Northwest Territories Air Quality Report 2006

Department of Environment and Natural Resources

Northwest
Territories

Table of Contents

INTRODUCTION

The Environmental Protection Division (EPD) of the Department of Environment and Natural Resources (ENR) monitors air quality in the Northwest Territories. ENR maintains and operates the NWT Ambient Air Quality Monitoring Network, consisting of four monitoring stations located in Yellowknife, Fort Liard, Norman Wells and Inuvik. Each station is capable of continuously sampling and analysing a variety of air pollutants and meteorological conditions. The Yellowknife station is operated in partnership with the National Air Pollution Surveillance (NAPS) program – a joint federal/provincial/territorial monitoring network tracking urban air quality trends throughout Canada.

ENR also monitors acid precipitation at Snare Rapids in cooperation with the Canadian Air and Precipitation Monitoring Network (CAPMoN) and conducts seasonal particulate sampling at Daring Lake.

The 2006 Annual Air Quality Report summarizes the air quality information collected in 2006, along with some discussion of trends. The report also provides information on network operations, the air pollutants monitored and the air quality standards used in assessing the monitoring results.

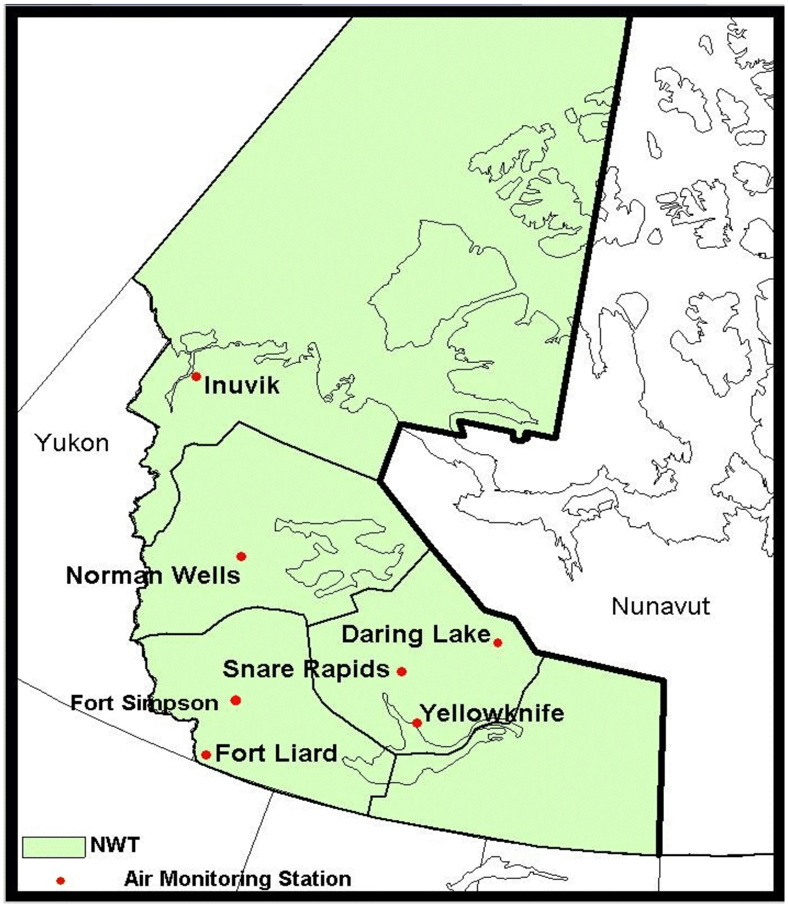
After reading this report, if you have questions or require further information you can contact:

Environmental Protection Division
Department of Environment and Natural Resources
Government of the Northwest Territories
P.O. BOX 1320
Yellowknife, NT X1A 2L9

Telephone: (867) 873-7654
Facsimile: (867) 873-0221

This report is also available on the Internet at www.enr.gov.nt.ca/eps/environ.htm.

OPERATIONS (NETWORK)



The NWT Air Quality Monitoring Network consists of four permanent monitoring stations located in Yellowknife, Inuvik, Fort Liard and Norman Wells. The stations are climate controlled trailers and include state of the art monitoring equipment capable of continuously sampling and analysing a variety of air pollutants and meteorological conditions. Pollutants monitored vary by station but include sulphur dioxide (SO_2), hydrogen sulphide (H_2S), fine particulate ($PM_{2.5}$), particulate (PM_{10}), ground level ozone (O_3), carbon monoxide (CO) and nitrogen oxides (NO_x) as well as wind speed, wind direction and temperature. For additional information on air pollutants see **Appendix B**. **Table 1** shows the breakdown of the NWT air monitoring network by substances and meteorological parameters monitored at each station.

Table 1:

Substances Monitored by Station

Stations	Particulate Matter			Gaseous					Precipitation	Meteor-logical Monitoring	
	TSP - Particulate	$PM_{2.5}$ - Fine Particulate	PM_{10} - Particulate	SO_2 Sulphur Dioxide	H_2S Hydrogen Sulphide	NO_x Nitrogen Oxides	O_3 Ground Level Ozone	CO Carbon Monoxide	Acidic Deposition	Wind Speed & Direction	Air Temperature
Yellowknife	√	√	√	√		√	√	√		√	√
Inuvik		√	√	√	√	√	√			√	√
Norman Wells		√		√	√	√	√			√	√
Fort Liard		√		√	√	√				√	√
Snare Rapids									√		
Daring Lake		√									√

Using a sophisticated data acquisition system (DAS) and communications software, data from each station is automatically transmitted every hour via telephone line and government intranet to ENR headquarters in Yellowknife, allowing almost real time review of community air quality by ENR staff. The data also undergoes a series of ‘on the fly’ validity checks before being archived by ENR’s data management, analysis and reporting system.

The Yellowknife station adjacent to Sir John Franklin High School is part of a larger national network that monitors the common or criteria air pollutants in urban centres across Canada. The National Air Pollution Surveillance (NAPS) Network is a joint federal/provincial/territorial program, incorporating 152 stations located in 55 cities, that monitor the same particulate and gaseous substances as those sampled in Yellowknife. Yellowknife data along with data from other cities is summarized and assessed, with results published in the NAPS annual data reports available at: http://www.etc-cte.ec.gc.ca/publications/napsreports_e.html .

The NAPS Network has a stringent quality assurance/quality control (QA/QC) program that ensures Canada-wide data is comparable. Participation in the NAPS program requires ENR to follow these QA/QC procedures at the Yellowknife site, and ENR, in turn, applies these procedures at the other stations.

The Fort Liard, Norman Wells and Inuvik stations are Territorial stations that were set up in response to increasing resource development activity in the NWT and the potential for the associated emissions to affect air quality. The primary objective of these stations is to establish baseline levels of SO_2, H_2S, NO_x, O_3 and PM ahead of development, as well as track the trends and cumulative impacts from source emissions should they occur.

ENR, with assistance from NWT Power Corporation staff, operates an acid precipitation collector at the Snare Rapids hydro-electric site. Daily rain and snow samples are collected and forwarded to the Canadian Air and Precipitation Monitoring Network (CAPMoN) for analysis. CAPMoN is a non-urban monitoring network with 28 measurement sites in Canada and one in the United States. Unlike NAPS, CAPMoN locates sites to limit the effect of anthropogenic sources. Most sites are remote and data is considered representative of background values.

ENR collects fine particulate data at the Daring Lake Tundra Ecosystem Research Station during the summer to establish typical background concentrations in the NWT. This research station is part of a circumpolar initiative called the Polar Continental Shelf Project and is designed as a research facility to conduct long-term research and monitoring of the tundra ecosystem.

Table 2 shows all of the various government affiliations involved with all of the monitoring stations.

Table 2:

NWT Air Quality Network

	Partnership/Contract	Stations	Network
Environment & Natural Resources – Environmental Protection Division Northwest Territories		Yellowknife	National Air Pollution Surveillance Environment Canada Environnement Canada
		Inuvik	Northwest Territories stations Northwest Territories
		Fort Liard	
		Norman Wells	
	NWT Power Corporation	Snare Rapids	Canadian Air and Precipitation Monitoring Environment Canada Environnement Canada
	NWT Tundra Ecological Research Station	Daring Lake	

Air quality monitoring in the NWT has evolved over time, beginning with a single TSP monitor in Yellowknife back in 1974, and progressing through various monitoring locations and equipment to reach the current stage of development. **Appendix A** traces the history of air quality monitoring in the NWT.

DEVELOPMENTS IN 2006

In 2006, the upgrading of the NWT air quality monitoring network continued with the addition of monitoring equipment as follows:

- Yellowknife - A BAM Particulate Matter (PM_{10}) monitor was installed and began collecting data in April.
- Inuvik - A BAM Particulate Matter (PM_{10}) monitor was installed and began collecting data in October.

The Partisol sampler operated for its first full year at the Sir John Franklin air monitoring trailer.

ENR completed the first phase of the Air Quality Monitoring Network web site and officially released it "live" on the government server. The website is available at: http://lisin.rwed-hq.gov.nt.ca/NWTAQ/NetworkSummary.aspx and links with the data management, analysis and reporting system to provide public access to 'almost real-time' air quality data for each monitoring location. Access to archived data is available by querying the database using web-based tools. The web site also provides additional information on the Government of the Northwest Territories (GNWT) Air Quality Monitoring Network, air pollutants, monitoring equipment, as well as links to monitoring information collected in other jurisdictions.

FUTURE PLANS

Improvements will be made to the Air Quality Monitoring Network web site based on user comments and feedback. The scope of the work includes database related modifications as well as web design improvements. The ultimate goal is to produce a web site that will provide useful and meaningful information to a broad range of users and be as intuitive as possible.

Continuous PM_{10} monitors will be added to the Norman Wells and Fort Liard stations to complete the particulate monitoring installations throughout the network.

The O_3 analyser scheduled for installation last year in Fort Liard will be installed this summer.

At the beginning of 2007, the Inuvik station was accepted as a designated NAPS network monitoring station – the most northerly station in the NAPS program. As part of the designation, the NAPS program has provided an ultra-low level CO analyser which is scheduled for installation this summer.

NWT AIR QUALITY STANDARDS

The Government of the NWT has adopted a number of concentration limits for protection of ambient (outdoor) air quality in the NWT. These limits apply to selected pollutants and are contained in the Guideline for Ambient Air Quality Standards in the Northwest Territories, established under the *NWT Environmental Protection Act*. They are summarized in **Table 3** below.

The NWT standards are used in the assessment of air quality monitoring data as well as determining the acceptability of emissions from proposed and existing developments. Where NWT standards are not available for a particular pollutant, the Canadian National Ambient Air Quality Objectives (national standards) or limits established in other jurisdictions are used.

