Air Quality in the Capital Regional District 2009

Prepared for:

Capital Regional District
Environmental Services Department
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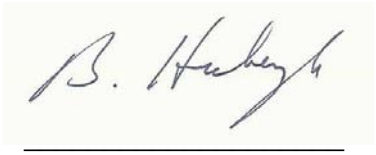

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EXECUTIVE SUMMARY

Air quality was monitored in the Capital Regional District (CRD) to assess the impact of solid waste burning and ambient air quality and to track trends in air quality. The monitoring was conducted under the Long Term Monitoring Program (LTMP), which was a partnership between the CRD and the British Columbia Ministry of the Environment (MoE), Royal Roads University and Environment Canada. The LTMP has been cancelled, and the 2009 annual report is the last one planned to be released by the CRD. SENES Consultants Limited (SENES) was contracted to provide an analysis and summary report of the monitoring data collected in 2009, including analysis of supporting meteorological information that was available over the same time period.

Ambient air concentrations of six air contaminants, collectively referred to as common air contaminants (CACs), are sampled on a frequent basis at the monitoring stations. The six CACs are carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ground-level ozone (O_3), particulate matter smaller than or equal to 10 microns (PM_{10}) and particulate matter smaller than or equal to 2.5 microns ($PM_{2.5}$).

In 2009, there were four air quality stations in the CRD that measured either gaseous contaminants and/or fine particulate matter. One station, on Saturna Island, is managed by Environment Canada, and records only gaseous pollutants. In previous years there were six continuous monitoring stations; however, monitoring was discontinued at Royal Roads University and Christopher Point stations in December 2008. In addition, carbon monoxide monitoring was discontinued at both Stellys and Langford in 2009, and all air quality monitoring at the Stellys Cross Roads site in Central Saanich was discontinued as of March 31, 2010. In addition, three 'Hi-Vol' sites that measured fine particulate matter were also discontinued at the end of 2008.

In addition to the fixed monitoring locations, the B.C. Ministry of the Environment's Mobile Air Monitoring Laboratory (MAML) conducted air quality sampling in the James Bay community from May 30th to August 24th, 2009. The MAML sampling was conducted in support of the James Bay Air Quality Study (JBAQS). Data analysis was prepared by the University of Victoria for the Vancouver Island Health Authority (VIHA) and the Ministry of the Environment.

Overall, data collection was more successful for 2009 than in previous years (i.e., 2007 and 2008) for most contaminants. Note that both ozone and sulphur dioxide data were collected by Environment Canada at the Saturna Island monitoring site through to the end of 2009, but sulphur dioxide data beyond 2007 has not yet been released for use and as such was not included in this report.

A primary focus of the annual air quality report was to assess the annual monitoring data with a set of CRD ambient air quality guidelines that were developed in 2004. In addition, comparisons to provincial and federal objectives and standards were made. Further temporal and spatial analyses were completed to examine trends in community air concentrations and to establish potential links between ambient concentrations and emission sources.

For the vast majority of the time in 2009, air quality remained good in the CRD. The CRD guideline for $PM_{2.5}$ was exceeded once at Stellys station and once at Victoria Topaz station on a separate day. The CRD ozone guideline was also exceeded once at Stellys station.

- The exceedance of the $PM_{2.5}$ guideline of 25 µg/m^3 occurred once at the Stellys monitoring station on November 1st, with a 24-hour average concentration of 29.9 µg/m^3, based on the continuous TEOM sampler. Concentrations recorded at each of the other $PM_{2.5}$ monitoring stations in the CRD on that date were much lower, indicating that the higher $PM_{2.5}$ concentration at Stellys was not experienced throughout a large portion of the CRD. The likely cause of the high concentration at the Stellys site on this date could not be determined, however high $PM_{2.5}$ readings in the CRD have been previously (e.g., Victoria Topaz in 2003) noted in association with fireworks on Halloween and it is possible (even likely) that this occurrence at Stellys was similarly related to this holiday.

- The $PM_{2.5}$ guideline was also slightly exceeded on December 9th at the Victoria Topaz monitoring station, with a 24-hour average concentration of 26.3 µg/m^3 based on the sequential Dichotomous (Dichot) sampler. The co-located continuous TEOM sampler recorded a $PM_{2.5}$ concentration on that date was 18.4 µg/m^3. TEOM samplers are recognized to have some loss of sample in colder seasons, and it is likely that the Dichot sampler provided a more reliable sample of $PM_{2.5}$ concentration on that date, and that the CRD guideline was indeed exceeded. The guideline was not exceeded at Stellys station on this date. Data for Langford station was unavailable. The likely cause of the high concentration at the Topaz site on this date could not be determined.

- The maximum 8-hour rolling average ozone concentration at Stellys station of 122 µg/m^3 on July 29th exceeded the CRD guideline value of 120 µg/m^3. The ozone episode was also observed at Langford and Saturna Island stations, and was associated with the issuance of an Air Quality Advisory by the Ministry of the Environment. The pattern of increased ozone concentrations in the afternoon hours of a summer day suggests the influence of photochemical production of O_3 on this occasion at all stations. Unlike past monitoring years, the exceedance of the CRD guideline occurred at Stellys station rather than Saturna Island. However, higher ozone levels at Saturna Island persisted well into the evening hours whereas levels at Stellys and Langford quickly dropped in late afternoon, mirroring the ozone episodes that occurred in both May 2007 and 2008. The

anticipated exceedance of the Provincial Ambient Air Quality Objective of 160 µg/m^3 which triggered the issuance of the air quality advisory did not occur.

Due to the limited temporal and spatial extent of exposure to the $PM_{2.5}$ and ozone guideline exceedances, related health effects for community members could not be determined with confidence.

Although the CRD remains in attainment of the Canada-Wide Standards (CWS) for both $PM_{2.5}$ and ozone, there has been a continuous upward trend in 4th highest 8-hour average ozone concentrations at the Stellys site for the period of record (2003-2009). The cessation of all air quality sampling at this location as of March 2010 will preclude any possibility of determining whether or not this trend would continue into the future which could lead to non-attainment of the CWS.

A statistical tool was developed for the CRD in 2006 for the purpose of assessing trends in air quality concentrations over a period of five or more years. The tool assesses whether a statistically significant trend (increase or decrease) in annual mean and 98th percentile concentrations exists over the period. In addition, a trend in the proportion of measurements above the applicable CRD guideline is assessed. Statistically significant trends at the mean and/or 98th percentile level were found for all contaminants except NO_2. Significant trends were present for CO, $PM_{2.5}$ and PM_{10} monitoring data at Victoria Topaz over the period 1998-2009, O_3 for the period 2003-2009 at Stellys and SO_2 at Saturna Island for the period 1998-2007. Trends were determined to be as follows:

- a decrease of 4%/year in annual 98th percentile concentrations of CO at Topaz;
- a decrease of 2%/year in the annual mean concentration of $PM_{2.5}$ at Topaz;
- a decrease of 4%/year in the annual mean concentration of PM_{10} at Topaz;
- a decrease of 5%/year in annual mean concentrations of SO_2 at Saturna Island;
- a decrease of 12%/year in annual 98th percentile concentrations of SO_2 at Saturna Island; and,
- an increase of 3%/year in the annual mean concentration of O_3 Stellys.

It should be noted that the 22% per year increase in ozone concentrations above the CRD guideline at Saturna Island identified in the 2008 annual report is absent from the 2009 trends analysis. If 2010 ozone levels are comparable to 2009 observations, it is expected that the CWS for ground level ozone will not be exceeded at the implementation date of the standard (2010).

Similarly, the significant trend towards lower annual mean and 98th percentile SO_2 concentrations based on 1998-2008 data at Topaz station was not present for the 1998-2009

period due to higher than expected SO_2 concentrations in 2008 and 2009. This suggests that a shift in the trend may be occurring, although the reasons for such a possible reversal are not clear. In the annual air quality report for the CRD in 2008, cruise ships were identified as contributing to some of the highest peak 1-hour average SO_2 concentrations observed at the Topaz station, and there has been a fairly large increase in cruise ship visits to the Victoria Harbour over the past decade, from a low of 26 visits in 1998 to a total of 201 visits in 2008 and 215 in 2009. While it is possible that the increase in cruise ship visits to Victoria has contributed to the reversal in the trend toward lower SO_2 concentrations at Topaz in 2008 and 2009, this cannot be conclusively determined. In the absence of available SO_2 monitoring data from Saturna Island for 2008 and 2009, it is unclear whether the changes in the long-term SO_2 trends at Topaz represent a change in regional concentrations or a local effect that is limited to the Topaz station alone.

The MAML sampling in support of the JBAQS was specifically established to determine the effects of cruise ship emissions on the James Bay community. The sampling results for 2009 indicated that NO, NO_2 and SO_2 levels were always highest at both the MAML and Topaz monitoring locations on days when cruise ships were in port, as compared with days when cruise ships were not in port. Although no existing Provincial air quality objectives or CRD guidelines were exceeded at these locations during the monitoring period, the recently proposed level for a new 1-hour average SO_2 primary air quality standard in the United States was exceeded approximately 1.5% of the time at the MAML site. In addition, the World Health Organization (WHO) guideline value for 24-hour average SO_2 concentrations was exceeded 16% of the time at the MAML location and 3.5% of the time at the Topaz site. The WHO guideline value for 10-minute average SO_2 concentrations (meant to provide protection against acute exposure to peak SO_2 concentrations), was also exceeded on three occasions during the MAML monitoring period.

In response to the MAML monitoring results and other previous analyses of the impacts of cruise ship emissions on air quality in the CRD, VIHA concluded that there are occasions when the SO_2 levels are sufficiently elevated so as to cause health impacts in some individuals, particularly those with chronic respiratory conditions. These impacts could affect the quality of life and well-being of some area residents, and there is a statistical possibility that, in a worst-case scenario, excess deaths could occur over the course of a year if the adverse health effects from exposure to these pollutants are not properly managed.

In summary, ambient concentrations of the common air contaminants monitored in the CRD remain relatively low compared with all provincial and federal guidelines objectives and standards, and the CRD was in attainment of the Canada Wide Standards (CWS) for ground level ozone and $PM_{2.5}$ in 2009 based on the available data. Overall, the majority of CAC show no strong upward or downward trends over time, with the exception of decreasing trends (1998 to 2007) for sulphur dioxide at the Saturna Island site, and an increasing trend in peak ozone levels

at Stellys which, if continued, could eventually exceed the CWS. A small decrease in carbon monoxide, $PM_{2.5}$ and PM_{10} is present at the Topaz site only. There is also a small increasing trend in the mean annual ozone concentration at Stellys station and ozone levels appear to be approaching the CRD guideline. However, there is also evidence that SO_2 concentrations from time-to-time do exceed existing or proposed international standards or guidelines, and reach levels that could adversely affect the health of some residents of the CRD.

1.0 INTRODUCTION

An ambient air quality monitoring program in the Capital Regional District (CRD) area was conducted from 1996 to 2009 as a partnership between the CRD, the B.C. Ministry of the Environment and others. One of the goals of the Long Term Monitoring Program (LTMP) was to investigate the contribution of solid waste burning to regional particulate matter (PM) air concentrations. It was also recognized that solid waste burning releases many other air contaminants, including common air contaminants (CACs) and possibly toxic compounds. All CACs were monitored under the LTMP. An additional goal of the LTMP was to establish a reliable baseline of air quality data for all CACs to enable trend analysis. The CRD reported on the air quality data collected within the monitoring network, but the LTMP has now been cancelled, and the 2009 annual report is the last one planned to be released by the CRD.

Meteorological data was collected to support the LTMP at some stations. In addition, other meteorological stations in the CRD are used to characterize weather and climate in the region, or to assess local winds for industrial or other purposes. As well, the University of Victoria facilitates the operation of a school-based weather network that includes data from up to 74 individual stations[1].

Air Quality data were collected and analysed for several reasons, including the following:

- to provide information on air quality to the public;
- to conduct long-term trend analysis;
- to fulfill Federal reporting requirements (re: Canada Wide Standards); and,
- to compare ambient concentrations to air quality objectives.

The CRD monitoring network was designed to characterize the air quality in the region and to support the initiatives described above. Air quality monitoring locations were chosen to capture air concentrations that are representative of either larger geographic areas, or 'areas of interest' where higher contaminant air concentrations are suspected, or other reasons. Local topography and the location(s) of pollutant sources can indicate how well a monitoring location represents an area. In most cases, a monitoring location should not be overly influenced by a single emission source. With the advent of the Canada Wide Standards (CWS) for ozone and particulate matter, to be implemented by 2010, 'community-oriented' monitoring sites were required. These sites are described as locations where people live, work and play[2].

[1] See http://www.victoriaweather.ca/

[2] Canadian Council of Ministers for the Environment, 2000. Guidance Document on Achievement Determination: Canada Wide Standards for Particulate Matter and Ozone. www.ccme.ca.

1.1 MONITORING STATIONS

In 2009, air contaminants were sampled at four air quality monitoring stations in the Capital Regional District (CRD). Each station sampled all or some of the common air contaminants (CACs), namely: carbon monoxide (CO), nitrogen oxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ground-level ozone (O_3) and particulate matter (PM). There are two sub-fractions of particulate matter; $PM_{2.5}$ (particles with a diameter of less than or equal to 2.5 microns) as respirable PM, and PM_{10} (particles with less than or equal to 10 microns) as inhalable PM.

In 2008, a network review (SENES 2008)[3] was conducted and recommendations made as to the number and location of regional air quality monitoring stations. The results of the review were implemented at the end of 2008. Christopher Point was discontinued after December 2008 as the funding from Environment Canada for the Georgia Basin Ecosystem Initiative ended. All air quality monitoring at Royal Roads University was also discontinued from the monitoring network at the end of 2008, as was CO monitoring at all locations except Victoria Topaz. In addition, all HiVol monitoring of PM_{10} at the Oak Bay Recreational Centre, and the Braefoot and Keating Elementary Schools was discontinued in the CRD per the recommendations of the review. Although data for 2009 were still available, all monitoring at the Stellys Cross Roads site was discontinued as of March 31, 2010 with the cancellation of the LTMP.

All of the air quality and meteorological stations operating in 2009 in the CRD are included in Table 1.1. The contaminants and meteorological parameters monitored at each location are also listed. Their locations are indicated in Figure 1.1

Of the active stations, Victoria Topaz station has the longest record of continuous data capture of all the CRD stations. It is operated as part of the National Air Pollution Surveillance program (NAPS). The Victoria Topaz station and Lakewood Elementary School station in Langford record all of the common air contaminants. The monitor at Stellys Cross Roads in Central Saanich recorded all CACs except SO_2. Continuous monitoring data from these three stations for 2009 were made available by the B.C. Ministry of the Environment.

The Saturna Island monitoring station is part of the Canadian Air and Precipitation Monitoring (CAPMON) network of primarily rural monitoring stations. Both ozone and sulphur dioxide data are collected by Environment Canada at the Saturna Island monitoring site; however SO_2 data beyond 2007 has not yet been released for use.

Beginning in 2007, a Partisol sampler was installed at Langford to sample $PM_{2.5}$ as a check against the continuous $PM_{2.5}$ sampler data (see Section 4.3 of this report). Victoria Topaz also

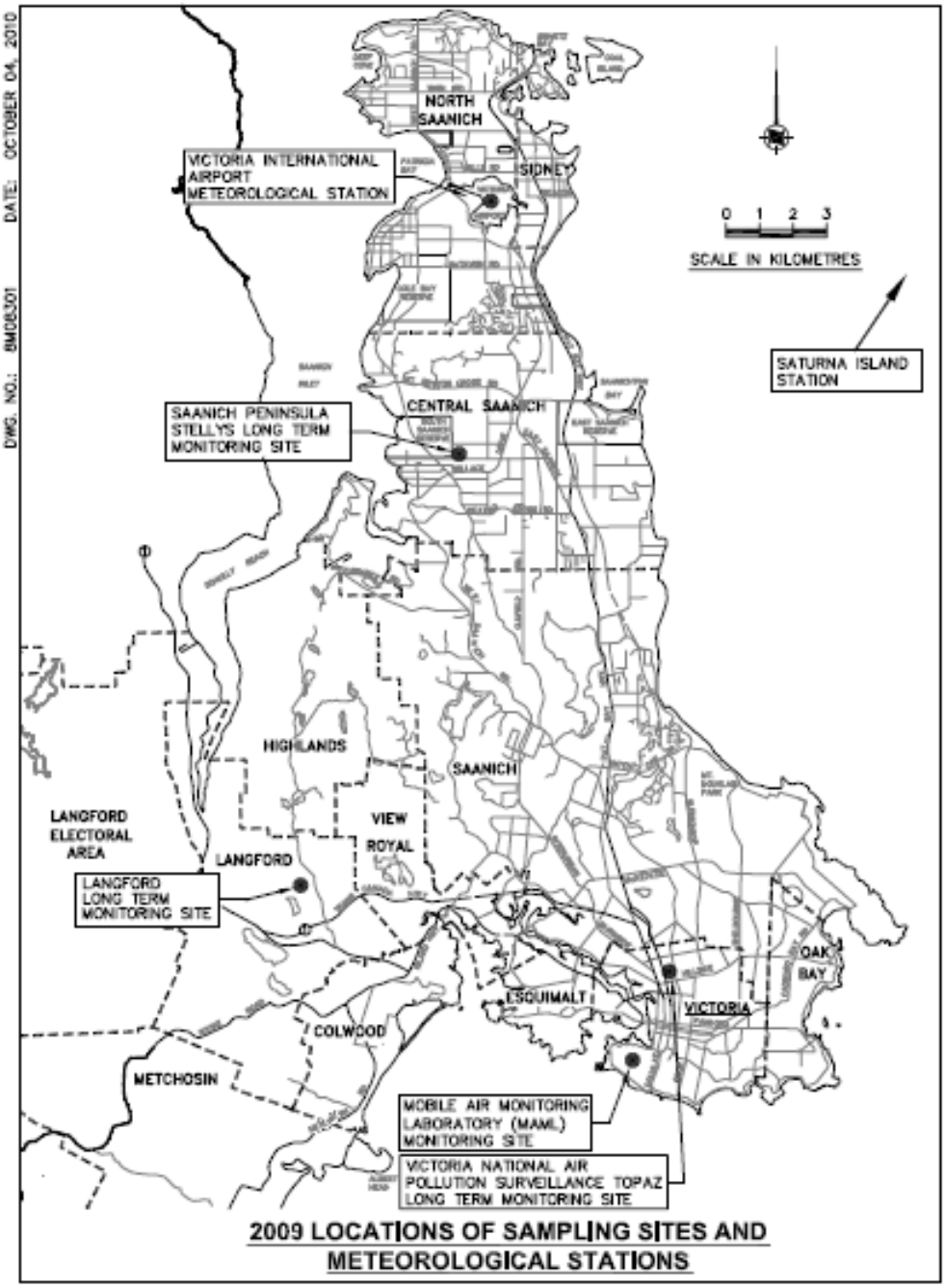
has a Partisol sampler to check against $PM_{2.5}$ data as well as a Dichot sampler for monitoring $PM_{2.5}$ and PM_{10}. Topaz's Partisol sampler was discontinued in April 2009. The Hi-Vol (PM_{10}) sampler at Stellys was replaced by a $PM_{2.5}$ Partisol sampler for the 2009 monitoring program. All Partisol and Dichot measurements are collected on a one-in-six day cycle. This type of sampling technique requires PM to be collected on filters which are sent to a laboratory for measurement.

Table 1.1
Air Quality Monitoring Stations in the Capital Regional District, 2009

Monitoring Location	Type of Site	Parameters Monitored		
		Gaseous	Particulate Matter	Meteorology
Victoria, Topaz Avenue	NAPS[1] Long Term Monitoring Site	CO, NO, NO_2 SO_2 & O_3	Dichot $PM_{2.5}$ /PM_{10} $PM_{2.5}$ (Partisol) $PM_{2.5}$ (C-TEOM)	WS, WD, T, P, RH, Precip
Langford[2]	Long Term Monitoring Site	NO, NO_2 SO_2 & O_3	$PM_{2.5}$ (Partisol) $PM_{2.5}$ (C-TEOM)	WS, WD, T, P, RH,
Stellys, Saanich Peninsula[3]	Long Term Monitoring Site	NO, NO_2 & O_3	$PM_{2.5}$ (Partisol) $PM_{2.5}$ (C-TEOM)	WS, WD, T, P, RH
Saturna Island	CAPMoN[4] Site	SO_2 & O_3		WS, WD, T, P, RH, others
Victoria International Airport	Environment Canada meteorological station			WS, WD, T, P, RH, others

Notes:
WS – wind speed; WD – wind direction; T – temperature; P – Pressure; RH – relative humidity; Precip - precipitation
Dichot - sequential sampling using a Dichotomous sampler
Partisol – sequential sampling using constant air flow Partisol sampler
C-TEOM – continuous sampling using Tapered Element Oscillating Microbalance samplers
1- National Air Pollution Surveillance
2- Station began operating in November 2002 and was moved in August 2005. PM_{10} monitoring discontinued in December 2008. CO monitoring was discontinued on January 12, 2009.
3- Station began operating in August, 2003. Hi-Vol PM_{10} sampler converted to a $PM_{2.5}$ Partisol sampler in December 2008. CO monitoring was discontinued on January 12, 2009.
4- Canadian Air and Precipitation Monitoring Network

[3] SENES Consultants Limited 2008. Capital Regional District Air Quality Monitoring Review. Prepared for the Capital Regional District, Environmental Services Department, November 2008.


DWG. NO.: BM08J01 DATE: OCTOBER 04, 2010
NORTH SAANICH
SIDNEY
VICTORIA INTERNATIONAL AIRPORT METEOROLOGICAL STATION
0 1 2 3
SCALE IN KILOMETRES
SATURNA ISLAND STATION
CENTRAL SAANICH
SAANICH PENINSULA STELLYS LONG TERM MONITORING SITE
HIGHLANDS
SAANICH
LANGFORD ELECTORAL AREA
VIEW ROYAL
LANGFORD
LANGFORD LONG TERM MONITORING SITE
OAK BAY
ESQUIMALT
VICTORIA
COLWOOD
METCHOSIN
MOBILE AIR MONITORING LABORATORY (MAML) MONITORING SITE
VICTORIA NATIONAL AIR POLLUTION SURVEILLANCE TOPAZ LONG TERM MONITORING SITE
2009 LOCATIONS OF SAMPLING SITES AND METEOROLOGICAL STATIONS

Overall, data collection was more successful for 2009 than in previous years (i.e., 2007 and 2008) for most contaminants. Data were missing at the monitoring sites for the following periods:

Monitoring Location	CO	NO/NO_2	SO_2	O_3	$PM_{2.5}$
Victoria Topaz	Jan 19; Feb 8-9; Apr 15,22-23,27; May 23; Dec 31	Apr 28; Aug 10-14; Oct 23-27	Apr 16; June 28-29; Aug 8; Sep 21; Oct 16	Dec 30-31	May 24
Stellys	Jan 12 onward	May 3, 14; Nov 25-26		May 3	Feb 24-25; Mar 2, 5; Dec 30-31
Langford	Jan 12 onward	Feb 18-19; June 18; Jul 22; Sep 12-16; Oct 4-7, 15-16; Dec 6-10,22,29-31.	Feb 20; Jun 18-19; Jul 7-9, 30; Aug 1-14; Oct 15-16; Dec 6-10; 29-31	Jan 3-6; Feb 18-19; June 18; Oct 15-16; Dec 6-10; Dec 29-31	Jan 19-20; Jul 22; Sep 12-16; Oct 4-6,15-16; Dec 6-10,22,29-31.
Saturna Island			N/A	Nov 17; 19-20	

N/A – Not Available

1.2 MOBILE AIR MONITORING LABORATORY (MAML)

The Ministry of the Environment provided MAML monitoring in the James Bay community from May 30th to August 24th, 2009. Sampling was conducted for NO, NO_2, SO_2, PM_{10} and $PM_{2.5}$. The MAML was located on Montreal Street, adjacent to the community gardens at the northwest corner of Macdonald Park.

The monitoring was conducted in support of the James Bay Air Quality Study (JBAQS), with data analysis and reporting being provided by the Spatial Science Laboratory at the University of Victoria. The primary purpose of the sampling program was to determine the potential impact of emissions from cruise ships docking at Ogden Point on air quality in the James Bay community. The results of the analysis are presented in the report by Poplawski and Setton (2010) [4].

