and Project Millennium emission scenarios based on prorating the 1998 values. The estimated existing heavy metals emissions is 29 kg/d. The variation between scenarios reflects a small forecasted change in the PM emissions. Table 3-20 lists the estimated PAH emissions rates for the same scenarios. Total PAHs are expected to remain approximately at the existing emission rate of 0.1 kg/d.

A fly ash specific gravity of 2.31 has been assumed (Theodore and Buonicore 1988). Wet deposition scavenging coefficients of 0.66×10^{-3} h $s^{-1}mm^{-1}$ liquid and 0.22×10^{-3} h $s^{-1}mm^{-1}$ ice have been assumed based on BOVAR (1996d).

Table 3-19 Heavy Metal Emission Rates from the Suncor FGD Stack

Metal	Existing [a] (kg/d)	Baseline [b] (kg/d)	Millennium [b] (kg/d)
Aluminum	3.3	3.6	3.3
Antimony	0.027	0.029	0.027
Arsenic	0.043	0.048	0.043
Barium	0.45	0.49	0.45
Beryllium	<0.0047	<0.0052	<0.0047
Cadmium	0.006	0.0066	0.006
Chromium	1.9	2.1	1.9
Cobalt	0.097	0.11	0.097
Copper	0.16	0.18	0.16
Iron	14	15	14
Lead	0.31	0.34	0.31
Manganese	0.83	0.91	0.83
Mercury	0.0051	0.0056	0.0051
Molybdenum	0.39	0.42	0.39
Nickel	2.8	3.1	2.8
Selenium	1.7	1.9	1.7
Silver	<0.024	<0.026	<0.024
Tin	<0.31	<0.34	<0.31
Titanium	0.42	0.47	0.42
Vanadium	1.5	1.7	1.5
Zirconium	<0.31	<0.34	<0.31
Zinc	0.57	0.62	0.57
TOTAL	**29**	**32**	**29**

(a) CONOR 1998, Stack Survey, Preliminary results.
(b) Prorated based on predicted PM emissions.

3.3.1.2 Powerhouse Stack

The Powerhouse stack (31F-7A/B) acts as a bypass stack during periods when the FGD process is down and also services the emissions from up to five natural gas fired boilers. The large gas fired boiler is normally on-line on a near full-time basis. The four smaller boilers are used to provide power when one of the three-coke-fired boilers is down. The emissions from the gas fired boilers (31F-7A) contain low amounts of NO_x and SO_2. Table 3-21 summarizes the stack and emission parameters associated with this stack (31F-7B) under FGD bypass operations. When the Powerhouse stack services the emissions from three coke-fired boilers (referred to as 31F-7B), the FGD unit is by-passed and the emissions contain NO_x and large amounts of SO_2. The FGD bypass is operational up to 5% of the time based on the expected down-time of the newly commissioned FGD. Table 3-22 summarizes the stack and emission parameters associated with this stack (31F-7A) for average annual and under normal operations. The low Baseline and Project Millennium emission rates from the 31F-7B stack reflect the 5% annual operational time.

Table 3-20 PAH Emission Rates from the Suncor FGD Stack

PAH	Existing [a] (kg/d)	Baseline [b] (kg/d)	Millennium [b] (kg/d)
Acenaphthene	0.00053	0.00059	0.00053
Acenaphylene	0.00034	0.00037	0.00034
Anthracene	0.0016	0.0018	0.0016
1,2-Benzathracene	0.00055	0.00061	0.00055
Benzo(b&j)fluoranthene	0.0041	0.0045	0.0041
Benzo(k)fluoranthene	<0.00047	<0.00052	<0.00047
Benzo(a)fluorene	0.00061	0.00067	0.00061
Benzo(b)fluorene	0.00031	0.00035	0.00031
Benzo(g,h,i)perylene	0.00057	0.00063	0.00057
Benzo(a)pyrene	<0.00047	<0.00052	<0.00047
Benzo(e)pyrene	0.00031	0.00035	0.00031
Camphene	0.0011	0.0012	0.0011
Carbazole	0.00055	0.00061	0.00055
1-Chloronaphthalene	<0.00047	<0.00052	<0.00047
2-Chloronaphthalene	<0.00047	<0.00052	<0.00047
Chrysene	0.00077	0.00085	0.00077
Dibenz(a,j)acridine	<0.00047	<0.00052	<0.00047
Dibenz(a,h)acridine	<0.00047	<0.00052	<0.00047
Dibenz(a,h)anthracene	<0.00047	<0.00052	<0.00047
Dibenzothiophene	0.0019	0.0021	0.0019
7,12-dimethylbenz(a)anthracene	<0.00047	<0.00052	<0.00047
1,6-Dinitropyrene	<0.00047	<0.00052	<0.00047
1,8-Dinitropyrene	<0.00047	<0.00052	<0.00047
Fluoranthene	0.0041	0.0046	0.0041
Fluorene	0.0029	0.0032	0.0029
Ideno(1,2,3-cd)pyrene	<0.00047	<0.00052	<0.00047
Indole	0.0011	0.0012	0.0011
1-Methylnaphthalene	0.0049	0.0054	0.0049
2-Methylnaphthalene	0.007	0.0078	0.007
Naphthalene	0.037	0.04	0.037
Nitro-pyrene	0.00071	0.00078	0.00071
Perylene	0.00031	0.00035	0.00031
Phenanthrene	0.018	0.019	0.018
Pyrene	0.0025	0.0028	0.0025
Retene	0.0055	0.0061	0.0055
Total	**0.10**	**0.11**	**0.10**

[a] CONOR 1998, Stack Survey, Preliminary results.
[b] Prorated based on predicted PM emissions.

Table 3-21 Summary of Stack and Emission Parameters Associated With the Suncor Powerhouse (31F-7B) Stack from Coke Fired Boilers

Emission Scenario		Existing	Baseline	Millennium
Exit Velocity	[m/s]	28.8	30.5	30.5
Exit Temperature	°C]	244	193	193
SO_2 Emission	[t/cd] ([t/sd])	44.4 (171) [(a)]	12.8 (259)	12.8 (259)
NO_x Emission	[t/cd]	21.3	1.07	0.96
CO Emission	[t/cd]	18.3	0.92	0.83
VOC Emission	[t/cd]	0.005	0.008	0.008
PM Emission	[t/cd]	0.24	0.24	0.24

[(a)] Based on 95th percentile CSEM rate which approximates nominal 2 coke fired boiler rate.
Note: the higher existing rates reflect commissioning period of the FGD.

Table 3-22 Summary of Stack and Emission Parameters Associated With the Suncor Powerhouse (31F-7A) Stack from Gas Fired Boilers

Emission Scenario		Existing	Baseline	Millennium
Exit Velocity	(m/s)	7.01	7.01	7.01
Exit Temperature	(°C)	166	166	166
SO_2 Emission	[t/cd]	n/a	0.3	1.2
NO_x Emission	[t/cd]	n/a	2.8	1.9
CO Emission	[t/cd]	n/a	2.4	1.6
VOC Emission	[t/cd]	n/a	n/a	n/a
PM Emission	[t/cd]	n/a	n/a	n/a

n/a Estimate not available.

3.3.1.3 Incinerator Stack

The incinerator stack services the sulphur recovery plant that removes a nominal 98% of the sulphur in the acid gas with a SuperClaus™ recovery processes. Table 3-23 summarizes the stack and emission parameters associated with this stack.

The incinerator stack is equipped with a CSEM to measure flue gas SO_2 concentration, velocity and temperature on a continuous basis. Four manual stack surveys are conducted each year to determine flue gas SO_2 concentrations, total gas flows and temperatures. The Existing emission rates are based on CSEM emissions and the Baseline and Project Millennium emissions have been estimated based on expected production rates.

The average SO_2 emissions are expressed on a stream day (t/sd) and a calendar day basis (t/cd).

NO_x and CO emissions are not normally measured during the stack surveys. However, NO_x was measured during Stack Survey 91-4 and CO was measured during Stack Survey 89-1 (BOVAR 1996a). These are the most recent surveys when NO_x and CO were measured. The average emission rates measured for NO_x and CO are 0.11 and 5.5 t/d, respectively, when the incinerator was operating at nominal rates of 20 m/s and 500 °C.

Table 3-23 Stack and Emission Parameters Associated With the Suncor Incinerator Stack

Emission Scenario		Existing	Baseline	Millennium
Volume Flow	[10^6 m^3/d]	2.19	2.19	2.19
Fired Duty Rating	[MMBTU/h]	29.1	29.1	35.0
Exit Velocity	[m/s]	24.4	24.4	29.3
Exit Temperature	[°C]	463	463	463
SO_2 Emissions	[t/cd] ([t/sd])	17.9 (19.4)	18.8 (19.1)	12.3 (10.2)
NO_x Emission (a)	[t/cd]	0.057	0.057	0.069
CO Emission (b)	[t/cd]	2.9	2.9	3.4
VOC Emission (c)	[t/cd]	0.051	0.051	0.051
PM Emission (d)	[t/cd]	0.032	0.032	0.038

(a) NO_x Emission factor from Bantrel, 0.082 kg/MMBTU.

(b) Prorated CO emissions based on 1989 stack survey, and NO_x emission estimate assuming products of incomplete combustion, equivalent to 3638 kg/10^6 m^3 fuel consumed.

(c) VOC estimates based on U.S. EPA emission factor, assuming 83% of THC emissions are VOCs (AP42, Table 1.4-3, 1995), 23.24 kg/10^6 m^3 fuel consumed.

(d) PM_{10} emission factor from U.S. EPA (Table 1.3-10, 1995), 0.045 kg/MMBTU.

3.3.1.4 Tail Gas Treatment Unit

Sulphur recovery for Project Millennium will be achieved through the addition of the a Tail Gas Treatment Unit (TGTU) which will operate at 99.7% efficiency. The TGTU is serviced by a Thermal Oxidizer stack (53F-0610). Table 3-24 lists the Project Millennium emission estimates for the TGTU. The same emission factor estimates were used for the new TGTU as were applied to the 8F-5 Incinerator.

Table 3-24 Stack and Emission Parameters Associated With the Suncor TGTU Thermal Oxidizer Stack

Emission Scenario		Existing	Baseline	Millennium
Volume Flow	[10^6 m^3/d]	--	--	6.93
Fired Duty Rating	[MMBTU/h]	--	--	38.5
Exit Velocity	[m/s]	--	--	30.5
Exit Temperature	[°C]	--	--	399
SO_2 Emissions	[t/cd] ([t/sd])	--	--	8.7 (5.2)
NO_x Emission (a)	[t/cd]	--	--	0.076
CO Emission (b)	[t/cd]	--	--	3.8
VOC Emission (c)	[t/cd]	--	--	0.161
PM Emission (d)	[t/cd]	--	--	0.042

(a) NO_x Emission factor from Bantrel, 0.082 kg/MMBTU.

(b) Prorated CO emissions based on 1989 stack survey, and NO_x emission estimate assuming products of incomplete combustion, equivalent to 3638 kg/10^6 m^3 fuel consumed.

(c) VOC estimates based on U.S. EPA emission factor, assuming 83% of THC emissions are VOCs (AP42, Table 1.4-3, 1995), 23.24 kg/10^6 m^3 fuel consumed.

(d) PM_{10} emission factor from U.S. EPA (Table 1.3-10, 1995), 0.045 kg/MMBTU.

3.3.1.5 Gas Turbine Generators

To supply power requirements for Project Millennium, two 45 MW Gas Turbine Generators (GTGs) are being proposed. These generators will be equipped with low NO_x burners and will be serviced by a routine emission stack and a bypass stack for use when steam is not required from the heat recovery steam generators. The power generated from the two proposed GTGs will supplement power already being produced through Suncor Energy Services. Table 3-25 lists Project Millennium emission estimates for the GTGs.

U.S. EPA emission factors are not available for turbine generators to estimate CO, VOC and particulates. The emission factors for natural gas combustion based on large industrial boilers were used to estimate these emissions.

Table 3-25 Stack and Emission Parameters Associated With the Suncor Gas Turbine Generators

Emission Scenario		Existing	Baseline	Millennium	
				GTG 1	GTG 2
Fired Duty Rating	[MMBTU/h]	--	--	290	290
Exit Velocity	[m/s]	--	--	34.4	34.4
Exit Temperature	[°C]	--	--	164	164
SO_2 Emissions	[t/cd] ([t/sd])	--	--	0.55	0.55
NO_x Emission	[t/cd]	--	--	1.8	1.8
CO Emission (a)	[t/cd]	--	--	0.14	0.14
VOC Emission (a)	[t/cd]	--	--	0.0049	0.0049
PM_{10} Emission (b)	[t/cd]	--	--	0.042	0.042

(a) CO and VOC estimates based on U.S. EPA emission factor, assuming 83% of THC emissions are VOCs (AP42, Table 1.4-3, 1995).

(b) PM_{10} emission factor from U.S. EPA (Table 1.3-10, 1995).

3.3.1.6 Secondary Stacks

The Suncor fixed plant operations are serviced by numerous secondary stacks that are either fired with natural gas or refinery gas. Table 3-26, Table 3-27 and Table 3-28 provide secondary stack and emission parameters for the Existing, Baseline and Project Millennium emission cases, respectively. The following provides a summary for each emission case:

- Existing case (Table 3-26): A total of 16 secondary stacks result in 2.0 t/cd of SO_2 and 2.3 t/cd of NO_x emissions.
- Baseline case (Table 3-27): An additional two stacks (associated with Units 25-F-1 and 25F-2) result in a total of 18 stacks. The SO_2 emissions are 2.8 t/cd and the NO_x emissions are 2.4 t/cd.

- Project Millennium case (Table 3-28): An additional 12 stacks result in a total of 30 secondary sources. The SO_2 emissions increase to 4.7 t/cd and the NO_x emissions increase to 4.0 t/cd.

U.S. EPA emission factors were used to estimate CO, VOC and particulates emissions. The emission factors for natural gas combustion based on the respective fired duty rating of each stack equipment were used to estimate these emissions. The emission factors are listed in Table 3-29. The estimates assume that Suncor refinery gas fuel is used in each unit. Suncor refinery gas has a higher heating value and higher emissions than natural gas.

Table 3-26 Existing Secondary Source Emission Rates

ID	Description	Temp °C	Velocity m/s	Fired Duty MMBTU/h	SO_2 t/cd	NO_x t/cd	CO t/cd	PM_{10} t/cd	VOC t/cd
5F-1A	Diluent Tower Feed Heater	460	5.79	55.02	0.070	0.099	2.3E-02	8.8E-03	1.7E-03
5F-1B	Diluent heater	460	5.49	55.02	0.070	0.099	2.3E-02	8.8E-03	1.7E-03
5F-2	Coker Feed Heater	454	8.53	121.25	0.150	0.176	5.7E-02	1.8E-02	2.1E-03
5F-3	Coker Feed Heater	454	10.97	155.00	0.200	0.225	7.3E-02	2.3E-02	2.1E-03
5F-4	Coker Feed Heater	454	10.97	155.00	0.200	0.225	7.3E-02	2.3E-02	2.1E-03
5F-5	Diluent Tower Feed Heater	374	16.15	152.50	0.200	0.112	7.1E-02	2.2E-02	1.8E-03
5F-6	Coker Feed Heater	454	6.71	155.00	0.200	0.225	7.3E-02	2.3E-02	2.1E-03
7F-1	Naphtha Charge Heater	454	4.57	22.90	0.028	0.042	9.4E-03	3.7E-03	1.1E-03
7F-2	Naphtha Depropanizer Reboiler	460	5.55	29.50	0.036	0.054	1.2E-02	4.7E-03	1.4E-03
7F-10	Kerosene Charge Heater	454	7.92	36.90	0.050	0.067	1.5E-02	5.9E-03	1.3E-03
7F-11	Kerosene Stripper Reboiler	454	6.10	46.50	0.057	0.084	1.9E-02	7.4E-03	1.7E-03
7F-20A	Gas Oil Charge heater	460	9.45	21.12	0.028	0.038	8.6E-03	3.4E-03	6.9E-04
7F-20B	Gas Oil Charge heater	460	9.45	21.12	0.028	0.038	8.6E-03	3.4E-03	6.9E-04
7F-20C	Gas Oil Charge heater	460	9.45	21.12	0.028	0.038	8.6E-03	3.4E-03	6.9E-04
6F-2	Hydrogen Reforming Furnace	293	13.11	482.41	0.620	0.701	2.3E-01	7.1E-02	9.0E-03
6F-5	Hydrogenation Preheat Furnace	454	5.88	20.80	0.028	0.038	8.5E-03	3.3E-03	7.4E-04
				Total	**2.0**	**2.3**	**0.71**	**0.23**	**0.031**

Table 3-27 Baseline Secondary Source Emission Rates

ID	Description	Temp °C	Velocity m/s	Fired Duty MMBTU/h	SO_2 t/cd	NO_x t/cd	CO t/cd	PM_{10} t/cd	VOC t/cd
5F-1A	Diluent Tower Feed Heater	460	5.49	53.40	0.088	0.103	2.2E-02	8.6E-03	1.7E-03
5F-1B	Diluent heater	460	5.49	53.40	0.088	0.103	2.2E-02	8.6E-03	1.7E-03
5F-2	Coker Feed Heater	454	8.23	114.80	0.193	0.179	5.4E-02	1.7E-02	2.1E-03
5F-3	Coker Feed Heater	454	8.23	114.80	0.193	0.179	5.4E-02	1.7E-02	2.1E-03
5F-4	Coker Feed Heater	454	8.23	114.80	0.193	0.179	5.4E-02	1.7E-02	2.1E-03
5F-5	Diluent Tower Feed Heater	374	10.97	104.30	0.175	0.082	4.9E-02	1.5E-02	1.8E-03
5F-6	Coker Feed Heater	454	8.23	114.80	0.193	0.179	5.4E-02	1.7E-02	2.1E-03
7F-1	Naphtha Charge Heater	454	4.57	22.90	0.035	0.043	9.4E-03	3.7E-03	1.1E-03
7F-2	Naphtha Depropanizer Reboiler	460	5.55	29.50	0.044	0.055	1.2E-02	4.7E-03	1.4E-03
7F-10	Kerosene Charge Heater	454	7.92	36.90	0.061	0.069	1.5E-02	5.9E-03	1.3E-03
7F-11	Kerosene Stripper Reboiler	454	6.10	46.50	0.079	0.087	1.9E-02	7.4E-03	1.7E-03
7F-20A	Gas Oil Charge heater	460	9.45	21.12	0.035	0.039	8.6E-03	3.4E-03	6.9E-04
7F-20B	Gas Oil Charge heater	460	9.45	21.12	0.035	0.039	8.6E-03	3.4E-03	6.9E-04
7F-20C	Gas Oil Charge heater	460	9.45	21.12	0.035	0.039	8.6E-03	3.4E-03	6.9E-04
6F-2	Hydrogen Reforming Furnace	293	13.11	482.41	0.788	0.721	2.3E-01	7.1E-02	9.0E-03
6F-5	Hydrogenation Preheat Furnace	454	5.88	20.80	0.035	0.039	8.5E-03	3.3E-03	7.4E-04
25F-1	Charge Heater	213	3.96	97.60	0.166	0.076	4.0E-02	1.6E-02	3.2E-03
25F-2	Vacuum Heater	204	4.57	211.00	0.368	0.165	9.9E-02	3.1E-02	3.6E-03
				Total	**2.8**	**2.4**	**0.76**	**0.25**	**0.038**

Table 3-28 Project Millennium Secondary Source Emission Rates

ID	Description	Temp °C	Velocity m/s	Fired Duty MMBTU/h	SO_2 t/cd	NO_x t/cd	CO t/cd	PM_{10} t/cd	VOC t/cd
5F-1A	Diluent Tower Feed Heater	460	5.49	54.0	0.080	0.100	2.2E-02	8.7E-03	1.7E-03
5F-1B	Diluent heater	460	5.49	54.0	0.080	0.100	2.2E-02	8.7E-03	1.7E-03
5F-2	Coker Feed Heater	454	8.53	123.0	0.190	0.183	5.8E-02	1.8E-02	2.1E-03
5F-3	Coker Feed Heater	454	8.53	123.0	0.190	0.183	5.8E-02	1.8E-02	2.1E-03
5F-4	Coker Feed Heater	454	8.53	123.0	0.190	0.188	5.8E-02	1.8E-02	2.1E-03
5F-5	Diluent Tower Feed Heater	374	10.97	105.6	0.170	0.081	4.9E-02	1.5E-02	1.8E-03
5F-6	Coker Feed Heater	454	5.18	123.0	0.190	0.184	5.8E-02	1.8E-02	2.1E-03
7F-1	Naphtha Charge Heater	454	6.71	34.3	0.050	0.063	1.4E-02	5.5E-03	1.1E-03
7F-2	Naphtha Depropanizer Reboiler	460	8.47	44.4	0.070	0.081	1.8E-02	7.1E-03	1.4E-03
7F-10	Kerosene Charge Heater	454	8.84	40.7	0.060	0.075	1.7E-02	6.5E-03	1.3E-03
7F-11	Kerosene Stripper Reboiler	454	6.71	51.4	0.080	0.094	2.1E-02	8.2E-03	1.7E-03
7F-20A	Gas Oil Charge heater	460	9.45	21.2	0.030	0.039	8.7E-03	3.4E-03	6.9E-04
7F-20B	Gas Oil Charge heater	460	9.45	21.2	0.030	0.039	8.7E-03	3.4E-03	6.9E-04
7F-20C	Gas Oil Charge heater	460	9.45	21.2	0.030	0.039	8.7E-03	3.4E-03	6.9E-04
6F-2	Hydrogen Reforming Furnace	293	14.60	530.2	0.850	0.782	2.5E-01	7.8E-02	9.0E-03
6F-5	Hydrogenation Preheat Furnace	454	5.88	22.8	0.040	0.042	9.3E-03	3.6E-03	7.4E-04
25F-1	Charge Heater	213	4.88	119.4	0.210	0.094	5.6E-02	1.7E-02	2.0E-03
25F-2	Vacuum Heater	204	4.88	221.3	0.380	0.173	1.0E-01	3.2E-02	3.8E-03
5F1	New Diluent Heater	460	5.49	64.0	0.100	0.049	2.6E-02	1.0E-02	2.1E-03
52F0101A	Diluent Tower Fired Heater	232	7.62	113.5	0.160	0.088	5.3E-02	1.7E-02	1.9E-03
52F0101B	Diluent Tower Fired Heater	232	7.62	113.5	0.160	0.088	5.3E-02	1.7E-02	1.9E-03
52F0300	Coker Charge Heaters	232	7.62	267.5	0.370	0.210	1.3E-01	3.9E-02	4.5E-03
52F0301	Coker Charge Heaters	232	7.62	267.5	0.370	0.210	1.3E-01	3.9E-02	4.5E-03
SUNNHT	NHT Plant	454	7.62	49.1	0.070	0.039	2.0E-02	7.9E-03	1.6E-03
SUNDHT	DHT Plant	454	7.62	87.6	0.120	0.068	3.6E-02	1.4E-02	2.8E-03
SUNGOHT	GOHT	510	7.62	57.3	0.080	0.046	2.3E-02	9.2E-03	1.9E-03
SUNHRF	Hydrogen Reforming Furnace	232	7.62	254.7	0.360	0.192	1.2E-01	3.7E-02	4.3E-03
SUNHPF	Hydrogenation Preheat Furnace	454	7.62	11.9	0.020	0.009	4.9E-03	1.9E-03	3.8E-04
SUNMIL	Millennium Mine 250,000lb Boiler	166	31.70	100.0	0	0.500	4.7E-02	1.5E-02	1.7E-03
				Total	**4.7**	**4.0**	**1.42**	**0.52**	**0.09**

Table 3-29 U.S. EPA Emission Factors for Natural Gas Combustion based on Industrial Boilers

[kg/10^6 m^3]	Large [(a)]	Medium [(b)]	Small [(c)]
NO_x	8,800	2,240	1,600
CO	640 (764)	560 (669)	330 (394)
VOC	23.4 (28)	44 (53)	84 (101)
PM_{10}	200 (239)	219 (262)	192 (229)

(a) Utility/large industrial boilers (>100 MMBTU/h).
(b) Small industrial boilers (10-100 MMBTU/h).
(c) Commercial boilers (0.3 -10 MMBTU/h).
Emission factors are listed for: Natural Gas 929 BTU/ft^3 (Refinery Gas 1110 BTU/ft^3).

3.3.1.7 Flare Emissions

The Suncor plant is serviced by several flare stacks which are used to dispose of waste gas streams on both a continuous and intermittent basis. Emissions associated with these flare stacks are as follows:

- The high pressure hydrocarbon flare stack (19F-1) is used to dispose of waste gas streams on a continuous basis in addition to being used on an intermittent basis for plant start-up, shut-down, maintenance and upset conditions. Under these conditions, an additional low pressure hydrocarbon stack (19F-3) is used to handle additional volumes of gas.

- The acid flare stack (19F-2) is used to dispose sour gas under amine and/or sulphur recovery plant start-up, shut-down, maintenance and upset conditions. A continuous pilot services the flare stack.
- The hydrogen plant flare stack (6F-3) is used to dispose of excess hydrogen on a continuous basis and during plant start-up, shut-down and maintenance operations. A continuous pilot services the flare stack.

The high pressure hydrocarbon flare stack (19F-1) is the only flare that produces significant emissions on a continuous basis. Stack and emission parameters associated with this stack are provided in Table 3-30. The proposed Millennium project will produce the following changes to the plant flare system:

- Continuous emissions from the high pressure hydrocarbon stack are projected to decrease significantly.
- The new plant facilities will be serviced by an additional hydrocarbon stack (59F-0001) that will be used under plant start-up, shut-down, maintenance and upset conditions.
- A new sour water stripper flare stack (SWS) will be used under plant start-up, shut-down, maintenance and upset conditions.

Under normal operations, the only emissions from these stacks result from the flare stack pilots and igniters which are small sources of NO_x, CO_2 and CO.

The source characteristics required by dispersion models (e.g., SCREEN3) that address flare stacks explicitly (e.g., SO_2 emission rates, heat released) are provided in Table 3-30. For models that do not address flare stacks explicitly (e.g., ISC, CALPUFF) pseudo parameters are provided that allow these models to simulate flare stacks.

Table 3-30 Summary of Continuous Emissions From the Hydrocarbon Flare

Emission Scenario		Existing	Baseline	Millennium
Total Volume to Flare	[m^3/s]	0.346	0.346	0.008
Heat of Combustion	[MJ/m^3]	41	40.0	38.4
Pseudo Parameters				
Height	[m]	105	105	100
Diameter	[m]	1.22	1.22	0.18
Velocity	[m/s]	20	20	20
Temperature	[°C]	1000	1000	1000
SO_2 Emissions	[t/cd] ([t/sd])	12.4 (12.5)	12.6 (7.3)	10.6 (1.3)
NO_x Emissions	[t/cd]	0.10	0.10	0.03
CO Emission	[t/cd]	0.27	0.20	0.01
VOC Emission	[t/cd]	0.045	0.033	0.002
PM_{10} Emission	[t/cd]	0.007	0.005	0.0003

3.3.2 Fugitive Plant Sources

Suncor has several fugitive sources of VOC emissions:

- Primary (Plant 3) and Secondary (Plant 4) extraction vents;
- South Tank Farm;
- North Tank Farm and Project Millennium Tank Farm;
- Delayed Cokers during decoke operations; and
- Plant-wide valves, flanges, seals, etc.

Two of these VOC emission sources, the Primary and Secondary extraction vents emissions and the South Tank Farm emissions have been captured with the recently commissioned Vapour Recovery Unit (VRU). The VRU has a nominal up-time of 90% and therefore emissions have been significantly reduced. Fugitive emissions from the Delayed Cokers (included in the estimate of fugitive emission from Upgrading) is difficult to measure and difficult to estimate. The estimates provided in Table 3-31 are based on Suncor professional judgement.

Table 3-31 Fugitive VOC Emissions From the Suncor Fixed Plant

Unit	Description	Existing [t/cd]	Baseline [t/cd]	Millennium [t/cd]
STFarm	South Tank Farm	3.1	3.2	3.7
Plant3	Extraction Plants 3	8.0	5.0	3.1
Plant4	Extraction Plants 4	0.92	1.1	2.3
20D	North/Millennium Tank Farm	0.3	0.3	0.3
Upgrading	Upgrading Fixed Plants 5,6,7,8	6.4	7.7	13.7
Plant 6	Hydrogen	--	--	0.036
Plant 25	DRU/VAC	--	--	0.038
Plant 52	DRU/DCU/GRU/	--	--	0.15
Plant 53	Sulphur Block	--	--	0.033
Plant 54	Hydrogen	--	--	0.033
Plant 55	NHT/KHT/GOHT	--	--	0.10
Total		**18.7**	**17.3**	**23.5**

Note: RS represent approximately 1% of VOC emissions based on vent gas surveys of Plant 3 and Plant 4.

Speciation of the VOCs for the Plant Fugitive emissions are listed in Table 3-32. This speciation was based on the VOC characterization study done by Clearstone (1997) for Syncrude which assumes similar VOC emissions from both the Suncor and Syncrude plants.

Whereas pond fugitive emissions will correlate to a combination of ambient temperature and wind speed, the fugitive emissions from the fixed plant are expected to be less dependent on the ambient conditions. This is because the emission rates are expected be more influenced by plant process parameters (e.g., plant temperatures, process rates and pressures). The plant fugitive emissions would therefore be expected to be much more uniform over the course of a year than the tailings pond emissions discussed in Section 3.7.1.

Table 3-32 **Fugitive HC and RS Emission from the Suncor Plant Area**

Source	Existing	Baseline	Millennium
General, [kg/d]			
Total hydrocarbon (C1+)	20,090	18,240	24,302
Methane (C1)	1,340	920	800
C2+	18,750	17,320	23,502
Human Health, [kg/d]			
C2 to C4 alkanes and alkenes	1,651	1,544	2,299
C5 to C8 Alkanes and alkenes	8,814	5,615	10,133
C9 to C12 alkanes and alkenes (a)	5,205	2,770	7,161
Cyclohexane	1	1	1
Benzene	437	374	477
C6 to C8 non-benzene aromatics	1,864	1,743	2,385
Total aldehydes	0	0	0
Total ketones	0	0	0
Total RS	171	131	151
Photochemical, [kg/d]			
Methane (C1)	1,340	920	800
Ethane (C2)	134	130	186
C3 to C4 alkanes	1,251	1,227	1,738
C5 to C8 alkanes (b)	12,170	11,094	14,903
C9 to C12 alkanes	1,296	1,248	1,742
C13+ alkanes	128	127	181
Ethylene (C2)	32	32	45
C3 to C4 alkenes	234	232	330
C5 to C8 alkenes	213	193	258
C9 to C12 alkenes	340	299	391
C13+ alkenes	1	1	2
Benzene (C6)	437	374	477
C6 to C8 non-benzene aromatics	1,864	1,743	2,385
C9 to C12 aromatics	649	621	865

(a) Unknown speciation are placed in C9 to C12 category for health assessment.
(b) Unknown speciation are placed in C5 to C8 category for photochemical assessment.

3.3.3 Summary of Suncor Plant Emissions

The Suncor emissions are summarized in Table 3-33, Table 3-34 and Table 3-35 for the Existing, Baseline and Project Millennium scenarios, respectively. The following are noted on the changes in emissions between the scenarios:

- The annual average SO_2 emissions (i.e., calendar day rates) are reduced between the Existing scenario (from 81 t/cd) and the Baseline scenario (65 t/cd). There is a predicted increase of SO_2 annual average emissions by 8% for Project Millennium. This annual average reflects the total SO_2 emission for the Suncor operations, including all large and small combustion sources of fuel gas containing sulphur.

- Under normal operating conditions (i.e., stream day rates), the SO_2 emissions are predicted to increase 10% between the Existing and Baseline scenarios, but a net decrease is predicted for the Project Millennium scenario (to 43.8 t/sd).
- Total NO_x emissions are predicted to increase from 50 t/d (Existing 1997) to 67.7 t/d for Project Millennium. Approximately half of the NO_x emissions are estimated fleet emissions.
- CO emissions are expected to decrease due to the commissioning of the FGD. However, these estimate are largely based on emission factors that contain some uncertainty for these large sources.
- The largest source of particulates is the FGD stack. Emission levels increase from the Existing scenario to the Project Millennium scenario by 10% due to the increase in particulates from combustion in the furnace stacks and mine fleet.
- Fugitive VOC and RS emissions show the largest change between scenarios. These emissions are dominated by the predicted emissions which are directly linked to production rates. Production rates will directly affect mine face emissions and tailings pond emissions. Fixed plant VOC fugitive emissions (i.e., excluding the mine face and tailings emissions that will be discussed in Section 3.6 and Section 3.7) are predicted to increase from approximately 20 t/d to 25 t/d.

Under upset conditions, the operation of the FGD bypass or HC flaring can result in significant SO_2 emission on a short term basis (a few hours for flaring or a few days for the FGD operation, depending on the nature of the upset).

Table 3-33 Summary of Existing (1997) Suncor Emissions

Source	Emission Rates (t/cd)					
	SO_2 (c)	NO_x	CO	PM (a)	VOC	RS
Powerhouse Stack (d)	44.4 (0.31)	21.3 (e)	18.3 (e)	0.24 (e)	0.005	n/a
FGD Stack	4.5 (10)	17.8 (e)	15.3 (e)	2.6 (e)	0.102	n/a
Sulphur Incinerator	17.9 (19.4)	0.057	2.9	0.032	0.051	n/a
Upgrading Furnaces	2.0 (2.1)	2.3	0.71	0.23	0.031	--
Flaring (Continuous and Acid Gas)	12.4 (12.5)	0.10	0.27	0.045	0.007	--
Plant Fugitive (c)	-	-	-	-	18.7	0.17
Mine Fleet	0.04 (0.04)	8.2	2.6	0.28	0.5	--
Tailings Ponds	-	-	-	-	83	1.0
Mine Surface (b)	-	-	-	-	3.3	0.021
Plant sub-Total	**81.0 (44.3)**	**23.8**	**22.2**	**3.12**	**18.9**	**0**
Total	**81.0 (44.3)**	**32.0**	**24.8**	**3.4**	**106**	**1.2**

n/a Data not available.
\- Not a source of this emission.
(a) Assumed as PM_{10}.
(b) Estimated based on Syncrude data.
(c) Bracketed numbers are stream day rates [t/sd].
(d) Emissions are for the coke fired boilers only.
(e) Emissions are equivalent calendar day rates. emissions will result from Powerhouse or FGD stack but not simultaneously.

Table 3-34 Summary of Baseline (Current + Approved) Suncor Emissions

Source	Emission Rates (t/cd)					
	SO_2 (c)	NO_x	CO	PM (a)	VOC	TRS
Powerhouse Stack (d)	13.1 (0.31)	3.9	3.3	0.2	0.008	n/a
FGD Stack	18.0 (18.9)	29.8	25.7	2.8	0.15	n/a
Sulphur Incinerator	18.8 (19.1)	0.1	2.9	0.03	0.051	n/a
Upgrading Furnaces	2.8 (2.9)	2.5	0.8	0.3	0.038	--
Flaring (Continuous and Acid Gas)	12.6 (7.3)	0.1	0.2	0.005	0.033	--
Plant Fugitive (e)	-	-	-	-	17.3	0.13
Mine Fleet	0.04 (0.04)	11.3	0.6	0.1	0.27	--
Tailings Ponds	-	-	-	-	102.0	1.3
Mine Surface (b)	-	-	-	-	5.57	0.035
Plant sub-Total	**65.3 (48.5)**	**36.4**	**32.9**	**3.3**	**17.6**	**0.13**
Total	**65.3 (48.6)**	**47.7**	**33.5**	**3.4**	**125**	**1.5**

n/a Data not available.

\- Not a source of this emission.

(a) Assumed as PM_{10}.

(b) Estimated based on Syncrude data.

(c) Bracketed numbers are stream day rates [t/sd].

(d) Emissions from the powerhouse stack are the total emissions from the gas fired boilers and annualized coke fired boiler emissions.

(e) Includes Tank Farms, Extraction and Upgrading.

Table 3-35 Summary of Suncor Project Millennium Emissions

Source	Emission [t/cd]					
	SO_2 (a)	NO_x	CO	PM (b)	VOC	RS
Powerhouse stack (f)	14.0 (1.2)	2.9	2.5	0.2	0.008	n/a
FGD stack	18.7 (19.7)	29.7	25.6	2.6	0.2	n/a
Millennium mine boilers / GTGs (c)	1.1 (1.2)	4.1	0.3	0.1	0.01	-
Sulphur incinerator	12.3 (10.2)	0.064	3.4	0.038	0.06	n/a
Tail gas treatment unit	8.7 (5.2)	0.029	3.8	0.04	0.2	n/a
Upgrading furnace stacks	4.7 (4.9)	3.8	1.4	0.5	0.063	-
Flaring - continuous and acid gas	10.6 (1.3)	0.191	0.2	0.01	0.041	0.011
Plant Fugitive (d)	-	-	-	-	23.3	0.15
Mine fleet	0.08 (0.08)	26.9	1.4	0.3	0.8	-
Tailings ponds	-	-	-	-	200.2	2.4
Mine surface(e)	-	-	-	-	8.1	0.052
Plant sub-Total	**70.1 (43.72)**	**40.8**	**37.2**	**3.5**	**23.9**	**0.25**
Total	**70.2 (43.8)**	**67.7**	**38.6**	**3.8**	**233**	**2.7**

n/a data not available.

\- not a source of this emission.

(a) Bracketed numbers are stream day rates, [t/sd].

(b) Assumed as PM_{10}.

(c) Gas turbine generators.

(d) Includes Tank farms, Extraction and Upgrading.

(e) Estimated based on Syncrude data.

(f) Emissions from the powerhouse stack are the total emissions from the gas fired boilers and annualized coke fired boiler emissions.

3.4 OTHER PLANT SOURCES

Other Existing, Baseline and planned plant facilities will have continuous point source and fugitive emissions. Emission estimates are provided for these facilities from a combination of preliminary engineering estimates and extrapolation of existing data. For plant sources where only NO_x emission data are provided, the CO, VOC and PM_{10} emissions are calculated on the basis of the following emission ratios: CO/NO_x = 23%, VOC/NO_x = 2% and PM_{10}/NO_x = 9%. The use of these uniform factors is based on the common use of natural gas as a fuel for all plants.

3.4.1 Aurora Mine

The Aurora mines will be comprised of four operating trains. A single train operation at the north mine is associated with the Syncrude Mildred Lake Baseline emission scenario. The nominal bitumen production capacity ranges from 108,000 bbl/d for a single train Aurora Mine (North) operation to 431,000 bbl/d for the four train Aurora Mine (North and South) operation.

Table 3-36 provides the stack parameters associated with this single train scenario (three stacks). The full four train operation is associated with the Syncrude Mildred lake Application Emission Scenario. Table 3-37 provides the corresponding parameters for the eight stacks associated with the four train operating scenario.

Table 3-36 Emissions Associated With Aurora North Mine (one train; normal winter operating conditions) for the Baseline Scenario

Parameter		OTHRSG1(a)	Boiler1	Boiler2	Total
UTM location North		6,350,746	6,350,33	6,350,733	-
UTM location East		469,402	469,370	469,390	-
Stack Height	[m]	25.0	25.0	25.0	-
Exit Diameter	[m]	3.27	2.74	2.74	-
Exit Velocity	[m/s]	33.5	26.3	26.3	-
Exit Temperature	[°C]	187	182	182	-
NO_x Emissions	[t/d]	0.66	0.40	0.40	1.46
CO Emissions	[t/d]	0.15	0.09	0.09	0.33
VOC Emissions	[t/d]	0.01	0.01	0.01	0.03
PM_{10} Emissions	[t/d]	0.06	0.04	0.04	0.14

(a) Includes emissions from GTG1 and duct firing from OTHRSG1.
From: BOVAR Environmental (1996).

CO, VOC and PM_{10} emissions estimates were not provided in the Aurora application. The values provided in Table 3-36 and Table 3-37 are based on scaling of the emissions values according to the average ratio for the existing Mildred Lake sources.

The emission estimates provided in Table 3-36 and Table 3-37 are based on normal winter operating conditions. Under these conditions, the NO_x emissions from the one and four train operations are 1.46 and 4.76 t/d, respectively. Corresponding summer NO_x emissions are 0.83 and 2.56 t/d, respectively.

3.4.2 Shell Muskeg River Mine and Lease 13 East

Shell Canada has submitted an Application and Environmental Impact Assessment for the development of the Muskeg River Mine Project located on the western portion of Lease 13 (Shell 1997). Shell has also disclosed an interest in the further development of Lease 13 East. The nominal bitumen production capacities of the proposed Muskeg River and Lease 13 East developments are 150,000 bbl/d and 200,000 bbl/d, respectively.

The Muskeg River Mine plant will be serviced by six fired heaters and two boilers (eight stacks). The total winter NO_x emission is 1.87 t/d (Table 3-38). During the summer, when energy requirements are reduced, the corresponding NO_x emission is 1.37 t/d.

The Lease 13 East plant emissions were scaled from the Muskeg River Mine values on the basis of bitumen production. This scaling was only applied to the fired heaters and boilers and the emissions are provided in Table 3-39. The respective Lease 13 East winter and summer NO_x emissions are 2.45 and 1.83 t/d, respectively.

3.4.3 Mobil Kearl Oil Sands Project

Mobil Oil's proposed Lease 36 Kearl Oil Sands Project is comprised of a 130,000 bbl/d mine and associated upgrader. The mine will be a truck and shovel operation. Air emissions from the proposed extraction plant and upgrader were extrapolated from the Syncrude operations as preliminary engineering data specific to Kearl Oil Sands Project are not available. Specifically, extraction emissions were scaled from an Aurora North Mine plant on the basis of production and upgrader emissions were scaled from the proposed Syncrude 8-3 coker. Emission parameters for the proposed Kearl Oil Sands Project operation are provided in Table 3-40. Estimated NO_x and SO_2 emissions are 4.4 and 4.8 t/d, respectively.

3.4.4 Petro-Canada MacKay River

The proposed Petro-Canada SAGD development has an initial design production capacity of 20,000 bbl/d of bitumen. The preliminary design is for six steam generators, each producing 230 MMBTU/h. Each boiler was assumed to be serviced by a separate stack whose parameters are provided in Table 3-41. Total NO_x emissions are 1.36 t/d.

3.4.5 Koch (SOLV-EX)

Koch (formerly SOLV-EX) has approval for a combined bitumen and metal extraction plant located near Bitumount. While construction has started, the plant has not been commissioned. Table 3-42 provides the design stack parameters associated with this operation. Total NO_x and SO_2 emissions are 0.7 and 3.5 t/d, respectively.

3.4.6 Northstar UTF

Emissions parameters for the Baseline Northstar Underground Test Facility (UTF) are provided in Table 3-43. Total NO_x emissions are about 0.2 t/d.

Table 3-37 Emissions Associated With Aurora North and South Mines (four trains; normal winter operating conditions) for the CEA Scenario

Parameter	Aurora North				Aurora South				Total
	OTHRSG1(a)	OTHRSG2(b)	Boiler1	Boiler2	OTHRSG1(a)	OTHRSG2(b)	Boiler1	Boiler2	
UTM location North	6,350,746	6,350,779	6,350,733	6,350,733	6,342,667	6,342,700	6,342,653	6 342 653	-
UTM location East	469,402	469,402	469,370	469,390	484,164	484,164	484,151	484 131	-
Stack Height [m]	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	-
Exit Diameter [m]	3.27	3.27	2.74	2.74	3.27	3.27	2.74	2.74	-
Exit Velocity [m/s]	33.9	33.9	37.7	37.7	33.9	33.9	37.7	37.7	-
Exit Temperature [°C]	187	187	182	182	187	187	182	182	-
NO_x Emissions [t/d]	0.62	0.62	0.57	0.57	0.62	0.62	0.57	0.57	4.76
CO Emissions [t/d]	0.14	0.14	0.13	0.13	0.14	0.14	0.13	0.13	1.08
VOC Emissions [t/d]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08
PM_{10} Emissions [t/d]	0.06	0.06	0.05	0.05	0.06	0.06	0.05	0.05	0.44

(a) Includes emissions from GTG1 and duct firing from OTHRSG1.

(b) Includes emissions from GTG2 and duct firing from OTHRSG2.

From: BOVAR Environment (1996).

Table 3-38 Emissions Associated With the Muskeg River Mine (winter conditions) for the CEA Scenario

Source	Fired Heaters						Boilers		Space Heating	Flare Pilot	Total
	1	2	3	4	5	6	1	2			
UTM location North	6,346,240	6,346,240	6,346,240	6,346,240	6,346,240	6,346,240	6,346,125	6,346,125	-	-	-
UTM location East	469,565	469,580	469,595	469,610	469,625	469,640	469,600	469,575	-	-	-
Stack height [m]	25	25	25	25	25	25	25	25	-	-	-
Stack diameter [m]	1.986	1.986	1.986	1.986	1.986	1.986	1.136	1.136	-	-	-
Exit Velocity [m/s]	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	-	-	-
Exit Temperature [°C]	182	182	182	182	182	182	182	182	-	-	-
NO_x Emissions [t/d]	0.272	0.272	0.272	0.272	0.272	0.272	0.058	0.058	0.122	0.001	1.87
CO Emissions [t/d]	0.116	0.116	0.116	0.116	0.116	0.116	0.033	0.033	0.071	0.00	0.83
VOC Emissions [t/d]	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.002	0.005	0.0001	0.03
PM_{10} Emissions [t/d]	0.036	0.036	0.036	0.036	0.036	0.036	0.013	0.013	0.027	0.0002	0.27

Table 3-39 Emissions Associated With the Lease 13 East Mine (winter conditions) for the CEA Scenario

Source	Fired Heaters						Boilers		Space Heating	Flare Pilot	Total
	1	2	3	4	5	6	1	2			
UTM location North	6,348,582	6,348,582	6,348,582	6,348,582	6,348,582	6,348,582	6,348,467	6,348,467	-	-	-
UTM location East	477,188	477,203	477,218	477,233	477,248	477,263	477,198	477,223	-	-	-
Stack Height [m]	25	25	25	25	25	25	25	25	-	-	-
Exit Diameter [m]	1.986	1.986	1.986	1.986	1.986	1.986	1.136	1.136	-	-	-
Exit Velocity [m/s]	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	-	-	-
Exit Temperature [°C]	182	182	182	182	182	182	182	182	-	-	-
NO$_x$ Emissions [t/d]	0.363	0.363	0.363	0.363	0.363	0.363	0.077	0.077	0.122	0.001	2.45
CO Emissions [t/d]	0.154	0.154	0.154	0.154	0.154	0.154	0.045	0.045	0.071	0.000	1.09
VOC Emissions [t/d]	0.005	0.005	0.005	0.005	0.005	0.005	0.003	0.003	0.005	0.0001	0.04
PM$_{10}$ Emissions [t/d]	0.048	0.048	0.048	0.048	0.048	0.048	0.017	0.017	0.027	0.0002	0.35

Table 3-40 Emissions Associated with the Kearl Oil Sands Mine for the CEA Scenario

	Extraction				Upgrader		Total
	Stack 1	Stack 2	Stack 3	Stack 4	Stack 5	Stack 6	
UTM location North	6,351,500	6,351,500	6,351,500	6,351,500	6,351,500	6,351,500	-
UTM location East	485,500	485,520	485,540	485,560	485,580	485,600	-
Stack Height [m]	25.0	25.0	25.0	25.0	45.0	76.0	-
Exit Diameter [m]	3.0	3.0	2.5	2.5	2.0	4.0	-
Exit Velocity [m/s]	24.4	24.4	27.4	27.4	10.0	10.4	-
Exit Temperature [°C]	187	187	182	182	200	75	-
NO$_x$ Emissions [t/d]	0.37	0.37	0.34	0.34	1.48	1.50	4.4
SO$_2$ Emissions [t/d]	0.0	0.0	0.0	0.0	0.0	4.8	4.8
CO Emissions [t/d]	0.09	0.09	0.08	0.08	0.34	0.35	1.0
VOC Emissions [t/d]	0.01	0.01	0.01	0.01	0.03	0.03	0.1
PM$_{10}$ Emissions [t/d]	0.03	0.03	0.03	0.03	0.13	0.14	0.39

Table 3-41 Emissions Associated With the Petro-Canada MacKay River SAGD for the CEA Scenario

Boiler		1	2	3	4	5	6	Total
UTM location North		6,326,273	6,326,273	6,326,273	6,326,273	6,326,273	6,326,273	-
UTM location East		446,425	446,445	446,465	446,485	446,505	446,525	-
Stack Height	[m]	27	27	27	27	27	27	-
Exit Diameter	[m]	1.34	1.34	1.34	1.34	1.34	1.34	-
Exit Velocity	[m/s]	27.5	27.5	27.5	27.5	27.5	27.5	-
Exit Temperature	[°C]	280	280	280	280	280	280	-
NO_x Emissions	[t/d]	0.23	0.23	0.23	0.23	0.23	0.23	1.36
CO Emissions	[t/d]	0.11	0.11	0.11	0.11	0.11	0.11	0.69
VOC Emissions	[t/d]	0.004	0.004	0.004	0.004	0.004	0.004	0.024
PM_{10} Emissions	[t/d]	0.014	0.014	0.014	0.014	0.014	0.014	0.086

Table 3-42 Emissions Associated With the Koch (SOLV-EX) Mining and Extraction Facilities for the CEA Scenario

Stack Unit	Main A4/A11	Heater A7	Heater A10	Boilers and Turbine A12/A14	Soaker Furnace A3	Salt Dryer A6	Heater A15	Alumina Dryer A8	$FeSO_4$ Dryer A9	K_2SO_4 Dryer A17	Dryer A5	By-Product Dryer A19	Total
UTM location North	6,360,112	6,360,112	6,360,112	6,360,112	6,360,112	6,360,112	6,360,112	6,360,112	6,360,112	6,360,112	6,360,112	6,360,112	-
UTM location East	479,535	479,555	479,575	479,595	479,615	479,635	479,655	479,675	479,695	479,715	479,735	479,755	-
Stack Height [m]	60	35	33	33	38	53	53	33	25	33	35	25	-
Exit Diameter [m]	1.35	0.20	0.20	1.60	1.20	1.85	0.90	1.0	0.20	0.20	1.20	0.8	-
Exit Velocity [m/s]	18.86	15.58	14.42	17.39	12.45	18.02	14.22	16.69	12.47	11.86	17.67	17.25	-
Exit Temperature [°C]	250	230	230	230	230	200	230	80	80	80	80	100	-
NO_x Emissions [t/d]	0.027	0.004	0.004	0.21	0.12	0.16	0.078	0.071	0.0	0.0	0.0	0.0	0.65
SO_2 Emissions [t/d]	2.2	0.009	0.008	0.64	0.0	0.48	0.17	0.086	0.0	0.0	0.0	0.0	3.5
CO Emissions [t/d]	0.006	0.001	0.001	0.048	0.028	0.037	0.018	0.016	-	-	-	-	0.156
VOC Emissions [t/d]	0.005	0.0001	0.0001	0.0042	0.0024	0.0032	0.0016	0.0014	-	-	-	-	0.014
PM_{10} Emissions [t/d]	0.0025	0.0004	0.0004	0.0193	0.0110	0.0147	0.0072	0.0065	0.0072	0.0048	0.26	0.09	0.424

Source: SOLV-EX Corporation (1995).

Table 3-43 Emissions Associated With the Northstar UTF for the CEA Scenario

	Steam Generator 1	Steam Generator 2	Steam Generator 3	Steam Generator 4	Glycol Heater	Heater (winter)	Total
Energy Input [MW]	14.6	14.6	7.3	7.3	1.2	-	-
UTM location North	6,324,250	6,324,240	6,324,240	6,324,240	6,324,240	6,324,376	-
UTM location East	444,000	444,012	444,022	444,032	444,042	443,870	-
Stack Height [m]	12.2	12.2	12.2	12.2	7.3	-	-
Exit Diameter [m]	0.54	0.91	0.54	0.54	0.31	-	-
Exit Velocity [m/s]	39.7	14.1	29.0	29.0	15.1	-	-
Exit Temperature [°C]	193	193	260	260	300	-	-
NO$_x$ Emissions [t/d]	0.067	0.067	0.034	0.034	0.005	0.009	0.22
CO Emissions [t/d]	0.02	0.02	0.01	0.01	0.001	0.002	0.06
VOC Emissions [t/d]	0.001	0.001	0.001	0.001	0.0	0.0	0.004
PM$_{10}$ Emissions [t/d]	0.006	0.006	0.003	0.003	0.0	0.001	0.019

3.4.7 Gulf Surmont

Gulf Canada Resources Limited has disclosed an intent to operate a SAGD project with a bitumen production capacity of 100,000 bbl/d (Gulf Canada 1997). The operation is comprised of five phases, each with a production capacity of 20,000 bbl/d. Preliminary engineering indicate that each site will be serviced by six natural gas fired steam generators. The assumed location coordinates for each of the boiler stacks are presented in Table 3-44. Each boiler is assumed to be serviced by a separate stack whose emissions are provided in Table 3-45. The expected NO_x emissions for all five sites are 6.8 t/d.

