Air Quality in the Capital Regional District 2006

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TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Air quality is monitored in the Capital Regional District (CRD) to assess ambient air quality and to track trends. The monitoring is conducted under the long term monitoring program (LTMP), which is a partnership between the CRD and the British Columbia Ministry of the Environment (BC Environment), Royal Roads University and Environment Canada. SENES Consultants Limited (SENES) was contracted to provide an analysis and summary report of the monitoring data collected in 2006, including analysis of supporting meteorological information that was available over the same time period.

There are six air quality stations in the CRD that measure either gaseous contaminants and/or fine particulate matter. In 2006, however, the Langford station was not in operation. One station, on Saturna Island, is managed by Environment Canada, and records only gaseous pollutants. In addition, there are three 'Hi-Vol' stations that measure fine particulate matter only.

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 ($PM_{2.5}$).

Data collection was less successful for 2006 than in previous years, hampering data analysis for the annual report. Data were missing at four of the monitoring sites for the following periods:

Monitoring Location	CO	NO/NO_2	SO_2	O_3	$PM_{2.5}$
Victoria Topaz	**Dec**		**Aug 1- 17**		
Royal Roads				**Mar 2 – Jul 13**	
Stellys	**Jan 1 – Jul 12 Sep 7 – 14 Dec**	**Jan 1 – Jul 12 Dec**			**Jan 1 – Dec 31**
Christopher Point	**Feb 5 - 15 Jul 1 – Aug 29**			**Jun 8 - 23**	**Feb 4-15 Jul 28- Aug 15 Sep 9 – Nov 1**

A primary focus of the annual air quality report is 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 2006, air quality remained relatively good in the CRD. The CRD guideline for PM_{10} was exceeded once at each of two locations (Victoria Topaz and Stellys) on separate dates. There were also two slight exceedences of the CRD guideline for ground level ozone at Christopher Point and Saturna Island, meaning that exposure to elevated ozone concentrations was very low for CRD residents. Due to the limited temporal and spatial extent of exposure to both the PM_{10} and ozone exceedences, related health effects for community members could not be determined with confidence.

The ozone concentration recorded at Christopher Point on May 16th was 123.2 µg/m^3, only slightly over the guideline value. The ozone concentration recorded at Saturna Island on September 3rd was also only slightly over the guideline having a value of 123.5 µg/m^3.

One exceedence of the PM_{10} guideline of 50 µg/m^3 occurred at the Victoria Topaz monitoring station on May 5th of the year, with a 24-hour average concentration of 53 µg/m^3. Concentrations recorded at each of the other PM_{10} monitoring stations in the CRD on that date were much lower, indicating that the higher PM_{10} concentration at Topaz was not experienced throughout a large portion of the CRD. The likely cause of the high concentration at the Victoria Topaz site on this date could not be determined. A second exceedence of the CRD guideline for PM_{10} occurred at the Stellys monitoring site on September 2nd, with a 24-hour average concentration of 58 µg/m^3. Concentrations recorded at each of the other PM_{10} monitoring stations in the CRD on that date were much lower, indicating that the high PM_{10} concentration was limited to the Stellys site. The date of this exceedence at Stellys coincided with the timing of the Saanich Fair, and the higher PM_{10} levels may have been related to increased traffic levels near this location on that particular weekend.

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. There were no statistically significant trends found for CO, NO_2, ground level ozone or respirable particulate matter ($PM_{2.5}$) concentrations for any of the monitoring locations. The exceptions was for SO_2 monitoring data at Victoria Topaz over the period 1998-2006 and at Saturna Island for 1998-2005, for which trends were determined to be as follows:

- a decrease of 14%/year in annual mean concentrations at Topaz;
- a decrease of 13%/year in annual 98th percentile concentrations at Topaz;
- a decrease of 5%/year in annual mean concentrations at Saturna Island; and,
- a decrease of 13%/year in annual 98th percentile concentrations at Saturna Island.

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 2006. Overall, the majority of CAC show no upward or downward trends over time, with the exception of sulphur dioxide.

1.0 INTRODUCTION

The Capital Regional District (CRD) has been in partnership with the B.C. Ministry of Environment (formerly the Ministry of Water, Land and Air Protection – MWLAP) and others in conducting an ambient air quality monitoring program in the CRD area since 1996. One of the initial 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 is also recognized that solid waste burning releases many other air contaminants, including common air contaminants (CACs) and toxic compounds. All CACs are 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 has committed to reporting on the air quality data collected within the monitoring network.

Meteorological data is 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 are 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 is designed to characterize the air quality in the region and to support the initiatives described above. Air quality monitoring locations are 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 are necessary. These sites are described as locations where people live, work and play[2].

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

1.1 MONITORING STATIONS

Air contaminants are sampled at six air quality monitoring stations in the Capital Regional District (CRD). Each station samples 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 sampled; $PM_{2.5}$ (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.

All of the air quality and meteorological stations 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.

The 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). Victoria Topaz and Christopher Point record all of the common air contaminants. Royal Roads University collects particulate matter in the form of $PM_{2.5}$, nitrogen oxides and ground level ozone. The monitor at Stellys Cross Roads in Central Saanich records all CACs except SO_2, although technical difficulties with the monitor at this station resulted in no $PM_{2.5}$ monitoring being available for 2006. The Langford station did not operate in 2006 as it was being re-located. Data from these stations were made available by the B.C. Ministry of Environment.

The Saturna Island monitoring station is part of the Canadian Air and Precipitation Monitoring (CAPMON) network of primarily rural monitoring stations.

There are three high volume sampler (Hi-Vol) equipped stations that collect PM_{10} data in the CRD at the Oak Bay Recreational Centre, and at the Braefoot and Keating Elementary Schools. 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.

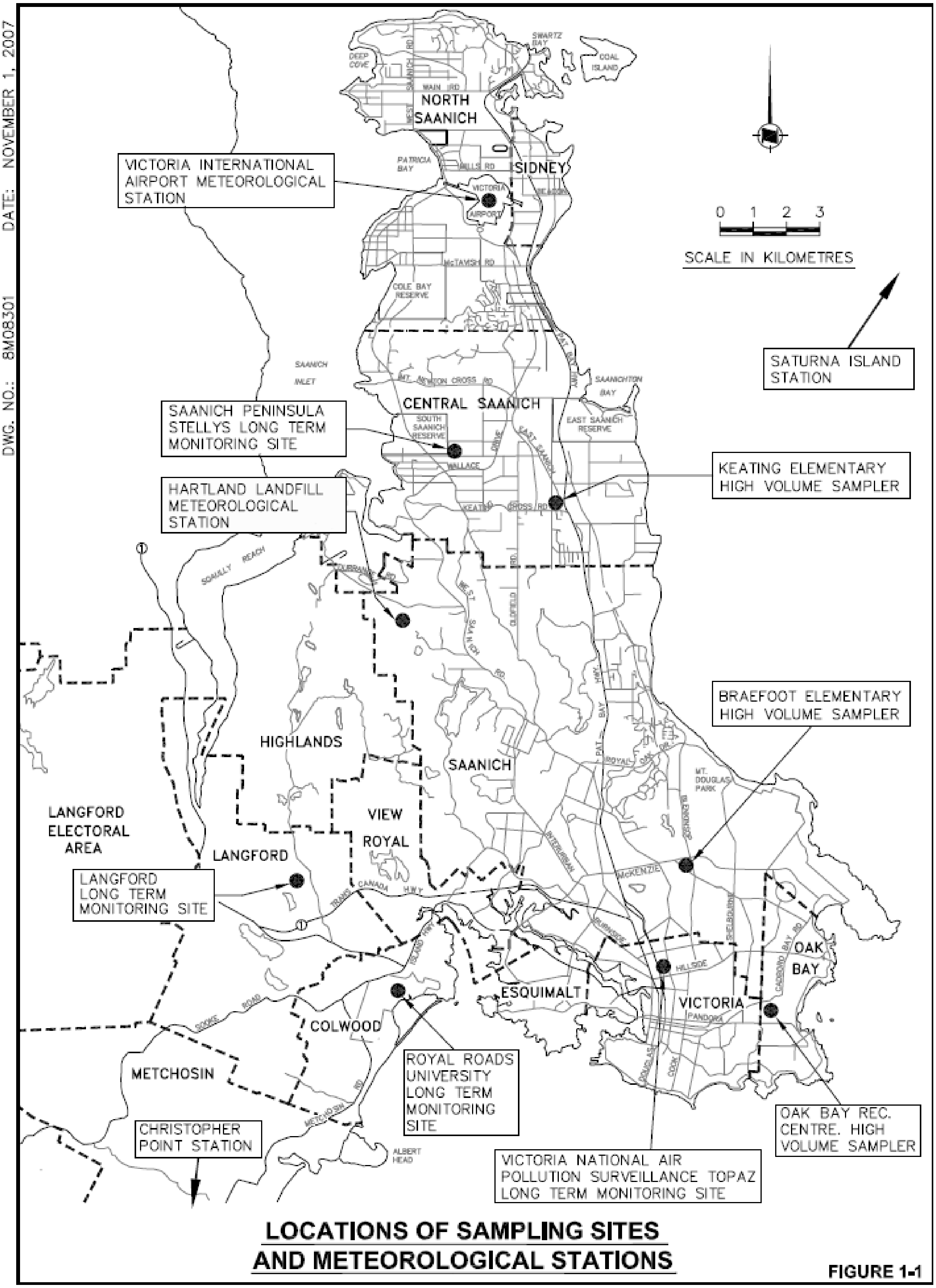
[2] Canadian Council of Ministers for the Environment, 2000. Guidance Document on Achievement Determination: Canada Wide Standards for Particulate Matter and Ozone. www.ccme.ca.

Table 1.1
Air Quality Monitoring Stations in the Capital Regional District, 2006

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	PM_{10} (S-Hi-Vol) PM_{10} & $PM_{2.5}$ (Dichot) $PM_{2.5}$ (C-TEOM)	WS, WD, T, RH
Royal Roads University	Long Term Monitoring Site	NO, NO_2, & O_3	PM_{10} (C-TEOM) $PM_{2.5}$ (C-TEOM)	WS, WD, T, RH
Stellys, Saanich Peninsula[3]	Long Term Monitoring Site	CO, NO, NO_2 & O_3	PM_{10} (Partisol) $PM_{2.5}$ (C-TEOM)	WS, WD
Christopher Point[4]	Long Term Monitoring Site	CO, NO, NO_2, SO_2 & O_3	$PM_{2.5}$ (C-TEOM)	
Langford[2]	Long Term Monitoring Site		$PM_{2.5}$ (C-TEOM)	WS, WD
Saturna Island	CAPMoN[5] Site	SO_2 & O_3		WS, WD
Oak Bay Recreational Centre[6]	PM sampling site (Hi-Vol)		PM_{10} (S-Hi-Vol)	
Braefoot Elementary School[7]	PM sampling site (Hi-Vol)		PM_{10} (S-Hi-Vol)	
Keating Elementary School[8]	PM sampling site (Hi-Vol)		PM_{10} (S-Hi-Vol)	
Victoria International Airport	Environment Canada met station			WS, WD, T, RH, others
Hartland Landfill	Local met station			WS, WD, RH

Notes:

WS – wind speed; WD – wind direction; T – temperature; RH – relative humidity
S-Hi-Vol - sequential sampling using a High Volume sampler
Dicot - 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, but was not operation in 2006
3- Station began operating in August, 2003
4- Station began operation in September 2005
5- Canadian Air and Precipitation Monitoring Network
6- Particulate matter sampling site since October 1996
7- Particulate matter sampling site since November 1999
8- Particulate matter sampling site since November 1999



LOCATIONS OF SAMPLING SITES AND METEOROLOGICAL STATIONS

FIGURE 1-1

1.2 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 of the need to update existing national and provincial air quality objectives and guidelines in Canada. The current provincial objective level for PM_{10} was established in 1995, and 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 the health effects of these air pollutants.