Table 3:

NWT Ambient Air Quality Standards

Parameter and Standard	Concentration (µg/m³)*	Concentration (ppbv)**
Sulphur Dioxide (SO_2)		
1-hour average	450	172
24-hour average	150	57
Annual arithmetic mean	30	11
Ground Level Ozone (O_3)		
8-hour running average	127	65
Total Suspended Particulate (TSP)		
24-hour average	120	
Annual geometric mean	60	
Fine Particulate Matter ($PM_{2.5}$)		
24-hour average	30	

* Micrograms per cubic metre
** Parts per billion by volume

The Guideline for Ambient Air Quality Standards in the Northwest Territories provides additional information on the application of the NWT standards and the pollutants of concern. For additional information on air pollutants see **Appendix B**.

YELLOWKNIFE AIR QUALITY


Sir John Franklin Station

ENR, in partnership with the Canadian NAPS, operates the air quality monitoring station in Yellowknife.

This station is located at the Sir John Franklin High School and continuously monitors all criteria air pollutants O_3, SO_2, NO_x, CO, TSP and fine particulate ($PM_{2.5}$). Coarse particulate (PM_{10}), was added to the monitoring program in April 2006. The station also monitors wind speed, wind direction, and temperature which greatly assist in identifying possible sources of unusual or elevated readings.

A second station, located on the roof of the Post Office was closed at the end of 2005 and the equipment, consisting of a TSP (dust) High Volume sampler (Hi-Vol) and a Partisol Dichotomous fine particulate sampler, moved to the Sir John Franklin High School station. Hi-vol data was collected concurrently at both sites for two years (2004 and 2005) to check comparability of readings between the sites.

The air quality monitoring results from the consolidated station at Sir John Franklin are discussed in the following sections, with historical particulate data from the old Post Office site included where applicable.

TOTAL SUSPENDED PARTICULATE (TSP)

Yellowknife's greatest source of TSP is dust from roads, especially in the spring when the snow cover disappears and exposes winter sand and gravel applications on city streets to the effects of wind and vehicle disturbance. Forest fires, mining activities and combustion products from vehicles, heating and electricity generation also raise TSP levels.

Every six days on a predetermined schedule, TSP samples are collected over a 24-hour period (midnight to midnight) using a Hi-Vol air sampler. The sampler draws a measured volume of air through a filter to collect the suspended particulate. The filters are sent to Environment Canada's NAPS laboratory in Ottawa for analysis. TSP is measured as the weight of the particles collected on the filter divided by the volume of air drawn through the filter. Results are expressed in micrograms of particulate per cubic metre of air ($\mu g/m^3$). Arsenic levels are also determined in the samples collected.

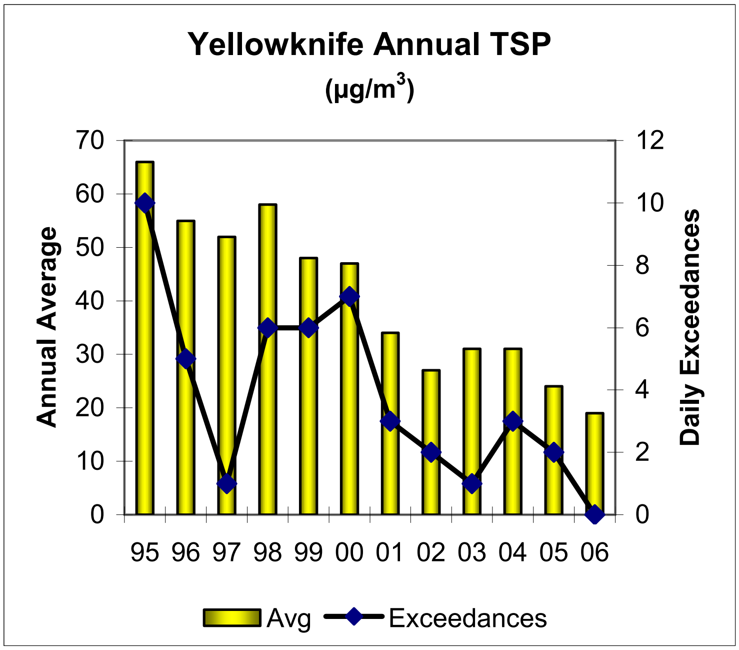
Table 4:

	Sir John Franklin		
µg/m^3	2005	2005	2006
	TSP	Arsenic	TSP
Highest (24-hr.)	151	0.04	90
Lowest (24-hr.)	2	0	3
Annual Average	20	.001	19

Fifty-six Hi-Vol air samples were collected during 2006. **Table 4** summarizes the 2005 and 2006 TSP results including the annual average (geometric mean) as well as the 2005 arsenic results. The 2006 arsenic data was not available for the release of this report due to analytical delays at the NAPS laboratory.

The bars in **Figure 1** track annual average TSP levels in Yellowknife over the last decade (Post Office station 1995-2005; Sir John Franklin station 2006). In 2006, the annual average was 19µg/m^3. This is the lowest annual level ever recorded in Yellowknife and is well below the NWT annual standard of 60µg/m^3.

Figure 1:

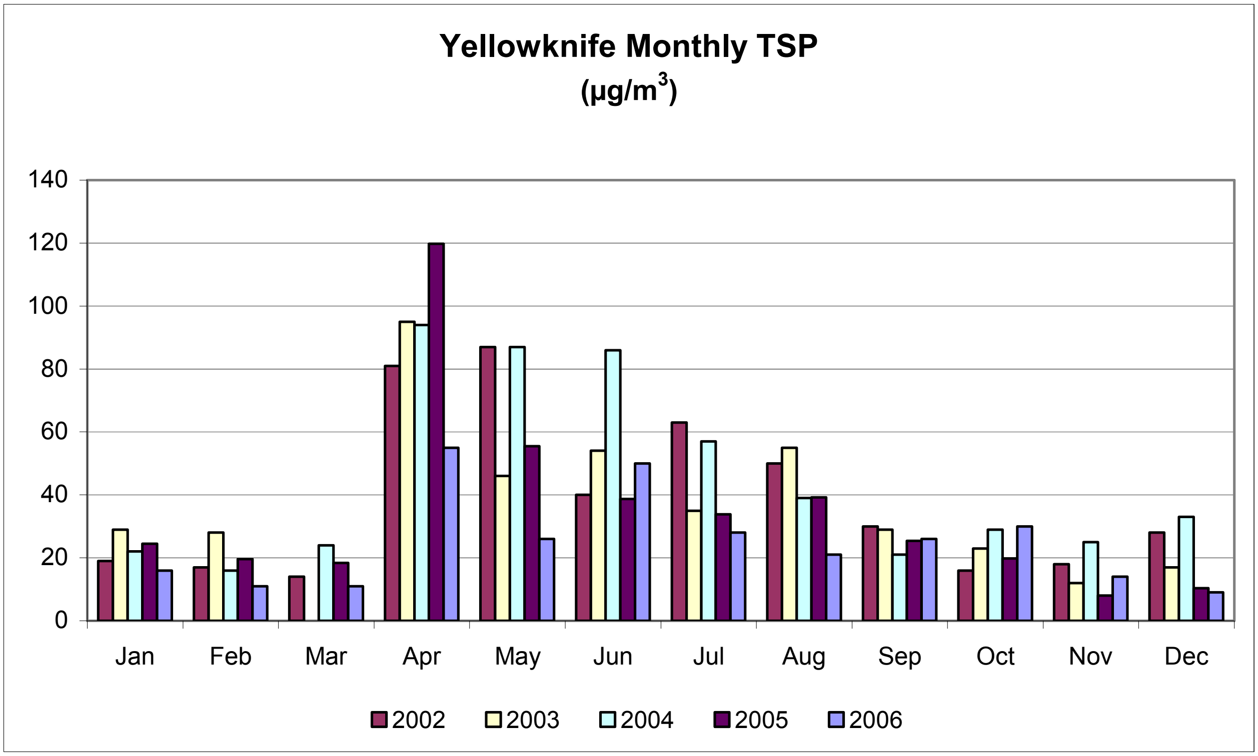


The line in **Figure 1** shows the number of times during the year that the NWT 24-hour standard (120µg/m^3) was exceeded. There were no exceedances in 2006 as compared to 2 in 2005.

Since the early 1990's, dust conditions in Yellowknife have improved - largely due to the City of Yellowknife's efforts to clean roads throughout the spring and summer as well as ongoing paving of graveled areas. Overall there is a downward trend in annual TSP levels. It is likely that the slight increases seen in the 2003 and 2004 data simply reflect the typical annual variations due to weather conditions and the intermittent sampling schedule.

Figure 2 tracks the average TSP level for each month for the last five years and clearly demonstrates the effects of springtime dust events. 2006 monthly averages followed the usual pattern with higher TSP levels in April through June, although the spring levels were much lower than average.

Figure 2:



FINE PARTICULATE $PM_{2.5}$ AND COARSE PARTICULATE PM_{10}

ENR uses two methods of sampling the smaller size fractions of PM in Yellowknife – a filter-based Partisol Dichotomous sampler and a Beta Attenuation Mass Monitor (BAM). The BAM methodology provides continuous, almost real-time (hourly) analysis of particulate concentrations, while the Partisol samples on a 24-hour basis every six days. The Partisol sampler simultaneously collects both the 2.5µm and less, and the 2.5 to 10µm particulate size fractions on a filter media. The filters require laboratory analysis to determine particulate concentrations and, unlike the BAM, do not provide timely information for real time air quality assessment. However, the filters can also be analysed for a whole suite of additional parameters including metals. The Partisol compliments the BAM in that particle identification can be determined which provides more in depth information about fine particulate. In April 2006, a second BAM configured to sample PM_{10} was added to the station.

Only one $PM_{2.5}$ BAM reading at the Sir John Franklin station in 2006 exceeded the NWT 24-hour standard (30µg/m^3). This exceedance was influenced by forest fire smoke. The maximum 24-hour $PM_{2.5}$ value occurred on June 27 and coincided with forest fires burning in Wood Buffalo National Park. Review and analysis of the results and wind information from the Sir John Franklin station and other meteorological stations clearly indicated the effects of fine particulate transport predominantly from the Wood Buffalo fires.

Figure 3 shows the monthly averages and daily maximums measured at the Sir John Franklin station in 2006. The highest daily maximum concentration was 36µg/m^3. The highest hourly concentration recorded was 90µg/m^3.