1.3 CRD AIR QUALITY GUIDELINES

The Canada Wide Standards (CWS) include regulatory air quality criteria for ground-level ozone and fine particulates ($PM_{2.5}$). In addition, there are National Ambient Air Quality Objectives (NAAQOs) for other CACs. However, jurisdictions within British Columbia have the flexibility to define ambient air quality guidelines that are more stringent than the national criteria. There is a growing awareness that there may need to be an update of existing national and provincial air quality objectives and guidelines in Canada.

[4] Poplawski, K. And E. Setton 2010. *MAML – Mobile Air Monitoring Laboratory: Data Collection Report – James Bay Air Quality Study June-August 2009.* Prepared for the Vancouver Island Health Authority and the B.C. Ministry of the Environment by the University of Victoria Spatial Science Laboratory, Victoria, BC.

The current provincial objective level for PM_{10} was established in 1995, while the provincial and national objectives for CO, SO_2 and NO_2 have not been reviewed since the mid-1970's. Consequently, the existing provincial and national objectives for these pollutants may not reflect the current knowledge and understanding of their health effects.. Updated guidelines are under discussion at the federal/provincial government levels, and the Ministry of Healthy Living and Sport has announced its intention to establish a provincial framework to guide the development of air quality objectives in British Columbia[5]. The U.S. Environmental Protection Agency[6,7] has proposed changes to the primary National Ambient Air Quality Standards for both NO_2 and SO_2 and it would be reasonable to expect that similar updates to federal and provincial ambient air quality objectives may be adopted in Canada in the near future.

The CWS reflect a more recent federal initiative to update ambient air quality criteria, in particular for air contaminants that may have higher potential to adversely affect human or environmental health. The CWS are expressed as standards to be achieved by 2010. However, the CWS also has requirements beyond the numeric targets for O_3 and $PM_{2.5}$. These requirements are identified as *keeping clean areas clean* and *continuous improvement*, which are meant as guidance for those areas that are already in attainment of the CWS. The concept of keeping clean areas clean has been described [8] as a framework on managing ambient concentrations of particulate matter and ozone below the CWS to minimize any increase in ambient concentrations and, ideally, maintain or reduce ambient concentrations.

Although management of air quality rests with senior government, the CRD established a set of ambient air quality guidelines for each of the CACs in 2004. These guidelines assist with reporting air quality data. The upper-bound guidelines are protective of human and environmental health and are equal to or lower (more stringent) than applicable provincial or federal ambient air quality objectives or standards. Any exceedances of the CRD guidelines are identified and investigated each year.

The CRD guidelines are specified in Table 1.2. Analysis of ambient monitoring data in the following sections specifically addresses the CRD guidelines. In addition, adherence to the CWS is discussed for $PM_{2.5}$ and ozone. Appendix B provides a discussion of all relevant provincial and federal objectives, including a compliance analysis of CRD ambient CAC concentrations.

[5] http://www.bcairquality.ca/

[6] U.S. Environmental Protection Agency 2010. Primary National Ambient Air Quality Standard for Sulfur Dioxide; Final Rule. Federal Register, Part II, 40 CFR Parts 50, 53 and 58, June 22, 2010.

[7] Primary National Ambient Air Quality Standard for Nitrogen Dioxide; Final Rule. Federal Register, Part III, 40 CFR Parts 50 and 58, February 9, 2009.

[8] Schutte, A, and I. Liepa 2003. *Continuous Improvement and Keeping Clean Areas Clean: An Issues Paper*. Prepared for the Air Pollution Prevention Directorate, Transboundary Air Issues Branch, Environmental Protection Service, Environment Canada and the Canadian Council of Ministers of the Environment by Levelton Engineering Limited, Richmond, BC.

Table 1.2
Air Quality Guidelines for the Capital Regional District

Averaging Period	Guideline Concentration (µg/m^3)					
	NO_2	**SO_2**	**CO**	**O_3**	**PM_{10}**	**$PM_{2.5}$**
1-hour	200					
8-hour			5500	120		
24-hour		125			50	25

Note: all averaging periods are sequential, with the exception of O_3, which uses rolling averages

2.0 METEOROLOGY IN THE CRD

Meteorological data were collected and analysed at five meteorological stations in the CRD during 2009. Each station is identified in Table 2.1 below, along with the general parameters collected each hour. The data were collected from the MoE data archives, with the exception of Saturna Island and Victoria Airport data which was obtained from Environment Canada's National Climate and Data Information Archive[9].

Table 2.1
Meteorological Stations in the CRD

STATION	OPERATION*	METEOROLOGICAL DATA COLLECTED**	WIND CAPTURE RATE (%)
Victoria Topaz	MoE, EC NAPS	WS, WD, T, RH, Precip, P	97.0
Stellys	MoE	WS, WD, T, RH, P	99.6
Langford Lakewood Elementary School	MoE	WS, WD, T, RH, P	99.0
Saturna Island	EC CAPMoN	WS, WD, T, RH, Precip, P, Cloud, Ceil	97.6
Victoria Airport	EC	WS, WD, T, RH, Precip, P, Cloud, Ceil	100

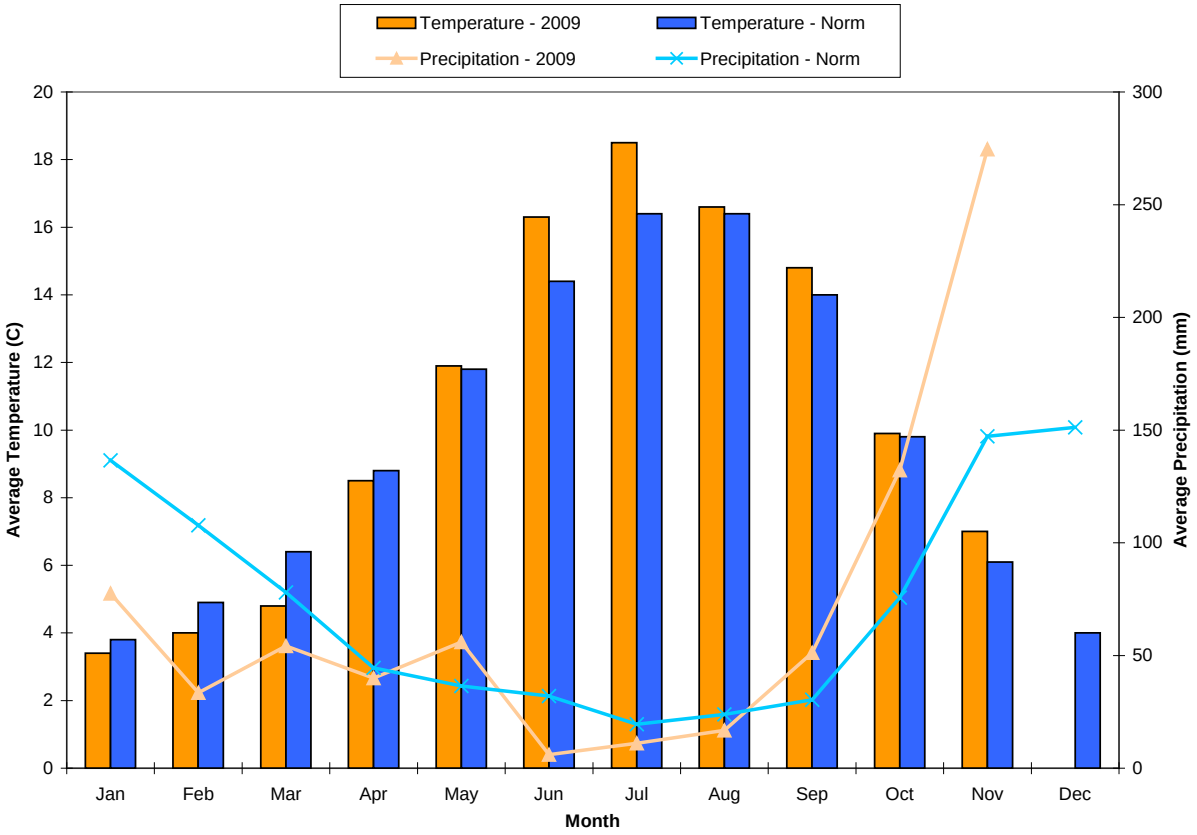
*EC = Environment Canada, CAPMoN = Canadian Air and Precipitation Monitoring Network, NAPS = National Air Pollution Surveillance.

**WS = wind speed, WD = wind direction, T = dry bulb temperature, RH = relative humidity, Precip = precipitation (rain+snow) amounts, P = pressure, Cloud = cloud cover, Ceil = ceiling.

The monthly average temperatures and monthly total precipitation levels for 2009 are compared to the climate norm (1971 – 2000) in Figure 2.1. Monthly values were missing for December 2009. Average temperatures were comparable to the norm throughout most of the year with the exception of June and July, which had mean temperatures about 2 degrees higher than the norm, and March, which experienced temperatures roughly 2 degrees lower than the norm. During the fall months (September, October and November) and also in May, precipitation was higher than the norm. For all remaining months, precipitation levels were close to or slightly lower than the norm.

[9] Environment Canada 2009. National Climate Data and Information Archive. http://www.climate.weatheroffice.gc.ca/climateData/canada_e.html

Figure 2.1
2009 Monthly Average Temperature and Precipitation at the Victoria Airport



A wind rose diagram shows the frequency of wind direction (direction ***from*** which the wind blows) and wind speed at a station. Wind rose diagrams are included in Appendix A for five stations analysed for 2009 (Victoria Topaz, Stellys, Langford, Saturna Island and Victoria Airport).

3.0 GASEOUS POLLUTANTS

The gaseous air contaminants that are sampled at the monitoring stations in the CRD are carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and ozone (O_3). Ambient air concentrations are measured by gas samplers that take a representative volume of the ambient air every few seconds. However, the complete, continuous record for each of the gases tends to be highly variable and difficult to interpret with respect to both emission sources and health or environmental effects. Because of this, the data records are re-averaged to produce 1-hour average concentrations, which are recorded and archived. From these 1-hour averages, further analysis allows determination of 8-hour, 24-hour, monthly and annual average concentration amounts.

Gas monitors are calibrated regularly with NIST traceable standards. Due to recalibration, hourly concentrations can be missed and for each pollutant, the percent of missing data is recorded. If calibration tends to occur during one specific hour of the day, it can result in poor data capture for that particular hour. Hourly concentrations are used to construct diurnal trend graphs for each of the CACs; therefore, poor data capture may lead to anomalous values. For example, calibration often occurred between 1:00 am to 2:00 am during cooler months (October to March) and resulted in a peak in concentration at 1:00 am as seen on some of the diurnal trend graphs below. Data capture was sometimes as low as 50% for this particular hour of the day.

For monitoring sites administered by the B.C. Ministry of Environment, gaseous pollutants recorded in parts per billion (ppb) or parts per million (ppm) were converted to micrograms per cubic metre ($\mu g/m^3$) at 20^0C and 1 atmosphere (atm). CAPMoN ozone data for Saturna Island recorded by Environment Canada are reported in ppb at 0^0C and 1 atm. In this report, the Saturna Island ozone data have been converted to $\mu g/m^3$ by multiplying ppb by a factor 2, without accounting for hourly differences in temperature and pressure.

A statistical analysis was conducted on each station's datasets. The mean, maximum, minimum, standard deviation and percentile concentrations were calculated to determine the variability among stations and the variability in concentration amounts throughout the year in 2009. The 98^{th} percentile concentration represents the value that is only exceeded 2% of the time during the year.

The data obtained for each sampling location were analysed to obtain 1-hour, 8-hour, 24-hour, annual average concentrations and appropriate percentile distributions for comparison with CRD ambient air quality guidelines and provincial and federal objectives and standards, as well as for trend analysis. Where there were missing data in the record, analysis was limited to only those periods when there was more than 75% data capture (e.g., at least 18 hours of data for a 24-hour average and 6 hours of data for an 8-hour average). Similarly, for comparisons of

month-to-month variability in concentrations, only those months with at least 80% data capture[10] in each month were considered. For pollutants where there was less than 80% data capture for the year, no trend analysis is presented because a representative analysis cannot be produced when 20% of the data are missing.

3.1 CARBON MONOXIDE (CO)

Carbon monoxide is produced by both natural and anthropogenic sources (e.g., automobile emissions, home heating). Natural sources include volcanic eruptions, forest fires, the decomposition of organic materials and the oxidation of methane and non-methane hydrocarbons in the atmosphere. Anthropogenic emissions of CO are primarily a product of the incomplete combustion of fossil fuels. CO is an odourless, colourless, tasteless gas.

In 2009, CO data was collected at Victoria Topaz, but was discontinued at both Stellys and Langford after January 12th in accordance with the recommendations of the network review completed in 2008.

The hourly concentrations of CO are summarized in Table 3.1. Eight-hour sequential average concentrations of CO for Topaz are summarized in Table 3.2. There were no exceedances of the CRD 8-hour guideline of 5500 µg/m³ at Topaz in 2009, and generally, values were well below the guideline level.

Table 3.1
Hourly Averaged CO Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
5	25	50	75	98	99					
Victoria Topaz										
116	344	571	726	1421	1700	3781	0	580	325	5%

"--" denotes that not enough data was available to complete a statistical analysis

[10] Note that the Canadian Council of Ministers of the Environment (CCME) considers an annual $PM_{2.5}$ data set to be complete if at least 75% of the scheduled sampling in each quarter of the year has valid data. For ozone, the CCME, the requirement is that an ozone monitoring day must have valid data for 75% of possible hours in a day (i.e., 18 out of 24 hours) to compute a valid 8-hour average, and that the annual data set must have valid monitoring days for at least 75% of the days from April through September.

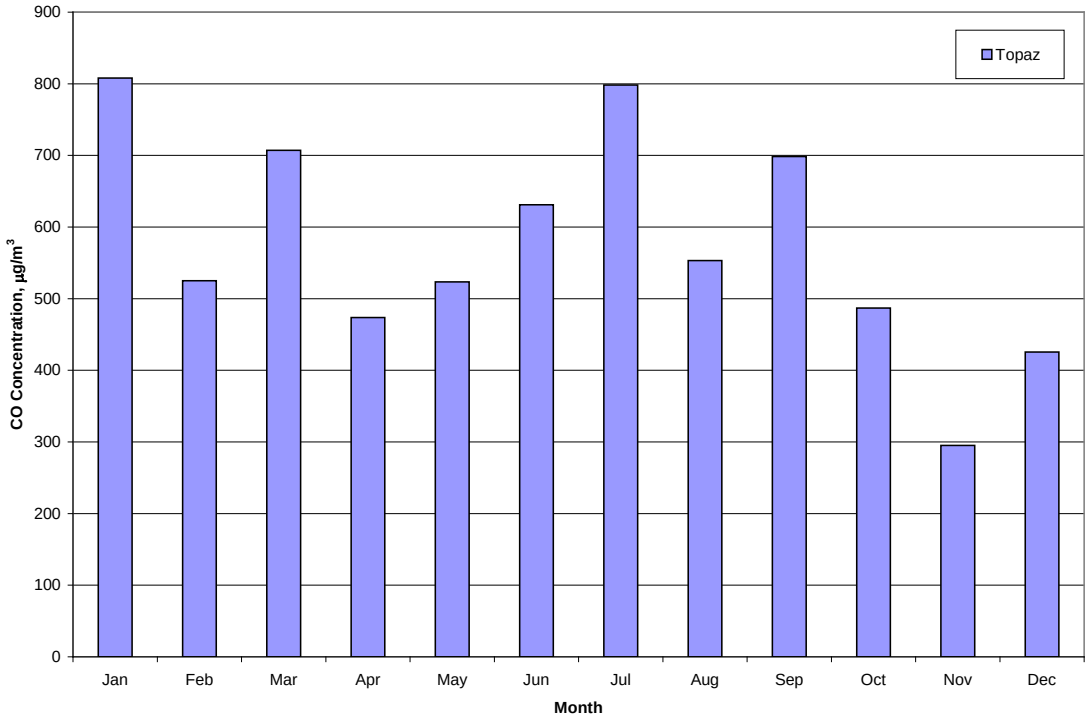
Table 3.2
8-Hour Sequentially Average CO Concentrations in the CRD[a]

Percentile Values						Max µg/m^3	Min µg/m^3	Mean µg/m^3	Std. Dev. µg/m^3	Percent of 8-h Averages > CRD Guideline (5500 µg/m^3)	Missing Values[a] % of Total 8-h Averages
5	25	50	75	98	99						
Victoria Topaz											
180	386	572	748	1173	1329	1966	16	579	267	0%	1%

Notes:
[a] An 8-hour average concentration was determined for every interval having 6 or more hours of data available.
"--" denotes that not enough data was available to complete a statistical analysis

Figure 3.1 shows the mean monthly 8-hour average carbon monoxide concentrations at Victoria Topaz. Concentrations at Topaz showed no significant monthly pattern. However, compared to 2008 data, concentrations at Topaz were much lower in 2009. For example, the mean 8-hour average CO concentration in July 2008 was approximately 1075 µg/m^3 and in July 2009, the mean 8-hour average concentration was 798 µg/m^3.

Figure 3.1
Mean Monthly 8-Hour Average CO Concentrations at Victoria Topaz



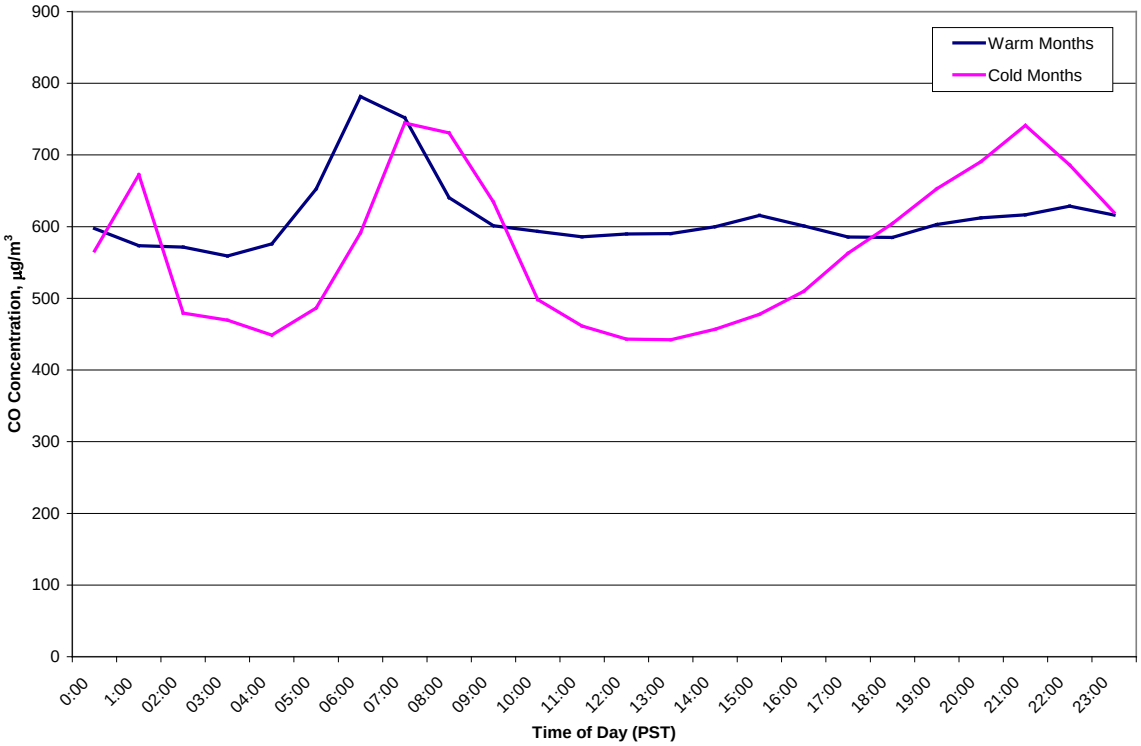
The average diurnal patterns of CO concentrations at Victoria Topaz during the warmer (April to September) and cooler (October to March) months are shown in Figure 3.2. Rush hour traffic emissions in the morning in are indicated by the peak in concentration at approximately 7:00 am PST in cooler months, and 6:00 am PST in warmer months (the difference in time of day for the peak value is due to daylight savings time). This morning peak in concentration can be accounted for by the increase in vehicle emissions during this time of day combined with a lower mixing layer in the atmosphere. A more gradual increase in CO concentrations observed in the late evening in hours during the cool months is due to a lowering of the atmospheric mixing height towards the end of the day.

CO concentrations are typically higher during the cooler months than the warmer months because the decrease in the depth of the mixed layer is, on average, more pronounced in the winter than in the summer, and because residential heating contributes to increased CO emissions at night during cooler months. However, as indicated in Figure 3.1, the 8-hour average CO concentrations at the Topaz site were elevated during the months of May through August. This unexpected trend was first observed in 2008 [11], but such elevated CO concentrations were not present at Topaz during these months in previous years (e.g., 2005 or 2007; 2006 had missing CO data during this period). The reason for the elevated CO concentrations during the summer months at Topaz over the last two years could not be determined.

It should also be mentioned that during the cooler months, automatic calibration often occurred at 1:00 am PST resulting in poor data capture (53%). As a result, the peak in CO concentration seen occurring at 1:00 am may be exaggerated due the large amount of missing data for this hour.

[11] SENES Consultants Limited 2009. Capital Regional District Air Quality Monitoring Review. Prepared for the Capital Regional District, Environmental Services Department, November 2009.

Figure 3.2
Average Diurnal CO Pattern for Victoria Topaz During Cold Months (October – March) and Warm Months (April – September)



3.2 NITROGEN OXIDES

The oxides of nitrogen, NO and NO_2 (= NO_x) are produced primarily by fossil fuel combustion, biomass burning and released from soils (primarily fertilized soils). The reaction of nitrogen with oxygen results in the production of nitrogen oxides (NO_x) during fuel combustion. NO_x can be produced through biological or atmospheric processes, but monitoring of NO_x in urban areas is generally associated with concerns about emissions from combustion processes. In particular, monitoring is generally conducted for two oxides of nitrogen: nitric oxide (NO) and nitrogen dioxide (NO_2). NO and NO_2 are released in significant quantities during combustion and have been identified as important pollutants in the lower atmosphere because they are ozone precursors and can contribute to the formation of secondary fine particles as nitrates.

NO_2 acts mainly as an irritant affecting the mucosa of the eyes, nose, throat, and respiratory tract. Nitrogen dioxide (NO_2) has an orangey-red colour and irritating odour at high enough concentrations. NO_2 is corrosive due to its high potential for oxidation and can cause a reduction in visibility in its role as a smog-forming constituent.

In 2009, NO_x was monitored at Victoria Topaz, Stellys and Langford.

3.2.1 Nitric Oxide (NO)

Table 3.3 summarizes the NO levels measured at the three monitoring locations in the CRD in 2009.

As indicated in Table 3.3, the Victoria Topaz station had the greatest maximum hourly concentration and the highest hourly mean concentration of NO, while Stellys had the lowest. This is likely because the Topaz station is located in close proximity to Blanshard Street and thus influenced by traffic. There are no CRD guidelines or other regulatory criteria for NO.

Table 3.3
Hourly Averaged NO Concentrations in the CRD

Percentile Values						Max	Min	Mean	Std. Dev.	Missing Values
5	25	50	75	98	99	µg/m^3	µg/m^3	µg/m^3	µg/m^3	% of Total Hours
Victoria Topaz										
0.2	1.0	2.9	8.0	75.7	100.7	354.1	0	9.2	20.2	7%
Stellys										
0.2	0.9	1.6	2.9	14.9	22.2	74.5	0	2.7	4.2	5%
Langford										
0.4	0.9	1.6	3.7	42.1	69.9	208.2	0	5.0	13.0	9%

3.2.2 Nitrogen Dioxide (NO_2)

Tables 3.4 and 3.5 provide hourly and 24-hr averaged NO_2 concentrations, respectively. There were no exceedances of the CRD 1-hour NO_2 guideline of 200 µg/m³, and values were generally well below the guideline value. Victoria Topaz experienced higher 1-hour and 24-hour average NO_2 concentrations over those measured at Langford and Stellys. As with the NO concentrations, the higher NO_2 levels at Topaz were likely due to the station's close proximity to a main thoroughfare. Hourly and 24-hour maximum and mean NO_2 concentrations were fairly similar between Stellys and Langford, but were slightly higher at Langford.