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[3] 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.

The CRD established a set of ambient air quality guidelines for each of the CACs in 2004. 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 exceedences 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.

[3] 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/m³)					
	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

For 2006, meteorological data was analysed from five stations in the CRD. The specific parameters monitored are listed below in Table 2.1. Environment Canada provided the meteorological data for the Victoria Airport for this report. The 2006 data from Saturna Island were not available at the time of report preparation.

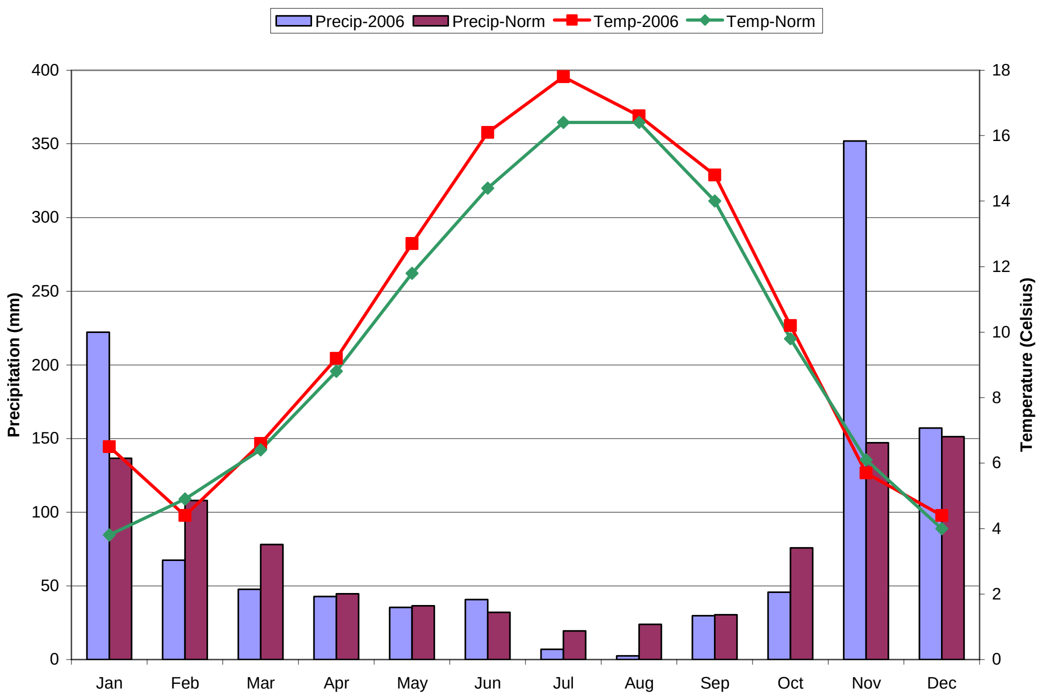
Table 2.1
Meteorological Stations in the CRD

STATION	OPERATION*	METEOROLOGICAL DATA COLLECTED**	WIND CAPTURE RATE (%)
Royal Roads University (Colwood)	Royal Roads University	WS, WD, T	99.4
Victoria Topaz	BC Environment, EC NAPS	WS, WD, T, RH	99.8
Stellys	BC Environment	WS, WD, T	99.6
Hartland Landfill	CRD Landfill Staff	WS, WD	100
Victoria Airport	EC	WS, WD, T, RH, Precip, Cloud	100
Saturna Island	EC CAPMoN	WS, WD	Not available for 2006

* 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, Cloud = cloud cover.

Figure 2.1 shows the 2006 average monthly temperature and precipitation at the Victoria Airport. The climate normals (1971 to 2000) for temperature and precipitation have been added to the figure to show the average monthly precipitation and temperature differences between 2006 and the normal climate averages in the CRD. The average monthly temperatures were higher during January and during the spring and summer of 2006 compared to the climate normals. In November and January of 2006, there was a significantly higher amount of precipitation compared to the climate normal, while the spring and summer months had either near normal or below normal precipitation levels (July and August). However, total precipitation in 2006 was slightly greater than normal. The drier conditions in the spring and summer likely contributed to some of the higher PM_{10} levels observed at some of the monitoring locations (e.g., Topaz, Keating) while the higher than normal precipitation in November probably reduced PM_{10} concentrations to similar levels (10-15 $\mu g/m^3$) at all five monitoring locations (see Figure 4.1, Section 4.1).

Figure 2.1
2006 Monthly Average Temperature and Precipitation at the Victoria Airport



A wind rose diagram shows the frequency of wind direction (from the direction the wind comes from) and the wind speed at a station. Wind rose diagrams are included in Appendix A for each station with complete datasets (Victoria Airport, Christopher Point, Victoria Topaz, Royal Roads University, Hartland Landfill, and Stellys).

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.

The gas samplers automatically recalibrate frequently to ensure accuracy. Occasionally, due to recalibration, hourly concentrations can be missed. For each pollutant, the percent of missing data is recorded. For monitoring sites administered by the B.C. Ministry of Environment, gaseous pollutants recorded in parts per billion (ppb) or parts per million (ppm) are converted by the Ministry to micrograms per cubic metre ($\mu g/m^3$) at 20^0C and 1 atmosphere (atm). Conversely, 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 because these were not available for the report.

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 2006. 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 80% 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[4] in each

[4] 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 have 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.

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 and the decomposition of materials. Human emissions of CO are primarily caused by the incomplete combustion of fossil fuels. CO is an odourless, colourless, tasteless gas.

CO data is collected at Victoria Topaz, Stellys and Christopher Point. There was no data collection for carbon monoxide at Victoria Topaz and Stellys for the month of December, and the monitor at Christopher Point did not operate from July 1st to August 29th. The CO monitor at the Stellys station was not installed until July 13th.

The hourly concentrations are summarized in Table 3.1. Eight-hour sequential average concentrations for Topaz, Stellys and Christopher Point, are summarized in Table 3.2. There were no exceedences of the CRD 8-hour guideline of 5500 µg/m³ in 2006, 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										
100	300	600	900	2200	2700	5100	0	695.1	531.8	12.9
Stellys										
0	100	200	300	600	700	1600	0	204.4	154.5	64.2
Christopher Point										
300	300	600	1000	1400	1400	1600	0	693.4	345.0	13.0

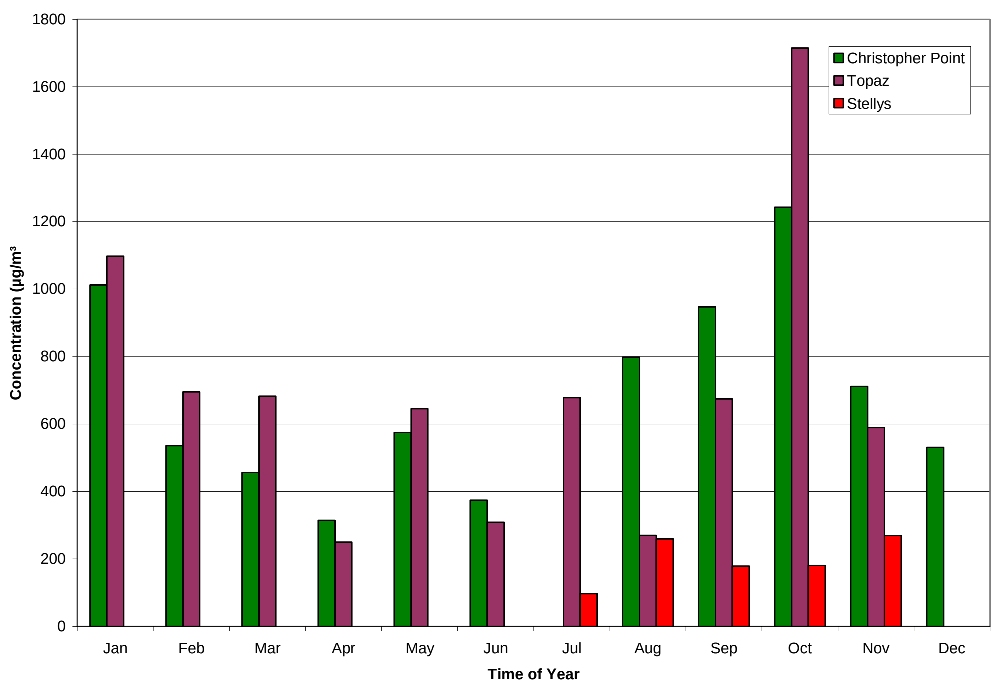
Table 3.2
8-Hour Sequentially Average CO Concentrations in the CRD

Percentile Values 5	25	50	75	98	99	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
Victoria Topaz											
157	350	600	875	2005	2340	3071.4	100	696.0	475.3	0	9.5
Stellys											
25	112	200	275	523	550	737.5	0	205.0	127.7	0	62.7
Christopher Point											
263	375	600	988	1388	1400	1450.0	162.5	689.7	347.0	0	18

Note: An 8-hour average concentration was determined for every interval having 6 or more hours of data available.

Figure 3.1 shows the mean monthly 8-hour average carbon monoxide concentrations at Christopher Point, Stellys and Victoria Topaz. Concentrations were highest in the early autumn (i.e., October) at both Christopher Point and Topaz. CO levels at Stellys remained low throughout the available period of monitoring data from June to November.

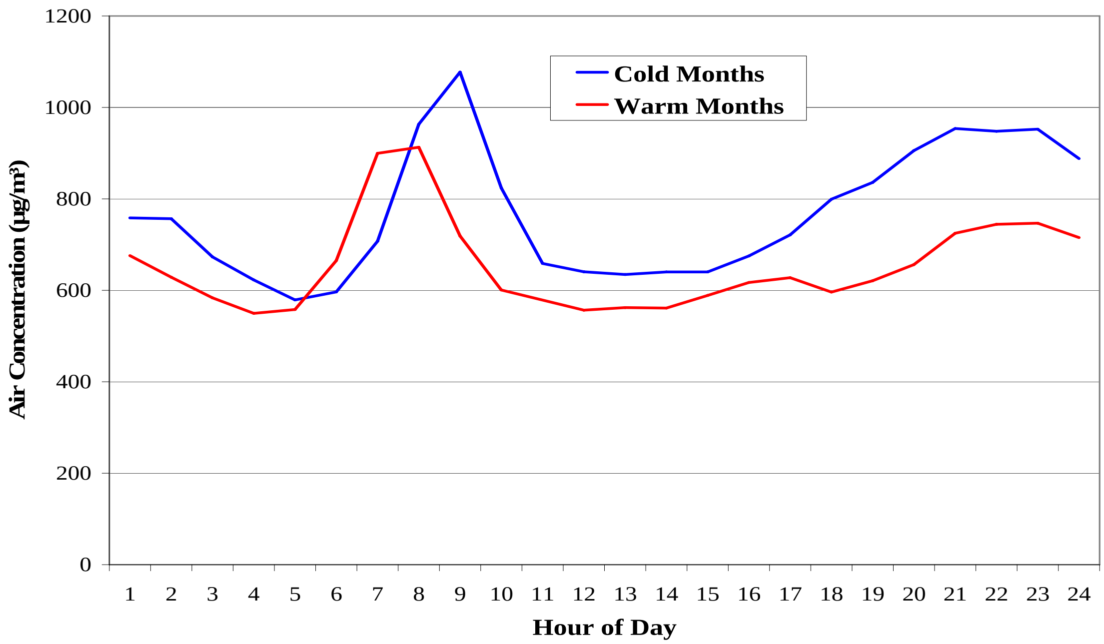
Figure 3.1
Mean Monthly 8-Hour Average CO Concentrations at Christopher Point, Stellys and Victoria Topaz



The average diurnal patterns of CO concentrations at Victoria Topaz during the warmer (April to October) and cooler (November to March) months are shown in Figure 3.2. Rush hour traffic emissions in the morning in all months of the year (warm and cool months) are indicated by the peak concentrations at approximately 9:00 am PST in cooler months, and 8:00 am PST in warmer months (i.e., the difference in time of day for the peak value is due to daylight savings time). This morning peak in concentrations 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 in the late evening in hours is due to a lowering of the atmospheric mixing height towards the end of the day. CO concentrations are 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.