Figure 3:

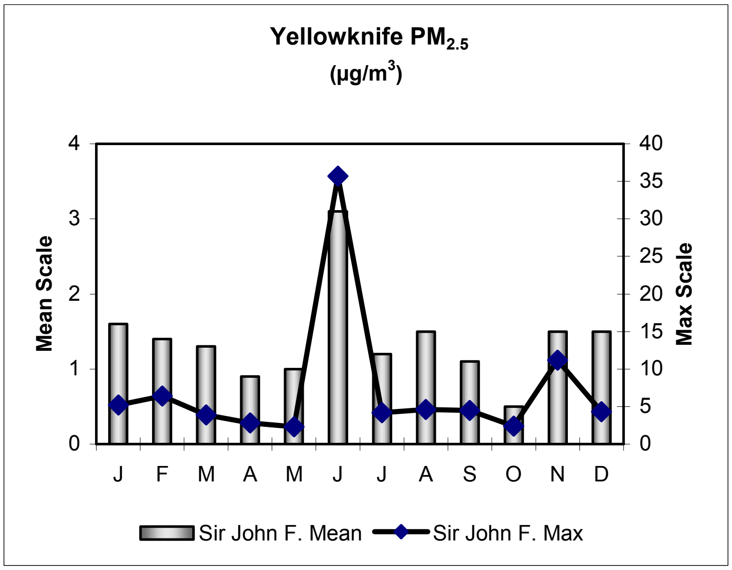
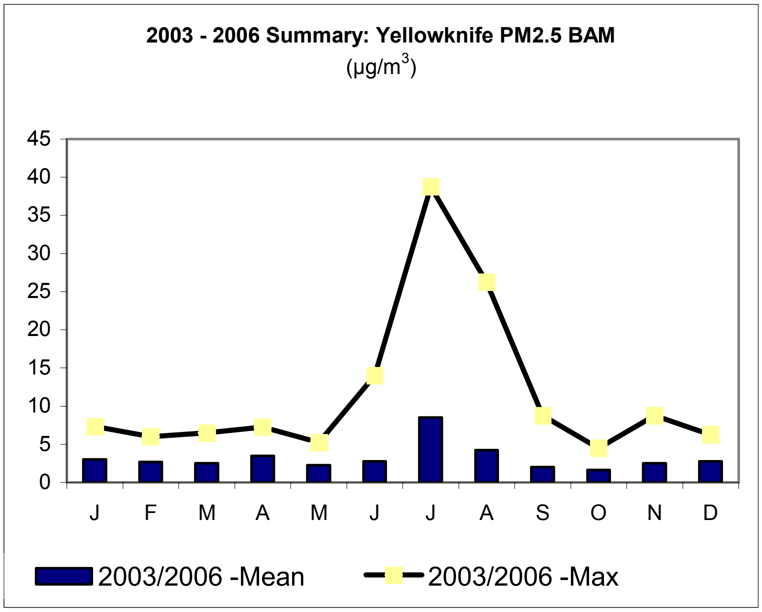


Figure 4 summarizes the $PM_{2.5}$ BAM data over the last four years, showing the overall mean and overall daily maximum for each month. Overall means for each month are low and very consistent ranging from 3-10µg/m^3, with an increase in July which reflects the influence of forest fire events. The July and August maximums were a direct result of smoke from forest fires. If the forest fire events are ignored, then the daily maximums decline considerably, falling within a range of 5-9µg/m^3. Based on the results gathered so far, it appears that $PM_{2.5}$ concentrations in Yellowknife are consistently low, with the greatest

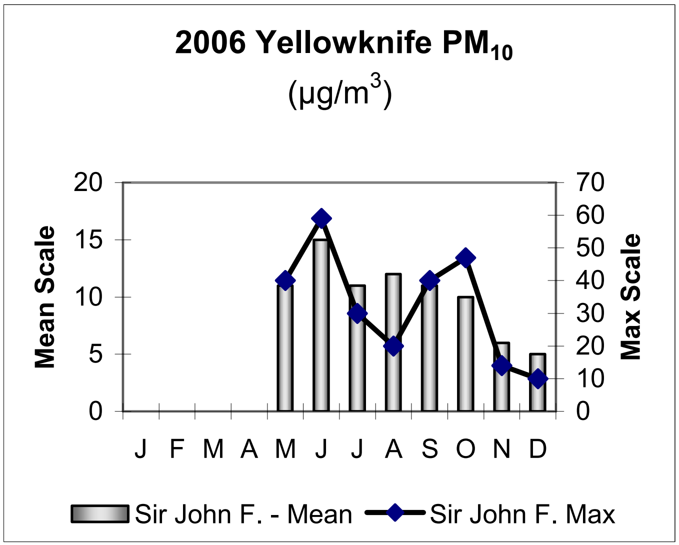
Figure 4:



short-term influences being smoke from forest fires.

In late April 2006 a second BAM, configured to sample PM_{10} was installed at the Sir John Franklin station. **Figure 5** shows the PM_{10} monthly averages and daily maximums measured at the station in 2006. The highest daily maximum concentration was 59µg/m^3. The highest hourly concentration recorded was 362µg/m^3.

Figure 5:



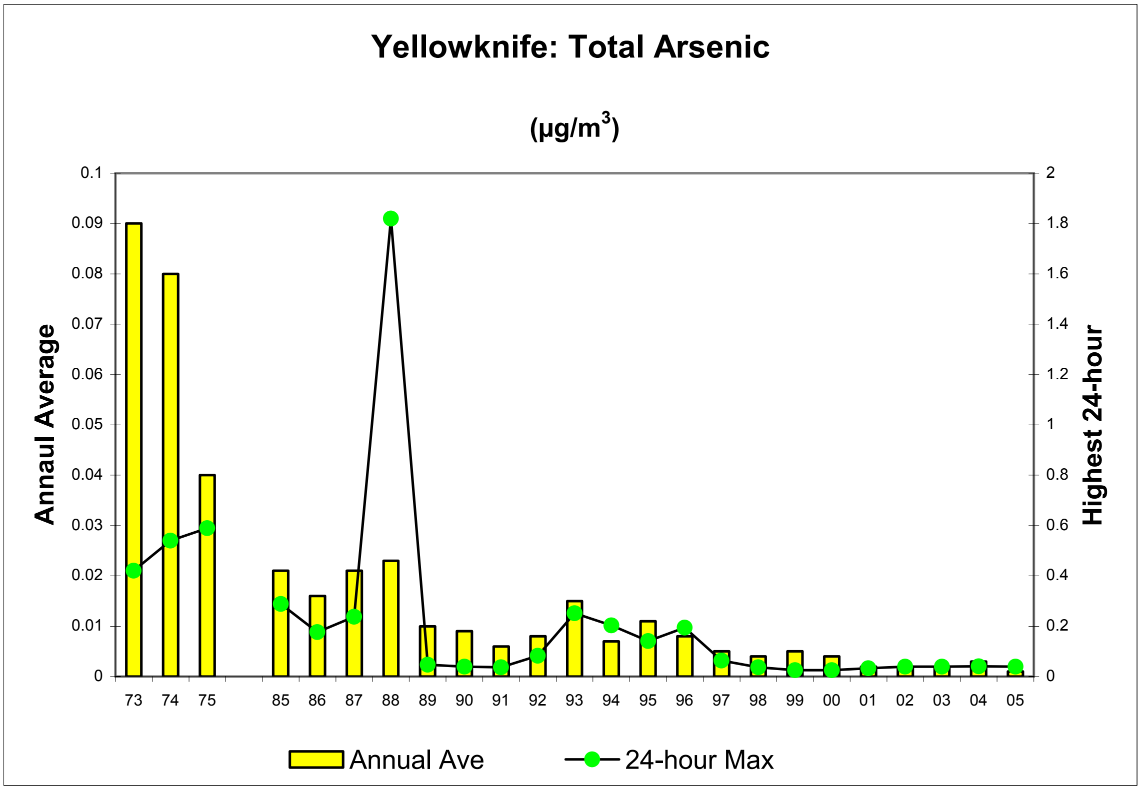
The NWT has not adopted a standard for PM_{10} but several Canadian jurisdictions (e.g. BC, Ontario, Newfoundland and Labrador) have adopted a PM_{10} concentration of 50µg/m^3 (24-hour average) as an acceptable limit. There was one exceedence of this limit in June.

ARSENIC

TSP filters are analysed to determine arsenic concentrations. Unfortunately, analytical delays at the NAPS laboratory often result in a 1-year time lag between arsenic data and the annual air quality report. Consequently, arsenic data for 2006 is not available for inclusion in this Report, although the 2005 data that was unavailable last year is. Analyses of the 2006 TSP filters will likely be completed by the end of June and results will be included in the 2007 Air Quality Report. ENR is discussing the time lag issue with NAPS in an effort to achieve more timely analysis.

Figure 6 summarizes the historical concentrations of arsenic measured in Yellowknife up to 2005. The bars represent annual averages while the line shows the highest total arsenic level measured over a 24-hour period for a given year. It is apparent that arsenic concentrations in Yellowknife have fallen from the historical elevated concentrations in the 1970s and 1980s. No exceedances of the Ontario Guideline (0.3µg/m^3) have occurred since 1988 and the average arsenic concentration over the last decade is 0.006µg/m^3 - below all but the most stringent World Health Organisation (WHO) risk estimate concentration (see Appendix B). In recent years, the overall average has decreased further to less than 0.003µg/m^3.

Figure 6:



The maximum 24-hour concentration in 2005 was 0.04µg/m^3 - almost an order of magnitude lower than the Ontario Guideline. The annual average (geometric mean) concentration in 2005 was 0.001µg/m^3, considerably lower than all but the most conservative risk estimate concentration provided by the WHO.

Studies in the U.S. show an average arsenic concentration in air of <0.001 - 0.003µg/m^3 in remote areas, with concentrations of 0.020 - 0.030µg/m^3 in urban areas, while Canadian urban areas range from 0.0005 to 0.017µg/m^3 (WHO, 2000). Yellowknife arsenic results over the last decade indicate annual concentrations ranging from 0.002 to 0.015µg/m^3 - comparable to concentrations measured in other urban areas. Since 1999, the levels have decreased and the annual average concentrations (0.002-0.004µg/m^3) are similar to those in remote areas.

Based on the previous discussion, it appears that concentrations of airborne arsenic in Yellowknife are typical of those found in remote areas and that health risks due to inhalation are minimal.

SULPHUR DIOXIDE (SO_2)

Continuous monitoring for SO_2 has been conducted in Yellowknife at several locations since 1992.

In the past, the largest sources of SO_2 in the Yellowknife area were the gold mine ore roasters, the most recent being Giant Mine. The highest levels of SO_2 in the Yellowknife area were measured downwind from the mine. Since the mine was closed in 1999, only background levels have been recorded.

Figure 7 shows the general trends in SO_2 levels measured in Yellowknife air from 1994 to 2006. The bars track the annual average and the line shows the number of times in each year that the NWT one-hour standard was exceeded. As illustrated by the graph, the number of exceedances has fallen to zero since the closure of Giant Mine in 1999.