Table 3-44 Assumed Stack Co-ordinates for the Gulf Surmont and JACOS Hangingstone Projects for the CEA Scenario

Facility		UTM location (N)	UTM location (E)
Gulf Surmont			
Location 1	Stack 1	6,225,425	501,445
	Stack 2	6,225,785	501,539
	Stack 3	6,225,795	501,539
	Stack 4	6,225,805	501,539
	Stack 5	6,225,815	501,539
	Stack 6	6,225,825	501,539
Location 2	Stack 1	6,225,425	500,845
	Stack 2	6,225,785	500,939
	Stack 3	6,225,795	500,939
	Stack 4	6,225,805	500,939
	Stack 5	6,225,815	500,939
	Stack 6	6,225,825	500,939
Location 3	Stack 1	6,216,875	498,095
	Stack 2	6,217,235	498,189
	Stack 3	6,217,245	498,189
	Stack 4	6,217,255	498,189
	Stack 5	6,217,265	498,189
	Stack 6	6,217,275	498,189
Location 4	Stack 1	6,226,825	512,045
	Stack 2	6,227,185	512,139
	Stack 3	6,227,195	512,139
	Stack 4	6,227,205	512,139
	Stack 5	6,227,215	512,139
	Stack 6	6,227,225	512,139
Location 5	Stack 1	6,208,025	509,295
	Stack 2	6,208,385	509,389
	Stack 3	6,208,395	509,389
	Stack 4	6,208,405	509,389
	Stack 5	6,208,415	509,389
	Stack 6	6,208,425	509,389
JACOS Hangingstone			
	Stack	6,237,042	457,965
	Flare	6,237,042	457,985

Table 3-45 Emissions Associated With Gulf Canada Surmont SAGD Sites for the CEA Scenario

Boiler	1	2	3	4	5	6	Single Site Total
Heat duty [MMBTU/h]	200	200	200	200	200	200	-
Stack Height [m]	27	27	27	27	27	27	-
Exit Diameter [m]	1.34	1.34	1.34	1.34	1.34	1.34	-
Exit Velocity [m/s]	27.5	27.5	27.5	27.5	27.5	27.5	-
Exit Temperature [°C]	280	280	280	280	280	280	-
NO$_x$ Emissions [t/d]	0.23	0.23	0.23	0.23	0.23	0.23	1.36
CO Emissions [t/d]	0.11	0.11	0.11	0.11	0.11	0.11	0.69
VOC Emissions [t/d]	0.004	0.004	0.004	0.004	0.004	0.004	0.024
PM$_{10}$ Emissions [t/d]	0.014	0.014	0.014	0.014	0.014	0.014	0.086

3.4.8 JACOS Hangingstone

The JACOS Hangingstone SAGD development has a nominal bitumen production capacity of 12,000 bbl/d. Worst case estimates of SO$_2$ and NO$_x$ are listed in Table 3-46. Estimates of CO, VOC and PM$_{10}$ were based on preliminary estimates assuming that the emissions for JACOS would be the same emission characteristics corresponding to two Petro-Canada SAGD boilers. Based on the information provided in Table 3-41, the expected JACOS NO$_x$ emissions are 2.0 t/d and 0.02 t/d for SO$_2$. The assumed location co-ordinates for the JACOS Hangingstone site are presented in Table 3-44.

Table 3-46 Emissions Associated with the JACOS CEA Scenario (Worst Case)

Boiler	Stack	Flare	Single Site Total
Stack Height [m]	12	20.1 (c)	-
Exit Diameter [m]	0.91	.02 (c)	-
Heat Released [cal/s]	-	732	-
Exit Velocity [m/s]	19.8	20	-
Exit Temperature [°C]	96	1000	-
SO$_2$ Emissions (a) [t/d]	-	0.02	.02
NO$_x$ Emissions (a) [t/d]	2.0	-	2.0
CO Emissions (b) [t/d]	.110	.110	0.22
VOC Emissions(b) [t/d]	.004	.004	0.008
PM$_{10}$ Emissions(b) [t/d]	.014	.014	0.028

(a) Worst Case Estimate from JACOS.
(b) Preliminary Estimate based on Gulf Canada Surmount.
(c) Flare stack pseudo parameters.

3.4.9 Fugitive Emissions

These facilities listed in this section will be sources of fugitive VOC emissions. Given that fugitive emissions are process dependent, each of the facilities have quite different operations and construction contractors, and that the details for the facilities are not available, fugitive VOC emission specific to each plant site were not estimated.

3.4.10 Northland Forest Products Mill

The Northland Forest Products Mill (Northland) is located approximately 20 km north of Fort McMurray. The major emission source at the facility is the conical burner that is a source of: particulates, SO_2, CO, VOC and NO_x to the atmosphere. Conical burners typically represent a large source of CO (25 t/d) and VOC (2.12 t/d) emissions (Table 3-47). Although conical burners are being phased out in favour of other technologies, the Northland conical burner was assumed to continue operation for the Baseline and future Application scenerios.

Since this is the only mill in the Fort McMurray area, there is a high volume of trucking associated with forest operations in the vicinity. These vehicle emissions have not been accounted for in this emissions inventory.

Table 3-47 Emissions Associated with the Northlands Forest Products Mill

Parameter		Conical Burner [a]
UTM Location North		6,286,040
UTM Location East		477,831
Elevation	[m]	228
Stack Height	[m]	20
Stack Diameter	[m]	5
Exit Velocity	[m/s]	2.5
Exit Temperature	[°C]	370
NO_x Emissions	[t/d]	0.190
SO_2 Emissions	[t/d]	0.02
CO Emissions	[t/d]	25.0
VOC Emissions	[t/d]	2.12
PM_{10} Emissions	[t/d]	0.190

[a] Based on BOVAR (1996a)

3.4.11 Other Plant Emissions Summary

Table 3-48 summarizes the emissions associated with other plants in the region. The VOC and PM_{10} emissions are based on combustion emission and do not include the contribution from fugitive sources. For the Koch (SOLV-EX)operations, the provided emissions rates were assumed to be PM_{10}. A summary of total 'Other' emissions is listed in Table 3-49. The total mass emissionS are comparatively small compared to the emission from Syncrude and Suncor. However, predicted ambient ground level concentration of each pollutant will be affected by all emissions and may be sensitive to source characteristics such as stack heights (which are either estimated or based on preliminary engineering designs).

Table 3-48 Summary of Fixed Plant Emissions from Other Plant Emissions in the Oil Sands Region

Plant	SO_2 [t/d]	NO_x [t/d]	CO [t/d]	VOC [t/d]	PM_{10} [t/d]
Aurora North (1 train)	0.0	1.46	0.33	0.03	0.14
Aurora North & South (4 trains)	0.0	4.76	1.08	0.08	0.44
Shell Muskeg River	0.0	1.87	0.83	0.03	0.27
Shell Lease 13 East	0.0	2.45	1.09	0.04	0.35
Mobil Kearl Oil Sands Mine	17.4	4.6	1.0	0.10	0.39
Petro-Canada MacKay River	0.0	1.36	0.69	0.024	0.086
Kock (SOLV-EX)	3.5	0.65	0.16	0.014	0.424
Northstar UTF	0.0	0.22	0.06	0.004	0.019
Gulf Surmont	0.0	6.8	3.45	0.12	0.43
JACOS Hangingstone	0.02	2.0	0.22	0.008	0.028
Northlands Forest Products	0.02	0.19	25.0	2.12	0.19

Table 3-49 Summary of Fixed Plant Emissions from Other Plants for Selected Scenarios

Emission	Existing [(a)] [t/d]	Baseline [(b)] [t/d]	CEA [(c)] [t/d]
SO_2	0.02	3.52	20.9
NO_x	0.41	2.52	26.4
CO	25.1	25.6	33.9
VOC	2.12	2.17	2.57
PM_{10}	0.21	0.77	2.77

(a) Based on Northstar UTF and Northlands Forest Products.
(b) Based on Aurora North (1 Train), Koch and Northstar UTF and Northlands Forest Products.
(c) Based on all facilities.

3.5 MOBILE SOURCES

The oil sands mining approach is shifting from the use of electrically powered drag lines, bucket wheels and conveyor belts to the use of diesel fuelled trucks and shovels. Products of diesel combustion include trace amounts of SO_2, NO_x, CO, PM_{10}, VOC and PAH. Emission rates from mine fleets were estimated on the basis of predicted fuel consumption and the application of fuel consumption emission factors. The geometry of the mine pits and other areas where diesel fuelled vehicles were used to characterize the fugitive emission sources for dispersion modelling.

3.5.1 Emission Factors

The emission factors applied to the diesel emissions are based on a composite of emission factors obtained from a number of different sources (Table 3-50). These include those provided by Environment Canada (1991) for a mix of mining equipment, the U.S. EPA (1985) for off-road haul trucks, the U.S. EPA (1995) for large stationary diesel engines and those provided by Westerholm et al. (1991). The two latter sources provide a more comprehensive list and quantification for trace organic (HC) and polycyclic aromatic hydrocarbons (PAH). The average NO_x emission factor based on the literature values is 41 kg/10^3L. The emission factors for hydrocarbon compounds were grouped according to human health and photochemical (ozone precursor) considerations.

Table 3-50 Factors Used to Estimate Emissions From Mine Fleet Exhausts

Grouping	Emission Factor kg/ 10^3 L
Criteria Compounds	
CO	14.79
NO_x	(See Text)
SO_2	2.78
PM_{10}	1.59
$PM_{2.5}$	1.33
General	
Total hydrocarbon (C1+)	2.79
Methane (C1)	0.29
C2+	2.51
Human Health	
C2 to C4 alkanes and alkenes	1.437
C5 to C8 alkanes and alkenes	0.525
C9 to C12 alkanes and alkenes (a)	0.494
Cyclohexane	0.000
Benzene	0.021
C6 to C8 non-benzene aromatics	0.030
Total aldehydes	0.340
Total ketones	0.093
Total RS	0.000
Photochemical	
Methane (C1)	0.285
Ethane (C2)	0.163
C3 to C4 alkanes	0.285
C5 to C8 alkanes (b)	0.520
C9 to C12 alkanes	0.494
C13+ alkanes	0.000
Ethylene (C2)	0.817
C3 to C4 alkenes	0.171
C5 to C8 alkenes	0.005
C9 to C12 alkenes	0.000
C13+ alkenes	0.000
benzene (C6)	0.021
C6 to C8 non-benzene aromatics	0.030
C9 to C12 aromatics	0.000

Emission factors can vary with engine type, truck load, fuel composition and environmental factors. Emission factors can also be expressed in a number of differing units (e.g., g/BHP-h or kg/10^3L). Suncor estimated emissions of primary pollutants (SO_2, NO_x, CO, PM_{10}, THC) based on fuel consumption and duty of the vehicle fleet. Several different emission factors were available from Syncrude and Suncor for NO_x:

- Existing Syncrude mine fleet: 51 kg/10^3L;
- Future (Application) Syncrude mine fleet: 61 kg/10^3L;
- Blended existing and future Syncrude mine fleet: 56 kg/10^3L;
- Existing Suncor mine fleet: 46 kg/10^3L;
- Baseline Suncor mine fleet: 47 kg/10^3L; and
- Future (Project Millennium) Suncor mine fleet: 52 kg/10^3L.

The Syncrude and Suncor values were applied to respective Syncrude and Suncor operations and the future Syncrude mine fleet value was applied to the non-Syncrude (except for Suncor) mine fleets. There were also differences in the emission factors for VOCs, aromatics, aldehydes and PAHs provided by Suncor and those in Table 3-51. For the purposes of this assessment, however, the values in Table 3-51 were used since they are more conservative.

The U.S. EPA stationary source factors indicate about 85% of the PM emissions are in the PM_{10} size fraction and about 72% in the $PM_{2.5}$ size fraction. This compares to Bagley et al. (1996) who reported that most of the PM in a diesel exhaust is in the sub-micron range (less than 1 μm in diameter).

3.5.2 Mine Parameters

3.5.2.1 Syncrude Base Mine

The existing Mildred Lake facilities are serviced by the Mildred Lake Base Mine. The Base Mine is subdivided into three areas; the East Base Mine, West Base Mine and North Mine. The East Base Mine and West Base Mine use drag line, windrow, bucket wheel reclaimer, conveyer belt technology while the North mine is a shovel and truck, hydrotransport operation. Diesel consumption at the East Base and West Base Mines is associated with the use of shovels and trucks to remove overburden while diesel consumption at the North Mine is associated with both overburden and ore mining activities. Overburden activities are limited to the top 20 m of the mine pit while mining activities take place down to the base of the pit.

Table 3-52 provides the estimated fuel consumption and mine pit parameters associated with the Mildred Lake Base Mine. "Other" describes non-mining diesel activities such as reclamation, reject hauling and road construction that take place outside the mine pits.

Table 3-51 Factors Used to Estimate PAH From Mine Fleet Exhausts

Compound	Emission Factor kg/10^3 L
Napthalene	2.14E-03
Acenapthylene	1.52E-04
Acenaphthene	7.68E-05
Fluorene	2.10E-04
Phenanthrene	6.18E-04
Anthracene	2.29E-05
Fluoranthene	5.48E-05
Pyrene	4.32E-05
Benz(a)anthracene	5.55E-06
Chrysene	1.53E-05
Benzo(b)fluoranthene	1.82E-05
Benzo(k)fluoranthene	2.07E-06
Benzo(a)pyrene	2.17E-06
Indeno(1,2,3-W)pyrene	3.45E-06
Dibenz(a,h)anthracene	5.69E-06
Benzo(g,h,l)perylene	4.70E-06
3-Methylphenanthrene	2.40E-04
2-Methylanthracene	2.75E-04
4-+9-Methylphenanthrene	2.96E-04
1-Methylphenanthrene	2.46E-04
Benzo[a]fluorene	4.96E-06
2-Methylpyrene	4.09E-06
Benzo[ghi]fluoranthene	2.88E-06
Cyclopenta[cd]pyrene	3.46E-07
Benzo[e]pyrene	3.07E-07
Perylene	3.84E-08
Indeno[1,2,3-cd]fluoranthene	1.92E-07
Picene	3.84E-08
2-Methylfluorene	4.61E-07
Benzo[ghi]perylene	2.69E-07
Coronene	3.84E-08
1-Nitropyrene	3.07E-06
Dibenzothiophene	3.27E-07
4-Methyldibenzothiophene	5.38E-07
3-Methyldibenzothiophene	8.45E-07
Total	**0.0044**

Table 3-52 Syncrude Mildred Lake Base Mine Pit Parameters

Scenario	Parameter	North Mine	West Base Mine	East Base Mine	Other
Existing 74/76 MMbbl/y 1996/1997	Fuel Consumption [10^3 L/d]	111	46	29	31
	UTM(a) location North	6,321,428	6,316,068	6,320,141	-
	UTM location East	457,555	460,474	463,819	-
	East-West Pit Width [km]	1.2	0.8	2.4	-
	North-South Pit Width [km]	2.2	2.0	1.6	-
	Mine Area [km^2]	2.6	1.6	3.8	-
	Pit Volume [10^6 m^3]	110	70	77	-
	Effective Depth [m]	45	44	20	-
	Rotation Angle [°]	-33	-21	0	-
Baseline 94 MMbbl/y 2001	Fuel Consumption [10^3 L/d]	300	18	0	31
	UTM location North	6,321,063	6,316,008	-	-
	UTM location East	457,337	460,031	-	-
	East-West Pit Width [km]	2.3	2.2	-	-
	North-South Pit Width [km]	1.6	1.2	-	-
	Mine Area [km^2]	3.7	2.6	-	-
	Pit Volume [10^6 m^3]	180	90	-	-
	Effective Depth [m]	49	36	-	-
	Rotation Angle [°]	0	-21	-	-
CEA	Fuel Consumption [10^3 L/d]	284	23	0	26
	UTM location North	6,321,163	6,316,321	-	-
	UTM location East	455,832	458,794	-	-
	East-West Pit Width [km]	3.7	1.6	-	-
	North-South Pit Width [km]	2.2	2.3	-	-
	Mine Area [km^2]	8.1	3.7	-	-
	Pit Volume [10^6 m^3]	500	100	-	-
	Effective Depth [m]	61	27	-	-
	Rotation Angle [°]	0	0	-	-

(a) UTM location refers to the southwest corner of the rectangular pit.

3.5.2.2 Suncor Mines

Table 3-53 provides the estimated fuel consumption and mine pit parameters associated with the Suncor Lease 86/17, Steepbank and Millennium Mines. Emission estimates for the criteria pollutants were determined by Suncor taking into account the duty and fuel consumed for the range of equipment in use. VOC, RS and PAH emission estimates were determined based on Table 3-50 and Table 3-51. Bitumen will be supplied by the Lease 86/17 and Steepbank mine pits for the Baseline emission scenario. For the CEA emission scenario, bitumen will be supplied by the Millennium mine pit only. All diesel combustion emissions are assumed to occur in the respective mine pits.

Table 3-53 Suncor Mine Pit Parameters

Scenario	Parameter	Lease 86/17 Mine	Steepbank	Project Millennium
Existing 29 MMbbl/y 1997	Fuel Consumption [10^3 L/d]	179	0	0
	UTM(a) location North	6,319,200	-	-
	UTM location East	466,536	-	-
	East-West Pit Width [km]	2.5	-	-
	North-South Pit Width [km]	1.28	-	-
	Mine Area [km^2]	3.2	-	-
	Pit Volume [10^6 m^3]	141	-	-
	Effective Depth [m]	44	-	-
	Rotation Angle [°]	0	-	-
Baseline 38 MMbbl/y	Fuel Consumption [10^3 L/d]	104	138	0
	UTM location North	6,319,270	6,316,130	-
	UTM location East	466,600	473,480	-
	East-West Pit Width [km]	2.63	0.85	-
	North-South Pit Width [km]	1.57	1.45	-
	Mine Area [km^2]	4.1	1.2	-
	Pit Volume [10^6 m^3]	182	43	-
	Effective Depth [m]	44	35	-
	Rotation Angle [°]	0	0	-
CEA	Fuel Consumption [10^3 L/d]	0	0	521
	UTM location North	-	-	6,310,600
	UTM location East	-	-	479,100
	East-West Pit Width [km]	-	-	2.5
	North-South Pit Width [km]	-	-	3.15
	Mine Area [km^2]	-	-	7.9
	Pit Volume [10^6 m^3]	-	-	630
	Effective Depth [m]	-	-	80
	Rotation Angle [°]	-	-	0

(a) UTM location refers to the southwest corner of the rectangular pit.

3.5.2.3 Syncrude Aurora Mine

For the Baseline and Application operation scenarios, Mildred Lake facility will also obtain bitumen from the Aurora Mine. The Aurora mines will be a shovel and truck, hydro-transport operation, like the Base North mine. Table 3-54 provides the estimated fuel consumption and mine pit parameters associated with the Syncrude Aurora North and South Mines. All diesel use was assumed to take place in the mine pits.

Table 3-54 Syncrude Aurora North and South Mine Pit Parameters

Parameter		Aurora North 215,000 bbl/d		Aurora South 215,000 bbl/d	
	Scenario	Baseline	CEA	Baseline	CEA
Fuel Consumption	[10^3 L/d]	100	214	0	162
UTM[(a)] location North		6,351,537	6,351,537	-	6,344,587
UTM location East		466,965	466,965	-	482,935
East-West Pit Width	[km]	1.8	2.0	-	2.0
North-South Pit Width	[km]	0.9	3.0	-	3.0
Mine Area	[km^2]	1.6	6.0	-	6.0
Pit Volume	[10^6 m^3]	100	500	-	500
Effective Depth	[m]	61	83	-	83
Rotation Angle	[°]	0	0	-	0

(a) UTM location refers to the southwest corner of the rectangular pit.

3.5.2.4 Shell Muskeg River Mine and Lease 13 East Mine

Table 3-55 provides the estimated fuel consumption and mine pit parameters associated with the Shell Muskeg River Mine and the Lease 13 East Mine. The Lease 13 East fuel consumption was based on extrapolating the Muskeg River Mine values based on production. All diesel use was assumed to take place in the mine pits.

Table 3-55 Shell Muskeg River Mine, Shell Lease 13 East Mine and Mobil Kearl Mine Parameters

Parameter	Scenario	Muskeg River Mine 150,000 bbl/d CEA	Shell Lease 13 East 200,000 bbl/d CEA	Mobil Kearl 130,000 bbl/d CEA
Fuel Consumption	[10^3 L/d]	227	303	130
UTM[(a)] location North		6,348,605	6,345,225	6,352,288
UTM location East		469,245	475,945	483,120
East-West Pit Width	[km]	3.0	3.0	2.5
North-South Pit Width	[km]	1.5	1.5	1.5
Mine Area	[km^2]	4.5	4.5	3.8
Pit Volume	[10^6 m^3]	284	284	225
Effective Depth	[m]	63	63	60
Rotation Angle	[°]	0	0	0

(a) UTM location refers to the southwest corner of the rectangular pit.

3.5.2.5 Mobil Kearl Oil Sands Mine

Table 3-55 provides the estimated fuel consumption and mine pit parameters associated with the Kearl Oil Sands Mine. The fuel consumption rate was based on extrapolating the Aurora North value on the basis of production. All diesel use was assumed to take place in the mine pits.

3.5.2.6 Transportation Sources

The main north-south traffic corridor is Highway 63 which links Fort McMurray to Edmonton and to the oil sands facilities. The highway extends further north to the Athabasca Bridge (Lougheed Bridge) and Fort McKay. The majority of the traffic on the highway occurs between Fort McMurray and the oil sands facilities.

Traffic is comprised of automobiles and light trucks (gasoline fueled) and of buses for transporting personnel to work (diesel fueled) as well as large trucks that provide supplies and carry products to and from the plants (diesel fueled). The traffic will result in emissions from products of fuel combustion and from the eroding and entrainment of road materials. Table 3-56 provides a summary of the estimated emissions from this highway traffic.

Table 3-56 Estimated Emissions From Highway Vehicles

Emissions	Emission [a] Factor [g/VMT]	Baseline [t/cd]			CEA [t/cd]		
		Ft. McMurray to Suncor	Suncor to Syncrude	Total	Ft. McMurray to Suncor	Suncor to Syncrude	Total
Roadway Length [km]		28	19	47	28	19	47
Vehicle Use [AADT]		4,300	3,200	7,500	6,800	4,800	11,600
[VMT/cd]		74,232	38,078	112,310	117,390	57,117	174,508
SO_2	0.42	0.03	0.02	0.05	0.05	0.02	0.07
NO_x	3.1	0.23	0.12	0.35	0.36	0.18	0.54
CO	10.6	0.79	0.40	1.2	1.2	0.61	1.9
CO_2	211.3	16	8	24	25	12	37
VOC	1.9	0.14	0.07	0.21	0.22	0.11	0.33
PM_{10}	2.9	0.21	0.11	0.32	0.34	0.16	0.50

[a] VMT = Vehicle Mile Travelled, AADT = Annual Average Daily Traffic

3.5.2.7 Residential Sources

The two primary communities in the region are Fort McMurray with a current population 34,706 (12,955 homes) and Fort McKay with current population 322 (110 homes). The forecasted population for Fort McMurray is 49,500 (16,571 homes) and Fort McKay is 330 (110 homes). Potential emission sources in these areas include:

- Products of combustion resulting from residential and commercial space heating, and from heating of water for domestic purposes.
- Residential combustion of wood in fireplaces and wood stoves.
- Local vehicle traffic which produces products of combustion and particulates due to tire/road interactions.
- Local light industry operations such as maintenance facilities (i.e. vehicle repairs, welding shops).
- Local bulk fuel and gasoline service stations that handle and transfer fuel.

- Products of combustion from residential use of wood for recreational or supplemental heating purposes.

Table 3-57 lists the estimated emissions from residential sources for the current and forecasted CEA scenarios. Table 3-58 lists the dispersion modelling parameters used to characterize the sources.

Table 3-57 Emissions From Residential Sources

Scenario	Community	Community	Estimated Emissions [t/cd]					
			SO_2	NO_x	CO	CO_2	VOC	PM_{10}
Baseline	Fort McKay	Local Vehicle Usage	0.0000	0.0001	0.0002	0.0	0.0001	0.0001
		Wood Stove Heating	0.0000	0.0000	0.0033	0.05	0.0007	0.0004
		Fireplaces	0.0000	0.0001	0.0112	0.15	0.0102	0.0015
		Natural Gas Heating	0.0000	0.0067	0.0028	9.2	0.0008	0.0004
		Totals	**0.000**	**0.007**	**0.018**	**9.4**	**0.012**	**0.002**
	Fort McMurray	Hospital Incinerator[a]	0.0005	0.0007	0.006	-	-	0.0030
		Local Vehicle Usage	0.14	0.90	3.4	68	1.4	0.92
		Wood Stove Heating	0.0007	0.0048	0.39	5.8	0.08	0.05
		Fireplaces	0.0021	0.014	1.3	18	1.2	0.18
		Natural Gas Heating	0.0020	0.099	0.14	440	0.04	0.02
		Totals	**0.14**	**1.02**	**5.26**	**532**	**2.73**	**1.17**
CEA	Fort McKay	Local Vehicle Usage	0.0000	0.0001	0.0002	0.0000	0.0001	0.0001
		Wood Stove Heating	0.0000	0.0000	0.0033	0.0492	0.0007	0.0004
		Fireplaces	0.0000	0.0001	0.0112	0.15	0.0102	0.0015
		Natural Gas Heating	0.0000	0.0067	0.0028	9.2	0.0008	0.0004
		Totals	**0.000**	**0.007**	**0.018**	**9.4**	**0.012**	**0.002**
	Fort McMurray	Hospital Incinerator	0.0005	0.0007	0.0060	0.0000	-	0.0030
		Local Vehicle Usage	0.2223	1.5	5.6	111	2.3	1.5
		Wood Stove Heating	0.0009	0.0061	0.50	7.4	0.11	0.067
		Fireplaces	0.0027	0.017	1.7	23	1.5	0.23
		Natural Gas Heating	0.0026	0.16	0.17	564	0.049	0.022
		Totals	**0.23**	**1.66**	**7.95**	**705**	**4.00**	**1.83**

[a] BOVAR Environmental 1996, Assumed operational.

Table 3-58 Source Characteristics for Highway and Residential Sources

Parameter	Highway	Fort. McKay	Fort. McMurray
UTM location North	462,507	468,100	476,008
UTM location East	6,331,720	6,337,400	6,282,130
East-West Pit Width [km]	0.030	0.5	5.0
North-South Pit Width [km]	28	0.5	5.0
Area [km^2]	0.84	0.25	25
Rotation Angle [°]	78	0	0

3.5.3 Summary of Emission Estimates

Based on the emission factors provided in Table 3-50 and Table 3-51, and the fuel consumption values provided in Table 3-52 to Table 3-55, emission of criteria, hydrocarbon and PAH compounds associated with each mine were calculated. For the purposes of evaluation, the diesel fuel use associated with the Syncrude "Other" category is assumed to be consumed in the Base Mine. This is consistent with the assumption for the other mines where all fuel is also assumed to be consumed in the mine pits.

Table 3-59 lists the criteria and hydrocarbon emissions and Table 3-60 lists the PAH emissions. Table 3-61 summarizes these emission estimates of NO_x, VOC (C_{2+}), aldehyde and PAH emissions for selected operation scenarios. The following are noted with respect to mine fleet exhaust emissions:

- NO_x emissions are expected to increase from the 22 to 37 t/cd range for the Existing and Baseline emission scenarios, respectively to 109 t/cd for the CEA emission scenario.
- VOC (C_{2+}) emissions are expected to increase from 1.2 to 1.7 t/cd range for the Existing and Baseline emission scenarios, respectively to 4.8 t/cd for the CEA emission scenario.
- Aromatic HC emissions are expected to increase from 0.014 to 0.021 t/cd range for the Existing and Baseline emission scenarios, respectively to 0.06 t/cd for the CEA emission scenario.
- Aldehyde emissions are expected to increase from 0.16 to 0.23 t/cd range for the Existing and Baseline emission scenarios, respectively to 0.65 t/cd for the CEA emission scenario.
- PAH emissions are expected to increase from 0.0021 to 0.0031 t/cd range for the Existing and Baseline emission scenarios, respectively to 0.0085 t/cd for the CEA emission scenario.

The estimation of these emissions is based on the application of uniform emission factors to the estimated fuel use. There are expected to be year-to-year variations in the fuel use values used to estimate the emissions.

Table 3-59 Criteria and Hydrocarbon Emissions Associated with Mine Fleet Emissions

Operator		Syncrude Base Mine							Suncor				Syncrude		Syncrude	Shell		Mobil
Mine		North	West	East	North	West	North	West	Base	Base	Steep 1	Millenium	Aurora N	Aurora N	Aurora S	Muskeg	Lease 13 E	Kearl
Status		Existing	Existing	Existing	Baseline	Baseline	CEA	CEA	Existing	Baseline	Baseline	CEA	Baseline	CEA	CEA	CEA	CEA	CEA
Fuel Use (10^3 L/cd)	kg/10^3 L	130	124	34	316	33	307	36	179	104	138	521	100	214	162	227	303	130
Criteria, [t/d]																		
CO	14.79	1.9	1.8	0.5	4.7	0.5	4.5	0.5	2.6	1.5	2.0	7.7	1.5	3.2	2.4	3.4	4.5	1.9
NOx	(a)	6.6	6.3	1.7	17.7	1.8	17.2	2.0	8.2	4.8	6.5	26.9	6.1	13.1	9.9	13.8	18.5	7.9
SO2	2.78	0.36	0.35	0.09	0.88	0.09	0.85	0.10	0.04	0.02	0.02	0.08	0.28	0.59	0.45	0.63	0.84	0.36
CO2	2711	351	337	92	857	89	832	98	485	282	374	1412	271	580	439	615	821	352
PM10	1.59	0.21	0.20	0.05	0.50	0.05	0.49	0.06	0.28	0.16	0.22	0.83	1.00	0.34	0.26	0.36	0.48	0.21
PM2.5	1.33	0.17	0.17	0.05	0.42	0.04	0.41	0.05	0.24	0.14	0.18	0.69	0.13	0.29	0.22	0.30	0.40	0.17
General, [kg/d]																		
Total hydrocarbon (C1+)	2.79	361.5	346.9	94.5	882.2	92.1	857.0	100.5	499.7	290.3	385.2	1454.5	279.2	597.4	452.2	633.7	845.9	362.9
Methane (C1)	0.29	36.9	35.4	9.6	90.1	9.4	87.5	10.3	51.0	29.6	39.3	148.5	28.5	61.0	46.2	64.7	86.4	37.1
C2+	2.51	324.6	311.4	84.8	792.1	82.7	769.5	90.2	448.7	260.7	345.9	1305.9	250.7	536.4	406.1	569.0	759.5	325.9
Human Health (kg/d)																		
C2 to C4 alkanes and alkenes	1.437	186.0	178.5	48.6	454.0	47.4	441.0	51.7	257.1	149.4	198.2	748.5	143.7	307.4	232.7	326.1	435.3	186.8
C5 to C8 Alkanes and alkenes	0.525	68.0	65.2	17.8	165.9	17.3	161.1	18.9	94.0	54.6	72.4	273.5	52.5	112.3	85.0	119.2	159.0	68.2
C9 to C12 alkanes and alkenes	0.494	64.0	61.4	16.7	156.1	16.3	151.6	17.8	88.4	51.4	68.2	257.3	49.4	105.7	80.0	112.1	149.7	64.2
Cyclohexane	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzene	0.021	2.7	2.6	0.7	6.6	0.7	6.4	0.7	3.7	2.2	2.9	10.8	2.1	4.4	3.4	4.7	6.3	2.7
C6 to C8 non-benzene aromatics	0.030	3.9	3.8	1.0	9.6	1.0	9.3	1.1	5.4	3.2	4.2	15.8	3.0	6.5	4.9	6.9	9.2	4.0
Total aldehydes	0.340	44.0	42.2	11.5	107.3	11.2	104.3	12.2	60.8	35.3	46.9	176.9	34.0	72.7	55.0	77.1	102.9	44.2
Total ketones	0.093	12.0	11.6	3.1	29.4	3.1	28.5	3.3	16.6	9.7	12.8	48.4	9.3	19.9	15.1	21.1	28.2	12.1
Total RS	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Photochemical, [kg/d]																		
Methane (C1)	0.285	36.9	35.4	9.6	90.1	9.4	87.5	10.3	51.0	29.6	39.3	148.5	28.5	61.0	46.2	64.7	86.4	37.1
Ethane (C2)	0.163	21.2	20.3	5.5	51.6	5.4	50.1	5.9	29.2	17.0	22.5	85.1	16.3	35.0	26.5	37.1	49.5	21.2
C3 to C4 alkanes	0.285	37.0	35.5	9.7	90.2	9.4	87.6	10.3	51.1	29.7	39.4	148.7	28.5	61.1	46.2	64.8	86.5	37.1
C5 to C8 alkanes	0.520	67.3	64.6	17.6	164.2	17.1	159.5	18.7	93.0	54.0	71.7	270.7	52.0	111.2	84.2	118.0	157.4	67.6
C9 to C12 alkanes	0.494	64.0	61.4	16.7	156.1	16.3	151.6	17.8	88.4	51.4	68.2	257.3	49.4	105.7	80.0	112.1	149.7	64.2
C13+ alkanes	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
Ethylene (C2)	0.817	105.8	101.5	27.6	258.1	26.9	250.7	29.4	146.2	84.9	112.7	425.5	81.7	174.8	132.3	185.4	247.4	106.2
C3 to C4 alkenes	0.171	22.2	21.3	5.8	54.1	5.7	52.6	6.2	30.6	17.8	23.6	89.2	17.1	36.6	27.7	38.9	51.9	22.3
C5 to C8 alkenes	0.005	0.7	0.7	0.2	1.7	0.2	1.6	0.2	0.9	0.5	0.7	2.7	0.5	1.1	0.9	1.2	1.6	0.7
C9 to C12 alkenes	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C13+ alkenes	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
benzene (C6)	0.021	2.7	2.6	0.7	6.6	0.7	6.4	0.7	3.7	2.2	2.9	10.8	2.1	4.4	3.4	4.7	6.3	2.7
C6 to C8 non-benzene aromatics	0.030	3.9	3.8	1.0	9.6	1.0	9.3	1.1	5.4	3.2	4.2	15.8	3.0	6.5	4.9	6.9	9.2	4.0
C9 to C12 aromatics	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(a) See Text

Table 3-60 PAH Emissions Associated with Mine Fleet Emissions

Operator	Syncrude Base Mine							Suncor				Syncrude			Shell		Mobil
Mine	North	West	East	North	West	North	West	Base	Base	Steep 1	Millenium	Aurora N		Aurora S	Muskeg	Lease 13	Kearl
Status	Existing	Existing	Existing	Baseline	Baseline	CEA	CEA	Existing	Baseline	Baseline	CEA	Baseline	CEA	CEA	CEA	CEA	CEA
Fuel Use	130	124	34	316	33	307	36	179	104	138	521	100	214	162	227	303	130
Napthalene	2.8E-01	2.7E-01	7.2E-02	6.7E-01	7.0E-02	6.6E-01	7.7E-02	3.8E-01	2.2E-01	2.9E-01	1.1E+00	2.1E-01	4.6E-01	3.5E-01	4.8E-01	6.5E-01	2.8E-01
Acenapthylene	2.0E-02	1.9E-02	5.1E-03	4.8E-02	5.0E-03	4.7E-02	5.5E-03	2.7E-02	1.6E-02	2.1E-02	7.9E-02	1.5E-02	3.2E-02	2.5E-02	3.4E-02	4.6E-02	2.0E-02
Acenaphthene	9.9E-03	9.5E-03	2.6E-03	2.4E-02	2.5E-03	2.4E-02	2.8E-03	1.4E-02	8.0E-03	1.1E-02	4.0E-02	7.7E-03	1.6E-02	1.2E-02	1.7E-02	2.3E-02	1.0E-02
Fluorene	2.7E-02	2.6E-02	7.1E-03	6.6E-02	6.9E-03	6.5E-02	7.6E-03	3.8E-02	2.2E-02	2.9E-02	1.1E-01	2.1E-02	4.5E-02	3.4E-02	4.8E-02	6.4E-02	2.7E-02
Phenanthrene	8.0E-02	7.7E-02	2.1E-02	2.0E-01	2.0E-02	1.9E-01	2.2E-02	1.1E-01	6.4E-02	8.5E-02	3.2E-01	6.2E-02	1.3E-01	1.0E-01	1.4E-01	1.9E-01	8.0E-02
Anthracene	3.0E-03	2.8E-03	7.7E-04	7.2E-03	7.6E-04	7.0E-03	8.2E-04	4.1E-03	2.4E-03	3.2E-03	1.2E-02	2.3E-03	4.9E-03	3.7E-03	5.2E-03	6.9E-03	3.0E-03
Fluoranthene	7.1E-03	6.8E-03	1.9E-03	1.7E-02	1.8E-03	1.7E-02	2.0E-03	9.8E-03	5.7E-03	7.6E-03	2.9E-02	5.5E-03	1.2E-02	8.9E-03	1.2E-02	1.7E-02	7.1E-03
Pyrene	5.6E-03	5.4E-03	1.5E-03	1.4E-02	1.4E-03	1.3E-02	1.6E-03	7.7E-03	4.5E-03	6.0E-03	2.2E-02	4.3E-03	9.2E-03	7.0E-03	9.8E-03	1.3E-02	5.6E-03
Benz(a)anthracene	7.2E-04	6.9E-04	1.9E-04	1.8E-03	1.8E-04	1.7E-03	2.0E-04	9.9E-04	5.8E-04	7.7E-04	2.9E-03	5.6E-04	1.2E-03	9.0E-04	1.3E-03	1.7E-03	7.2E-04
Chrysene	2.0E-03	1.9E-03	5.2E-04	4.8E-03	5.0E-04	4.7E-03	5.5E-04	2.7E-03	1.6E-03	2.1E-03	8.0E-03	1.5E-03	3.3E-03	2.5E-03	3.5E-03	4.6E-03	2.0E-03
Benzo(b)fluoranthene	2.4E-03	2.3E-03	6.2E-04	5.8E-03	6.0E-04	5.6E-03	6.6E-04	3.3E-03	1.9E-03	2.5E-03	9.5E-03	1.8E-03	3.9E-03	3.0E-03	4.1E-03	5.5E-03	2.4E-03
Benzo(k)fluoranthene	2.7E-04	2.6E-04	7.0E-05	6.5E-04	6.8E-05	6.4E-04	7.4E-05	3.7E-04	2.2E-04	2.9E-04	1.1E-03	2.1E-04	4.4E-04	3.4E-04	4.7E-04	6.3E-04	2.7E-04
Benzo(a)pyrene	2.8E-04	2.7E-04	7.3E-05	6.9E-04	7.2E-05	6.7E-04	7.8E-05	3.9E-04	2.3E-04	3.0E-04	1.1E-03	2.2E-04	4.6E-04	3.5E-04	4.9E-04	6.6E-04	2.8E-04
Indeno(1,2,3-W)pyrene	4.5E-04	4.3E-04	1.2E-04	1.1E-03	1.1E-04	1.1E-03	1.2E-04	6.2E-04	3.6E-04	4.8E-04	1.8E-03	3.4E-04	7.4E-04	5.6E-04	7.8E-04	1.0E-03	4.5E-04
Dibenz(a,h)anthracene	7.4E-04	7.1E-04	1.9E-04	1.8E-03	1.9E-04	1.7E-03	2.0E-04	1.0E-03	5.9E-04	7.9E-04	3.0E-03	5.7E-04	1.2E-03	9.2E-04	1.3E-03	1.7E-03	7.4E-04
Benzo(g,h,l)perylene	6.1E-04	5.8E-04	1.6E-04	1.5E-03	1.6E-04	1.4E-03	1.7E-04	8.4E-04	4.9E-04	6.5E-04	2.4E-03	4.7E-04	1.0E-03	7.6E-04	1.1E-03	1.4E-03	6.1E-04
3-Methylphenanthrene	3.1E-02	3.0E-02	8.1E-03	7.6E-02	7.9E-03	7.4E-02	8.6E-03	4.3E-02	2.5E-02	3.3E-02	1.3E-01	2.4E-02	5.1E-02	3.9E-02	5.5E-02	7.3E-02	3.1E-02
2-Methylanthracene	3.6E-02	3.4E-02	9.3E-03	8.7E-02	9.1E-03	8.4E-02	9.9E-03	4.9E-02	2.9E-02	3.8E-02	1.4E-01	2.7E-02	5.9E-02	4.5E-02	6.2E-02	8.3E-02	3.6E-02
4-+9-Methylphenanthrene	3.8E-02	3.7E-02	1.0E-02	9.3E-02	9.8E-03	9.1E-02	1.1E-02	5.3E-02	3.1E-02	4.1E-02	1.5E-01	3.0E-02	6.3E-02	4.8E-02	6.7E-02	9.0E-02	3.8E-02
1-Methylphenanthrene	3.2E-02	3.1E-02	8.3E-03	7.8E-02	8.1E-03	7.5E-02	8.9E-03	4.4E-02	2.6E-02	3.4E-02	1.3E-01	2.5E-02	5.3E-02	4.0E-02	5.6E-02	7.5E-02	3.2E-02
Benzo[a]fluorene	6.4E-04	6.2E-04	1.7E-04	1.6E-03	1.6E-04	1.5E-03	1.8E-04	8.9E-04	5.2E-04	6.8E-04	2.6E-03	5.0E-04	1.1E-03	8.0E-04	1.1E-03	1.5E-03	6.4E-04
2-Methylpyrene	5.3E-04	5.1E-04	1.4E-04	1.3E-03	1.4E-04	1.3E-03	1.5E-04	7.3E-04	4.3E-04	5.6E-04	2.1E-03	4.1E-04	8.8E-04	6.6E-04	9.3E-04	1.2E-03	5.3E-04
Benzo[ghi]fluoranthene	3.7E-04	3.6E-04	9.7E-05	9.1E-04	9.5E-05	8.8E-04	1.0E-04	5.2E-04	3.0E-04	4.0E-04	1.5E-03	2.9E-04	6.2E-04	4.7E-04	6.5E-04	8.7E-04	3.7E-04
Cyclopenta[cd]pyrene	4.5E-05	4.3E-05	1.2E-05	1.1E-04	1.1E-05	1.1E-04	1.2E-05	6.2E-05	3.6E-05	4.8E-05	1.8E-04	3.5E-05	7.4E-05	5.6E-05	7.8E-05	1.0E-04	4.5E-05
Benzo[e]pyrene	4.0E-05	3.8E-05	1.0E-05	9.7E-05	1.0E-05	9.4E-05	1.1E-05	5.5E-05	3.2E-05	4.2E-05	1.6E-04	3.1E-05	6.6E-05	5.0E-05	7.0E-05	9.3E-05	4.0E-05
Perylene	5.0E-06	4.8E-06	1.3E-06	1.2E-05	1.3E-06	1.2E-05	1.4E-06	6.9E-06	4.0E-06	5.3E-06	2.0E-05	3.8E-06	8.2E-06	6.2E-06	8.7E-06	1.2E-05	5.0E-06
Indeno[1,2,3-cd]fluoranthene	2.5E-05	2.4E-05	6.5E-06	6.1E-05	6.3E-06	5.9E-05	6.9E-06	3.4E-05	2.0E-05	2.7E-05	1.0E-04	1.9E-05	4.1E-05	3.1E-05	4.4E-05	5.8E-05	2.5E-05
Picene	5.0E-06	4.8E-06	1.3E-06	1.2E-05	1.3E-06	1.2E-05	1.4E-06	6.9E-06	4.0E-06	5.3E-06	2.0E-05	3.8E-06	8.2E-06	6.2E-06	8.7E-06	1.2E-05	5.0E-06
2-Methylfluorene	6.0E-05	5.7E-05	1.6E-05	1.5E-04	1.5E-05	1.4E-04	1.7E-05	8.3E-05	4.8E-05	6.4E-05	2.4E-04	4.6E-05	9.9E-05	7.5E-05	1.0E-04	1.4E-04	6.0E-05
Benzo[ghi]perylene	3.5E-05	3.3E-05	9.1E-06	8.5E-05	8.9E-06	8.3E-05	9.7E-06	4.8E-05	2.8E-05	3.7E-05	1.4E-04	2.7E-05	5.8E-05	4.4E-05	6.1E-05	8.1E-05	3.5E-05
Coronene	5.0E-06	4.8E-06	1.3E-06	1.2E-05	1.3E-06	1.2E-05	1.4E-06	6.9E-06	4.0E-06	5.3E-06	2.0E-05	3.8E-06	8.2E-06	6.2E-06	8.7E-06	1.2E-05	5.0E-06
1-Nitropyrene	4.0E-04	3.8E-04	1.0E-04	9.7E-04	1.0E-04	9.4E-04	1.1E-04	5.5E-04	3.2E-04	4.2E-04	1.6E-03	3.1E-04	6.6E-04	5.0E-04	7.0E-04	9.3E-04	4.0E-04
Dibenzothiophene	4.2E-05	4.1E-05	1.1E-05	1.0E-04	1.1E-05	1.0E-04	1.2E-05	5.8E-05	3.4E-05	4.5E-05	1.7E-04	3.3E-05	7.0E-05	5.3E-05	7.4E-05	9.9E-05	4.2E-05
4-Methyldibenzothiophene	7.0E-05	6.7E-05	1.8E-05	1.7E-04	1.8E-05	1.7E-04	1.9E-05	9.6E-05	5.6E-05	7.4E-05	2.8E-04	5.4E-05	1.2E-04	8.7E-05	1.2E-04	1.6E-04	7.0E-05
3-Methyldibenzothiophene	1.1E-04	1.1E-04	2.9E-05	2.7E-04	2.8E-05	2.6E-04	3.0E-05	1.5E-04	8.8E-05	1.2E-04	4.4E-04	8.5E-05	1.8E-04	1.4E-04	1.9E-04	2.6E-04	1.1E-04
Total PAH	**0.58**	**0.55**	**0.15**	**1.40**	**0.15**	**1.36**	**0.16**	**0.80**	**0.46**	**0.61**	**2.32**	**0.44**	**0.95**	**0.72**	**1.01**	**1.35**	**0.58**

Table 3-61 Summary of Mine Fleet Emission Totals for Selected Scenarios

Pollutant	Existing	Baseline	CEA	Project Millennium	Syncrude Application
Criteria, [t/d]					
CO	6.9	10.2	28.1	14.3	10.1
NO_x	22.9	36.9	109.3	52.5	36.6
SO_2	0.8	1.3	3.9	1.3	1.3
CO_2	1265	1873.1	5150.3	2629.4	1856.8
PM_{10}	0.74	1.9	3.0	2.4	1.9
$PM_{2.5}$	0.62	0.9	2.5	1.3	0.9
General, [kg/d]					
Total hydrocarbon (C1+)	1303	1929.0	5304.1	2707.9	1912.3
Methane (C1)	133	197.0	541.6	276.5	195.3
C2+	1170	1732.1	4762.5	2431.4	1717.0
Human Health, [kg/d]					
C2 to C4 alkanes and alkenes	670	992.7	2729.5	1393.5	984.1
C5 to C8 alkanes and alkenes	245	362.7	997.3	509.1	359.6
C9 to C12 alkanes and alkenes	230	341.3	938.5	479.1	338.3
Cyclohexane	0.0	0.0	0.0	0.0	0.0
Benzene	9.7	14.4	39.5	20.2	14.2
C6 to C8 non-benzene aromatics	14.2	21.0	57.8	29.5	20.8
Total aldehydes	158	234.7	645.3	329.4	232.6
Total ketones	43	64.2	176.7	90.2	63.7
Total RS	0.0	0.0	0.0	0.0	0.0
Photochemical, [kg/d]					
Methane (C1)	133	197.0	541.6	276.5	195.3
Ethane (C2)	76	112.9	310.3	158.4	111.9
C3 to C4 alkanes	133	197.2	542.2	276.8	195.5
C5 to C8 alkanes	242	359.1	987.3	504.0	355.9
C9 to C12 alkanes	230	341.3	938.5	479.1	338.3
C13+ alkanes	0.00	0.0	0.0	0.0	0.0
Ethylene (C2)	381	564.3	1551.7	792.2	559.4
C3 to C4 alkenes	80	118.3	325.3	166.1	117.3
C5 to C8 alkenes	2.5	3.6	10.0	5.1	3.6
C9 to C12 alkenes	0.0	0.0	0.0	0.0	0.0
C13+ alkenes	0.0	0.0	0.0	0.0	0.0
Benzene (C6)	9.7	14.4	39.5	20.2	14.2
C6 to C8 non-benzene aromatics	14	21.0	57.8	29.5	20.8
C9 to C12 aromatics	0.0	0.0	0.0	0.0	0.0

3.6 FUGITIVE MINE SOURCES

Mine surfaces are heterogeneous mixtures of freshly exposed faces, older faces, dump piles, windrows, rejects, pit floors and bench tops. These surfaces, comprised of oil sand, are sources of fugitive VOC and RS emissions that depend on the age of an exposed surface, ambient temperature and windspeed.

3.6.1 Emission Factors

Emission factors for HC and RS emissions were obtained from the 1997 fugitive emission survey conducted at Syncrude (Clearstone 1997). These emission factors are based on measurements that were obtained during the last half of July and early August 1997. This period was characterized by hot and sunny conditions with temperatures exceeding 30°C on some of the study days. Fluxes from various exposed surfaces were measured using enclosed flux chamber measurements at multiple locations. For reasons that will be discussed in detail in Section 3.7.1, the measurements obtained from this program are likely to be representative of the average annual emissions. During the cooler winter months, the emissions factors are estimated to be 35% lower and during the windier transition months of May and September, the emission factors are estimated to be 60% greater. The values presented in this section are referenced to the month of July.

Table 3-62 presents composite emission factors for the North Mine, West Base Mine and East Base Mine. There are differences between the emission factors derived for each mine. These differences can reflect both differences in the mining approaches as well as the limited sampling locations. The emission factors have been grouped according to human health and photochemical (ozone precursor) considerations.

Table 3-62 Fugitive HC and RS Emission Factors (kg/km^2/d) for the Syncrude Base Mine

Grouping	North Mine	West Base Mine	East Base Mine	Composite
General, [kg/km^2/d]				
Total hydrocarbon (C1+)	3,749	4,420	1,755	3,308
Methane (C1)	2,759	2,641	1,421	2,274
C2+	990	1,779	334	1,034
Human Health, [kg/km^2/d]				
C2 to C4 alkanes and alkenes	10	36	60	35.1
C5 to C8 Alkanes and alkenes	12	27	20	19.8
C9 to C12 alkanes and alkenes (a)	956	1,698	248	967
Cyclohexane	0	2	1	0.78
Benzene	0.076	-	0.013	0.030
C6 to C8 non-benzene aromatics	0.97	0.72	0.64	0.78
Total aldehydes	0	0	0	0
Total ketones	0	0	0	0
Total RS	4.47	6.34	8.98	6.60
Photochemical, [kg/km^2/d]				
Methane (C1)	2,759	2,641	1,421	2274
Ethane (C2)	7	31	42	26.5
C3 to C4 alkanes	3	4	14	7.1
C5 to C8 alkanes (b)	907	1,621	237	922
C9 to C12 alkanes	36.6	63.7	19.9	40.1
C13+ alkanes	8.80	13.01	3.46	8.42
Ethylene (C2)	0	0	0	0
C3 to C4 alkenes	0.61	0.91	2.98	1.50
C5 to C8 alkenes	5.40	9.11	2.21	5.57
C9 to C12 alkenes	18.7	31.3	9.79	19.9
C13+ alkenes	2.28	3.23	1.16	2.23
Benzene (C6)	0.08	0.00	0.01	0.030
C6 to C8 non-benzene aromatics	0.97	0.72	0.64	0.78
C9 to C12 aromatics	0.50	0.59	0.09	0.39

(a) Unknown is placed in C9 to C12 category for health assessment
(b) Unknown is placed in C5 to C8 category for photochemical assessment

3.6.2 Emission Estimates

The average emission flux values, listed Table 3-62, were applied to the mines identified in Section 3.5.2, based on the respective area of each mine pit. The emission estimates are provided in Table 3-63:

- Syncrude Base Mine. For the existing base mines, the mine specific emission factors were applied to the respective mines. For the Baseline and CEA operation scenarios, the North Mine emissions associated with freshly exposed faces were scaled according to the projected mine area. For the Baseline emission scenario, the West Base Mine emissions were scaled according to production rate as most of the emissions result from the windrow piles.
- Suncor Mines. The composite emission factors in Table 3-62 were applied to the Existing, Baseline and CEA operation scenarios on the basis of the projected surface area for each mine.
- Aurora, Muskeg, Lease 13 East and Kearl Lake Mines. The composite emission factors were applied to the Existing and CEA operation scenarios on the basis of the projected surface area for each mine.

Table 3-64 contains a summary of VOC and RS emissions for the selected development scenarios. In summary, the following are noted with respect to fugitive VOC and RS emissions from the mines:

- Fugitive VOC emissions are predicted to increase from between approximately 11 and 14 t/d in the Existing and Baseline scenario to 46 t/d in the CEA scenario.
- Fugitive RS emissions are predicted to increase from the between approximately 0.074 and 0.088 t/d in the Existing and Baseline scenarios to approximately 0.29 t/d in the CEA scenario.

These emission rates are representative of average annual rates. Short term model results should take into account that on cool winter days, a lower rate is expected and on windy days a higher rate may be expected. As with any estimate of fugitive emission from heterogeneous surfaces, there is considerably more uncertainty than those associated with point sources.