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



3.2 NITROGEN OXIDES

The reaction of nitrogen with oxygen results in the production of nitrogen oxides (NO_x). 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.

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.

NO_x is monitored at Victoria Topaz, Royal Roads University, Stelly and Christopher Point. Note that NO_x monitoring at Stellys did not begin until July 13, 2006 and there was no valid data at this site for December.

3.2.1 Nitric Oxide (NO)

Table 3.3 summarizes the NO levels measured at four locations in the CRD in 2006. The high percentage of missing data at Stellys is due to the fact that the station did not begin recording data until July 13th.

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 Christopher Point had the lowest. This is likely because of the Topaz station's location in close proximity to Blanshard Street. There are no CRD guidelines or other regulatory criteria for NO.

Table 3.3
Hourly Averaged NO Concentrations in the CRD

Percentile Values						Max $\mu g/m^3$	Min $\mu g/m^3$	Mean $\mu g/m^3$	Std. Dev. $\mu g/m^3$	Missing Values % of Total Hours
5	**25**	**50**	**75**	**98**	**99**					
Victoria Topaz										
1	1	5	13	97	131	353.0	0	12.5	24.4	3.6
Royal Roads University										
0	0	0	1	25	39	103.5	0	2.4	7.2	4.7
Stellys										
0	0	1	4	21	29	108.5	0	3.2	6.1	62.6
Christopher Point										
0	0	0	1	10	14	42.4	0	1.2	2.8	5.6

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 exceedences of the CRD 1-hour NO_2 guideline of 200 $\mu g/m^3$, and values were generally well below the guideline value. Victoria Topaz experienced significantly higher 1-hour and 24-hour average NO_2 concentrations over those measured at Christopher Point, Stellys and Royal Roads. 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 NO_2 concentrations were generally lower at Christopher Point than at either Stellys or Royal Roads, but 24-hour average concentrations were fairly similar between all three stations.

Figure 3.3 shows monthly 24-hour average NO_2 levels in 2006. There is no obvious seasonal pattern to NO_2 concentrations at the Victoria Topaz site, except that levels were highest in September and October. By comparison, the NO_2 levels at Royal Roads were lowest during the spring and summer months (April - August), possibly due to lower traffic levels on campus after the end of the spring term.

Table 3.4
Hourly Averaged NO_2 Concentrations in the CRD

Percentile Values 5	25	50	75	98	99	Max µg/m^3	Min µg/m^3	Mean µg/m^3	Std. Dev. µg/m^3	Percent of 1-h Averages > CRD Guideline (200 µg/m^3)	Missing Values % of Total Hours
Victoria Topaz											
6	12	19	33	61	69	97.5	0	23.3	15.0	0	4.6
Royal Roads University											
0	2	8	13	31	34	53.5	0	9.1	8.3	0	4.7
Stellys											
0	4	8	13	29	34	66.9	0	9.1	7.9	0	62.6
Christopher Point											
0	2	4	12	33	39	65	0	7.5	8.6	0	5.6

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

Percentile Values 5	25	50	75	98	99	Max µg/m^3	Min µg/m^3	Mean µg/m^3	Std. Dev. µg/m^3	Missing Values % of Total 24-h Averages
Victoria Topaz										
11	18	22	29	42	45	50.2	3.8	23.3	8.4	0.8
Royal Roads University										
2	5	8	13	22	24	26.8	0	9.1	5.6	0.5
Stellys										
3	6	9	11	20	23	25.5	0.2	9.1	4.4	61
Christopher Point										
0	3	6	11	25	28	37.9	0	7.5	6.5	6.0

Figure 3.3
Mean Monthly 24-Hour Average NO_2 Concentrations at Victoria Topaz, Royal Roads, Christopher Point and Stellys

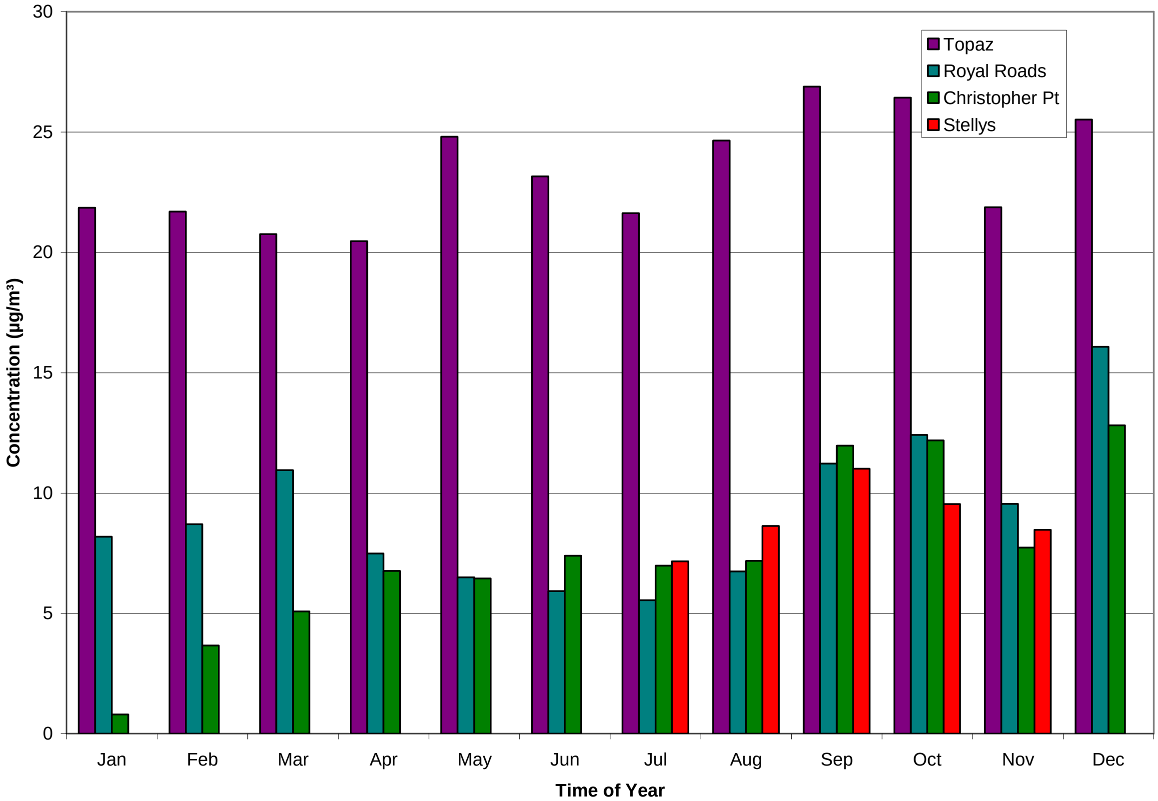


Figure 3.4 and 3.5 show the average diurnal pattern of hourly NO_2 concentrations during the cooler and warmer months of the year, at Victoria Topaz, Royal Roads University, Stellys, and Christopher Point. There is a distinct concentration peak in the morning and another later in the evening in both cooler and warmer periods of the year. The diurnal patterns for the Stellys data are less certain as they were determined from an incomplete data set, (i.e., based on data from July through November only).

The early morning peak at around 9:00 am PST at three of the sites (Victoria Topaz, Royal Roads, and Stellys) in the cooler months is likely related to the morning traffic rush of commuters going to work or school. This peak in morning NO_2 concentrations is most pronounced at the Victoria Topaz site, and is present in the warmer summer months as well. The morning peak in NO_2 levels is much reduced during the warmer months of the year at both Royal Roads and Stellys, and is entirely absent at Christopher point during all times of the year.

Figure 3.4
Average Diurnal NO_2 Pattern for all Stations during Cooler Months (November-April)

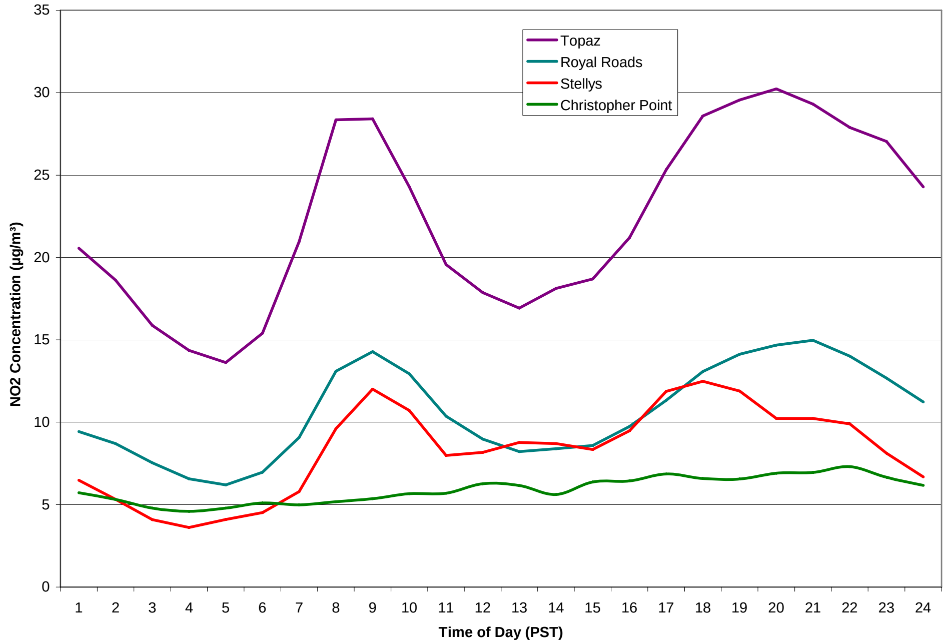
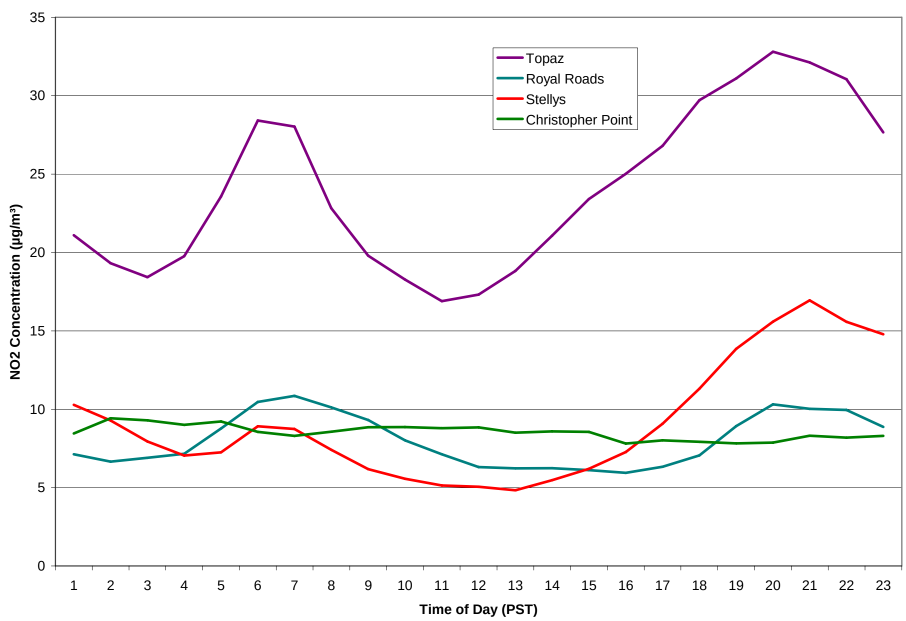


Figure 3.5
Average Diurnal NO_2 Pattern for all Stations during Warmer Months (May-October)



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 Victoria Topaz and Royal Roads 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. It is worth noting that the evening increase in NO_2 levels is not present at Christopher Point.