Figure 7:

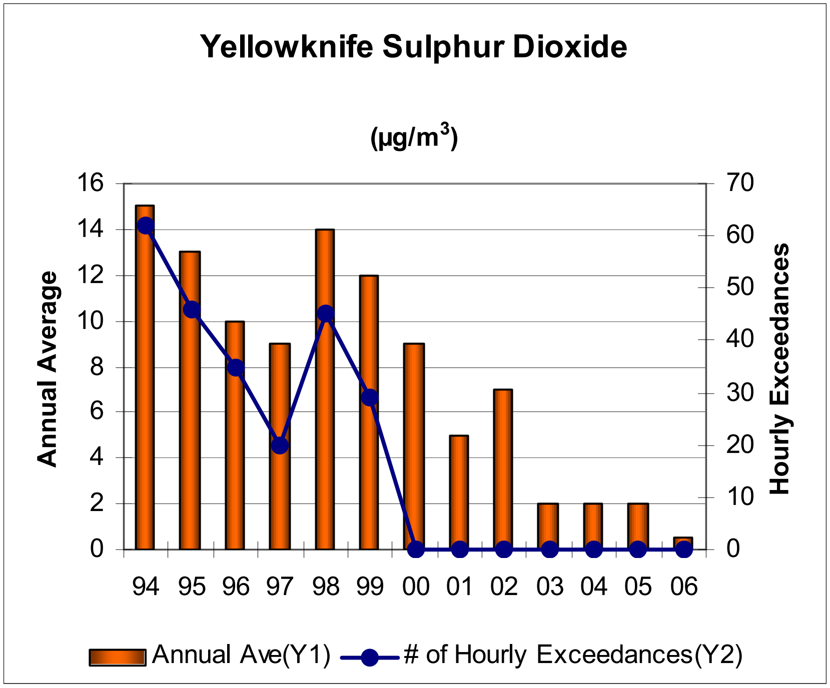


Figure 8:

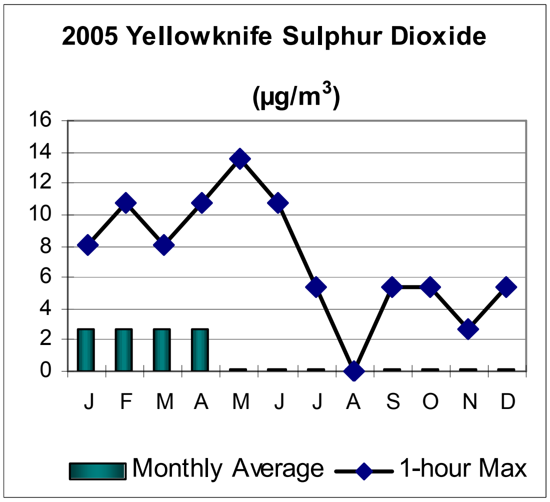
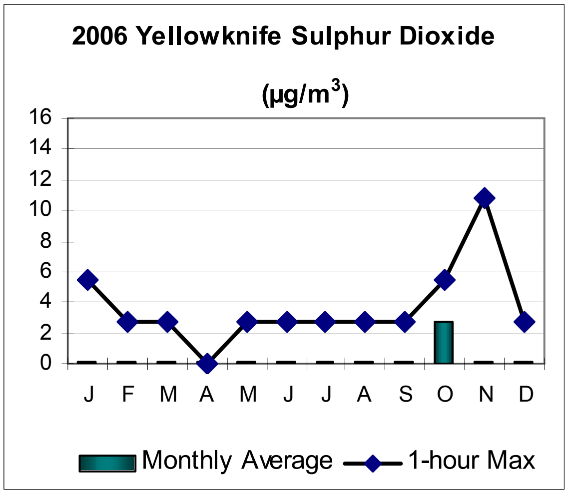


Figure 9:



Figures 8 and 9 show the 2005 and 2006 monthly averages and highest hourly concentrations. The 2006 data continued the trend of recent years, with no exceedances of the NWT hourly (450µg/m^3) and 24-hour (150µg/m^3) standards. The annual average was less than 1µg/m^3, a level which is well below the NWT (30µg/m^3) standard.

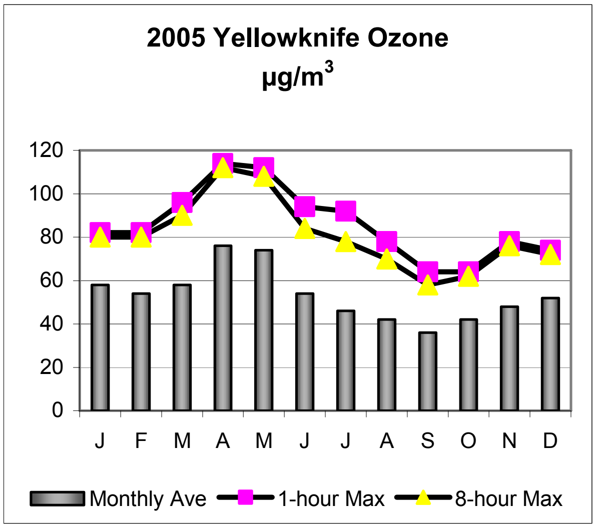
The vast majority of the hourly concentrations recorded in 2006 were only background or slightly greater, with a maximum concentration of 11µg/m^3. The concentrations reflect naturally occurring SO_2, usually in the range of 3 to 4µg/m^3, and small amounts from the burning of fossil fuels.

GROUND LEVEL OZONE (O_3)

A continuous O_3 analyzer has been operated in Yellowknife since 1998. The current analyzer has been operating at the Sir John Franklin station since February of 2003.

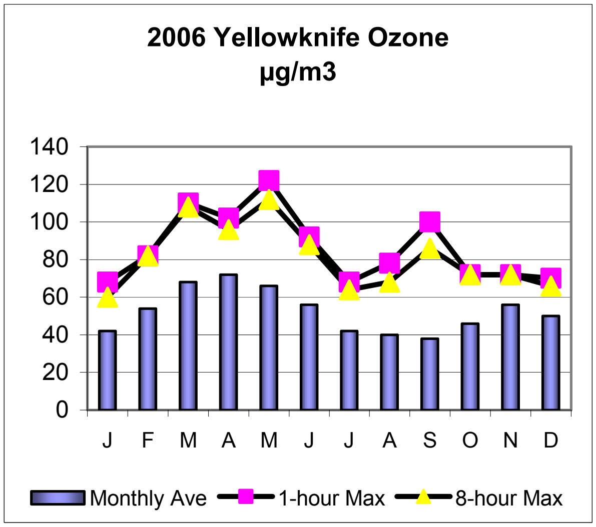
Detectable concentrations of O_3 exist even in remote areas due to naturally occurring sources of the precursor gases such as forest fires and volatile organic compounds (VOC) emissions from trees and the introduction of stratospheric ozone to lower elevations resulting from atmospheric mixing processes. These background concentrations typically are in the range of 40 to 80µg/m^3. In large urban areas (and areas downwind), ozone concentrations can be much higher than typical background due to the additional emissions of precursor gases.

Figure 10:



Figures 10 and 11 show the hourly and 8-hour maximums recorded for 2005 and 2006, together with the monthly averages. Neither the 1-hour national standard nor the 8-hour NWT standard was exceeded in Yellowknife during 2005 or 2006.

Figure 11:



The **Figures** illustrate the typical spring maximum which commonly occurs at remote monitoring stations located in mid to high latitudes in the Northern hemisphere and the source of which is the subject of considerable scientific debate. Typical monthly ozone concentrations at remote sites in Canada range between 40 and 80µg/m^3 and Yellowknife concentrations for both years fell below or within this range, indicating that most of the O_3 detected is likely naturally occurring or background.

NITROGEN OXIDES (NO_X)

The instrumentation provides continuous information on NO, NO_2 and NO_x. However, the focus is on NO_2 due to the greater health concerns associated with this pollutant and the availability of air quality standards for comparison.

The 2006 results indicated that there were no exceedances of the 1-hour and 24-hour national standards for NO_2. The maximum one-hour average was 80µg/m^3 and the annual average was 8µg/m^3.

Figures 12 and **13** show the 2005 and 2006 monthly averages and highest hourly concentrations. Both the highest monthly averages and the highest hourly concentrations occurred during the winter months. This is likely caused by increased emissions from fuel combustion for residential and commercial heating, and idling vehicles, as well as short-term "rush hour" traffic influences. The effects of these emissions on winter-time air quality can be increased when combined with stagnant meteorological conditions. Cold, calm days can result in an atmospheric situation where the normal decrease in air temperature with elevation is reversed and a zone of colder air is present at ground level. This zone of colder air and the lack of wind act to restrict dispersion and trap pollutants close to the ground.

Figure 12:

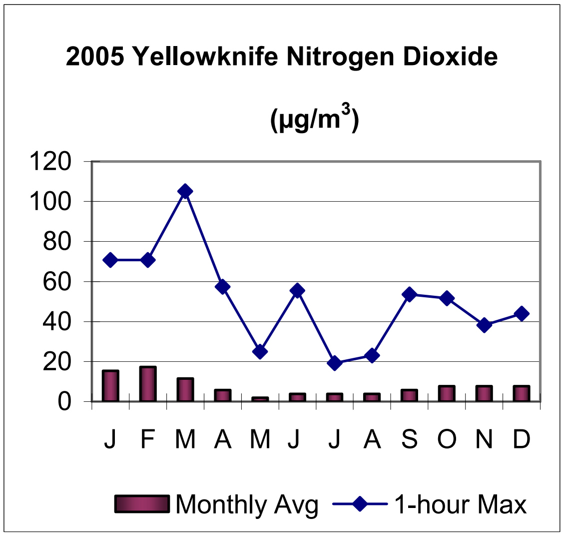
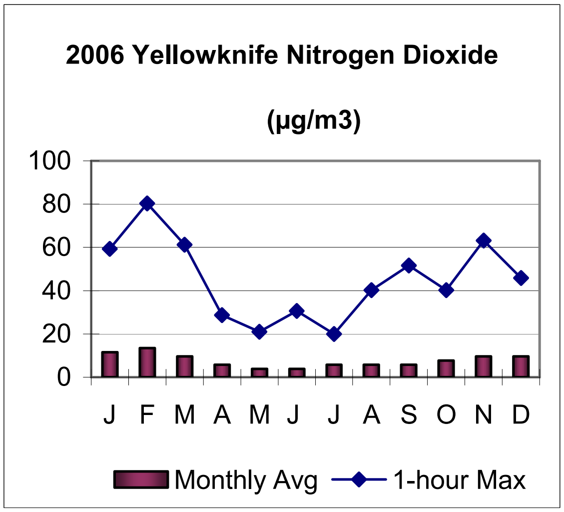


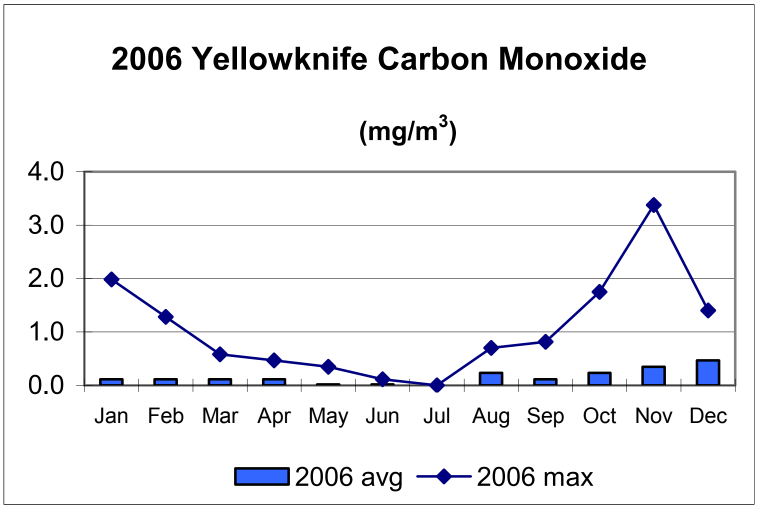
Figure 13:



CARBON MONOXIDE (CO)

2006 data continued the extremely low CO readings measured in 2005 and were well below the federal standards. Given the absence of heavy traffic volumes in Yellowknife, low levels of CO are expected. In 2006 the maximum 1-hour average was 3.4 mg/m^3 and the annual average was 0.2 mg/m^3. **Figure 14** shows the 2006 monthly averages and highest hourly concentrations.