Table 3-63 Fugitive VOC and RS Emissions from Exposed Mine Surfaces

Operator	Syncrude Base Mine (c)							Suncor				Syncrude			Shell		Mobil
Mine	North	West	East	North	West	North	West	Base	Base	Steep 1	Millenium	Aurora N		Aurora S	Muskeg	Lease 13	Kearl
Status	Existing	Existing	Existing	Baseline	Baseline	CEA	CEA	Existing	Baseline	Baseline	CEA	Baseline	CEA	CEA	CEA	CEA	CEA
Mine Area [km^2]								3.20	4.13	1.23	7.88	1.62	6.00	6.00	4.50	4.50	3.75
General, [kg/d]																	
Total hydrocarbon (C1+)	5422	8578	12905	15358	3562	21490.8	1980.7	10585	13658	4077	26049	5359	19847	19847	14885	14885	12404
Methane (C1)	3990	5126	10450	11065	2129	15306.6	1183.6	7276	9388	2802	17905	3683	13642	13642	10231	10231	8526
C2+	1432	3452	2455	4294	1434	6184.2	797.1	3309	4270	1275	8144	1675	6205	6205	4654	4654	3878
Human Health, [kg/d]												0.0					
C2 to C4 alkanes and alkenes	14.1	69.4	440	34.1	28.8	43.5	16.0	112	145	43	276	56.8	210.5	211	157.9	157.9	131.6
C5 to C8 Alkanes and alkenes	17.7	52.0	150	53.3	21.6	77.0	12.0	63	82	24	156	32.1	119.0	119	89.2	89.2	74.3
C9 to C12 alkanes and alkenes (a)	1382	3297	1826	4150	1369	5982.5	761.2	3096	3995	1192	7619	1567	5805	5805	4353	4353	3628
Cyclohexane	0.0	3.0	5.7	0.0	1.3	0.0	0.7	2.5	3.2	1.0	6.1	1.3	4.7	4.7	3.5	3.5	2.9
Benzene	0.1	0.0	0.1	0.3	0.0	0.4	0.0	0.1	0.1	0.0	0.2	0.0	0.2	0.2	0.1	0.1	0.1
C6 to C8 non-benzene aromatics	1.4	1.4	4.7	4.0	0.6	5.7	0.3	2.5	3.2	1.0	6.1	1.3	4.7	4.7	3.5	3.5	2.9
Total aldehydes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total ketones	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total RS	6.5	12.3	66.0	19.9	5.1	28.9	2.8	21	27	8	52	10.7	39.6	39.6	29.7	29.7	24.7
Photochemical, [kg/d]												0.0					
Methane (C1)	3990	5126	10450	11065	2129	15306.6	1183.6	7276	9388	2802	17905	3683	13642	13642	10231	10231	8526
Ethane (C2)	9.6	59.3	311.9	21.3	24.6	25.5	13.7	84.9	109.6	32.7	208.9	43	159	159	119.4	119.4	99.5
C3 to C4 alkanes	3.6	8.4	105.7	10.3	3.5	14.5	1.9	22.6	29.2	8.7	55.6	11.4	42.4	42.4	31.8	31.8	26.5
C5 to C8 alkanes (b)	1312	3147	1742	3937	1306.7	5673.7	726.5	2949	3806	1136	7258	1493	5530	5530	4147.5	4147.5	3456.2
C9 to C12 alkanes	53.0	124	146	161.2	51.3	233.8	28.5	128	165	49	316	64.9	240.4	240.4	180.3	180.3	150.3
C13+ alkanes	12.7	25.3	25.4	39.1	10.5	57.1	5.8	27.0	34.8	10.4	66.3	13.6	50.5	50.5	37.9	37.9	31.6
Ethylene (C2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3 to C4 alkenes	0.9	1.8	21.9	2.5	0.7	3.5	0.4	4.8	6.2	1.8	11.8	2.4	9.0	9.0	6.7	6.7	5.6
C5 to C8 alkenes	7.8	17.7	16.3	23.8	7.3	34.5	4.1	17.8	23.0	6.9	43.9	9.0	33.4	33.4	25.1	25.1	20.9
C9 to C12 alkenes	27.1	60.8	72.0	81.5	25.2	117.5	14.0	63.8	82.4	24.6	157.1	32.3	119.7	119.7	89.8	89.8	74.8
C13+ alkenes	3.3	6.3	8.5	10.2	2.6	14.8	1.4	7.1	9.2	2.7	17.5	3.6	13.4	13.4	10.0	10.0	8.3
benzene (C6)	0.1	0.0	0.1	0.3	0.0	0.4	0.0	0.1	0.1	0.0	0.2	0.0	0.2	0.2	0.1	0.1	0.1
C6 to C8 non-benzene aromatics	1.4	1.4	4.7	4.0	0.6	5.7	0.3	2.5	3.2	1.0	6.1	1.3	4.7	4.7	3.5	3.5	2.9
C9 to C12 aromatics	0.7	1.1	0.7	2.2	0.5	3.2	0.3	1.3	1.6	0.5	3.1	0.6	2.4	2.4	1.8	1.8	1.5

(a) Unknown speciation are placed in C9 to C12 category for health assessment
(b) Unknown speciation are placed in C5 to C8 category for photochemical assessment
Note: Exposed mine surface emission estimates are based on mine pit area

Table 3-64 Summary of Fugitive HC, VOC and RS Emissions for Selected Development Scenarios

Source	Existing	Baseline	CEA	Suncor Project Millennium	Syncrude Application
General, [kg/d]					
Total hydrocarbon (C1+)	37,490	42,014	131,389	50,328	46,566
Methane (C1)	26,842	29,067	90,667	34,782	32,363.2
C2+	10,648	12,948	40,721	15,547	14,201.3
Human Health, [kg/d]					
C2 to C4 alkanes and alkenes	635.5	307.7	1204.4	395.7	304.3
C5 to C8 Alkanes and alkenes	282.7	213	735.7	263	227.1
C9 to C12 alkanes and alkenes (a)	9,601	12,273	38,306.7	1,4705	13,497.7
Cyclohexane	11.2	6.8	26.1	8.7	6.2
Benzene	0.3	0.4	1.3	0.5	0.5
C6 to C8 non-benzene aromatics	10	10.1	31.4	12	11.5
Total aldehydes	0	0	0	0	0
Total ketones	0	0	0	0	0
Total RS	105.8	70.7	247	87.7	77.4
Photochemical, [kg/d]					
Methane (C1)	26,842	29,067	90,667.2	34,782	32,363
Ethane (C2)	465.7	231.2	904.4	297.8	224.5
C3 to C4 alkanes	140.3	63.1	246.9	80.8	65.7
C5 to C8 alkanes (b)	9,150	11,678.7	36,469.4	13,994.7	12,835
C9 to C12 alkanes	451	491.4	1570	593.4	541.2
C13+ alkanes	90.4	108.4	337.6	129.5	121.7
Ethylene (C2)	0	0	0	0	0
C3 to C4 alkenes	29.4	13.6	52.7	17.4	14.3
C5 to C8 alkenes	59.6	70	220.4	84	77.5
C9 to C12 alkenes	223.7	246	782.4	296.1	270.8
C13+ alkenes	25.2	28.3	88.8	33.9	31.7
benzene (C6)	0.3	0.4	1.3	0.5	0.5
C6 to C8 non-benzene aromatics	10	10.1	31.4	12	11.5
C9 to C12 aromatics	3.8	5.4	16.5	6.4	6.2

(a) Unknown speciation are placed in C9 to C12 category for health assessment

(b) Unknown speciation are placed in C5 to C8 category for photochemical assessment

3.7 FUGITIVE TAILINGS SOURCES

The handling of tailings can result in the following:

- Settling Basins that receive liquid effluent from primary extraction only;
- Settling Basins that receive liquid effluent from both primary and secondary extraction;
- Sand storage areas that receive sand from the primary extraction;
- End pit lakes that will be comprised of mature fine tailings (MFT) in the lower layer and an accompanying water cap; and

- Consolidated or composite tailings (CT) comprised of a mixture of MFT, tailings sand and gypsum. The surface of a CT area may be capped with overburden for a dry land reclamation or a water layer for wetland reclamation.

Settling Basins receive effluent from the extraction plants that can contain hydrocarbon and reduced sulphur (RS) compounds from residual bitumen and/or diluent. Chemical and biological reactions in the pond can modify the HC and RS speciation profile. The volatilization of these HC and RS compounds will depend on the nature of the received effluent, the temperature of the pond, ambient temperature, wind speed and area of open water surface. Emissions of HC and RS from dry landscapes will depend more on ambient temperature. The emissions factors have been grouped according to human health and photochemical (ozone precusor) considerations.

3.7.1 Syncrude Based Emission Factors

The 1997 fugitive emission study determined surface emission fluxes for the following:

- Mildred Lake Settling Basin (MLSB) (water surface);
- West Mine in-pit pond (water surface);
- Southwest Sand Storage (SWSS) area (water surface);
- Mildred Lake Settling Basin beach (dry land); and
- Southwest Sand Storage area (dry land).

Fluxes from water and wetted soil surfaces were monitored using enclosed flux chambers. An overall flux estimate for a given type of surface was estimated from multiple samples at several locations. Actual emission may differ from the those derived from the flux chamber measurements due to differences in wind speeds and ambient temperature. A mass transfer model was configured using average wind speeds and ambient temperatures to assess the monthly variability of VOC and RS emissions (Table 3-65). Compared to the measurement period (July), May and September result in 60% increases in flux rates due to increased wind speeds. The low temperatures observed in December result in 35% lower flux rates. On average, the July measurements are within 5% of the annual average, based on this mass transfer model estimate. The emission fluxes and emission estimates presented in this section are referenced to the month of July.

Table 3-66 summarizes emission fluxes from the water surface areas. The largest fluxes are associated with the Mildred Lake Settling Basin for methane (C_1). The largest fluxes of RS are associated with the Southwest Sand Storage area pond.

Table 3-67 summarizes emission fluxes for the dry land surfaces. The larger fluxes are associated with the Southwest Sand Storage area. The overall fluxes of HC for the dry land surfaces are considerably less than those for the water surfaces.

Table 3-65 Seasonal Variation of Fugitive HC and RS Emissions Based on Monthly Average Temperatures and Wind Speeds

Month	Temperature [°C]	Wind Speed [m/s]	Percentage of July
January	-15	3.2	65
February	-15	3.5	76
March	-1.4	3.6	98
April	4.9	3.8	120
May	11.5	1.0	158
June	16.9	3.0	123
July	18.3	2.9	100
August	17.9	3.1	113
September	10.5	4.0	158
October	3.7	3.4	99
November	-5.2	3.2	77
December	-13.2	3.0	63
Average	**2.8**	**3.4**	**105**

3.7.2 Suncor Based Emission Factors

Suncor has estimated emission factors from their tailings ponds based on monitoring programs conducted in July of 1997 (Conor 1997, Hatch 1997). The monitoring was associated with ambient temperatures ranging between 17 and 22 °C. Ambient wind speeds ranged between 6 to 27 km/hr. Table 3-68 provides a summary of the emission fluxes from these surfaces. The fluxes resulting from the pond that receives effluent from the primary and secondary extraction processes (Pond 1) are significantly larger than those from the other ponds. No VOC and only some RS emissions were detected from the ponds other than Pond 1. The maximum emission rate from these ponds were used to estimate the emission rates from non-primary or non-secondary extraction ponds in the future scenarios. Emissions from CT ponds are expected to be minimal, however, the above emission estimates were applied to these ponds as well.

Table 3-66 Fugitive HC and RS Emission Factors for Selected Mildred Lake Tailings Surfaces (Water Surfaces)

Surface	Mildred Lake Settling Basin	Southwest Sand Storage Area	West & East In-Pit Pond
General, [kg/km^2/d]			
Total hydrocarbon (C1+)	6,050.8	365.4	1,774.1
Methane (C1)	4,956.8	45.6	1,704.6
C2+	1,094.0	319.8	69.4
Human Health, [kg/km^2/d]			
C2 to C4 alkanes and alkenes	0	0	0
C5 to C8 alkanes and alkenes	73	1	5
C9 to C12 alkanes and alkenes (a)	956.7	289.9	60.3
Cyclohexane	2	0	0
Benzene	3.974	0.163	0.245
C6 to C8 non-benzene aromatics	38.21	1.80	2.63
Total aldehydes	0	0	0
Total ketones	0	0	0
Total RS	5.26	7.12	3.62
Photochemical, [kg/km^2/d]			
Methane (C1)	4,956.8	45.6	1,704.6
Ethane (C2)	0	0	0
C3 to C4 alkanes	0	0	0
C5 to C8 alkanes (b)	977.06	276.76	64.13
C9 to C12 alkanes	39.19	14.51	0.83
C13+ alkanes	3.01	2.54	0.18
Ethylene (C2)	0	0	0
C3 to C4 alkenes	0	0.01	0
C5 to C8 alkenes	11.46	0	0.10
C9 to C12 alkenes	2.21	0.03	0.03
C13+ alkenes	0.18	0	0
Benzene (C6)	3.97	0.16	0.24
C6 to C8 non-benzene aromatics	38.21	1.80	2.63
C9 to C12 aromatics	18.68	23.97	1.32

(a) Unknown is placed in C9 to C12 category for the health assessment.

(b) Unknown is placed in C5 to C8 category for the photochemical assessment.

Table 3-67 Fugitive HC and RS Emission Factors for Selected Mildred Lake Tailings Surfaces (Dry Land Surfaces)

Surface	Mildred Lake Settling Basin	Southwest Sand Storage Area
General, [kg/km^2/d]		
Total hydrocarbon (C1+)	24.1	333.1
Methane (C1)	8.1	6.9
C2+	16.0	326.2
Human Health, [kg/km^2/d]		
C2 to C4 alkanes and alkenes	0	0
C5 to C8 alkanes and alkenes	0	0
C9 to C12 alkanes and alkenes (a)	14.7	324.6
Cyclohexane	0	0
Benzene	0.026	-
C6 to C8 non-benzene aromatics	0.34	1.48
Total aldehydes	0	0
Total ketones	0	0
Total RS	3.32	8.81
Photochemical, [kg/km^2/d]		
Methane (C1)	8.1	6.9
Ethane (C2)	0	0
C3 to C4 alkanes	0	0
C5 to C8 alkanes (b)	14.1	321
C9 to C12 alkanes	0.53	3.95
C13+ alkanes	0.21	-
Ethylene (C2)	0	0
C3 to C4 alkenes	0	0
C5 to C8 alkenes	0	0
C9 to C12 alkenes	0.06	0
C13+ alkenes	0	0
Benzene (C6)	0.03	0
C6 to C8 non-benzene aromatics	0.34	1.48
C9 to C12 aromatics	0.79	0.12

(a) Unknown is placed in C9 to C12 category for the health assessment.

(b) Unknown is placed in C5 to C8 category for the photochemical assessment.

Table3-68 Fugitive HC and RS Emission Factors for Selected Suncor Tailings Surfaces (Water Surfaces)

Surface	Pond1 (c)	Pond 1A (d)	Pond 2/3	Pond 4 (e)
General, [kg/km^2/d]				
Total hydrocarbon (C1+)	72,700	597.5	24.5	146.5
Methane (C1)	10,708	597.5	24.5	146.5
C2+	61,992	0.0	0.0	0.0
Human Health, [kg/km^2/d]				
C2 to C4 alkanes and alkenes	16.5	0.0	0.0	0.0
C5 to C8 alkanes and alkenes	35,494	0.0	0.0	0.0
C9 to C12 alkanes and alkenes (a)	12,899	0.0	0.0	0.0
Cyclohexane	8,724	0.0	0.0	0.0
Benzene	0.0	0.0	0.0	0.0
C6 to C8 non-benzene aromatics	4,134	0.0	0.0	0.0
Total aldehydes	0.0	0.0	0.0	0.0
Total ketones	0.0	0.0	0.0	0.0
Total RS	725	12.0	0.0	0.8
Photochemical, [kg/km^2/d]				
Methane (C1)	10,709	597.5	24.5	146.5
Ethane (C2)	0.0	0.0	0.0	0.0
C3 to C4 alkanes	16.5	0.0	0.0	0.0
C5 to C8 alkanes (b)	32,442	0.0	0.0	0.0
C9 to C12 alkanes	8,533	0.0	0.0	0.0
C13+ alkanes	1,433	0.0	0.0	0.0
Ethylene (C2)	0.0	0.0	0.0	0.0
C3 to C4 alkenes	0.0	0.0	0.0	0.0
C5 to C8 alkenes	10,848	0.0	0.0	0.0
C9 to C12 alkenes	3,861	0.0	0.0	0.0
C13+ alkenes	0.0	0.0	0.0	0.0
Benzene (C6)	133	0.0	0.0	0.0
C6 to C8 non-benzene aromatics	6,151	0.0	0.0	0.0
C9 to C12 aromatics	1,456	0.0	0.0	0.0

(a) Unknown is placed in C9 to C12 category for the health assessment.
(b) Unknown is placed in C5 to C8 category for the photochemical assessment.
(c) Emission factor used for Suncor Secondary Extraction ponds.
(d) Emission factor used for Suncor Recycle Water ponds.
(e) Emission factor used for Suncor CT, MFT and FGD ponds.

3.7.3 Tailings Facility Parameters

Table 3-69 provides a summary of the tailings impoundment surfaces for Existing, Baseline and CEA emission scenario. Each area was assumed to be rectangular in shape. The UTM co-ordinates refer to the southwest corner of the rectangular area. The length of each side is equal to the square root of the area.

Table 3-69 Physical Parameters of Tailings Impoundment Areas Associated with VOC and RS Emissions

Scenario	Operator	Emission	Surface Type	Effluent Source	Area [km^2]	Side [km]	Elev. [m]	UTM East	UTM North
Existing	Syncrude	Mildred Lake Settling Basin	Water	P & S	13.0	3.6	349	460,470	6,323,660
		West Mine In-Pit Pond	Water	MFT	4.7	2.2	291	461,460	6,317,380
		South West Sand Storage Pond	Water	P	2.9	1.7	380	452,780	6,315,080
		Mildred Lake Settling Basin Beach	Dry	P	8.4	2.9	352	459,340	6,323,310
		South West Sand Storage Area	Dry	P	7.1	2.7	382	452,650	6,314,390
	Suncor	Pond 1	Water	S	1.3	1.2	322	471,422	6,315,572
		Pond 1A	Water	R	0.6	0.8	312	470,562	6,315,512
		Pond 2/3	Water	P	3.7	1.9	363	468,038	6,315,488
		Pond 4	Water	FGD	0.6	0.8	363	468,747	6,318,047
		Pond 5	Water	CT	2.0	1.4	332	467,089	6,317,789
Baseline	Syncrude	Mildred Lake Settling Basin	Water	P & S	11.7	3.4	349	460,470	6,323,660
		West Mine In-Pit Pond	Water	MFT	6.0	2.4	291	461,460	6,317,380
		East Mine In-Pit Pond	Water	MFT	7.7	2.8	291	464,150	6,317,250
		South West Sand Storage Pond	Water	P	7.0	2.6	380	452,780	6,315,080
		Mildred Lake Settling Basin Beach	Dry	P	18.3	4.3	352	459,340	6,323,310
		South West Sand Storage Area	Dry	P	16.0	4.0	382	452,650	6,314,390
	Suncor	Pond 1	Water	MFT	1.3	1.2	322	471,422	6,315,572
		Pond 1A	Water	R	0.6	0.8	312	470,562	6,315,512
		Pond 2/3	Water	P & S	3.7	1.9	363	468,038	6,315,488
		Pond 4	Water	FGD	0.6	0.8	363	468,747	6,318,047
		Pond 5	Water	CT	2.0	1.4	332	467,089	6,317,789
		Pond 6	Water	CT	3.2	1.8	302	466,100	6,319,700
	Syncrude Aurora	North Mine Settling Basin	Water	P	2.5	1.6	345	472,990	6,350,590
CEA	Syncrude	Mildred Lake Settling Basin	Water	P & S	11.5	3.4	349	460,470	6,323,660
		West Mine In-Pit Pond	Water	MFT	6.5	2.5	291	461,460	6,317,380
		East Mine In-Pit Pond	Water	MFT	10.2	2.8	291	464,150	6,317,250
		South West Sand Storage Pond	Water	P	23.0	4.8	382	452,650	6,314,390
		Mildred Lake Settling Basin Beach	Dry	P	18.5	4.3	352	459,340	6,323,310
		South West Sand Storage Area	Dry	P	23.0	4.8	382	452,650	6,314,390
	Suncor	Pond 1	Water	CT	1.3	1.2	322	471,422	6,315,572
		Pond 1A	Water	R	0.6	0.8	312	470,562	6,315,512
		Pond 2/3	Water	P & S	3.7	1.9	363	468,038	6,315,488
		Pond 4	Water	FGD	0.6	0.8	363	468,747	6,318,047
		Pond 5	Water	CT	2.0	1.4	332	467,089	6,317,789
		Pond 6	Water	CT	3.2	1.8	302	466,100	6,319,700
		Pond 7	Water	CT	4.3	2.1	335	474,258	6,314,758
		Pond 8a	Water	MFT	1.5	1.2	365	475,135	6,310,735
		Pond 8b	Water	MFT	1.5	1.2	365	475,135	6,310,235
		Pond 9	Water	CT	8.2	2.9	350	476,070	6,311,820
		Pond 10	Water	CT	8.4	2.9	360	479,005	6,311,305
		Pond 11	Water	CT	0.9	0.9	355	480,929	6,309,229
	Syncrude Aurora	North Mine Settling Basin	Water	P	3.5	1.9	345	472,990	6,350,590
		South Mine Settling Basin	Water	P	3.5	1.9	385	486,630	6,338,430
	Shell	Muskeg River Mine Pond	Water	P & S	6.8	2.6	360	464,930	6,341,680
		Lease 13 East Pond	Water	P & S	6.8	2.6	360	477,430	6,340,710
	Mobil	Kearl Lake Pond	Water	P & S	3.5	1.9	360	478,800	6,351,100

P = Effluent from primary extraction (Sand, water and trace amounts of bitumen).
S = Effluent from secondary extraction (Water, fines and diluent).
R = Plant recycle water.
MFT = Mature fine tails transferred from another pond.
FGD = Gypsum/FGD recycle pond water.
CT = CT Pond/Deposits.

3.7.4 Tailings Emission Estimates

The estimated emission flux values from Tables 3-66 through Table 3-68 were applied to the tailings surfaces identified in Tables 3-69 on the basis of surface area. The Syncrude emission factors were applied to Syncrude and non-Suncor facilities. The Suncor emission factors were only applied to the Suncor facilities. The emission estimates are provided in the following tables:

- Table 3-70 Existing Syncrude and Suncor tailings areas (1997).
- Table 3-71 Baseline Syncrude, Suncor and Aurora North tailings areas
- Table 3-72 CEA tailings areas.

Fugitive VOC emissions are predicted to increase from 100 t/d (Existing) to 243 t/d (CEA). Fugitive RS emission are predicted to increase from 1.2 t/d (Existing) to 2.9 t/d (CEA). These fugitive emission estimates are based on estimated observed emission rates on warm summer days. Short-term lower emission rates would be expected during cooler periods. Lower yet emission rates would be expected when the water surfaces are partially covered with ice during the winter. Estimates of fugitive emissions from heterogeneous surfaces are considered to have more uncertainty than those associated with point sources.

Table 3-70 Fugitive VOC and RS Emissions From the Existing Tailings Ponds

	Syncrude					Suncor					Total
Surface Type	**water**	**water**	**water**	**dry**	**dry**	**water**	**water**	**water**	**water**	**water**	
Impoundment	**MLSB**	**W In-Pit**	**SWSS**	**MLSB**	**SWSS**	**Pond 1**	**Pond 1A**	**Pond 2/3**	**Pond 4**	**Pond 5**	
Area (km^2)	12.9	4.8	2.9	8.4	7.1	1.3	0.6	3.7	0.6	2.0	44.5
General, (kg/d)											
Total hydrocarbon (C1+)	78,242	8,507	1,076	202	2,373	97,284	360	91	95	296	188,527
Methane (C1)	64,096	8,174	134	68	49	14,329	360	91	95	296	87,692
C2+	14,146	333	942	134	2,324	82,955	0	0	0	0	100,834
Human Health, (kg/d)											
C2 to C4 alkanes and alkenes	0	0	0	0	0	22	0	0	0	0	22
C5 to C8 Alkanes and alkenes	947	23	4	0	0	62,483	0	0	0	0	63,457
C9 to C12 alkanes and alkenes [a]	12,371	289	854	123	2,313	20,450	0	0	0	0	36,399
Cyclohexane	22	0	0	0	0	1,256	0	0	0	0	1,279
Benzene	51	1	0	0	0	178	0	0	0	0	231
C6 to C8 non-benzene aromatics	494	13	5	3	11	6,774	0	0	0	0	7,300
Total aldehydes	0	0	0	0	0	0	0	0	0	0	0
Total ketones	0	0	0	0	0	0	0	0	0	0	0
Total RS	68	17	21	28	63	1,012	7.2	0.0	0.5	1.7	1,218
Photochemical, (kg/d)											
Methane (C1)	64,096	8,174	134	68	49	14,329	360	91	95	296	87,692
Ethane (C2)	0	0	0	0	0	0	0	0	0	0	0
C3 to C4 alkanes	0	0	0	0	0	22	0	0	0	0	0
C5 to C8 alkanes [b]	12,634	307	815	118	2,285	43,412	0	0	0	0	16,159
C9 to C12 alkanes	507	4	43	4	28	11,419	0	0	0	0	586
C13+ alkanes	39	1	7	2	0	1,917	0	0	0	0	49
Ethylene (C2)	0	0	0	0	0	0	0	0	0	0	0
C3 to C4 alkenes	0	0	0	0	0	0	0	0	0	0	0
C5 to C8 alkenes	148	0	0	0	0	14,516	0	0	0	0	149
C9 to C12 alkenes	29	0	0	0	0	5,166	0	0	0	0	29
C13+ alkenes	2	0	0	0	0	0	0	0	0	0	2
benzene (C6)	51	1	0	0	0	178	0	0	0	0	53
C6 to C8 non-benzene aromatics	494	13	5	3	11	8,231	0	0	0	0	525
C9 to C12 aromatics	242	6	71	7	1	1,948	0	0	0	0	326

(a) Unknown is placed in C9 to C12 category for health assessment.
(b) Unknown is placed in C5 to C8 category for photochemical assessment.

Table 3-71 Fugitive VOC and RS Emissions From the Baseline Tailings Ponds

	Syncrude						Suncor						Aurora N	Total
Surface Type	water	water	water	water	dry	dry	water	water	water	water	water	water	water	
Impoundment	MLSB	W In-Pit	E In-Pit	SWSS	MLSB	SWSS	Pond 1	Pond 1A	Pond 2/3	Pond 4	Pond 5	Pond 6	pond	
Area (km^2)	11.7	6	7.7	7	18.3	16	1.3	0.6	3.7	0.6	2.0	3.2	2.5	78.3
General, (kg/d)														
Total hydrocarbon (C1+)	76,067	10,755	13,660	2,546	318	5,330	196	360	119,647	95	296	475	914	230,659
Methane (C1)	58,107	10,330	13,126	321	148	111	196	360	17,624	95	296	475	114	101,303
C2+	17,960	425	535	2,225	170	5,220	0	0	102,023	0	0	0	800	129,358
Human Health, (kg/d)														
C2 to C4 alkanes and alkenes	0	0	0	0	0	0	0	0	27	0	0	0	0	27
C5 to C8 Alkanes and alkenes	1,201	29	37	10	0	0	0	0	58,414	0	0	0	4	59,695
C9 to C12 alkanes and alkenes (a)	15,712	369	464	2,015	156	5,194	0	0	21,228	0	0	0	725	45,863
Cyclohexane	28	0	0	0	0	0	0	0	14,358	0	0	0	0	14,386
Benzene	65	1	2	1	0	0	0	0	0	0	0	0	0	69
C6 to C8 non-benzene aromatics	625	16	20	13	4	24	0	0	6,803	0	0	0	4	7,509
Total aldehydes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total ketones	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total RS	86	22	28	50	35	141	1.1	7.2	1,193.7	0.5	1.7	2.7	18	1,587
Photochemical, (kg/d)														
Methane (C1)	58,107	10,330	13,126	321	148	111	0	0	17,624	0	0	0	114	99,881
Ethane (C2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3 to C4 alkanes	0	0	0	0	0	0	0	0	27	0	0	0	0	27
C5 to C8 alkanes (b)	16,046	393	494	1,924	149	5,131	0	0	53,392	0	0	0	692	78,221
C9 to C12 alkanes	643	5	6	101	6	63	0	0	14,044	0	0	0	36	14,904
C13+ alkanes	49	1	1	18	2	0	0	0	2,358	0	0	0	6	2,435
Ethylene (C2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3 to C4 alkenes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C5 to C8 alkenes	188	1	1	0	0	0	0	0	17,853	0	0	0	0	18,043
C9 to C12 alkenes	36	0	0	0	1	0	0	0	6,354	0	0	0	0	6,391
C13+ alkenes	3	0	0	0	0	0	0	0	0	0	0	0	0	3
benzene (C6)	65	1	2	1	0	0	0	0	219	0	0	0	0	288
C6 to C8 non-benzene aromatics	625	16	20	13	4	24	0	0	10,123	0	0	0	4	10,829
C9 to C12 aromatics	304	8	10	169	8	2	0	0	2,396	0	0	0	60	2,957

Table 3-72a Fugitive VOC and RS Emissions From the CEA Tailings Ponds

	Syncrude						Aurora		Shell		Mobil
Surface Type	**water**	**water**	**water**	**water**	**dry**	**dry**	**water**	**water**	**water**	**water**	**water**
Impoundment	**MLSB**	**W In-Pit**	**E In-Pit**	**SWSS**	**MLSB**	**SWSS**	**pond**	**pond**	**pond**	**pond**	**pond**
Area (km^2)	**11.5**	**6.5**	**10.2**	**2**	**18.5**	**23**	**3.5**	**3.5**	**6.8**	**6.8**	**3.5**
General, (kg/d)											
Total hydrocarbon (C1+)	69,584	11,531	18,095	731	446	7,662	1,279	1,279	41,145	41,145	21,178
Methane (C1)	57,003	11,080	17,387	91	150	159	160	160	33,706	33,706	17,349
C2+	12,581	451	708	640	296	7,504	1,119	1,119	7,439	7,439	3,829
Human Health, (kg/d)											
C2 to C4 alkanes and alkenes	0	0	0	0	0	0	0	0	0	0	0
C5 to C8 Alkanes and alkenes	842	31	49	3	0	0	5	5	498	498	256
C9 to C12 alkanes and alkenes (a)	11,002	392	615	580	271	7,467	1,015	1,015	6,506	6,506	3,348
Cyclohexane	19	0	1	0	0	0	0	0	12	12	6
Benzene	46	2	2	0	0	0	1	1	27	27	14
C6 to C8 non-benzene aromatics	439	17	27	4	6	34	6	6	260	260	134
Total aldehydes	0	0	0	0	0	0	0	0	0	0	0
Total ketones	0	0	0	0	0	0	0	0	0	0	0
Total RS	60	24	37	14	61	203	25	25	36	36	18
Photochemical, (kg/d)											
Methane (C1)	57,003	11,080	17,387	91	150	159	160	160	33,706	33,706	17,349
Ethane (C2)	0	0	0	0	0	0	0	0	0	0	0
C3 to C4 alkanes	0	0	0	0	0	0	0	0	0	0	0
C5 to C8 alkanes (b)	11,236	417	654	554	260	7,376	969	969	6,644	6,644	3,420
C9 to C12 alkanes	451	5	8	29	10	91	51	51	266	266	137
C13+ alkanes	35	1	2	5	4	0	9	9	20	20	11
Ethylene (C2)	0	0	0	0	0	0	0	0	0	0	0
C3 to C4 alkenes	0	0	0	0	0	0	0	0	0	0	0
C5 to C8 alkenes	132	1	1	0	0	0	0	0	78	78	40
C9 to C12 alkenes	25	0	0	0	1	0	0	0	15	15	8
C13+ alkenes	2	0	0	0	0	0	0	0	1	1	1
benzene (C6)	46	2	2	0	0	0	1	1	27	27	14
C6 to C8 non-benzene aromatics	439	17	27	4	6	34	6	6	260	260	134
C9 to C12 aromatics	215	9	13	48	15	3	84	84	127	127	65

Table 3-72b Fugitive VOC and RS Emissions From the CEA Tailings Ponds

Operator	Suncor												Total
Surface Type	water	water	water	water	water	water	water	water	water	water	water	water	
Impoundment	Pond 1	Pond1A	Pond2/3	Pond4	Pond5	Pond6	Pond7	Pond8a	Pond8b	Pond9	Pond10	Pond11	
Area (km^2)	1.3	0.6	3.7	0.6	2.0	3.2	4.3	1.5	1.5	8.2	8.4	8.9	83.3
General, (kg/d)													
Total hydrocarbon (C1+)	196	360	234,821	95	296	475	636	222	222	1,199	1,223	1,301	455,122
Methane (C1)	196	360	34,588	95	296	475	636	222	222	1,199	1,223	1,301	211,763
C2+	0	0	200,233	0	0	0	0	0	0	0	0	0	243,358
Human Health, (kg/d)													
C2 to C4 alkanes and alkenes	0	0	53	0	0	0	0	0	0	0	0	0	54
C5 to C8 Alkanes and alkenes	0	0	114,645	0	0	0	0	0	0	0	0	0	116,832
C9 to C12 alkanes and alkenes (a)	0	0	41,662	0	0	0	0	0	0	0	0	0	80,377
Cyclohexane	0	0	28,178	0	0	0	0	0	0	0	0	0	28,228
Benzene	0	0	0	0	0	0	0	0	0	0	0	0	120
C6 to C8 non-benzene aromatics	0	0	13,351	0	0	0	0	0	0	0	0	0	14,544
Total aldehydes	0	0	0	0	0	0	0	0	0	0	0	0	0
Total ketones	0	0	0	0	0	0	0	0	0	0	0	0	0
Total RS	1.1	7.2	2,342.8	0.5	1.7	2.7	3.6	1.3	1.3	6.8	6.9	7.4	2,922
Photochemical, (kg/d)													
Methane (C1)	196	360	34,588	95	296	475	636	222	222	1,199	1,223	1,301	211,763
Ethane (C2)	0	0	0	0	0	0	0	0	0	0	0	0	0
C3 to C4 alkanes	0	0	53	0	0	0	0	0	0	0	0	0	54
C5 to C8 alkanes (b)	0	0	104,788	0	0	0	0	0	0	0	0	0	143,930
C9 to C12 alkanes	0	0	27,563	0	0	0	0	0	0	0	0	0	28,928
C13+ alkanes	0	0	4,627	0	0	0	0	0	0	0	0	0	4,743
Ethylene (C2)	0	0	0	0	0	0	0	0	0	0	0	0	0
C3 to C4 alkenes	0	0	0	0	0	0	0	0	0	0	0	0	0
C5 to C8 alkenes	0	0	35,038	0	0	0	0	0	0	0	0	0	35,368
C9 to C12 alkenes	0	0	12,470	0	0	0	0	0	0	0	0	0	12,535
C13+ alkenes	0	0	0	0	0	0	0	0	0	0	0	0	5
benzene (C6)	0	0	430	0	0	0	0	0	0	0	0	0	550
C6 to C8 non-benzene aromatics	0	0	19,867	0	0	0	0	0	0	0	0	0	21,061
C9 to C12 aromatics	0	0	4,703	0	0	0	0	0	0	0	0	0	5,492

4 AMBIENT AIR QUALITY

4.1 INTRODUCTION

4.1.1 Objectives

The management of an airshed that is shared by multiple users requires an understanding of the air quality changes associated with the operation of emission sources. The objectives of this section are to:

- Identify current ambient air quality monitoring programs in the Athabasca oil sands airshed;
- Summarize the current ambient air quality observations; and
- Identify spatial and temporal trends and correlation with respect to meteorology.

The end-product of this section is an understanding of the current air quality observed in the Athabasca oil sands airshed. This information can be used as a basis for further air quality assessments.

4.1.2 Approach

Suncor, Syncrude and Alberta Environmental Protection maintain ambient air quality monitoring programs in the oil sands region. These monitoring programs are comprised of both continuous and passive monitoring. The selected approach was based on reviewing the data collected by these programs for the 5½ year period starting January 1, 1990 and finishing June 30, 1995. These data are supplemented by additional programs that were of limited duration. This section concludes by providing a summary and providing recommendations.

4.1.3 Definition of Terms

Given the technical nature of this subject, it is useful to identify terminology used to facilitate a common understanding. Table 4-1 provides definitions of technical terms relating to ambient air quality that are used in the report.

Table 4-1 Definition of Ambient Air Quality Terms

Term	Definition
Air Quality	A description of the type and amount of trace constituents in the ambient air that can be described as a contaminants. A contaminant (or pollutant) has the connotation of being derived from human activities.
Ambient Air	Ambient air refers to that portion of the atmosphere that can be described as the breathing zone for the inhabitants of the earth's surface. Contaminants contained in the ambient air are of concern because of their potential effects on human health, vegetation and materials. Ambient air does not usually include air quality in the workplace or in residences.
Ambient Air Quality Guidelines	An ambient air quality guideline is a numerical concentration intended to prevent deterioration of air quality. A guideline is generally based on the lowest-observable-effect on a sensitive receptor.
Airshed	A geographical region that shares one or more of the following: similar terrain, similar meteorology, similar sources, similar receptors. For the purposes of this report, the Athabasca oil sands region airshed was arbitrarily selected as the area located within 60 km of the Suncor and Syncrude oil sands operations.
Concentration	The amount of a given component of the atmosphere is usually expressed as a concentration on a volume basis as percent (%), parts per million (ppm) or parts per billion (ppb) or on a mass basis as micrograms per cubic metre of air ($\mu g/m^3$) or milligrams per cubic metre of air (mg/m^3).
Receptor	A biological or physical entity that is exposed to air emissions. Vegetation and humans are examples of biological receptors. Soils and water are examples of physical receptors.
Continuous Monitoring	A continuous monitoring station is comprised of commercially available analyzers enclosed in a heated/air conditioned shelter. An ambient air stream is drawn past a fast response detector whose electrical response is proportional to the concentration of a selected contaminant in the gas stream. The continuous concentration information is summarized as one-hour averages.
Passive Monitoring	A passive monitoring station is comprised of a reactive surface that is exposed to the ambient air for a nominal 30 day period. At the conclusion of the exposure period, the reactive material is analyzed to provide a measure of exposure.
Deposition	The contaminant removal rate from the atmosphere and precipitation chemistry relate to the long-term deposition of contaminants and potential acidifying effects (that is "acid rain") on surface water and soil systems. The sum of dry and wet deposition provides the cumulative loading to an ecosystem.
Dry Deposition	Contaminants can be removed from the atmosphere by direct contact with surface features (such as vegetation). This process is referred to as dry deposition and is usually expressed as a flux in units of kg/ha/y (kilograms of contaminant per hectare of land surface area per year (annum)).
Wet Deposition	Contaminants can also be removed from the atmosphere by precipitation. The precipitation chemistry is defined by the concentrations of various chemical species in the precipitation. These chemical species can result from naturally occurring particulate and gaseous compounds as well as from pollutant emissions. Wet deposition is expressed in the same units as dry deposition.
Precipitation Chemistry	Trace gases and particulates in the atmosphere can be dissolved in water droplets that ultimately form precipitation. The composition of the precipitation will be comprised of positively charged compounds (anions) and negatively charged compounds (cations).

4.2 OVERVIEW OF MONITORING PROGRAMS

Ambient air quality monitoring in the region is comprised of continuous monitoring, passive monitoring, regional precipitation monitoring and specialized studies.

4.2.1 Continuous Monitoring

A considerable amount of monitoring activity has been undertaken in the oil sands area. Some of these monitoring sites are shown in Figure 4-1 and the programs include the following:

- Suncor has conducted continuous ambient air quality monitoring in the vicinity of their plant since 1975. They currently have five stations where they measure SO_2 (all five stations), H_2S (all five stations) and total hydrocarbons (THC) (four stations).
- Syncrude has conducted continuous ambient air quality monitoring in the vicinity of their plant since 1979. They currently have five stations where they measure SO_2 (all five stations), H_2S (all five stations), NO_x (one station) and THC (two stations).
- Alberta Environmental Protection has monitored ambient air quality at stations in Fort McMurray and Fort McKay since 1977 and 1983, respectively. Both stations measure H_2S, SO_2 and THC. The Fort McMurray station also measures NO_x, O_3 and CO.
- AOSERP established two ambient air quality monitoring stations at Birch Mountain and Bitumount in 1977. The Birch Mountain station measured SO_2 and O_3 and the Bitumount station measured O_3, SO_2, NO_2, CO, HC and H_2S. Both stations were shut down in 1980 (Strosher 1981).
- Ambient monitoring at the SandAlta lease was undertaken by Gulf Canada Resources Ltd. and Alberta Environment. The monitoring undertaken by Gulf was from the period April 1981 to February 1982. The Alberta Environment monitoring period started May 1983 and continued until March 1986 (Morrow and Murray 1982, Murray 1984 and Hansen 1985, 1986).
- OSLO established an air quality monitoring program in March 1988 to collect air quality data at their proposed oil sands site. The program was completed in December 1989 (Concord Environmental Corporation 1990).
- A background monitoring station was established at the SOLV-EX Lease 5 location in September 1996.

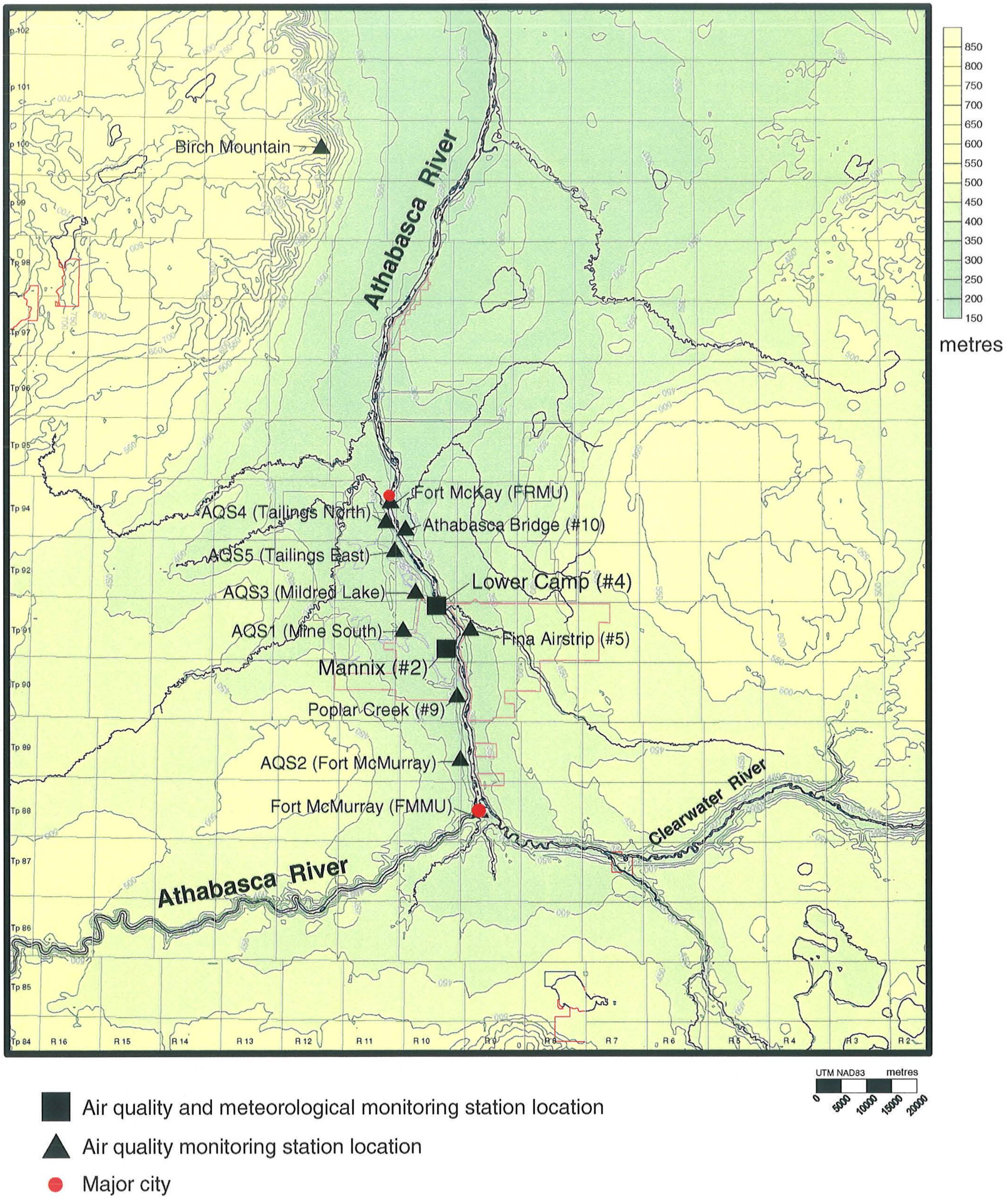


Figure 4-1 Locations of Continuous Air Quality Monitoring Stations

This assessment focuses on current programs (i.e., Suncor, Syncrude and Alberta Environmental Protection). Table 4-2 summarizes the periods that the Suncor, Syncrude and Alberta Environmental Protection monitoring stations have been in operation. The Suncor stations are identified by both a site name as well as a numerical designation, whereas the Syncrude stations are identified by a numerical designation. Both operators have relocated stations in the past 5 years as part of their network review with respect to current needs.

Table 4-3 summarizes the parameters that are currently being monitored at each station. The core parameters at each station include the contaminants SO_2 and H_2S and the meteorological parameters wind speed and wind direction. Selected stations also monitor NO_x (NO and NO_2), O_3, THC and CO.

Table 4-4 summarizes the locations of the current monitoring stations with respect to the powerhouse stack at Suncor and the main stack at Syncrude. Due to the valley location of the Suncor facility, many of the monitoring sites are located at higher elevations than those associated with the Suncor plant site.

Table 4-2 Continuous Ambient Air Quality Monitoring Programs Operated by Suncor, Syncrude and Alberta Environmental Protection

Operation Station / Site			Period
Suncor			
Supertest Hill[a] (#1)			1975 to July 1990
Mannix (#2)			1975 to date
Ruth Lake[b] (#3)			1975 to October 1990
Lower Camp (#4)			1975 to date
Fina Airstrip (#5)			1975 to date
Poplar Creek[a] (#9)			July 1990 to date
Athabasca Bridge[b] (#10)			October 1991 to date
Syncrude			
AQS1	•	South of Mine	1979 to July 1993
	•	Moved 800 m West	July 1993 to date
AQS2	•	Northwest of Tailings Pond	1979 to November 1990
	•	Moved to Fort McMurray	November 1990 to date
AQS3	•	Mildred Lake Airstrip	1979 to date
AQS4	•	North of Tailings Pond	1979 to date
AQS5	•	East of Tailings Pond	1979 to date
Alberta Environmental Protection			
FMMU		Fort McMurray	1977 to date
FRMU		Fort McKay	1983 to date

[a] The Supertest trailer was moved to Poplar Creek in July 1990.

[b] The Ruth Lake trailer was moved to Athabasca Bridge in October 1991.

Table 4-3 Summary of Parameters Currently Monitored on a Continuous Basis

Operation	Station	U	θ	SO_2	H_2S	NO_x	THC	O_3	CO
Suncor	Mannix (#2)	✓	✓	✓	✓	×	✓	×	×
	Lower Camp (#4)	✓	✓	✓	✓	×	✓	×	×
	Fina Airstrip (#5)	✓	✓	✓	✓	×	×	×	×
	Poplar Creek (#9)	✓	✓	✓	✓	×	✓	×	×
	Athabasca Bridge (#10)	✓	✓	✓	✓	×	✓	×	×
Syncrude	AQS1 (Mine South)	✓	✓	✓	✓	×	×	×	×
	AQS2 (Fort McMurray)	✓	✓	✓	✓	×	✓	×	×
	AQS3 (Mildred Lake)	✓	✓	✓	✓	×	×	×	×
	AQS4 (Tailings North)	✓	✓	✓	✓	✓	✓	×	×
	AQS5 (Tailings East)	✓	✓	✓	✓	×	×	×	×
Alberta Environmental Protection	FMMU (Fort McMurray)	✓	✓	✓	✓	✓	✓	✓	✓
	FRMU (Fort McKay)	✓	✓	✓	✓	×	✓	×	×

✓ = currently being monitored
× = not being monitored
U = wind speed
θ = wind direction
SO_2 = sulphur dioxide
H_2S = hydrogen sulphide
NO_x = oxides of nitrogen
THC = total hydrocarbons
O_3 = ozone
CO = carbon monoxide

Table 4-4 Location of the Ambient Air Quality Monitoring Stations With Respect to the Syncrude Main Stack and the Suncor Stack

	From Suncor				From Syncrude			
Station	Distance [a] (km)	Elevation Difference (m)	Direction [a]	Wind[b] (degrees)	Distance [a] (km)	Elevation Difference (m)	Direction [a]	Wind[b] (degrees)
Suncor								
Mannix	11.5	31	SE	314	3.8	76	S	7
Lower Camp	6.9	-60	E	278	3.8	-15	NNW	152
Fina	13.1	28	ESE	292	3.5	73	E	280
Poplar Creek	19.4	-55	SE	326	12	-10	S	353
Athabasca Bridge	11.3	-62	S	188	17	-17	SE	158
Syncrude								
AQS1 (Mine South)	5.5	2	SE	345	7.5	47	W	83
AQS2 (Fort McMurray)	29.0	35	SSE	335	22.0	80	S	355
AQS3 (Mildred Lake)	3.5	15	ENE	288	7.5	60	NW	135
AQS4 (Tailings North)	12.4	-39	N	175	19.3	6	NNW	150
AQS5 (Tailings East)	7.0	-30	N	179	14.3	15	NW	142
Alberta Environmental Protection								
Fort McMurray	42.9	-50	SSE	336	35.9	-5	SSE	346
Fort McKay	16.0	-60	N	178	22.3	-15	NNW	156

[a] Distances and directions with respect to powerhouse stack at Suncor and main stack at Syncrude.

[b] Wind direction required to advect plume from stack to the station.

4.2.2 Passive Monitoring

Suncor, Syncrude and AEP all maintain passive monitoring sites in the region for the purposes of measuring total sulphation and hydrogen sulphide. In 1991, Syncrude applied for and received permission to reduce their number of static monitoring stations from 40 to 30. Table 4-5 outlines the number of passive stations in the area in 1994.

Table 4-5 Summary of the Passive Monitoring Network in the Oil Sands Region

Operator:	Suncor	Syncrude	AEP
Number of Stations	40	30	6
Total Sulphation	Yes	Yes	Yes
H_2S	Yes	Yes	Yes

Although these data can be used to characterize pollution patterns, the results are not readily comparable to any of the current guidelines. For this reason, the results of the passive monitoring network have not been referenced in this document.

4.2.3 Precipitation Chemistry

Precipitation quality is measured at several locations in northern Alberta and Saskatchewan. Table 4-6 identifies these stations and their associated locations with respect to the Athabasca oil sands region of Alberta.

Table 4-6 Location of Monitoring Station Where Precipitation Chemistry Data Were Collected

Location	Distance (km)	Direction	Degrees/Sector
Fort McMurray	36	166°	SSE
Fort Chipewyan	190	5°	N
Fort Vermilion	310	302°	WNW
High Prairie	360	242°	SW
Beaver Lodge	530	250°	SW
Cold Lake	300	162°	SSE
Vegreville	395	186°	S
Cree Lake	285	74°	ENE

All the stations except for Cree Lake are located in Alberta and operated by Alberta Environmental Protection. The Cree Lake station is located in Saskatchewan and is operated by Environment Canada.

Precipitation and snow pack samples were collected in the oil sands area during the period 1976 to 1984. These data have been critically reviewed by Davis et al. (1985). The efforts associated with this precipitation and snow pack sampling have been discontinued. The only sites with ongoing sampling in the region are the stations operated by Alberta Environmental Protection.

4.2.4 Specialized Studies

In addition to routine ambient air quality studies, a number of short-term specialized studies have been undertaken to characterize the air quality in the region. These include:

- A second ambient air quality station in Fort McMurray. This station was operated by AEP for the period October 1, 1991 to June 30, 1992;
- Measurements of ambient hydrocarbon (HC) and reduced sulphur (RS) species compounds in the vicinity of the Suncor and Syncrude plants;
- Odour assessments associated with the operation of the Suncor plant;
- Qualitative odour assessments that have become a part of the operational procedures by RAQCC to identify odour events, track the sources and ensure follow-up corrective actions have taken place; and
- Measurement of deposition through the use of throughfall and stemflow measurements of precipitation in the period 1975 to 1978.

While these specialized studies do not have the same continuity as the ongoing monitoring programs, they do provide period "snapshots" that enhance the understanding of regional air quality.

4.3 AIR QUALITY GUIDELINES

4.4 AIR QUALITY GUIDELINES AND OBJECTIVES

The impact of air emissions introduced into the atmosphere by industrial activities can be broad. The emissions can have direct and indirect effects on humans, other animals, vegetation, soil, water and visibility. For this reason, environmental regulatory agencies have established maximum ambient air concentration limits.

4.4.1 Ambient Concentration Criteria

Table 4-7 presents the Alberta provincial guidelines and the Canadian federal government air quality objectives for regulated compounds. The compounds include: sulphur dioxide (SO_2), hydrogen sulphide (H_2S), nitrogen dioxide (NO_2), carbon monoxide (CO), oxidants expressed as ozone (O_3) and suspended particulates. These guidelines and objectives refer to averaging periods ranging from one hour to one year. In addition, the federal government has established three levels of objectives (Environment Canada 1981). The levels are described below:

- The maximum desirable level defines the long-term goal for air quality and provides a basis for an anti-degradation policy for the unpolluted parts of the country and for the continuing development of control technology.
- 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 maximum tolerable level denotes a concentration of an air contaminant that requires abatement (mitigation) without delay to avoid further deterioration to an air quality that endangers the prevailing Canadian lifestyle or ultimately, to an air quality that poses a substantial risk to public health.

In Alberta, the maximum concentrations in ambient air are currently specified as guidelines for SO_2, H_2S, NO_2, CO, oxidants expressed as O_3 (ozone) and total suspended particulate matter (Government of Alberta 1993).

Table 4-7 Federal, Alberta and Other Government Ambient Air Quality Guidelines and Objectives

			Federal Objectives(a)		
	Alberta Guidelines		Desirable	Acceptable	Tolerable
SO_2 (µg/m^3)					
Annual	30	(0.01 ppm)	30	60	--(b)
24-Hour	150	(0.06 ppm)	150	300	800
1-Hour	450	(0.17 ppm)	450	900	--
H_2S (µg/m^3)					
24-Hour	4	(0.003 ppm)	--	5(c)	--
1-Hour	14	(0.01 ppm)	1(c)	15(c)	--
NO_2 (µg/m^3)					
Annual	60	(0.03 ppm)	60	100	--
24-Hour	200	(0.11 ppm)	--	200	300
1-Hour	400	(0.21 ppm)	--	400	1000
CO (mg/m^3)					
8-Hour	6	(5 ppm)	6	15	20
1-Hour	15	(13 ppm)	15	35	--
Oxidants (µg/m^3)(d)					
Annual	--	--	--	30	--
24-Hour	50	(0.025 ppm)	30	50	--
1-Hour	160	(0.082 ppm)	100	160	300
Suspended Particulates (µg/m^3)					
Annual(e)	60	--	60	70	--
24-Hour	100	--	--	120	400
PM_{10}(f)					
24-Hour(g) (h)	--	--	--	--	--
Annual(h)	--	--	--	120	400
$PM_{2.5}$(i)					
24-Hour(h)	(i)	--	--	--	--
Annual(h)	(i)	--	--	--	--

(a) At a temperature of 25°C and pressure of 101.3 kPa.
(b) '--' = not applicable.
(c) Proposed.
(d) As ozone (O_3).
(e) As a geometric mean.
(f) PM_{10} - particulate matter emissions with particle diameter less than 10 µm.
(g) Based on BC and Ontario 24 hour PM_{10} - 50 µg/m^3.
(h) Based on U.S. EPA 24 hour PM_{10} - 150 µg/m^3.
(i) $PM_{2.5}$ - particulate matter emissions with particle diameter less than 2.5 µm. Based on U.S. EPA 24 hour $PM_{2.5}$ - 65 µg/m^3 Annual $PM_{2.5}$ - 15 µg/m^3.