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 will drop to 15 parts per million (ppm) in 2007, which will further lower automobile 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 lead to the formation of sulphuric acid (H_2SO_4) in the atmosphere. 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 dissolves in water vapour in the atmosphere. Particulate matter ($PM_{2.5}$) concentrations in the atmosphere can increase when sulphates combine with other compounds in the atmosphere.

Table 3.6 lists the average hourly SO_2 concentration at Christopher Point and Victoria Topaz, the only two sites in the CRD network with hourly data available in 2006. Table 3.7 lists the 24-hr sequential average SO_2 concentrations at these two locations.[5] Data for Saturna Island in 2006 were not available for the annual report. A summary of 24-hour average SO_2 concentrations measured at Saturna Island over the period 1998-2005 is provided in Appendix C.

Table 3.6 indicates that hourly averaged SO_2 concentrations are essentially undetectable at both sites at least 50% of the time, and are similar at both sites 98% of the time. The remaining 2% of the time, SO_2 levels at Victoria Topaz are significantly higher than at Christopher Point. Table 3.7 indicates that 24-hour average SO_2 concentrations are approximately twice as high at

[5] 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.

Victoria Topaz compared to Christopher Point, but that all 24-hour average levels at both locations during 2006 were well below the CRD guideline value of 125 µg/m³.

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	0	0	3	13	19	77.0	0	2.5	4.6	8.7
Christopher Point										
0	0	0	3	8	11	27.0	0	1.4	2.5	5.4

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
5	25	50	75	98	99						% of Total 24-h Averages
Victoria Topaz											
0	0.7	2	3	10	14	15.1	0	2.5	2.5	0	5.2
Christopher Point											
0	0	1	2	5	7	8.6	0	1.4	1.5	0	6.0

Figure 3.6 shows monthly averaged SO_2 concentrations at the Victoria Topaz and Christopher Point stations. The Topaz station had higher concentrations from February to August, whereas the Christopher Point station had higher concentrations during September/October and December/January. However, given the very low concentrations, this variability in month-to-month concentrations is not particularly significant.

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

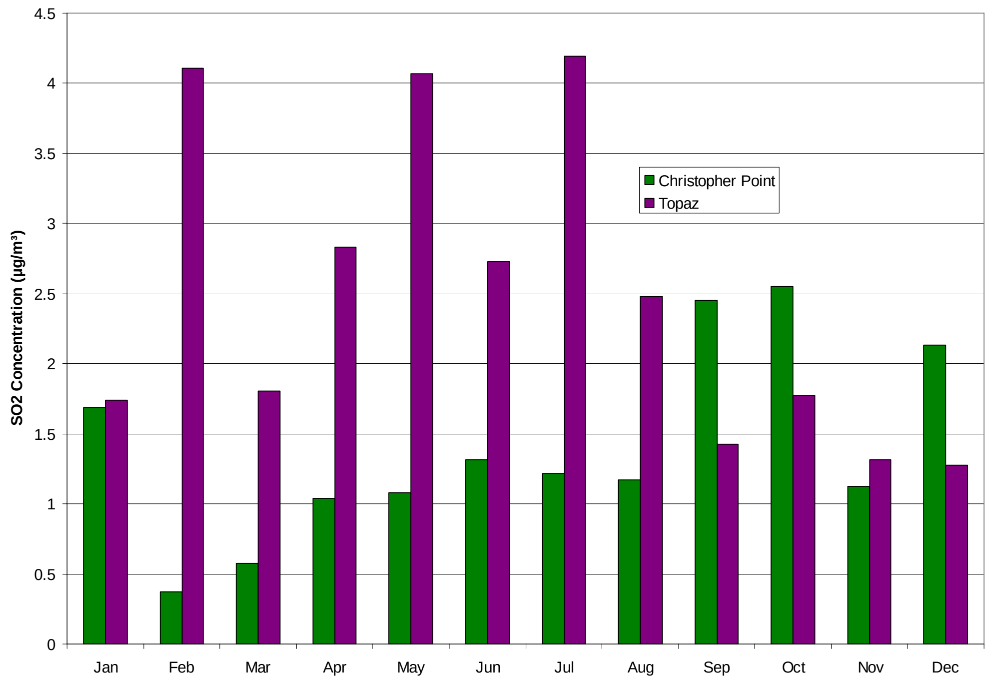


Figure 3.7 shows the average diurnal SO_2 concentrations for Victoria Topaz and Christopher Point during the cooler months (November to April), while Figure 3.8 shows the pattern for the warmer months (May to October) of the year. During the cooler months of the year, the Topaz site has a pronounced peak in SO_2 levels in the morning (9:00 am PST), with a lower peak in the evening at 9:00 pm PST. In the warmer months of the year, the pattern is reversed, with a more prominent peak in SO_2 levels in the evening (7:00 pm PST), and a lower peak in the morning (8:00 am PST). By comparison, the SO_2 levels at Christopher Point are more evenly distributed throughout the day in all seasons, with slightly higher levels during the midday hours in the warmer months.

Topaz has higher SO_2 levels throughout the year as compared to Christopher Point. This is likely because of the localized differences with respect to the location of each of these stations. Christopher Point is located in a coastal and more rural area, where there are likely to be fewer SO_2 emission sources and more wind movement coming from the ocean to help disperse concentrations. In Figures 3.7 and 3.8, all months show a morning peak coinciding with rush hour commuting traffic. This peak is again significantly larger at the Topaz station for the cooler months. There is a second peak in the evening around 8:00 pm PST in all months of the year. At the Topaz station, the peak associated with the warmer months is significantly larger than at Christopher Point.

Figure 3.7
Average Diurnal SO_2 Pattern for Victoria Topaz and Christopher Point for the Cooler Months (November to April)

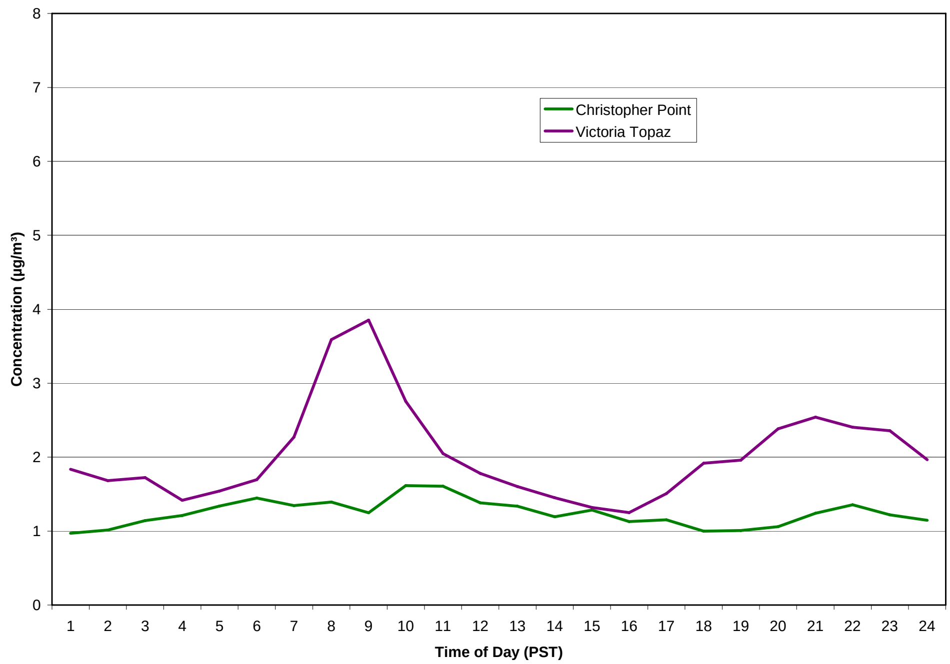
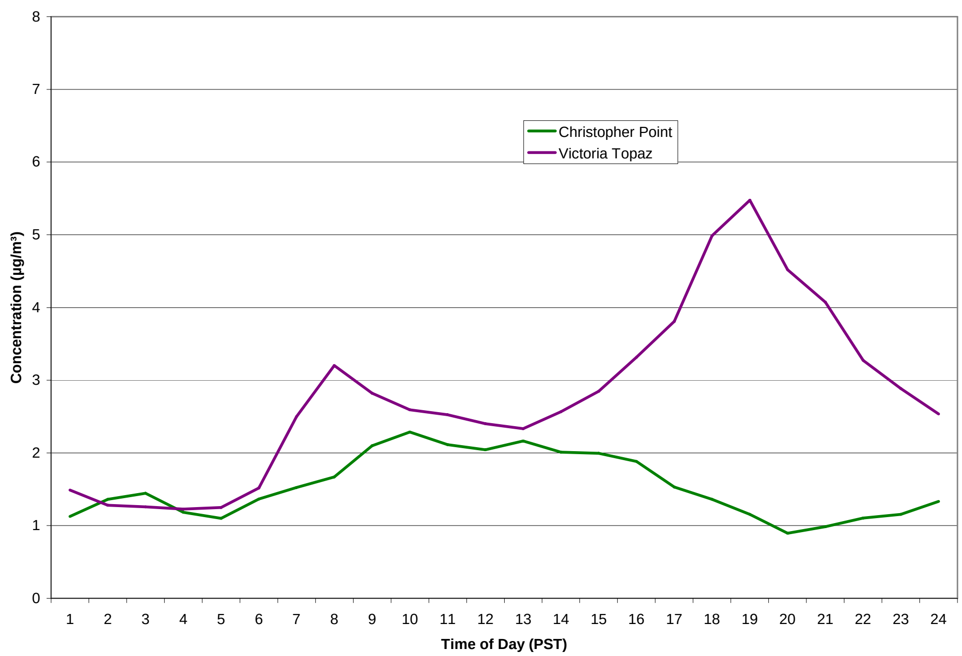


Figure 3.8
Average Diurnal SO_2 Pattern for Victoria Topaz and Christopher Point for the Warmer Months (May to October)



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. Ozone can be removed ('scavenged') by destructive reactions with NO_x. 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.

Ozone is monitored at Victoria Topaz, Royal Roads University, Stellys, Christopher Point 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 2006 to federal/provincial objectives is discussed in Appendix B.

Table 3.9 shows the 8-hour rolling average concentrations at Christopher Point, Stellys, Topaz Royal Roads and Saturna Island. Although ozone levels were generally well below the CRD guideline value of 120 µg/m³ (8-hour average), there were two exceedences of the guideline in 2006. Christopher Point and Saturna Island each measured one event where concentrations were over 120 µg/m³.. By comparison, in 2005 there were eight such exceedences, with seven being recorded at Saturna Island and one at Royal Roads University. During 2006, the Royal Roads monitoring station had missing data during the critical period of March 2nd to July 13th when elevated ozone concentrations were most likely to have occurred.