Figure 3.3 shows monthly 24-hour average NO_2 levels in 2009. There was not enough data available in December at Langford station to calculate an average monthly value. At all stations, NO_2 levels appear to be the lowest in the spring or early summer (i.e., April to June). Specifically, the lowest NO_2 concentrations occurred in June at Topaz and Langford, and in May at Stellys.

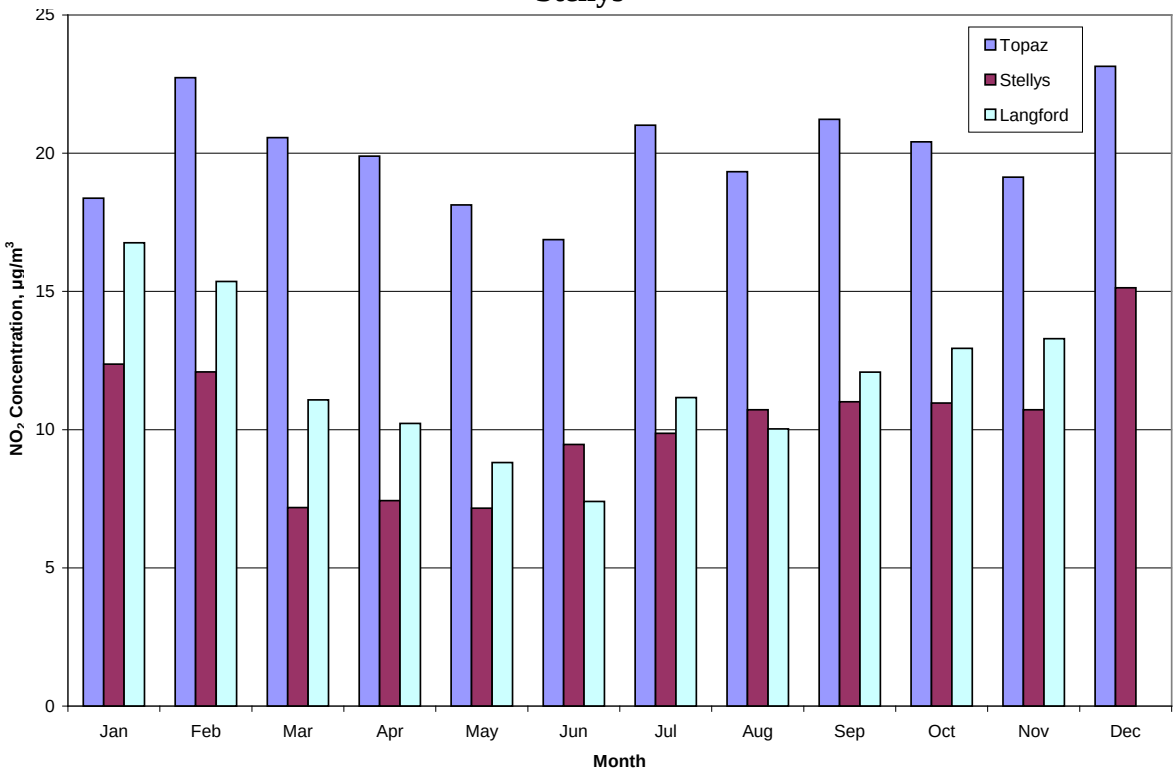
Table 3.4
Hourly Averaged NO_2 Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Percent of 1-h Averages > CRD Guideline (200 µg/m³)	Missing Values % of Total Hours
5	25	50	75	98	99						
Victoria Topaz											
4.2	9.8	16.7	26.7	57.2	63.6	100.4	0	20.1	13.7	0%	7%
Stellys											
1.9	5.1	8.5	13.6	30.7	34.2	53.6	0	10.3	7.3	0%	5%
Langford											
1.8	5.4	10.1	16.6	36.5	41.1	72.7	0	12.1	8.9	0%	9%

Table 3.5
24-Hour Sequential Averaged NO_2 Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total 24-h Averages
5	25	50	75	98	99					
Victoria Topaz										
9.1	14.0	19.5	24.1	39.7	40.5	43.0	2.1	20.1	7.7	3%
Stellys										
4.3	7.4	9.8	13.0	21.2	23.1	27.0	2.0	10.4	4.3	1%
Langford										
4.3	8.4	11.6	15.3	24.7	26.2	29.0	2.4	12.0	5.3	7%

Figure 3.3
Mean Monthly 24-Hour Average NO_2 Concentrations at Victoria Topaz, Langford and Stellys



Figures 3.4 and 3.5 show the average diurnal pattern of hourly NO_2 concentrations during the cooler and warmer months of the year at Victoria Topaz, Stellys and Langford. As can be seen in Figure 3.4, there is a distinct concentration peak in the morning and another later in the evening in the cooler months. In the warmer periods of the year, concentrations also peak in the morning but increase more gradually to a peak in the evening hours.

The early morning peak between 7:00 to 8:00 am PST at all sites is likely related to the morning traffic rush of commuters travelling to work or school. This peak in morning NO_2 concentrations is most pronounced at the Victoria Topaz site. The late evening peak occurs between 6:00 and 7:00 pm PST in the cold months and closer to 8:00 or 9:00 pm PST in the warm months.

A more gradual increase in NO_2 concentrations in the late evening hours is due to a lowering of the atmospheric mixing height towards the end of the day. NO_2 concentrations are higher during the cooler months than the warmer months at all three of the sites because the decrease in the depth of the mixed layer is, on average, more pronounced in the winter than in the summer, and because residential heating contributes to increased NO_x emissions at night during cooler months. This trend is also apparent in Figure 3.3, which shows that the lowest monthly NO_2 averages occur in late spring and early summer.

Figure 3.4
Average Diurnal NO_2 Pattern for all Stations during Cooler Months (October-March)

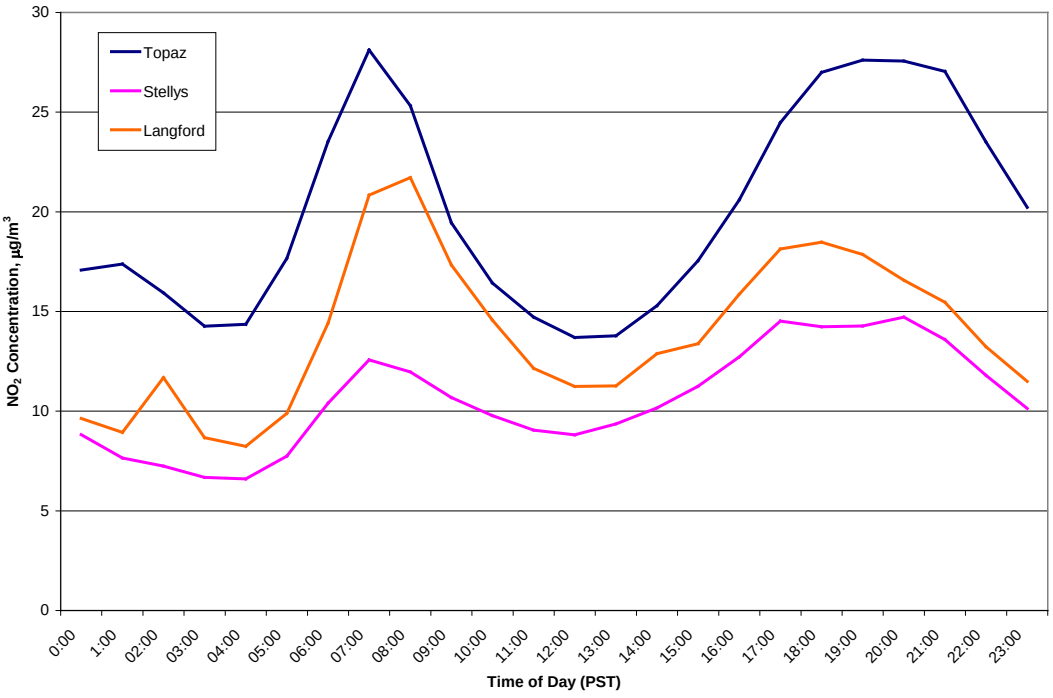
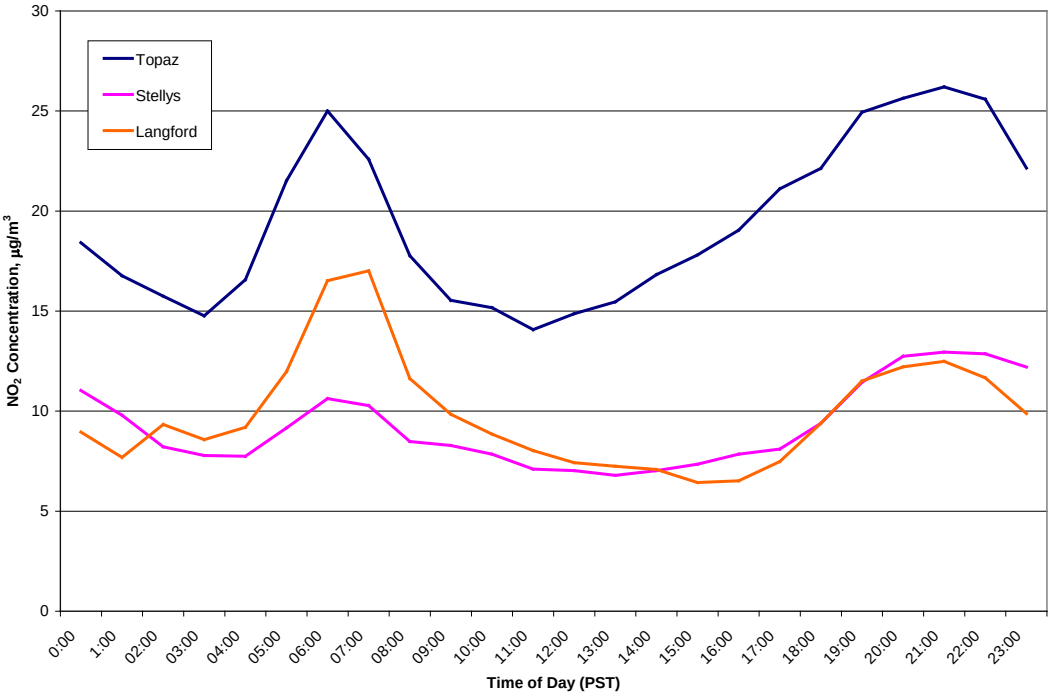


Figure 3.5
Average Diurnal NO_2 Pattern for all Stations during Warmer Months (April-September)



3.3 SULPHUR DIOXIDE (SO_2)

Sulphur oxides (SO_x) are released during the combustion of sulphur bearing fuels. Sulphur dioxide (SO_2) makes up the great majority of SO_x in the lower atmosphere. Due to a significant lowering of sulphur levels in gasoline and on-road diesel, SO_2 emissions from motor vehicles have declined considerably over the past decade. Sulphur levels in on-road diesel were reduced to 15 parts per million (ppm) in 2006 which further lowered mobile source SO_2 emissions. A similar sulphur reduction initiative for marine fuels may occur in the near future.

Sulphur dioxide is a colourless gas, with an irritating odour at sufficiently high concentrations. Emissions of SO_2 can be oxidized in the atmosphere, leading to the formation of sulphuric acid (H_2SO_4). Background levels of SO_2 tend to be very low, meaning measurable concentrations are usually connected to anthropogenic activity, and occur in or near urban areas. Ambient levels of SO_2 tend to be relatively low in the CRD, due to the absence of large scale emission sources.

The major sources of emissions are fossil fuel combustion, industrial processes and geothermal activity. SO_2 can produce acid rain when it is oxidized in the atmosphere or within water droplets. Nucleation involving sulphuric acid in the atmosphere can lead to the production of new particles which can affect particulate matter ($PM_{2.5}$) concentrations.

Table 3.6 lists the average hourly SO_2 concentrations at Langford and Victoria Topaz; the only two locations in the CRD network with hourly SO_2 data available in 2009. Table 3.7 lists the 24-hr sequential average SO_2 concentrations at these two locations[12]. As with the 2008 monitoring year, 2009 SO_2 data for Saturna Island was not available for the preparation of this report.

Table 3.6 indicates that the Victoria Topaz station had the greater maximum hourly concentration and the highest hourly mean concentration of SO_2, while Langford had the lowest. As with the NO_x concentrations, the higher SO_2 levels at Topaz are likely due to the station's close proximity to a main thoroughfare. Table 3.7 indicates that all 24-hour average levels at both locations during 2009 were well below the CRD guideline value of 125 µg/m³.

[12] SO_2 monitoring data at Saturna Island is only available for 24-hour averages. Although the data record dates back to 1998, the data has not been included in previous CRD annual air quality reports.

Table 3.6
Hourly Averaged SO_2 Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
5	25	50	75	98	99					
Victoria Topaz										
0.5	1.3	2.1	3.4	20.2	35.0	167.9	0	3.6	7.2	5%
Langford										
0.3	1.0	1.6	2.4	5.8	6.7	14.9	0	1.8	1.3	12%

Table 3.7
24-Hour Sequentially Averaged SO_2 Concentrations

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Percent of 24-h Averages > CRD Guideline (125 µg/m³)	Missing Values % of Total 24-h Averages
5	25	50	75	98	99						
Victoria Topaz											
1.1	1.7	2.5	4.0	16.8	19.7	29.6	0.3	3.6	3.6	0%	1%
Langford											
0.6	1.2	1.7	2.3	4.1	4.4	4.8	0.0	1.8	0.9	0%	10%

Figure 3.6 shows monthly averaged SO_2 concentrations at the Victoria Topaz and Langford stations. In August and December 2009, not enough data was available to calculate a monthly average for Langford station. The Topaz station had higher SO_2 concentrations than Langford station for all months of the year where data was available. The largest difference in SO_2 concentration occurred during the summer months (June and July) when the average monthly concentration at Topaz was almost four times greater than the concentration at Langford. As with 2008, Topaz experienced the highest SO_2 concentrations during the summer months. However, given the very low concentrations of SO_2, the variability in month-to-month concentrations may not be particularly significant.

Figure 3.6
Mean Monthly 24-hour Average SO_2 Concentrations at Victoria Topaz and Langford

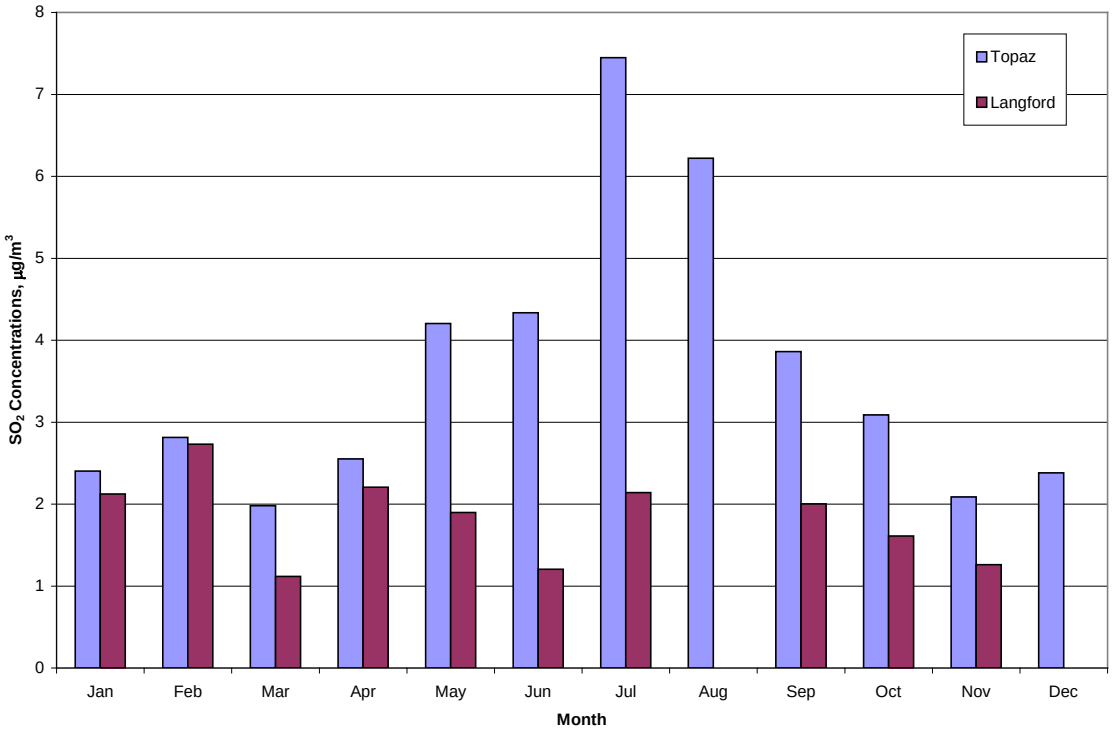
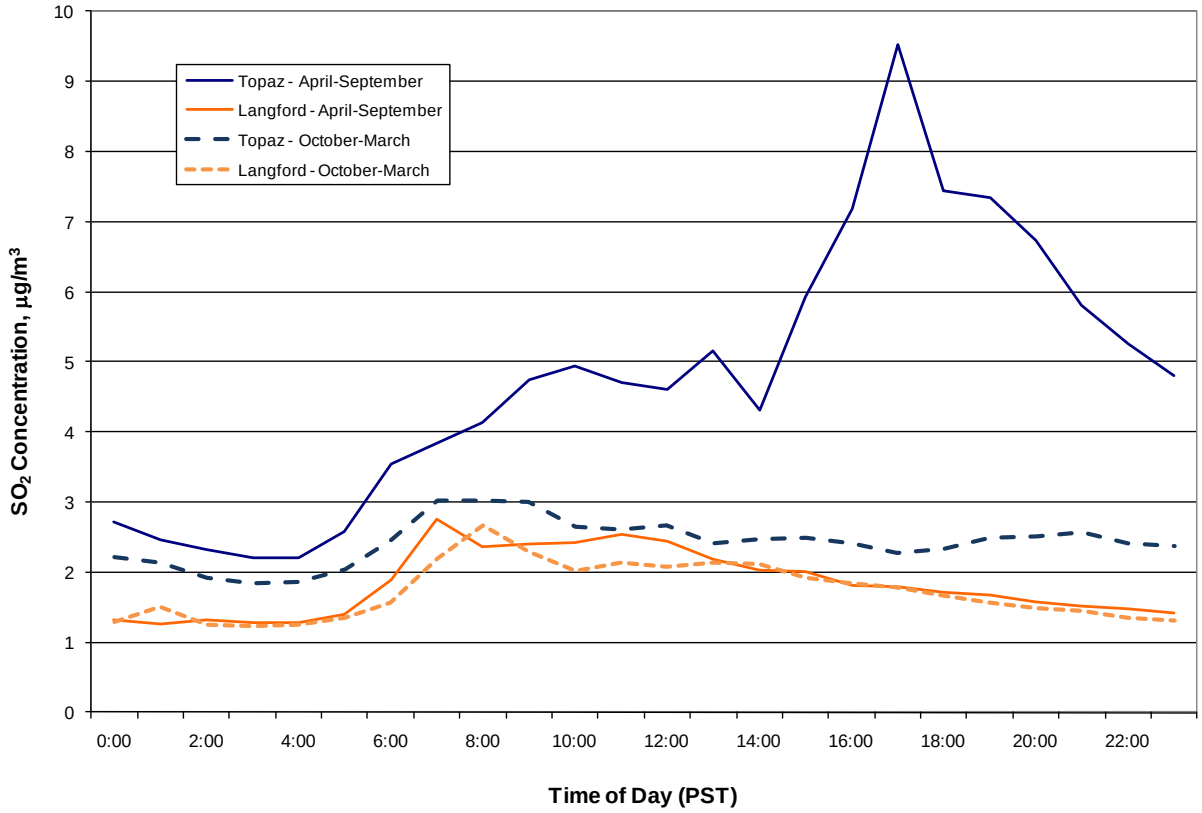


Figure 3.7 shows the average diurnal SO_2 concentrations for Victoria Topaz and Langford. During the cooler months of the year (October-March), the Topaz site has a small peak in SO_2 levels in the morning (8:00 am PST), similar to one seen at Langford. Thereafter, SO_2 decreases throughout the day following the 8:00 am peak at both stations. The morning peak at Topaz and Langford may be traffic related, although all diesel vehicles are currently mandated to use low sulphur fuel.

The analysis of cruise ship operations presented in SENES (2009)[11] showed that summertime evening peaks in SO_2 concentrations at the Topaz site were related to cruise ship emissions. The same is expected to be true for 2009 although no correlation analysis was completed. Langford station continues to show a slight peak in the morning (7:00 am PST) during warmer months, similar to the levels seen during the colder months of the year, indicating that the cruise ship emissions have little impact on SO_2 concentrations in Langford.

Figure 3.7
Average Diurnal SO_2 Pattern for Victoria Topaz and Langford



3.4 GROUND LEVEL OZONE (O_3)

Ozone is a photochemical oxidant that is formed in the atmosphere from chemical reactions involving NO_x, ultraviolet radiation (sunlight), oxygen and hydrocarbons (HC). Ozone is a natural component of the atmosphere, with peak concentrations experienced in the lower stratosphere. In the lower troposphere, ground level zone (O_3) is a secondary pollutant and can be formed at considerable distances from the origin(s) of the primary pollutants. Relatively high ground level concentrations can be caused by anthropogenic emissions of NO_x and HC, or by natural processes, such as stratospheric intrusion. Stratospheric intrusion involves atmospheric motions that bring ozone-rich air from very high altitudes to the surface.

Variations in weather patterns from year to year can have a large effect on community concentrations of ground level ozone. Currently, it is believed that springtime weather conditions favour the potential for stratospheric intrusion. Higher temperatures and solar insolation in the summer favour production of ozone from NO_x and HC released in urban areas. The formation of ozone depends on a rather complex set of reactions that are sensitive to relative

concentrations of pollutant precursors. In addition, ozone can be titrated by NO to produce NO_2. This can result in ozone concentrations decreasing near NO source regions such as near combustion sources within a city. However this can result in the NO_x being transported from these centres and producing ozone down wind of the source. It is common in many urban areas to observe a decrease in ground-level ozone concentrations during periods of peak NO_x emissions.

The Federal air quality objectives for ground-level ozone are considered to be outdated, and the 24-hour average objective level is commonly exceeded in many urban and rural locations throughout Canada. The CWS for ozone is based on more up-to-date scientific, health and environmental information. Comparison of CRD ground-level ozone concentrations to the CRD guideline and the CWS is shown in the tables and discussion that follows. Comparison of CRD concentrations to provincial and federal objectives is provided in Appendix B.

In 2009, ozone was monitored at Victoria Topaz, Stellys, Langford and Saturna Island. Hourly average ozone concentrations are summarized in Table 3.8. There is no CRD guideline value for hourly averaged ozone concentrations. The comparison of hourly maximum concentrations in 2009 to federal/provincial objectives is discussed in Appendix B.