With the exception of oxidants and the proposed federal one-hour average objective for H_2S, the Alberta Environment guidelines are equal to the most stringent of the federal objectives. The Alberta guidelines for oxidants are less strict when compared with the Federal Air Quality objectives since rural ozone concentrations in Alberta have been observed to exceed the Federal Desirable Level (Angle and Sandhu 1986, 1989).

The primary focus on Particulate Matter (PM) emissions is the inhalable fraction, with diameters less than 10 μm (referred to as PM_{10}) and the respirable fraction, with diameters less than 2.5 μm (referred to as $PM_{2.5}$), not Total Suspended Particulate (TSP) matter. Neither Alberta nor the federal government have adopted PM_{10} or $PM_{2.5}$ guidelines; the values provided in Table 4-7 reflect those adopted by B.C., Ontario and the U.S. EPA.

The Federal-Provincial Advisory Committee on Air Quality (FPACAQ) periodically conducts critical reviews of the existing federal air quality objectives to ensure that they are consistent with the information given in current literature. In 1987, the committee published critical reviews of the current federal objectives for sulphur dioxide (FPACAQ 1987a) and nitrogen dioxide (FPACAQ 1987b). In addition, the World Health Organization (WHO) conducted a critical literature review to recommend air quality standards which could be applied to the European community (WHO 1987). Their review focussed on the most recent scientific knowledge and the effects on human health and vegetation. The results of these reviews are summarized below.

4.4.1.1 Sulphur Dioxide (SO_2)

The FPACAQ reviewers confirmed that adequate protection against acute and chronic injury to native vegetation with the existing *acceptable* SO_2 objective levels: 1-hour average of 900 μg/m^3 (0.34 ppm), 24-hour average of 300 μg/m^3 (0.12 ppm), and annual average of 60 μg/m^3 (0.02 ppm). From their literature review, a 1-hour exposure of 1820 μg/m^3 (0.70 ppm) has been identified as the lower threshold for acute damage to forest trees under conditions which are especially conducive to plant injury (after Dreisinger and McGovern 1970 and Dreisinger 1965). Chronic injury to trees is expected to appear when annual concentrations fall in the 44 μg/m^3 (0.017 ppm) to 21 μg/m^3 (0.008 ppm) range (Linzon 1971).

By comparison, the recommended WHO guidelines are more restrictive than the federal *acceptable* objectives, the federal 24-hour *desirable* objective and the Alberta 24-hour guideline. The WHO guidelines are: 24-hour average of 103 μg/m^3 (0.038 ppm), and annual average of 30 μg/m^3 (0.01 ppm). The Alberta annual guideline and annual federal desirable objective are equivalent to the WHO recommendations. The WHO number are based on recommendations by the International Union of Forest Research Organizations (IUFRO).

The WHO identified the lowest-observed-effect level of a human health concern is 1,005 μg/m^3 (0.38 ppm) as a 10-minute average. The WHO recommended guideline for SO_2 is 503 μg/m^3 (0.19 ppm) as a 10-minute average, which provides a safety factor of two. The 503 μg/m^3 (0.19 ppm) value as a 10-minute average corresponds to a calculated value of 344 μg/m^3 (0.13 ppm) as a one-hour average. The FPACAQ reviewers, however, noted that healthy exercising individuals experience only minor transient effects when exposed to short term levels of less than 2,600 μg/m^3 (1 ppm). It was also noted that asthmatics, with sufficiently heavy exercise, could experience symptoms at levels as low as 1,059 μg/m^3 (0.4 ppm). This level was deemed inappropriate by FPACAQ for establishing guidelines, as it was based on an artificial exposure scenario. This explains the reasons for the differences between the one-hour standard proposed by WHO 344 μg/m^3 (0.13 ppm) and the current acceptable level proposed by the Federal and Provincial governments 450 μg/m^3 (0.17 ppm).

4.4.1.2 Hydrogen Sulphide (H_2S)

The lowest-adverse-effect level is 15 mg/m^3 (10,700 ppb), which is when eye irritation is caused. The recommended health guideline for H_2S is 150 μg/m^3 (107 ppb), with an averaging time of 24 hours. In order to avoid odour complaints, however, the WHO recommended a guideline level of 7 μg/m^3 (5 ppb) as a 30-minute average. This latter value is more stringent than the Alberta one-hour guideline of 14 μg/m^3 (10 ppb).

4.4.1.3 Nitrogen Dioxide (NO_2)

The WHO recommends NO_2 guidelines of 400 μg/m^3 (0.21 ppm) and of 150 μg/m^3 (0.08 ppm) as one-hour and 24-hour averages, respectively. The one-hour value is based on the lowest-observed-effect level in asthmatics of 550 μg/m^3 (0.29 ppm). The 24-hour value was selected to create a margin of protection against chronic effects. The WHO 24-hour average guideline 150 μg/m^3 (0.08 ppm) is more stringent than that proposed by Alberta 200 μg/m^3 (0.11 ppm).

The FPACAQ identified temporary effects were possible for short term exposures in the range of 200 to 400 μg/m^3. Epidemiological data were noted which confirmed that effects have been observed for annual exposures of 100 μg/m^3 (0.05 ppm). Insufficient evidence was found regarding 24-hour exposures, therefore, FPACAQ recommended eliminating the 24-hour federal objective.

4.4.1.4 Carbon Monoxide (CO)

The WHO recommendations for carbon monoxide (CO) are designed to protect non-smokers and are as follows:

- 100 mg/m^3 (87 ppm) as a 15-minute average;
- 60 mg/m^3 (52 ppm) as a 30-minute average;
- 30 mg/m^3 (26 ppm) as a 1-hour average; and
- 10 mg/m^3 (8.7 ppm) as an 8-hour average.

The Alberta values of 15 mg/m^3 (13 ppm) as a 1-hour average and 6 mg/m^3 (5 ppm) as an 8-hour average are more stringent than the WHO recommendations.

4.4.1.5 Particulates

The effect of particulates on human health depends on the size range of the particulates:

- Total suspended particulates (TSP) includes all particulates that are suspended in the ambient air. These particulates can be as large as 30 µm in diameter. Particulates larger than 30 µm that are introduced into the air settle out quickly due to gravitational effects;
- Particulates smaller than 10 µm in diameter (PM_{10}) are readily inhaled into the upper respiratory tract; and
- Particulates smaller than 2.5 µm in diameter ($PM_{2.5}$) can be inhaled deeply into pulmonary tissue.

In recognition of the greater sensitivity to smaller particles, air quality guidelines for particulates are being expressed in terms of PM_{10}. While Alberta has not adopted PM_{10} guidelines, B.C. has an interim PM_{10} guideline of 50 µg/m^3 which is based on the 24-hour objective adopted by California. The California objective recognizes that the U.S. National Primary Objective of 150 µg/m^3 may not be sufficient to protect human health. Most of the recent scientific literature relating to PM_{10} effects on human health was published after the WHO report.

4.4.1.6 Ozone (O_3)

Ozone is not directly emitted from industrial sources. Ozone is a strong oxidizing agent and can occur in the troposphere due to chemical reactions with oxides of nitrogen and hydrocarbons. The WHO recommended guidelines to prevent adverse human health effects and are as follows:

- 146 to 195 µg/m^3 (75 to 100 ppb) as a one-hour average; and
- 98 to 117 µg/m^3 (50 to 60 ppb) as an 8-hour average.

The recommended guidelines to prevent adverse effects on vegetation are as follows:

- 195 $\mu g/m^3$ (100 ppb) as a one-hour average;
- 64 $\mu g/m^3$ (33 ppb) as a 24-hour average; and
- 59 $\mu g/m^3$ (30 ppb) as a 100-day average (over a growing season).

These values are similar to those proposed for Alberta.

4.4.2 Deposition Criteria

Deposition includes both wet and dry processes and can result in the long-term accumulation of emissions in aquatic and terrestrial ecosystems. Wet processes involve the removal of emissions vented into the atmosphere by precipitation. Dry processes involve the removal by direct contact with surface features (e.g., vegetation). Both wet and dry deposition are expressed as a flux in units of "kg/ha/y." Because several chemical species of nitrogen, sulphur and base cations are considered in the estimate of deposition, the flux is expressed in "keq/ha/y" where "keq" refers to hydrogen ion equivalents (1 keq = 1 kmol H^+). The deposition of sulphur and nitrogen compounds to these systems has been associated with changes in water and soil chemistry and with the acidification of water and soil.

Table 4-8 presents target loading values that have been considered for application to the deposition of acidic compounds in Alberta. The preferred AEP method is based on the Potential Acid Input (PAI) that is similar to the acid neutralizing capacity (ANC) except the negligible contribution of oceanic salt contribution has not been included (i.e., $[Na^+]$ and $[Cl^-]$). The calculation of the PAI is based on sulphur compounds (e.g., SO_2 gas, SO_4^{2-} particle), nitrogen compounds (e.g., NO gas, NO_2 gas, HNO_3 gas, NO_3^- particle) and base cations (e.g., Ca^{2+} particle, Mg^+ particle and K^+ particle).

The critical target loading recommended by the Target Loading Subgroup (1996) is for sensitive systems and is based on the European Approach outlined in the World Health Organization document (WHO 1994). This approach specifies target loads of 0.25, 0.5, 1.0 and 1.5 keq/ha/y that range from the most sensitive to least sensitive ecosystems. The terrestrial sensitivities depend on the geology of the parent material. The surface water sensitivities depend on the base cation concentration and runoff amounts. In Alberta, an interim critical load of 0.25 keq/ha/y is being proposed for sensitive soils; aquatic ecosystems loadings have not yet been defined.

Table 4-8 Deposition Target Loadings for Acid Forming Emissions

Form	Loading[a]	Comments	Reference
Wet Sulphate Deposition	20 kg/ha/y (Target)	SO_4^{2-} not strongly correlated with H^+ in western Canada. Does not include dry deposition or NO_x precursors.	US-Canada Memorandum of Intent (1983)
Acidifying Potential (AP)	0.12 to 0.31 keq/ha/y (Critical)	Does not include dry deposition or NO_x precursors. $AP = [SO_4^{2-}]-([Ca^{2+}]+[Mg^{2+}])$	Interim Acid Deposition Target Loadings Task Group (1990)
Effective Acidity (EA)	0.1 to 0.7 keq/ha/y depending on soil sensitivity (Critical)	Various forms account for wet and dry deposition and NO_x precursors. Accounts for soil response to deposition. $EA = [H^+] + 1.15\ [NH_4^+] - 0.7\ [NO_3^-] + [SO_2] + [SO_4^{2-}]$	Alberta Environment (1990) and Peake and Fong (1992)
Acid Neutralizing Capacity (ANC)	0.25 to 1.5 keq/ha/y depending on ecosystem (Critical)	Includes wet and dry deposition of all components. e.g., $ANC = ([Ca^{2+}] + [Mg^{2+}] + [K^+] + [Na^+]) - ([SO_4^{2-}] + [NO_3^-] + [NH_4^+] + [Cl^-])$	World Health Organization (1994)
Potential Acid Input (PAI)	0.25 keq/ha/y (Critical)	For sensitive soils. Includes SO_x and NO_x, wet and dry deposition and baseline precipitation. $PAI = ([SO_4^{2-}] + [NO_3^-] + [NH_4^+]) - ([Ca^{2+}] + [Mg^+] + [K^+])$	Target Loading Subgroup (1996)

[a] Target Load: Maximum level of atmospheric deposition, which provides long-term protection from adverse ecological consequences, and is practically and politically achievable.
Critical Load: Highest load that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems.

4.5 SULPHUR DIOXIDE (SO_2)

Air quality data from the continuous SO_2 analyzers were reviewed to determine the magnitudes and frequencies of relatively large SO_2 concentrations. In particular, all hours when the hourly average SO_2 concentration exceeded 450 µg/m^3 (0.17 ppm) were identified. The observed SO_2 concentrations were compared to regulatory and WHO guidelines. Trends with respect to meteorology and time of occurrence were also determined. Finally, an estimation of a representative background SO_2 concentration was made.

4.5.1 Comparison to Air Quality Guidelines

Table 4-9 provides a summary of the number of hours per year when the 450 µg/m^3 (0.17 ppm) guideline as a one-hour average was exceeded for each station. In general, the average number of times when the 450 µg/m^3 (0.17 ppm) guideline was exceeded ranged from 34 to 79 per year between 1993 and 1996. The number of occurrences dropped off in 1996 and 1997, with only 4 exceedances observed during 1997.

Table 4-9 Number of Hourly SO_2 Concentrations Greater Than 0.17 ppm (450 $\mu g/m^3$)

Station	1993	1994	1995	1996	1997	Total	Average
Mannix (#2)	9	21	20	10	1	61	12.2
Lower Camp (#4)	3	6	5	3	0	17	3.4
Fina (#5)	14	16	21	11	3	65	13.0
Poplar Creek (#9)	0	4	4	3	3	14	3.5
Athabasca Bridge (#10)	2	6	2	0	0	10	2.0
AQS1 (Mine South)	3	7	3	1	0	14	2.8
AQS2 (Fort McMurray)	0	5	6	0	0	11	2.2
AQS3 (Mildred Lake)	4	8	5	2	0	19	3.8
AQS4 (Tailing North)	0	3	3	2	0	8	1.6
AQS5 (Tailing East)	0	1	0	2	0	3	0.6
Fort McMurray (FMMU)	0	0	1	0	0	1	0.2
Fort McKay (FRMU)	1	2	2	0	0	5	1.0
Total	**36**	**79**	**72**	**34**	**7**	**225**	**45**

In a similar manner, Table 4-10 presents the number of times that the federal acceptable objective of 900 $\mu g/m^3$ (0.34 ppm) were exceeded. In general, the concentrations exceeded this objective an average of 7 times annually, with the lowest number occurring in 1997.

Table 4-10 Number of Hourly SO_2 Concentrations Greater Than 0.34 ppm (900 $\mu g/m^3$)

Station	1993	1994	1995	1996	1997	Total	Average
Mannix (#2)	0	3	13	0	0	16	3
Lower Camp (#4)	0	0	5	0	0	5	1.4
Fina (#5)	3	0	3	3	0	9	1.2
Poplar Creek (#9)	0	1	0	0	2	3	0.6
Athabasca Bridge (#10)	0	0	0	0	0	0	0
AQS1 (Mine South)	0	2	0	0	0	2	0.4
AQS2 (Fort McMurray)	0	0	0	0	0	0	0
AQS3 (Mildred Lake)	0	1	0	0	0	1	0.2
AQS4 (Tailing North)	0	0	0	0	0	0	0
AQS5 (Tailing East)	0	0	0	0	0	0	0
Fort McMurray (FMMU)	0	0	0	0	0	0	0
Fort McKay (FRMU)	0	0	0	0	0	0	0
Total	3	7	21	3	2	36	7

4.5.2 Trends with Time and Meteorology

SO_2 exceedance hours were classified according to concentration, month, time of day, wind speed and wind direction to help identify trends. The analysis results in a histogram format are presented on a station-by-station basis in the following figures:

- Figure 4-2 Suncor Mannix (#2)
- Figure 4-3 Suncor Lower Camp (#4)
- Figure 4-4 Suncor Fina (#5)
- Figure 4-5 Suncor Poplar Creek (#9)
- Figure 4-6 Suncor Athabasca Bridge (#10)
- Figure 4-7 Syncrude AQS1 (Mine South)
- Figure 4-8 Syncrude AQS2 (Fort McMurray)
- Figure 4-9 Syncrude AQS3 (Mildred Lake)
- Figure 4-10 Syncrude AQS4 (Tailing North)
- Figure 4-11 Syncrude AQS5 (Tailing East)
- Figure 4-12 Fort McMurray (FMMU)
- Figure 4-13 Fort McKay (FRMU)

SO_2 concentrations greater than 0.17 ppm and less than or equal to 0.18 ppm are plotted as 0.17 ppm and values greater than 0.18 ppm but less than 0.19 ppm are plotted as 0.18 ppm and so on. The wind directions and wind speeds shown in the figures were obtained from the wind sensors located at the respective monitoring stations. The figures also show the wind directions required to transport a plume from the two plants to the monitoring station in question.

Trends identified from the figures are summarized below:

- Exceedances were observed most frequently during daytime hours (0900 to 1600 hours);
- Exceedances were associated with wind speeds less than 11 km/h;
- In many cases, there was a clear downwind/upwind relationship between the location of the plant and the wind direction; and
- In other cases, the monitoring station was not downwind from either of the plants. The cause of this may be the meander of the plumes which do not follow a linear trajectory.

In summary, the high SO_2 concentrations that are observed in the region are, for the most part, well correlated with one of the two oil sands plants being clearly located upwind of the station at which the exceedance is recorded, with day-time hours and with wind speeds less than 11 km/h. High concentrations tend to occur more frequently in the late winter/spring and summer periods. The day-time occurrence of high SO_2 concentrations indicate that the convective and/or limited trapping meteorological conditions are responsible for the SO_2 events as most of the SO_2 emissions in the region result from relatively tall stacks at Suncor and Syncrude.

Figure 4-2 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Suncor (Station #2) Mannix

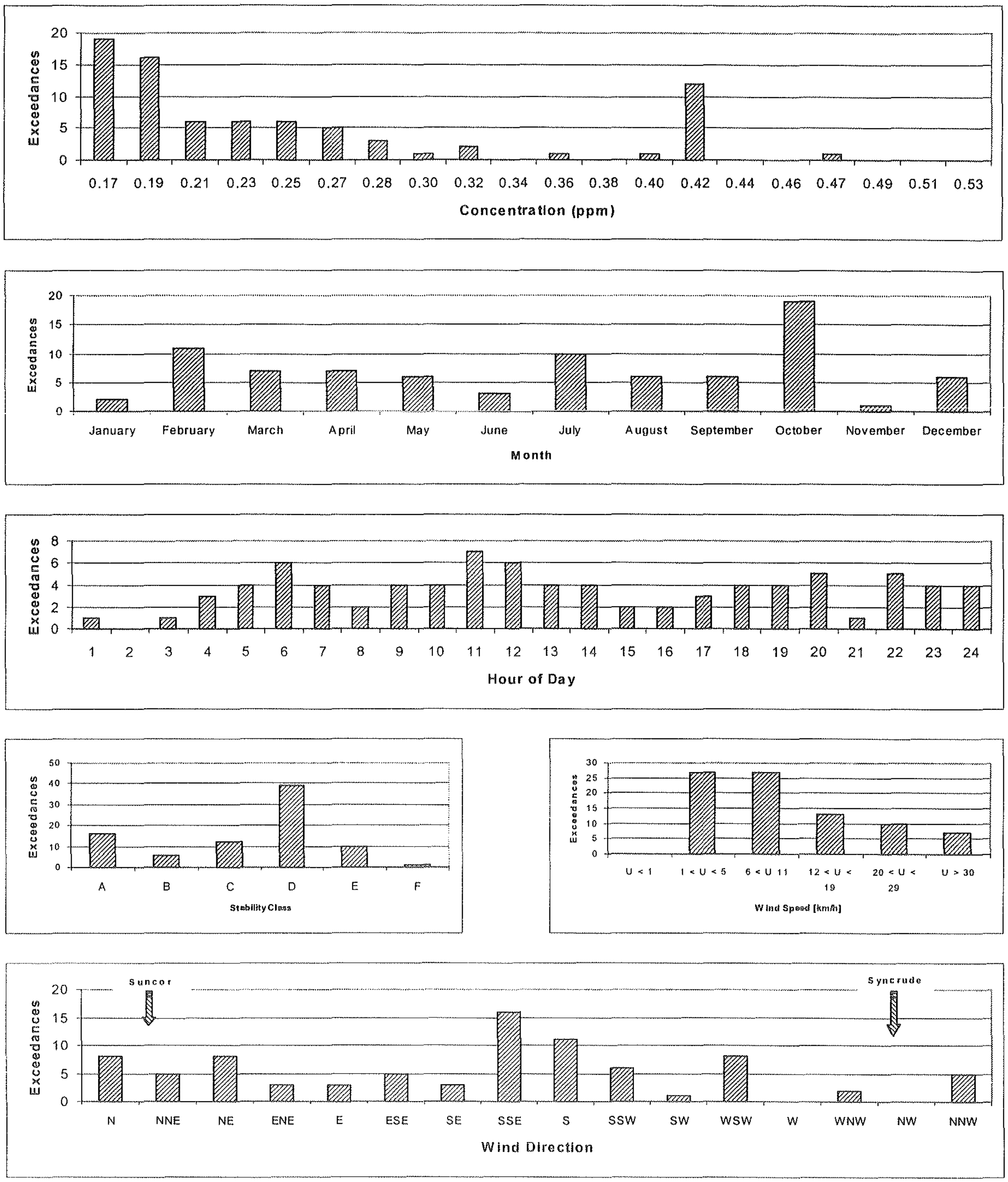


Figure 4-3 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Suncor (Station #4) Lower Camp

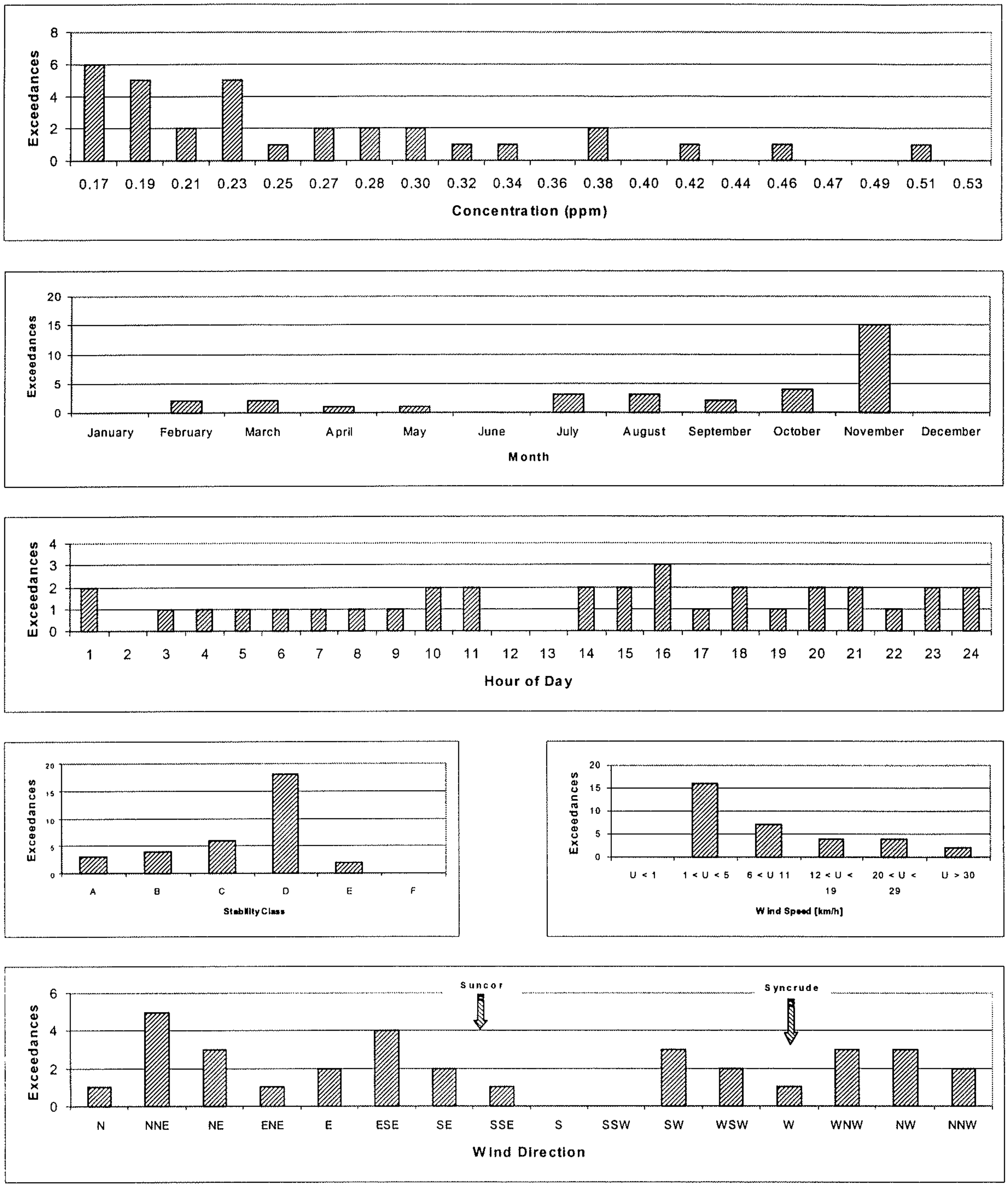


Figure 4-4 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Suncor (Station #5) Fina

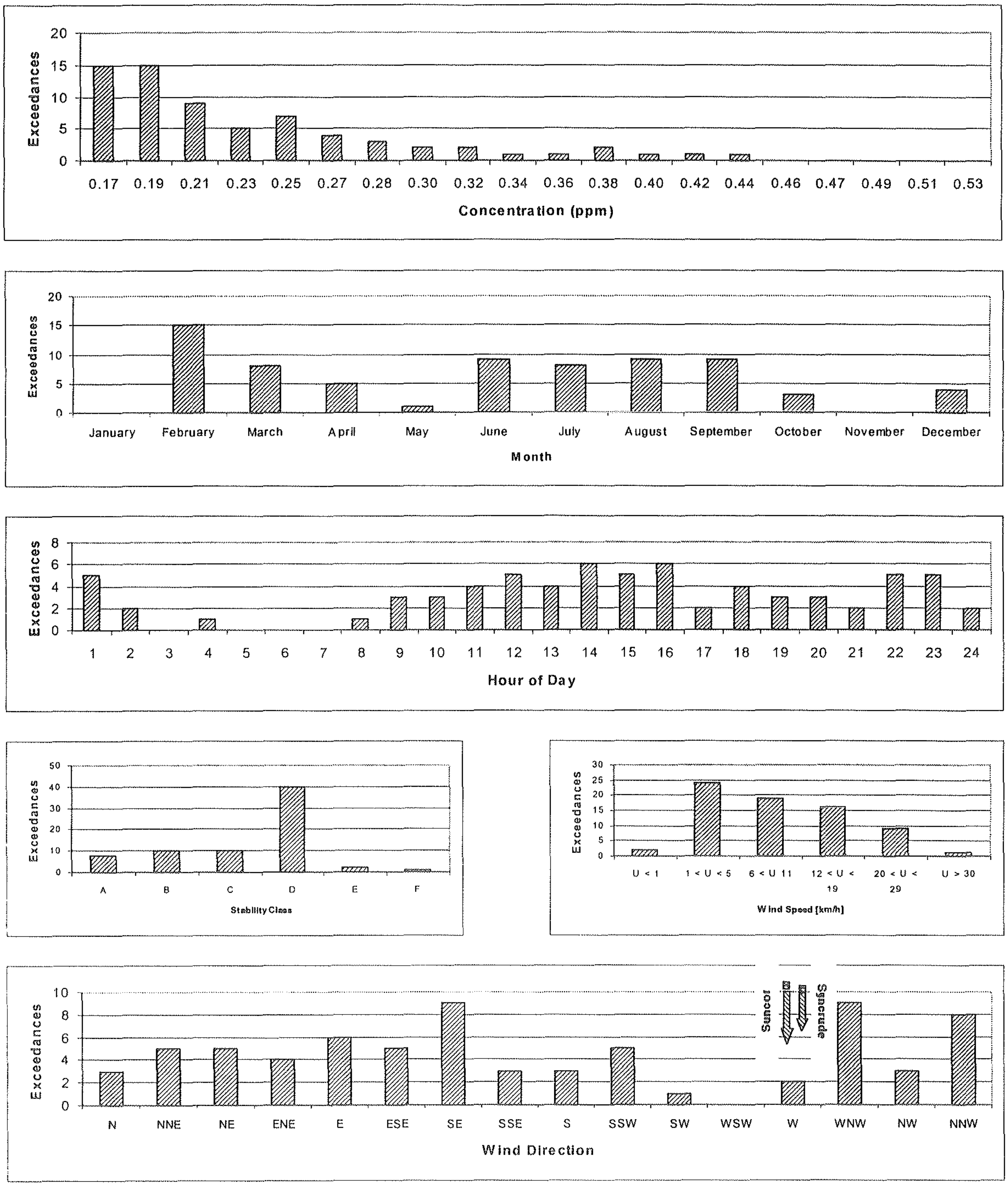


Figure 4-5 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Suncor (Station #9) Poplar Creek

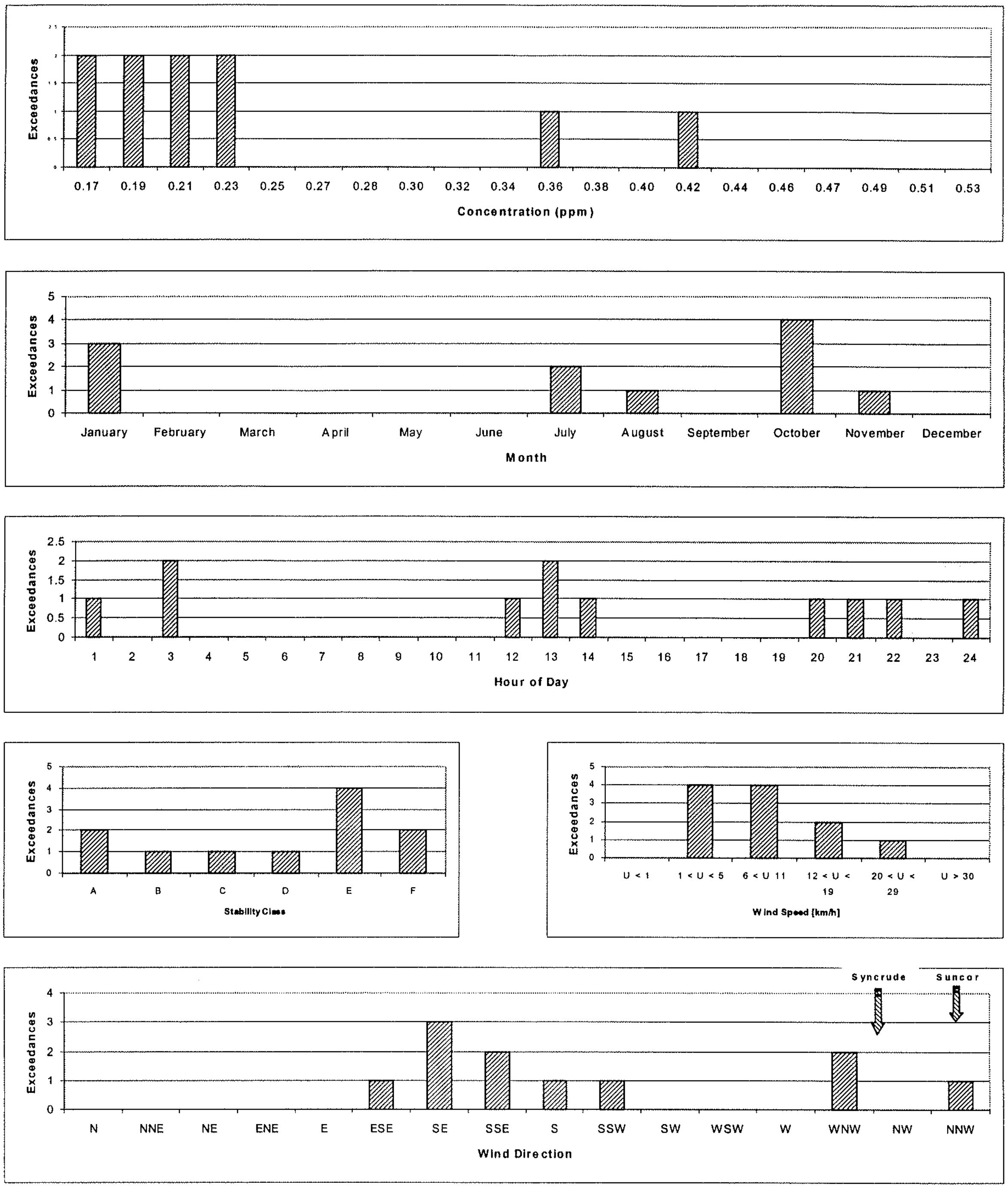


Figure 4-6 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Suncor (Station #10) Athabasca Bridge

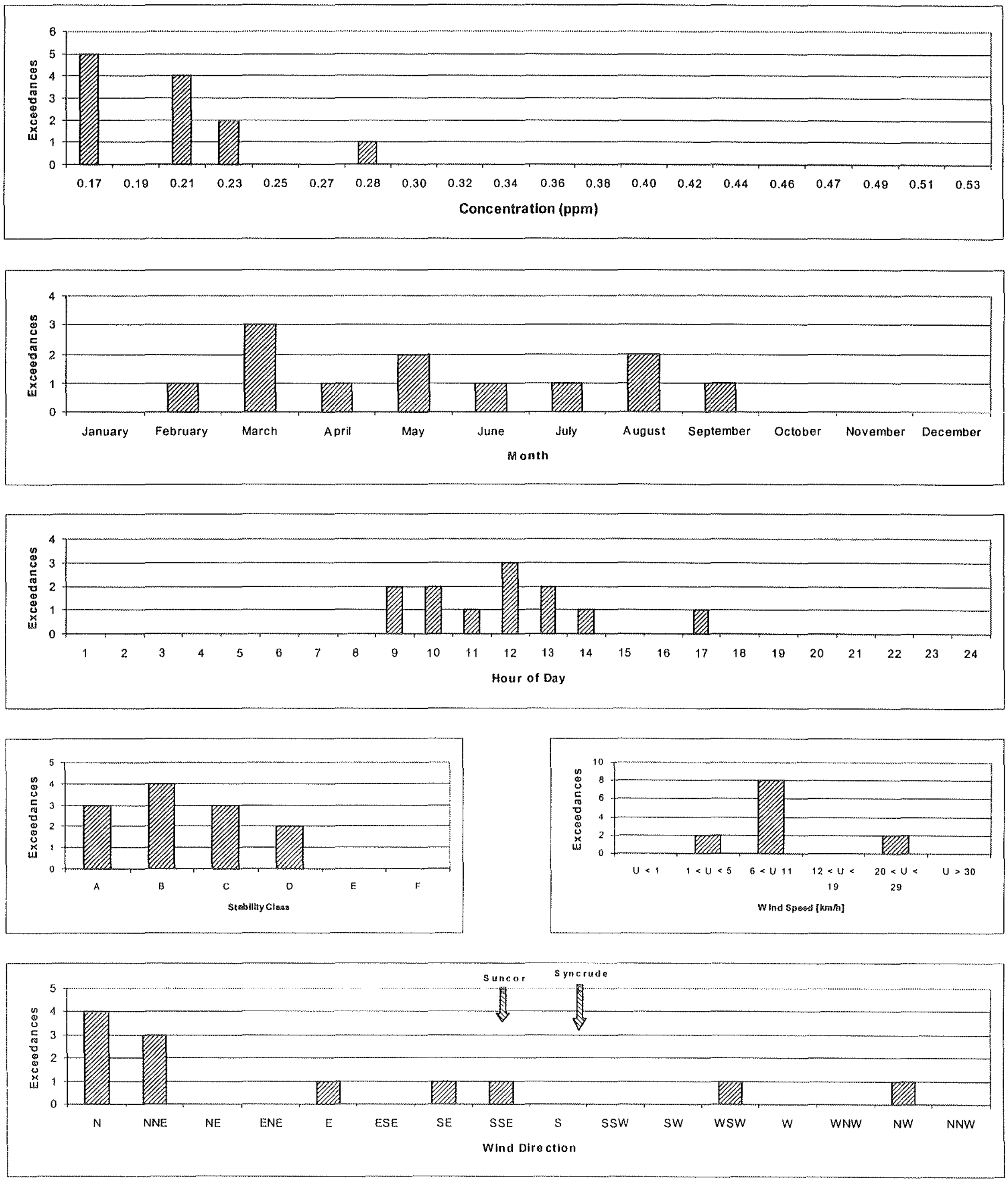


Figure 4-7 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Syncrude AQS1 (Mine South)

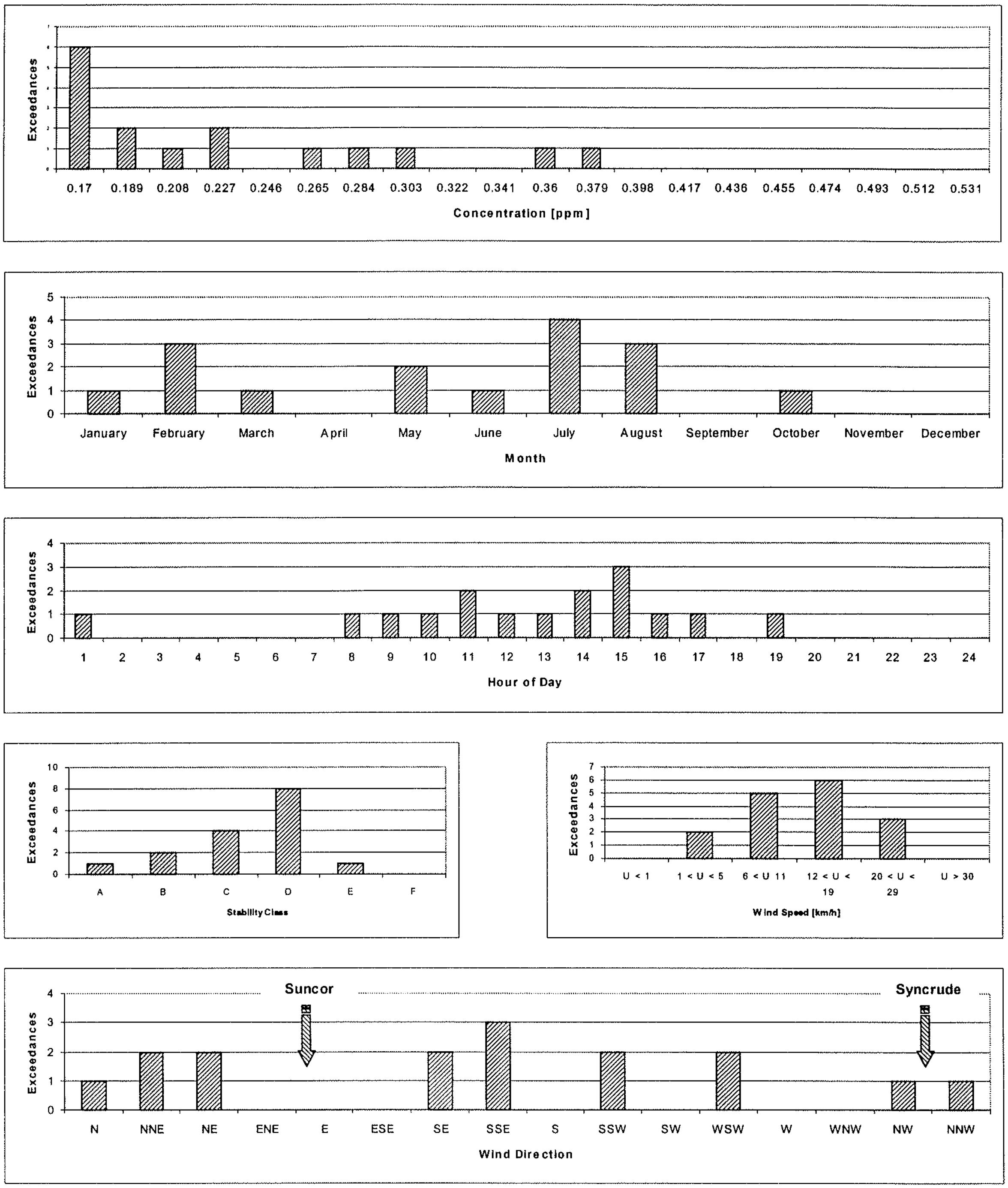


Figure 4-8 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Syncrude AQS2 (Fort McMurray)

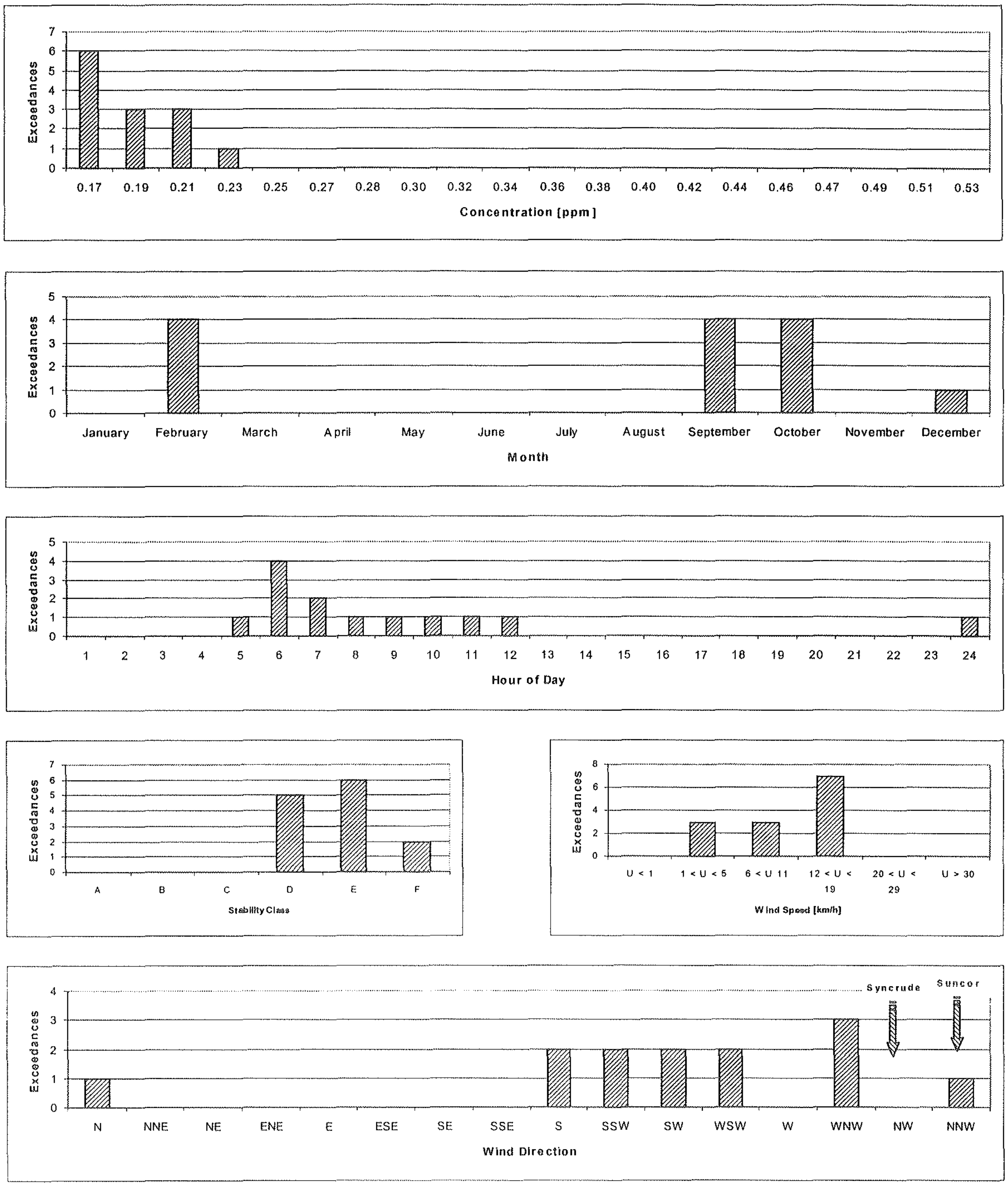


Figure 4-9 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Syncrude AQS3 (Mildred Lake)

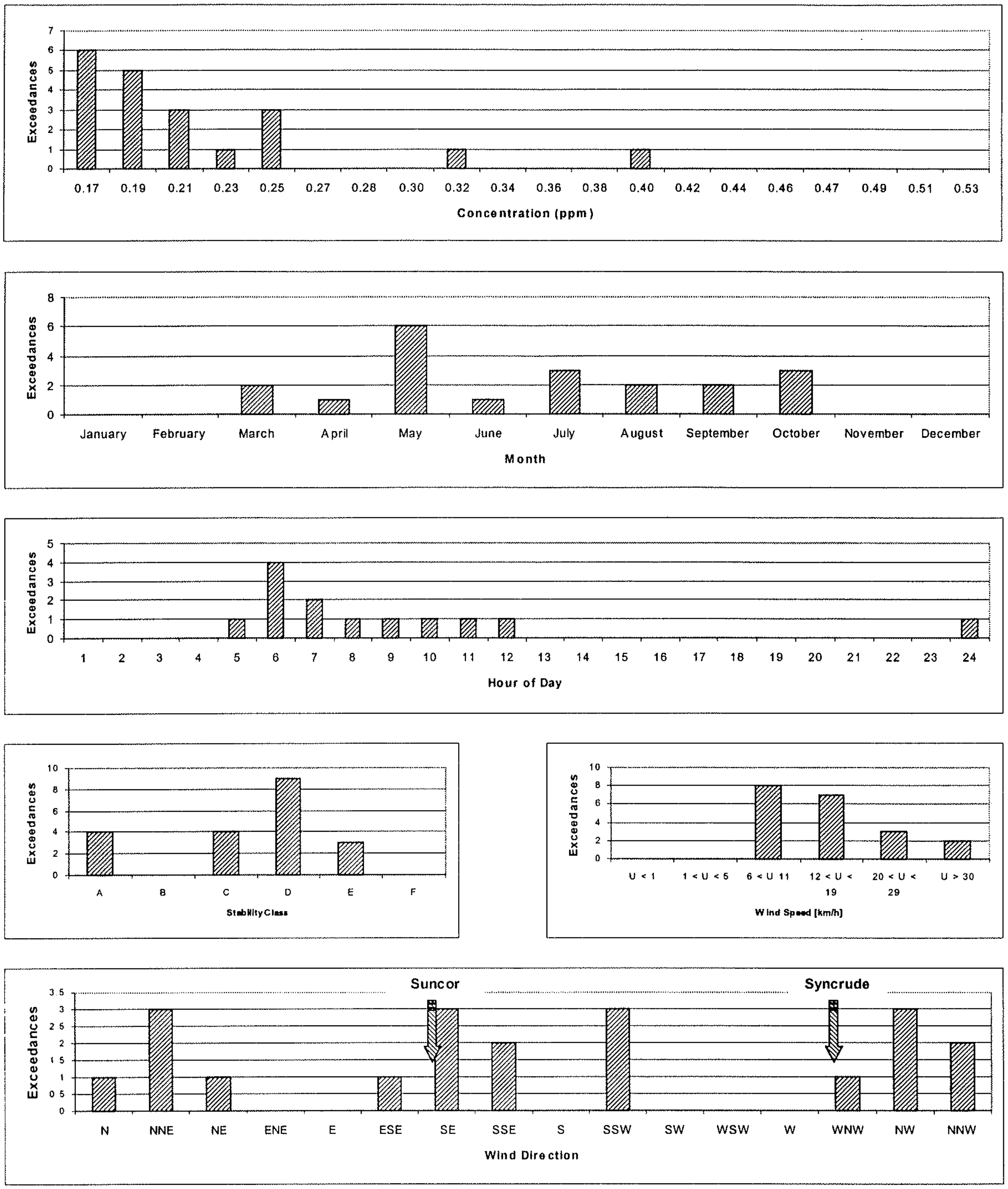


Figure 4-10 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Syncrude AQS4 (Tailings North)

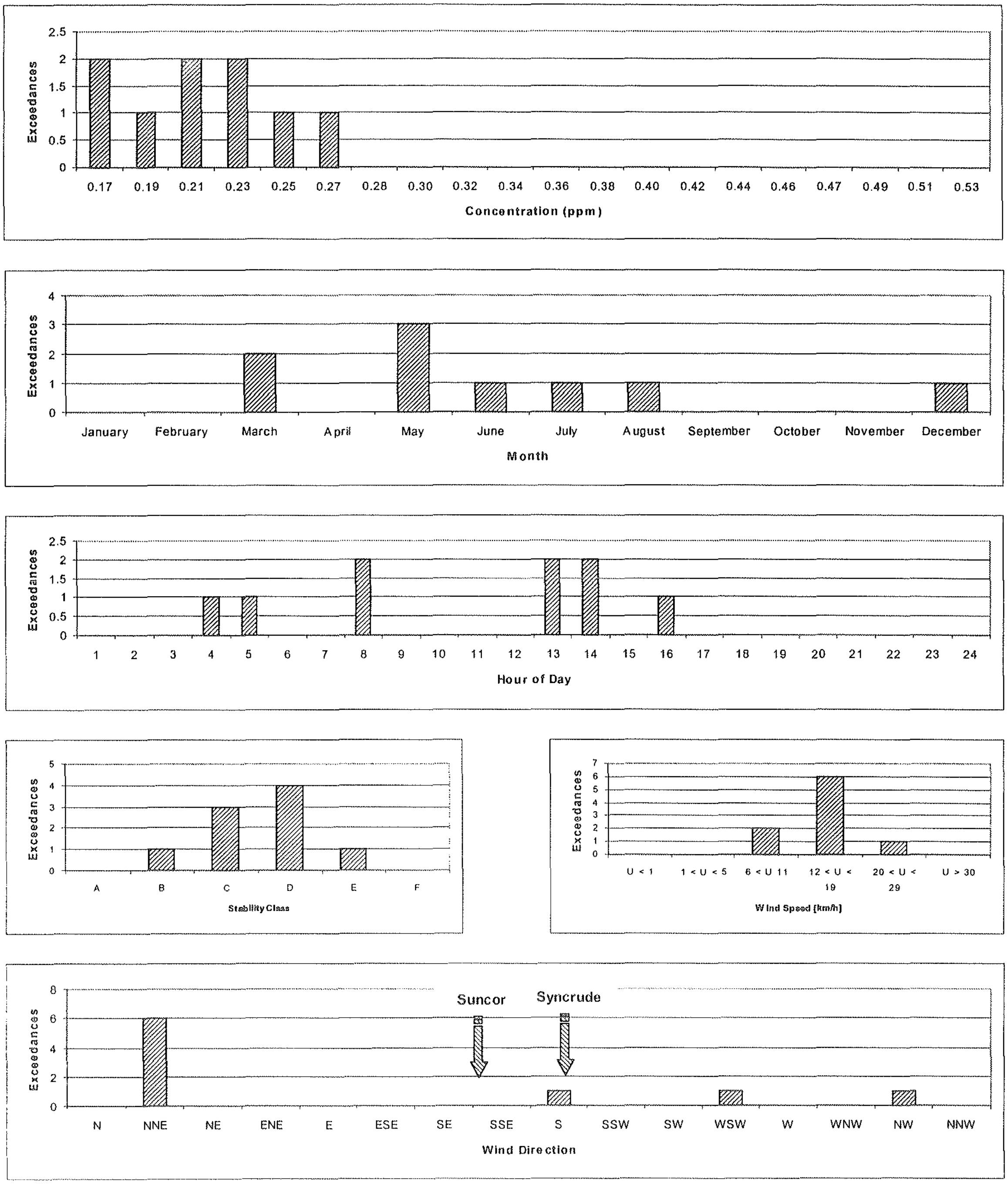


Figure 4-11 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Syncrude AQS5 (Tailings East)

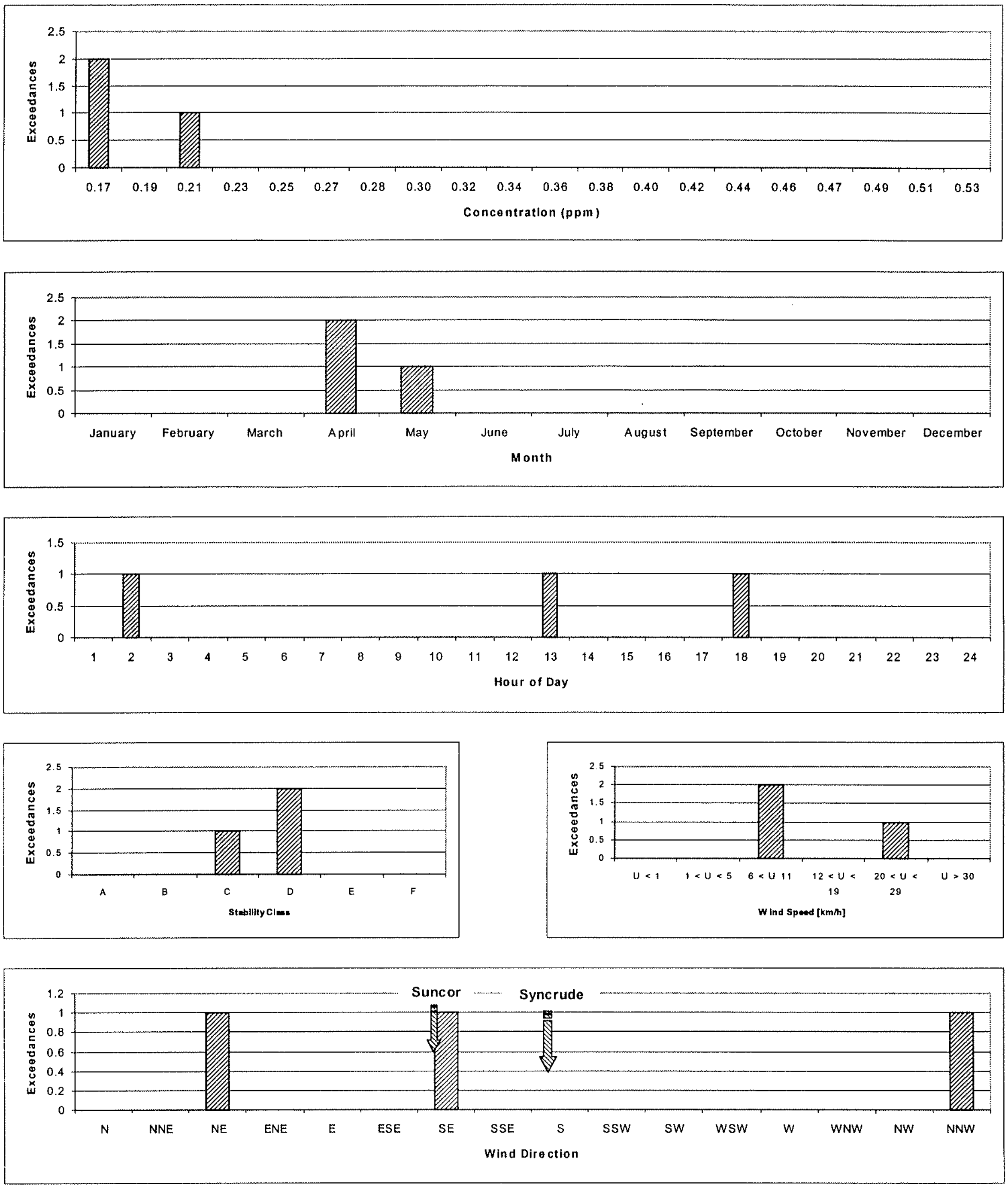


Figure 4-12 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Fort McMurray (FMMU)