Figure 14:



INUVIK AIR QUALITY

The focus of the monitoring station in Inuvik is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time.

In addition to SO_2, H_2S, NO_x, O_3 and $PM_{2.5}$, a PM_{10} monitor was added to the station in October 2006. Both the NO_x and the O_3 analyzers were supplied by Environment Canada (Yellowknife office).

HYDROGEN SULPHIDE (H_2S)

The data collected in 2006 continues to indicate very low H_2S concentrations in Inuvik – essentially non-detectable. Most of the readings are less than 1μg/m^3, which is below the detectable limits of the instrumentation and within the 'noise' range.

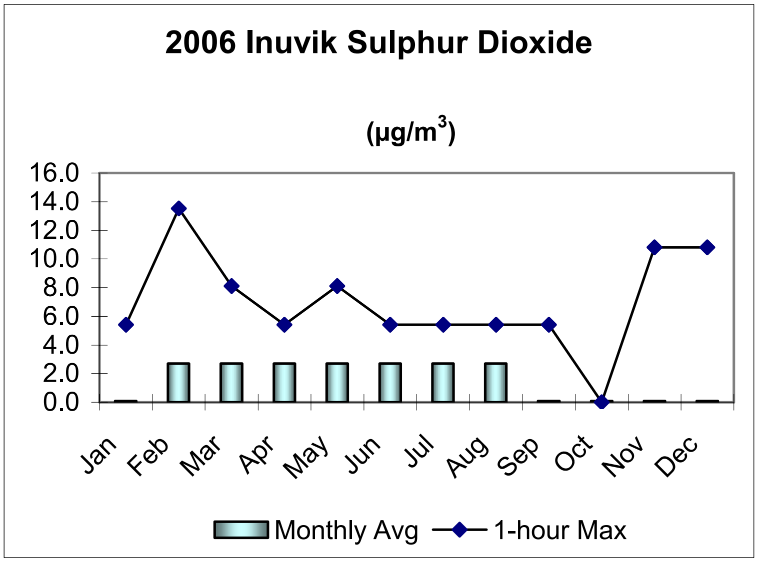
There were no exceedances of the Alberta Guidelines and the maximum recorded 1-hour average was 6μg/m^3.

SULPHUR DIOXIDE (SO_2)

The SO_2 concentrations measured in 2006 were very low and similar to last year's results, with no exceedances of the NWT standards. The overall average was 2μg/m^3 and the maximum 1-hour average was 14μg/m^3.

Figure 15 shows the monthly averages and maximum hourly concentrations for 2006.

Figure 15:



NITROGEN OXIDES (NO_X)

As discussed in the Yellowknife section of the report, the focus of NO_x monitoring is on the NO_2 portion in determining air quality, although NO is certainly of interest for other reasons (e.g. assessment of secondary pollutant formation). The data collected in Inuvik in 2006 shows that there were no exceedances of the 1-hour and 24-hour national standards for NO_2. The maximum 1-hour average was 57µg/m^3 and the annual average was 2µg/m^3.

Figure 16:

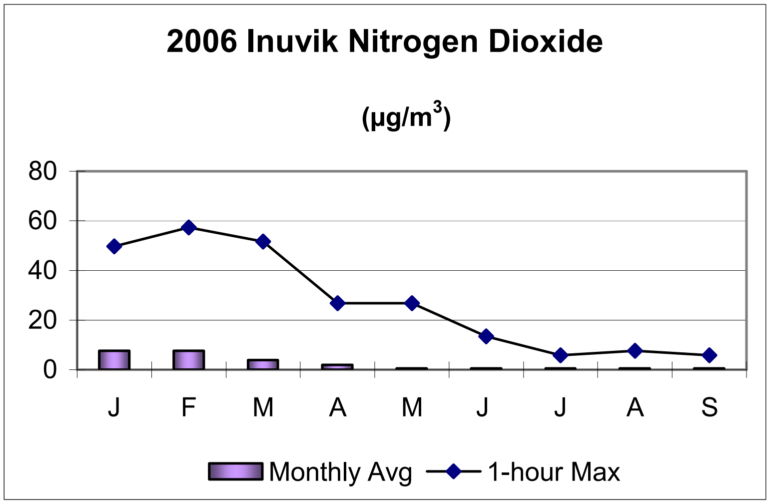


Figure 16 shows the 2006 monthly averages and highest hourly concentrations. Unfortunately, the analyser suffered a serious breakdown in October, which necessitated lengthy repairs and resulted in no data collection for the remainder of 2006.

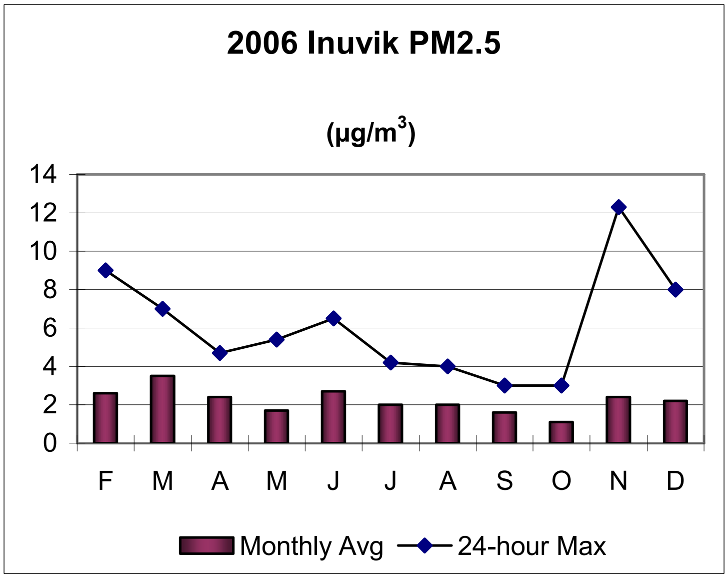
As with Yellowknife, both the highest monthly averages and the highest hourly concentrations occurred during the winter months. The February maximum 1-hour average was the direct result of a winter inversion and discussions with regional staff indicated that vehicle idling was the main culprit. A similar situation occurred in 2004 when the maximum 1-hour average also resulted during the winter under the same conditions. Meteorological data collected over the last three winters has shown that Inuvik is prone to winter inversions and experiences more inversion days than the other three regions. It is not uncommon in the middle of winter to see consecutive days of extremely cold temperatures accompanied with very low wind speeds (calms), reducing dispersal of pollutants.

FINE PARTICULATE ($PM_{2.5}$)

The 2006 BAM readings produced an annual average of 2µg/m^3 - less than half the 2005 annual average. There were no exceedances of the NWT standard for $PM_{2.5}$ which was expected, as there were no significant forest fire events during the summer of 2006.

Figure 17 shows the monthly averages and daily maximums measured at the Inuvik station in 2006. The maximum 24-hour $PM_{2.5}$ value of 12µg/m^3 occurred during the month of November and was associated with a cold weather inversion.

Figure 17:



GROUND LEVEL OZONE (O_3)

The Inuvik station began collecting O_3 data in April of 2005 so 2006 is the first year that data was collected in all months. Neither the 1-hour national standard nor the 8-hour NWT standard was exceeded in 2006. The typical 'spring time maximum' also occurred at this site and is consistent with the Yellowknife and Norman Wells stations, which also experiences a peak in O_3 levels during the spring months.

Figure 18:

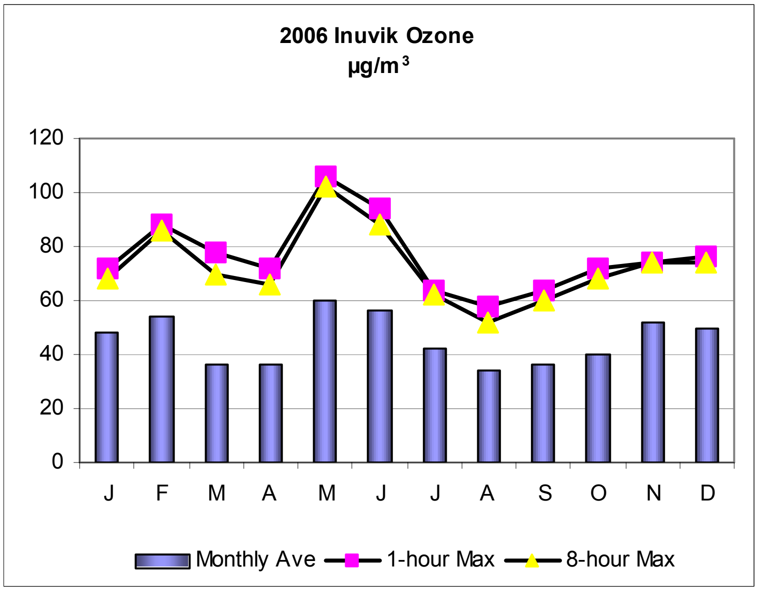


Figure 18 shows the hourly and 8-hour maximums as well as the monthly averages recorded for 2006.

FORT LIARD AIR QUALITY

The focus of the monitoring station in Fort Liard is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time.

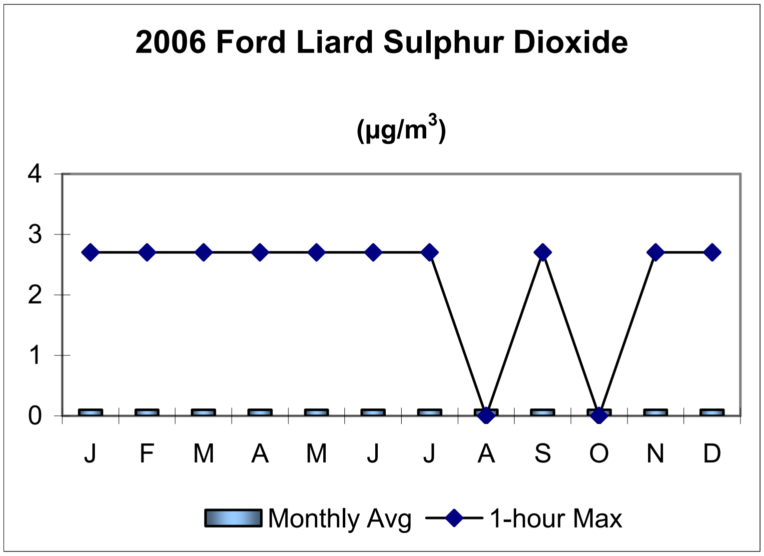
HYDROGEN SULPHIDE (H_2S)

The maximum hourly H_2S concentration in 2006 was 3µg/m^3 and the vast majority of readings were less than 1µg/m^3, essentially within the detection limits or 'noise' range of the analyzer. H_2S in Fort Liard is, therefore, considered largely non-detectable.