Table 3.8
Hourly Averaged Ozone Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
5	25	50	75	98	99					
Victoria Topaz										
3	20	39	55	82	86	126	0	38	23	5%
Stellys										
5	23	42	61	88	94	136	0	42	24	5%
Langford										
2	19	39	58	88	94	144	0	40	25	8%
Saturna Island										
26	42	56	70	98	106	130	2	57	19	2%

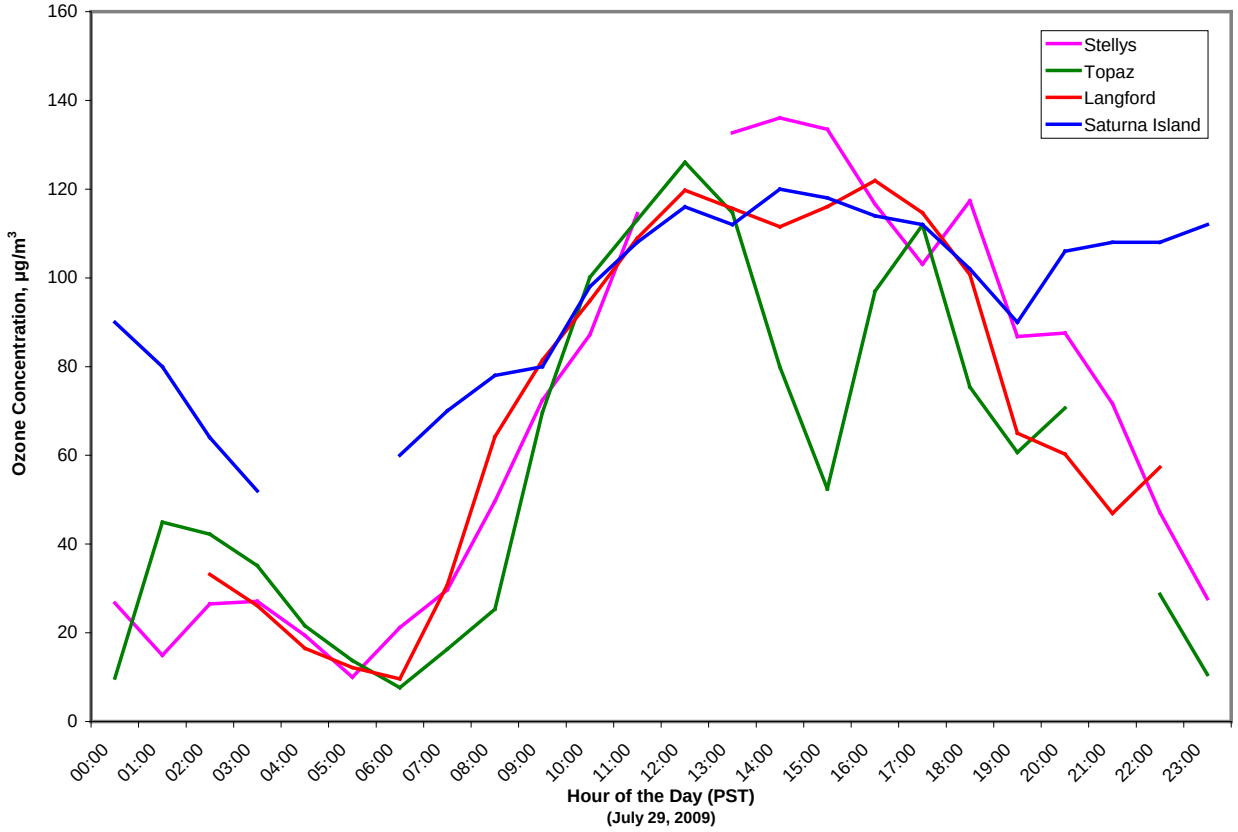
Table 3.9 shows the 8-hour rolling average concentrations at Stellys, Topaz, Langford and Saturna Island. Ozone levels were below the CRD guideline value of 120 µg/m³ (8-hour rolling average) for all stations except for one incident on July 29th at Stellys.

Table 3.9
8-Hour Rolling Average Ozone Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	% of 8-h Averages > CRD Guideline (120 µg/m³)	Missing Values % of Total 8-h Averages
5	25	50	75	98	99						
Victoria Topaz											
7	23	38	52	79	82	99	0	38	19	0%	1%
Stellys											
9	26	42	58	83	89	122	0	42	21	0.01%	1%
Langford											
6	23	39	55	82	86	116	0	39	21	0%	5%
Saturna Island											
28	44	56	68	93	100	115	4	56	18	0%	1%

The ozone episode on July 29th, depicted in Figure 3.8, occurred at all of the CRD monitoring sites, but achieved its highest level at Stellys. Ozone levels measured at each station were quite comparable from approximately 8:00 a.m. until early afternoon on July 29th. Although the ozone levels at Stellys were only slightly above the CRD guideline value and did not exceed the guideline value at any of the other ozone monitoring stations in the CRD, the Ministry of Environment issued an Air Quality Advisory for the CRD on this date because the ozone concentrations were expected to exceed the hourly averaged Provincial Ambient Air Quality Objective of 160 µg/m^3 (82 ppb) that afternoon. The monitoring data from the CRD stations indicates that the provincial objective was not actually exceeded at any of the monitoring sites.

Figure 3.8
Ozone Episode in the CRD July 29, 2009



The exceedance of the CRD guideline recorded at Stellys occurred on July 29th. The maximum hourly concentration recorded on this date was 136 µg/m^3, for a maximum 8-hour rolling average of 122 µg/m^3. The latter value may underestimate the actual 8-hour average due to the missing hourly reading at noon on this date. Although the monitoring data showed simultaneous increases in ozone concentrations at other monitoring sites in the CRD at the start of the episode (indicated in Figure 3.8), elevated levels at Stellys, Topaz and Langford stations declined significantly during the late afternoon hours, whereas elevated concentrations tended to persist into the evening hours at Saturna Island. This ozone episode was different from past years (e.g., 2007 and 2008) in that the exceedance was observed at Stellys station rather than Saturna Island. However, the episode was similar to past years in that elevated ozone concentrations persisted at Saturna Island into the evening.

As discussed in SENES (2009)[11], the strong diurnal signal in ozone observed in the CRD is dominated by ozone production in the morning, and then NO titration in the afternoon

and through the night[13]. This is enhanced by strong low level stability (in episode conditions) over land which isolates O_3 and NO in the lowest tens of metres, reducing ozone to low levels. In the absence of local NO emissions (as is the case on Saturna Island), and surface based inversions, O_3 will remain high through most of the night.

Due to the limited temporal, and uncertain spatial extent of available monitoring data, community exposure to ground-level ozone concentrations above the CRD guideline value and any related health effects cannot be determined within a suitable degree of confidence.

CWS compliance requires that the annual 4th highest, daily maximum 8-hour average concentration averaged over three consecutive years does not exceed 65 parts per billion (which is equivalent to 127.6 µg/m³). Furthermore, CWS guidelines state that achievement of the CWS standard should be based on data from monitoring stations that are representative of "neighbourhood" or "urban scale" exposure levels where people live, work or play. The lowest ozone concentrations in a metropolitan area may occur near the urban centre where scavenging by traffic-derived NO_x emissions can reduce ozone levels, while maximum ozone concentrations may occur downwind of the urban fringe.

Table 3.10 lists the maximum and annual 4th highest 8-hour average ozone concentrations recorded at each of the ozone monitoring locations in the CRD for the period 1998-2009. The year-to-year variations in the maximum 8-hour average ozone concentrations for the period 1998-2009 are depicted in Figure 3.9. The data indicate that maximum ozone levels at Saturna Island have consistently been above the CRD guideline value of 120 µg/m^3 over the period 2005-2008, but dropped to just below the CRD guideline in 2009. The period of record at Stellys is short, but levels have approached the CRD guideline level in past years and for the first time since monitoring began in 2003, ozone levels at Stellys station exceeded the CRD guideline in 2009. By comparison, the ozone levels at Victoria Topaz have never exceeded the CRD guideline at any time during this period. Data for Langford were excluded from Figure 3.9 as there were only two years of available data.

[13] Dr. D. Steyn, Professor, Atmospheric Science, Department of Earth and Ocean Sciences, University of British Columbia, personal communication 7 November 2008.

Table 3.10
Summary of 8-Hour Ozone Levels (µg/m^3) in the CRD (1998-2009)

	Victoria Topaz		Stellys		Langford		Saturna Island	
	Max.	4th Highest	Max.	4th Highest	Max.	4th Highest	Max.	4th Highest
1998	109	85					143	111
1999	96	89					111	96
2000	105	91					111	97
2001	97	86					121	109
2002	110	86					117	104
2003	103	85	85[a]	79[a]			139	113
2004	106	86	114	95			117	104
2005	113	85	108	94			127	103
2006	111	95	119	101			124	114
2007	109	106	115	109			134	131
2008	105	103	107	104	107	105	136	129
2009	99	97	122	114	116	113	115	113
CRD Guideline	120		120		120		120	
CWS		127.6		127.6		127.6		127.6

Notes:

a Monitoring from September 16 to December 31, 2003
Max. – Maximum 8-hour average concentration for the year
4th High – 4th highest 8-hour average concentration for the year

Figure 3.10 shows the trend in the 4th highest ozone concentrations over the period 1998-2009. Data for Langford were excluded from Figure 3.10 as there is only two years of existing data. The available data indicate that there is relatively little year-to-year variation in the 4th highest concentrations, especially at Victoria Topaz. Saturna Island has had the highest fluctuations and while the period of record at Stellys is still too short to make definitive conclusions, ozone concentrations appear to be approaching the CWS. Moreover, although the annual 4th highest ozone concentrations at all four monitoring stations are all currently below the CWS value of 127.6 µg/m^3, the discontinuation of monitoring at the Stellys site as of March 31, 2010 means that it will not be possible to determine whether the trend towards higher ozone concentrations at this location would have continued, possibly leading to exceedance of the CWS in future years.

Figure 3.9
Maximum 8-Hour Average Ozone Levels in the CRD (1998-2008)

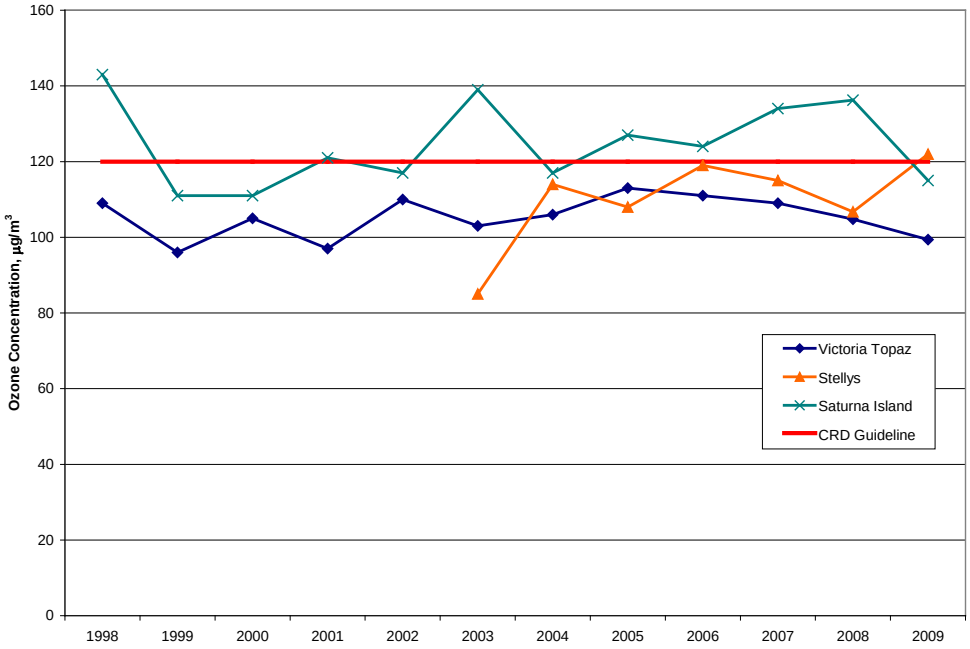
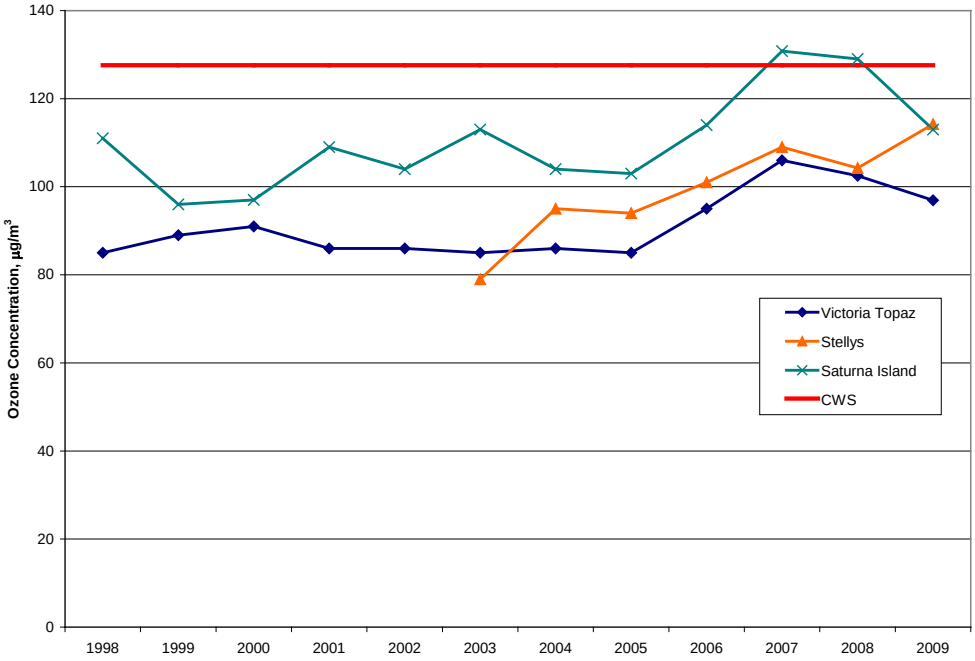


Figure 3.10
4th Highest 8-Hour Average Ozone Levels in the CRD (1998-2009)



It should be noted that the data in Table 3.10 and Figures 3.9 and 3.10 indicate that there has been a trend toward increasing ozone concentrations at the Stellys site since the inception of monitoring in 2003. With the cancellation of monitoring at this site as of March 31, 2010, it will not be possible to determine whether this trend will continue into the future.

Since the 4th highest ozone values on Saturna Island were 131 µg/m^3 and 129 µg/m^3 in 2007 and 2008, respectively, it was anticipated that Saturna Island may exceed the CWS in 2009 if ozone concentrations remained elevated. However, in 2009, the 4th highest 8-hour average ozone concentration on Saturna Island was only 113 µg/m^3, therefore, the CWS was not exceeded.

Previously, the Saturna Island ozone data have been used to demonstrate CWS compliance, as this station has experienced the highest ozone concentrations of all of the monitoring stations in the CRD. However, this station is not representative of the concentrations experienced in metropolitan areas, and therefore use of the station to demonstrate compliance is conservative. Although Langford station is located in an appropriate area, there are an insufficient number of consecutive years of data available to demonstrate CWS compliance. Instead, attainment of the CWS was based on the data collected at the Topaz and Stellys sites.

Over the three year period of 2007-2009 at Stellys and Topaz, the 4th highest 8-hour rolling average concentration did not exceed 65 parts per billion (127.5 µg/m^3) (Table 3.11). The averages over the three years for the two stations were 109 µg/m^3 and 102 µg/m^3, respectively, indicating that the CRD satisfies the CWS for ground-level ozone.

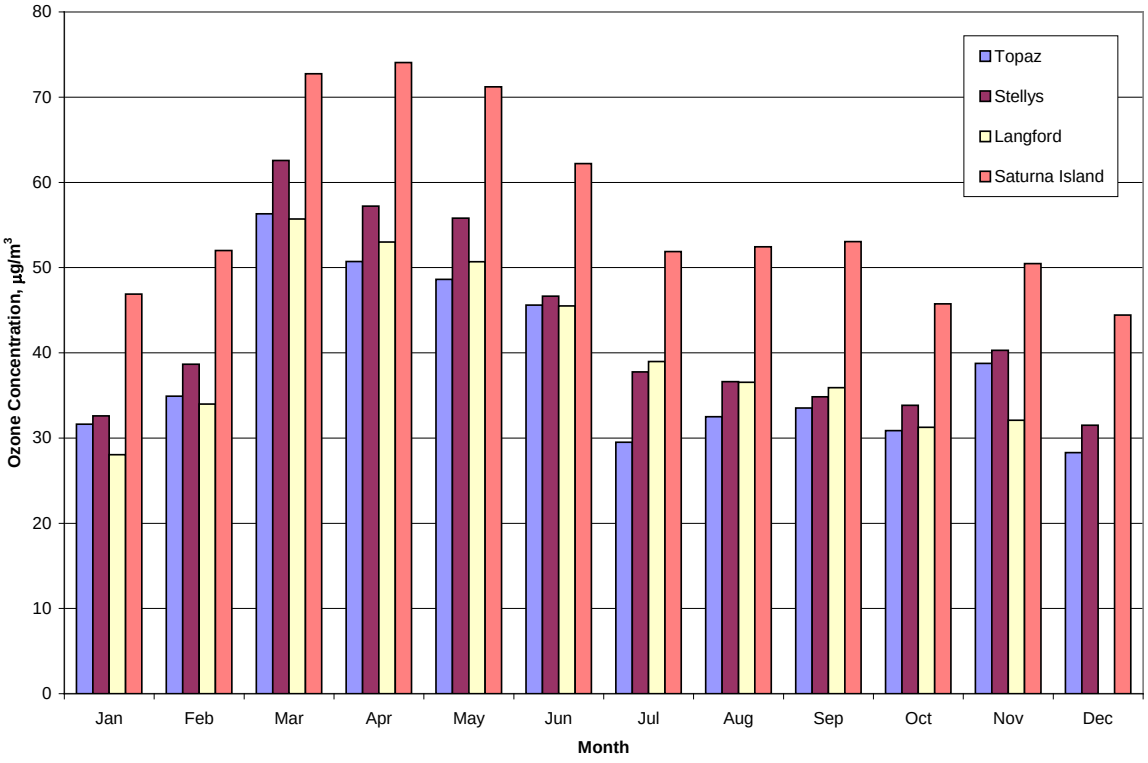
Table 3.11
4th Highest Daily Maximum 8-hour Average Ozone Concentrations at Topaz and Stellys, and Saturna Island 2007-2009

Year	Concentration (µg/m^3)		
	Stellys	**Topaz**	**Saturna Island**
2007	109	106	131
2008	104	103	129
2009	114	97	113
3-year Average	**109**	**102**	**124**

Figure 3.11 shows mean monthly 8-hour rolling average ozone concentrations for Topaz, Langford, Stellys and Saturna Island. Ozone concentrations are generally highest during the spring months (i.e., March, April and May). This is consistent with patterns observed in previous years, and the higher concentrations in March and April are generally considered to be

due to stratospheric ozone being brought to the surface rather than from photochemical ozone production in the troposphere. Ozone concentrations were generally lower from October to December.

Figure 3.11
Mean Monthly 8-Hour Rolling Averaged Ozone Concentrations



Figures 3.12 and 3.13 show average daily ozone concentrations during the warmer and cooler months of the year for Topaz, Stellys and Langford. For each station, in both warmer and cooler months, there is a trough in ozone concentration levels around 5:00 am or 6:00 am PST (warmer months) and 7:00 am PST (cooler months) and a peak in concentration levels at around 1:00 pm PST (cooler months) and at around 2:00 pm or 3:00 pm PST (warmer months). In the warmer months, the morning trough and afternoon peaks are more pronounced for all stations, especially Saturna Island.

Figure 3.12
Average Diurnal Ozone Pattern During Cooler Months (October - April)

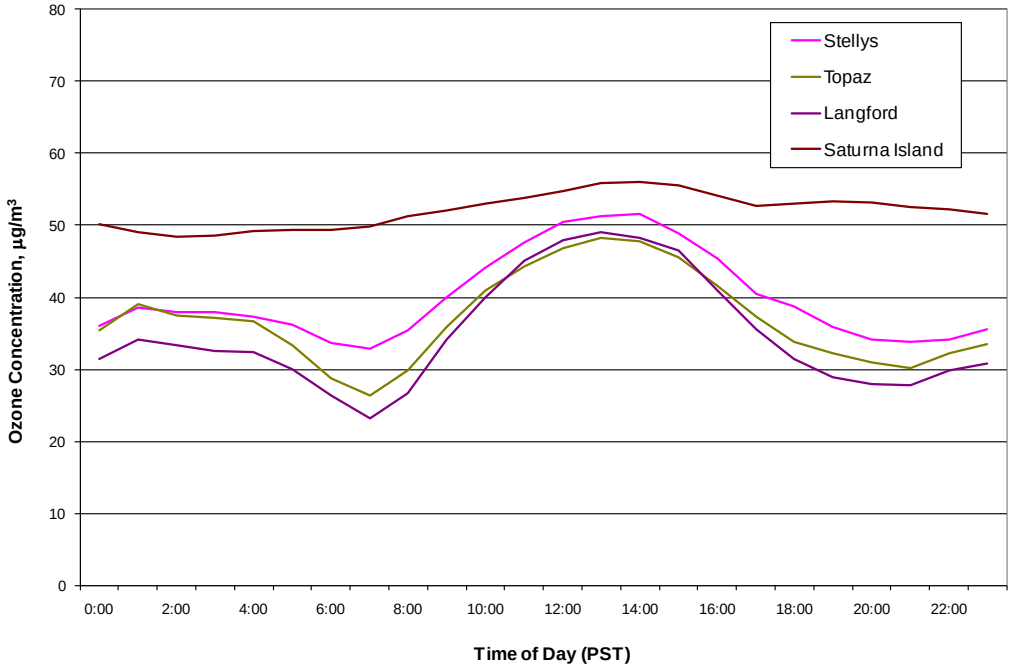
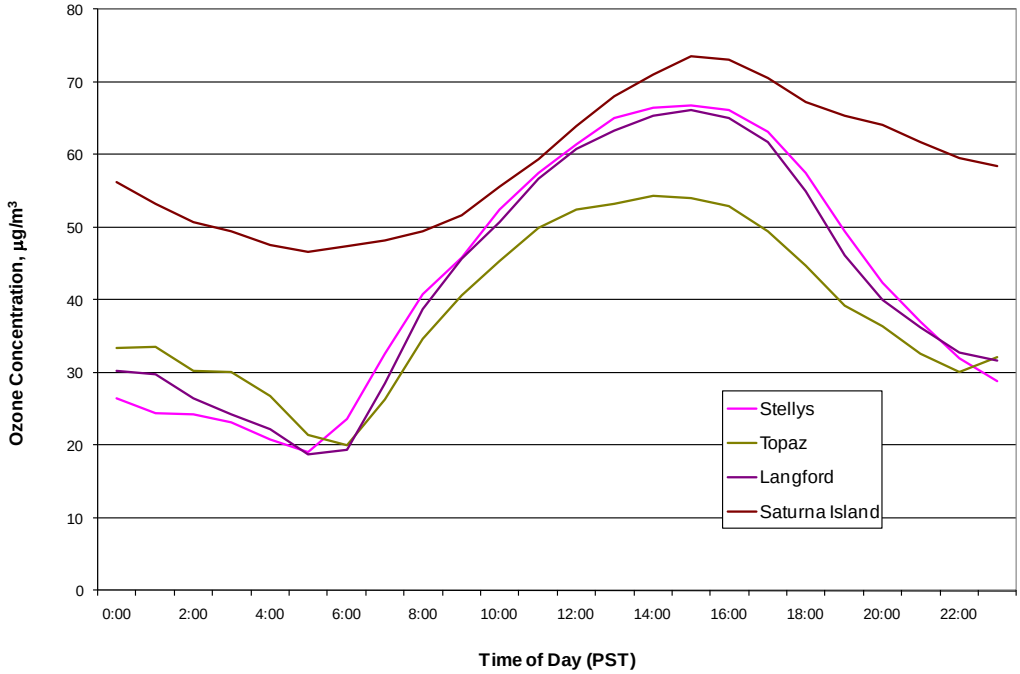


Figure 3.13
Average Diurnal Ozone Pattern During Warmer Months (May - October)



During the warmer spring and summer months (Figure 3.13), the afternoon peak in ozone levels is likely caused by increased solar insolation and warmer temperatures which are needed to drive the chemical transformation of NO and VOC to form ozone. The trough present in the morning relates to increased NO emissions from traffic during the morning rush hour. The higher NO levels chemically react with ozone, resulting in lower ozone levels. The morning trough in ozone levels in the cooler months is likely due to the same mechanism. The remainder of the diurnal variation during the cooler months results from similar ozone/NO interaction, with lower NO_x levels during the daytime hours, and higher NO levels in the early morning and evening hours. Comparatively, the diurnal variation at Saturna Island, an isolated area, is less pronounced during the cooler months. This suggests that ozone production in this area is more influenced by warmer temperatures and higher solar insolation and is less influenced by diurnal variations in NO levels.

The minimum in the ozone concentration observed in the early morning is likely due to the titration of ozone by NO which is emitted by automobiles. Ozone increases following the morning rush hour as photochemical processes begin to play a more dominant role. In addition, breakup of nocturnal boundary layers are occurring and ozone from aloft is mixed down. Throughout the day, ozone concentrations are higher due to its photochemical production in the presence of NO and NMHC's. As the solar radiation decreases in the evening, the production of ozone decreases and its losses become dominant and the concentration decreases. The loss of ozone is primarily due to its reaction with NO and its loss to the surface. This can be even more pronounced due to the presence of a nocturnal boundary layer which traps emissions close to the surface.