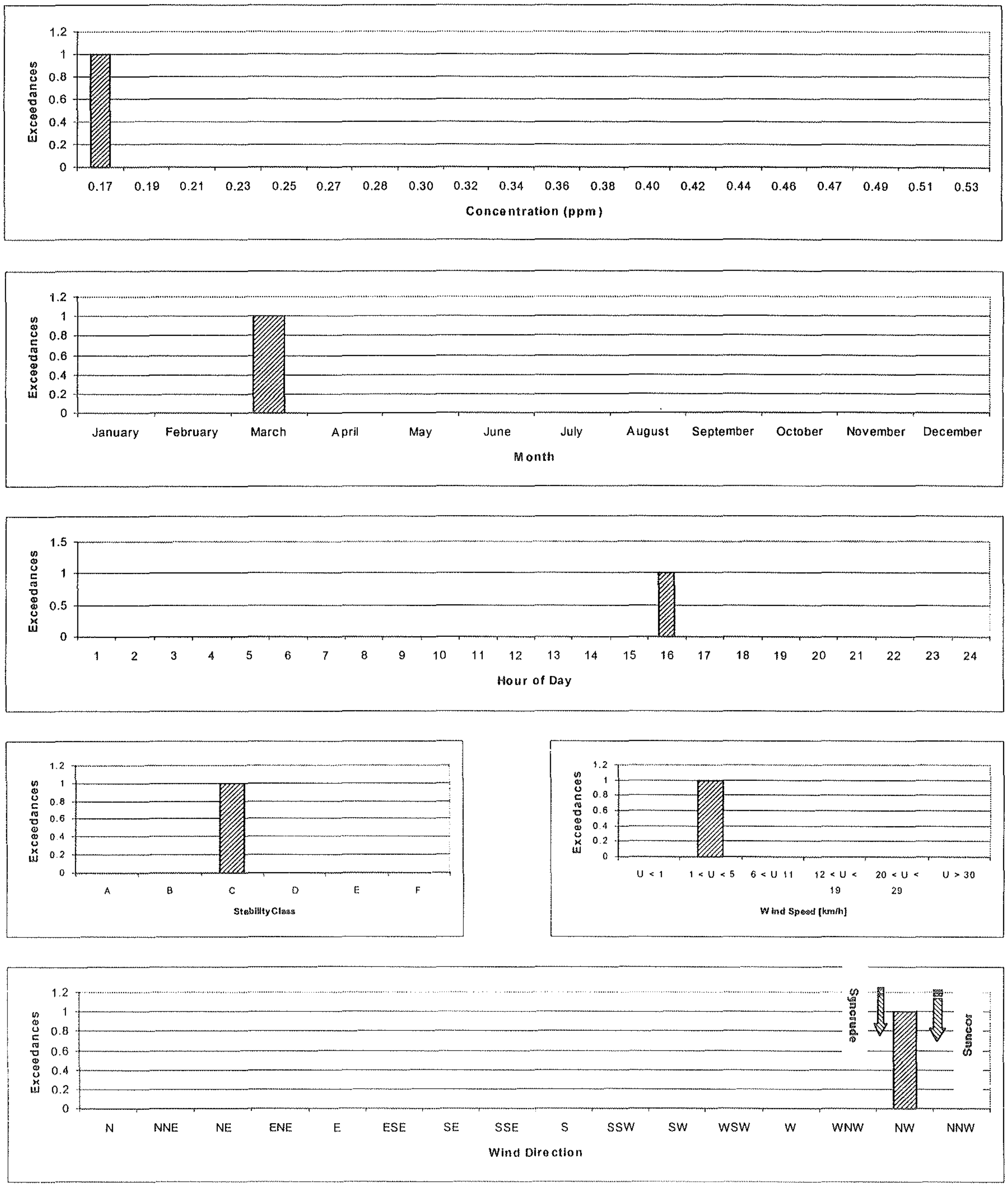
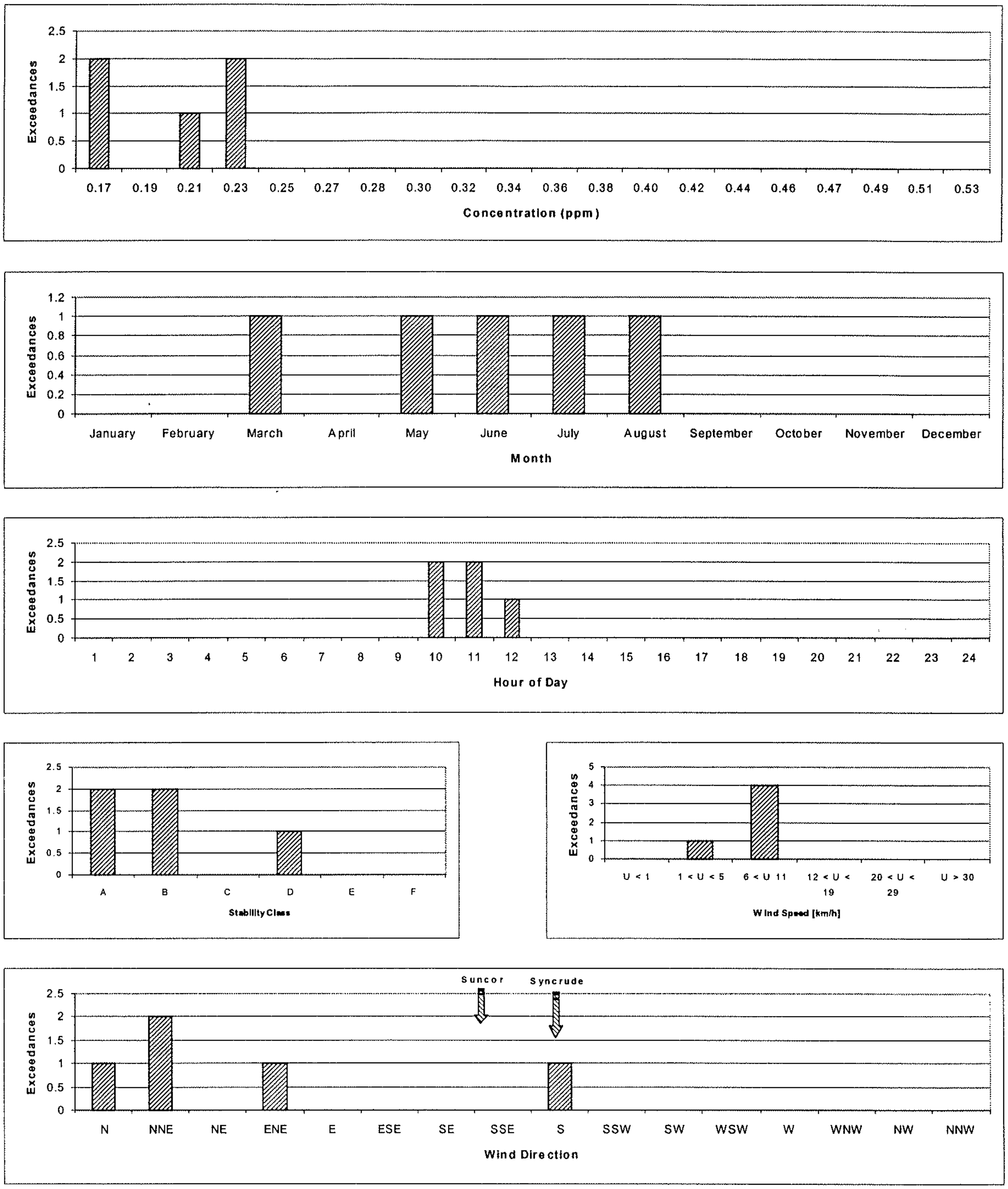


Figure 4-13 Hourly Average SO_2 Concentrations Greater Than 0.17 ppm and Associated Conditions at Fort McKay (FRMU)



4.5.3 Background SO_2 and SO_4^{2-} Concentrations

It is difficult to define a regional background SO_2 concentration that would exist in the absence of the current oil sands operations since the background values would, on average, be less than the level of detection of the SO_2 analyzers. For this reason, annual average background concentrations cannot be derived from the monitoring network in the oil sands region.

Integrated sampling allows low concentration measurements to be undertaken. These samplers draw a low volume of air through an absorbing medium for weekly or monthly periods. The absorbing medium is then analyzed and the average concentration for the exposure period can be determined. To determine representative background concentrations, data was collected using this type of sampler at Cree Lake (Saskatchewan) Station. Environment Canada's Figure 4-14 and Tables 4-11 and 4-12 show the SO_2 and SO_4^{2-} values for 1990 up to the time in 1993 when the monitoring was cancelled. The data indicate:

- The smallest SO_2 values in the 0.3 to 0.8 $\mu g/m^3$ (0.1 to 0.3 ppb) range occur in the summer season; and
- The largest SO_2 values in the 2 to 4 $\mu g/m^3$ (0.8 to 1.5 ppb) range occur in the winter season.

This difference is likely due to the more stable air masses during the winter that would result in the long-range transport of higher concentrations to greater distances. Furthermore, during winter the removal rate (i.e., deposition) is expected to be lower due to reduced vegetation activity. Similar seasonal trends are observed for SO_4^{2-} as for SO_2. On the average, the SO_4^{2-} values are about 74% of the SO_2 values.

Additional baseline data were also available from the Environment Canada station at Cree Lake, the Acid Deposition Research Project (ADRP) site at Fortress Mountain (Legge and Kruppa 1990) and the Hightower Ridge station (1996) operated by the West Central Airshed Society (1997). The average background concentrations observed at these stations are summarized in Table 4-13. These values were deemed to be representative of the background values that could occur in the Athabasca oil sands area in the absence of local oil sands activity.

Figure 4.14 SO_2 and SO_4^{2-} Concentrations Measured at the Environment Canada Monitoring Station Located at Cree Lake Saskatchewan (January 1990 to May 1993)

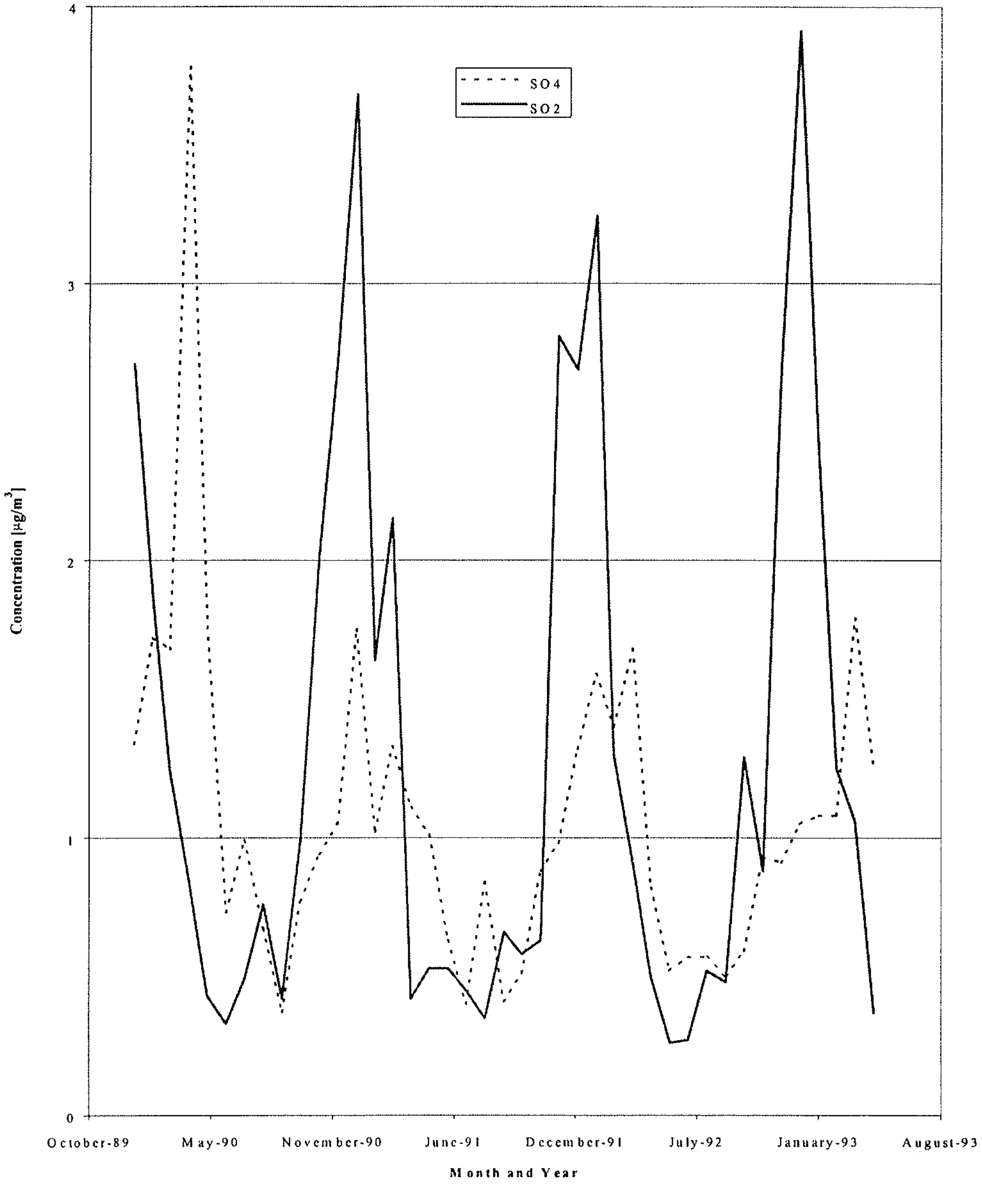


Table 4-11 SO_2 Concentrations (µg/m^3) Measured in Cree Lake (Shaw 1995, Personal Communication)

Month	1990	1991	1992	1993	Average
January	2.71	3.68	2.69	3.91	3.25
February	1.86	1.64	3.24	2.39	2.33
March	1.24	2.15	1.30	1.25	1.49
April	0.85	0.42	0.90	1.06	0.81
May	0.43	0.53	0.50	0.37	0.46
June	0.33	0.53	0.26	-	0.38
July	0.49	0.45	0.27	-	0.41
August	0.76	0.35	0.52	-	0.54
September	0.42	0.66	0.48	-	0.52
October	0.99	0.58	1.29	-	0.95
November	2.01	0.63	0.88	-	1.50
December	2.73	2.81	2.66	-	2.73
Average	**1.23**	**1.20**	**1.33**	**1.84**	**1.28**

Table 4-12 SO_4^{2-} Concentrations (µg/m^3) Measured in Cree Lake (Shaw 1995, Personal Communication)

Month	1990	1991	1992	1993	Average
January	1.34	1.75	1.32	1.05	1.37
February	1.72	1.02	1.59	1.08	1.35
March	1.68	1.33	1.40	1.08	1.37
April	3.78	1.11	1.68	1.79	1.14
May	1.76	1.01	0.82	1.26	1.21
June	0.73	0.63	0.52	-	0.63
July	0.99	0.40	0.57	-	0.65
August	0.67	0.84	0.57	-	0.69
September	0.37	0.41	0.50	-	0.43
October	0.77	0.51	0.59	-	0.62
November	0.94	0.88	0.93	-	0.92
December	1.05	0.98	0.91	-	0.98
Average	**1.32**	**0.91**	**0.95**	**1.25**	**0.95**

Table 4-13 Background SO_2 and SO_4^{2-} Concentrations Applicable to the Study Area

Site	SO_2		SO_4^{2-}
	(µg/m^3)	(ppb)	(µg/m^3)
Hightower Ridge (1986)	1.1	0.41	0.58
Fortress Mountain (1985 to 1987)	1.4	0.51	0.51
Cree Lake (1988 to 1995)	1.2	0.45	0.99
Average	**1.2**	**0.46**	**0.69**

4.6 HYDROGEN SULPHIDE (H_2S)

The air quality data from the continuous H_2S analyzers were reviewed to determine the magnitudes and frequencies of relatively large H_2S concentrations. In particular, all hours when the hourly average H_2S concentration exceeded 0.01 ppm (10 ppb or 14 $\mu g/m^3$) were identified. The observed H_2S concentrations were compared to regulatory guidelines. Trends with respect to meteorology and time of occurrence were also determined.

4.6.1 Comparison to Air Quality Guideline

Table 4-14 provides a summary of the number of hours per year when the 1-hour Alberta guideline of 0.01 ppm was exceeded for each monitoring station. Concentrations of H_2S in excess of the Alberta guideline of 0.10 ppm (14 $\mu g/m^3$) have been observed at all locations. The most frequent exceedances have been observed at the Mannix station. Exceedances have been decreasing with 1997 measuring the lowest number in the five year period.

The H_2S concentrations above the Alberta Guideline were mainly observed during the summer months and the month of January.

Table 4-14 Number of Hourly H_2S Concentrations Greater Than 0.01 ppm (14 $\mu g/m^3$)

Station	1993	1994	1995	1996	1997	Total	Average
Mannix (#2)	24	42	10	16	6	98	19.6
Lower Camp (#4)	2	2	4	12	4	24	4.8
Poplar Creek (#9)	0	0	4	0	0	4	0.8
Athabasca Bridge (#10)	1	2	2	2	0	7	1.4
AQS1 (Mine South)	4	10	0	1	0	15	3.0
AQS2 (Fort McMurray)	3	13	0	0	0	16	3.2
AQS3 (Mildred Lake)	3	1	0	3	0	7	1.4
AQS4 (Tailing North)	5	6	2	0	0	13	2.6
AQS5 (Tailing East)	0	0	2	0	0	2	0.4
Fort McMurray (FMMU)	0	5	0	0	0	5	1.0
Fort McKay (FRMU)	0	0	2	1	0	3	0.6
Total	**42**	**81**	**26**	**35**	**10**	**194**	**39**

4.6.2 Trends with Time and Meteorology

H_2S exceedance hours were classified according to month, time of day, wind speed and wind direction to identify trends. The analysis results in a histogram format are presented on a station-by-station basis in the following figures:

- Figure 4-15 Suncor Mannix (#2)
- Figure 4-16 Suncor Lower Camp (#4)
- Figure 4-17 Suncor Fina (#5)
- Figure 4-18 Suncor Poplar Creek (#9)
- Figure 4-19 Suncor Athabasca Bridge (#10)
- Figure 4-20 Syncrude AQS1 (Mine South)
- Figure 4-21 Syncrude AQS2 (Fort McMurray)
- Figure 4-22 Syncrude AQS3 (Mildred Lake)
- Figure 4-23 Syncrude AQS4 (Tailing North)
- Figure 4-24 Syncrude AQS5 (Tailing East)
- Figure 4-25 Fort McMurray (FMMU)
- Figure 4-26 Fort McKay (FRMU)

The trends identified from these figures are summarized below:

- Exceedances are most frequently observed during the summer (June, July, August) and autumn (September, October, November) periods.
- Exceedances were observed during the night-time more frequently than during the day-time.
- In some cases, the exceedances were clearly related to the location of the plant, while in other cases, the wind relationships were not as evident.

In summary, the high H_2S concentrations that are observed in the region are, for the most part, well correlated with one of the two oil sand plants being clearly located upwind, with night-time hours and with wind speeds less than 8 km/h. High concentrations tend to be observed more frequently during the summer months.

Figure 4-15 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Suncor (Station #2) Mannix

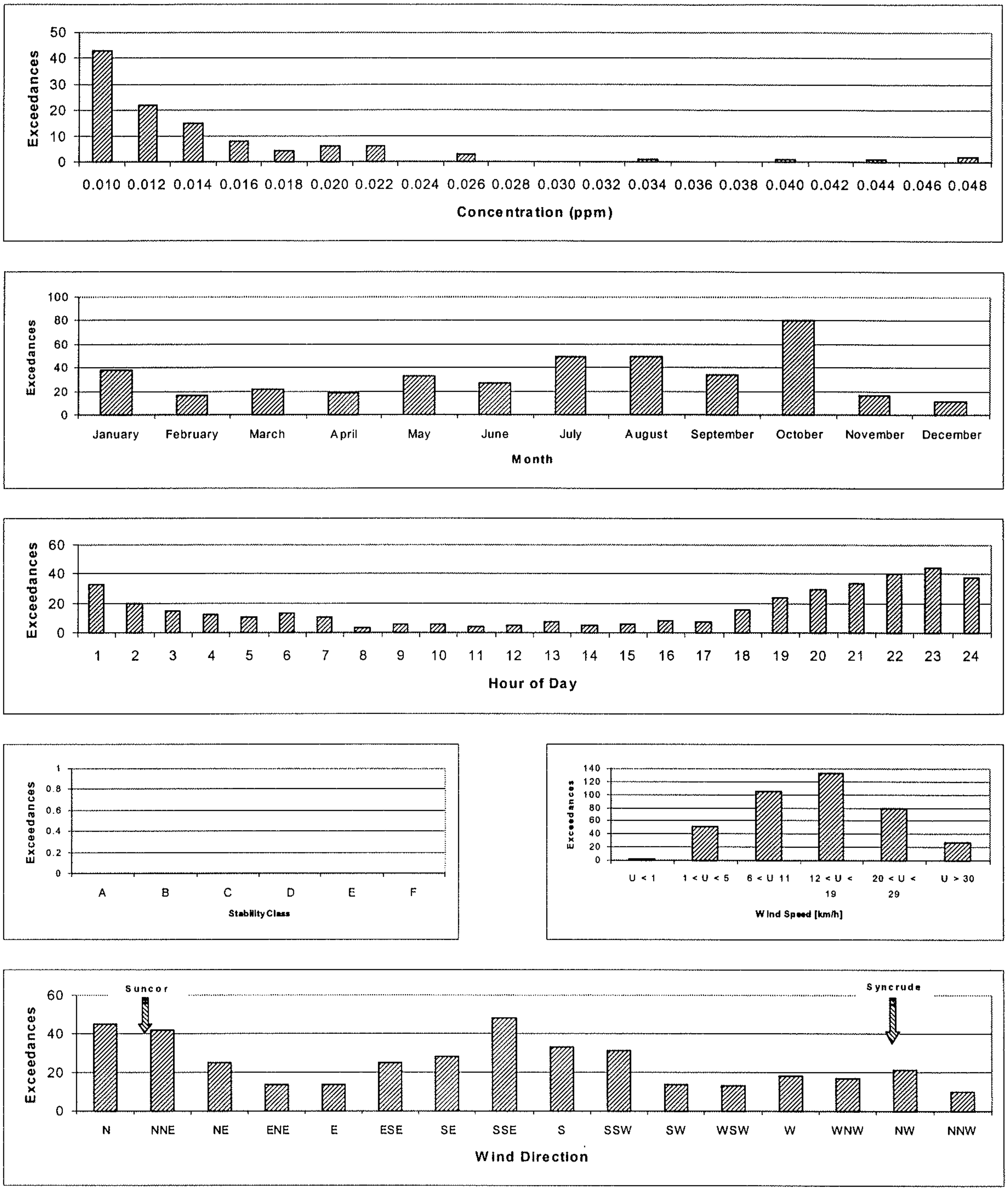


Figure 4-16 **Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Suncor (Station #4) Lower Camp**

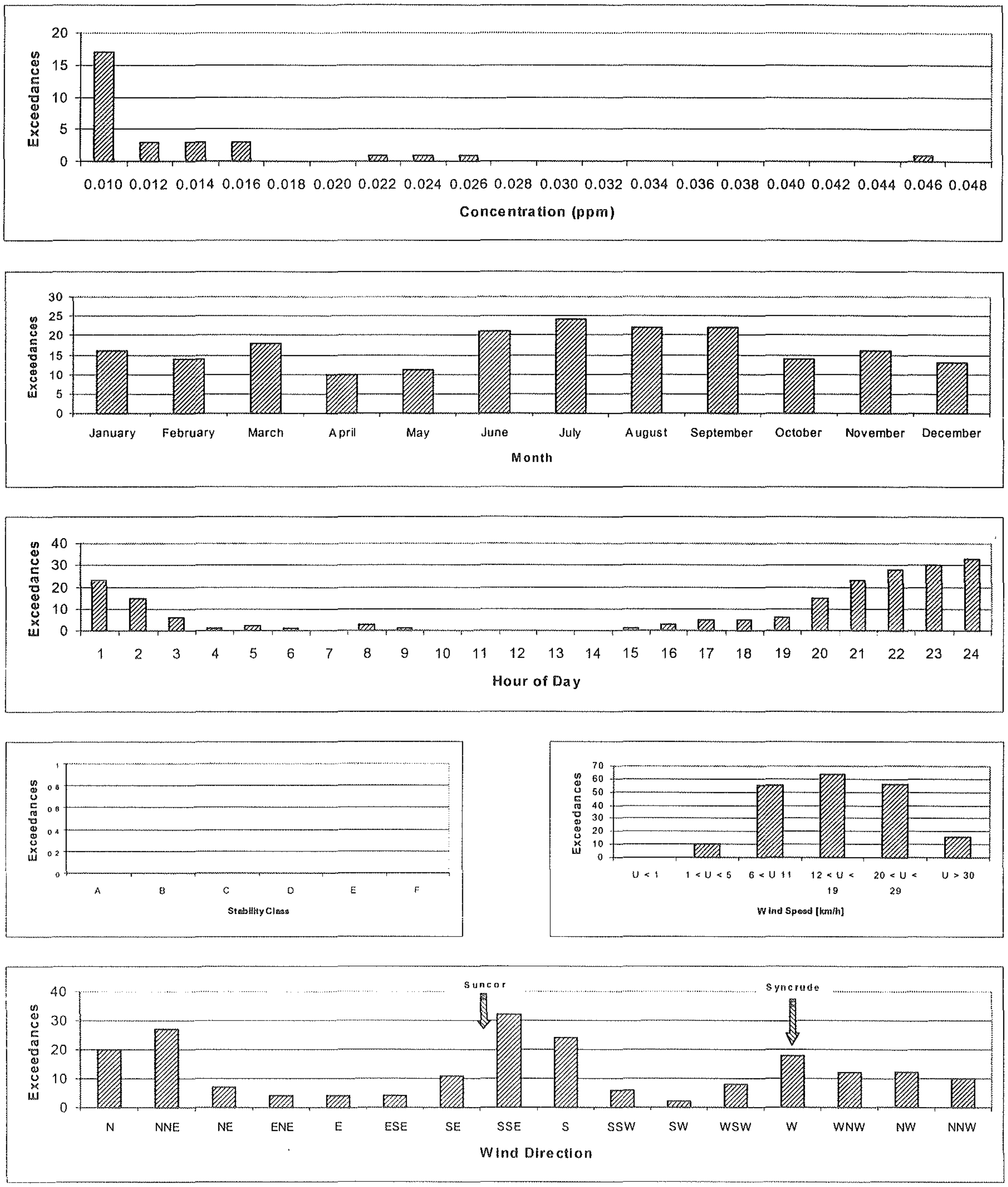


Figure 4-17 **Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Suncor (Station #5) Fina**

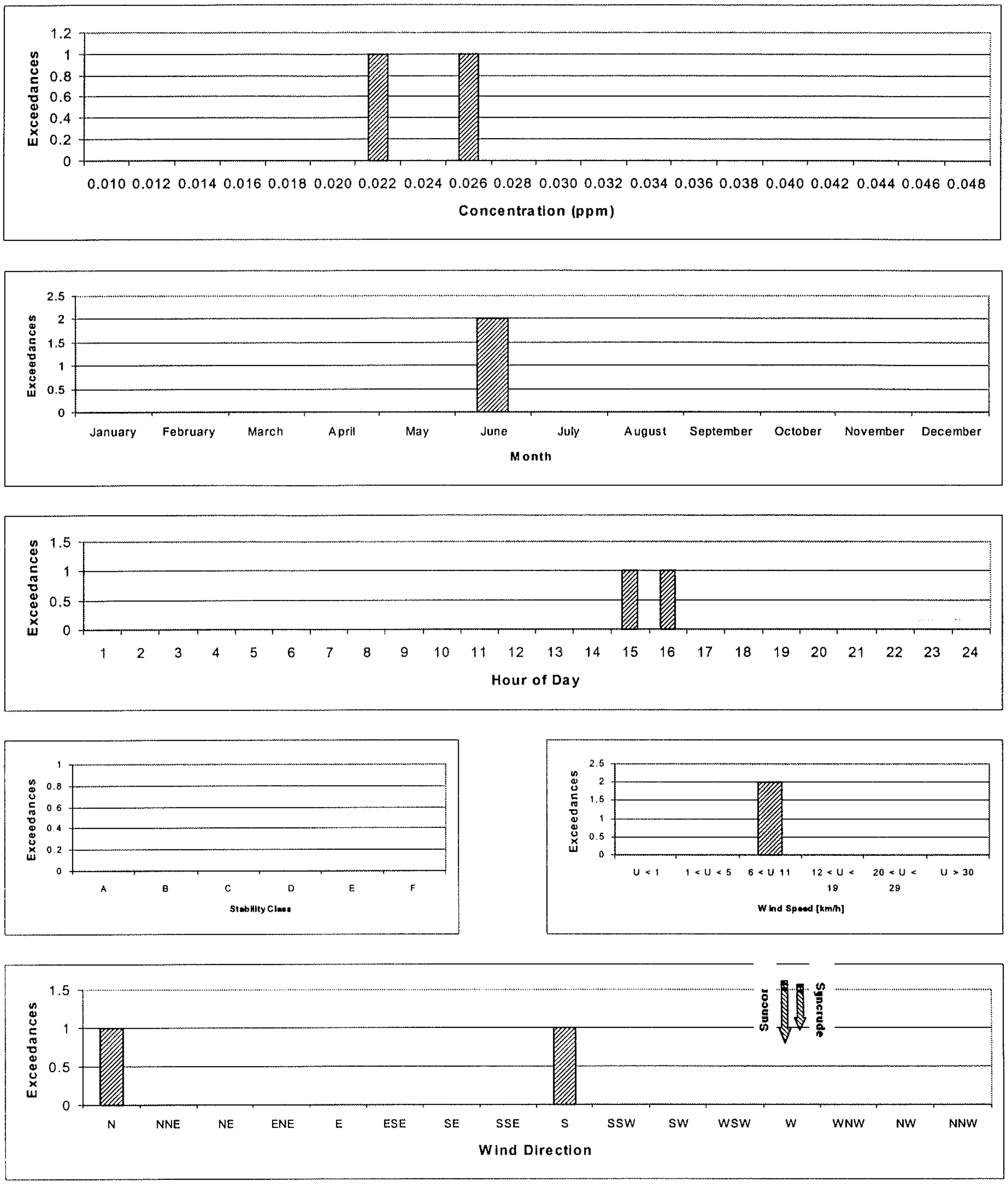


Figure 4-18 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Suncor (Station #9) Poplar Creek

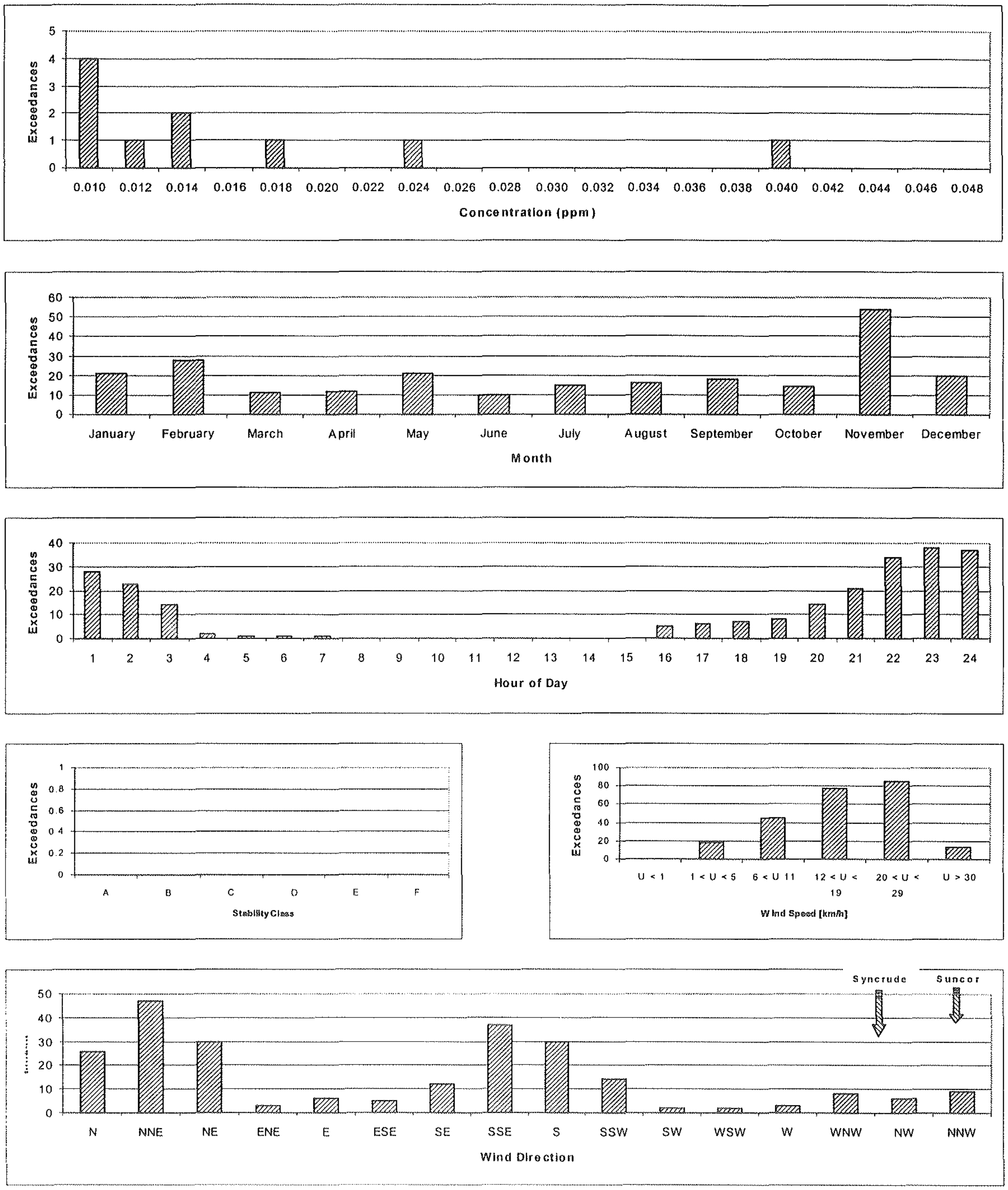


Figure 4-19 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Suncor (Station #10) Athabasca Bridge

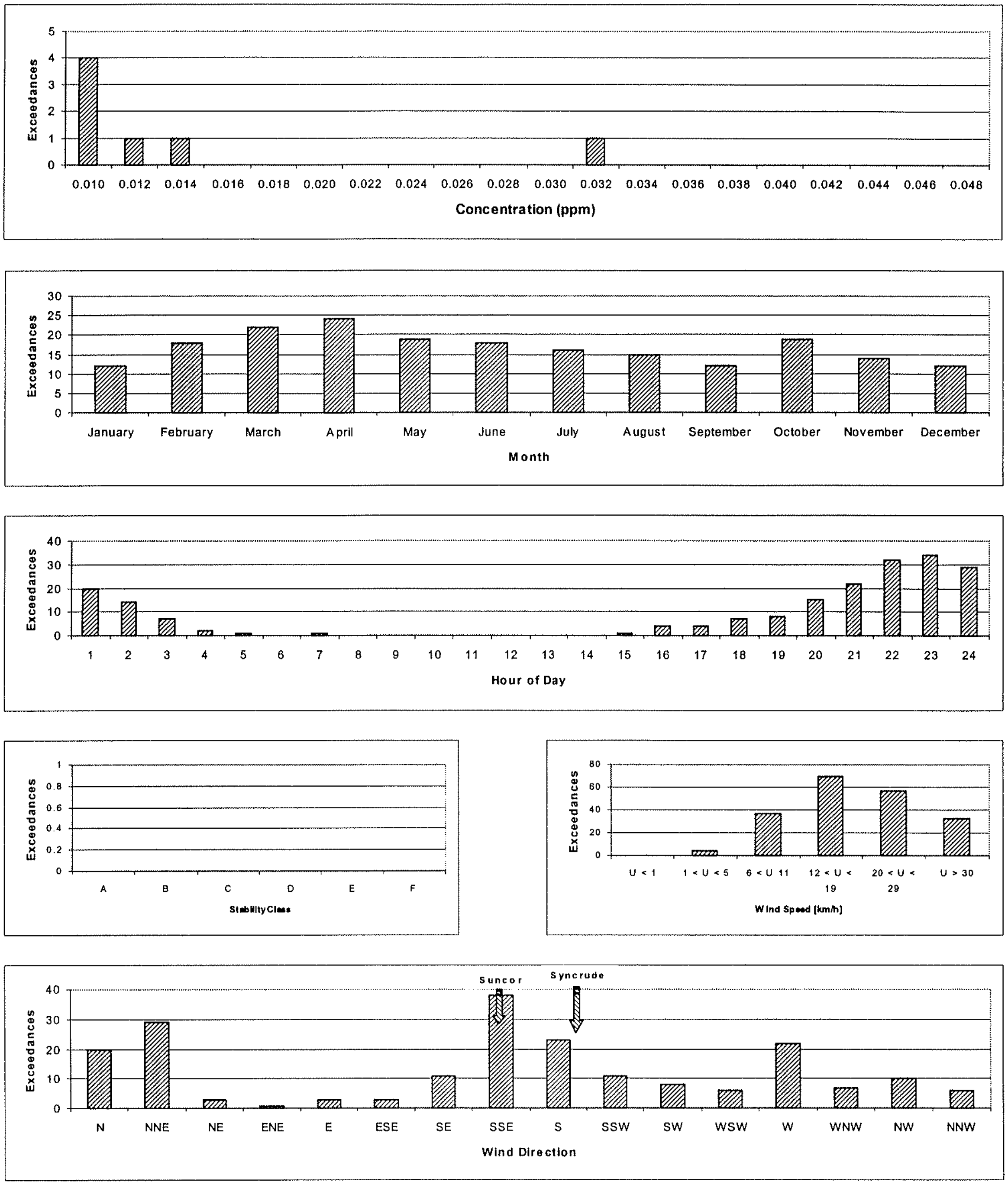


Figure 4-20 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Syncrude AQS1 (Mine South)

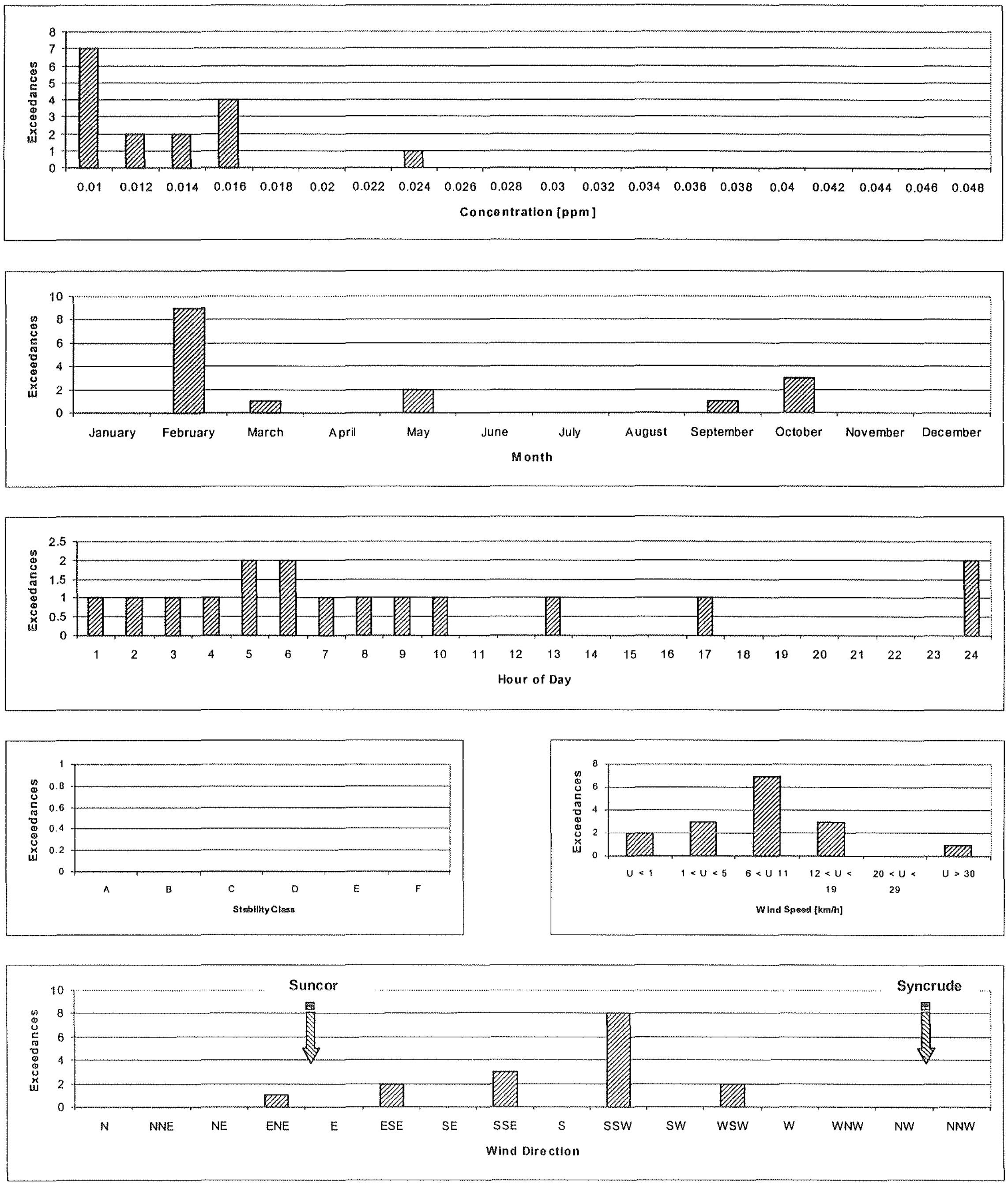


Figure 4-21 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Syncrude AQS2 (Fort McMurray)

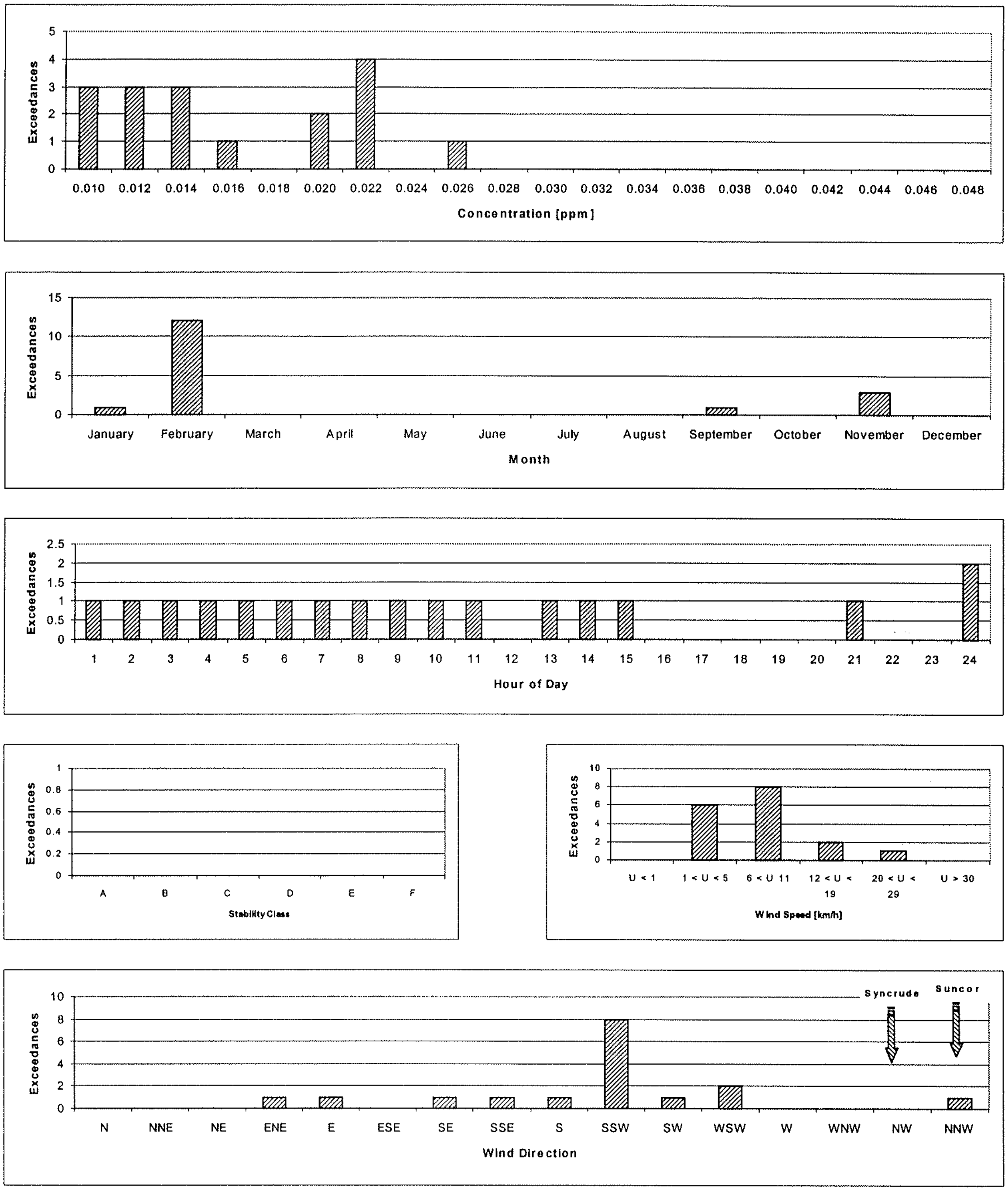


Figure 4-22 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Syncrude AQS3 (Mildred Lake)

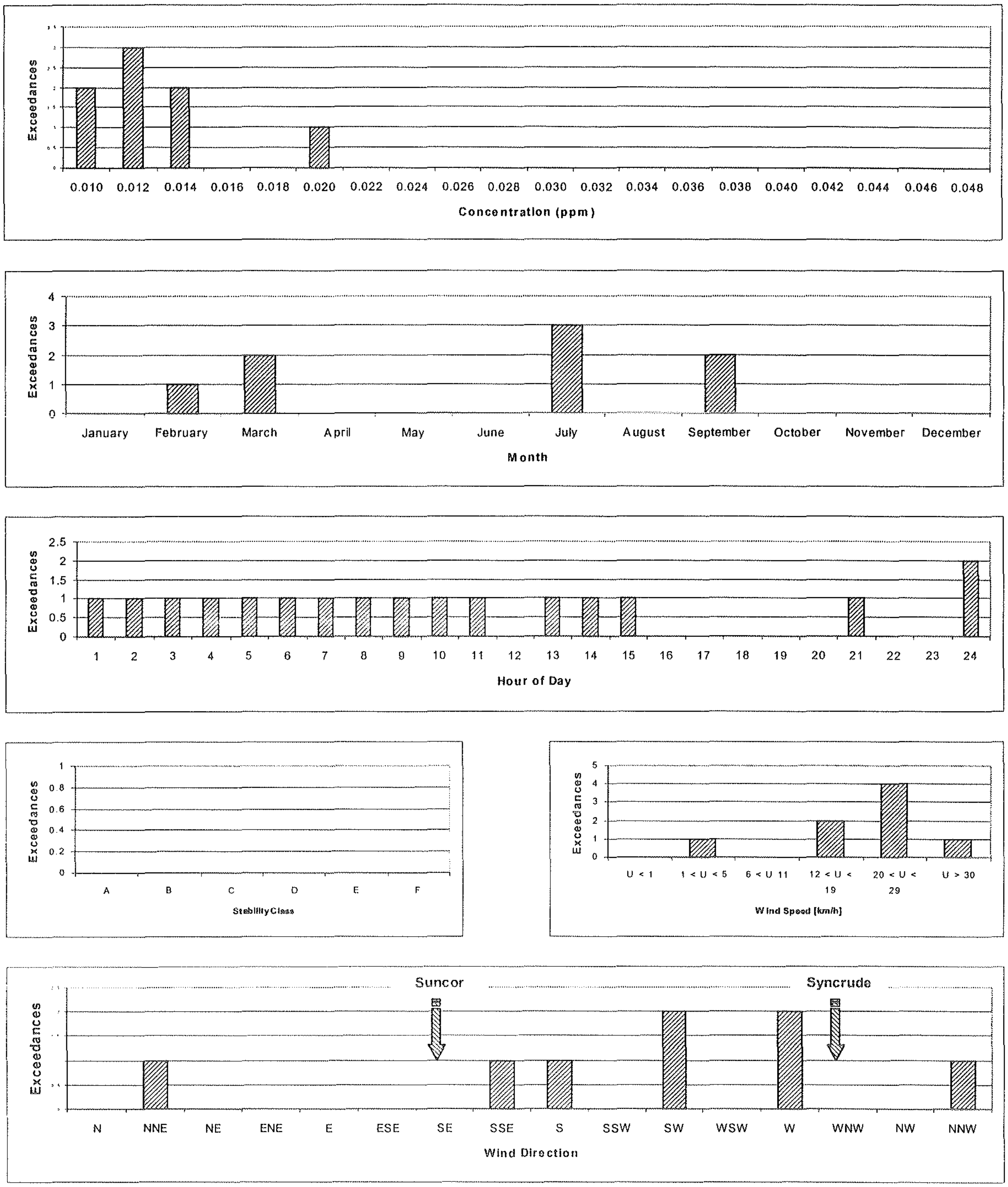


Figure 4-23 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Syncrude AQS4 (Tailings North)

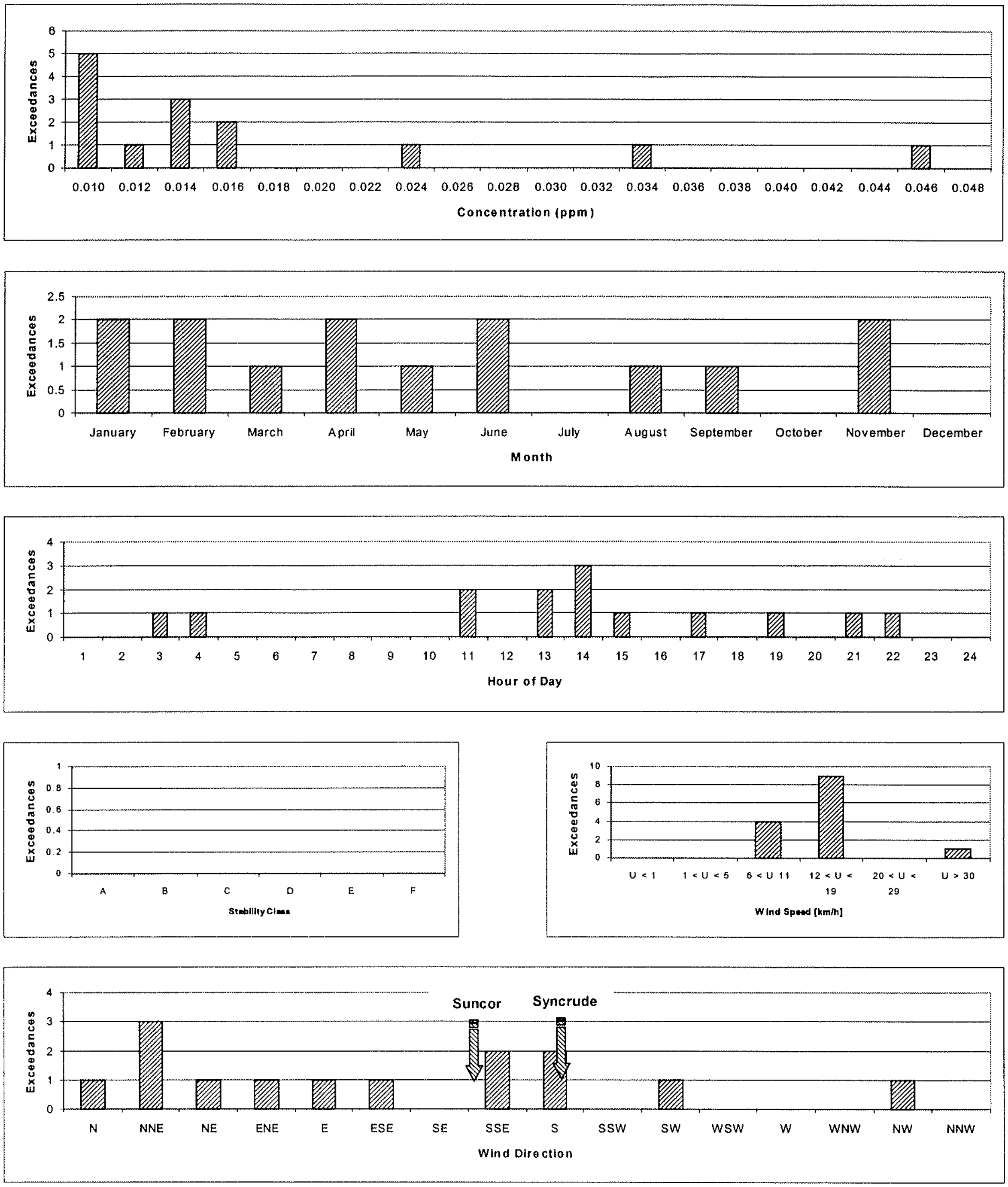


Figure 4-24 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Syncrude AQS5 (Tailings East)