SULPHUR DIOXIDE (SO_2)

The monthly average and maximum hourly concentrations for 2006 are shown in **Figure 19**. As in previous years, there were no hourly or 24-hour exceedances of the NWT standards in 2006, with a maximum 1-hour average value of only 3µg/m^3. The monthly averages were very low, with values less than 1µg/m^3 - consistent with those measured over the last four years as shown in **Figure 20**.

Figure 19:



Elevated 1-hour SO_2 values occur occasionally in Fort Liard, but these are rare isolated peaks and still far below the NWT 1-hour standard. Overall, the data indicates that SO_2 concentrations in Fort Liard are within the expected range of background values and there appears to be no impact on community air quality from oil and gas development in the area.

Figure 20:

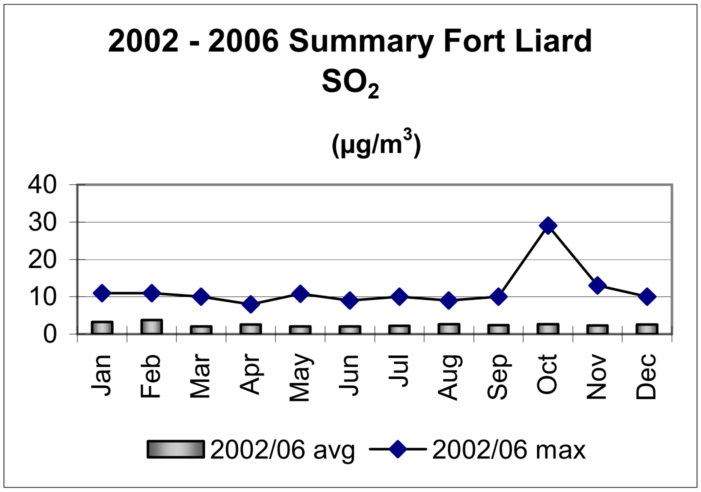


Figure 20 provides a summary by month of 2002-2006 SO_2 data gathered in Fort Liard (the bars represent the overall mean concentration and the line represents the overall maximum 1-hour average).

FINE PARTICULATE ($PM_{2.5}$)

The 2006 annual $PM_{2.5}$ average concentration was 3µg/m^3, which is the same as the 2005 annual average. The maximum daily average was 12µg/m^3 and there were no exceedances of the NWT 24-hour standard for $PM_{2.5}$ due largely to the absence of forest fires.

Figure 21:

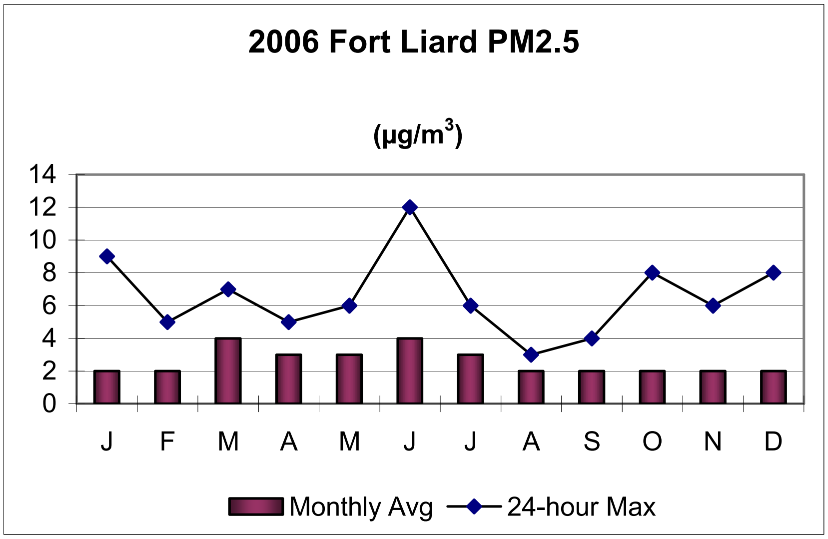


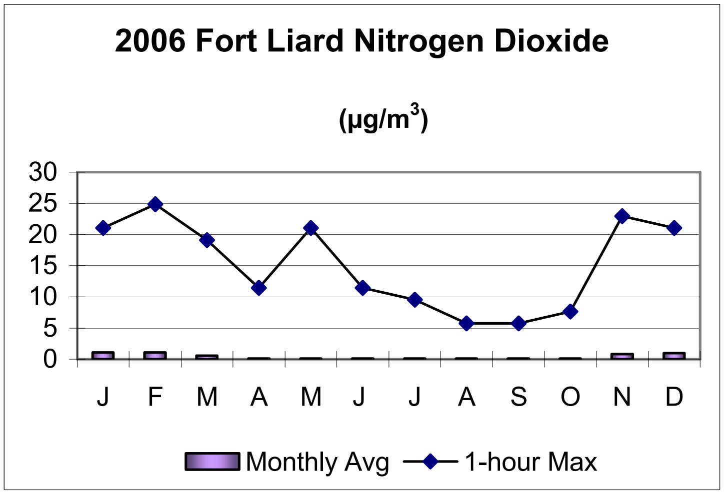
Figure 21 shows the monthly averages and daily maximums measured at the Fort Liard station in 2006.

NITROGEN OXIDES (NO_X)

The 2006 readings show that NO_2 concentrations continue to remain very low, with no exceedances of the 1-hour and 24-hour national standards. The 'annual' average was less than 1µg/m^3 and the 1-hour maximum concentration was 25µg/m^3.

Figure 22 shows the 2006 monthly averages and highest hourly concentrations. The maximum NO_2 concentrations occurred during winter, as was the case for the three other network stations. The overall lower levels (compared to the other three stations) are probably reflective of the generally lower emissions due to a smaller community base.

Figure 22:



NORMAN WELLS AIR QUALITY

The focus of the monitoring station in Norman Wells is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time.

HYDROGEN SULPHIDE (H_2S)

As in 2005, the 2006 data from the station continued to produce extremely low readings with no exceedances of the Alberta Guidelines. Most hourly averages were essentially zero with a maximum 1-hour concentration of 3µg/m^3.

SULPHUR DIOXIDE (SO_2)

The 2006 SO_2 monitoring program produced similar results to the Fort Liard, Yellowknife and Inuvik stations. The 1-hour maximum was 5µg/m^3. Overall SO_2 concentrations were generally very low. The annual average was 3µg/m^3 and no exceedances of the NWT standards occurred.

Figure 23:

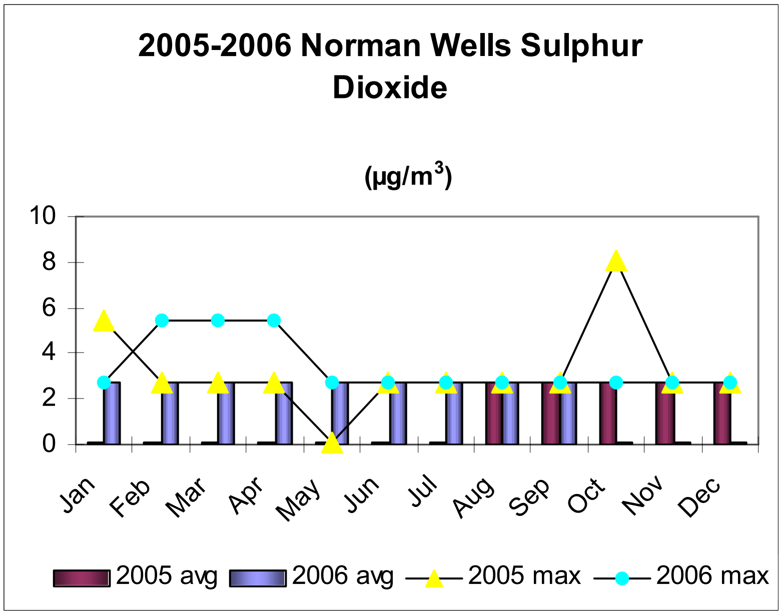


Figure 23 shows a comparison of monthly means and 1-hour maximums for 2005 and 2006.

NITROGEN OXIDES (NO_X)

2006 is the first year that a complete annual data set was collected. Results show that there were no exceedances of the 1-hour and 24-hour national standards for NO_2. As with the other 3 network stations, NO_2 levels increase in the winter months. The maximum 1-hour average was 57µg/m^3 and the overall average was 2µg/m^3.

Figure 24:

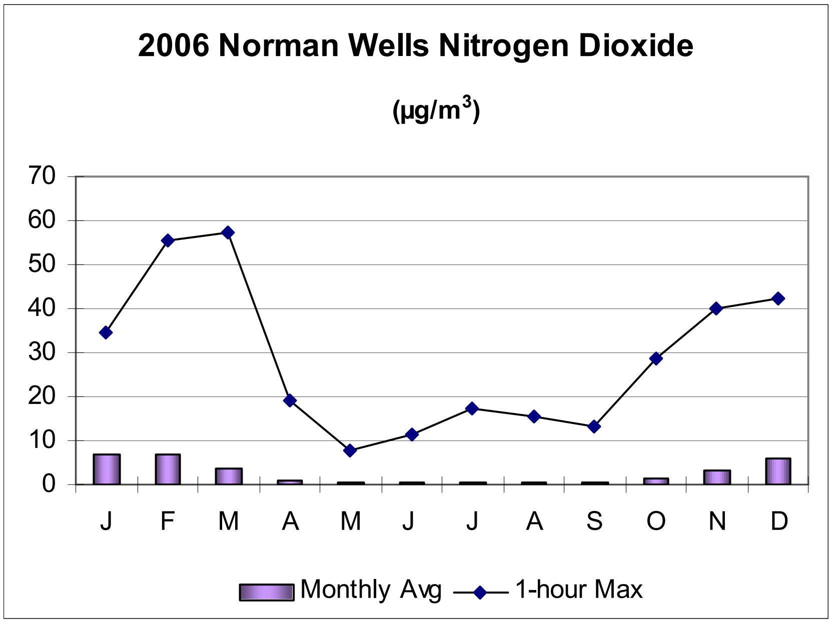
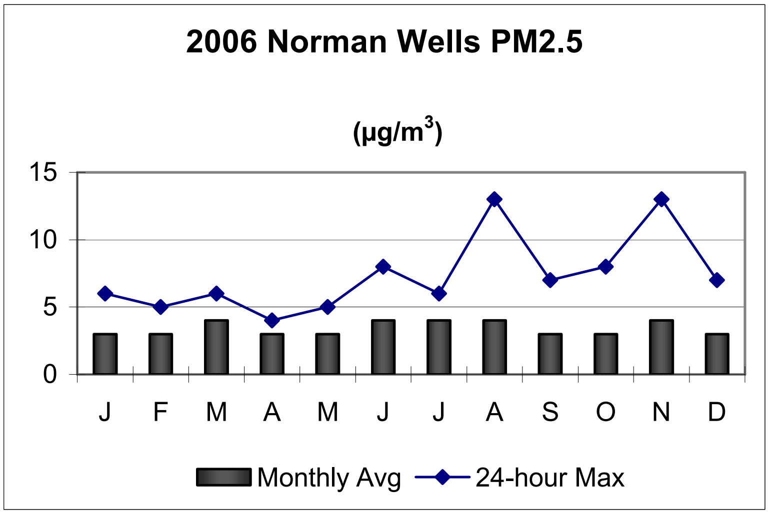


Figure 24 shows the 2006 monthly averages and highest hourly concentrations.