4.0 PARTICULATE MATTER

Suspended particulate matter (PM) can either be emitted into the atmosphere as primary particulates or produced in the atmosphere as secondary particulates. Primary particulate matter originates from natural sources such as dust disturbed by the action of wind, and from anthropogenic sources, such as the combustion of fuels. Fuel combustion tends to produce smaller PM, whereas fugitive dust tends to be of a larger size fraction. Secondary particles are produced through nucleation within the atmosphere and can grow through the accumulation of material of both gas-phase and particulate matter to its surface. PM can remain suspended in air for as little as a few seconds to as long as several days or even weeks and longer. Loss of particulate matter can either occur by dry deposition (settling) or wet deposition (precipitation). Ambient PM is measured in the CRD as both 'inhalable' particulate matter, which is the fraction of suspended particles with diameters of 10 micrometres (µm) or less and 'respirable' particulate matter, which have diameters of 2.5 µm or less. These fractions are denoted as PM_{10} and $PM_{2.5}$ respectively.

There is significant interest in community levels of $PM_{2.5}$, as health research has indicated the smaller size range of suspended particles can have negative effects on human health at concentrations typically observed in urban areas. For this reason, $PM_{2.5}$ is one of two common air contaminants (along with ground level ozone) with CWS criteria. Exposure to $PM_{2.5}$ can aggravate pulmonary and cardiovascular disease, increase the occurrence of asthmatic attacks and increase the risk of premature mortality. An additional adverse effect that can be related to ambient PM concentrations is the reduction of visibility.

Since there are few significant industrial emission sources in the CRD, much of the PM is released by motor vehicle and marine vessel exhaust, roadway emissions (dust) due to traffic activity, residential home heating and residential burning. The contribution of residential ('backyard') burning to monitored $PM_{2.5}$ concentrations in the CRD during allowed burn days was assessed in the 2004 air quality assessment[14], as well as in the 2008 air quality assessment[11].

In 2009, three different ambient PM sampling (measuring) devices were used in the CRD. Tapered Element Oscillating Microbalance (TEOM) samplers are used to collect air concentrations of $PM_{2.5}$ that are recorded as hourly averaged concentrations. These samplers run continuously, with periodic maintenance depending on how quickly the sampling filter reaches capacity. Partisol and Dichotomous (Dichot) samplers are used to collect either PM_{10} or $PM_{2.5}$ sequentially on a cycle of one in every six days and utilize a low-volume of airflow for sample collection.

[14] SENES Consultants Ltd., 2005. *Air Quality in the Capital Regional District 2004*. Prepared for the Capital Regional District.

The two types of sequential samplers collect particulate matter on a filter, from midnight of one day to midnight of the next. Once a collection period has ended, the filter is analyzed in a laboratory to determine the 24-hour concentration.

The sequential Dichot sampler at the Topaz station is part of the National Air Pollution Surveillance (NAPS) network managed by Environment Canada. All sequential high volume (Hi-Vol) samplers used to determine 24-hour concentrations of PM_{10} were discontinued at the end of 2008.

It should be noted that each type of PM sampling instrument has its own bias, in that measured amounts may be over- or under-estimated by a small amount simply due to the process the instrument uses to determine an ambient concentration. This means that two co-located $PM_{2.5}$ samplers may produce ambient PM concentrations that differ. In addition, each PM sampler may be influenced by positional bias that exists due to the location of the air quality station within the community.

4.1 INHALABLE PARTICULATE MATTER (PM_{10})

As mentioned previously, all sequential high volume (Hi-Vol) samplers were discontinued in December 2008. As such, only PM_{10} data collected using a Dichot sampler at Victoria Topaz station is available for 2009.

PM_{10} data for the Dichotomous sampler at Victoria Topaz are summarised in Table 4.1. The mean PM_{10} concentration at Topaz in 2009 was 12.9 µg/m^3 which is comparable to 2008 levels (mean value of 12.7 µg/m^3). However, data capture was much poorer in 2009 which may lead to anomalous results. The CRD guideline for PM_{10} was not exceeded.

Table 4.1
2009 Dichot Sequential 24-Hour Mean PM_{10} (Victoria Topaz)

Statistic	PM_{10}
Mean (µg/m^3)	12.9
Std. Dev. (µg/m^3)	6.5
Maximum (µg/m^3)	34.4
98th percentile (µg/m^3)	31.4
# > CRD Guideline (50 µg/m^3)	0
# of Samples	50
Percent Missing (%)	18%

4.2 FINE PARTICULATE MATTER ($PM_{2.5}$)

Table 4.2 shows the hourly averaged $PM_{2.5}$ concentrations at three TEOM-equipped monitoring stations in the CRD: Victoria Topaz; Stellys; and, Langford. Unlike past years, Stellys station had good data capture in 2009.

There is no CRD guideline for hourly averaged $PM_{2.5}$ concentrations, nor any provincial or federal objectives or standards. However, the use of ambient air quality objectives for averaging periods shorter than 24 hours has been raised in a comprehensive review of objectives, standards and guidelines in other jurisdictions[15]. For this reason, the hourly averaged $PM_{2.5}$ values are reported for the CRD.

Table 4.3 provides a statistical summary of the 24-hour averaged $PM_{2.5}$ concentrations at the three monitoring locations. There was one exceedance of the CRD guideline of 25 µg/m^3 at Stellys station. On November 1st, the $PM_{2.5}$ concentration at Stellys station was 29.9 µg/m^3. $PM_{2.5}$ concentrations were much lower at the other stations on this day. Therefore, it is likely that this was an isolated event. In previous years, elevated $PM_{2.5}$ concentrations have been noted at other CRD locations (e.g., Victoria Topaz in 2003) in relation to fireworks on the night of Halloween. It is possible that such activity also occurred on the night preceding Halloween in 2009 in the vicinity of Stellys that would offer some explanation for the elevated levels of fine particulate matter.

Table 4.2
Hourly Averaged $PM_{2.5}$ Concentrations at TEOM Sites in the CRD

Percentile Values						Max µg/m^3	Min µg/m^3	Mean µg/m^3	Std. Dev. µg/m^3	Missing Values % of Total Hours
5	25	50	75	98	99					
Victoria Topaz										
0	2	4	6.9	20	24	88	0	5.1	4.9	1%
Stellys										
0	1.5	3.8	6.5	17	21	111	0	4.7	4.8	4%
Langford										
0	11	3	5.2	14	17	53	0	4.0	3.6	5%

[15] SENES Consultants Limited 2005. Development of Options for a New Provincial $PM_{2.5}$ Air Quality Objective. Prepared for the British Columbia Lung Association, Vancouver, BC.

Table 4.3
24-Hour Sequentially Averaged $PM_{2.5}$ Concentrations in the CRD

Percentile Values						Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Percent of 24-h Averages > CRD Guideline (25 µg/m³)	Missing Values % of Total 24-h Averages
5	25	50	75	98	99						
Victoria Topaz											
1.7	3.0	4.6	6.6	14	15	18	0.7	5.1	3.0	0%	0.3%
Stellys											
1.3	2.7	4.0	5.8	13	14	29.9	0.1	4.7	3.0	0.3%	1.9%
Langford											
1.2	2.3	3.4	4.9	12	13	16	0.6	3.9	2.4	0%	6.0%

$PM_{2.5}$ data for the Dichotomous sampler at Topaz and the Partisol samplers at Stellys and Langford are summarised in Table 4.4. The $PM_{2.5}$ Partisol sampler at Victoria Topaz station was discontinued in April of 2009 and as a result, there was insufficient data to complete a statistical analysis. The CRD guideline value was exceeded on one day based on the Dichotomous sampler on December 9th. On this day, $PM_{2.5}$ concentrations were much lower at Stellys station, therefore it is likely that this was a localised event. However, data from both the $PM_{2.5}$ TEOM and Partisol samplers at Langford station were not operating on this day so a definitive conclusion cannot be made.

Table 4.4
Sequential Dichot and Partisol 24-Hour Mean $PM_{2.5}$ Concentrations at Victoria Topaz, Langford and Stellys

Statistic	Victoria Topaz		Langford	Stellys
	Dichot	Partisol[1]	Partisol	Partisol
Mean (µg/m³)	7.2	--	4.7	5.9
Std. Dev. (µg/m³)	4.6	--	3.2	3.4
Maximum (µg/m³)	26.3	--	20	14.0
98th percentile (µg/m³)	20.8	--	12.1	13.8
# > CRD Guideline (25 µg/m³)	2%	--	0	0.0
# of Samples	50	--	57	59.0
Percent Missing (%)	18%	--	7%	3%

Notes:
[1]$PM_{2.5}$ Partisol sampler discontinued in April 2009.
"--" denotes not enough data for statistical analysis.

As indicated in Table 4.4, the CRD guideline for $PM_{2.5}$ of 25 µg/m^3 was exceeded once at the Victoria Topaz site on December 9th with a 24-hour average concentration of 26.3 µg/m^3 based on the sequential Dichotomous (Dichot) sampler. However, the co-located continuous TEOM sampler recorded a $PM_{2.5}$ concentration on that date of only 18.4 µg/m^3. TEOM samplers are recognized to have some loss of sample in colder seasons, and it is likely that the Dichot sampler provided a more reliable sample of $PM_{2.5}$ concentration on that date, and that the CRD guideline was indeed exceeded. However, the guideline was not exceeded at Stellys station on this date. As previously mentioned, the CRD guideline was also exceeded once at Stellys station on November 1st, but no other exceedances occurred during 2009.

For the purposes of demonstrating compliance with the $PM_{2.5}$ CWS, the CCME considers an annual $PM_{2.5}$ data set to be complete if at least 75% of the scheduled sampling in each quarter of the year has valid data. Compliance with the CWS for $PM_{2.5}$ (30 µg/m³, 24-hour average) is determined by calculating 24-hour $PM_{2.5}$ concentrations each midnight-to-midnight period during the year from monitoring sites that meet the "neighbourhood" or "urban" criteria as defined in the CWS Guidance Document on Achievement Determination[16]. The consecutive three year average 98th percentile concentration must meet the CWS criteria of 30 µg/m³. It should be noted that the Stellys station likely does not meet the siting requirement, as it is situated in a rural setting (but within 250 metres of a residential area to the west of the station). Nevertheless, Stellys has been included in the determination of CWS achievement. For the first time, the $PM_{2.5}$ data for Langford was included in the CWS determination since the data record now covers a 3-year period (February 2007 to December 2009).

Table 4.5 lists the 98th percentile $PM_{2.5}$ concentrations for 2007, 2008 and 2009 at the Victoria Topaz Langford and Stellys monitoring sites. The average 98th percentile over the 3 consecutive years was 14 µg/m³ for Victoria Topaz and 10 µg/m³ for Langford. Therefore, the CRD is currently in compliance with the CWS for respirable particulate matter.

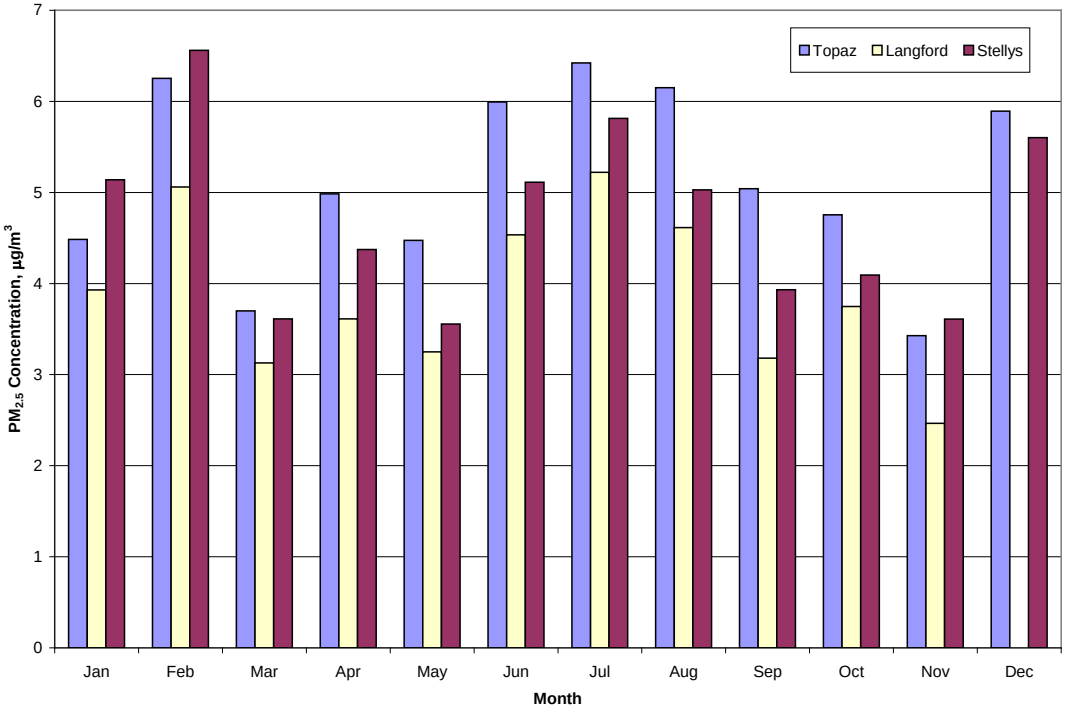
Table 4.5
98th Percentile $PM_{2.5}$ Concentrations for Topaz, Langford and Stellys (2007-2009)

Year	Concentration (µg/m^3)		
	Topaz	**Langford**	**Stellys**
2007	15	9	17
2008	13	10	11
2009	14	12	13
3-year Average	**14**	**10**	**14**

[16] Canadian Council of Ministers for the Environment, 2000. Guidance Document on Achievement Determination: Canada Wide Standards for Particulate Matter and Ozone. www.ccme.ca.

Figure 4.1 shows the monthly average $PM_{2.5}$ concentrations from the TEOM samplers at Topaz, Langford and Stellys. There was an insufficient amount of data available in December at Langford station. Topaz had higher concentrations than Langford for all months of the year where data was available, and concentrations at Topaz were slightly higher than Stellys for majority of the months. This is likely due to higher traffic levels near the Topaz station (i.e., increased road dust and vehicle emissions on Blanshard Street). No reason for elevated levels at Stellys could be determined due to poor data capture in past years.

Figure 4.1
Mean Monthly 24-Hour Average $PM_{2.5}$ Concentrations in the CRD



Figures 4.2 and 4.3 show the monthly average diurnal $PM_{2.5}$ concentrations for the TEOM sites during the cooler (October to March) and warmer (April to September) months of the year. The patterns indicate pronounced morning and evening peaks in $PM_{2.5}$ concentrations at all stations during the cooler months, with Stellys being less significant. Open burning of waste and woodstove usage, especially in October, are the likely cause for the higher $PM_{2.5}$ concentrations at that time of year.

During the warmer months, morning peaks for all stations continue to be pronounced, while the evening peak does not. Morning peaks are attributable to rush hour traffic as well as the breakup of morning inversion layers in the atmosphere, while the less significant evening peaks are more likely to be associated with the re-establishment of a lower mixed layer in the atmosphere.

Figure 4.2
Average Diurnal $PM_{2.5}$ Pattern in the CRD during the Cooler Months (October – March)

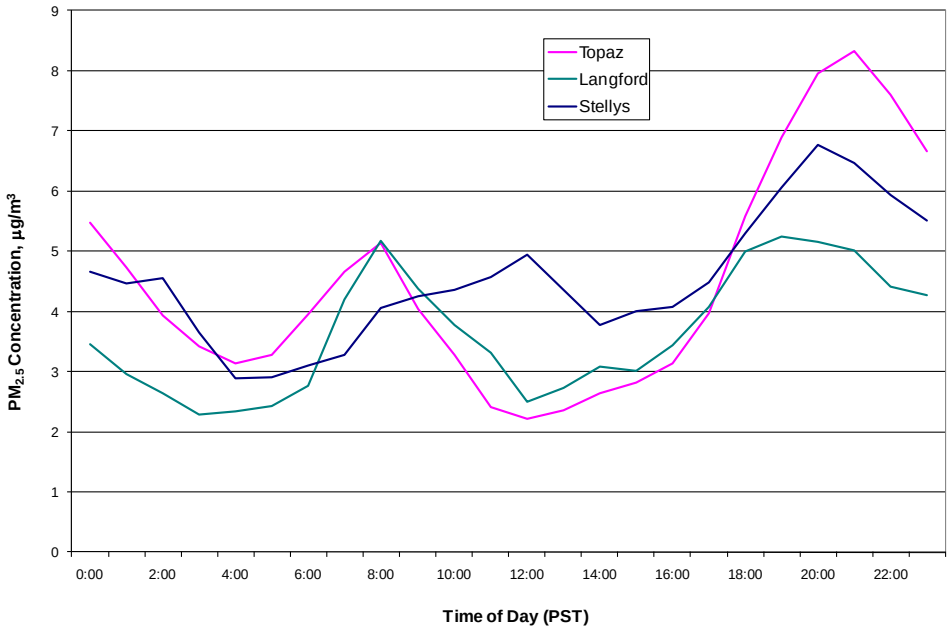
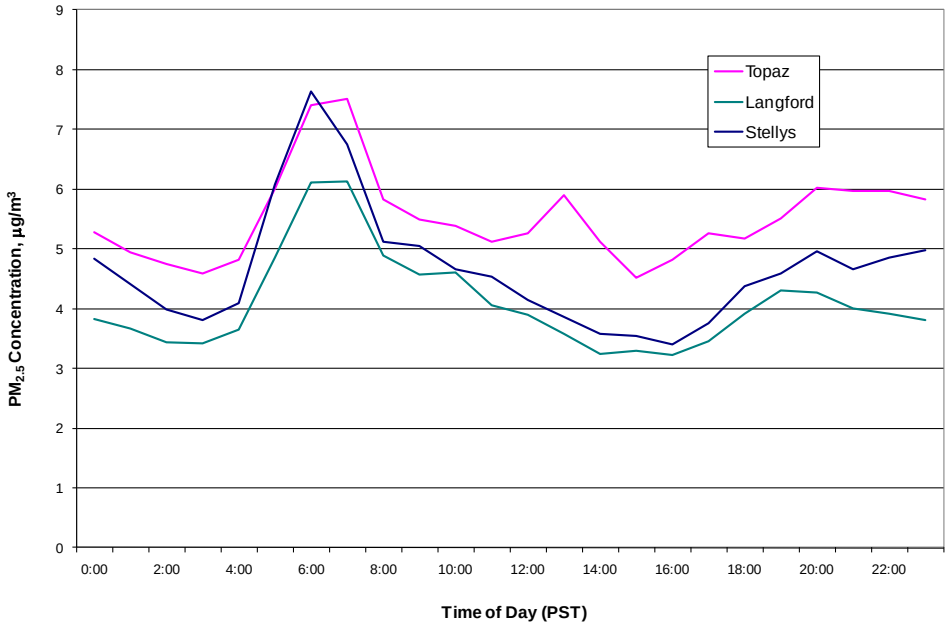


Figure 4.3
Average Diurnal $PM_{2.5}$ Pattern in the CRD during the Warmer Months (April – September)



4.3 COMPARISON BETWEEN CONTINUOUS AND SEQUENTIAL SAMPLING DATA

This section presents comparisons between continuous TEOM sampled data and sequential sampled data (i.e., Partisol and Dichot) at three locations (Victoria Topaz, Stellys and Langford). This analysis was first performed on 2007 data as a check of data quality.

Figure 4.4 shows the comparison between TEOM, Partisol and Dichot data. Partisol data was not collected after April 7th. From the available data, Figure 4.4 shows that Partisol and Dichot $PM_{2.5}$ data agreed very well. The figure also shows that data collected at Victoria Topaz using the sequential Partisol sampler was consistently higher than the values collected using the TEOM sampler. The TEOM and Dichot sampler data agreed the most during the warmer months, but less during the colder months. As discussed previously, TEOM samplers tend to experience sample loss during colder temperatures, explaining the differences in the data presented in Figure 4.4.

Figure 4.4
Comparison of $PM_{2.5}$ Data at Victoria Topaz

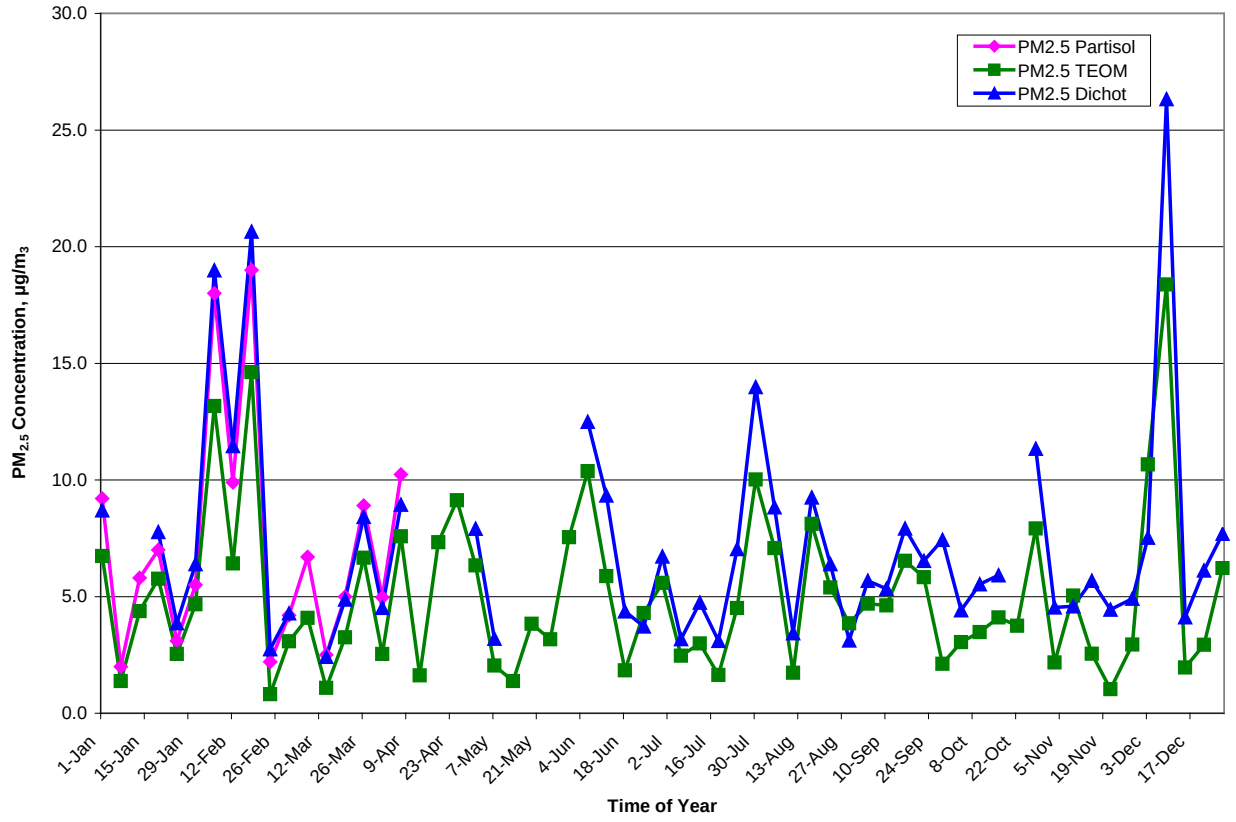
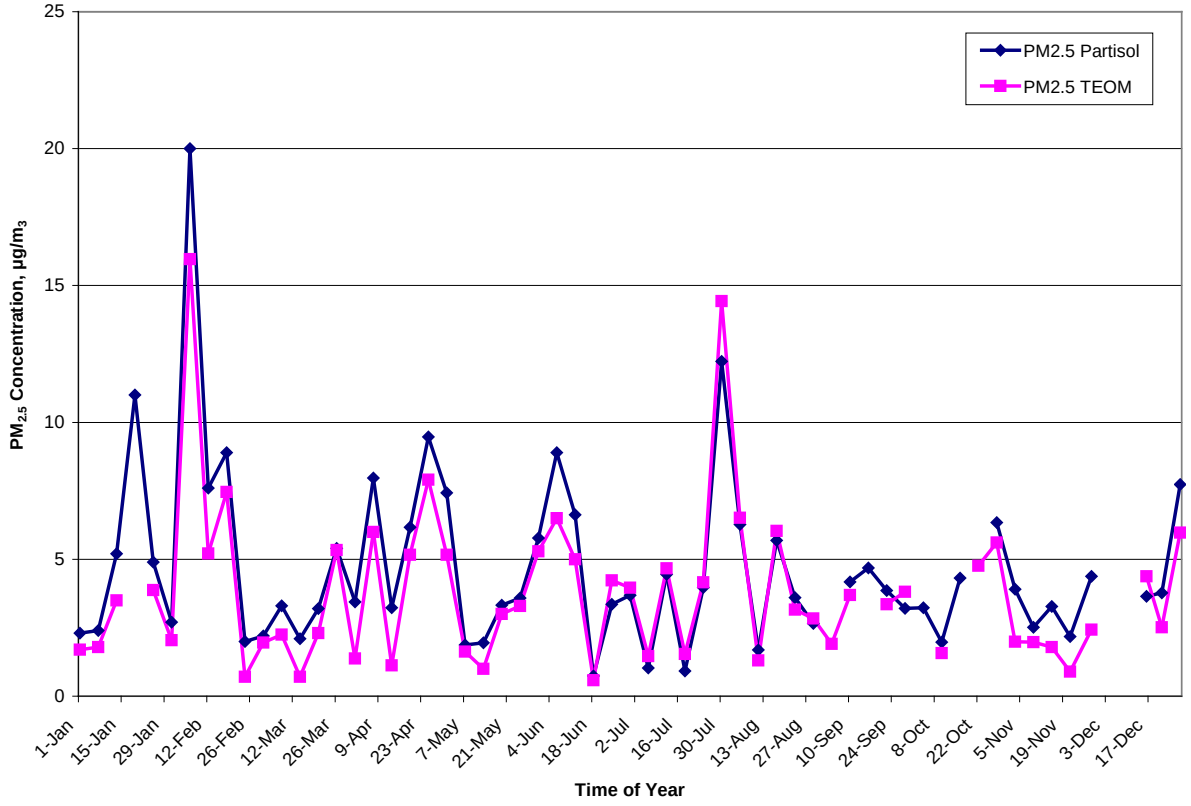


Figure 4.6 shows the comparison between Partisol and TEOM $PM_{2.5}$ concentrations measured at Langford Lakewood Elementary School. When TEOM data was available, the data indicate that the Partisol sampler and TEOM have good agreement at this station, especially during the late summer and early fall months. Neither instrument consistently measured $PM_{2.5}$ concentrations higher (or lower) than the other which is similar to what was observed in 2008. This is unlike 2007 data, which showed that the Partisol sampler consistently measured $PM_{2.5}$ concentrations higher than the TEOM.