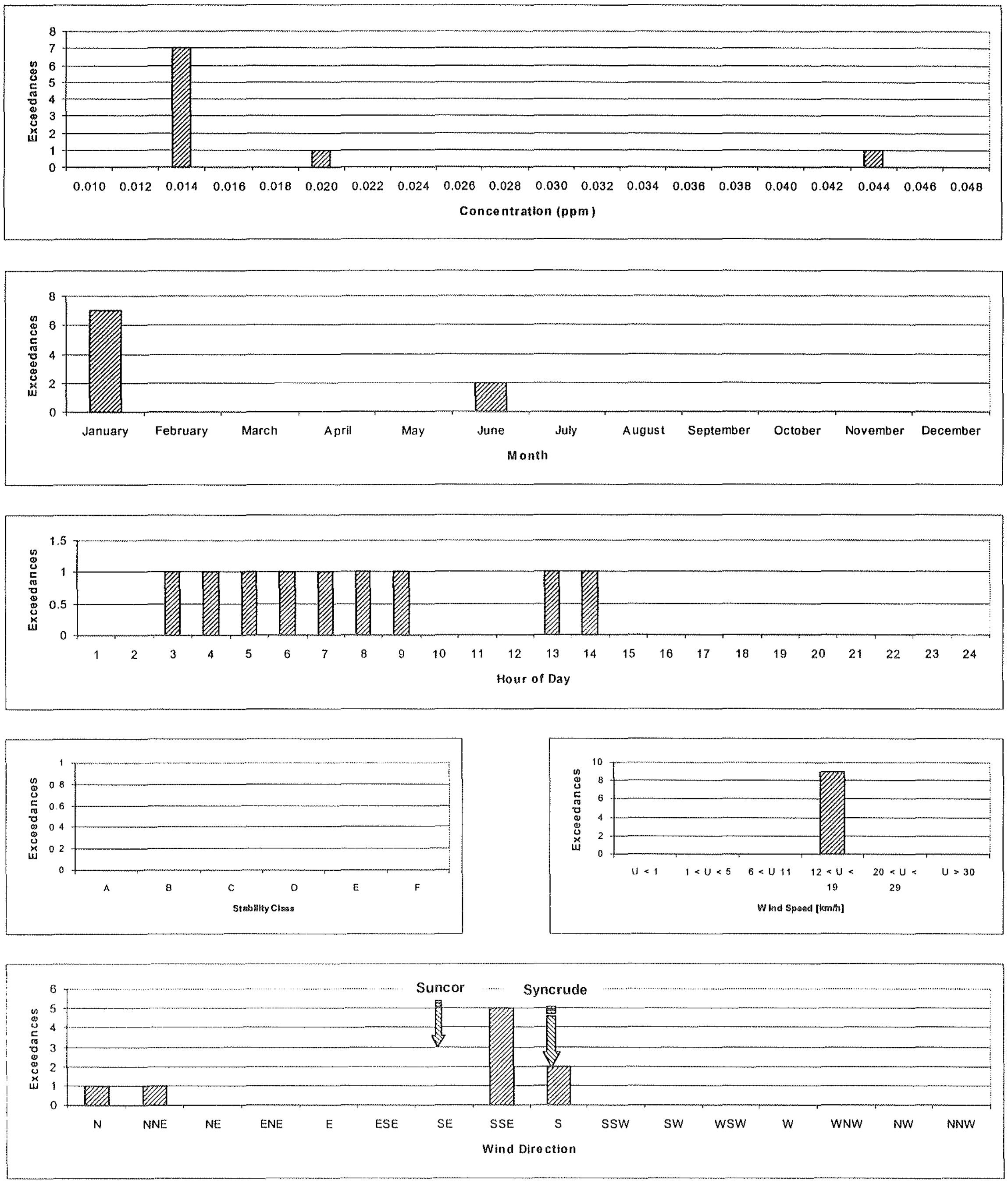


Figure 4-25 **Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Fort McMurray (FMMU)**

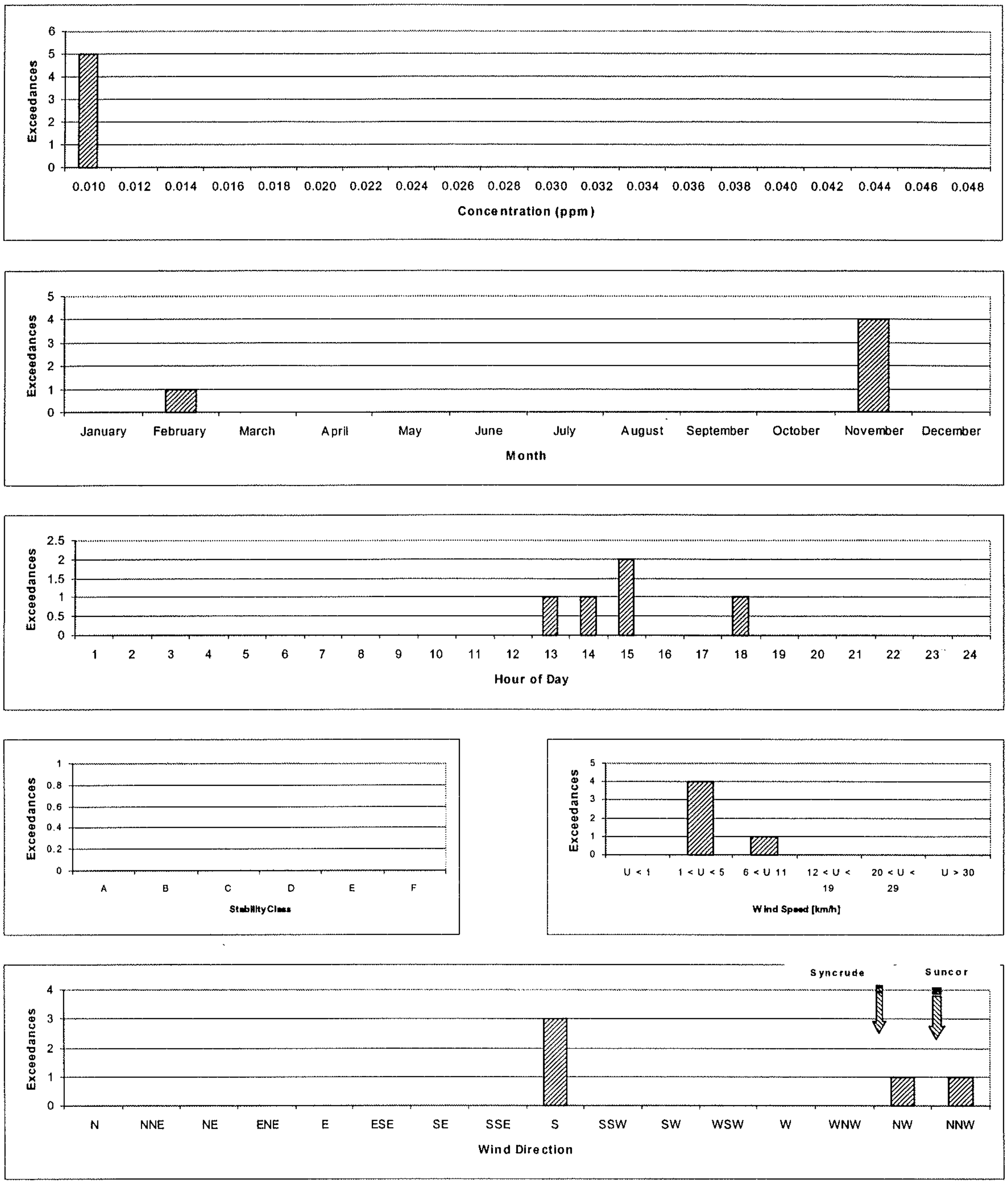
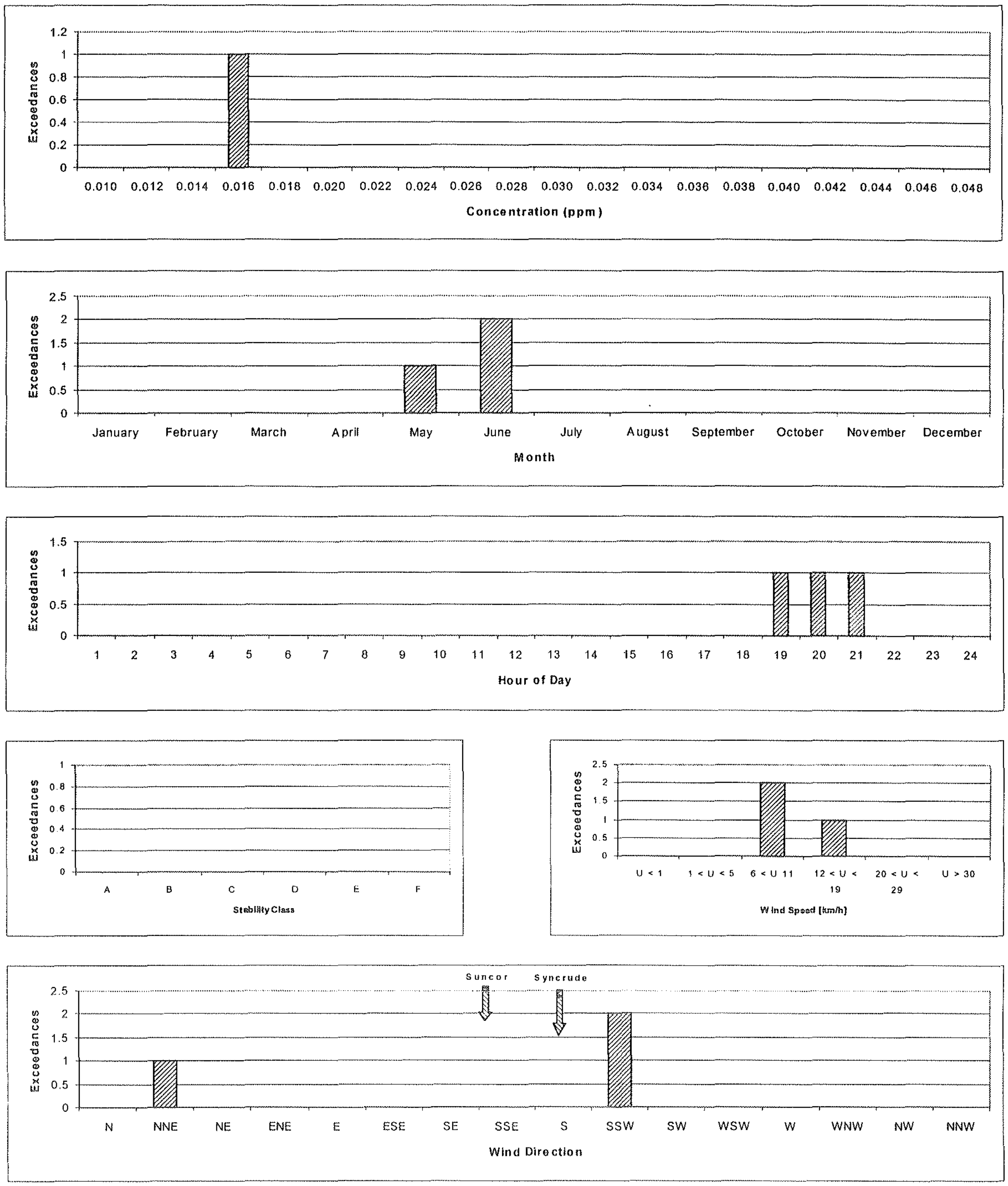


Figure 4-26 Hourly Average H_2S Concentrations Greater Than 0.010 ppm and Associated Conditions at Fort McKay (FRMU)



4.6.3 Special Ambient Monitoring for TRS Compounds

A number of field studies have been conducted in the region to identify and quantify RS emissions and ambient concentrations. Ambient RS emissions are dependent on plant facilities and operating practices. The results presented in this section span more than a decade and as a consequence, some of the earlier measurements may not be representative of the current facilities and operating conditions. Nonetheless, the earlier studies are presented here for the purposes of completeness. For the purposes of presentation, the studies have been grouped according to their sponsors.

4.6.3.1 Alberta Environmental Protection

A mobile air monitoring survey of the Fort McKay - Fort McMurray corridor was conducted in the summer of 1990 during the scheduled Suncor turnaround (Environmental Protection Service 1991). Observations were made prior to shut-down (May 18 to 20: 3 days), during shut-down (May 21 to 24: 4 days), after shut-down (May 28, 29: 2 days), during plant start-up (June 28 to July 10: 8 days) and following plant start-up (July 27 and September 26 to 28: 4 days).

The survey made use of two mobile monitoring units (AQML and BT5). The AQML unit was instrumented to measure CO, H_2S, THC, SO_2, NO_x and O_3. The BT-5 unit was instrumented to measure H_2S, SO_2 and THC. Specific monitoring sites were identified and observations for a minimum of 10 minutes were taken at each site. When elevated concentrations were noted or when odours were observed, whole air samples were collected in Tedlar bags for further speciation.

The report provided a very limited H_2S analyse and one of the conclusions was that the Suncor turnaround "did not appear to be a major impact on regional air quality". While the AEP report was minimal in deriving conclusions, the following are noted:

- The highest H_2S values were observed during the shut-down period; and
- During the mobile monitoring period, odour complaints were received and reviewed. Both Syncrude and Suncor were identified as sources of odourous emissions.

4.6.3.2 Syncrude Canada

Background H_2S observations were collected near the Thickwood Hills forest tower located about 30 km southwest of the oil sands facilities and 30 km northwest of the town of Fort McMurray (Concord Scientific Corporation 1982). Two sites near the Thickwood Hills forest tower were selected, a forest site and a bog site. H_2S levels ranged from 0.03 to

0.50 ppb (0.04 to 0.71 $\mu g/m^3$) at the bog site and from 0.13 to 0.56 ppb (0.18 to 0.78 $\mu g/m^3$) at the forest site. The larger observed values were associated with smoke and haze from forest fires burning in the region. The maximum observed values upwind and downwind of identified plant sources are listed in Table 4-15.

Table 4-15 Maximum Observer Upwind and Downwind H_2S Ambient Concentrations Associated With Syncrude Plant Sources

Source	H_2S (ppb)	H_2S ($\mu g/m^3$)
Recycle Pond	6.2	8.7
Effluent Pond Inlet	30	4.2
Mine Sump Basin	16	2.2
Tailings Pond	0.56	0.78
Coke Cells	0.26	0.36
Coke Settling Basin Inlet	47	66
Sulphur Loading Areas	200	280
API Separator	1.2	1.7
Entire Facility	6.0	8.4

4.6.3.3 Suncor Monitoring

Suncor conducts two fugitive emission surveys per calendar year (one in the spring and the other in the summer) for compounds such as H_2S, TRS, TS and THC. The surveys are conducted using a mobile monitor to collect data in the vicinity of the plant and tailings ponds, and are typically conducted for a 3 to 5 day period. The maximum readings depend upon the operating conditions of the plant, the ability of the operator to find a location downwind of a fugitive source and on the prevailing meteorological conditions during the survey.

Table 4-16 summarizes the maximum one-minute averages observed during each survey. The variability of the maximum values provided in the table does not indicate any clear trends. Perhaps more importantly, the interpretive reports that accompany these surveys indicate in general that the maximum values occur downwind of the inlet to Tailings Pond 1, the tank farms and the plant area.

Table 4-16 Maximum Ambient Concentrations Observed During the Fugitive Emissions Monitoring at the Suncor Plant

Year	Month	H_2S (ppb)	TRS (ppb)	TS (ppb)	Averaging Period (minutes)
1989	September/October	262	208	N/A	15
1990	July	133	N/A	497	15
	September	115	877	1081	15
1991	February	N/A	N/A	N/A	N/A
	August	27	N/A	41	1
1992	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A
1993	April	24	40	N/A	1
	October	124	180	N/A	1
1994	April	93	> 133[a]	N/A	1
	October	45	> 114[a]	N/A	1
1995	N/A	N/A	N/A	N/A	N/A

[a] The inequality indicates that the reading exceeded the maximum range of the analyzer.

4.7 OXIDES OF NITROGEN (NO_X)

The most comprehensive monitoring results for oxides of nitrogen (NO_x) are available for the Syncrude AQS4 (Tailings North) and the AEP Fort McMurray stations. The Syncrude station reports total NO_x while the AEP Fort McMurray station reports NO_x, NO and NO_2.

4.7.1 Comparison to Air Quality Guidelines

For this comparison the Syncrude NO_x data and the AEP NO_x and NO_2 data were compared to the 1-hour Alberta NO_2 air quality objective of 0.21 ppm (400 $\mu g/m^3$).

4.7.2 Trends with Time and Meteorology

To identify trends according to month, time of day, wind speed and wind direction, hourly data when the NO_x concentration exceeded 0.21 ppm were reviewed. NO_x data from AQS4 and Fort McMurray, along with the Fort McMurray NO_2 data are presented in Figures 4-27, 4-28 and 4-29.

Trends from these figures are identified below:

- Higher NO_x concentrations were observed most frequently during the winter (November to February);
- Higher NO_x concentrations occurred most frequently during afternoon and evening hours; and

Figure 4-27 Hourly Average NO_x Concentrations Greater Than 0.21 ppm and Associated Conditions at AQS4

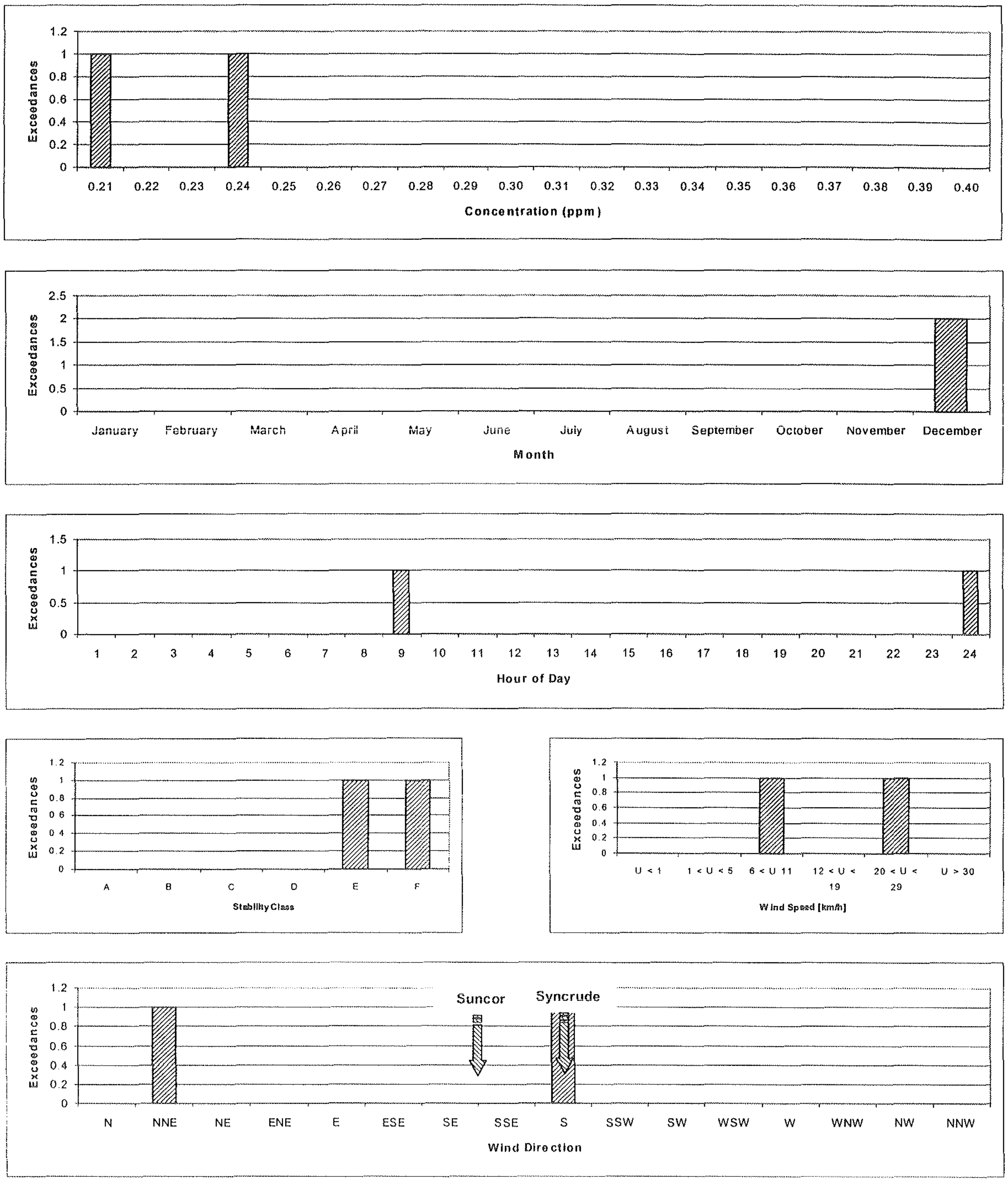


Figure 4-28 Hourly Average NO_x Concentrations Greater Than 0.21 ppm and Associated Conditions at AEP Fort McMurray

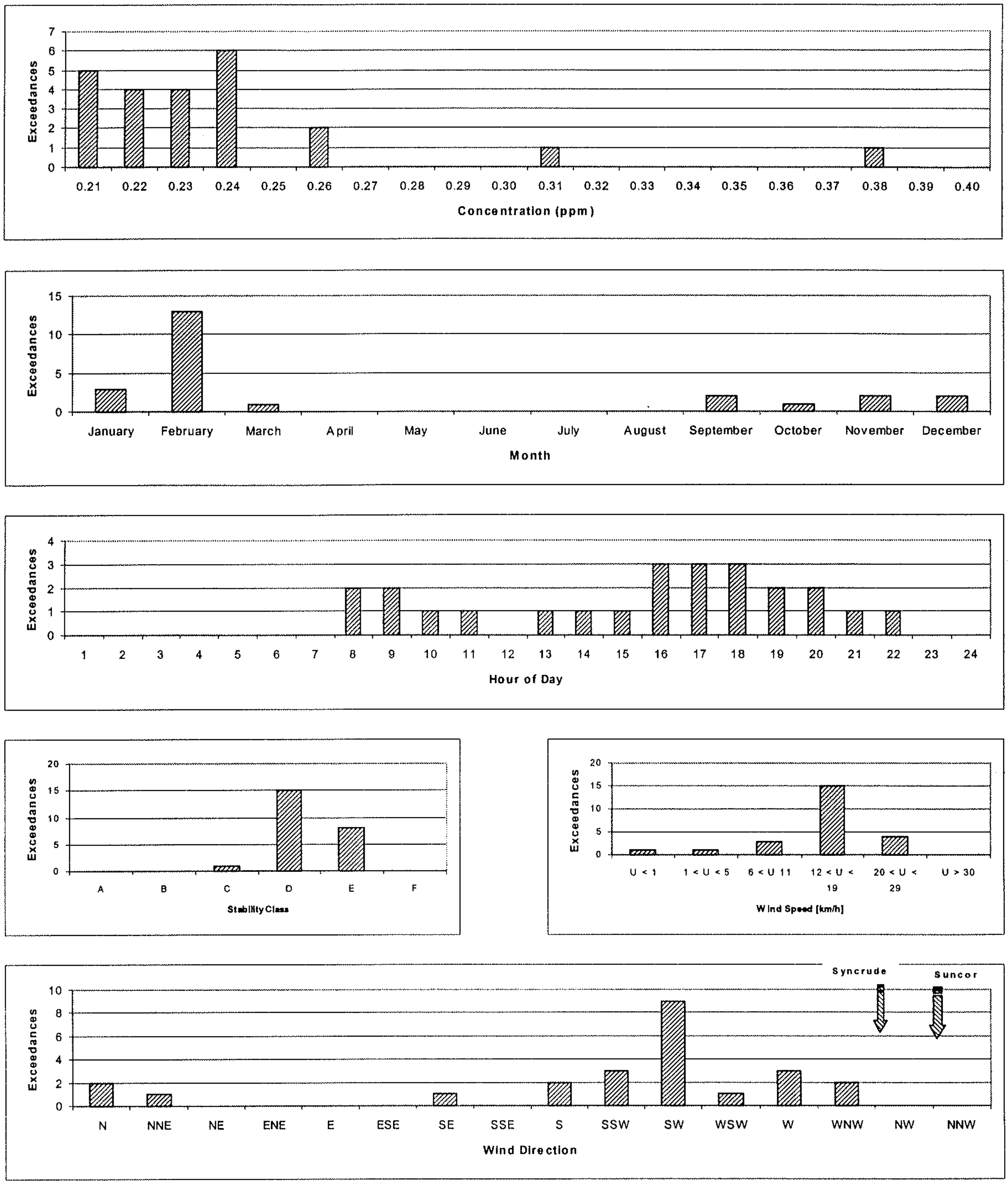
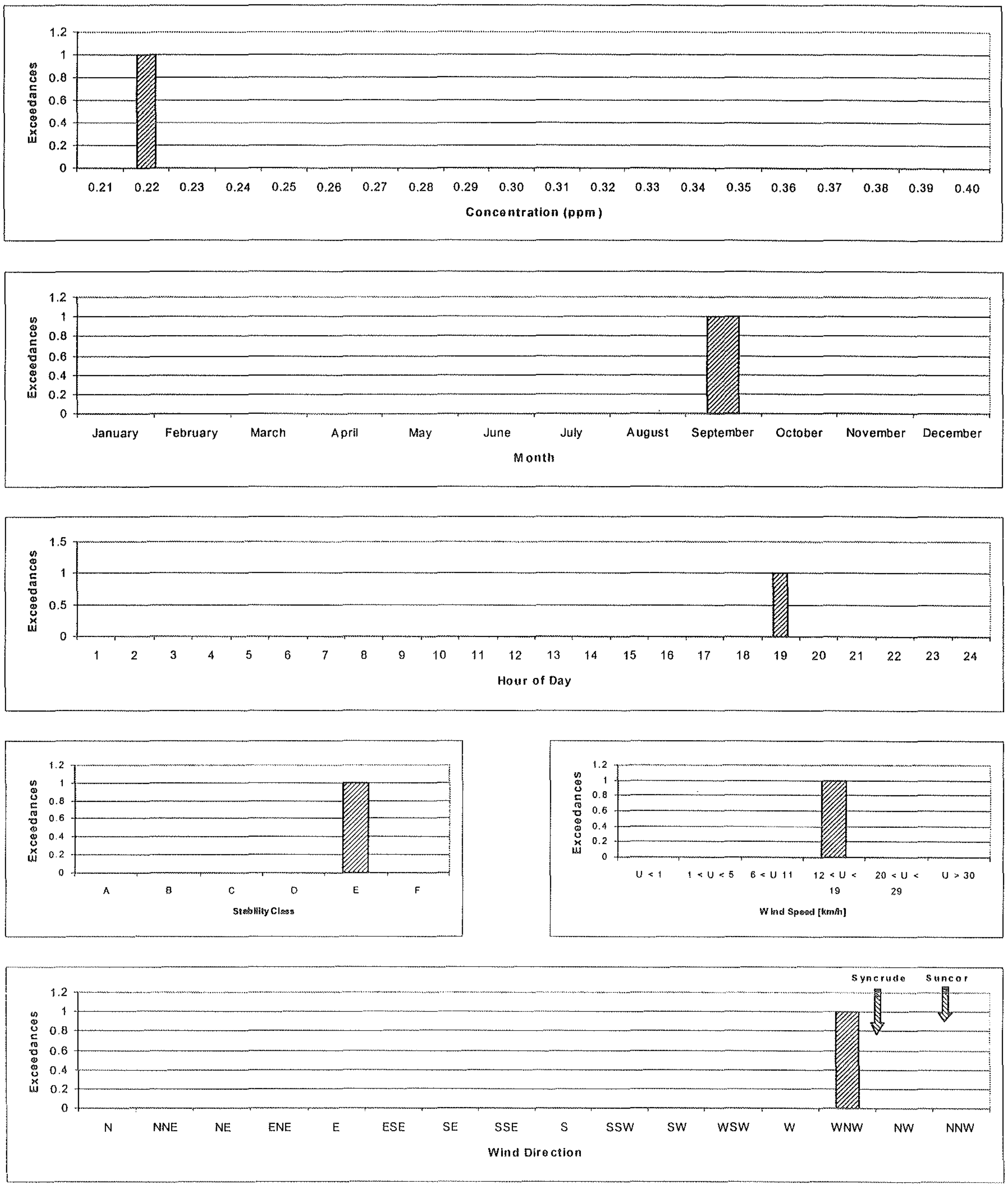


Figure 4-29 Hourly Average NO_2 Concentrations Greater Than 0.21 ppm and Associated Conditions at AEP Fort McMurray



- In summary, maximum NO_x concentrations are likely associated with emissions from residential wood combustion and/or local traffic within Fort McMurray.

4.7.3 NO_x and NO_2 Relationships

The ambient concentrations of nitrogen dioxide (NO_2) are of the greatest interest when modelling emissions of NO_x. However, the majority of models are not able to perform the necessary chemical transformations to calculate the NO_2 values directly.

Using the observed data in the vicinity of the Syncrude north mine pit, Conor Pacific (1998) established a ratio between the measured NO_x and NO_2 concentrations. In general, it was noted that the NO_2 accounted for nearly 80% of the measured NO_x when the NO_x concentrations were relatively low (i.e. <0.05 ppm). At relatively large NO_x concentrations (i.e., >0.5 ppm) the NO_2 concentrations were about 13% of the NO_x concentrations.

Conor Pacific (1998) suggested an empirical formulation to calculate the ambient NO_2 concentrations, given a predicted value of NO_x. This formulation is listed below.

$$NO_2 = 0.10 \times NO_X{}^{0.392}$$

4.7.4 Background Concentrations of Nitogen Compounds

Once in the atmosphere, NO is readily oxidized to form NO_2. These gases can in turn be transformed into gaseous nitric acid (HNO_3), ammonium particles (NH_4^+) and nitrate particles (NO_3^-). Typical background levels of NO and NO_2 are low as these compounds readily react with ambient ozone (O_3) and methane (CH_4) to form HNO_3. The background levels of NO_x (NO, and NO_2) range from 10 to 15% of the total airborne nitrogen compounds in background areas to as much as 60% near to combustion sources (Ridley, 1991). Table 4-17 summarizes the observed concentrations of the nitrogen compounds at the available background sites.

Table 4-17 Background HNO_3, NH_4^+ and NO_3^- Concentrations Applicable to the Study Area

Site	HNO_3		NH_4^+	NO_3^-
	(μg/m³)	(ppb)	(μg/m³)	(μg/m³)
Hightower Ridge (1986)	0.10	0.27	0.18	0.09
Fortress Mountain (1985 to 1987)	0.11	0.31	—	0.13
Cree Lake (1988 to 1995)	0.06	0.15	0.20	0.05
Average	**0.10**	**0.23**	**0.19**	**0.09**

Another important nitrogen based compound in the atmosphere is ammonia (NH_3). In Alberta, Fort Saskatchewan is the only station at which ammonia is monitored on a regular basis. The available concentrations of the NH_3 observed at this monitoring station have been summarized in Table 4-18. The overall average ammonia concentration observed for the period from 1996 to 1997 was 1.146 $\mu g/m^3$, which will be assumed to represent the background levels in the study area.

In summary, higher NO_x concentrations are observed in Fort McMurray than near Fort McKay (Syncrude AQS4; Tailings North). The high concentrations observed in Fort McMurray are likely associated with local traffic. At the monitoring locations, it is unlikely that adverse synergistic effects to vegetation could result from simultaneous exposures to both SO_2 and NO_2.

4.8 OZONE (O_3)

Ozone concentrations are only measured at the AEP Fort McMurray station. The tables and figures in this section are based on computer databases provided by Alberta Environmental Protection (AEP). Some discrepancies between values provided in the supplied computer database files and those contained in the annual reports were found.

4.8.1 Comparison to Air Quality Guidelines

Hours when the hourly average O_3 concentration exceeded 0.082 ppm (160 $\mu g/m^3$ or 82 ppb) and all days when the daily average O_3 concentration exceeded 0.025 ppm (50 $\mu g/m^3$ or 25 ppb) at the Fort McMurray monitoring station were identified. Table 4-19 shows the observed number of exceedances in Fort McMurray. The results indicate the mean and median O_3 values are 23 and 21 ppb, respectively. Maximum hourly values range from 58 to 91 ppb over the period January 1990 to August 1997. There have been 20 exceedances (annual average = 2.5) of the AEP 1-hour guideline of 82 ppb since 1990. Maximum daily values ranged from 43 to 68 ppb. The average number of days when the daily average O_3 concentration exceeded 25 ppb is 135 days per year. Exceedances of the daily ozone guideline have been observed 50 to 90% of the time in rural areas in Alberta, compared to 10 to 40% of the time in urban areas (Angle and Sandhu 1989).

Table 4-18 Background Ammonia (NH_3) Concentrations From Fort Saskatchewan

Hour of Day	1996		1997		Average
	($\mu g/m^3$)	(ppm)	($\mu g/m^3$)	(ppm)	($\mu g/m^3$)
00:00 to 00:59	0.696	0.001	0.696	0.001	0.696
01:00 to 01:59	1.392	0.002	0.696	0.001	1.044
02:00 to 02:59	1.392	0.002	0.696	0.001	1.044
03:00 to 03:59	0.696	0.001	0.696	0.001	0.696
04:00 to 04:59	0.696	0.001	0.696	0.001	0.696
05:00 to 05:59	0.696	0.001	0.696	0.001	0.696
06:00 to 06:59	0.696	0.001	0.696	0.001	0.696
07:00 to 07:59	1.392	0.002	0.696	0.001	1.044
08:00 to 08:59	1.392	0.002	0.696	0.001	1.044
09:00 to 09:59	2.088	0.003	0.696	0.001	1.392
10:00 to 10:59	2.088	0.003	0.696	0.001	1.392
11:00 to 11:59	2.088	0.003	1.392	0.002	1.740
12:00 to 12:59	2.088	0.003	1.392	0.002	1.740
13:00 to 13:59	2.784	0.004	1.392	0.002	2.088
14:00 to 14:59	2.088	0.003	1.392	0.002	1.740
15:00 to 15:59	2.088	0.003	0.696	0.001	1.392
16:00 to 16:59	2.088	0.003	0.696	0.001	1.392
17:00 to 17:59	2.088	0.003	0.696	0.001	1.392
18:00 to 18:59	1.392	0.002	0.696	0.001	1.044
19:00 to 19:59	1.392	0.002	0.696	0.001	1.044
20:00 to 20:59	1.392	0.002	0.696	0.001	1.044
21:00 to 21:59	1.392	0.002	0.696	0.001	1.044
22:00 to 22:59	0.696	0.001	0.696	0.001	0.696
23:00 to 23:59	0.696	0.001	0.696	0.001	0.696
Average	**1.479**	**0.002**	**0.812**	**0.001**	**1.146**

Table 4-19 Summary of Hourly and Daily O_3 Concentrations Observed at Fort McMurray

Station	1990	1991	1992	1993	1994	1995	1996	1997[a]	1990-1997
Hourly Statistics									
Mean (ppb)	25	22	21	22	24	25	18	21	23
Median (ppb)	22	21	20	21	22	23	17	20	21
Maximum (ppb)	89	65	59	91	77	71	58	61	91
N ≥ 82 ppb (h/y)	16	0	0	4	0	0	0	0	2.5
Daily Statistics									
Mean (ppb)	25	22	21	22	24	25	18	21	23
Median (ppb)	23	22	21	21	23	25	17	21	22
Maximum (ppb)	68	43	43	54	58	50	44	44	68
N ≥ 25 (ppb) (d/y)	156	131	91	127	153	86	98	86	135

[a] Up to August 30, 1997.

4.8.2 Trends with Time and Meteorology

There were no exceedances of ozone guideline value of 82 ppb during the period from November 1, 1993 through October 31, 1997.

4.8.3 Background Ozone Concentrations

Over the period from 1977 to 1980, background ozone concentrations were monitored by the Alberta Oil Sands Environmental Research Program (AOSERP) at stations located at Birch Mountain and Bitumount. The results of this monitoring program indicate that the ozone concentrations were higher than those observed in Fort McMurray between 1990 and 1997. The higher values observed at these stations have been associated with periods when the ozone precursor (NO_x and VOC) emissions were at their lowest levels. This suggests that the elevated ozone concentrations could be associated with natural processes.

Observations of background ozone concentrations have also been made at other remote locations in Alberta. At Fortress Mountain (1985 to 1987) a maximum value of 122 ppb and an average concentration 43 ppb were recorded; at High Tower Ridge (1996 to 1997) a maximum concentration of 88 ppb and an average of 40 ppb were recorded; while at Beaverlodge (1997) the maximum and average concentrations were 46 ppb and 25 ppb, respectively.

4.9 CARBON MONOXIDE (CO)

Carbon monoxide concentrations are measured only at Fort McMurray. The discussion in this section is based on computer databases provided by Alberta Environmental Protection (AEP).

4.9.1 Comparison to Air Quality Guidelines

The maximum hourly average value observed at Fort McMurray for the period November 1, 1993 to October 31, 1997 is 5.9 ppm (6,807 $\mu g/m^3$). The maximum values are much less than the one-hour average guideline value of 13 ppm (15,000 $\mu g/m^3$) for CO.

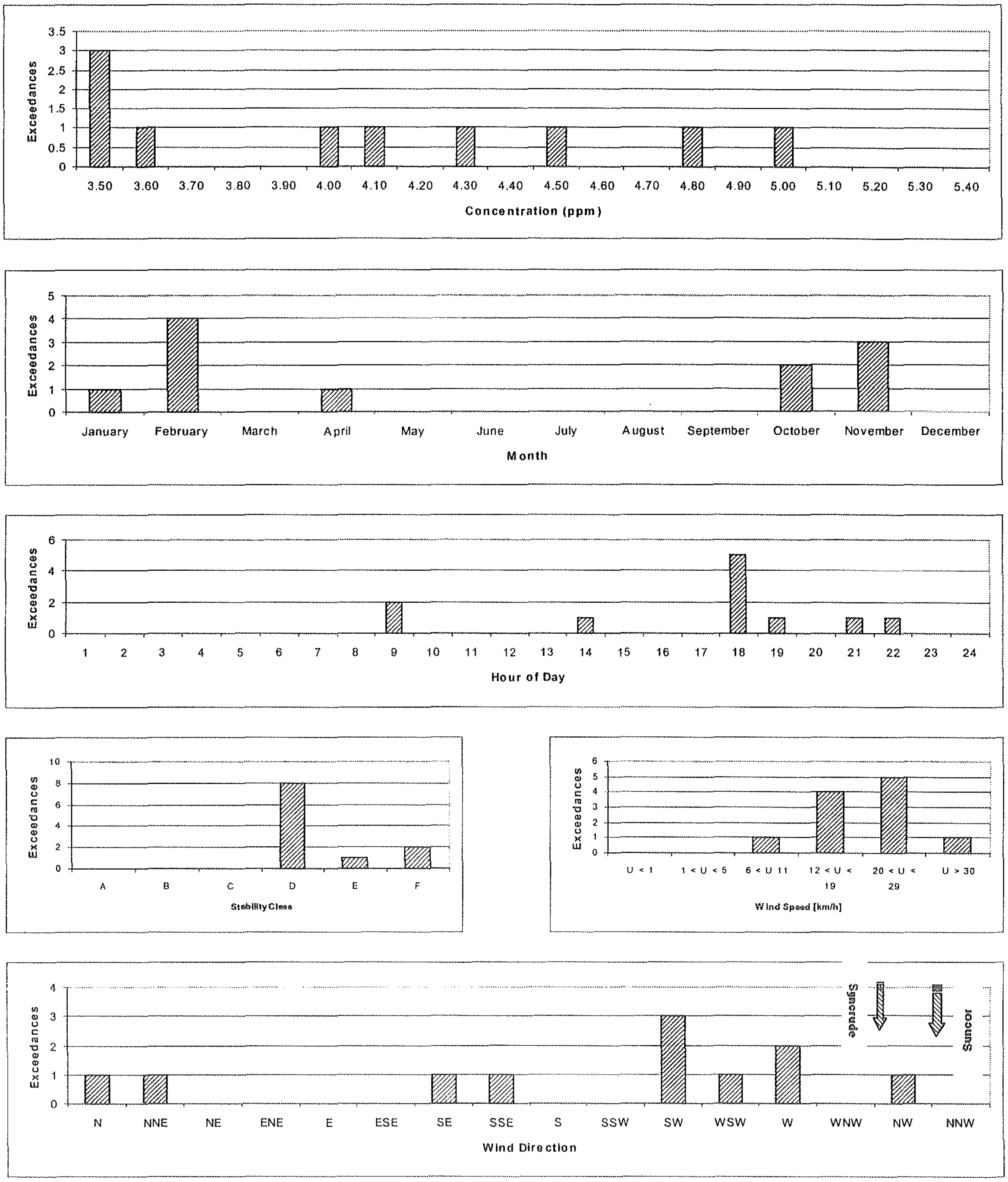
4.9.2 Trends with Time and Meteorology

Hours when the CO concentration exceeded 3.5 ppm were classified according to magnitude, month, time of day, wind speed and wind direction to help identify trends. The analysis which is presented in Figure 4-30 indicates:

- Higher CO concentrations are associated with the months October to March;
- Higher CO concentrations are associated with hours 9 to 23;
- Higher CO concentrations are associated with light wind speeds of 1 to 6 km/h (0.3 to 1.7 m/s); and
- Higher CO concentrations are associated with easterly and southerly wind directions.

Some of the trends associated with CO are similar to those associated with NO_x; there is a tendency for high levels to be observed during the winter period, under low wind speeds and in association with winds from the easterly and southerly directions. Both high NO_x and CO concentrations tend to occur during the evening hours rather than the morning hours. This may suggest that residential wood combustion (during winter evenings) is the potential source for these high values..

Figure 4-30 Hourly Average CO Concentrations Greater Than 3.5 ppm and Associated Conditions Observed at Fort McMurray.



4.10 HYDROCARBON (THC) AND VOLATILE ORGANIC COMPOUNDS (VOC)

Total hydrocarbon (THC) data are available from two Syncrude stations, four Suncor stations and the two AEP stations. Hydrocarbon emissions are an air quality concern since many of the constituents are ozone precursor chemicals. However, not all of the hydrocarbons are reactive in the atmosphere. The term volatile organic compounds (VOC), describes those species considered to be precursor chemicals. Since the most notable non-reactive chemical is methane (CH_4), it is common to exclude methane from the ambient hydrocarbon readings (NMHC) as an approximation of the ambient VOC levels. The ambient measurements of total hydrocarbon (THC), then, includes methane (CH_4) as well as non-methane (NMHC) components.

4.10.1 Maximum HC Values

There are no air quality guidelines for either the THC, CH_4 or NMHC components. Table 4-20 shows the median and maximum THC concentrations observed in the region. The median values range from 1.4 to 2.2 ppm. The median observed values are similar at each of the six stations. In general, maximum observed THC concentrations are in the 3 to 15 ppm range, however, five of the reported maxima are in excess of 30 ppm. Maximum THC values in excess of 15 ppm were reported at the Poplar Creek, Athabasca Bridge and Tailings North (AQS4) monitoring stations.

Table 4-20 Median and Maximum Observed THC Concentrations (ppm)

		Poplar Creek (#9)	Athabasca Bridge (#10)	AQS2 (Fort McMurray)	AQS4 (Tailings North)	Fort McMurray (FMMU)	Fort McKay (FRMU)
Median	1993	1.7	1.9	1.6	1.8	2.0	1.8
	1994	1.5	1.6	1.4	1.5	2.2	1.7
	1995	1.7	n/d[(a)]	1.6	1.7	2.0	1.6
	1996	1.7	n/d[(a)]	2.0	1.7	2.2	1.8
	1997	1.7	n/d[(a)]	n/d[(a)]	1.9	2.1	1.6
Maximum	1993	51.4	35.0	3.3	5.7	3.2	3.6
	1994	11.1	13.7	4.6	4.3	3.7	3.3
	1995	35.0	n/d[(a)]	6.1	14.6	3.2	8.3
	1996	35.0	n/d[(a)]	3.4	16.2	3.8	3.9
	1997	35.0	n/d[(a)]	n/d[(a)]	7.5	3.2	4.7

[(a)] No data.

4.10.2 Trends with Time and Meteorology

Hours when THC values exceeded 3.0 ppm were classified according to month, time of day, wind speed and wind direction to identify trends. The analysis is presented on a station-by-station basis in the following figures:

- Figure 4-31 Suncor Mannix (#2)
- Figure 4-32 Suncor Lower Camp (#4)
- Figure 4-33 Suncor Poplar Creek (#9)
- Figure 4-34 Suncor Athabasca Bridge (#10)
- Figure 4-35 Syncrude AQS2 (Fort McMurray)
- Figure 4-36 Syncrude AQS4 (Tailings North)
- Figure 4-37 AEP Fort McMurray (FMMU)
- Figure 4-38 AEP Fort McKay (FRMU)

The trends depicted in the figures are summarized below:

- THC concentrations in excess of 3 ppm are associated with all months of the year;
- THC concentrations greater than 3 ppm occur during all hours of the day;
- THC concentrations greater than 3 ppm are associated with a range of wind speeds from 1 km/h up to 27 km/h; and
- The wind direction distributions for THC concentrations greater than 3 ppm indicate sources to be the oil sands plants and the town sites of Fort McMurray and Fort McKay.

Figure 4-31 Hourly Average THC Concentrations Greater Than 3 ppm and Associated Conditions at the Suncor Mannix (#2) Station

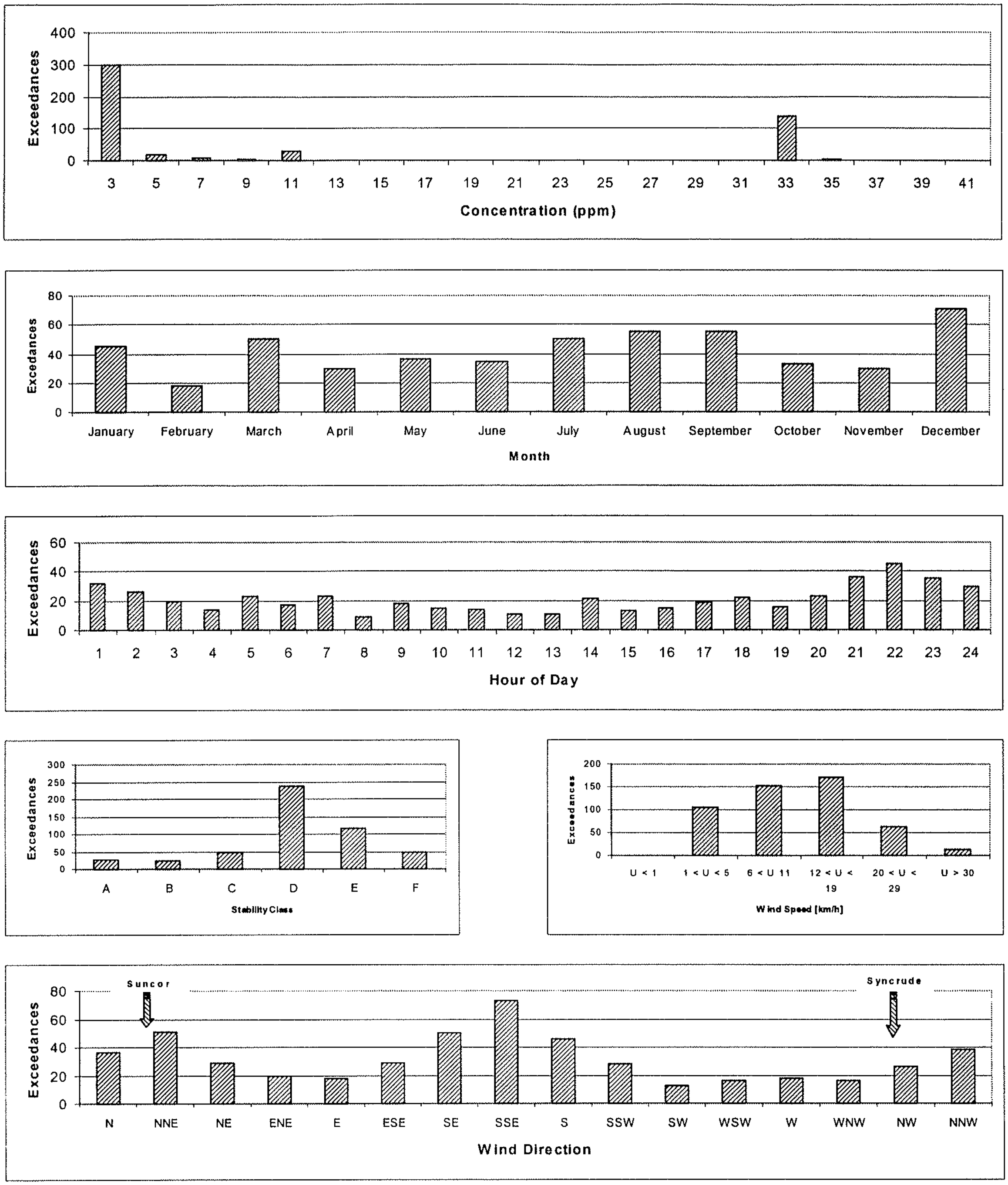


Figure 4-32 Hourly Average THC Concentrations Greater Than 3 ppm and Associated Conditions at the Suncor Lower Camp (#4) Station

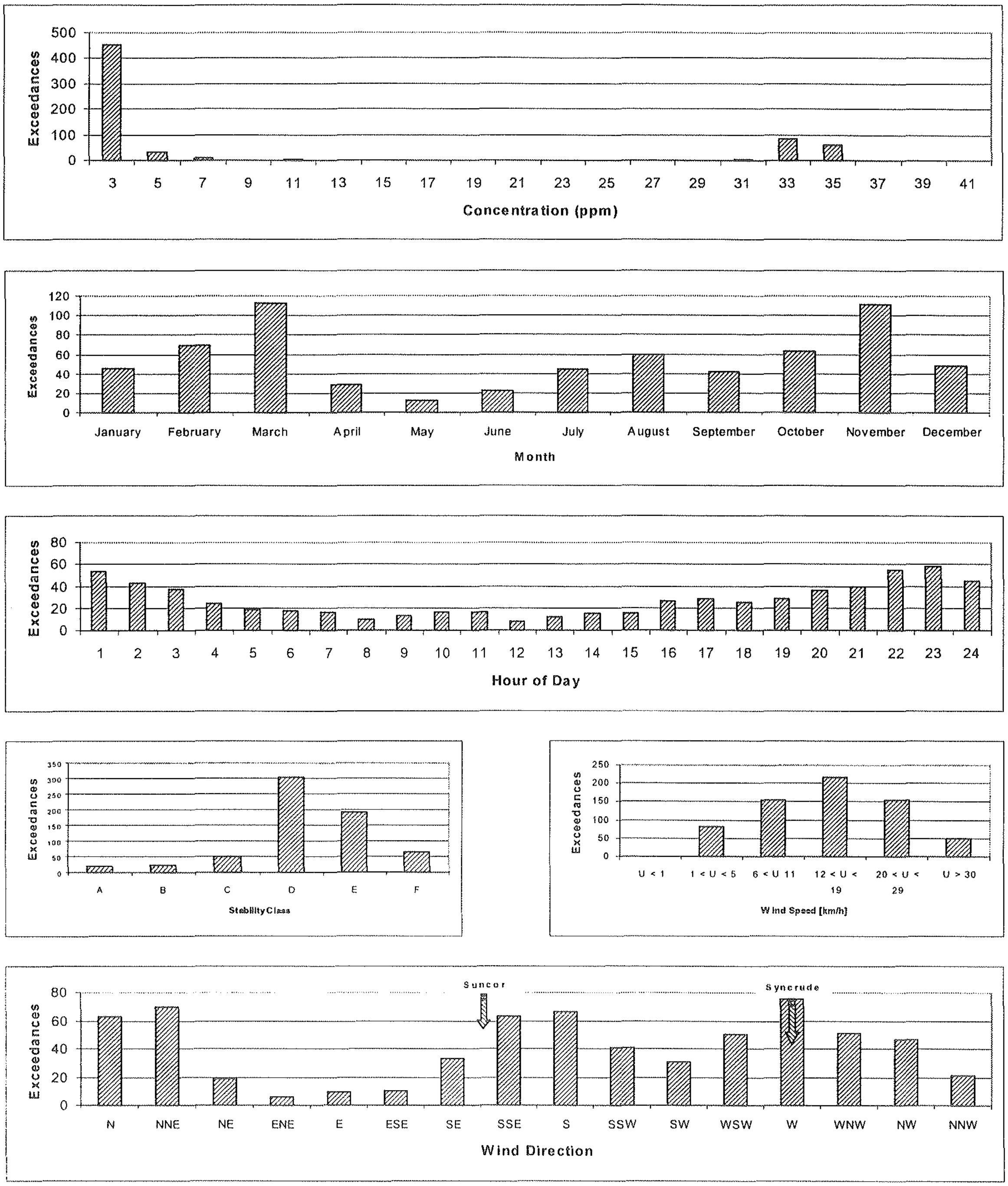


Figure 4-33 Hourly Average THC Concentrations Greater Than 3 ppm and Associated Conditions at the Suncor Poplar Creek (#9) Station

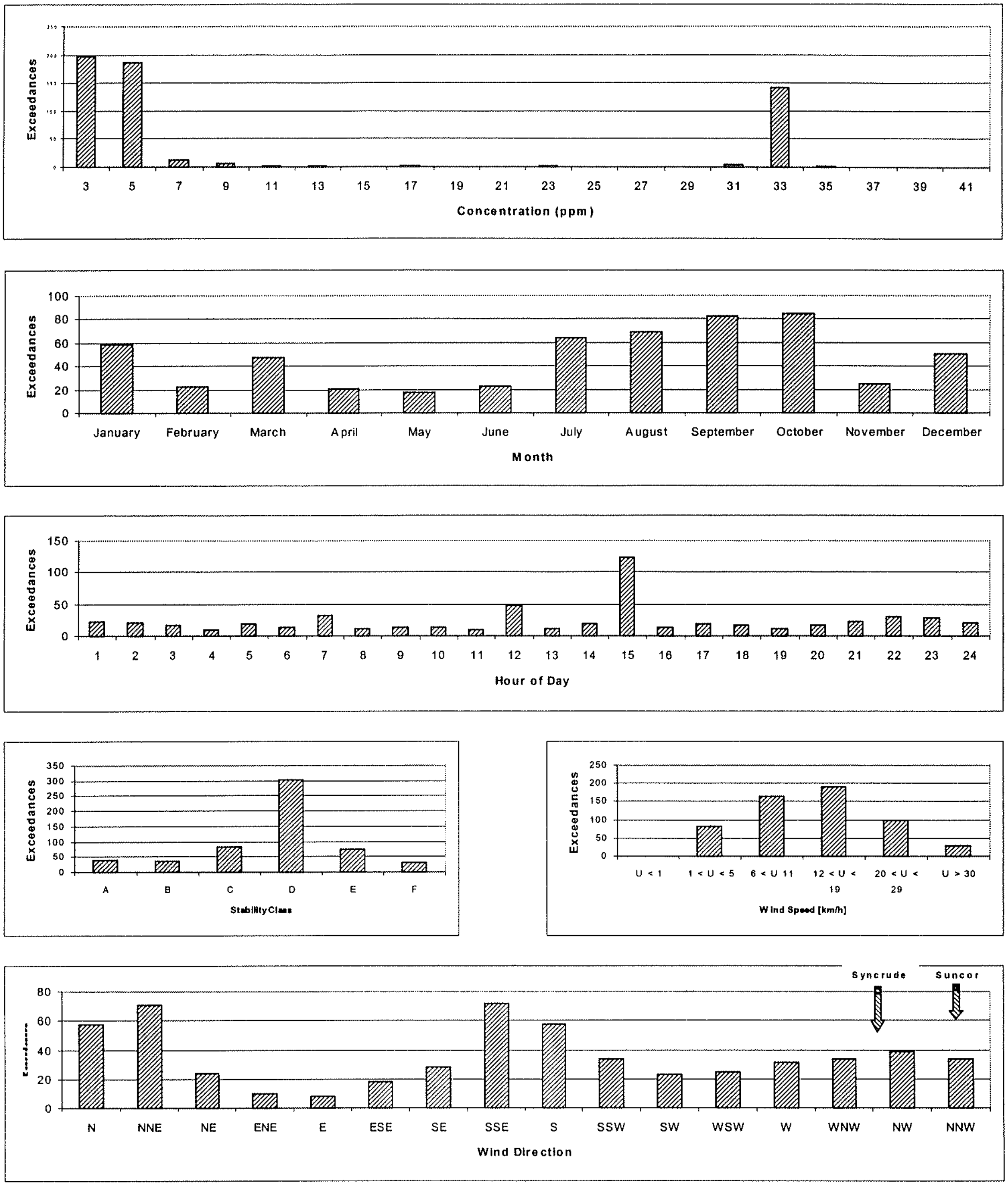


Figure 4-34 Hourly Average THC Concentrations Greater Than 3 ppm and Associated Conditions at the Suncor Athabasca Bridge (#10) Station