Table 3.8
Hourly Averaged Ozone Concentrations in the CRD

Percentile Values 5	25	50	75	98	99	Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
Victoria Topaz										
2	20	42	62	90	94	127.7	0	41.5	26.1	6.5
Royal Roads University										
2	18	38	58	92	96	111.7	0	39.3	25.2	39.3
Stellys										
4	26	50	70	100	106	139.7	0	48.5	27.1	10.5
Christopher Point										
18	40	54	72	98	104	129.7	0	55.2	21.4	8.5
Saturna Island										
32	48	62	76	104	110	144	0	62.1	19.1	6.0

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
5	**25**	**50**	**75**	**98**	**99**						**% of Total 8-h Averages**
Victoria Topaz											
5	24	41	58	85	89	108.3	0.29	41.5	22.7	0	0.4
Royal Roads University											
5	22	38	54	88	91	101.6	0	39.0	22.1	0	37.5
Stellys											
7	30	49	65	92	96	113.5	0	48.5	23.6	0	3.9
Christopher Point											
20	41	55	70	95	100	123.2	0	55.2	20.8	0.1	8.6
Saturna Island											
34	51	63	74	98	104	123.5	6.3	62.3	17.1	0.1	0.4

The ozone concentration recorded at Christopher Point on May 16th was 123.2 µg/m³, only slightly over the guideline value. The ozone concentration recorded at Saturna Island on September 3rd was also only slightly over the guideline having a value of 123.5 µg/m³. 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). 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, 98th percentile, and annual 4th highest 8-hour average ozone concentrations recorded at each of the ozone monitoring locations in the CRD, except Christopher Point. The year-to-year variation in the maximum 8-hour average ozone concentrations for the period 1998-2006 are depicted in Figure 3.9. The data indicate that maximum ozone levels at Satruna Island have frequently been at or above the CRD guideline value of 120 µg/m³, while the levels at Royal Roads have exceeded the guideline value once in the past 5 years. The period of record at Stellys is short, but indicates that levels can reach as high as the CRD guideline level. By comparison, the ozone levels at Victoria Topaz have never exceeded the CRD guideline at any time during this period.

Figure 3.9
Maximum 8-Hour Average Ozone Levels in the CRD (1998-2006)

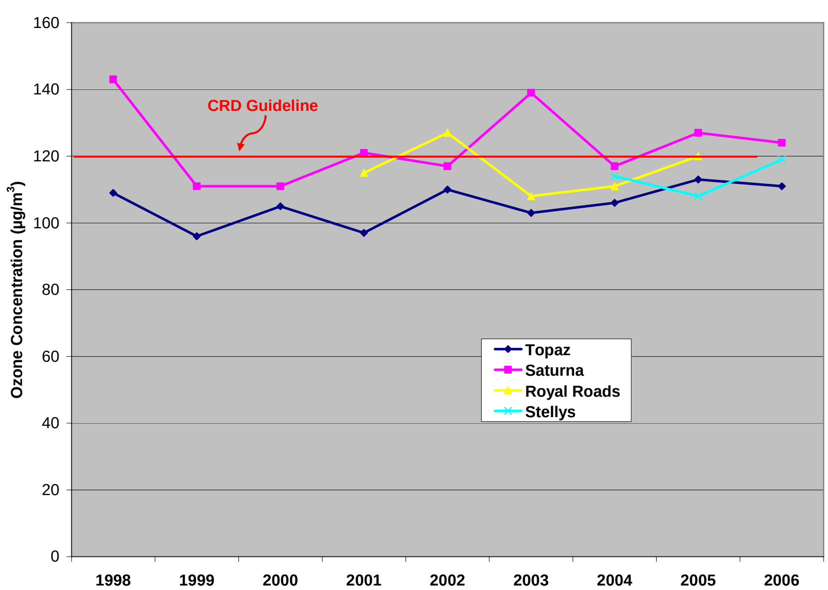


Table 3.10
Summary of Ozone Levels (μg/m³) in the CRD (1998-2006)

	Victoria Topaz		Royal Roads University		Stellys		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	115	97			121	109
2002	110	86	127	96			117	104
2003	103	85	108	100	85[b]	79[b]	139	113
2004	106	86	111	94	114	95	117	104
2005	113	85	120	101	108	94	127	103
2006	111	95	102[a]	93[a]	119	101	124	114
CRD Guideline	120		120		120		120	
CWS		127.6		127.6		127.6		127.6

Notes:

[a] Missing data from March 2 to July 13, 2006

[b] Monitoring from September 16 to December 31, 2003

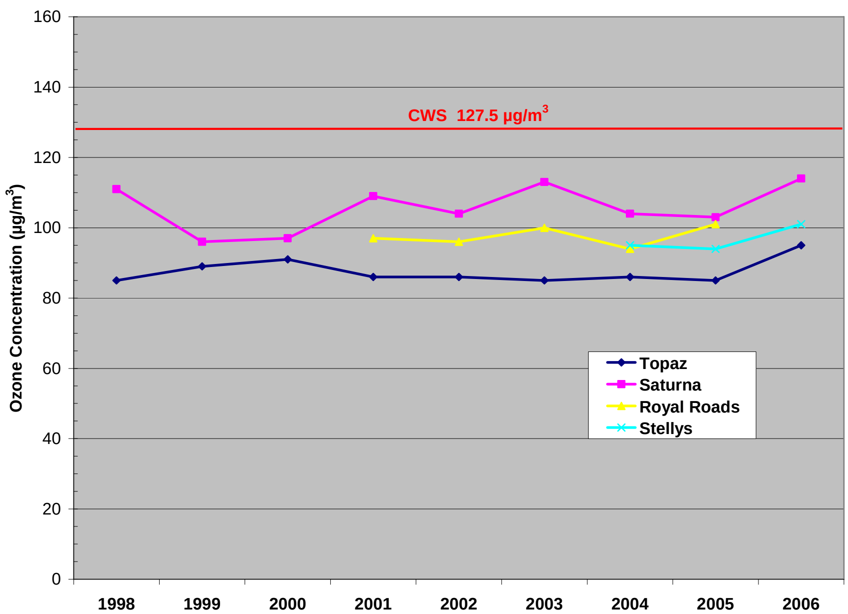
Max. – Maximum 8-hour average concentration for the year

98th Pct. - 98th percentile 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 4th highest ozone concentrations over the period 1998-2006. The data indicate that there is relatively little year-to-year variation in 4th highest concentrations, especially at Victoria Topaz. Saturna Island has had the highest fluctuations, while the period of record at Stellys is still too short to make definitive conclusions. Nevertheless, the annual 4th highest ozone concentrations at all four monitoring stations are well below the CWS value of 127.5 µg/m^3. Therefore, any combination of averaging between the four stations over tree consecutive years will yield a value less than the CWS.

Figure 3.10
4th Highest 8-Hour Average Ozone Levels in the CRD (1998-2006)



Previously, the Saturna Island ozone data have been used to demonstrate CWS compliance, as this station has had the highest concentrations experienced at the ozone monitoring stations in the CRD. This station is not representative of the concentrations experienced in metropolitan areas, and therefore use of the station to demonstrate compliance is conservative. Similarly, the location of the station at Christopher Point is not representative of areas where many people in the CRD are likely to be exposed, even though the highest average 8-hour average ozone concentration in 2006 at this location was one of two observed exceedences of the CRD guideline value. Moreover, due to the large amount of missing data for 2006 (i.e., 37.5%), Royal Roads could not be used for determining attainment of the CWS in 2006. Instead, attainment of the CWS was based on the data collected at the Stellys site.

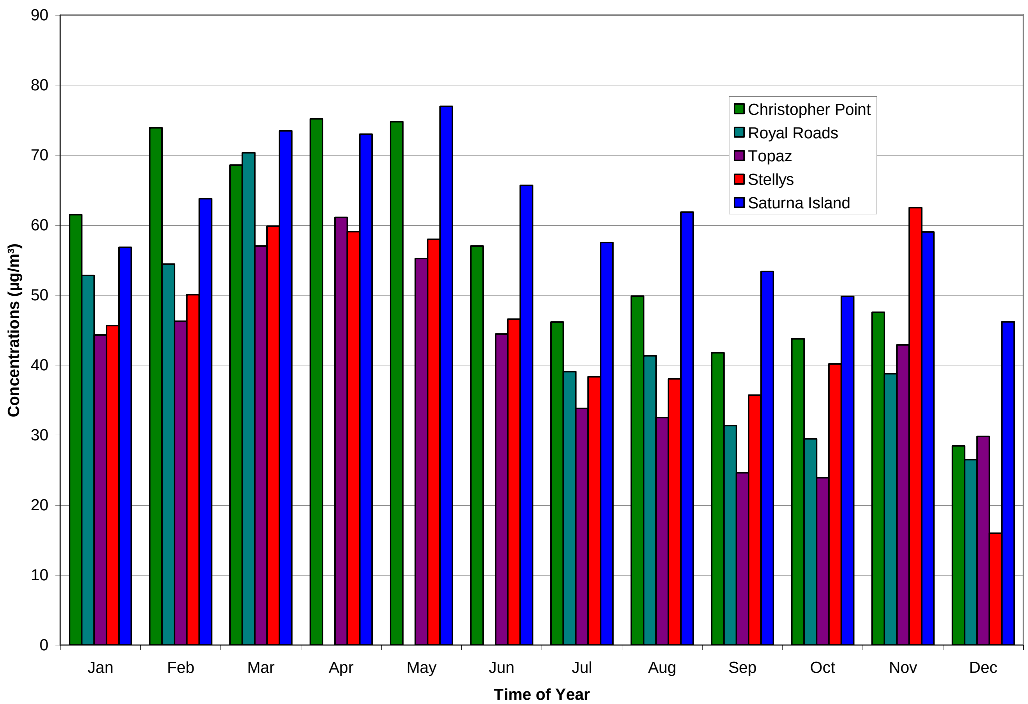
Over the three year period of 2004-2006 at Stellys, the 4th highest daily 8-hour rolling average maximum concentration did not exceed 65 parts per billion (127.5 µg/m³) (Table 3.11). The average over the three years was 96.7 µg/m³., indicating that the CRD satisfies the CWS for ground-level ozone.

Table 3.11
4th Highest Daily Maximum 8-hour Average Ozone Concentrations at Stellys, 2004-2006

Year	**Concentration** (µg/m³)
2004	95
2005	94
2006	101
3-year average	96.7

Figure 3.11 shows mean monthly 8-hour average ozone concentrations for Christopher Point, Royal Roads, Topaz, Stellys and Saturna Island. Ozone concentrations are generally highest during the spring months of March, April and May, as well as in February at Christopher Point. This is consistent with patterns observed in previous years. Ozone concentrations are lowest in late summer-early fall (September-October), and in early winter (December). It has generally been assumed that the spring maximum is caused by intensification of stratosphere-troposphere exchange (i.e., down-welling of stratospheric ozone into the troposphere) rather than from the photochemical generation of ozone in the troposphere from precursor emissions of NO_x and volatile organic compounds (VOC).

Figure 3.11
Mean Monthly 8-Hour Averaged Ozone Concentrations at Christopher Point, Royal Roads, Topaz, Stellys and Saturna Island



Figures 3.12 and 3.13 show average daily ozone concentrations during the warmer and cooler months of the year for Topaz, Royal Roads, Stellys, Christopher Point and Saturna Island. For each station, in both the warmer and the cooler months, there is a trough in concentration levels at around 7:00am or 8:00 am PST and a peak in concentration levels at around 3:00 pm PST. During the warmer spring and summer months (Figure 3.11), the afternoon peak in ozone levels is likely caused by increased solar insolation and warmer temperatures needed to drive the chemical transformation of NO_x and VOC to form ozone. The trough present in the morning relates to increased NO_x emissions from traffic during the morning rush hour. The higher NO_x 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_x interaction, with lower NO_x levels during the daytime hours (see Figures 3.4 and 3.5), and higher NO_x levels in the evening hours.