Figure 4.6
Comparison of $PM_{2.5}$ Data at Langford



For the first time, Partisol $PM_{2.5}$ concentrations were measured at Stellys station. Figure 4.7 shows the comparison between Partisol and TEOM sampler $PM_{2.5}$ concentrations measured at Stellys station. The figure indicates that the Partisol sampler and TEOM sampler generally have good agreement at this station during the spring and summer months and poorer agreement during the cooler months. As discussed previously, TEOM samplers tend to experience sample loss during colder temperatures.

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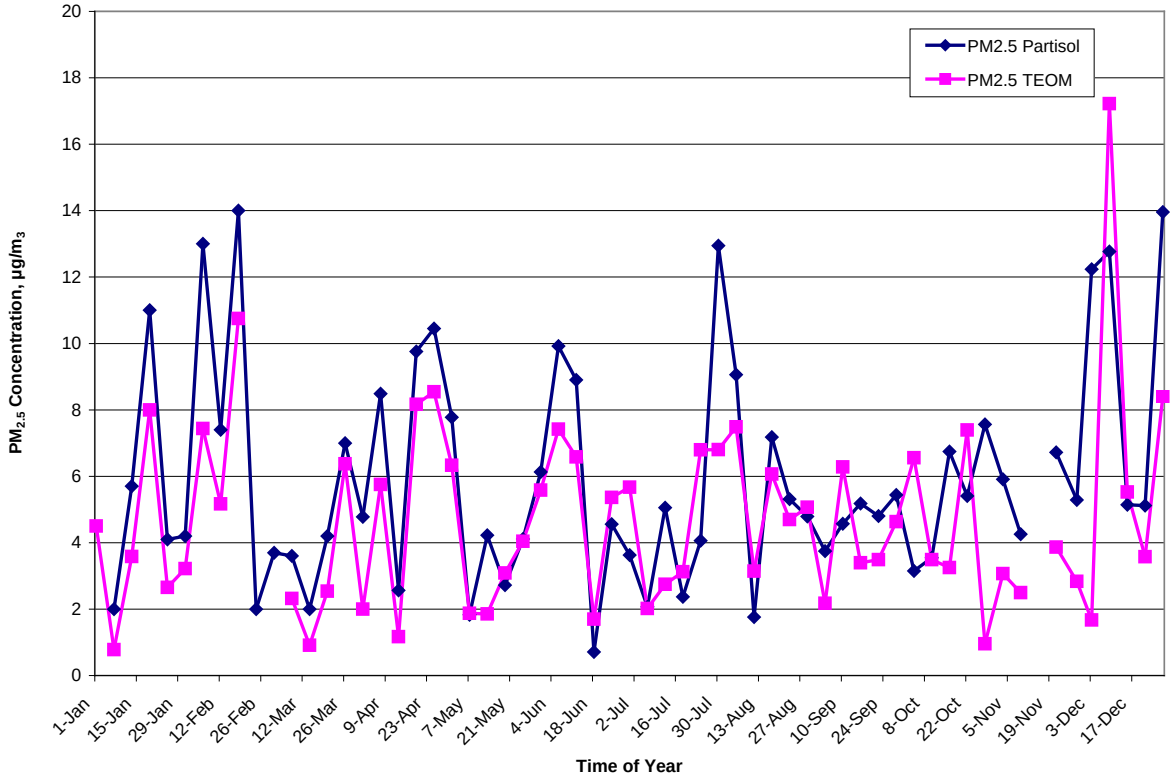
Figure 4.7
Comparison of $PM_{2.5}$ Data at Stellys



5.0 AIR QUALITY TRENDS IN THE CRD

SENES developed a statistical tool in 2006 to recognize and assess significant trends in air quality monitoring data from year-to-year in the CRD. The statistical variables this tool measures are the annual mean and 98th percentile concentration. The tool also identifies the annual number of CRD guideline exceedances.

Averaging periods suitable to the CRD guideline are used for each air contaminant. There must be at least 10 years of continuous data available for each station, for small trends to be effectively assessed. If the number of continuous years of available data is limited to less than 5 years, small trends may still be recognized, but may not be considered statistically significant. However, larger trends may be identified as significant even with a data record of less than 10 years. For the trend analyses presented in this section of the report, all available data for stations with five or more years of data were used.

Victoria Topaz, Saturna Island and now Stellys (ozone only) are the only stations that have enough continuous data for the tool to determine whether potential trends exist. Table 5.1 shows the trend analysis summary for 12 continuous years (1998-2009) at Victoria Topaz, 7 continuous years (2003-2009) at Stellys and 12 continuous years at Saturna Island; however, SO_2 data at Saturna Island is only available for the period 1998-2007.

As presented in SENES (2009)[11], the data indicate that SO_2 concentrations at Saturna Island have been steadily declining over the 1998-2007 period. The decline is detectable in both the 98th percentile and the annual average concentrations, although the decline in the mean annual concentration is lower (5% per year). While these trends are statistically significant, it should be noted that the absolute values of the SO_2 concentrations are relatively small.

The mean SO_2 concentration at the Victoria Topaz site in 2008 was much higher than expected based on the previous trend in declining SO_2 concentrations during the period 2000-2007 (a 12% decrease in the annual mean concentration and a 13% decrease in the 98th percentile). It was thought that the 2008 value could represent an outlier on an overall long term trend towards lower annual mean concentrations of SO_2. However, 2009 levels are similar to those experienced in 2008, and the trend towards decreasing SO_2 levels at Victoria Topaz is no longer present. This signals that a change in the trend may be occurring, but with only two years of higher SO_2 concentrations, it cannot be concluded that SO_2 concentrations are on the rise at Topaz.

In the absence of available SO_2 monitoring data from Saturna Island for 2008 and 2009, it is unclear whether the changes in the long-term SO_2 trends at Topaz represent a change in regional concentrations or a local effect that is limited to the Topaz station alone. In the annual air quality report for the CRD in 2008, cruise ships were identified as contributing to some of the highest

peak 1-hour average SO_2 concentrations observed at the Topaz station, and there has been a fairly large increase in cruise ship visits to the Victoria Harbour over the past decade, from a low of 26 visits in 1998 to a total of 201 visits in 2008 and 215 in 2009. While it is possible that the increase in cruise ship visits to Victoria has contributed to the reversal in the trend toward lower SO_2 concentrations at Topaz in 2008 and 2009, this cannot be conclusively determined. It is certainly true that the frequency of cruise ship visits to the Victoria Harbour increased from 1998 to 2007 at a time when overall SO_2 concentrations were decreasing. Therefore, it is possible that some other emission sources are responsible for the reversal in the trend line after 2007.

In addition, there has been a weaker trend to lower CO concentrations at the 98th percentile level at Victoria Topaz. There is also a slight decreasing trend to lower mean annual $PM_{2.5}$ and PM_{10} concentrations at Topaz. No other trends were found for NO_2 or O_3 data at Topaz. In contrast to 2008, there is no longer a trend toward an increase in the frequency of exceedances of the CRD ozone guideline.

Table 5.1
Summary of Trend Analysis for Victoria Topaz, Saturna Island and Stellys

Measure	CO	NO_2	SO_2	O_3	$PM_{2.5}$	PM_{10}
	Victoria Topaz (1998-2009)					
Annual mean	No Trend	No Trend	No Trend	No Trend	-2%/yr	-4%/yr
Annual 98th Percentile	-4%/yr	No Trend	No Trend	No Trend	No Trend	No Trend
	Stellys (2003-2009)					
Annual mean	--	--	--	3%	--	--
Annual 98th Percentile	--	--	--	No Trend	--	--
	Saturna Island (1998-2009)[1]					
Annual mean	--	--	-5%/yr	No Trend	--	--
Annual 98th Percentile	--	--	-12%/yr	No Trend	--	--
% Over CRD Guideline	--	--	--	No Trend	--	--

Notes:
1. Data for SO_2 at Saturna Island only available for the period 1998-2007
"--" denotes no data or not enough data for trend analysis.
A minimum of four years of continuous data with >80% data recovery is required to complete a trend analysis.
"No trend" indicates that no statistically significant trend can be detected at the 5% significance level.

For the first time, enough data was available to complete a trend analysis for ozone at Stellys station. There is a weak increasing trend in annual mean O_3 concentrations; however, no trend is detectable at the 98th percentile concentration. The increasing trend is consistent with Figure 3.11 which suggests that the 4th highest 8-hour rolling average ozone concentration has been approaching the CWS since 2003. Because the trend analysis tool was not specifically designed to track the trends in 4th highest 8-hour average ozone concentrations, no statistical

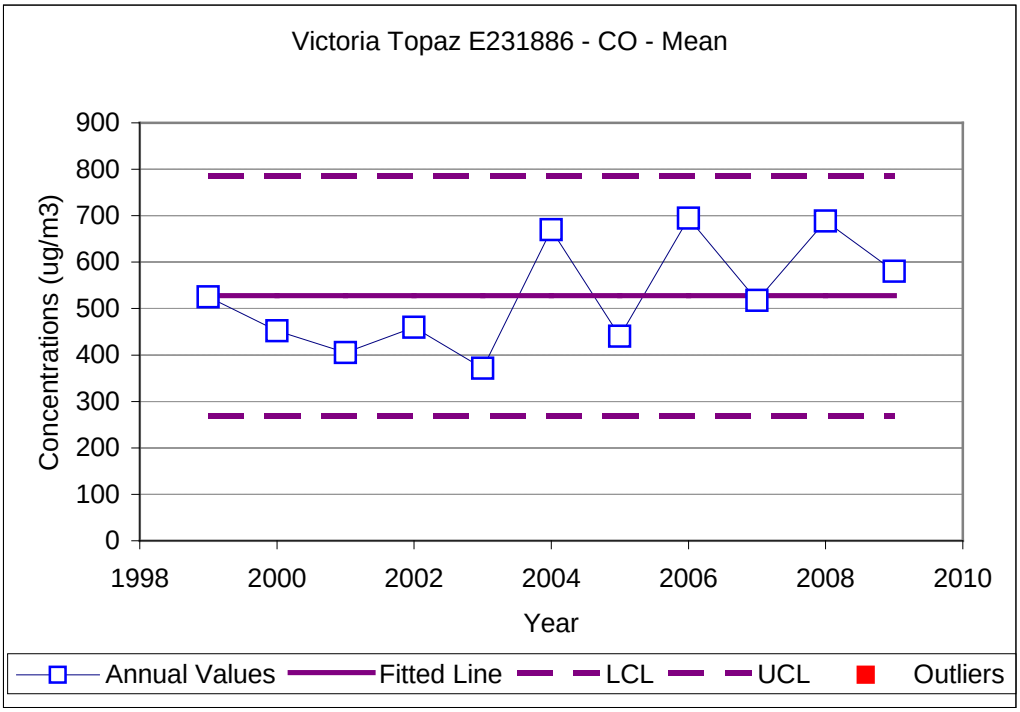
measure is provided of the trend in this parameter at the Stellys station. However, visual inspection of Figure 3.11 clearly indicates that the ozone levels have been steadily increasing over the period of record from 2003 to 2009. The discontinuance of all sampling at Stellys as of March 31, 2010 will preclude any possibility of determining whether or not this trend will continue into the future.

Figures 5.1 to 5.9 show the annual mean and 98th percentile concentration trends for each air contaminant for the period of record at Victoria Topaz, Stellys and Saturna Island. There was insufficient data to perform a trend analysis for Langford. Neither 2008 nor 2009 data for SO_2 were available for Saturna Island in time for the trend analysis so the analysis is the same as that presented in SENES (2009)[11].

Note that the mean concentration, not including the outliers identified during the regression trend analysis, is calculated as the standard deviation of the concentrations. Upper and lower limits (UCL and LCL) are calculated based on the observed mean, standard deviation and appropriate t-statistic for the selected confidence level. Outliers or unusual values are assessed if the annual value is outside the confidence limits. Further discussion of the methodology used for trend analysis is provided in SENES (2006)[17].

[17] SENES Consultants Limited 2006. Method to Assess Presence of Annual Trend or Unusual Values in Air Quality Data. Prepared for the Capital Regional District, Environmental Services Department, Victoria, BC. http://www.crd.bc.ca/airquality/documents/trend_method.pdf

Figure 5.1
CO Trend at Victoria Topaz



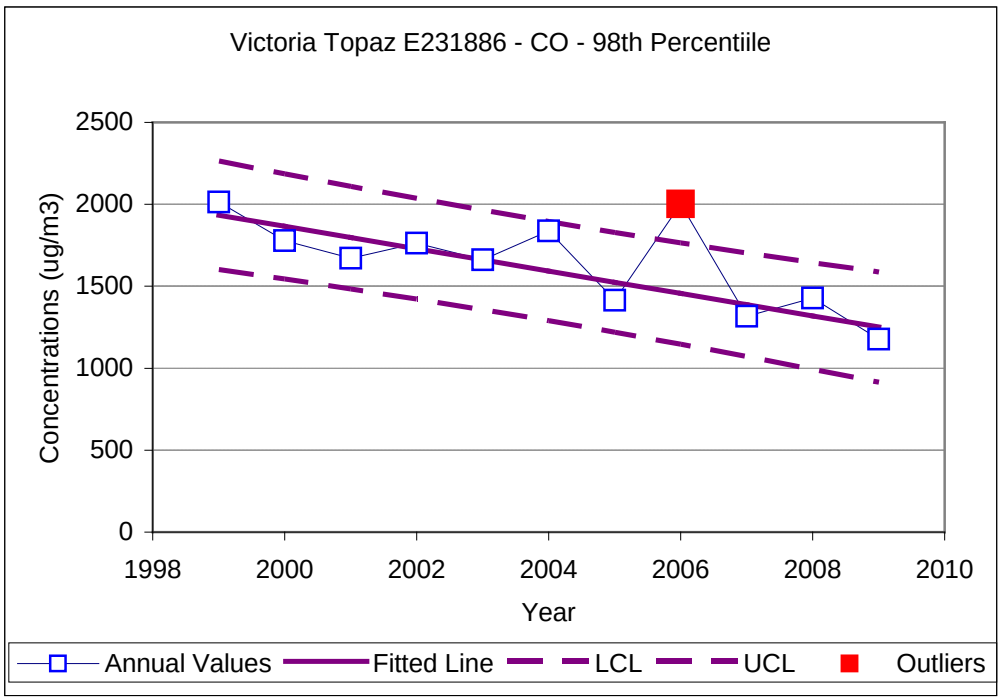
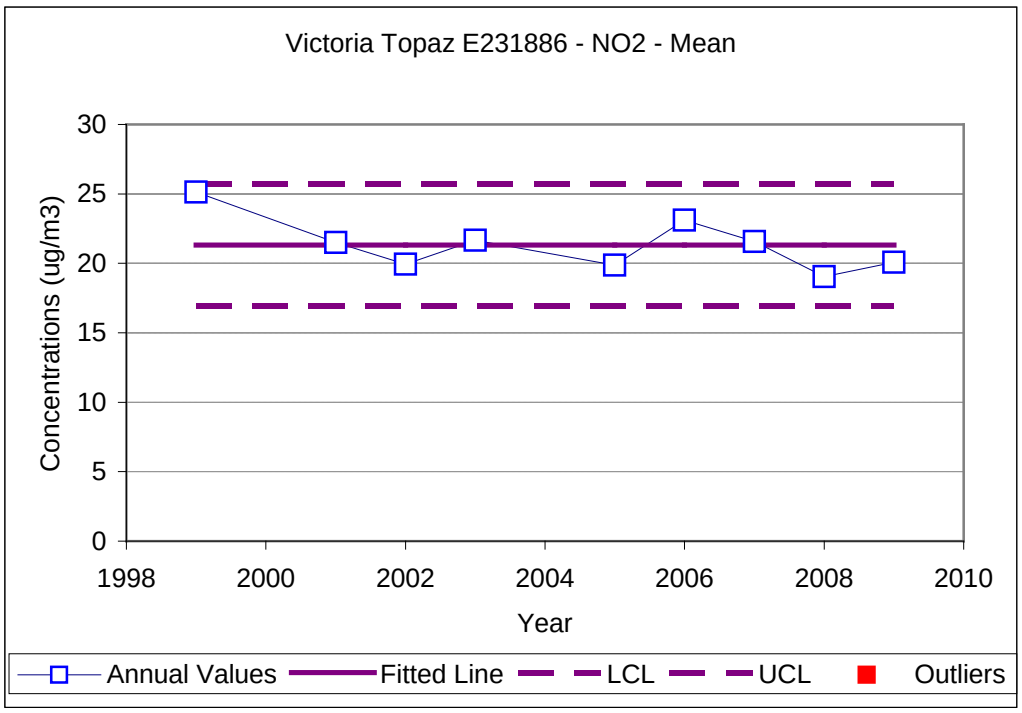


Figure 5.2
NO_2 Trend at Victoria Topaz



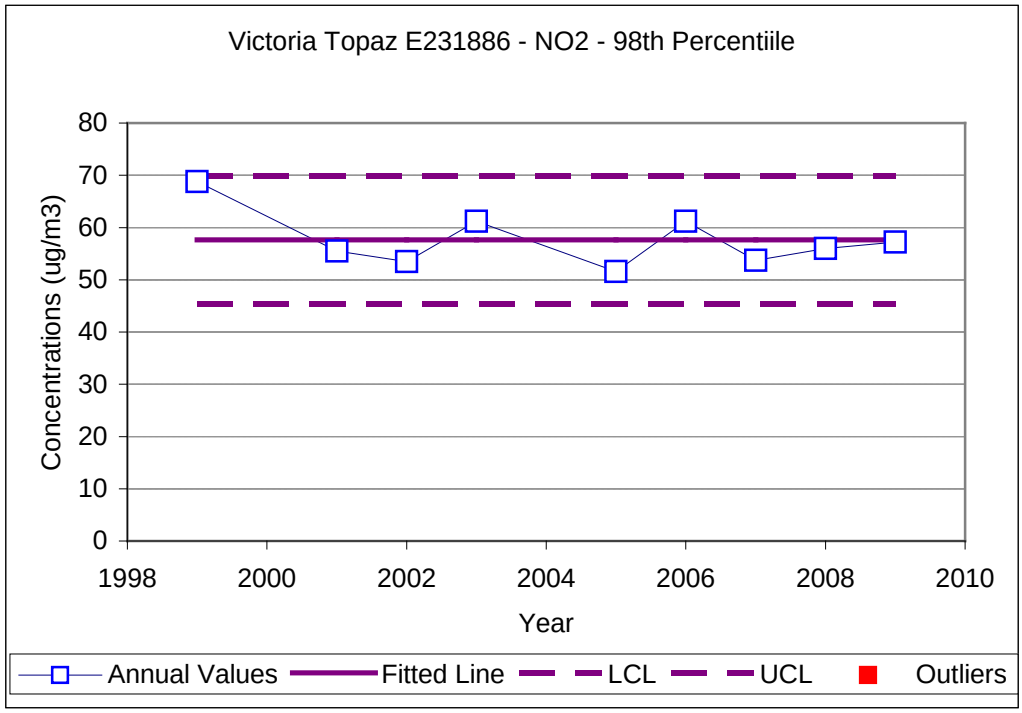
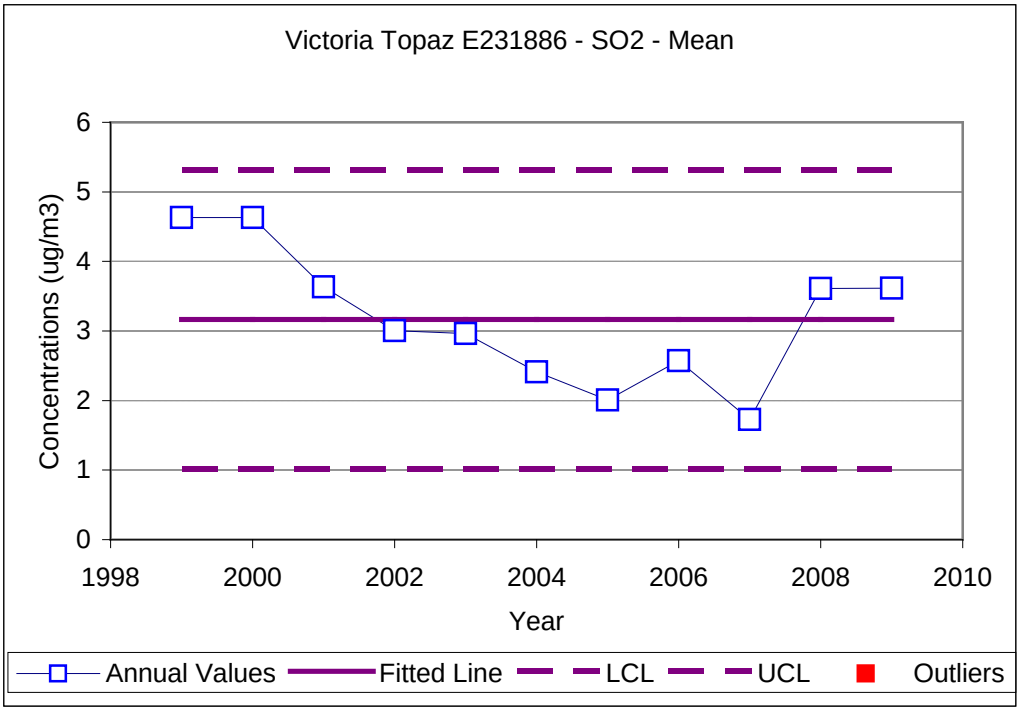