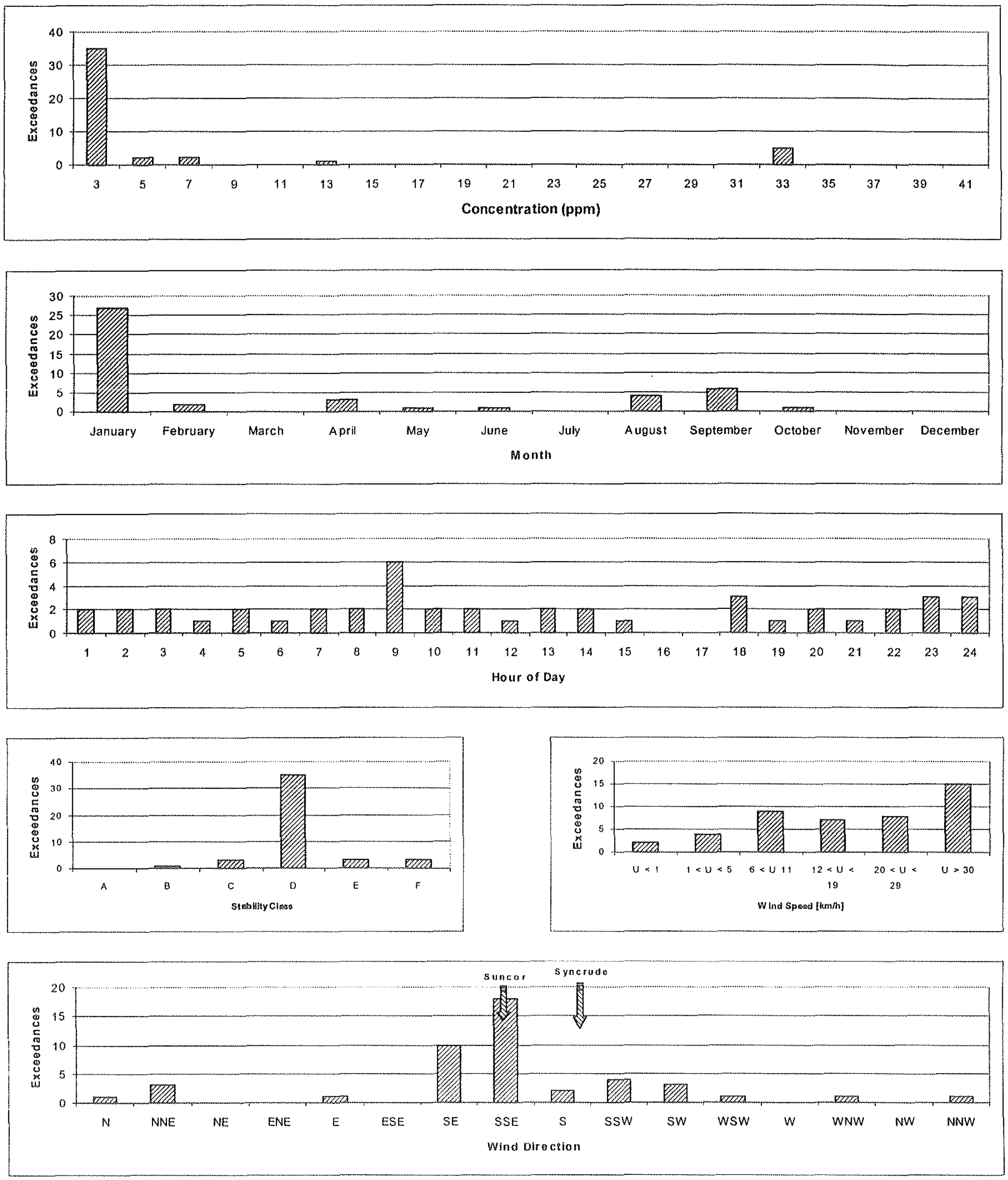


Figure 4-35 Hourly Average THC Concentrations Greater Than 3 ppm and Associated Conditions at the Syncrude AQS2 (Fort McMurray) Station

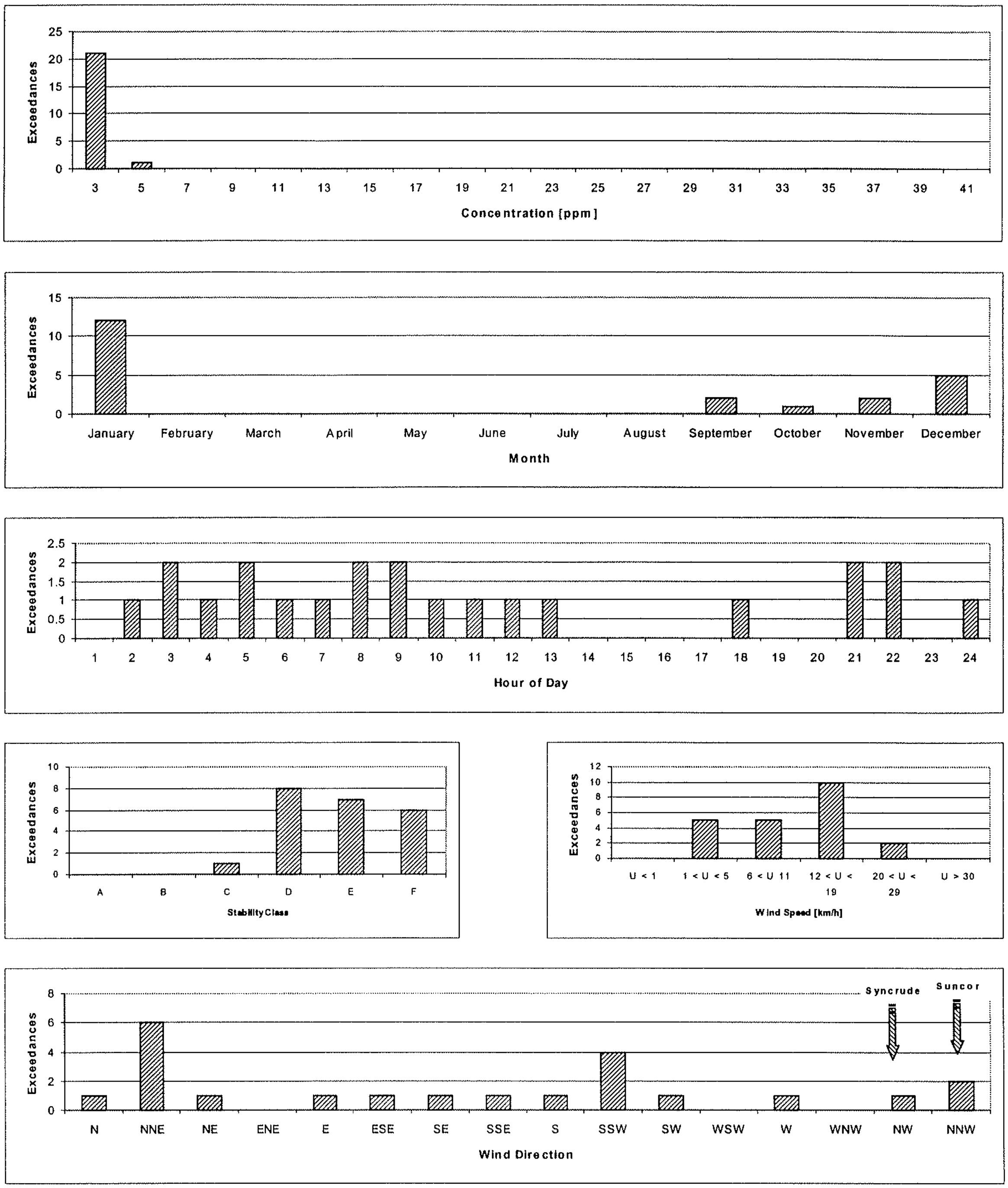


Figure 4-36 Hourly Average THC Concentrations Greater Than 3 ppm and Associated Conditions at the Syncrude AQS4 (Tailings North) Station

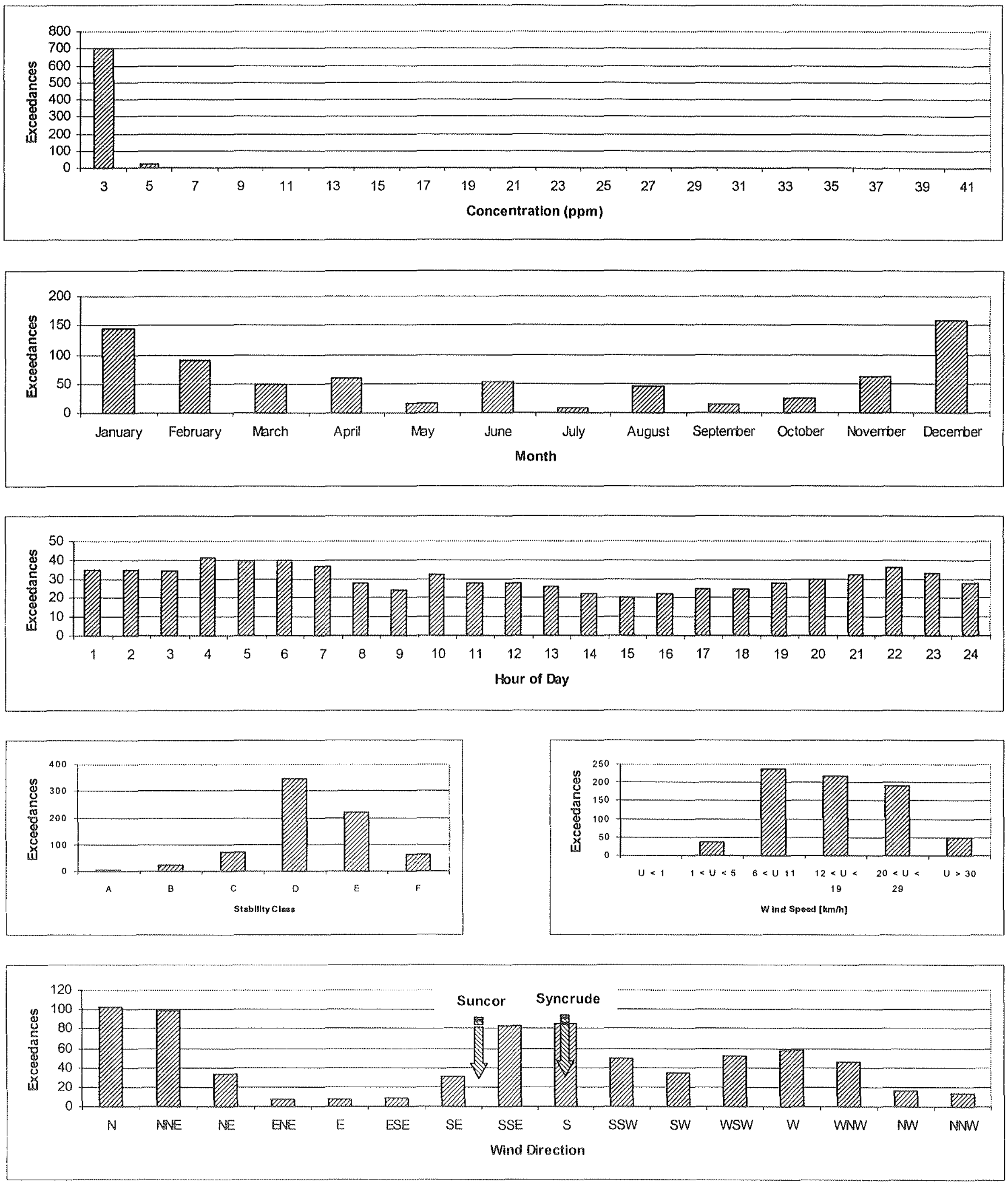


Figure 4-37 Hourly Average THC Concentrations Greater Than 3 ppm and Associated Conditions at the AEP Fort McMurray (FMMU) Station

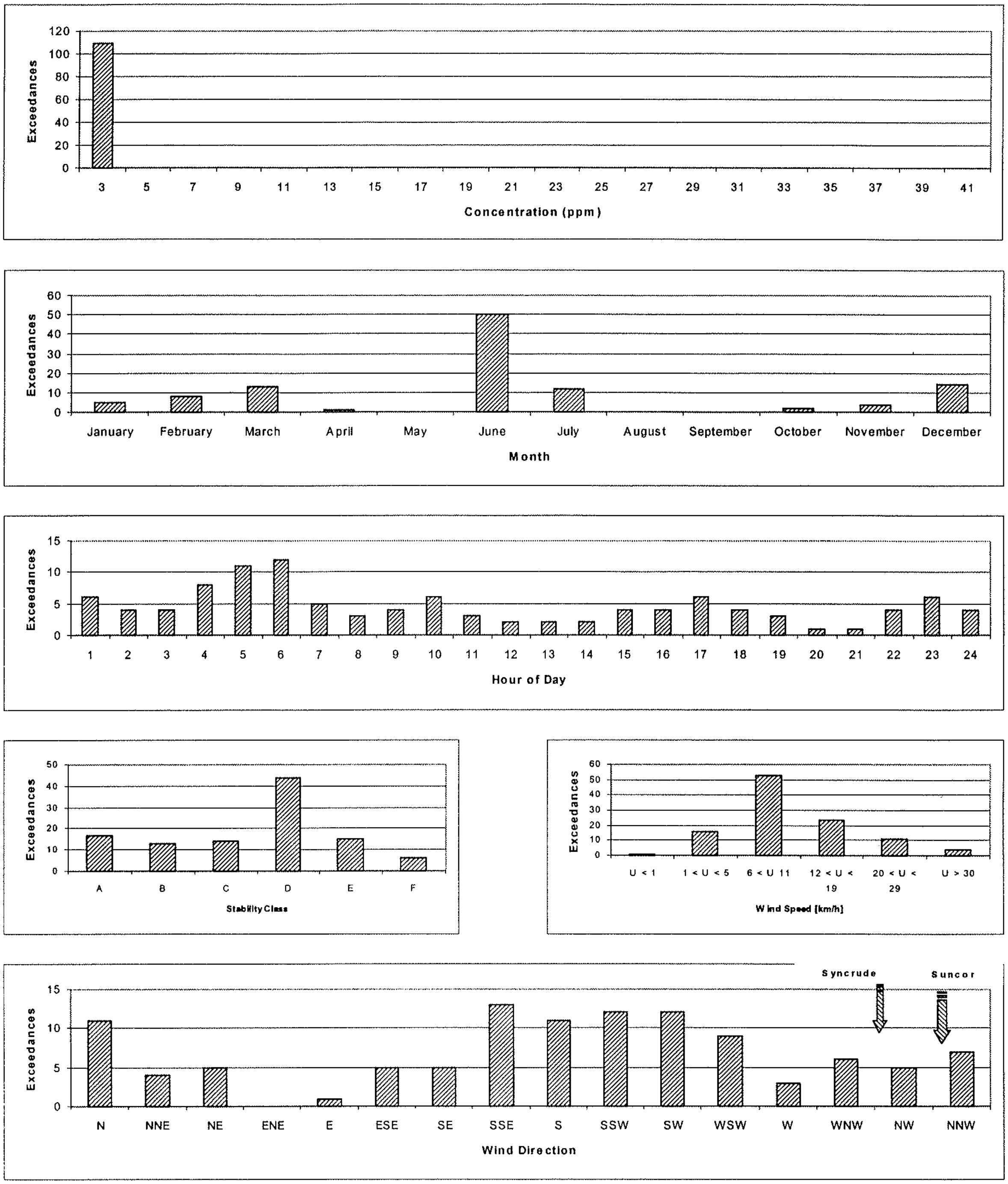
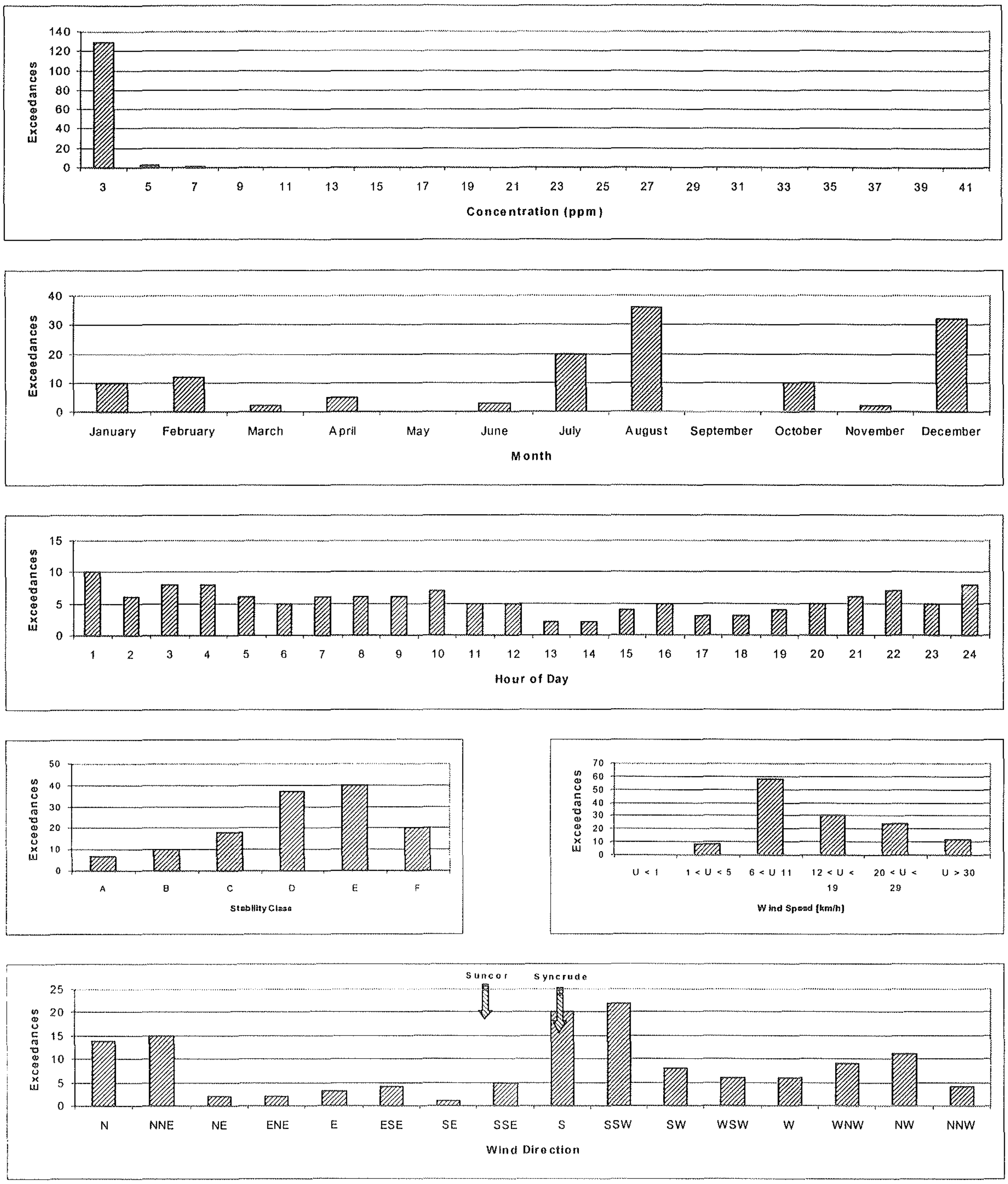


Figure 4-38 Hourly Average THC Concentrations Greater Than 3 ppm and Associated Conditions at the AEP Fort McKay (FRMU) Station



4.10.3 Background Hydrocarbon Concentrations

Most of the ambient THC is expected to be in the form of methane. For the purposes of providing a background comparison, the maximum and average methane concentrations observed during 1996 in the West Central Alberta Airshed (readings from Violet Grove, near Drayton) were 4.5 and 2.0 ppm, respectively. Typical atmospheric levels of methane are 1.7 ppm (e.g., Ahrens 1994). The maximum and average NMHC concentrations observed at Violet Grove were 4.6 and 0.02 ppm, respectively.

4.10.4 Special Ambient THC Monitoring

A number of field studies have been conducted in the region to identify and quantify THC emissions and ambient concentrations. Ambient THC emissions are dependent on plant facilities and operating conditions. The results presented in this section span more than a decade and as a consequence, some of the earlier measurements may not be representative of the current facilities and operating conditions. Nonetheless, the earlier studies are presented here for the purposes of completeness. For the purposes of presentation, the studies have been grouped according to their sponsors.

4.10.4.1 Alberta Environmental Protection

A mobile air monitoring survey of the Fort McKay - Fort McMurray corridor was conducted in the summer of 1990 during the scheduled Suncor turnaround (Environmental Protection Service 1991). Observations were made prior to shut-down (May 18 to 20: 3 days), during shut-down (May 21 to 24: 4 days), after shut-down (May 28, 29: 2 days), during plant start-up (June 28 to July 10: 8 days) and following plant start-up (July 27 and September 26 to 28: 4 days).

The survey made use of two mobile monitoring units. The AQML unit was instrumented to measure CO, H_2S, THC, SO_2, NO_x and O_3. The BT-5 unit was instrumented to measure H_2S, SO_2 and THC. Specific monitoring sites were identified and observations for a minimum of 10 minutes were taken at each site. When elevated concentrations were noted or when odours were observed, whole air samples were collected in Tedlar bags for further speciation.

The report provided a very limited analysis and one of the conclusions was that the Suncor turnaround "did not appear to be a major impact on regional air quality". While the AEP report was minimal in deriving conclusions, the following are noted:

- Relatively high THC values (greater than 20 ppm) were observed within both the Suncor (upgrading, tank farm, Pond 1 and API pond road) and Syncrude (effluent pond, extraction and API) facilities.
- THC values more distant from the two oil sands facilities were typically in the 1.5 to 3 ppm range although values of up to 9 ppm were observed. These latter high values were associated with highway traffic.
- On one occasion, high THC (greater than 20 ppm) appeared to be associated with a flaring event. This occurrence was also accompanied by high CO values which would suggest incomplete hydrocarbon combustion.

Tedlar bag samples were collected in the vicinity of the Suncor tailings Pond 1 (7 samples), the Suncor API (2 samples) and the Suncor north tank farm (2 samples). Additional samples were collected to characterize the Suncor Naphtha Recovery Unit and the Syncrude diverter stack emissions. Summaries of the average ambient concentrations observed in the vicinity of the Suncor tailings pond, API and north tank farm (NTF) are presented in Table 4-21. The ambient concentration information presented in the table occur in locations in the plant area where high values were observed. During post start-up operations, significantly higher concentrations were observed in the vicinity of the Suncor Pond 1 than during other periods. It is likely these values were obtained adjacent to an outfall and are more representative of source conditions rather than general conditions along the pond perimeter.

4.10.4.2 Syncrude Canada

The following studies have been conducted in the vicinity of the Syncrude facility:

- Ambient HC and RS measurements in the vicinity of the mine, process area and tailings pond (September 1987) (Concord Scientific Corporation 1988). Ambient concentration measurements were taken in the following areas through whole air sample collection (Tedlar bags) and subsequent analysis:
  - The perimeter of the extraction and upgrading complex (Julian Day 254 and 263).
  - Around the perimeter of the tailings pond dyke (Julian Day 254 and 263).
- Around the Coke Settling pond (Julian Day 263).
- Around the Syncrude site as a whole (Julian Day 265).
- The compounds identified at each of these locations and the associated maximum concentrations observed at the previously mentioned sites are provided in Table 4-22. The highest ambient hydrocarbon

concentrations were measured near the API separator. These values exceed those observed at other locations by factors of 10 to 100.

- Ambient HC measurements in the vicinity of the tailings pond (May and June 1992) (Concord Environmental Corporation 1992). Ambient air monitoring was conducted using passive sampling devices deployed around the perimeter of the tailings pond dyke to obtain measurements of VOCs. The nominal exposure period for these sampling devices was one week. The compounds identified and the associated maximum concentrations observed are provided in Table 4-23. Higher concentrations were observed near the Plant #6 outfall and in the vicinity of the bitumen recovery area along the general dyke area.
- Ambient HC measurements in the vicinity of Syncrude were conducted in March and April 1994 during plant shut-down (BOVAR-CONCORD Environmental 1994a). The results are summarized in Table 4-24. More compounds and larger associated concentrations are generally observed at the upgrading, extraction and tailings pond sites than at either the mine or background sites.

Table 4-21 Compounds Identified and Associated Ambient Air Concentrations Observed by Alberta Environment in 1990 at Suncor

Compound (µg/m^3)	Suncor Pond Shut-down and Post Shut-down	Suncor Pond Post Start-Up	Suncor	
			API	NTF
Cyclopentane	9.5	363	13.2	5.6
2-Methyl Pentane	36.1	1,730	54.6	23.3
Hexane	81.0	3,890	107.4	29.9
2,4-Dimethyl Pentane	4.8	-	-	1.94
Benzene	11.8	1,841	14.8	15.2
Thiophene	15.9	170	8.0	4.7
Cyclohexane	31.5	852	47.6	7.8
3-Methyl Hexane	31.7	535	48.7	8.7
2,2,4-Trimethyl Pentane	27.8	-	-	8.1
Heptane	72.4	2,075	108.9	18.2
Methyl Cyclohexane	43.1	690	60.5	10.2
2,5-Dimethyl Hexane	18.5	-	22.4	-
2,3,4-Trimethyl Pentane	17.5	-	-	1.6
Toluene	37.9	558	53.8	37.2
2-Methyl Thiophene	9.8	166	12.3	2.2
2,2,5-Trimethyl Hexane	7.7	-	7.5	-
Octane	35.7	217	51.2	8.2
Ethyl Benzene	11.0	116	26.2	7.0
M-Xylene	23.9	47.7	32.1	18.0
P-Xylene	10.3	44.6	12.1	7.4
Styrene	5.5	39.3	6.4	3.6
O-Xylene	11.5	52.2	13.0	8.8
Nonane	19.3	33.5	27.6	4.6
Trimethyl Benzene	14.3	18.2	16.4	11.9
Decane	15.0	-	20.7	6.4
Diethyl Benzene	2.8	-	2.3	1.1
Di-Isopropyl Benzene	1.9	-	-	3.8
THC-Benzene Equivalent (mg/m^3)	2.2	40.9	3.0	1.0

Table 4-22 Compounds Identified and Associated Maximum Ambient Air Concentrations ($\mu g/m^3$) Observed in the Vicinity of the Syncrude Facilities (1987)

Compound	Extraction / Upgrading 254 / 263 [a]	Tailings Pond 254 [a]	API Separator 263 [a]	Coke Settling Pond 263 [a]	Whole Site 265 [a]
C_1 - C_3	9.14	22.50	8.62	7.07	7.65
iso-C_4H_{10}	0.91	0.26	0.10	0.08	0.17
n-C_4H_{10}	0.7	0.06	0.72	0.48	0.27
Unknown	-	-	-	-	0.03
iso-C_5H_{12}	0.33	0.16	1.92	0.21	0.05
n-C_5H_{12}	0.57	0.01	5.13	0.32	0.03
Cyclopentane	0.25	-	3.30	0.19	-
2-Methylpentane	0.47	-	11.22	0.48	0.05
3-Methylpentane	0.22	-	6.03	0.26	0.01
n-Hexane	0.36	0.20	33.39	1.48	0.09
Unknown	-	-	0.36	-	-
Methylyclopentane	0.84	0.33	26.36	1.39	0.09
Benzene	0.43	0.10	3.28	0.40	0.05
Cyclohexane	0.24	0.06	10.73	0.53	-
2,3-Dimethylpentane	0.28	0.07	13.94	0.65	0.04
3-Methylhexane	0.76	0.22	38.50	1.91	0.12
n-Heptane	0.64	0.23	65.36	1.78	0.13
Methylcyclohexane	0.51	0.16	19.57	1.48	0.10
Branched Octane	0.17	0.06	6.03	0.50	0.05
Toluene	1.21	0.27	13.16	1.31	0.40
3-Methylheptane	0.68	0.19	21.68	1.71	0.22
2,3,4-Trimethylhexane	0.27	0.04	5.84	0.50	0.09
n-Octane	0.78	0.13	12.96	1.06	0.24
Branched Nonane	0.49	0.63	5.73	0.50	0.12
Ethylbenzene	0.42	-	2.05	0.18	0.10
m,p-Xylenes	1.47	0.12	3.83	0.63	0.38
o-Xylene	4.33	0.04	4.09	0.62	0.26
Unknown	-	-	-	-	0.02
normal-C_9H_{20}	0.48	-	1.93	0.28	0.12
Cumene	0.01	-	0.24	-	-
Unknown	-	-	0.47	-	0.05
UPG367 [b]	0.51	-	0.46	0.15	0.14
UPG377 [b]	1.11	0.20	1.17	0.12	0.13
UPG378 [b]	0.27	-	-	-	-
UPG387 [b]	0.29	0.07	0.36	0.16	0.08
n-Decane	0.31	-	0.45	0.23	0.09
C_1-C_{10}	17.43	23.90	326.08	26.07	9.54
C_5-C_{10}	10.24	3.06	318.37	18.88	2.77

[a] Julian Day

[b] Unified Petroleum Group, molecular weight

Table 4-23 Maximum Observed Hydrocarbon Concentrations (μg/m^3) Measured Along the Perimeter of the Syncrude Tailings Pond (May and June 1992)

Compound	Near Plant #6 Outfall	Bitumen Recovery Area	Perimeter
n-Pentane	16.8	3.5	7.8
Cyclopentane	35.9	0.8	1.1
nl-Hexane	664.1	925.8	50.3
2,4-Dimethylpentane	138.2	145.7	131.7
Benzene	20.7	1.2	0.8
Cyclohexane	47.5	2.3	1.8
2,3-Dimethylpentane	88.2	0.6	0.7
3-Methylhexane	318.3	1.7	2.1
Unknown-1	135.4	0.0	1.3
2,2,4-Trimethylpentane	127.2	39.6	35.1
normal-Heptane	1,137.3	4.3	5.5
Unknown-2	725.4	4.0	4.0
Unknown-3	334.3	1.5	1.7
Unknown-4	172.1	0.4	0.8
Toluene	513.6	8.3	4.3
Unknown-5	1,783.9	5.6	8.2
3-Methylheptane	556.2	1.9	2.7
2,2,5-Trimethylhexane	490.6	3.1	3.8
n-Octane	1,716.2	6.3	12.3
Unknown-6	150.6	4.0	5.3
Unknown-7	174.9	2.0	2.7
Unknown-8	63.3	0.9	0.5
Ethylbenzene	299.8	2.2	1.9
p-Xylene+ m-Xylene	684.4	9.0	5.8
o-Xylene	265.0	6.8	5.2
n-Nonane	654.6	4.5	4.1
n-Propylbenzene	54.5	13.6	13.3
Unknown-9	202.6	51.9	36.3
1,3,5-Trimethylbenzene	26.8	11.2	10.8
n-Decane+1,2,4-Trimethylbenzene	134.2	34.3	33.0
p-Cymene+1,2,3-Trimethylbenzene	31.4	2.7	2.3
Total C_5-C_{10} species	**11150**	**1275**	**289**

Table 4-24 Concentrations of Volatile Organic Compounds ($\mu g/m^3$) Measured in the Vicinity of the Syncrude Facility in 1994

	Tailings Pond Site	Upgrading and Extraction Sites	Mine Sites	Background Sites
n-Pentane	0.4	15.6	0	0.2
Cyclopentane	0	3.4	0	0
Hexane	5.3	19.0	0	9.4
2,4-Dimethylpentane	0	0.7	3.3	1.6
Cyclohexane/2,3-Dimethylpentane	1.9	5.6	0	0
3-Methylhexane	4.7	15.2	0	0
Benzene	0.6	587.1	0	0
iso-Octane	1.5	5.4	0	0
n-Heptane	15.5	60.6	0	0
2,2,5-Trimethylhexane	0.4	28.5	1.9	0.3
Toluene	15.5	4.5	0	0
n-Octane	23.8	52.4	0	0.9
Ethylbenzene	10.3	8.7	0	2.4
m,p-Xylene/n-Nonane	22.5	24.7	0	0
o-Xylene	9.1	7.8	0	0
Cumene	4.2	1.4	0	0
n-Propylbenzene	4.0	0.2	0.7	0
n-Decane	0	0	0	0
1,3,5-Trimethylbenzene	3.3	6.9	0	0
p-Cymene	0	0	0	0
1,2,3-TRimethylbenzene	7.8	8.9	7.5	7.0
1,2,4-Trimethylbenzene	3.4	8.0	8.2	6.1
Naphthalene	0	0	0	0

4.10.4.3 Suncor Monitoring

Suncor conducts two fugitive emission surveys per calendar year (one in the spring and the other in the summer) for compounds such as H_2S, TRS, TS and THC. The surveys are conducted using a mobile monitor. The maximum readings depend upon the operating conditions of the plant, the ability of the operator to find a location downwind of a fugitive source and on the prevailing meteorological conditions during the survey.

Table 4-25 summarizes the maximum one-minute averages observed during each survey. The variability of the maximum values provided in the table does not indicate any clear trends. Perhaps more importantly, the interpretive reports that accompany these surveys indicate in general that the maximum values occur downwind of the inlet to Tailings Pond 1, the tank farms and the plant area.

Table 4-25 Maximum Ambient Concentrations Observed During Fugitive Emissions Monitoring at the Suncor Plant

Year	Month	THC (ppm)	Averaging Period (minutes)
1989	September/October	174	15
1990	July	24	15
	September	54	15
1991	February	N/A	N/A
	August	19	1
1992	N/A	N/A	N/A
	N/A	N/A	N/A
1993	April	12	1
	October	64	1
1994	April	85	1
	October	15	1
1995	N/A	N/A	N/A

4.11 PARTICULATES

Syncrude has two high volume samplers in the area measuring TSP, typically particulates that have a mean aerodynamic diameter less than 30 µm. These data are collected for a 24 hour sampling period once every 6 days (~ 61 samples per year). One of the Syncrude stations is located at AQS2 (Fort McMurray) and the other at AQS4 (Tailings North). Limited Total suspended particulates (TSP) data are also available from the OSLO site (March to December 1988). Neither Suncor nor AEP operate any high volume samplers in the area.

Since January 1997, AEP has operated a continuous PM_{10} monitoring station in Fort McMurray. PM_{10} include those particles with a mean aerodynamic diameter less than 10 µm, and represents that fraction of the airborne particulate matter most likely to be inhaled by humans.

4.11.1 Comparison to Air Quality Guidelines

Table 4-26 provides a summary of the high volume measurements of total suspended particulate (TSP) that have been conducted at these two Syncrude sites. While there have been three exceedances of the 24-hour 100 $\mu g/m^3$ guideline, most of the observed values are within guideline levels. The highest value of 273 $\mu g/m^3$ that occurred in 1993 was attributed to a truck that was left running outside the monitoring station during a calibration visit. The annual geometric means are well below the 60 $\mu g/m^3$ guideline.

Table 4-26 Measured Statistics of TSP at the Syncrude AQS2 and AQS4 Monitoring Site

	AQS2 (Fort McMurray)	AQS4 (Tailings North)
1990		
Maximum	not operational	165
Number greater than 100 µg/m^3	not operational	1
Annual Geometric Mean	not operational	16.0 (Aug. to Dec.)
1991		
Maximum	64	96
Number greater than 100 µg/m^3	0	0
Annual Geometric Mean	14.9	19.0
1992		
Maximum	65	121
Number greater than 100 µg/m^3	0	1
Annual Geometric Mean	13.7	15.8
1993		
Maximum	79	273
Number greater than 100 µg/m^3	0	1
Annual Geometric Mean	12.9	16.6
1994		
Maximum	34	88
Number greater than 100 µg/m^3	0	0
Annual Geometric Mean	9.4	10.5

Figure 4-39 shows box plots of TSP data by month for each station. The 5, 25, 50, 75 and 95th percentile values for each month are shown. The ASQ2 (Fort McMurray) site has the largest median and 95th percentile values from March to October while the ASQ4 (Tailings North) site has large values in March to August and November to December.

Figure 4-40 show box plots of TSP data by year for each station. The 5, 25, 50, 75 and 95th percentile values for each year of monitoring are shown, along with a linear regression line. At ASQ2 (Fort McMurray) the largest TSP values were observed in 1992, while the ASQ4 (Tailings North) site had the highest observations in 1991. Both sites indicate a reduction in the magnitudes of the observed TSP values in time as indicated by the regression lines.

The overall maximum 24-hour TSP concentration observed at the OSLO site during the period from March to December 1988 was 62.7 µg/m^3. This value is below the Alberta 24-hour TSP guideline value of 100 µg/m^3.

Figure 4-39 **Box plots of 5, 25, 50 (median), 75 and 95th Percentile Values of Total Suspended Particulates (TSP) Collected at AQS2 (Fort McMurray) and AQS4 (Tailings North) by Month**

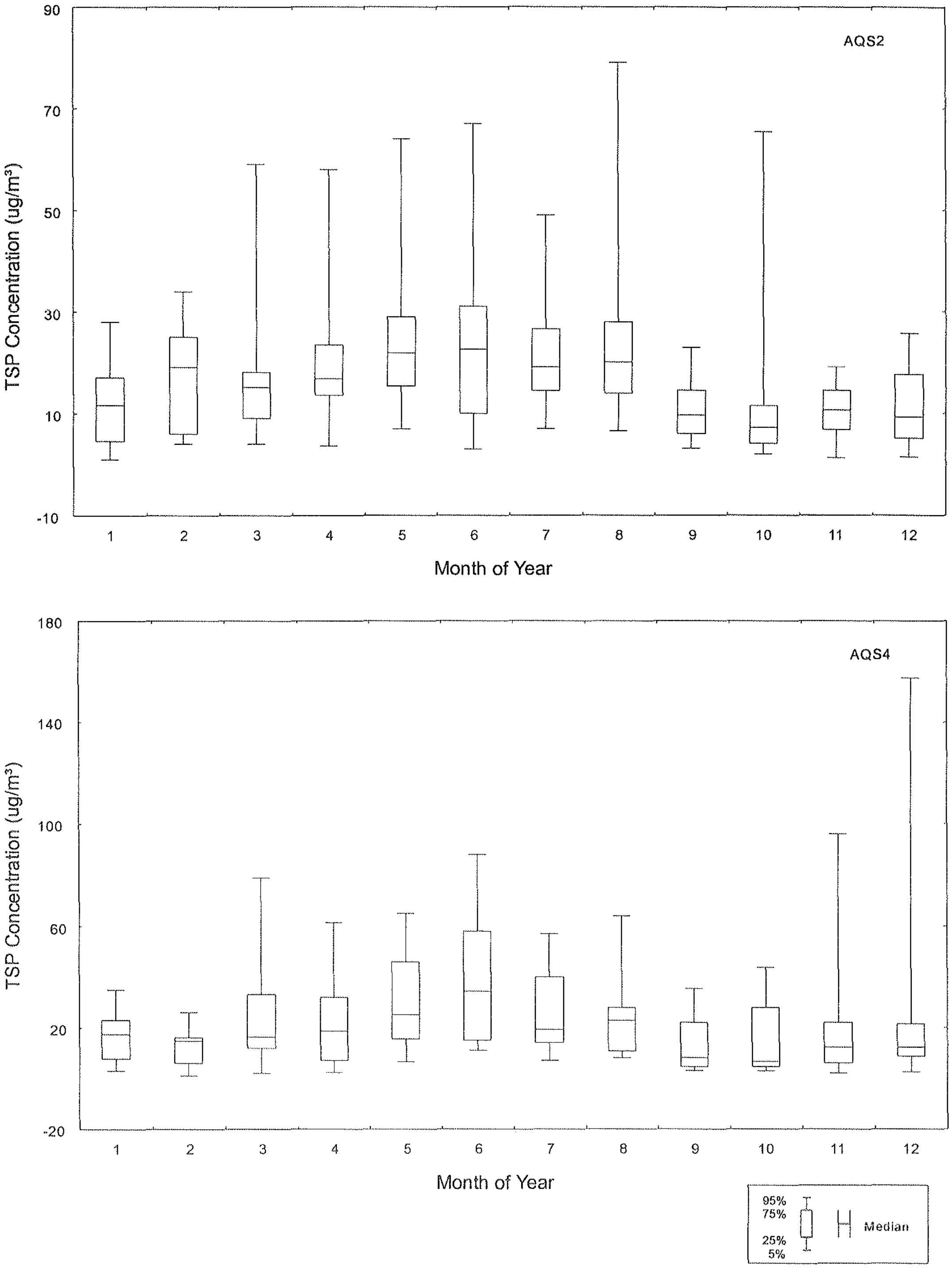
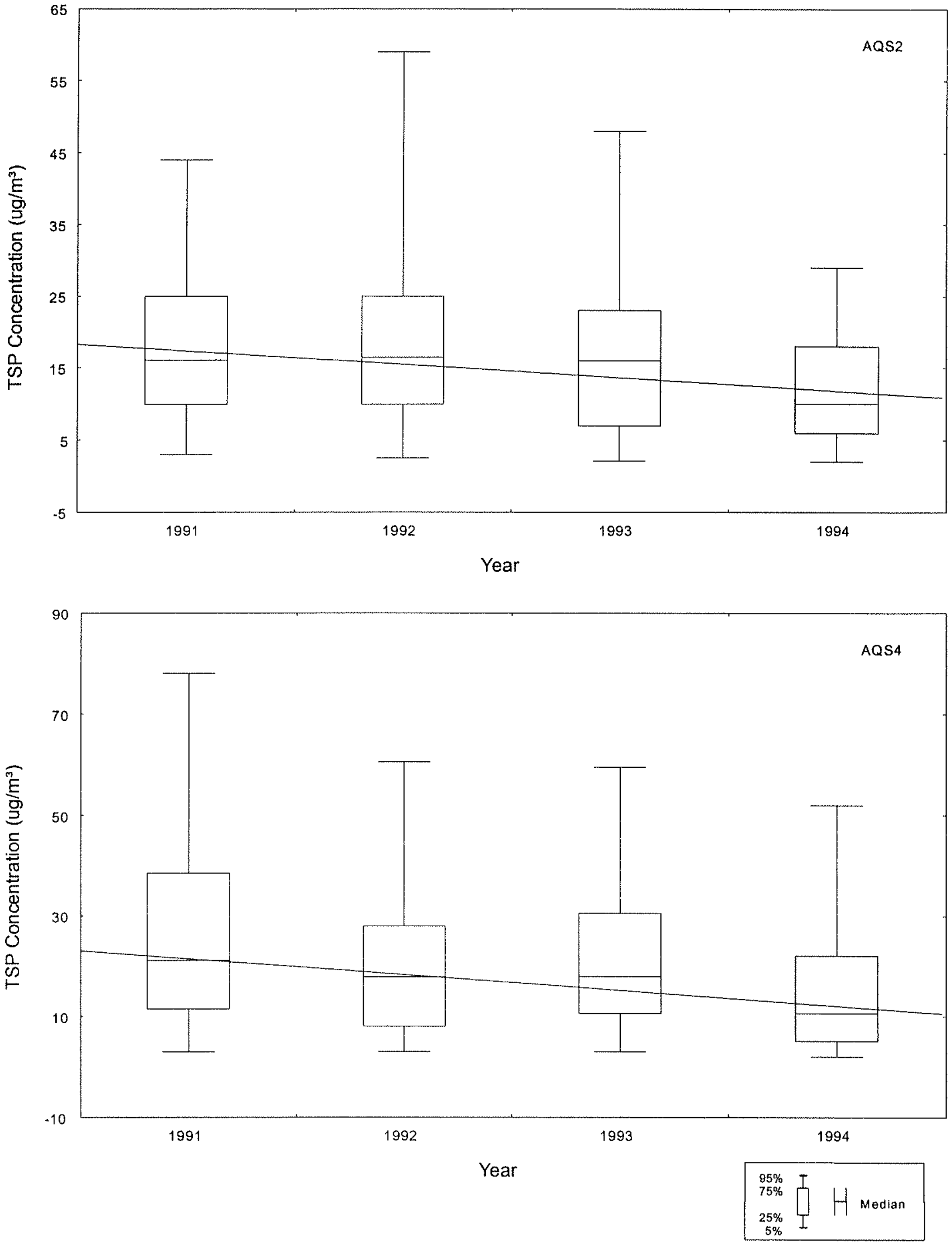


Figure 4-40 **Box Plots of 5, 25, 50 (median), 75 and 95th Percentile Values of Total Suspended Particulates (TSP) Collected at AQS2 (Fort McMurray) and AQS4 (Tailings North) by Month**



4.11.2 Background Acidifying Particulate Matter

Airborne particulate matter can play an important role in the acidifying process. Background and anthropogenic levels of sulphate (SO_4^{2-}), nitrate (NO_3^-) and ammonium (NH_4^+) contribute to the acidification process. Base cations (e.g., Ca^{2+}, Mg^{2+} and K^+), on the other hand, have the ability to neutralize acid inputs.

Background levels of acidic particulate matter have been observed at a number of remote locations, which are likely indicative of the background conditions in the study region. The background information summarized in Table 4-27 was gathered from the Environment Canada station at Cree Lake (1993 to 1995), the Acid Deposition Research Project (ADRP) site at Fortress Mountain (Legge and Kruppa, 1990) and the Hightower Ridge station (1996) operated by the West Central Airshed Society (1997).

Table 4-27 Background Levels of Acidic Particulates

Site	SO_4^{2-} (μg/m³)	NH_4^+ (μg/m³)	NO_3^- (μg/m³)
Hightower Ridge (1986)	0.58	0.18	0.09
Fortress Mountain (1985 to 1987)	0.51	—	0.13
Cree Lake (1988 to 1995)	0.99	0.20	0.05
Average	**0.69**	**0.19**	**0.09**

Ambient concentrations of base cations can be inferred from observed precipitation chemistry (Draaijers et al. 1997). This approach was used in recent studies (Conor Pacific 1997) to estimate the cation concentrations based on the precipitation observations at Cree Lake (1983 to 1992), Snare rapids (1989 to 1996), Fort Chipewyan (1992 to 1996) and Fort McMurray (1992 to 1996). The estimated base cation concentrations are listed in Table 4-28.

The data collected at the Cree Lake and Snare Rapids stations are not likely to be indicative of the conditions in the study area as these sites are both situated within the Canadian Shield, an area remote from possible sources of Ca^{2+}. The Fort Chipewyan data collection has been noted to be inferior to the Fort McMurray station, however, Fort McMurray readings were expected to be influenced by the local activities. The background readings for base used in recent studies in the area was the average of the Fort Chipewyan and Fort McMurray data. The background cation concentrations are assumed to be:

- Ca^{2+} 0. 36 μg/m³
- Mg^{2+} 0. 09 μg/m³
- K^+ 0. 15 μg/m³

Table 4-28 Background Observed and Inferred Base Cation Levels

Site	Cree Lake	Snare Rapids	Fort Chipewyan	Fort McMurray	Average
Ca^{2+}					
precipitation concentration (mg/L)	0.068	0.047	0.258	0.237	0.248
inferred air concentration (μg/m^3)	0.10	0.071	0.38	0.35	0.36
Mg^{2+}					
precipitation concentration (mg/L)	0.015	0.010	0.036	0.058	0.047
inferred air concentration (μg/m^3)	0.026	0.017	0.07	0.12	0.09
K^+					
precipitation concentration (mg/L)	0.028	0.022	0.082	0.034	0.058
inferred air concentration (μg/m^3)	0.069	0.057	0.21	0.09	0.15

4.12 BACKGROUND PAI IN NORTHEASTERN ALBERTA

4.12.1 Definition of Background

Background air quality for this assessment refers to the characteristics of the air flow entering the 148 x 169 km study area. The use of the term background, will represent biogenic (natural) sources and anthropogenic (industrial) sources outside the study area. This definition of background is different from that used in Cheng et al. (1997) in the assessment of total potential acid input in Alberta. The modelling domain for that western Canadian modelling study was much larger and the background in that assessment represented biogenic source contributions to air mass inflows only. Therefore, the numerical values for background in this study will be much greater.

4.12.2 Calculation Approach

Hourly concentrations, dry deposition and wet deposition values are calculated by CALPUFF (U.S. EPA 1995b) for each of SO_2, NO, NO_2, SO_4^{2-}, HNO_3 and NO_3^-.

Total sulphate equivalent deposition rate, $[SO_4^{2-}]_{dep}$, is calculated from the annual average sulphur species deposition rate predictions as follows:

$$\left[SO_4^{2-}\right]_{dep,equiv} = 1.5\left[SO_2\right]_{dep} + 1.0\left[SO_4^{2-}\right]_{dep}$$

Total nitrate equivalent deposition rate, $[NO_3]_{dep}$ is calculated from the annual average nitrogen species deposition rate predictions as follows:

$$\left[NO_3^-\right]_{dep,equiv} = 2.07\left[NO\right]_{dep} + 1.35\left[NO_2\right]_{dep} + 0.98\left[HNO_3\right]_{dep} + 1.0\left[NO_3^-\right]_{dep}$$

where all values are expressed in [kg/ha/y] and the leading constants are the respective ratios of molecular mass to the reference parameter. The above equations are applied to both wet and dry deposition.

The potential acid input (PAI) is calculated from the sulphur and nitrogen deposition rates from anthroprogenic sources within the RSA in addition to background PAI:

$$PAI = \frac{\left[SO_4^{2-}\right]_{dep,equiv}}{48} + \frac{\left[NO_3^-\right]_{dep,equiv}}{62} + PAI_{\mathrm{back}}$$

Where the background PAI (PAI_{back})accounts for SO_4^{2-} equivalent, NO_3^- equivalent and total base cations associated with the airflow into the study area (wet and dry).

Specifically, the background PAI will be given by:

$$PAI_{\mathrm{back}} = \frac{\left[SO_4^{2-}\right]_{\mathrm{dep,equiv,back}}}{48} + \frac{\left[NO_3^-\right]_{\mathrm{dep,equiv,back}}}{62} - \left(\frac{\left[Ca^{2+}\right]_{\mathrm{dep,back}}}{20} + \frac{\left[Mg^{2+}\right]_{\mathrm{dep,back}}}{24} + \frac{\left[K^+\right]_{\mathrm{dep,back}}}{39}\right)$$

where all values are expressed in [kg/ha/y] and the leading constants are the respective ratios of molecular mass to the reference parameter. The above values account for wet and dry deposition values for each component.

4.12.3 Wet PAI

Precipitation data from Fort Chipewyan, Fort Vermilion, High Prairie, Cold Lake, Cree Lake and Snare Rapids were reviewed. Data from Fort McMurray were not used since this site is expected to be significantly influenced by the oil sands sources. The selected sites surround the study area. On this basis, the average wet PAI is list in Table 4-29. The data in Table 4-29 are provided by two different agencies and the data for some sites are incomplete. Different time periods are also represented. However, these values are considered to be a good indication of wet PAI for air flow entering the region.

Table 4-29 Wet Background PAI From Selected Sites in Northeastern Alberta

Location	PAI [kg/ha/y]
Fort Chipewyan	0.02
Fort Vermilion	0.02
High Prairie	0.03
Cold Lake	0.06
Cree Lake	0.07
Snare Rapids	0.04
Average	**0.04**

4.12.4 Dry PAI (Sulphur Compound Contribution)

The primary contributors to dry PAI are SO_2 and SO_4^{2-}. There are limited locations where reliable annual average concentration measurements are collected. Available data is listed in Table 4-30. The SO_2 air concentration of 1.2 [$\mu g/m^3$] is much larger than the Environment Canada value of 0.25 [$\mu g/m^3$] assumed for the Cheng et al. (1997) Western Canadian modelling study. The value in Table 4-30 is assumed to be more applicable to the oil sands study area.

Table 4-30 Background SO_2 and SO_4^{2-} Concentrations Applicable to the Study Area

Site	SO_2		SO_4^{2-}
	($\mu g/m^3$)	(ppb)	($\mu g/m^3$)
Hightower Ridge (1986)	1.1	0.41	0.58
Fortress Mountain (1985 to 1987)	1.4	0.51	0.51
Cree Lake (1988 to 1995)	1.2	0.45	0.99
Average	**1.2**	**0.46**	**0.69**

4.12.5 Dry PAI (Nitrogen Compound Contribution)

Nitrate equivalent includes NO, NO_2, HNO_3, NH_4^+ and NO_3^-. Background values for some of these components are available from the same sites as the sulphate data, as listed in Table 4-31. The average values were adopted for the oil sands study area. There are no direct measurements available for NO and NO_2. Ridley (1991) suggests that NO and NO_2 are typically 10% of total nitrate equivalent and the tabulated values above have not been adjusted to account for this.