Figure 3.12
Average Diurnal Ozone Pattern During Cooler Months (November-March)

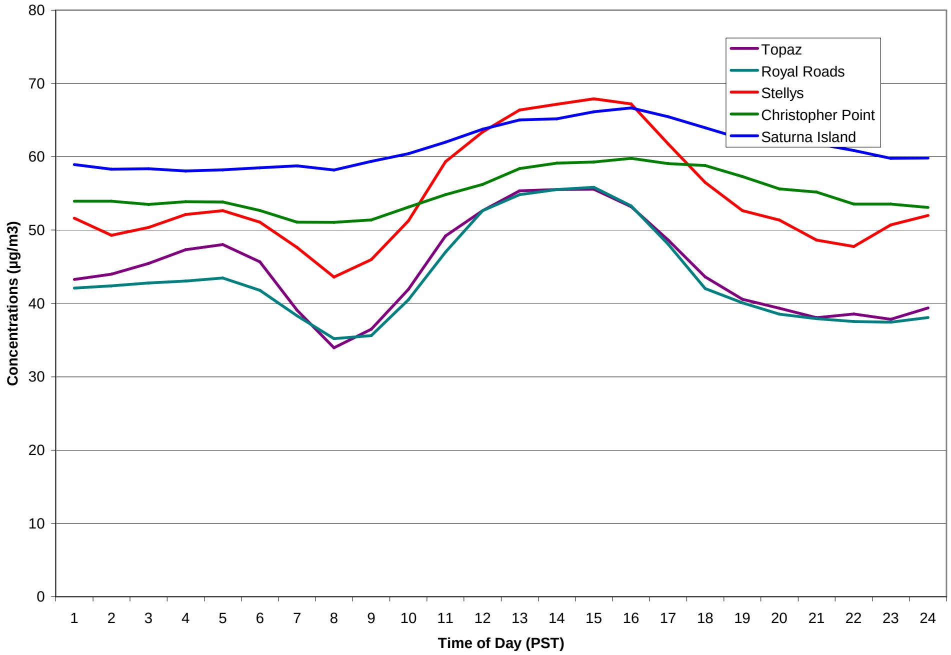
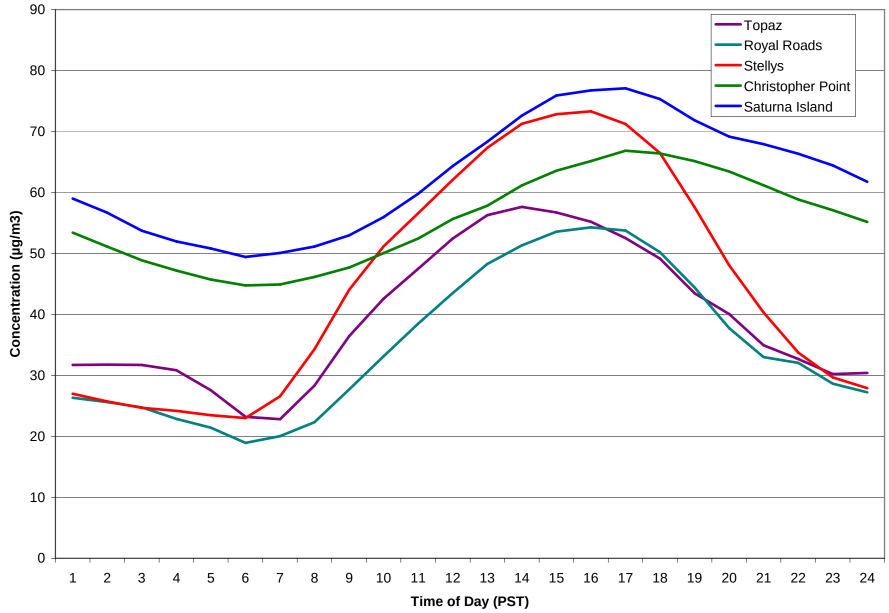


Figure 3.13
Average Diurnal Ozone Pattern During Warmer Months (April-October)



4.0 PARTICULATE MATTER

Suspended particulate matter (PM) can originate 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 dust tends to be of a larger size fraction. PM can remain suspended in air for as little as a few seconds to as long as several days or even weeks and longer. Precipitation tends to effectively remove PM from the air. 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 (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.

Primary PM describes matter emitted directly to the atmosphere, whereas secondary PM describes solid (or liquid) particles that are formed in the atmosphere from the chemical reactions of other compounds. 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[6].

Four different ambient PM sampling (measuring) devices are currently 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. Sequential high volume (Hi-Vol) samplers are used to determine 24-hour concentrations of PM_{10} on a cycle of one in every six days. One Partisol sampler is used to collect PM_{10} sequentially on the same schedule as the Hi-Vols, but utilizes a low-volume of airflow for sample collection.

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

There is also one dichotomous (Dichot) sampler, which produces 24-hour concentrations of both PM_{10} and $PM_{2.5}$ on the same one-in-six day rotation cycle. The Dichot sampler is part of the National Air Pollution Surveillance network managed by Environment Canada. However, Dichot data for 2006 was not available for analysis, and the data for 2005 was limited to only 5 samples during the month of January and first week in February of that year. Consequently, no analysis of Dichot data is provided in this report.

The three 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 lab to determine the 24-hour concentration.

It should be noted that each type of 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_{10} or $PM_{2.5}$ 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})

Table 4.1 provides a statistical summary of 24-hour average PM_{10} concentrations at five monitoring stations that are equipped with Hi-vol samplers: Victoria Topaz, Oak Bay, Braefoot Keating Elementary school and Royal Roads University. Table 4.2 shows the 24-hr average PM_{10} concentrations recorded at Stellys using a Partisol sampler. The data at Stellys were collected on the same 6-day cycle as the Hi-Vol samplers.

Table 4.1
Sequential Averaged 24-Hour Hi-Vol PM_{10} Concentrations in the CRD

Statistic	Topaz	Oak Bay	Braefoot	Royal Roads	Keating
Mean (μg/m^3)	18.4	12.7	10.6	10.8	13.3
Std. Dev. (μg/m^3)	10.2	5.1	3.9	4.3	5.4
Maximum (μg/m^3)	53.0	33.0	22.0	21	29.0
98th percentile (μg/m^3)	47	23	20	20.8	25
# > CRD Guideline (50 μg/m^3)	1	0	0	0	0
# of Samples	60	61	61	61	60
Percent Missing (%)	1.6	0	0	0	1.6

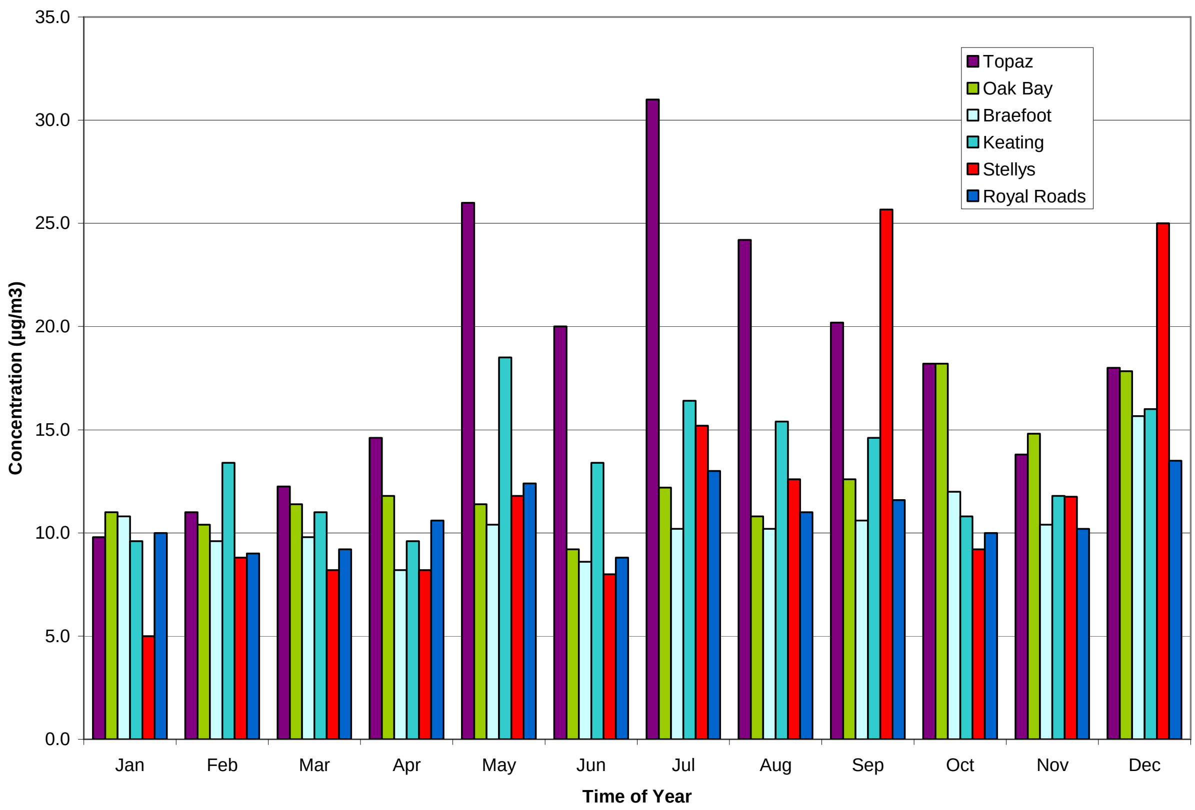
Table 4.2: 24-Hour Sequentially Averaged PM_{10} Concentration for Stellys

Statistic	Stellys
Mean (µg/m$_3$)	12.0
Std. Dev. (µg/m3)	9.0
Maximum (µg/m3)	58.0
98th percentile (µg/m3)	36
# > CRD Guideline (50µg/m3)	1
# of Samples	51
Percent Missing (%)	18

During 2006, the CRD 24-hour average guideline value of 50 µg/m^3 was exceeded at Topaz and Stellys. On May 5th, Topaz recorded a 24-hout average PM_{10} concentration of 53 µg/m^3. On this date, PM_{10} levels recorded at the other monitoring locations were much lower: 15 µg/m^3 at Stellys, 16 µg/m^3 at Oak Bay, 24 µg/m^3, at Keating Elementary, and 13 µg/m^3 at Braefoot Elementary School. Therefore, the exceedence of the guideline value was localized in the vicinity of the Topaz station and did not affect other areas of the CRD. At Stellys, the exceedence of the PM_{10} guideline value occurred on September 2nd, with a 24-hour average concentration of 58 µg/m^3. As with the exceedence of the guideline level at Topaz, the PM_{10} levels recorded at other monitoring sites were much lower: 28 µg/m^3 at Victoria Topaz, 23 µg/m^3 at Oak Bay, 25 µg/m^3 at Keating Elementary, and 18 µg/m^3 at Braefoot Elementary School. Therefore, the exceedence of the guideline value was localized in the vicinity of the Stellys station and did not affect other areas of the CRD. The date of the PM_{10} exceedence at Stellys coincided with the Saanich Fair. It is possible that increased traffic levels for the Fair contributed to the elevated levels observed at Stellys on September 2nd.

Figure 4.1 shows the monthly averaged 24-hour PM_{10} concentrations in the CRD at each of the five monitoring sites. During the cooler months, (November to April), the concentrations measured at all the stations were lower and similar in magnitude (exception being Stellys in December and January). This is likely because higher precipitation in winter suppresses fugitive dust emissions. Since winter precipitation is generally not localized, the whole CRD experiences similar rainfall intensities and amounts, leading to similar PM_{10} concentrations throughout. In the warmer months (May to August), Topaz had significantly higher PM_{10} levels than at other locations, and PM_{10} concentrations were somewhat higher at Keating from May through September than in the first four months of the year. This is likely due to drier conditions which tend to result in more roadway dust generation, and there is less precipitation to remove the particulate matter from the air. By comparison, PM_{10} levels at Oak Bay showed little variability in the first nine months of the year, increasing somewhat during October through December. The PM_{10} levels at Stellys displayed no distinct patter of seasonal variability, with the exception that levels were highest in October and December.