FINE PARTICULATE ($PM_{2.5}$)

Figure 25 shows the monthly averages and daily maximums measured at the Norman Wells station in 2006. There were no significant impacts from forest fires. The annual average was 3µg/m^3 and there were no exceedances of the NWT standard for $PM_{2.5}$.

Figure 25:



GROUND LEVEL OZONE (O_3)

2006 represents the first complete year of O_3 monitoring. No exceedences of the 1-hour national standard or the 8-hour NWT standard were observed in 2006. The elevated spring time levels were also evident at this site and are consistent with the Yellowknife and Inuvik stations which also experience a peak in O_3 levels during the spring months.

Figure 26:

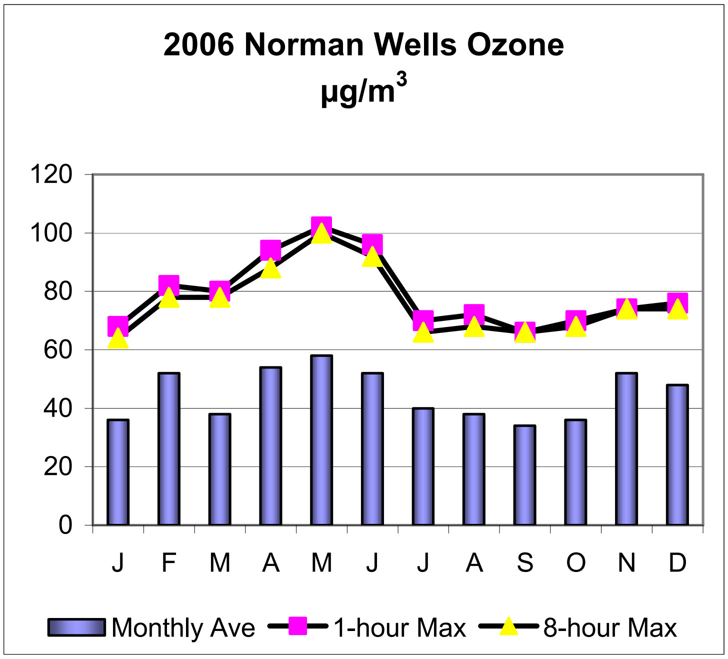


Figure 26 shows the hourly and eight hour maximums as well as the monthly averages recorded for 2006.

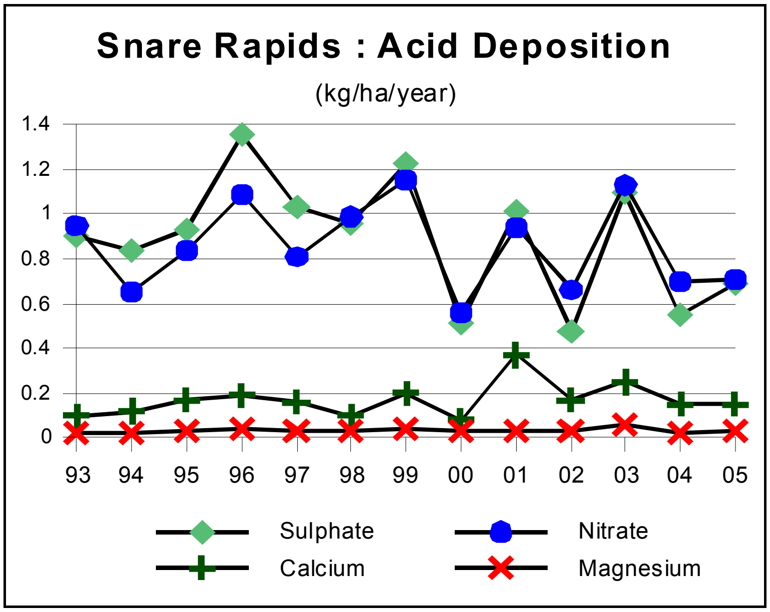
SNARE RAPIDS

Since 1989, ENR has operated a Canadian Air and Precipitation Monitoring (CAPMoN) station at the NWT Power Corporation's Snare Rapids hydro site. This site is located 150 kilometres northwest of Yellowknife. Rain and snow samples are collected on a daily basis and sent to Environment Canada's CAPMoN laboratory in Toronto for analysis. Quality assurance/quality control checks on the 2006 data had not been completed by Environment Canada in time for this report but the 2005 results not reported last year are included below.

ACID PRECIPITATION

Monitoring at the Snare Rapids hydro site in 2005 indicated negligible acid rain content. The average pH was 5.19. This is consistent with pH levels detected over the last 10 years (range pH 4.99 - 5.22) and is considered to be a typical background level associated with unpolluted areas. Annual deposition of sulphate was 0.69kg/ha/yr in 2005. **Figure 27** shows the deposition rates for sulphate, calcium, nitrate and magnesium.

Figure 27:

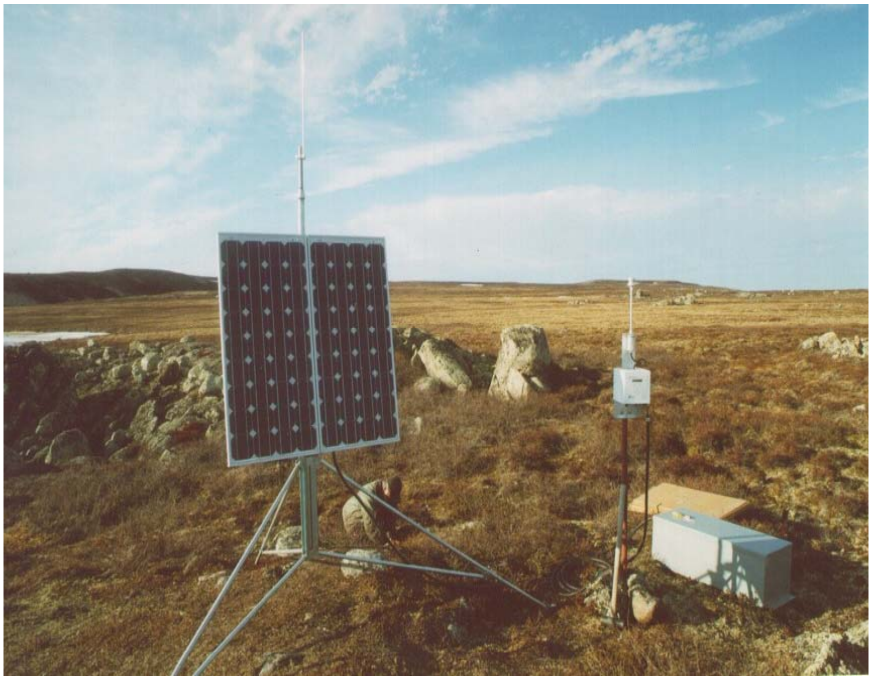


7 kg/ha/yr sulphate is the level considered to protect sensitive ecosystems in the NWT. In areas of eastern Canada, where acid rain is a serious environmental problem, sulphate deposition is in excess of 20 kg/ha/yr. Nitrate deposition at Snare Rapids is similarly low compared to eastern Canada. Sulphate and nitrate deposition rates remain well below levels that could cause an environmental effect in sensitive ecosystems.

DARING LAKE SEASONAL PARTICULATE

In summer of 2006, the short-term seasonal particulate monitoring program continued at the NWT Tundra Ecological Research Station located at Daring Lake. The program was a follow up to the PM_{10} monitoring program undertaken in summer of 2002 and the $PM_{2.5}$ monitoring program in 2003, 2004 and 2005. The monitoring program in 2006 continued the focus on the finer portion of particulate $PM_{2.5}$. As in the previous four years, a battery operated Mini-Partisol particulate sampler and solar panel were set up to gather information on background concentrations of particulate in the barren lands. The 2006 sampling program began on June 21st and finished on August 20th. The solar-powered system ran without incident in 2006.

A total of 18, 24-hour samples were obtained. Two samples had to be invalidated due to bug fragments on the filters. The overall concentrations were similar to last year, ranging from 0 to 5µg/m^3. The 2006 results were typical of background levels and were not influenced by forest fires as in previous years.



APPENDICES

APPENDIX A: MONITORING HISTORY

History of Air Quality Monitoring in the Northwest Territories	
1974	• Government of the NWT starts monitoring air quality in Yellowknife with the installation of a high-volume air sampler at the Post Office site.
1989	• Monitoring of acid precipitation at the Snare Rapids hydro-electric site begins.
1992	• SO_2 analyzer installed at the City Hall site.
1997	• SO_2 monitoring in N'dilo begins and continues until 2000.
1998	• O_3 analyzer added in Yellowknife to the City Hall site.
2000	• A SO_2 analyzer was installed in the ENR building in Fort Liard in March followed by a H_2S analyzer in October.
2002	• Daring Lake summer sampling of PM_{10} at Daring Lake begins. • City Hall SO_2 analyzer relocated to new air monitoring trailer located at Sir John Franklin High School.
2003	• Daring Lake summer sampling of $PM_{2.5}$ begins (the same sampler is used for PM_{10} and $PM_{2.5}$ monitoring) • Air monitoring trailers are installed in Inuvik, Norman Wells and Fort Liard. • CO and NO_x analyzers added to the Yellowknife station as well as a continuous fine particulate sampler ($PM_{2.5}$). • Norman Wells station monitors SO_2 and H_2S. • Inuvik station monitors SO_2, H_2S, NO_x, and $PM_{2.5}$. • Fort Liard station monitors SO_2 and H_2S. A $PM_{2.5}$ sampler is installed late in the year. • The O_3 analyzer that was operating at the City Hall location was relocated to the new Sir John Franklin Yellowknife station. • ENR initiates the upgrade of the Data Acquisition System moving to a specialized air monitoring system, which will allow more efficient and quality controlled data collection. • Continuous $PM_{2.5}$ samplers are installed in Inuvik and Fort Liard. • A second high-volume sampler is installed at the Sir John Franklin Yellowknife station.
2004	• $PM_{2.5}$ sampler is installed in Norman Wells. • Data Acquisition System (DAS) is significantly upgraded. New components are installed inside the stations and a new data management, analysis and reporting system is brought on-line.