Figure 5.3
SO_2 Trend at Victoria Topaz



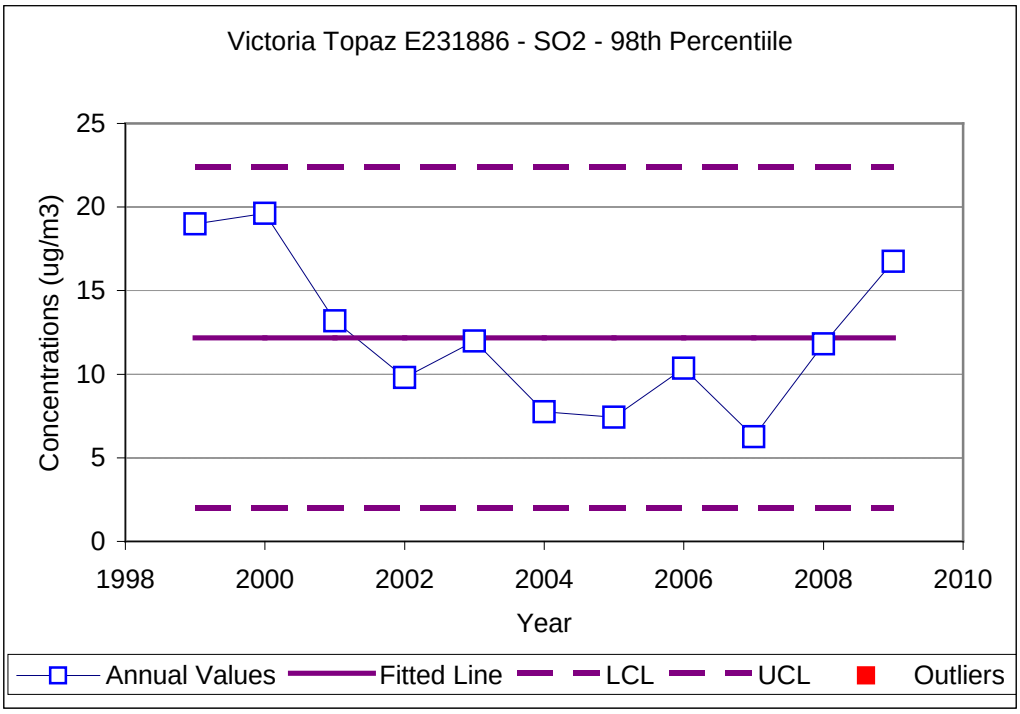
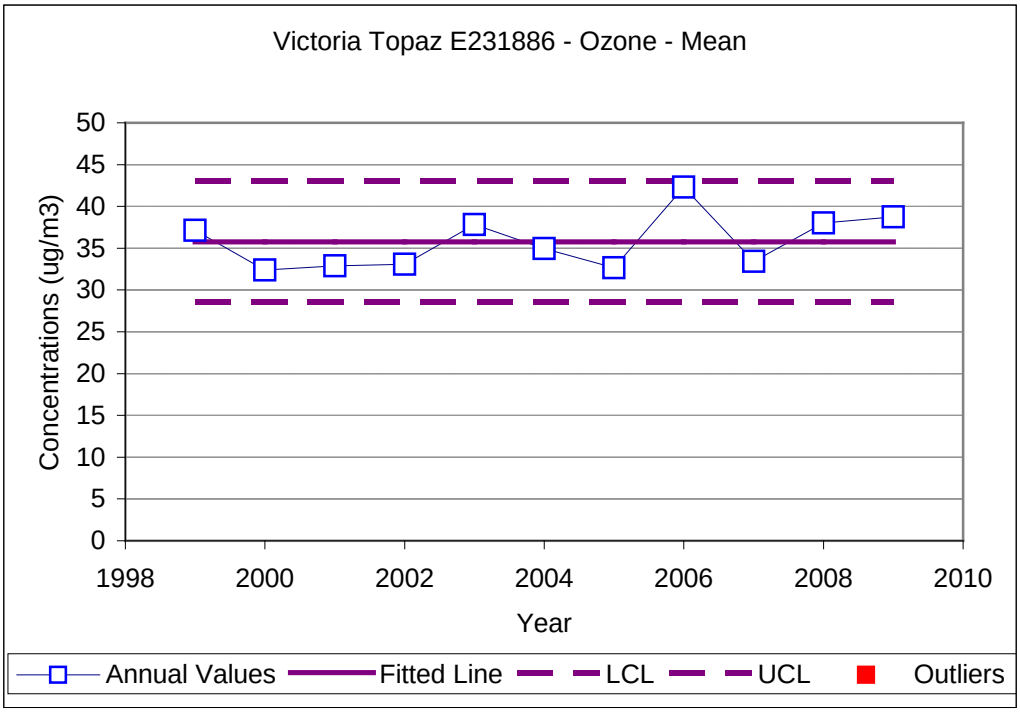


Figure 5.4
O_3 Trend at Victoria Topaz



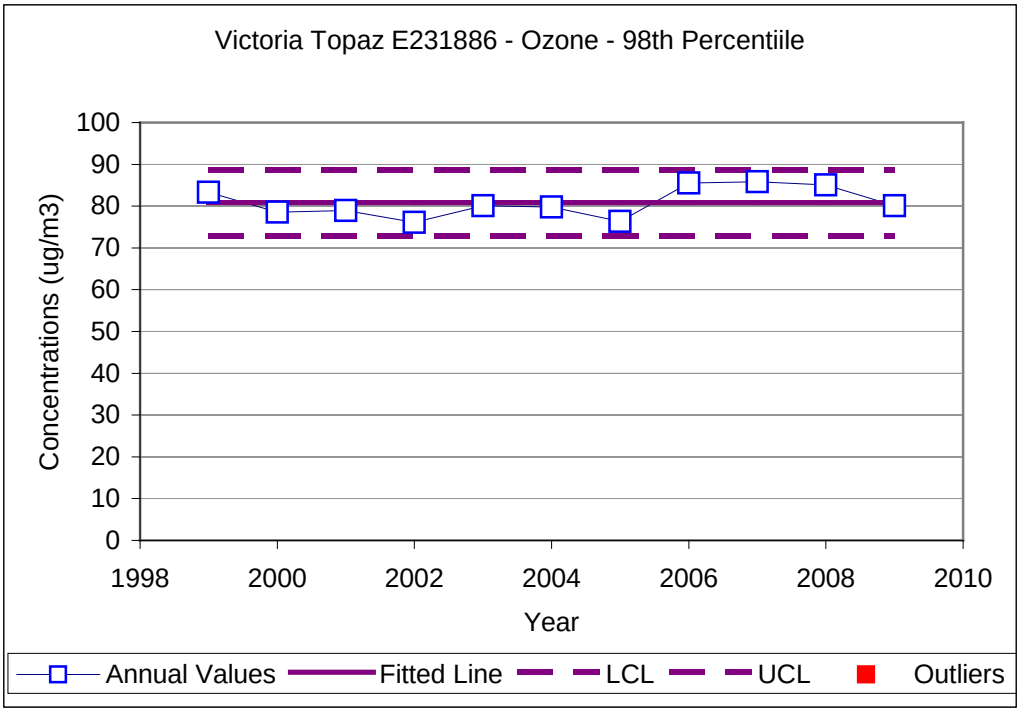
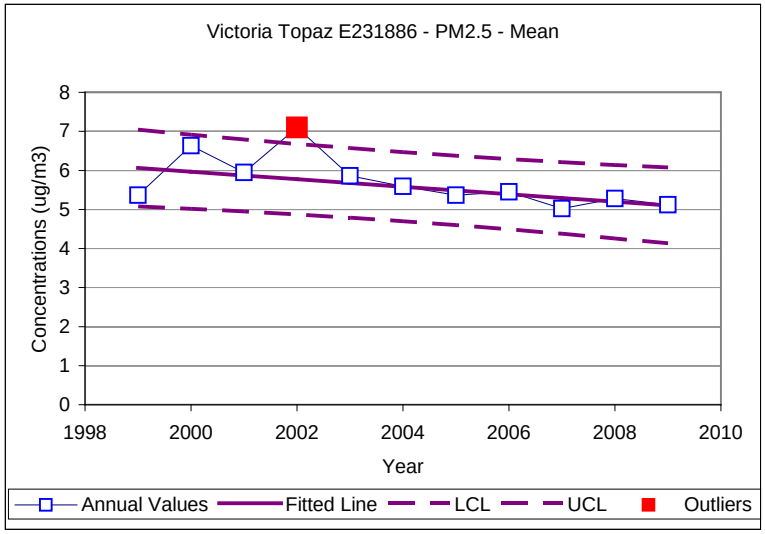
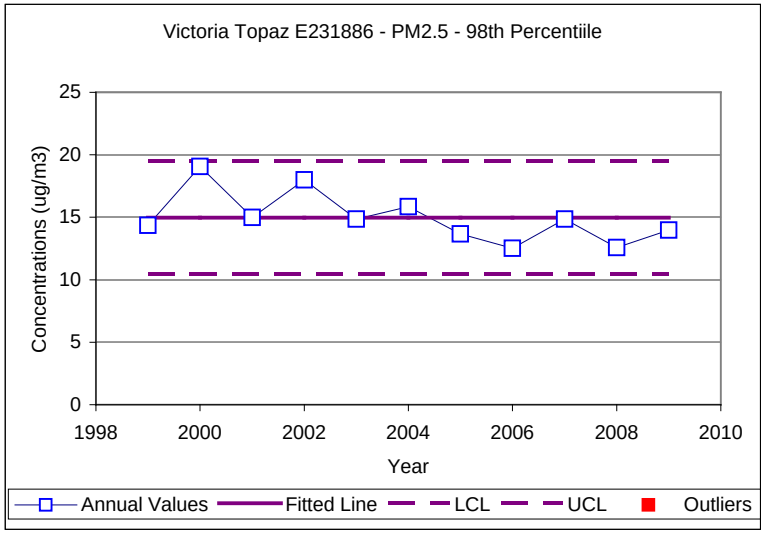


Figure 5.5
$PM_{2.5}$ Trend at Victoria Topaz





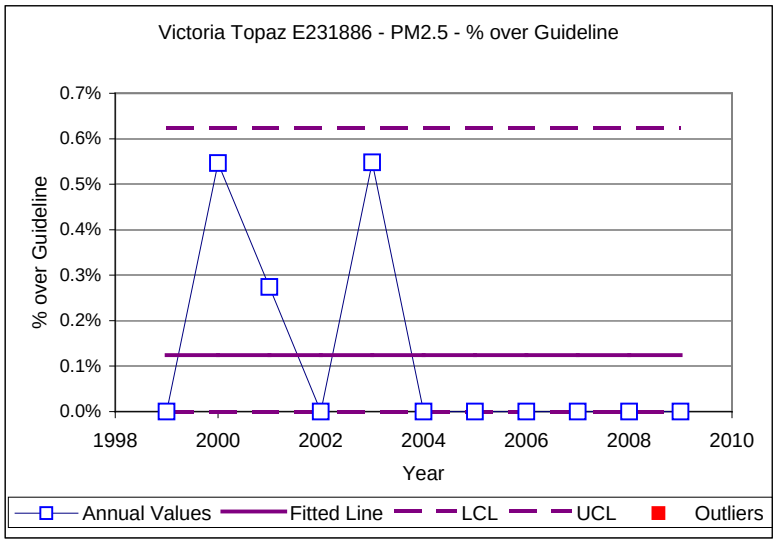
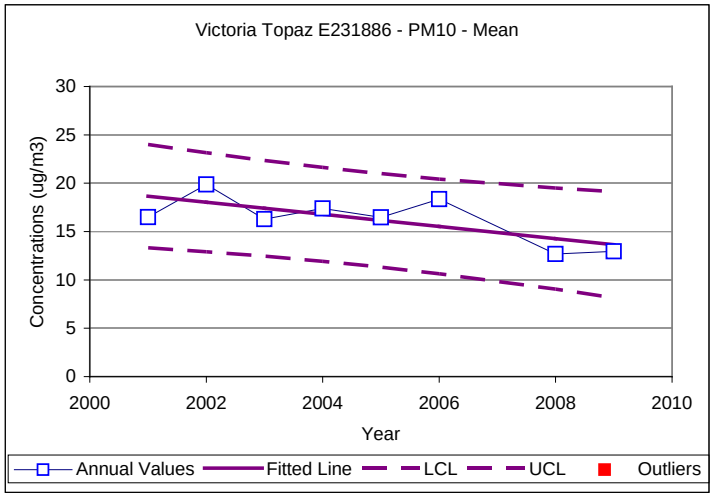
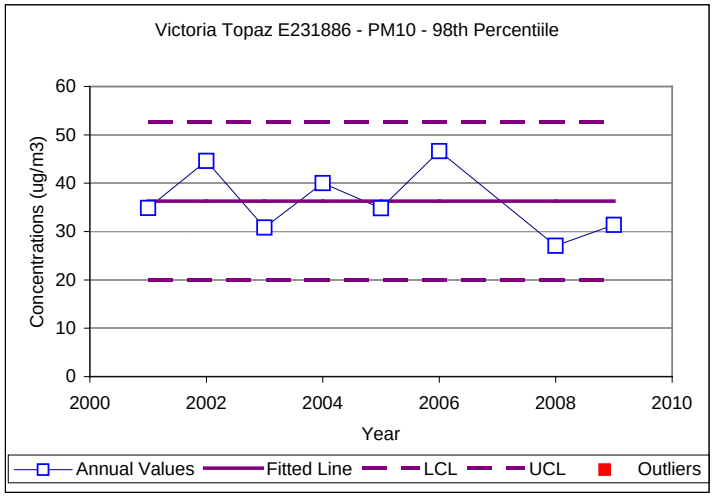


Figure 5.6
PM_{10} Trend at Victoria Topaz





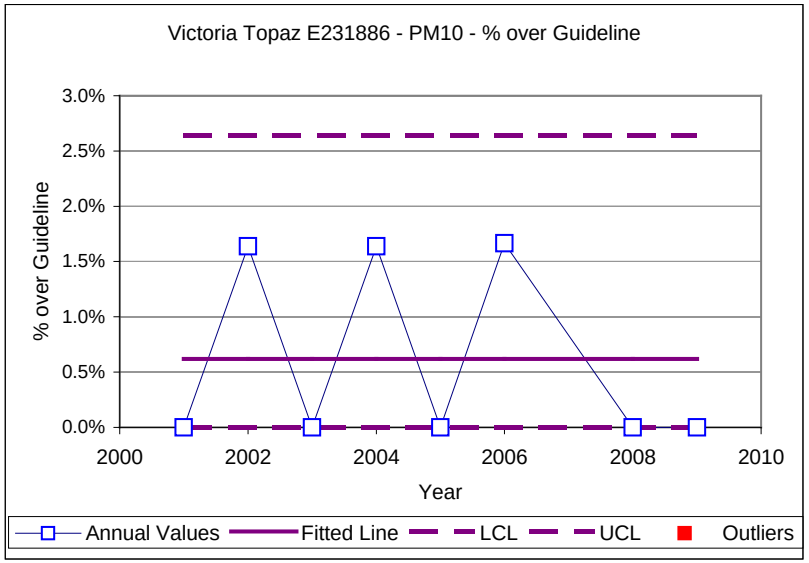
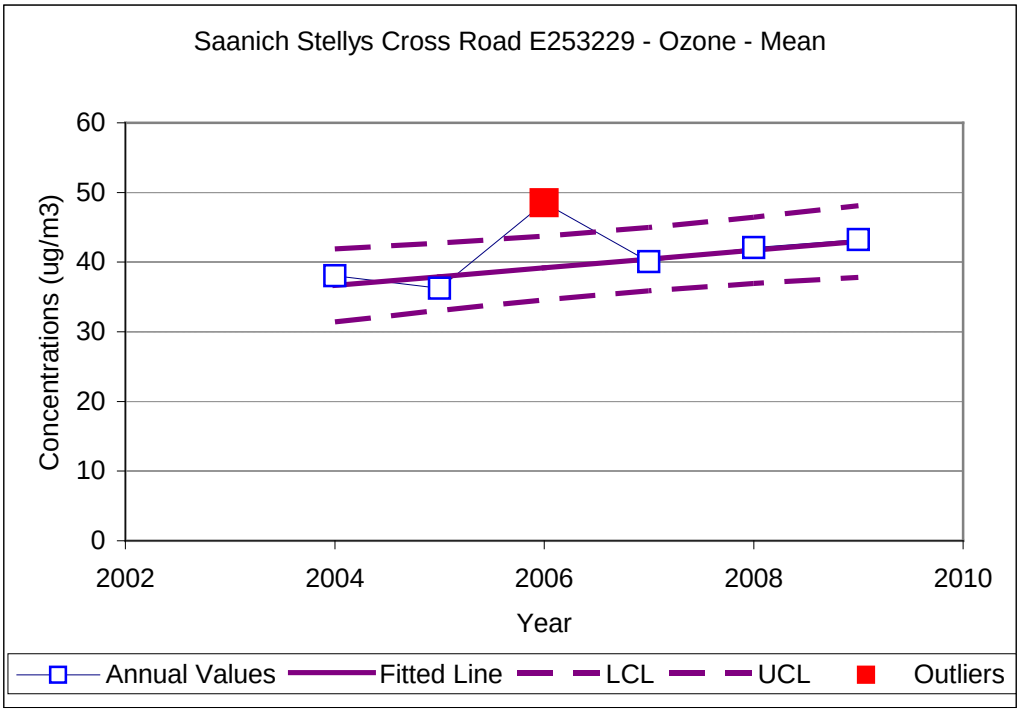


Figure 5.7
O_3 Trend at Stellys



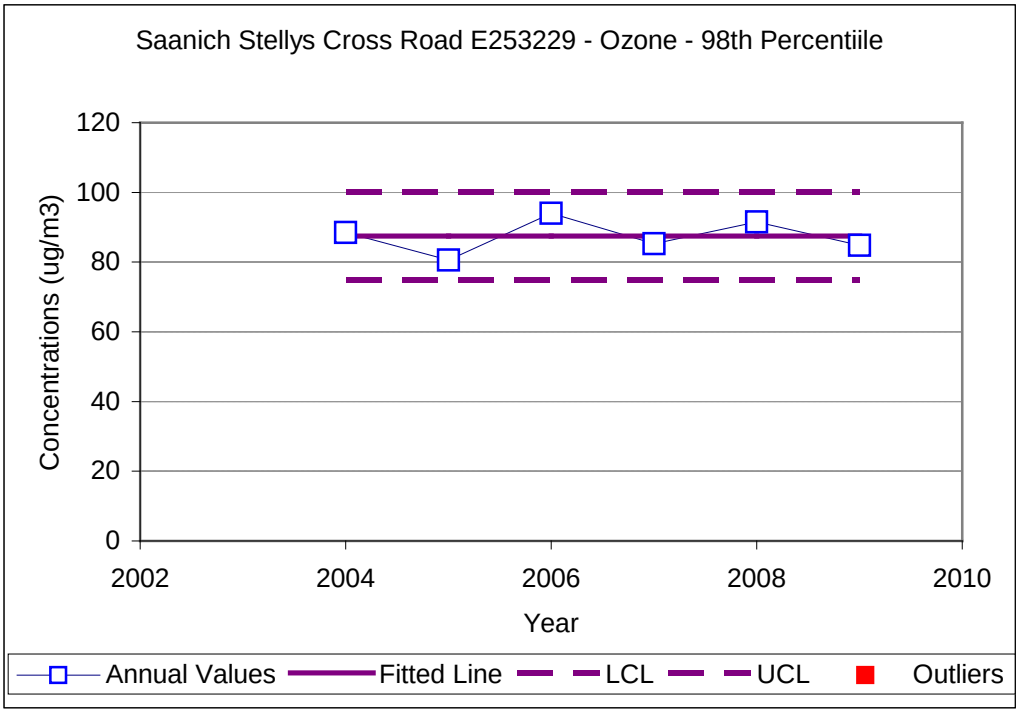


Figure 5.8
O_3 Trend at Saturna Island

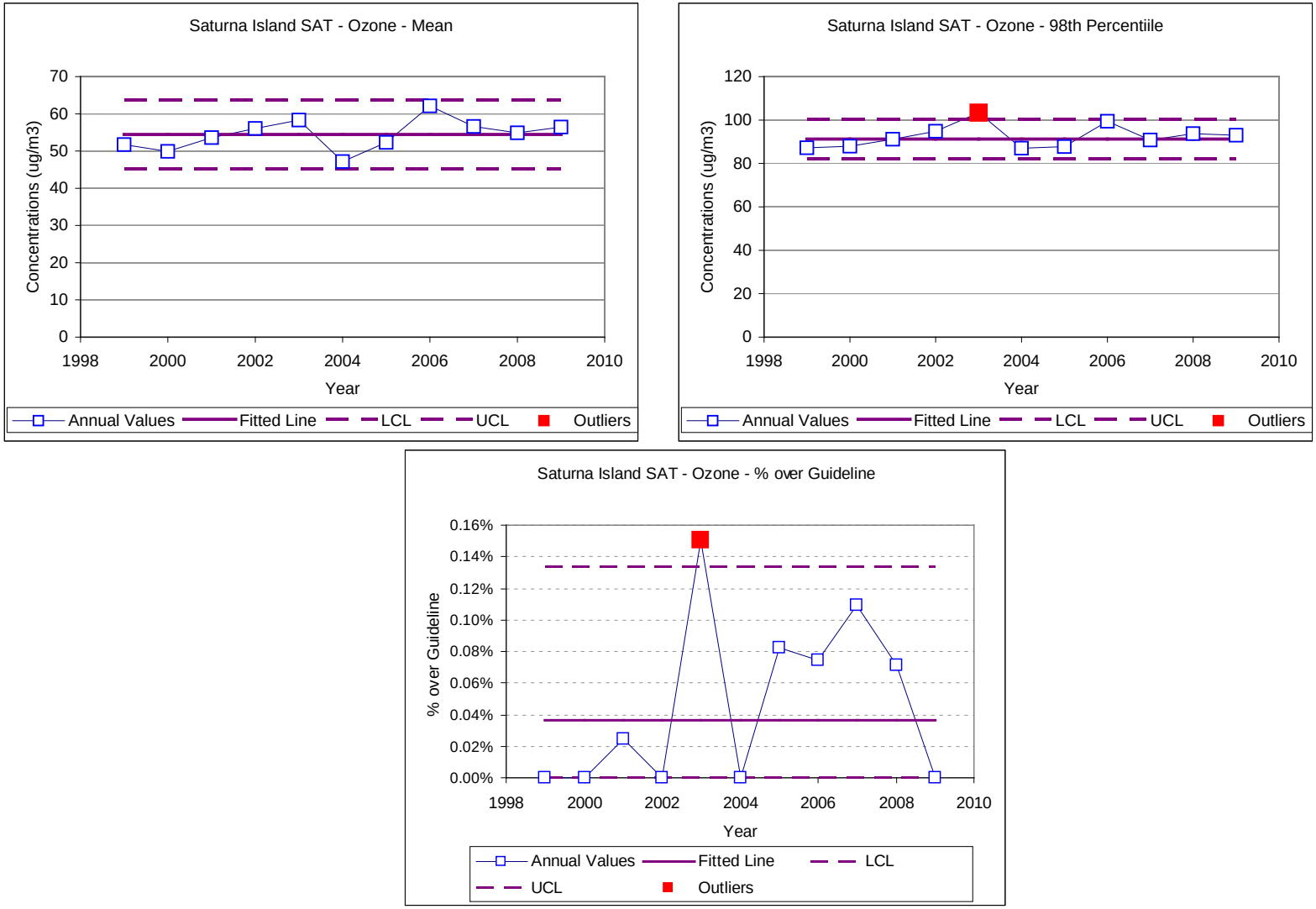
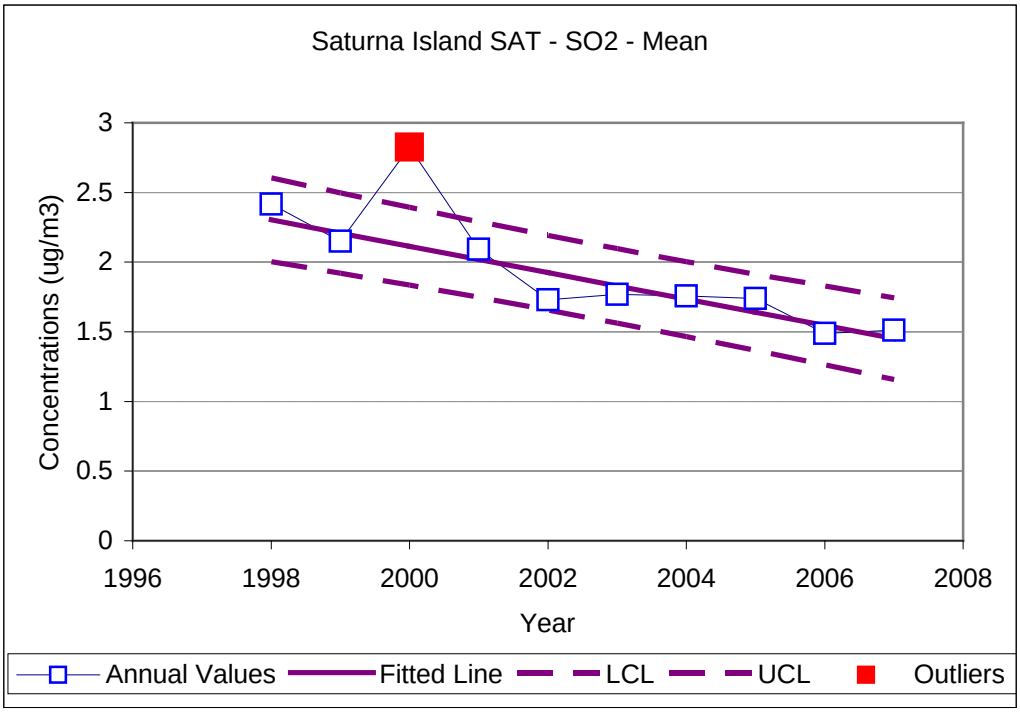
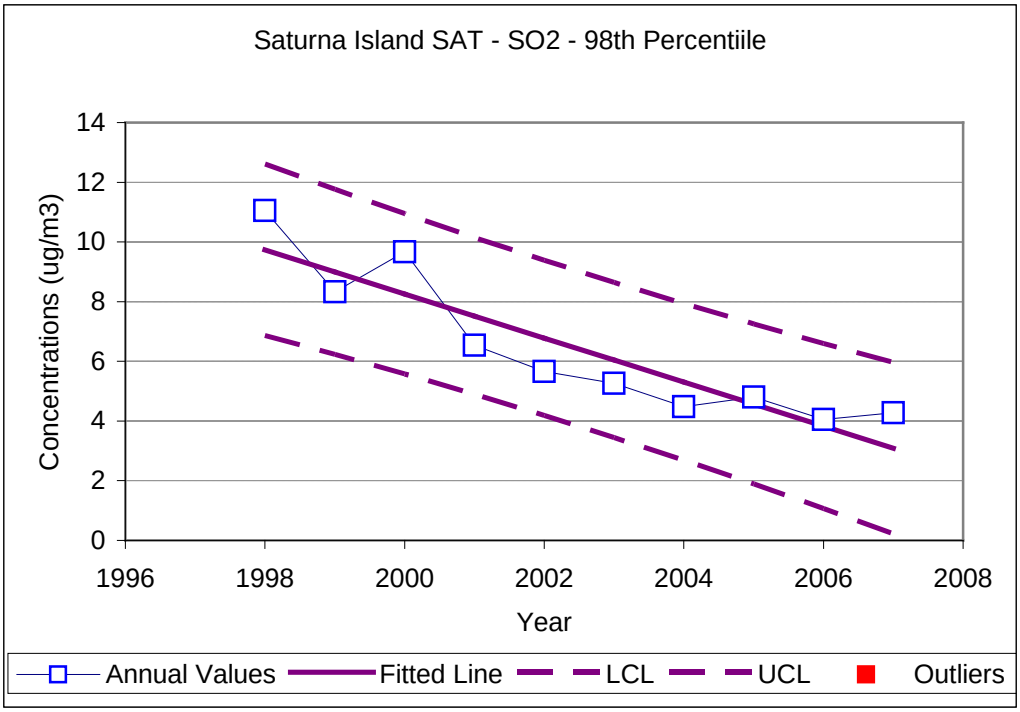