Figure 4.1
Mean Monthly 24-Hour Average PM_{10} Concentrations in the CRD



4.2 PARTICULATE MATTER ($PM_{2.5}$)

Table 4.3 shows the hourly averaged $PM_{2.5}$ concentrations at three of the four TEOM-equipped monitoring stations in the CRD: Victoria Topaz, Royal Roads University, and Christopher Point. Data for the Stellys station were considered to be invalid due to technical difficulties with the $PM_{2.5}$ monitor.

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[7]. For this reason, the hourly averaged $PM_{2.5}$ values should continue to be reported for the CRD.

[7] 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
Hourly Averaged $PM_{2.5}$ Concentrations at TEOM Sites in the CRD

Percentile Values 5	25	50	75	98	99	Max µg/m³	Min µg/m³	Mean µg/m³	Std. Dev. µg/m³	Missing Values % of Total Hours
Victoria Topaz										
0	2	4	7	22	26	74.0	0	5.6	5.5	1.2
Royal Roads University										
0	1	3	6	15	18	57.0	0	4.0	4.0	1.5
Christopher Point										
0	2	4	6	12	15	33.0	0	4.5	3.1	24.7

Table 4.4 provides a statistical summary of the 24-hour averaged $PM_{2.5}$ concentrations at three monitoring locations.

Table 4.4
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
5	25	50	75	98	99						% of Total 8-h Averages
Victoria Topaz											
2	3	5	7	14	15	22.8	0.6	5.6	3.1	0	1.1
Royal Roads University											
1	2	4	5	11	11	15.7	0.5	4.0	2.4	0	0.5
Christopher Point											
2	3	4	6	10	11	12.8	0.9	4.5	2.0	0	25.5

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 have 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[8]. 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. Therefore, Stellys was not included in the determination of CWS achievement.

Table 4.5 lists the 98th percentile $PM_{2.5}$ concentrations for 2004, 2005, and 2006 at the Topaz and Royal Roads monitoring sites. The average 98th percentile over the 3 consecutive years was 14.4 µg/m³. Therefore, the CRD is currently in compliance with the CWS for respirable particulate matter.

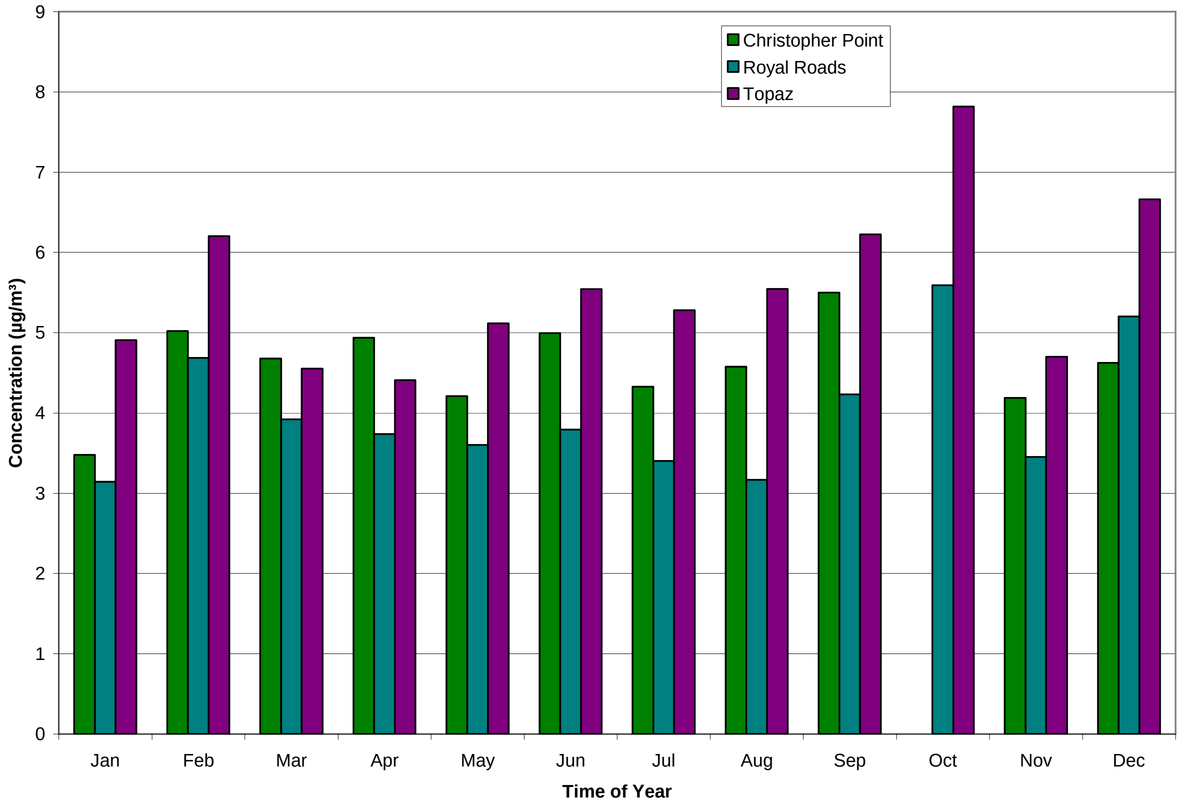
Table 4.5
98th Percentile $PM_{2.5}$ Concentrations for Topaz and Royal Roads (2004-2006)

Station	2004 (µg/m³)	2005 (µg/m³)	2006 (µg/m³)
Victoria Topaz	22	14	14
Royal Roads University	15	11	11

Figure 4.2 shows the monthly average $PM_{2.5}$ concentrations from the TEOM samplers. The month-to-month variations in $PM_{2.5}$ levels at the three sites were fairly similar, although Victoria Topaz had slightly higher concentrations than Christopher Point and Royal Roads University. This is probably due to higher traffic levels near the Topaz station (i.e., increased road dust and vehicle emissions on Blanshard Street).

Figures 4.3 and 4.54show the monthly average diurnal $PM_{2.5}$ concentrations for the TEOM sites during the cooler (November-March) and warmer (April-October) months of the year. The patterns indicate pronounced morning and evening peaks in $PM_{2.5}$ concentrations at Victoria Topaz during all seasons, as well as at Royals Roads during the cooler months. The morning peaks are attributable to rush hour traffic as well as the breakup of morning inversion layers in the atmosphere, while the evening peaks are more likely to be associated with the re-establishment of a lower mixed layer in the atmosphere. At Christopher Point, there is a smaller increase in $PM_{2.5}$ levels in the evening during cooler months of the year, but not so during the warmer months.

Figure 4.2
Mean Monthly 24-Hour Average $PM_{2.5}$ Concentrations in the CRD



[8] 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 4.3: Average Diurnal $PM_{2.5}$ Pattern in the CRD during the Cooler Months (November – March)

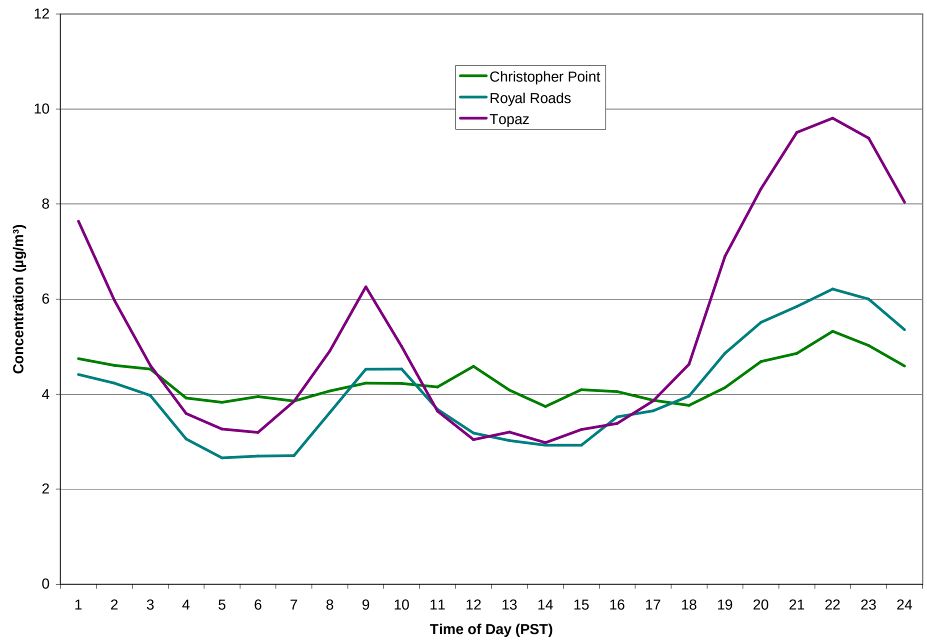
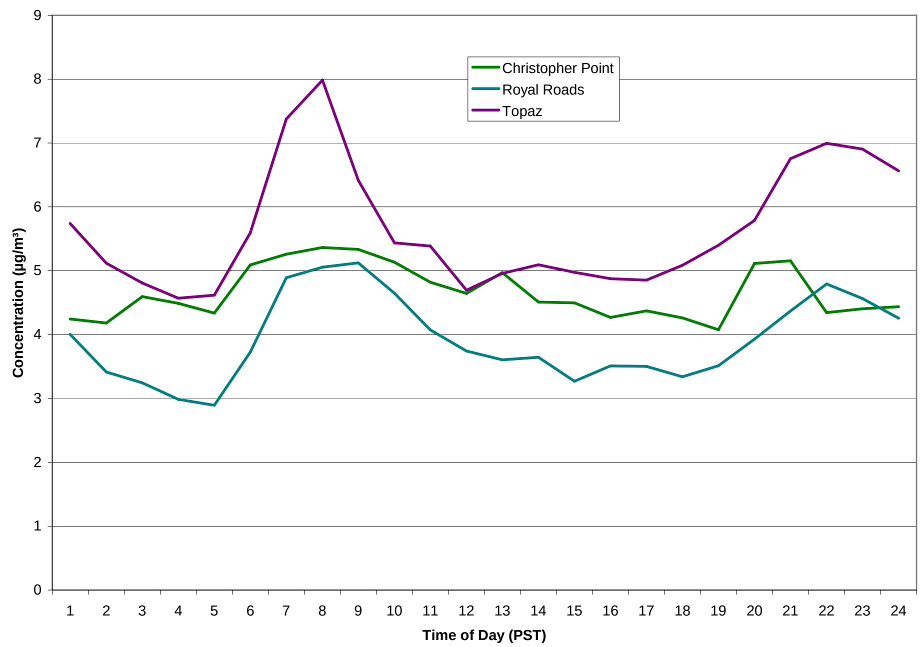


Figure 4.4: Average Diurnal $PM_{2.5}$ Pattern in the CRD during the Warmer Months (April – October)



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 exceedences.

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.

Victoria Topaz and Satruna Island are the only two stations that have enough continuous data for the tool to determine whether potential trends exist. Table 5.1 shows the trend analysis summary for 9 continuous years (1998-2006) at these two stations. The data indicate that SO_2 concentrations at Victoria Topaz have been steadily declining over this period at both locations. The decline at Victoria Topaz was detectable in both the 98th percentile 24-hour average concentrations, as well as for the annual average concentrations. This trend was also observed at Saturna Island at the 98th percentile over the period 1998-2005, although the decline in annual average values was lower than at the Topaz station. While these trends are statistically significant, it should be noted that the absolute values of the SO_2 concentrations at both locations are relatively small.

Table 5.1
Summary of Trend Analysis for Victoria Topaz and Saturna Island (1998 – 2006)

Measure	CO	NO_2	SO_2	O_3	$PM_{2.5}$	PM_{10}
	Victoria Topaz					
Annual mean	No trend	No trend	-14%/year	No trend	No trend	No trend
Annual 98th Percentile	No trend	No trend	-13%/year	No trend	No trend	No trend
	Saturna Island					
Annual mean	--	--	-5%/year	No trend	--	--
Annual 98th Percentile	--	--	-13%/year	No trend	--	--

Note: “-“ denotes no data or not enough data for trend analysis.
A minimum of four years of 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.