History of Air Quality Monitoring in the Northwest Territories (cont.)	
2005	• NO_x analyzer is installed in March at the Fort Liard station. • O_3 and NO_x analyzers are installed at the Norman Wells station in April. • O_3 analyzer purchased by Environment Canada (Yellowknife office) is installed at the Inuvik station in April. • Due to years of significant data loss caused by extreme cold, the Partisol Dichotomous fine particulate sampler at the Post office station in Yellowknife is relocated indoors at the Sir John Franklin station. • The Yellowknife Post Office station is officially closed after the last TSP sample ran on December 6th, 2005. • Development of an Air Quality web site begins. The web site will link with the data management, analysis and reporting system to provide public access to air quality data for each monitoring location. Access to archived data will also be available by querying the database using web-based tools.
2006	• Yellowknife - A BAM Particulate Matter (PM_{10}) monitor was installed and began collecting data in April. • Inuvik - A BAM Particulate Matter (PM_{10}) monitor was installed and began collecting data in October. • The Air Quality Monitoring Network web site was officially released.

APPENDIX B: AIR POLLUTANTS

The NWT air quality monitoring network tracks a number of different air pollutants. With the exception of arsenic and H_2S, these pollutants are known as Criteria Air Contaminants (CAC's). They represent the gases and compounds most often affecting community air quality and targeted by monitoring programs.

Arsenic is monitored in Yellowknife due to its association with metal ore roasting operations in the past and an ongoing concern during remediation work currently being undertaken at the former industrial sites.

H_2S is monitored at the air quality stations in Inuvik, Norman Wells and Fort Liard due to its association with oil and gas development activities.

TOTAL SUSPENDED PARTICULATE (TSP)

Total Suspended Particulate (TSP) is a general term for dust. TSP includes a wide variety of solid and liquid particles found floating in the air, with a size range of approximately 50 micrometers (µm) in diameter and smaller (a human hair is approximately 100 µm in diameter). While TSP can have environmental and aesthetic impacts, it is the smaller particles contained within TSP that are of concern from a human health perspective (see Particulate Matter ($PM_{2.5}$) and (PM_{10}) later in section). Road dust, forest fires, mining activities and combustion products from vehicles, heating and electricity generation contribute to TSP levels.

The NWT Ambient Air Quality Standard for TSP is 120µg/m^3) over a 24-hour period. The standard for the annual average is 60µg/m^3 (geometric mean).

ARSENIC

Arsenic is present in the environment in a variety of forms. The most common form in air is the inorganic compound arsenic trioxide. Natural sources of airborne arsenic include volcanoes and windblown dust from arsenic rich soils, while industrial activities such as smelting and burning of coal account for most of the man-made sources. The vast majority of airborne arsenic is associated with dust and therefore analysis of TSP samples provides a good indication of arsenic concentrations.

There are no NWT standards for arsenic compounds. The World Health Organization (WHO) Air Quality Guidelines, (WHO, 2000), state that inhaling inorganic arsenic compounds can contribute to human development of cancer and there is no safe limit. It is, therefore, important to minimize exposure as much as possible, since the cancer risk increases with exposure to higher concentrations.

As the threshold for arsenic compounds has not been set, it is difficult to determine an acceptable level. Ontario continues to use a 24-hour Guideline of 0.3µg/m^3 for total arsenic based on general toxicity, but the World Health Organization (WHO) suggest that a lifetime risk estimate approach should be used for assessment purposes. The WHO has calculated the following lifetime risk estimates of contracting cancer due to exposure to varying concentrations of arsenic in air:

0.066µg/ m^3 results in a theoretical risk of one person in 10,000
0.0066µg/ m^3 results in a theoretical risk of one person in 100,000
0.00066µg/ m^3 results in a theoretical risk of one person in 1,000,000

In simple terms, the above estimates indicate, for example, that in a population of 10,000 people, a lifetime exposure to an arsenic concentration of 0.066µg/ m^3 could theoretically result in one person contracting cancer. The Ontario Guideline provides a useful comparison for assessment of short-term (24-hour) arsenic measurements but the WHO approach is probably more applicable given the longer-term health risks associated with arsenic exposure.

PARTICULATE MATTER ($PM_{2.5}$) AND (PM_{10})

A sub-portion of TSP, these very small particulates are named for the diameter size of the particles contained within each group – PM_{10} contains particles with a diameter of 10 microns (1 millionth of a metre) or less, while $PM_{2.5}$ (a sub-portion of PM_{10}) contains particles with a diameter of 2.5 microns or less. The significance of these microscopic particles is that they are inhalable and associated with health effects including aggravation of existing pulmonary and cardiovascular disease. Generally, the smaller the particle, the greater the penetration into the lung and the greater the associated health risk.

Sources of inhalable particulates include road dust and wind blown soil, which make up the majority of the PM_{10} particles. Particles in the $PM_{2.5}$ size range primarily result from combustion of fossil fuels for industrial activities, commercial and residential heating, as well as vehicle emissions, forest fire smoke and chemical reactions between other gases emitted to the air.

The national Canada-wide Standards (CWS) process has set an acceptable limit for $PM_{2.5}$ but has not yet established a limit for PM_{10}. The CWS 24-hour average acceptable limit for $PM_{2.5}$ is 30µg/m^3 and this concentration has been adopted under the NWT Environmental Protection Act as the NWT Ambient Air Quality Standard for $PM_{2.5}$. Several Canadian jurisdictions (e.g. BC, Ontario, Newfoundland and Labrador) have adopted a PM_{10} concentration of 50µg/m^3 (24-hour average) as an acceptable limit.

SULPHUR DIOXIDE (SO_2)

SO_2 is a colourless gas, with a pungent odour at elevated concentrations, which can have negative effects on human and environmental health. Certain types of vegetation (especially lichens) are very sensitive to SO_2 impacts. SO_2 also plays a role in acid deposition and formation of secondary fine particulate through chemical reactions with other pollutants in the air.

There are some natural sources of SO_2 in ambient air (forest fires, volcanoes) but human activity is the major source. Emissions of SO_2 primarily result from the burning of fossil fuels containing sulphur. Sources include natural gas processing plants, gas plant flares and oil refineries, metal ore smelting, power generating plants and commercial or residential heating.

The NWT Ambient Air Quality Standards for SO_2 are 450 $\mu g/m^3$ (1-hour average), 150 $\mu g/m^3$ (24-hour average) and 30 $\mu g/m^3$ (annual average).

HYDROGEN SULPHIDE (H_2S)

Hydrogen sulphide (H_2S) is a colourless gas with a characteristic rotten egg odour. At high concentrations (parts per million range), it can be toxic, but typical ambient (outdoor) concentrations, even in areas impacted by industrial sources, tend to fall in the parts per billion (ppb) range. However, due to its low odour threshold, the presence of H_2S can be offensive and it has been associated with eye irritation and triggering feelings of nausea in sensitive individuals.

Industrial sources include oil and gas extraction, petroleum refining, sewage treatment facilities and pulp and paper mills. Natural sources include sulphur hot springs, swamps and sloughs which release H_2S as a by-product of organic decomposition.

There are no NWT standards for H_2S. The Alberta Ambient Air Quality Objectives provide an hourly limit of 14$\mu g/m^3$ (or 10ppb) and a 24-hour limit of 4$\mu g/m^3$ (or 3ppb), based on avoidance of odour.

NITROGEN OXIDES (NO_x)

Nitrogen oxides (NO_x) consist of a mixture of nitrogen based gases, primarily nitric oxide (NO) and nitrogen dioxide (NO_2). Emissions of both NO and NO_2 results from the high temperature combustion of fossil fuels. The predominant emission is NO which then rapidly converts to NO_2 through chemical reaction in the atmosphere. NO is a colourless and odourless gas, whereas NO_2 is a reddish-brown colour with a pungent, irritating odour. NO_2 is considered the more toxic and irritating of the two gases and, at elevated concentrations, is associated with both acute and chronic respiratory effects. Both gases play a role in the atmospheric reactions resulting in acid deposition and secondary pollutant formation (i.e. O_3 and fine particulate).

Because of the greater health effects of NO_2, development of air quality standards has focused on this gas, rather than NO or total NO_x. There are no NWT standards for NO_2 but the national standards provide values of 400$\mu g/m^3$ (1-hour average), 200$\mu g/m^3$ (24-hour average) and 60$\mu g/m^3$ (annual average).

GROUND LEVEL OZONE (O_3)

Ground level ozone (O_3) should not be confused with stratospheric O_3 which occurs at much higher elevations and forms a shield which protects life on the planet from the suns harmful ultraviolet radiation. The gas is the same but at ground level O_3 is regarded as undesirable due to its association with a variety of human health concerns, environmental impacts and property damage. O_3 is a highly reactive gas and is defined as a secondary pollutant. It is not emitted in large quantities from any source but is formed through a series of complex chemical reactions involving other pollutants called precursors (e.g. NO_x and volatile organic compounds or VOCs) in the presence of sunlight.

The national standards provide a Maximum Acceptable Level of 160µg/m^3 for O_3 based on a 1-hour average. The Canada-wide Standards (CWS) process has also set an acceptable limit of 65ppb or 127µg/m^3 based on an 8-hour average. The CWS 8-hour limit has been adopted under the NWT *Environmental Protection Act* as the NWT Ambient Air Quality Standard for O_3.

CARBON MONOXIDE (CO)

Carbon monoxide (CO) is a colourless, odourless and tasteless gas produced by the incomplete combustion of fuels containing carbon. The primary source is vehicle exhaust especially in cities with heavy traffic congestion. Other sources include industrial processes and fuel combustion for building heating. One natural source is wildfires.

CO affects humans and animals by interfering with the ability of the blood to transport oxygen around the body.

There are no NWT standards for CO but the most stringent national standards provide a value of 15mg/m^3 (1-hour average) and 6mg/m^3 (8-hour average). CO values are reported in mg/m^3 as opposed to other gaseous pollutants which are reported in µg/m^3.

ACID DEPOSITION

Acidity in precipitation is measured in pH units on a scale of 0 to 14. A value of seven indicates neutral, values less than seven indicate acidic conditions and values greater than seven indicate alkaline conditions. Even clean precipitation is slightly acidic—around pH5.6— due to the presence of naturally occurring concentrations of carbon dioxide, and minor amounts of sulphate and nitrate ions. The introduction of sulphur dioxide and nitrogen oxide emissions from combustion of fossil fuels for industrial, commercial and individual activities can result in an increase in acidic compounds in the atmosphere—often in areas far removed from the original emission sources. The removal of these sulphur and nitrogen compounds through atmospheric washout is reflected in the increased acidity (lower pH values) of precipitation. Calcium and magnesium ions—mostly from natural sources—act to neutralize acidity in precipitation.

Generally, precipitation with a pH value of 5.0 or less is termed ‘acidic’. However, assessment of acid precipitation is usually based on deposition to an area over a specified time period (e.g. kilograms per hectare per year, kg/ha/yr) rather than review of specific precipitation event parameters. Also, the degree of impact to a particular environment is influenced by its ‘buffering’ capacity or ability to tolerate the acidic inputs. Therefore, determination of acceptable limits usually requires a range of values to reflect the differing tolerances of various areas.