Table 4-31 **Background HNO_3, NH_4^+ and NO_3^- Concentrations Applicable to the Study Area**

Site	HNO_3		NH_4^+	NO_3^-
	(μg/m³)	(ppb)	(μg/m³)	(μg/m³)
Hightower Ridge (1986)	0.10	0.27	0.18	0.09
Fortress Mountain (1985 to 1987)	0.11	0.31	—	0.13
Cree Lake (1988 to 1995)	0.06	0.15	0.20	0.05
Average	**0.10**	**0.23**	**0.19**	**0.09**

4.12.6 Dry PAI (Base Cations)

There is not a good data set for base cations. Therefore, the ECIAEP approach has been adopted and values have been inferred from precipitation chemistry based on the approach given by Draaijers et al. where:

$$C_{air} = \frac{C_{prec}\,\rho}{188\ e^{0.227\,MMD}}$$

where: C_{air} = air concentration, [μg/m³]
C_{prec} = precipitation concentration, [mg/L]
ρ = density of air, 1200 [g/m³]
MMD = Mass Mean Diameter, [μm]

MMD values were adopted from Draaijers et al. (1997): 5.7 μm for Mg^{2+}, 6.3 μm for Ca^{2+}, and 4.1 μm for K^+. Therefore, the following relationships can be used to predict air concentration from the observed precipitation chemistry water concentrations:

$$C_{air}(\mathrm{Mg}^{2+}) = 1.75\ C_{prec}(\mathrm{Mg}^{2+})$$
$$C_{air}(\mathrm{Ca}^{2+}) = 1.53\ C_{prec}(\mathrm{Ca}^{2+})$$
$$C_{air}(\mathrm{K}^{2+}) = 2.52\ C_{prec}(\mathrm{K}^{2+})$$

The relationships in the above equations have been applied to the observed precipitation data listed in Table 4-32. The low Cree Lake, Snare Rapids and Fort Smith values are likely representative of air flow from the north and west, while the other sites account for air flow from southern Alberta which appears to have a greater base cation content. This approach is consistent with those values were are provided for the Fort Chipewyan and Fort McMurray data. The median value will be less influenced by short term high concentrations in the data set which may be representative of emission sources close to the monitoring site.

Legge and Kruppa (1990), list Ca^+, Mg^{2+} and K^+ observed at Birch Mountain (1976) and Fort Smith (1970) as listed in Table 4-32 (based on air flow from the Arctic and Pacific).

A summary of base cation concentrations for selected sites are listed in Table 4-32. The average values have been applied as being representative of base cation concentrations for the regional airshed.

Table 4-32 Background Base Cation Concentrations Applicable to the Study Area

	Ca^{2+}		Mg^{2+}		K^+	
	[mg/L]	[μg/m³]	[mg/L]	[μg/m³]	[mg/L]	[μg/m³]
Cree Lake (1983 to 1992)	0.068	0.10	0.015	0.026	0.028	0.071
Snare Rapids (1989 to 1996)	0.047	0.07	0.010	0.018	0.023	0.058
Fort Chipewyan (1992 to 1996)	0.258	0.39	0.076	0.063	0.082	0.207
Fort McMurray (1992 to 1996)	0.237	0.36	0.058	0.102	0.034	0.086
Fort Vermillian (1990 to 1993)	0.160	0.25	0.020	0.035	0.090	0.227
High Prairie (1990 to 1993)	0.210	0.32	0.030	0.053	0.110	0.277
Cold Lake (1990 to 1993)	0.140	0.21	0.030	0.053	0.050	0.126
Birch Mountain (1976)	–	0.026	–	0.021	–	0.024
Fort Smith (1970)	–	0.033	–	–	–	0.044

4.12.7 PAI (Conversion From Concentrations to Deposition)

The ambient air concentration [μg/m³] data can be converted to a deposition [kg/ha/y] using a deposition velocity V_d [cm/s] from:

$$Dep = Conc \times V_d \times 3.15$$

Where the constant 3.15 is a unit conversion factor to convert to [kg/ha/y].

The selection of appropriate deposition velocities provides a challenge as the resulting PAI will be very dependent on this selection. For this assessment, five sets of deposition velocities were used to illustrate the sensitivity:

- Bates (1996) developed a set of deposition velocities for Vegreville. SO_4^{2-} and cation deposition velocities were assumed to be the same since the diameters were assumed to he the same. This, however, is not the case as most of the sulphate is in the fine fraction and most of the base cations are in the coarse fraction;
- Values taken from Cheng (1993) assumed summer stability class D conditions (forest and woodland);

- Ruijgrok et al. (1997) estimates dry deposition values over a forest from SO_4^{2-}, NO_3^- and base cations. These values are larger than those reported elsewhere in the literature;
- Modified Bates values assuming the base cation depositions velocities are 4.4 times those for SO_4^{2-} based on the Ruijgrok et al. (1997) study (4.4 * 0.14 = 0.616); and
- Stability weighted Cheng (1993) deposition velocities.

The associated deposition velocities, total deposition and PAI are summarized in Tables 4-33 and 4-34. The results in the table indicate that the deposition velocity has a considerable effect on the calculated background PAI. Base cation deposition rates range from 0.007 to 0.271 keq/ha/y and dry PAI ranges from -0.116 to 0.072 keq/ha/y. The Bates' (1997) deposition velocities likely underestimate cation deposition. Similarly, the Ruijgrok et al. (1997) deposition velocities are likely on the high side. The Cheng and modified Bates provide similar base cation depositions but differ for non-cation values.

Table 4-33 Calculation of Background PAI Based on Varying Dry Deposition Velocity Schemes

		Bates (1996)			Cheng (1993)			Ruijgrok, PM (1997)		
		V_d	Deposition		V_d	Deposition		V_d	Deposition	
	[μg/m³]	[cm/s]	[kg/ha/y]	[keq/ha/y]	[cm/s]	[kg/ha/y]	[keq/ha/y]	[cm/s]	[kg/ha/y]	[keq/ha/y]
SO_2	1.20	0.37	1.40	0.043	0.35	1.32	0.041	0.37	1.40	0.043
SO_4^{2-}	0.69	0.14	0.30	0.006	0.5	1.09	0.023	1.15	2.50	0.053
NH_4	0.19	0.14	0.08	0.005	0.5	0.30	0.016	1.15	0.69	0.036
HNO_3	0.23	1.33	0.96	0.015	1.4	1.02	0.016	1.33	0.96	0.015
NO_3^-	0.09	0.26	0.07	0.001	0.5	0.14	0.002	1.15	0.33	0.005
Ca^{2+}	0.20	0.14	0.09	0.004	0.5	0.31	0.016	5.1	3.17	0.158
Mg^{2+}	0.05	0.14	0.02	0.002	0.5	0.07	0.006	5.1	0.74	0.061
K^+	0.12	0.14	0.05	0.001	0.5	0.20	0.005	5.1	1.99	0.052
Background dry PAI				**0.064**			**0.072**			**-0.116**
Base Cations				**0.007**			**0.027**			**0.271**
Wet Plus Dry PAI				**0.10**			**0.11**			**-0.08**

Table 4-34 Additional Calculations of Background PAI Based on Varying Dry Deposition Velocity Schemes

		Modified Bates			Cheng (1993) Slab Weighted		
		V_d	Deposition		V_d	Deposition	
	[$\mu g/m^3$]	[cm/s]	[kg/ha/y]	[keq/ha/y]	[cm/s]	[kg/ha/y]	[keq/ha/y]
SO_2	1.20	0.37	1.40	0.043	0.327	1.24	0.038
SO_4^{2-}	0.69	0.14	0.30	0.006	0.37	0.81	0.017
NH_4	0.19	0.14	0.08	0.005	0.37	0.22	0.012
HNO_3	0.23	1.33	0.96	0.015	1.327	0.96	0.015
NO_3^-	0.09	0.26	0.07	0.001	0.37	0.11	0.002
Ca^{2+}	0.20	0.616	0.38	0.019	0.37	0.23	0.011
Mg^{2+}	0.05	0.616	0.09	0.007	0.37	0.05	0.004
K^+	0.12	0.616	0.24	0.006	0.37	0.14	0.004
	Background dry PAI			**0.038**			**0.065**
	Base Cations			**0.033**			**0.020**
	Wet Plus Dry PAI			**0.08**			**0.10**

The total PAI assuming Bates, Cheng and modified Cheng is 0.10 keq/ha/y. The Ruijgrok et al. value is 0.09 due to extremely high deposition velocities associated with base cations. A Monte Carlo variability assessment based on the ranges of data provided, indicates a mean total PAI of between 0.09 and 0.10 keq/ha/y based on 10,000 simulations. The range in the estimates is approximately 0.0 to 0.26 keq/ha/y.

4.12.7.1 Conclusions

Based on the available data, the following background PAI appears representative of the oil sands region:

PAI Component	PAI Value [keq/ha/y]
Wet PAI	0.04
Dry PAI	0.06
Total PAI	0.10

4.12.8 Throughfall and Stemflow Studies

In the late 1970's, the University of Alberta conducted a series of canopy throughfall and stemflow studies in the region. For forested areas, the throughfall and stemflow method has been used to provide a measure of wet and dry deposition. The throughfall and stemflow method is based on the assumption that during dry periods, contaminants such as sulphate particulates will deposit and collect on tree canopy foliage. When rainfall occurs, the dry deposits are washed off and the sulphates in the rainfall collected below the forest canopy will be enhanced. This enhanced collection is a measure of the dry deposition. This approach assumes uptake and leaching within the canopy either offset each other or are negligible.

In the summer of 1976, field studies were conducted in the oil sands region which measured sulphate deposition in precipitation and in the throughfall and stemflow from trees (Nyborg et al. 1985). Dry deposition estimates are available from two field components of the Nyborg et al. report:

- The nutrient cycling study that was conducted during the summer of 1976; and
- Field studies of precipitation, throughfall and stemflow at 14 sites in the region.

The nutrient cycling study involved two sites; a control site near Algar forestry air strip, 101 km south-southwest of the emission source and an exposed site, 32 km southeast of the emission sources (Steepbank Airport, Fina airstrip). Table 4-35 lists the average sulphate content of precipitation, throughfall, stemflow and computed dry deposition for Trembling Aspen and Jack Pine.

Table 4-35 Average Sulphate, Throughfall and Stemflow Results

kg/ha/3 months	Control (Algar)	Exposed (Steepbank Airport)
Trembling Aspen		
Rain	1.11	>2.20
Throughfall	2.36	2.58
Stemflow	0.29	> 1.12
Dryfall	1.64	1.50
Jack Pine		
Rain	0.76	> 2.20
Throughfall	4.97	6.42
Stemflow	> 0.14	> 0.22
Dryfall	4.35	4.45

The results of the nutrient cycling study indicate:

- Sulphate deposition in throughfall and stemflow is greater than that in rainfall;
- Sulphate deposition in throughfall and stemflow is greater beneath a Jack Pine canopy than beneath a Trembling Aspen canopy. All things being equal, Jack Pine appears to be more efficient in removing sulphate from the atmosphere than Trembling Aspen;

- Most of the dry deposition is associated with throughfall instead of stemflow; and
- There does not appear to be a big difference between the controlled and exposed sites. At both sites, dry deposition is about 1.6 kg SO_4^{2-} /ha/3 months for Trembling Aspen and 4.4 kg/SO_4^{2-}/ha/3 months for Jack Pine.

These deposition values can be extrapolated to annual values by assuming that one-half the amount rainfall occurs during the summer. On this basis, dry deposition to Trembling Aspen and Jack Pine are about 3.2 kg SO_4^{2-}/ha/y and 8.8 kg SO_4^{2-}/ha/y, respectively. The wet deposition at both sites averaged about 3.1 kg SO_4^{2-}/ha/y.

The "field study" component involved the collection of precipitation, throughfall and stemflow samples at 14 sites collected in the summer of 1976. These sites, listed in Table 4-36, range in distance between 4 and 173 km from Suncor's operations. Table 4-36 also shows the rainfall, throughfall, stemflow and calculated dry values expressed as kg S/ha/month and as kg SO_4^{2-}/ha/y. The conversion is based on the collection period of 2.5 months and the assumption that one-half the rainfall occurs during this period. Comments with respect to information presented in Table 4-36 are:

- Wet deposition values expressed on an annual basis range from 2.4 to 9.0 kg SO_4^{2-}/ha/y. For the most part, the highest values occur relatively close (about 30 km or less) to the plant. At the more distant locations, the wet deposition values range from about 2.5 to 4 kg SO_4^{2-}/ha/y. This is consistent with the observations associated with the nutrient cycling study. For the purpose of comparison, the average wet sulphate deposition at Fort McMurray is about 4.6 kg SO_4^{2-}/ha/y. This Fort McMurray value is based on two operating oil sands facilities, whereas the values from the Nyborg et al. (1985) report were collected when only one oil sands plant was operating.
- The calculated dry deposition values exhibit a much greater range, with low and high values of 3.8 and 67 kg SO_4^{2-}/ha/y, respectively.

The calculated dry deposition at Algar of 21 kg SO_4^{2-}/ha/y is more than double the annual value of 8.8 kg SO_4^{2-}/ha/y calculated for the same site from the nutrient cycling portion of the study. Similarly, the calculated dry deposition at Steepbank Airport of 38 kg SO_4^{2-}/ha/y, is more than four times the value calculated for the site from the nutrient cycling portion of the study.

These differences and the extrapolation from individual measurements to a regional forest canopy indicate elements of uncertainty with respect to the following:

- Edge effects: Higher depositions are expected for trees located at the edge of a canopy than for trees located within the canopy;
- Canopy closure: Typically a forest canopy will not have a uniform 100% closure as there are open spaces between individual trees; and
- Regional canopy: The oil sands area is represented by a mosaic of various vegetation canopy types.

In summary, the limited throughfall and stemflow information collected in the region does indicate that dry deposition of sulphur compounds is as, or even more important than the wet deposition component. However, caution is advised in extrapolating individual plot measurements to the regional airshed.

Table 4-36 Rainfall, Throughfall and Stemflow Measurements in the Athabasca Oil Sands Area Collected Over the Period July to September 1976

		Rainfall		Throughfall		Stemflow		Dry
Site	**(km)**	**(kg S /ha/mo)**	**(kg SO_4^{2-} /ha/y)**	**(kg S /ha/mo)**	**(kg SO_4^{2-} /ha/y)**	**(kg S /ha/mo)**	**(kg SO_4^{2-} /ha/y)**	**(kg SO_4^{2-} /ha/y)**
Steepbank 2	4	0.60	9.0	0.8	12.0	0.19	2.9	5.9
Mildred Lake	11	0.47	7.1	1.3	19.5	0.14	2.1	14.6
Steepbank 1	17	0.19	2.9	1.5	22.5	ND	ND	19.7
MacKay River	21	0.21	3.2	4.5	67.5	0.16	2.4	66.8
Thickwood Hills	31	0.56	8.4	1.9	28.5	0.13	2.0	22.1
Steepbank A	32	0.17	2.6	2.7	40.5	ND	ND	38.0
Muskeg Mountain	38	0.29	4.4	1.0	15.0	0.19	2.9	13.5
Bitumount	39	0.16	2.4	1.0	15.0	0.10	1.5	14.1
Hangingstone River	67	0.25	3.8	2.2	33.0	0.13	2.0	31.2
Gordon Lake	75	0.25	3.8	1.2	18.0	0.01	0.2	14.4
Birch Mountain	79	0.25	3.8	1.3	19.5	0.01	0.2	15.9
Algar	101	0.25	3.8	1.6	24.0	0.06	0.9	21.2
Richardson	102	0.18	2.7	0.4	6.0	0.03	0.5	3.8
May	173	0.25	3.8	0.6	9.0	0.04	0.6	5.9

Dry = throughfall + stemflow + rainfall.
All measurements associated with coniferous trees (white spruce, black spruce and jack pine).

4.13 ODOUR EVALUATION STUDIES

A series of specialized studies have been conducted in the area with the intention of characterizing the odourous concentrations associated with the oil sands activities. These studies include:

- Limited ambient air quality monitoring program conducted at a second site in Fort McMurray;

- Ambient hydrocarbon (HC) and reduced sulphur (RS) species measurements conducted in the vicinity of the plant and tailings pond areas;
- Odour calculations to qualitatively identify sources and responses by an odour panel. Qualitative odour assessments have the advantage of evaluating odour potentials from mixtures of compounds whereas a detailed speciation tends to evaluate odours on a single compound basis; and
- Ongoing odour "patrols" to identify and track odours to identify sources or activities that produce the odours.

The following sections summarize these specialized studies.

4.13.1 Ongoing Odour Tracking

In response to the occurrence of odours and associated complaints, an "Odour Response Protocol" (ORP) was developed to address methods and procedures for odour incident investigations and follow-ups (Glen Lynn Engineering Ltd. 1990).

A review of the odour complaint information collected in response to the initiation of a regional odour response protocol indicated that the odour identification and tracking process appears to have resulted in a reduction of both the frequency and magnitude of odour incidents over the 1993 to 1997 period (Table 4-37).

Table 4-37 Oil Sands Odour Complaints Received by Alberta Environmental Protection 1993 - 1997

Year	Fort McMurray Complaints/Incidents	Fort McKay Complaints/Incidents
1993	263/116	22/18
1994	102/59	11/11
1995	62/40	19/9
1996	43/28	15/12
1997	13/10	4/4

4.13.2 Odour Assessment Studies

Suncor initiated a series of odour assessment studies over the period 1989 to 1994 with the objective of identifying and quantifying sources of odours from their facilities. The findings associated with the studies are provided as follows:

- An odour sensory study was undertaken to assess off-site odours associated with emissions from the Tailings Pond 1, the Powerhouse

Stack and the Extraction Plant 4 vents (Clayton Environmental Consultants Ltd. 1989a). An off-site panel comprised of 8 to 10 members was exposed to samples collected from these sources who provided a description of the associated odours and a determination of odour units. The study concluded that the emissions from the Tailings Pond 1 would create greater downwind odour problems than those from the Powerhouse Stack (the two major odour sources).

- A follow-up dispersion modelling study was undertaken to provide estimates of odours from emissions due to the Powerhouse stack and Tailings Pond 1 in downwind communities of Fort McMurray and Fort McKay (Clayton Environmental Consultants 1989b). The study concluded that the Powerhouse stack will not create adverse odours under most conditions and that Pond No. 1 emissions can create significant odours under low wind speed, night-time conditions.
- Additional odour sensory studies were conducted to rank odour emission sources from Plants 3 and 4 and the south tank farm, to evaluate any improvements around Tailings Pond 1 due to the operation of the Naphtha Recovery Unit NRU and to determine the effects of the incinerator stack emissions (Clayton Environmental Consultants 1989c). The report concludes that the emissions from the Tailings Pond 1 is still the major source, there appears to be some improvement in air quality due to the NRU and that the incinerator stack should not cause any odour problems in downwind communities.
- Viswanathan (1989) provided a summary of the odour assessment program conducted by Suncor during the 1988-1989 period. The conclusions of the assessment are:
  - Tailings Pond 1 is the major source of odours. Modelling indicated these emissions could cause odour complaints for distances up to 15 km. Operational problems (i.e., a leaking heat exchanger) increased the hydrocarbon emissions from the pond. Tailings Pond 1 was identified as a high potential odour causing source.
  - The Powerhouse stack emissions can cause odour complaints up to 6 km. The powerhouse stack is defined as low-medium potential to generate odour complaints.
  - The incinerator emissions are important within 4 km and the Plant 3, Plant 4 and South Tank Farm vents effects are within 2 km. These sources were defined as having a low contribution level.
- The ambient air analyzed in the vicinity of Tailings Pond 1 indicated the primary components were C_1 to C_5 hydrocarbons and H_2S.
- A review of odour incidents indicated that odours are associated with two types of meteorological conditions (ORTECH International 1992):
  - Persistent northwest wind with a significant upvalley component towards Fort McMurray. Low level emissions will be subject to building downwash effects and will be carried within the valley floor. Tall stack emissions are more likely to be carried out of the

valley. The net result is a stable flow that is trapped in the valley with winds flowing towards Fort McMurray.

- Along valley flow reversal from upvalley to downvalley occurs under a period of very light and variable winds. These conditions allow emissions to accumulate within the valley.
- Accompanying dispersion modelling indicated highest predicted odour concentrations at Fort McMurray under low wind speed (3.6 km/h) stable and neutral atmospheric conditions. The most significant sources were predicted to result from Plant 4 vents (50 to 70%) and from a Plant 3 vent (10 to 17%). The modelling did not include Tailings Pond 1.
- An assessment was conducted to determine odour thresholds for pure compounds (Ortech Corporation 1994). The results are as follows:

Table 4-38 Odour Thresholds of Pure Compounds

Compound	Ortech (1994) (ppb)	Literature Range (ppb)
H_2S	2.9	1.0 to 4.70
Ethyl mercaptan	0.2	0.32 to 1.00
n-butyl mercaptan	0.3	0.62
Thiophene	13.5	0.9 to 8.13
2-Methyl Thiophene	443	N/A
2,5-Dimethyl Thiophene	15.8	N/A

A review of the literature odour threshold values indicated ranges of several orders of magnitude. The literature values provided above represent what was identified as a "reliable" range.

4.13.3 Ambient Monitoring in Fort McMurray

Alberta Environmental Protection installed a second ambient air quality monitoring trailer in downtown Fort McMurray. Air quality data and observations were collected at this station for the period October 1, 1991 to June 30, 1992 and were compared to the permanent station located on the east bank of the Athabasca River adjacent to the Snye (Myrick 1992). The results are summarized as:

- Average SO_2 concentrations were 15% higher at the permanent station site than at the downtown station;
- Average H_2S concentrations were consistently high at the permanent station. During the period, the permanent station had five exceedances of the one-hour H_2S guideline compared to only one exceedance at the downtown station;

- During periods when odours were noted, the average SO_2 and H_2S concentrations were much higher (15 and 75% higher, respectively) than during the remainder of the monitoring period. THC concentrations were only 4% higherduring odour periods than during the remainder of the year.

4.13.4 Ambient THC and TRS Monitoring

A number of field studies have been conducted in the region to identify and quantify THC and TRS emissions and ambient concentrations. Ambient THC and TRS emissions are dependent on plant facilities and operating practices. The results presented in this section span more than a decade and as a consequence, some of the earlier measurements may not be representative of the current facilities and operating conditions. Nonetheless, the earlier studies are presented here for the purposes of completeness. For the purposes of presentation, the studies have been grouped according to their sponsors.

4.13.4.1 Alberta Environmental Protection

A mobile air monitoring survey of the Fort McKay - Fort McMurray corridor was conducted in the summer of 1990 during the scheduled Suncor turnaround (Environmental Protection Service 1991). Observations were made prior to shut-down (May 18 to 20: 3 days), during shut-down (May 21 to 24: 4 days), after shut-down (May 28, 29: 2 days), during plant start-up (June 28 to July 10: 8 days) and following plant start-up (July 27 and September 26 to 28: 4 days).

The survey made use of two mobile monitoring units. The AQML unit was instrumented to measure CO, H_2S, THC, SO_2, NO_x and O_3. The BT-5 unit was instrumented to measure H_2S, SO_2 and THC. Specific monitoring sites were identified and observations for a minimum of 10 minutes were taken at each site. When elevated concentrations were noted or when odours were observed, whole air samples were collected in Tedlar bags for further speciation.

The report provided a very limited analysis and one of the conclusions was that the Suncor turnaround "did not appear to be a major impact on regional air quality". While the AEP report was minimal in deriving conclusions, the following are noted:

- Relatively high SO_2 values (greater than 0.2 ppm) occurred when Suncor and Syncrude were flaring;
- The highest H_2S values were observed during the shut-down period;

- During the mobile monitoring period, odour complaints were received and reviewed. Both Syncrude and Suncor were identified as sources of odourous emissions; and
- Tedlar bag samples were collected in the vicinity of the Suncor tailings pond (7 samples), the Suncor API (2 samples) and the Suncor north tank farm (2 samples). Additional samples were collected to characterize the Suncor Naphtha Recovery Unit and the Syncrude diverter stack emissions. Table 4-39 summarizes the average ambient concentrations observed in the vicinity of the Suncor tailings pond, API and North Tank Farm (NTF). The ambient concentration information presented in the table occur in locations in the plant area where high values were observed.

Table 4-39 Compounds Identified and Associated Ambient Air Concentrations Observed by Alberta Environment in 1990

Compound ($\mu g/m^3$)	Suncor Pond Shut-down and Post Shut-down	Suncor Pond Post Start-Up	Suncor	
			API	NTF
Cyclopentane	9.5	363	13.2	5.6
2-Methyl Pentane	36.1	1730	54.6	23.3
Hexane	81.0	3890	107.4	29.9
2,4-Dimethyl Pentane	4.8	-	-	1.94
Benzene	11.8	1841	14.8	15.2
Thiophene	15.9	170	8.0	4.7
Cyclohexane	31.5	852	47.6	7.8
3-Methyl Hexane	31.7	535	48.7	8.7
2,2,4-Trimethyl Pentane	27.8	-	-	8.1
Heptane	72.4	2075	108.9	18.2
Methyl Cyclohexane	43.1	690	60.5	10.2
2,5-Dimethyl Hexane	18.5	-	22.4	-
2,3,4-Trimethyl Pentane	17.5	-	-	1.6
Toluene	37.9	558	53.8	37.2
2-Methyl Thiophene	9.8	166	12.3	2.2
2,2,5-Trimethyl Hexane	7.7	-	7.5	-
Octane	35.7	217	51.2	8.2
Ethyl Benzene	11.0	116	26.2	7.0
M-Xylene	23.9	47.7	32.1	18.0
P-Xylene	10.3	44.6	12.1	7.4
Styrene	5.5	39.3	6.4	3.6
O-Xylene	11.5	52.2	13.0	8.8
Nonane	19.3	33.5	27.6	4.6
Trimethyl Benzene	14.3	18.2	16.4	11.9
Decane	15.0	-	20.7	6.4
Diethyl Benzene	2.8	-	2.3	1.1
Di-Isopropyl Benzene	1.9	-	-	3.8
THC-Benzene Equivalent (mg/m^3)	2.2	40.9	3.0	1.0

4.13.4.2 Syncrude Canada

The following studies have been conducted in the vicinity of the Syncrude facility:

- Background H_2S observations were collected near the Thickwood Hills forest tower located about 30 km southwest of the oil sands facilities and 30 km northwest of the town of Fort McMurray (Concord Scientific Corporation 1982). Two sites near the Thickwood Hills forest tower were selected, a forest site and a bog site. H_2S levels ranged from 0.03 to 0.50 ppb (0.04 to 0.71 $\mu g/m^3$) at the bog site and from 0.13 to 0.56 ppb (0.18 to 0.78 $\mu g/m^3$) at the forest site. The larger observed values were associated with smoke and haze from forest fires burning in the region. The maximum observed values upwind and downwind of identified plant sources are listed in Table 4-40.

Table 4-40 **Upwind and Downwind H2S Concentrations Associated With Syncrude Activities**

Source	H_2S (ppb)
Recycle Pond	6.2
Effluent Pond Inlet	30
Mine Sump Basin	16
Tailings Pond	0.56
Coke Cells	0.26
Coke Settling Basin Inlet	47
Sulphur Loading Areas	200
API Separator	1.2
Entire Facility	6.0

Within and along the perimeter of each source area, relatively large H_2S concentrations can occur.

4.13.4.3 Suncor Monitoring

Suncor conducts two fugitive emission surveys per calendar year (one in the spring and the other in the summer) for compounds such as H_2S, TRS, TS and THC. The surveys are conducted using a mobile monitor to collect data in the vicinity of the plant and tailings ponds, and are typically conducted for a 3 to 5 day period. The maximum readings depend upon the operating conditions of the plant, the ability of the operator to find a location downwind of a fugitive source and on the prevailing meteorological conditions during the survey.

Table 4-41 summarizes the maximum one-minute averages observed during each survey. The variability of the maximum values provided in the table does not indicate any clear trends. Perhaps more importantly, the interpretive reports that accompany these surveys indicate in general that the maximum values occur downwind of the inlet to tailings pond 1, the tank farms and the plant area.

Table 4-41 Maximum Ambient Concentrations Observed During the Fugitive Emissions Monitoring at the Suncor Plant.

Year	Month	H_2S (ppb)	TRS (ppb)	TS (ppb)	Averaging Period (minutes)
1989	September/October	262	208	N/A	15
1990	July	133	N/A	497	15
	September	115	877	1081	15
1991	February	N/A	N/A	N/A	N/A
	August	27	N/A	41	1
1992	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A
1993	April	24	40	N/A	1
	October	124	180	N/A	1
1994	April	93	> 133(a)	N/A	1
	October	45	> 114(a)	N/A	1
1995	N/A	N/A	N/A	N/A	N/A

(a) The inequality indicates that the reading exceeded the maximum range of the analyzer.

5 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

GOLDER ASSOCIATES LTD.

Report prepared by:

Brian Zelt, Ph.D., P.Eng.
Environmental Engineer,
Air Quality Services

Report reviewed by:

John Gulley, M.Sc., P.Biol.
Oil Sands Project Director

Martin A. Rawlings, P.Eng.
Senior Air Quality Engineer

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APPENDIX I

SOURCE LOCATION PARAMETERS

Table I.1 Syncrude Mildred Lake Emission Source Location Parameters

	Source Identification				Source	Status	Elevation	UTM Location East	UTM Location North
OWNWER	Area	Sub-Area	ID	Description	Class		[m]	[m]	[m]
Syncrude	Mildred Lake	Main	SYNM	Main Stack 8-F4:	Point	OP	304	462,632	6,322,111
Syncrude	Mildred Lake	Secondary	GTG201	Gas Turbine 31 GTG 201	Point	OP	304	462,693	6,322,003
Syncrude	Mildred Lake	Secondary	GTG201b	Gas Turbine 31 GTG 201 Approved+applied	Point	OP	304	462,693	6,322,003
Syncrude	Mildred Lake	Secondary	GTG202	Gas Turbine 31 GTG 202	Point	OP	304	462,721	6,322,012
Syncrude	Mildred Lake	Secondary	GTG202b	Gas Turbine 31 GTG 202 Approved+applied	Point	OP	304	462,721	6,322,012
Syncrude	Mildred Lake	Secondary	71F1A	Bit. Heater 7-1F-1A	Point	OP	305	462,596	6,322,427
Syncrude	Mildred Lake	Secondary	71F1B	Bit. Heater 7-1F-1B	Point	OP	306	462,617	6,322,434
Syncrude	Mildred Lake	Secondary	72F1A	Bit. Heater 7-2F-1A	Point	OP	306	462,578	6,322,476
Syncrude	Mildred Lake	Secondary	72F1B	Bit. Heater 7-2F-1B	Point	OP	306	462,605	6,322,485
Syncrude	Mildred Lake	Secondary	81F6A	Steam Heat 8-1F-6A	Point	OP	305	462,662	6,322,261
Syncrude	Mildred Lake	Secondary	81F6B	Steam Heat 8-1F-6B	Point	OP	305	462,683	6,322,268
Syncrude	Mildred Lake	Secondary	82F6A	Steam Heat 8-2F-6A	Point	OP	304	462,570	6,322,231
Syncrude	Mildred Lake	Secondary	82F6B	Steam Heat 8-2F-6B	Point	OP	304	462,588	6,322,237
Syncrude	Mildred Lake	Secondary	91F1	Reformer Furnace 9-1F-1	Point	OP	307	463,084	6,322,453
Syncrude	Mildred Lake	Secondary	92F1	Reformer Furnace 9-2F-1	Point	OP	308	462,947	6,322,612
Syncrude	Mildred Lake	Secondary	93F1	Reformer Furnace 9-3F-1	Point	OP	308	463,167	6,322,474
Syncrude	Mildred Lake	Secondary	14F1	Diluent Reboiler 14F-1	Point	OP	306	462,647	6,322,475
Syncrude	Mildred Lake	Secondary	151F1	Hydrogen Heater 15-1F-1	Point	OP	308	462,879	6,322,400
Syncrude	Mildred Lake	Secondary	152F1	Hydrogen Heater 15-2F-1	Point	OP	308	462,904	6,322,408
Syncrude	Mildred Lake	Secondary	18F1	Hydrogen Heater 18-1F-1	Point	OP	307	463,221	6,322,485
Syncrude	Mildred Lake	Secondary	221F2	Hydrogen Heater 22-1F-2	Point	OP	308	463,028	6,322,657
Syncrude	Mildred Lake	Secondary	151F2	Fractionator Reboiler 15-1F-2	Point	OP	307	462,820	6,322,545
Syncrude	Mildred Lake	Secondary	152F2	Fractionator Reboiler 15-2F-2	Point	OP	307	462,850	6,322,555
Syncrude	Mildred Lake	Secondary	18F2	Fractionator Reboiler 18F-2	Point	OP	307	463,247	6,322,494
Syncrude	Mildred Lake	Secondary	221F3	Fractionator Reboiler 22-1F-3	Point	OP	308	463,032	6,322,644
Syncrude	Mildred Lake	Secondary	221F1	Bitumen Feed 22-1F-1	Point	OP	308	463,038	6,322,626
Syncrude	Mildred Lake	Secondary	21F7	Bit Heat N 21F-7	Point	OP	308	462,865	6,323,038
Syncrude	Mildred Lake	Secondary	21F8	Bit Heat N 21F-8	Point	OP	308	462,898	6,323,049
Syncrude	Mildred Lake	Secondary	21F9	Bit Heat N 21F-9	Point	OP	307	462,933	6,322,830
Syncrude	Mildred Lake	Secondary	21F10	Bit Heat N 21F-10	Point	OP	307	462,966	6,322,841
Syncrude	Mildred Lake	Secondary	21F50	Bit Heat E 21F-50	Point	OP	314	463,964	6,322,778
Syncrude	Mildred Lake	Secondary	21F51	Bit Heat E 21F-51	Point	OP	306	464,025	6,322,590
Syncrude	Mildred Lake	Secondary	21F52	Bit Heat E 21F-52	Point	OP	296	464,062	6,322,477
Syncrude	Mildred Lake	Secondary	21F53	Bit Heat E 21F-53	Point	OP	313	463,997	6,322,675
Syncrude	Mildred Lake	Secondary	120F101	Sulfreen Furnace 12-0F-101	Point	OP	306	462,741	6,322,333
Syncrude	Mildred Lake	Secondary	NGTG203	GTG 203	Point	DIS	307	463,555	6,322,330
Syncrude	Mildred Lake	Secondary	N73F1A	7-3 F-1A	Point	DIS	307	462,782	6,322,688
Syncrude	Mildred Lake	Secondary	N73F1B	7-3 F-1B	Point	DIS	307	462,777	6,322,702
Syncrude	Mildred Lake	Secondary	N83F6A	8-3 F-6A	Point	DIS	307	462,970	6,322,749
Syncrude	Mildred Lake	Secondary	N83F6B	8-3 F-6B	Point	DIS	307	462,965	6,322,764
Syncrude	Mildred Lake	Secondary	N94F1	9-4 F-1	Point	DIS	308	463,355	6,322,650
Syncrude	Mildred Lake	Secondary	N95F1	9-5 F-1	Point	DIS	307	463,528	6,322,658
Syncrude	Mildred Lake	Secondary	N153F1	15-3 F-1	Point	DIS	307	463,509	6,322,668
Syncrude	Mildred Lake	Secondary	N153F2	15-3 F-2	Point	DIS	307	463,495	6,322,663
Syncrude	Mildred Lake	Secondary	N181F3	18-1 F-3	Point	DIS	308	463,311	6,322,539
Syncrude	Mildred Lake	Secondary	N182F1	18-2 F-1	Point	DIS	307	463,393	6,322,630
Syncrude	Mildred Lake	Secondary	N182F2	18-2 F-2	Point	DIS	307	463,422	6,322,640
Syncrude	Mildred Lake	Secondary	N182F3	18-2 F-3	Point	DIS	307	463,408	6,322,635
Syncrude	Mildred Lake	Secondary	N371F1A	37-1F-1A	Point	APP	306	462,578	6,322,525
Syncrude	Mildred Lake	Secondary	N371F2A	37-1F-2A	Point	DIS	306	462,607	6,322,535
Syncrude	Mildred Lake	New 8-3	N83	NEW 8-3 STACK	Point	DIS	307	462,807	6,322,880
Syncrude	Mildred Lake	Fleet	SYNN	North Mine 1997	Area	OP	330	457,337	6,321,063
Syncrude	Mildred Lake	Fleet	SYNW	West Base Mine 1997	Area	OP	300	460,031	6,316,008
Syncrude	Mildred Lake	Fleet	SYNE	East Base Mine 1997	Area	OP	???	463,819	6,320,141
Syncrude	Mildred Lake	Fleet	SYNN2	North Mine 2001	Area	APP	330	455,832	6,321,163

Syncrude	Mildred Lake	Fleet	SYNW2	West Base Mine 2001	Area	APP	300	458,794	6,316,321
Syncrude	Mildred Lake	Fleet	SYNN3	North Mine 2007	Area	DIS	330	455,832	6,321,163
Syncrude	Mildred Lake	Fleet	SYNW3	West Base Mine 2007	Area	DIS	300	458,794	6,316,321
Syncrude	Mildred Lake	Mine Face	sMine1	North Mine 1997	Area	OP	330	457,337	6,321,063
Syncrude	Mildred Lake	Mine Face	sMine2	West Base Mine 1997	Area	OP	330	455,832	6,321,163
Syncrude	Mildred Lake	Mine Face	sMine3	East Base Mine 1997	Area	OP	300	460,031	6,316,008
Syncrude	Mildred Lake	Mine Face	sMine4	North Mine 2001	Area	APP	300	458,794	6,316,321
Syncrude	Mildred Lake	Mine Face	sMine5	West Base Mine 2001	Area	APP	219	466,965	6,351,537
Syncrude	Mildred Lake	Mine Face	sMine6	North Mine 2007	Area	DIS	330	455,832	6,321,163
Syncrude	Mildred Lake	Mine Face	sMine7	West Mine 2007	Area	DIS	252	482,935	6,344,587
Syncrude	Mildred Lake	Ponds	MLSB	Mildred Lake Basin	Area	OP	349	460,470	6,323,660
Syncrude	Mildred Lake	Ponds	MLSB2	Mildred Lake Basin	Area	APP	349	460,470	6,323,660
Syncrude	Mildred Lake	Ponds	MLSB3	Mildred Lake Basin	Area	DIS	349	460,470	6,323,660
Syncrude	Mildred Lake	Ponds	MLSBB	Mildred Lake Basin Beach	Area	OP	352	459,340	6,323,310
Syncrude	Mildred Lake	Ponds	MLSBB2	Mildred Lake Basin Beach	Area	APP	352	459,340	6,323,310
Syncrude	Mildred Lake	Ponds	MLSBB3	Mildred Lake Basin Beach	Area	DIS	352	459,340	6,323,310
Syncrude	Mildred Lake	Ponds	EinPit	East Mine In-Pit	Area	APP	291	464,150	6,317,250
Syncrude	Mildred Lake	Ponds	EinPit	East Mine In-Pit	Area	DIS	291	464,150	6,317,250
Syncrude	Mildred Lake	Ponds	WPit	West Mine In-Pit	Area	OP	291	461,460	6,317,380
Syncrude	Mildred Lake	Ponds	WPit2	West Mine In-Pit	Area	APP	291	461,460	6,317,380
Syncrude	Mildred Lake	Ponds	WPit3	West Mine In-Pit	Area	DIS	291	461,460	6,317,380
Syncrude	Mildred Lake	Ponds	SWSS	SW Sand Storage Area	Area	OP	382	452,650	6,314,390
Syncrude	Mildred Lake	Ponds	SWSS	SW Sand Storage Area	Area	APP	382	452,650	6,314,390
Syncrude	Mildred Lake	Ponds	SWSS	SW Sand Storage Area	Area	DIS	382	452,650	6,314,390
Syncrude	Mildred Lake	Ponds	SWSS	SW Sand Storage Pond	Area	OP	380	452,780	6,315,080
Syncrude	Mildred Lake	Ponds	SWSSP	SW Sand Storage Pond	Area	APP	380	452,780	6,315,080
Syncrude	Mildred Lake	Ponds	SWSS2	SW Sand Storage Pond	Area	DIS	380	452,780	6,315,080
Syncrude	Mildred Lake	--	SCLFUG	Plant site fugitive	point	OP	307	462,588	6,322,350

Table I.2 Other Sources Emission Source Location Parameters

	Source Identification				Source	Status	Elevation	UTM Location East	UTM Location North
OWNWER	Area	Sub-Area	ID	Description	Class		[m]	[m]	[m]
Syncrude	Aurora	Aurora	AUNSG1	OTHRSG1	Point	APP	289	469,402	6,350,746
Syncrude	Aurora	Aurora	AUNSG2	OTHRSG2	Point	DIS	289	469,402	6,350,779
Syncrude	Aurora	Aurora	SYNB1	Boiler 1	Point	APP	287	469,370	6,350,733
Syncrude	Aurora	Aurora	SYNB2	Boiler 2	Point	APP	287	469,390	6,350,733
Syncrude	Aurora	Aurora	AUSSG1	OTHRSG1	Point	DIS	349	484,164	6,342,667
Syncrude	Aurora	Aurora	AUSSG2	OTHRSG2	Point	DIS	349	484,164	6,342,700
Syncrude	Aurora	Aurora	SYNB3	Boiler 1	Point	DIS	349	484,151	6,342,653
Syncrude	Aurora	Aurora	SYNB4	Boiler 2	Point	DIS	347	484,131	6,342,653
Syncrude	Aurora	Fleet	SYNAN	Aurora North Mine	Area	APP	219	466,965	6,351,537
Syncrude	Aurora	Fleet	SYNAN2	Aurora North Mine Applied	Area	DIS	219	466,965	6,351,537
Syncrude	Aurora	Fleet	SYNAS	Aurora South Mine	Area	DIS	252	482,935	6,344,587
Syncrude	Aurora	Mine Face	aM1	Aurora North Mine	Area	APP	219	466,965	6,351,537
Syncrude	Aurora	Mine Face	aM2	Aurora North Mine Applied	Area	DIS	219	466,965	6,351,537
Syncrude	Aurora	Mine Face	aM3	Aurora South Mine	Area	DIS	252	482,935	6,344,587
Syncrude	Aurora	Ponds	SASP	South Aurora Water Pond	Area	DIS	385	486,630	6,338,430
Syncrude	Aurora	Ponds	SANP	North Aurora Water Pond	Area	DIS	345	472,990	6,350,590
Northstar UTF	--	--	NSSG1	Steam Generator 1	Point	OP	429	444,000	6,324,250
Northstar UTF	--	--	NSSG2	Steam Generator 2	Point	OP	444	440,012	6,324,240
Northstar UTF	--	--	NSSG3	Steam Generator 3	Point	OP	429	444,022	6,324,240
Northstar UTF	--	--	NSSG4	Steam Generator 4	Point	OP	429	444,032	6,324,240
Northstar UTF	--	--	NSGH	Glycol Heater	Point	OP	429	444,042	6,324,240
Northstar UTF	--	--	NSH1	Heater (Winter)	Point	OP	428	443,870	6,324,376
SOLV-EX	Bitumount	--	SOLVM	Main Stack(servicing both A4 & A11).	Point	OP	299	479,535	6,360,112
SOLV-EX	Bitumount	--	A7	Heater	Point	OP	297	479,555	6,360,112
SOLV-EX	Bitumount	--	A10	Heater	Point	OP	297	479,575	6,360,112
SOLV-EX	Bitumount	--	A12/A14	Boilers and Turbines	Point	OP	297	479,595	6,360,112
SOLV-EX	Bitumount	--	A3	Soaker Furnace	Point	OP	297	479,615	6,360,112
SOLV-EX	Bitumount	--	A6	Salt Dryer	Point	OP	297	479,635	6,360,112
SOLV-EX	Bitumount	--	A15	Heater	Point	OP	297	479,655	6,360,112
SOLV-EX	Bitumount	--	A8	Alumina Dryer	Point	OP	297	479,675	6,360,112
SOLV-EX	Bitumount	--	A9	FeSO4 Dryer	Point	OP	297	479,695	6,360,112
SOLV-EX	Bitumount	--	A17	K2SO4 Dryer	Point	OP	297	479,715	6,360,112
SOLV-EX	Bitumount	--	A5	Dryer	Point	OP	297	479,735	6,360,112
SOLV-EX	Bitumount	--	A19	By-Product Dryer	Point	OP	297	479,755	6,360,112
Northland Forest Products Mill	--	--	NFP	Facility	Point	OP	228	477,831	6,286,040
Traffic Highway	--	--	HighW	Cars/Light trucks	Area	OP	228	462,507	6,331,720
Fort McMurray sources	--	--	McMur	Cars/Light trucks/heating	Area	OP	228	476,008	6,282,130
Fort McKay sources	--	--	McKay	Cars/Light trucks/heating	Area	OP	228	468,100	6,337,400
Shell	Muskeg River Mine	--	MRFH1	Fired Heater #1	Point	DIS	275	469,565	6,346,240
Shell	Muskeg River Mine	--	MRFH2	Fired Heater #2	Point	DIS	269	469,580	6,344,240
Shell	Muskeg River Mine	--	MRFH3	Fired Heater #3	Point	DIS	282	465,595	6,346,240
Shell	Muskeg River Mine	--	MRFH4	Fired Heater #4	Point	DIS	275	469,610	6,346,240
Shell	Muskeg River Mine	--	MRFH5	Fired Heater #5	Point	DIS	275	469,625	6,346,240
Shell	Muskeg River Mine	--	MRFH6	Fired Heater #6	Point	DIS	275	469,640	6,346,240
Shell	Muskeg River Mine	--	MRB1	Boiler #1	Point	DIS	275	469,600	6,346,125
Shell	Muskeg River Mine	--	MRB2	Boiler #2	Point	DIS	275	469,575	6,346,125
Shell	Muskeg River Mine	--	MRSH	Space Heating	Point	DIS	275	469,575	6,346,150
Shell	Muskeg River Mine	--	MRFP	Flare Pilot	Point	DIS	275	469,575	6,346,150
Shell	Lease 13 East Mine	--	L13FH1	Fired Heater #1	Point	DIS	301	477,188	6,348,582
Shell	Lease 13 East Mine	--	L13FH2	Fired Heater #2	Point	DIS	301	477,203	6,348,582
Shell	Lease 13 East Mine	--	L13FH3	Fired Heater #3	Point	DIS	301	477,218	6,348,582
Shell	Lease 13 East Mine	--	L13FH4	Fired Heater #4	Point	DIS	301	477,233	6,348,582
Shell	Lease 13 East Mine	--	L13FH5	Fired Heater #5	Point	DIS	301	477,248	6,348,582

Shell	Lease 13 East Mine	--	L13FH6	Fired Heater #6	Point	DIS	301	477,263	6,348,582
Shell	Lease 13 East Mine	--	L13B1	Boiler #1	Point	DIS	302	477,198	6,348,467
Shell	Lease 13 East Mine	--	L13B2	Boiler #2	Point	DIS	302	477,223	6,348,467
Shell	Lease 13 East Mine	--	L13SH	Space Heating	Point	DIS	302	477,223	6,348,467
Shell	Lease 13 East Mine	--	L13F1	Flare Pilot	Point	DIS	302	477,223	6,348,467
Shell	Muskeg River Mine	Fleet	SHLMUS	Shell Muskeg River Mine	Area	DIS	280	469,245	6,348,605
Shell	Lease 13 East Mine	Fleet	SHL13	Shell Lease 13 Mine	Area	DIS	310	475,945	6,345,225
Shell	Muskeg River Mine	Mine Face	MRMine	Shell Muskeg River Mine	Area	DIS	280	469,245	6,348,605
Shell	Lease 13 East Mine	Mine Face	L13Min	Shell Lease 13 Mine	Area	DIS	310	475,945	6,345,225
Shell	Muskeg River Mine	Ponds	ShWP	Shell W est Water Pond	Area	DIS	360	464,930	6,341,680
Shell	Lease 13 East Mine	Ponds	ShEP	Shell East Water Pond	Area	DIS	360	477,430	6,340,710
Mobil	Kearl Mine	Fixed Plant	MKS1	Extraction - Stack 1	Point	DIS	322	485,500	6,351,500
Mobil	Kearl Mine	Fixed Plant	MKS2	Extraction - Stack 2	Point	DIS	322	485,520	6,351,500
Mobil	Kearl Mine	Fixed Plant	MKS3	Extraction - Stack 3	Point	DIS	322	485,540	6,351,500
Mobil	Kearl Mine	Fixed Plant	MKS4	Extraction - Stack 4	Point	DIS	322	485,560	6,351,500
Mobil	Kearl Mine	Fixed Plant	MKS5	Upgrader - Stack 5	Point	DIS	322	485,580	6,351,500
Mobil	Kearl Mine	Fixed Plant	MKS6	Upgrader - Stack 6	Point	DIS	322	485,600	6,351,500
Mobil	Kearl Mine	Fleet	MOBKL	Mobil Kearl Lake Mine	Area	DIS	320	483,120	6,352,288
Mobil	Kearl Mine	Mine Face	MBMINE	Mobil Kearl Lake Mine	Area	DIS	320	483,120	6,352,288
Mobil	Kearl Mine	Ponds	MBP	Mobil Kearl Lake Ware Pond	Area	DIS	360	478,800	6,351,100
Petro-Canada	--	--	MKB1	MacKay River Boiler #1	Point	DIS	377	446,425	6,326,273
Petro-Canada	--	--	MKB2	MacKay River Boiler #2	Point	DIS	377	446,445	6,326,273
Petro-Canada	--	--	MKB3	MacKay River Boiler #3	Point	DIS	377	446,465	6,326,273
Petro-Canada	--	--	MKB4	MacKay River Boiler #4	Point	DIS	377	446,485	6,326,273
Petro-Canada	--	--	MKB5	MacKay River Boiler #5	Point	DIS	377	446,505	6,326,273
Petro-Canada	--	--	MKB6	MacKay River Boiler #6	Point	DIS	372	446,525	6,326,273
Gulf-Canada	--	--	Gulf1-1	Surmont/location 1 /stack # 1	Point	DIS	619	501,445	6,225,425
Gulf-Canada	--	--	Gulf1-2	Surmont/location 1 /stack # 2	Point	DIS	619	501,539	6,225,785
Gulf-Canada	--	--	Gulf1-3	Surmont/location 1 /stack # 3	Point	DIS	619	501,539	6,225,795
Gulf-Canada	--	--	Gulf1-4	Surmont/location 1 /stack # 4	Point	DIS	619	501,539	6,225,805
Gulf-Canada	--	--	Gulf1-5	Surmont/location 1 /stack # 5	Point	DIS	619	501,539	6,225,815
Gulf-Canada	--	--	Gulf1-6	Surmont/location 1 /stack # 6	Point	DIS	619	501,539	6,225,825
Gulf-Canada	--	--	Gulf2-1	Surmont/location 2 /stack # 1	Point	DIS	623	500,845	6,225,425
Gulf-Canada	--	--	Gulf2-2	Surmont/location 2 /stack # 2	Point	DIS	623	500,939	6,225,785
Gulf-Canada	--	--	Gulf2-3	Surmont/location 2 /stack # 3	Point	DIS	623	500,939	6,225,795
Gulf-Canada	--	--	Gulf2-4	Surmont/location 2 /stack # 4	Point	DIS	623	500,939	6,225,805
Gulf-Canada	--	--	Gulf2-5	Surmont/location 2 /stack # 5	Point	DIS	623	500,939	6,225,815
Gulf-Canada	--	--	Gulf2-6	Surmont/location 2 /stack # 6	Point	DIS	623	500,939	6,225,825
Gulf-Canada	--	--	Gulf3-1	Surmont/location 3 /stack # 1	Point	DIS	678	498,095	6,216,875
Gulf-Canada	--	--	Gulf3-2	Surmont/location 3 /stack # 2	Point	DIS	671	498,189	6,217,235
Gulf-Canada	--	--	Gulf3-3	Surmont/location 3 /stack # 3	Point	DIS	671	498,189	6,217,245
Gulf-Canada	--	--	Gulf3-4	Surmont/location 3 /stack # 4	Point	DIS	671	498,189	6,217,255
Gulf-Canada	--	--	Gulf3-5	Surmont/location 3 /stack # 5	Point	DIS	671	498,189	6,217,265
Gulf-Canada	--	--	Gulf3-6	Surmont/location 3 /stack # 6	Point	DIS	671	498,189	6,217,275
Gulf-Canada	--	--	Gulf4-1	Surmont/location 4/stack # 1	Point	DIS	540	512,045	6,226,825
Gulf-Canada	--	--	Gulf4-2	Surmont/location 4/stack # 2	Point	DIS	540	512,139	6,227,185
Gulf-Canada	--	--	Gulf4-3	Surmont/location 4/stack # 3	Point	DIS	540	512,139	6,227,195
Gulf-Canada	--	--	Gulf4-4	Surmont/location 4/stack # 4	Point	DIS	540	512,139	6,227,205
Gulf-Canada	--	--	Gulf4-5	Surmont/location 4/stack # 5	Point	DIS	540	512,139	6,227,215
Gulf-Canada	--	--	Gulf4-6	Surmont/location 4/stack # 6	Point	DIS	540	512,139	6,227,225
Gulf-Canada	--	--	Gulf5-1	Surmont/location 5 /stack # 1	Point	DIS	555	509,295	6,208,025
Gulf-Canada	--	--	Gulf5-2	Surmont/location 5 /stack # 2	Point	DIS	555	509,389	6,208,385
Gulf-Canada	--	--	Gulf5-3	Surmont/location 5 /stack # 3	Point	DIS	555	509,389	6,208,395
Gulf-Canada	--	--	Gulf5-4	Surmont/location 5 /stack # 4	Point	DIS	555	509,389	6,208,405
Gulf-Canada	--	--	Gulf5-5	Surmont/location 5 /stack # 5	Point	DIS	555	509,389	6,208,415
Gulf-Canada	--	--	Gulf5-6	Surmont/location 5 /stack # 6	Point	DIS	555	509,389	6,208,425
JACOS	--	--	Jacos1	combined point point sources	Point	DIS	592	457,965	6,237,042
JACOS	--	--	Jacos2	Flare	Flare	DIS	592	457,985	6,237,042

Notes: Sub-Area: Secondary: secondary emissions from heaters and boilers; Fleet: mine fleet fugitive emissions; Mine Face: exposed mine surfaces fugitive emissions; Ponds: tailings areas fugitive emissions.

Class: Point: elevated stack emission sources; Area: ground level area source with initial sigma z; Flare: elevated stack emission with pseudo stack parameters.

Status: Op: currently operating (1997); App: approved emission for Baseline assessment; DIS: disclosed project for a future emission.