Figure 5.9
SO_2 Trend at Saturna Island





6.0 SUMMARY OF MAML MONITORING RESULTS

The complete results of the data analysis for the MAML monitoring program in 2009 are provided in the report by Poplawski and Setton (2010) prepared for VIHA and the Ministry of the Environment. The following provides a brief summary of those results extracted from the report.

Table 6.1 indicates that 10-minute average SO_2 concentrations were generally below the World Health Organization (WHO) guideline value of 500 µg/m^3 most of the time. However, peak concentrations reached 599.4 µg/m^3, and exceeded the WHO guideline value on 3 occasions.

Table 6.1
MAML 10-minute Average SO_2 Concentrations

Percentile	10-minute Average Concentration (µg/m^3)
90th	10.6
95th	39.4
96th	68.9
97th	105.9
98th	170.9
99th	264.3
100th	599.4

Table 6.2 lists the 1-hour average concentrations of NO_2, SO_2, PM_{10} and $PM_{2.5}$ recorded at the MAML site in 2009. The data indicate that the SO_2 concentrations exceeded the recently proposed level of 200 µg/m^3 (99th percentile, averaged over 3 consecutive years) as a new primary National Ambient Air Quality Standard (NAAQS) by the U.S. Environmental Protection Agency. The frequency of exceedance at the MAML site was about 1.5% of the time. In fact, the peak SO_2 concentration was more than double the numerical value of the proposed standard, and fell just short of the B.C. Level A and Federal Maximum Desirable objectives of 450 µg/m^3.

Table 6.3 lists the 24-hour average concentrations of contaminants measured at the MAML site in 2009. The data indicate that the WHO SO_2 guideline of 20 µg/m^3 was exceeded 16 percent of the time during the monitoring period. In fact, peak concentrations were over six times the WHO guideline value. The data analysis report also noted that the WHO guideline was exceeded on 3 occasions at the Topaz site during the same period.

Table 6.2
MAML 1-hour Average Concentrations

Percentiles	1-hour Average Concentrations (µg/m^3)			
	NO_2	SO_2	PM_{10}	$PM_{2.5}$
5th	2.4	0.2	3.0	2.0
25th	7.1	1.1	7.0	5.0
50th	13.4	2.7	10.0	7.0
75th	22.6	5.1	14.0	9.9
90th	34.4	14.3	19.0	14.0
95th	42.5	48.9	23.0	16.0
96th	46.1	80.6	25.0	16.0
97th	49.4	113.7	26.0	17.0
98th	55.5	164.6	28.0	18.0
99th	63.0	247.6	32.0	20.0
100th	78.5	447.8	61.0	32.0

Table 6.3
MAML 24-hour Average Concentrations

Percentiles	1-hour Average Concentrations (µg/m^3)			
	NO_2	SO_2	PM_{10}	$PM_{2.5}$
5th	5.9	1.2	4.6	3.1
25th	10.9	2.6	7.5	4.7
50th	15.9	3.9	10.0	6.9
75th	21.9	9.4	13.0	9.0
80th	24.1	14.0	14.0	9.8
84th	25.1	17.7	15.1	10.7
85th	25.5	22.0	15.3	11.0
90th	26.9	34.5	17.9	12.9
95th	28.8	55.4	20.6	14.9
98th	31.9	79.7	24.7	16.5
99th	33.5	102.7	25.5	16.6
100th	40.0	122.0	26.6	16.7

The analysis of the MAML data extended the analysis of cruise ship emission impacts on air quality in the CRD that was presented in the 2008 CRD annual air quality report. The MAML analysis indicated that NO, NO_2 and SO_2 concentrations at both the MAML and Topaz sites were always higher during periods when cruise ships were in port than periods when cruise ships were not in port, confirming the results presented for 2008.

Based on the results of the MAML monitoring program, as well as on the previous JBAQS monitoring and modelling studies and the analysis of cruise ship emission impacts at the Topaz site presented in the CRD 2008 annual air quality report, VIHA[18] concluded that cruise ship emissions in Victoria Harbour contribute to elevated levels of SO_2 in the CRD. From time-to-time, these levels exceed international standards or guidelines, and may have short-term negative health impacts in some individuals, particularly in those who already have chronic respiratory conditions. On occasion, these impacts may affect the quality of life and well-being of some residents in the CRD, and there is a statistical possibility that, in a worst-case scenario, the elevated levels of SO_2 could lead to mortality over the course of a year in those individuals whose disease is not properly managed.

[18] Vancouver Island Health Authority (VIHA) 2010. *Health Review and Response to James Bay Phase III Air Quality Monitoring*. Provided by R. Stanwick, Chief Medical Officer, VIHA, with Consultation from T. Kosatsky, Medical Director, Environmental Health Services, B.C. Centres for Disease Control, Scientific Director, National Collaborating Centre for Environmental Health, and Clinical Associate Professor, School of Population and Public Health, University of British Columbia.

7.0 CONCLUSION

A summary of comparisons of maximum pollutant concentrations in 2009 to the CRD guidelines and CWS levels are provided in Table 6.1. In general terms, air quality in the CRD was good and far below any applicable guidelines or objectives for most of the time during 2009. There was one exceedance of the $PM_{2.5}$ guideline based on the continuous TEOM sampler at Stellys, and one exceedance of the $PM_{2.5}$ guideline based on the sequential Dichot sampler at Topaz on a different day. There was also one exceedance of the ozone guideline value at Stellys station. In all cases, the level of exposure to the elevated concentrations was determined to be quite small for the CRD as a whole because the exceedances were localised in the vicinity of a single monitoring location in each case. There were no exceedances of the CRD guidelines for any other common air contaminants.

Table 7.1
Summary of Maximum Pollutant Concentrations (µg/m³) in the CRD for 2009

		Air Quality Criteria		**Monitoring Station**						
Contaminant	Averaging Period	CWS	CRD Guideline	Victoria Topaz		Stellys		Langford		Saturna Island
CO	8-hour*		5500	1966		--		--		
NO_2	1-hour*		200	100		54		73		
SO_2	24-hour*		125	30				5		N/A
O_3	8-hour**		120	100		**122**		116		115
PM_{10}	24-hour*		50	34 Dichot						
$PM_{2.5}$	24-hour*		25	18 TEOM	**26** Dichot	**30** TEOM	14 Part	16 TEOM	20 Part	
		Canada Wide Standards								
Ozone	8-hour**	127.6 [1]		102		109				124
$PM_{2.5}$	24-hour*	30 [2]		14				10		

Notes:
* Sequential averaging periods used.
** Rolling average periods used.
[1] Achievement by 2010, based on the annual 4th highest daily measurement, averaged over 3 consecutive years.
[2] Achievement by 2010, based on the 98th percentile ambient measurement annually, averaged over 3 consecutive years.
'"--" denotes that more than 90% of data is missing
TEOM - continuous sampling using Tapered Element Oscillating Microbalance samplers
Dichot – sequential Dichotomous sampler
Part – sequential Partisol sampler
N/A – not yet available
Values in **red** indicate that the CRD Guideline or CWS has been exceeded.

Data collection rates were quite good for the year, with two exceptions. Less than 10% of the data was missing overall with the exception of SO_2 at Langford station - approximately 12% of the SO_2 data was missing. Overall, the amount of missing data in 2009 was much less than in previous years for all active stations.

An exceedance of the $PM_{2.5}$ guideline of 25 µg/m^3 occurred once at the Stellys monitoring station on November 1st, with a 24-hour average concentration of 29.9 µg/m^3 based on the TEOM sampler. An exceedance of the guideline also occurred once at Topaz monitoring station on December 9th, with a 24-hour average of 26.3 µg/m^3 based on the Dichot sampler only. Concentrations recorded at each of the other $PM_{2.5}$ monitoring stations in the CRD during both incidences were much lower, indicating that the higher $PM_{2.5}$ concentration observed at Stellys and Topaz was not experienced throughout the CRD. Due to the limited temporal and spatial extent of exposure to the $PM_{2.5}$ exceedance, related health effects for community members could not be determined with confidence.

For the first time since monitoring began in 2003, there was an exceedance of the CRD ozone guidelines at the Stellys monitoring station on July 29th, with an 8-hour rolling average concentration of 1224 µg/m^3. Elevated ozone levels were also observed at Langford and Saturna Island stations, but not at Topaz. The Ministry of the Environment issued an Air Quality Advisory for this episode in the expectation that ozone levels would exceed the Provincial objective level of 160 µg/m^3 on the afternoon of July 29th, although high ozone concentrations quickly dropped off during the evening hours at Stellys and throughout the CRD.

With respect to long-term trends in air quality in the CRD:

- SO_2 concentrations at the Victoria Topaz site are low and were declining at a rate of about 12% per year over the period 1998-2008, and at about 9% per year in terms of the peak (98th percentile) concentration. However, the mean SO_2 concentration in both 2008 and 2009 were higher, resulting in the disappearance of the decreasing trend. This may represent an early indication of a change in the trend.

- A decline in SO_2 concentrations at the mean annual and 98th percentile levels has also occurred at Saturna Island (5% and 12% per year, respectively) over the period 2000-2007. SO_2 data for Saturna Island in 2008 and 2009 were not yet available to be included in this report.

- Weak trends toward lower CO, $PM_{2.5}$ and PM_{10} concentrations at Victoria Topaz are present. Both CO and PM_{10} have been declining at a rate of about 4% per year, and $PM_{2.5}$ at a rate of 2% per year. O_3 concentrations at Stellys have been increasing a rate of 3% per year and appear to be approaching the CRD guideline.

- In 2008, the Saturna Island O_3 trend analysis suggested that the frequency of CRD guideline exceedances was increasing. 2009 ozone levels were comparatively lower than 2007 and 2008 values and no significant trend is apparent in the 2009 trend analysis. Therefore, it is not expected that the Canada Wide Standard (CWS) standard will be exceeded in 2010 so long as ozone levels remain comparable to 2009.

No other statistically significant trends were identified for any of the other pollutants in the monitoring network. Because the trend analysis tool was not specifically designed to do so, the increasing trend in the 4th highest 8-hour average ozone concentrations could not be quantified, although visual inspection of the changes in concentrations clearly indicates that this measure of ozone concentrations has been increasing at this location.

At this time, there is no indication that the Canada Wide Standards (CWS) for respirable particulate matter ($PM_{2.5}$) will be exceeded at the implementation date (2010). Since ozone concentrations were high in both 2007 and 2008 at Saturna Island, it was expected that the ozone CWS would be exceeded in 2009. However, ozone levels were comparatively lower in 2009 and there is no longer a trend towards an increase in the frequency of ozone exceedances at Saturna Island. As a result, it is not anticipated that the CWS for ozone will be exceeded at the implementation date so long as 2010 ozone values remain similar to 2009 levels. However, with the end of all monitoring at the Stellys site as of March 31, 2010, it will not be possible to determine whether the ozone levels at this location would have remained in attainment of the CWS if the trend to higher values observed over the period 2003-2009 were to continue into the future.

The MAML sampling in support of the JBAQS was specifically established to determine the effects of cruise ship emissions on the James Bay community. The sampling results for 2009 indicated that NO, NO_2 and SO_2 levels were always highest at both the MAML and Topaz monitoring locations during periods when cruise ships were in port, as compared with periods when cruise ships were not in port. Although no existing Provincial air quality objectives or CRD guidelines were exceeded at these locations during the monitoring period, the recently proposed level for a new 1-hour average SO_2 primary air quality standard in the United States was exceeded approximately 1.5% of the time at the MAML site. In addition, the WHO guideline value for 24-hour average SO_2 concentrations was exceeded 16% of the time at the MAML location and 3.5% of the time at the Topaz site. The WHO guideline value for 10-minute average SO_2 concentrations (meant to provide protection against acute exposure to peak SO_2 concentrations), was also exceeded on three occasions during the MAML monitoring period. On the basis of the MAML monitoring results and other studies of the impact of cruise ship emissions in the Victoria Harbour, VIHA has concluded that the increased levels of SO_2 attributable to cruise ship may have short-term negative health impacts in some individuals, particularly in those who already have chronic respiratory conditions. On occasion, these

impacts may affect the quality of life and well-being of some residents in the CRD, and there is a statistical possibility that, in a worst-case scenario, the elevated levels of SO_2 could lead to mortality over the course of a year in those individuals whose disease is not properly managed.

Meteorological data were available from five monitoring stations in the CRD. These stations are co-located with the air quality monitoring stations, with the exception of the Victoria Airport station. Wind speed and direction data were summarised for each station as wind rose diagrams in Appendix A. In addition, a climate comparison was completed using data from the Environment Canada station at the Victoria Airport.

Appendix A: Meteorological Data

Table A.1 2009 Monthly Climate Data for Victoria International Airport[a]

Month	Mean Max Temp	Mean Temp	Mean Min Temp	Extreme Max Temp	Extreme Min Temp	Total Rainfall	Total Snow	Total Precip
	°C	°C	°C	°C	°C	mm	cm	mm
Jan	6.5	3.4	0.2	12.1	-5.9	74.5	3	77.5
Feb	8	4	0	11.2	-3	32.5	1	33.5
Mar	8.8	4.8	0.7	13.1	-4.4	52	2.2	54.2
Apr	13.5	8.5	3.5	18.4	-1.4	40	0	40
May	17.1	11.9	6.6	23.4	2.5	56	0	56
Jun	22	16.3	10.5	31.3	6.6	6	0	6
Jul	24.7	18.5	12.1	35	7.2	11.1	0	11.1
Aug	22	16.6	11.3	28.9	8.4	16.8	0	16.8
Sep	20	14.8	9.5	26.7	4	51.2	0	51.2
Oct	14.3	9.9	5.5	20.6	-1.9	132.2	0	132.2
Nov	9.9	7	4.1	12.8	-1.6	274.6	0	274.6
Dec								
Sum						**M**	**M**	**M**

M = Missing

Table A.2 Climate Normals (1971-2000) for Victoria International Airport[a]

Month	Mean Temp	Mean Max Temp	Mean Min Temp	Extreme Max Temp	Extreme Min Temp	Rainfall	Snowfall	Precipitation
	°C	°C	°C	°C	°C	mm	cm	mm
Jan	3.8	6.9	0.7	15.4	-15.6	121.8	15.2	136.6
Feb	4.9	8.4	1.4	18.3	-15	98.8	9	107.8
Mar	6.4	10.5	2.3	21.4	-10	75.8	2.4	78
Apr	8.8	13.4	4.1	26.3	-3.9	44.5	0	44.5
May	11.8	16.6	6.9	31.5	-1.1	36.5	0	36.5
Jun	14.4	19.3	9.3	33.3	2.1	32	0	32
Jul	16.4	21.9	10.8	36.1	4.1	19.5	0	19.5
Aug	16.4	22	10.8	34.4	4.4	23.9	0	23.9
Sep	14	19.4	8.4	31.1	-1.1	30.4	0	30.4
Oct	9.8	14.2	5.3	27.6	-4.4	75.6	0.2	75.7
Nov	6.1	9.5	2.7	18.3	-13.3	144.4	3.3	147.2
Dec	4	6.9	1	16.1	-14.4	138.3	13.8	151.2
Sum						**841.5**	**43.9**	**883.3**

[a] Sourced from Environment Canada, http://www.climate.weatheroffice.ec.gc.ca/climateData/

Figure A.1
2009 Wind Rose Diagram for Victoria International Airport

Figure A.2
2009 Wind Rose Diagram for Victoria Topaz

Figure A.3
2009 Wind Rose Diagram for Stellys

Figure A.4
2009 Wind Rose Diagram for Langford (January to June only)

Figure A.5
2009 Wind Rose Diagram for Saturna Island

Appendix B: Federal/Provincial Air Quality Objectives

The Canadian National Ambient Air Quality Objectives (NAAQO) is a three-tiered system. Each level has a specific concentration for an individual air contaminant, with one or more averaging periods used. The three levels are:

- The **Maximum Tolerable Level**, representing a time-averaged concentration, above which immediate action is necessary to protect the health of the general population.

- The **Maximum Acceptable Level**, representing a time-averaged concentration suitable to protect human health, animals, soils, water, vegetation, materials and visibility against the effects of air pollution.

- The **Maximum Desirable Level**, representing a time-averaged concentration that is a long term goal for air quality and also provides a benchmark for preserving air quality in the least polluted parts of the country.

Some of the effects of air contaminants above or below the three Federal objective levels are summarised in Table B.1.

British Columbia also has air quality criteria for ambient air concentrations defined at three levels. However, there are no consistent or official definitions for these objectives. For example, in the case of the Bulkley Valley, the levels have been interpreted in the same manner as the Federal objectives, but use simplified descriptions[19]. These levels are:

- **Level A;** below this level, air quality is 'good'. It represents the maximum desirable concentration.

- **Level B;** below this level (but above Level A), air quality is 'fair'. It represents the maximum acceptable concentration.

- **Level C;** below this level (but above Level B), air quality is 'poor'. Above this level, air quality is 'very poor'. It represents the maximum tolerable concentration.

All federal and provincial air quality criteria are presented in Table B.2. Ambient air quality levels in the CRD in 2009 are compared with federal and provincial objectives in Table B.3.

[19] Johnson, D., *Bulkley Valley Air Quality Management Plan.* February 1999. http://wlapwww.gov.bc.ca/ske/skeair/reports/BVAQMP1999.pdf

Table B.1:
National Ambient Air Quality Objectives
and Their Relationship to Some Health and Environmental Effects
(Source: Environment Canada 1991)[20]

POLLUTANT	GOOD RANGE (0-MAX. DESIRABLE)	FAIR RANGE (MAX. DESIRABLE-MAX. ACCEPTABLE)	POOR RANGE (MAX. ACCEPTABLE - MAX. TOLERABLE)	VERY POOR RANGE* (OVER THE MAX. TOLERABLE)
Sulphur Dioxide (SO_2)	no effects	increasing injury to species of vegetation	odorous; increasing vegetation damage and sensitivity	increasing sensitivity of patients with asthma and bronchitis
Total Suspended Particulate (TSP)	no effects	decreasing visibility	decreased visibility; evident soiling	increasing sensitivity of patients with asthma and bronchitis
Ground-Level Ozone (O_3)	no effects	increasing injury to some species of vegetation	decreasing performance by some athletes exercising heavily	light exercise produces effect in some patients with chronic pulmonary disease
Carbon Monoxide (CO)	no effects	no detectable impairment but blood chemistry changing	increasing cardiovascular symptoms in smokers with heart disease	increasing cardiovascular symptoms in non-smokers with heart disease; some visual impairment
Nitrogen Dioxide (NO_2)	no effects	odorous	odour and atmospheric discoloration; increasing bronchial reactivity in asthmatics	increasing sensitivity of patients with asthma and bronchitis

***The upper limit of the very poor range is not defined. At extremely high levels of any of these pollutants, symptoms would be worse than those listed.**

[20] Environment Canada 1991. *The State of Canada's Environment.* Government of Canada, Ministry of Supply and Services, Ottawa.

Table B.2 Federal and Provincial Air Quality Objectives For Contaminants Monitored in the CRD

Contaminant	Averaging Period	Canada Maximum Desirable	Canada Maximum Acceptable	BC Level A	BC Level B	BC Level C
Carbon Monoxide	1-hour	15000	35000	14300	28000	35000
	8-hour	6000	15000	5500	11000	14300
Nitrogen Dioxide	1-hour		400			
	24-hour		200			
	Annual Arithmetic Mean	60	100			
Sulphur Dioxide	1-hour	450	900	450	900	900 -1300
	24-hour	150	300	160	260	360
	Annual Arithmetic Mean	30	60	25	50	80
Ozone	1-hour	100	160			
	24-hour	30	50			
	Annual Arithmetic Mean		30			
Ambient Air Quality Objectives Established in 1995						
PM_{10}	24- hour			50		

Notes:

[1] All units in $\mu g/m^3$

Table B.3
Comparison of Maximum Observed Pollutant Concentrations (µg/m^3) in the CRD for 2009 with Provincial and Federal Objectives

Contaminant	Averaging Period*	B.C. or Federal Maximum Acceptable Level	Victoria Topaz	Stellys	Langford	Saturna Island
CO	1-hour	28000	3781	--	--	
	8-hour	11000	1919	--	--	
Nitrogen Dioxide	1-hour	400	99	54	72	
	24-hour	200	43	27	29	
	Annual	100	20	10	12	
Sulphur Dioxide	1-hour	900	168		15	N/A
	24-hour	300	30		5	N/A
	Annual	60	4		2	N/A
Ozone	1-hour	160	126	136	144	130
	24-hour	50	85	84	84	97
	Annual	50	38	42	39	57
PM10	24-hour	50	34			

"--" denotes that more than 90% of data is missing
N/A - data not yet available