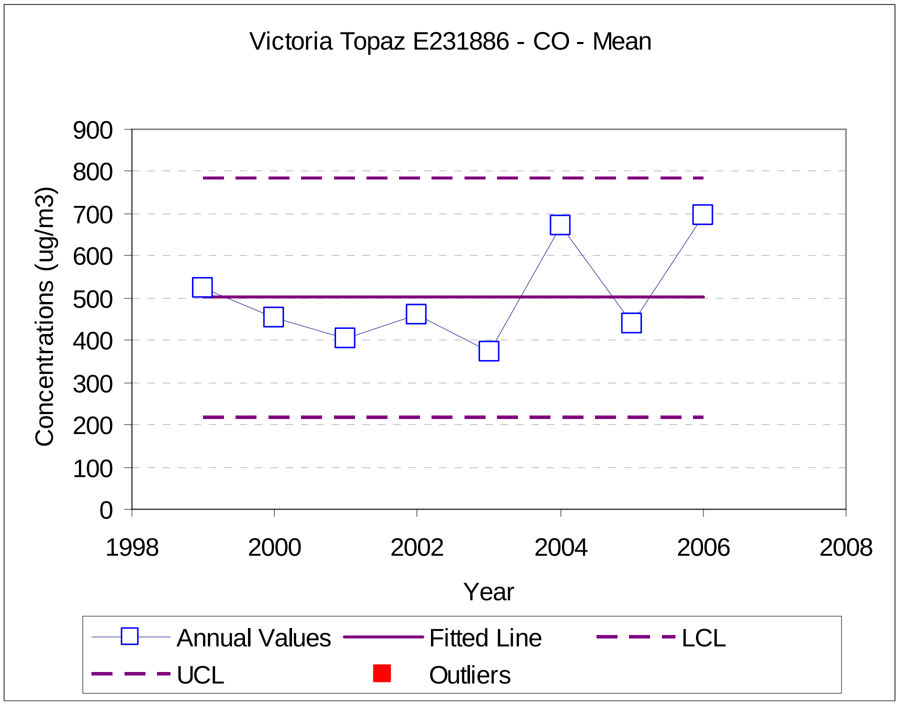
Although the overall trend in SO_2 concentrations at both Victoria Topaz and Saturna Island has been downward, there is a suggestion in Figures 5.3 and 5.13 that this trend may have levelled off since 2004 at Victoria Topaz and since 2002 at Saturna Island. Additional data collection in future years will be required to confirm this suggestion.

No other trends were found for CO, NO_2, O_3, $PM_{2.5}$ or PM_{10} data, although there appears to be the suggestion of a weak downward trend in mean $PM_{2.5}$ concentrations post-2002 at both Topaz and Royal Roads.

Figures 5.1 to 5.13 show the annual mean and 98th percentile concentration trends for each air contaminant for the period of record at Victoria Topaz, Royal Roads, Stellys and Saturna Island. 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)[9].

[9] 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.

Figure 5.1
CO Trend at Victoria Topaz



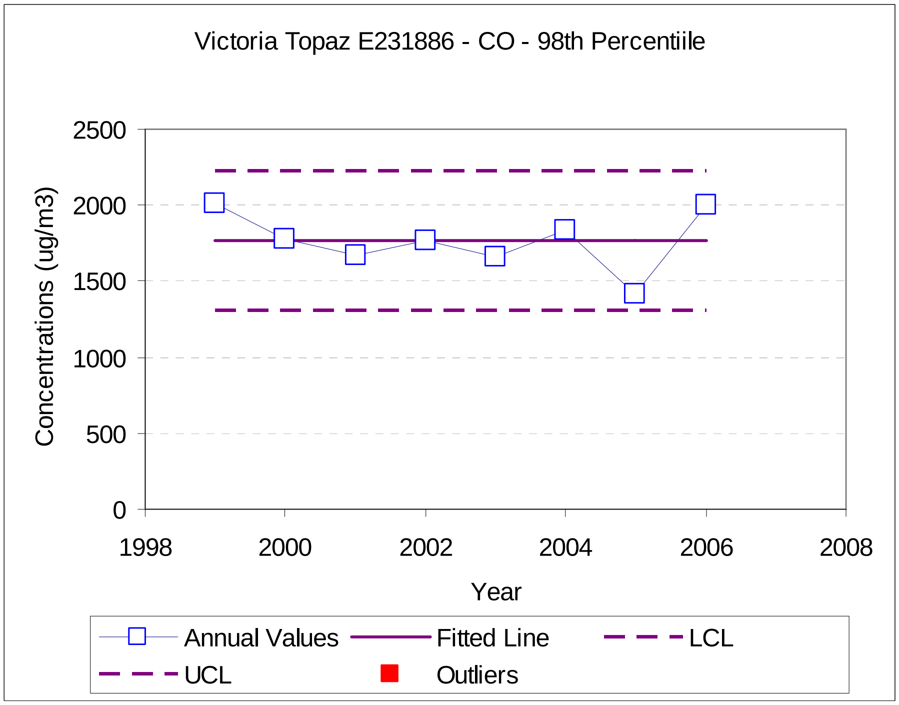
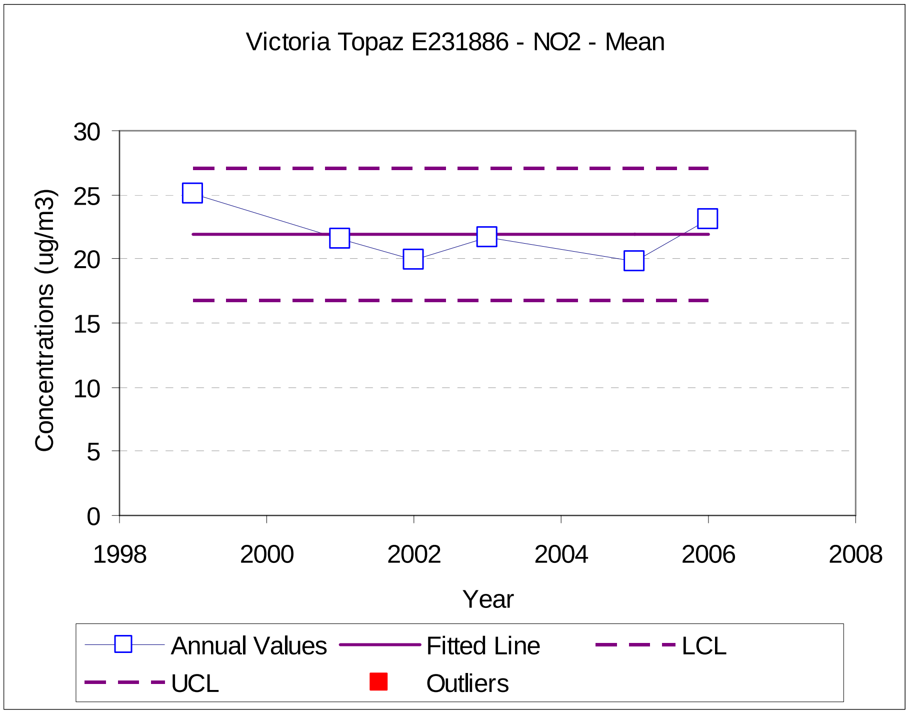


Figure 5.2
NO_2 Trend at Victoria Topaz



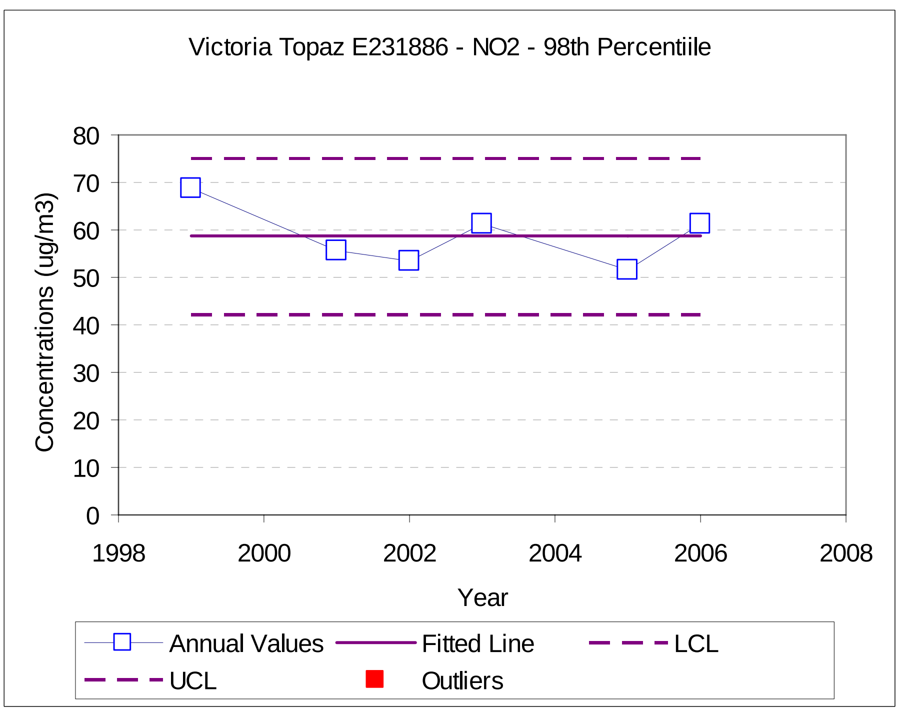


Figure 5.3
SO_2 Trend at Victoria Topaz

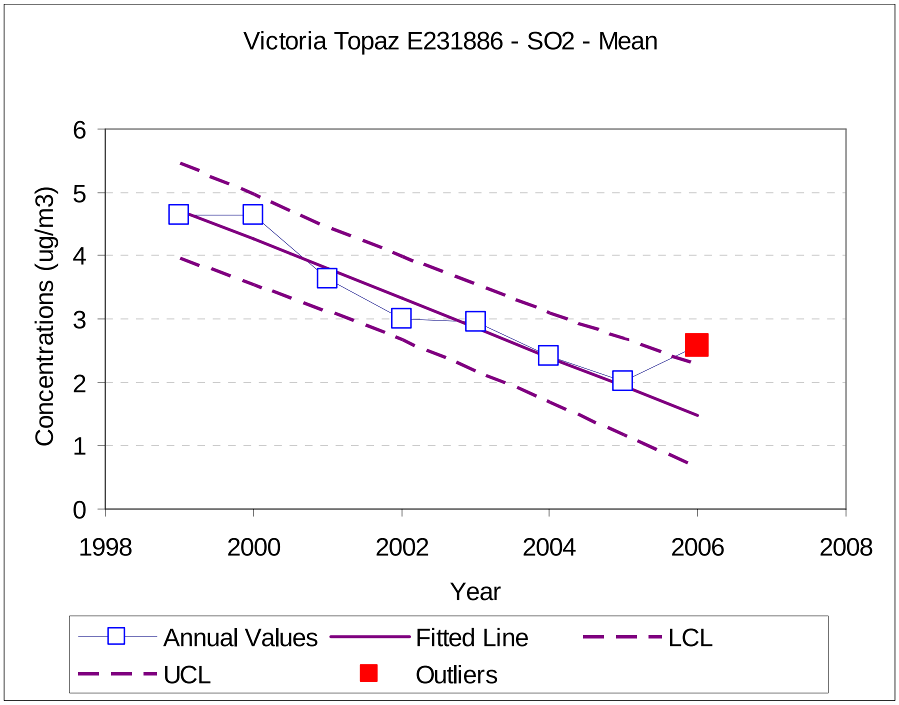
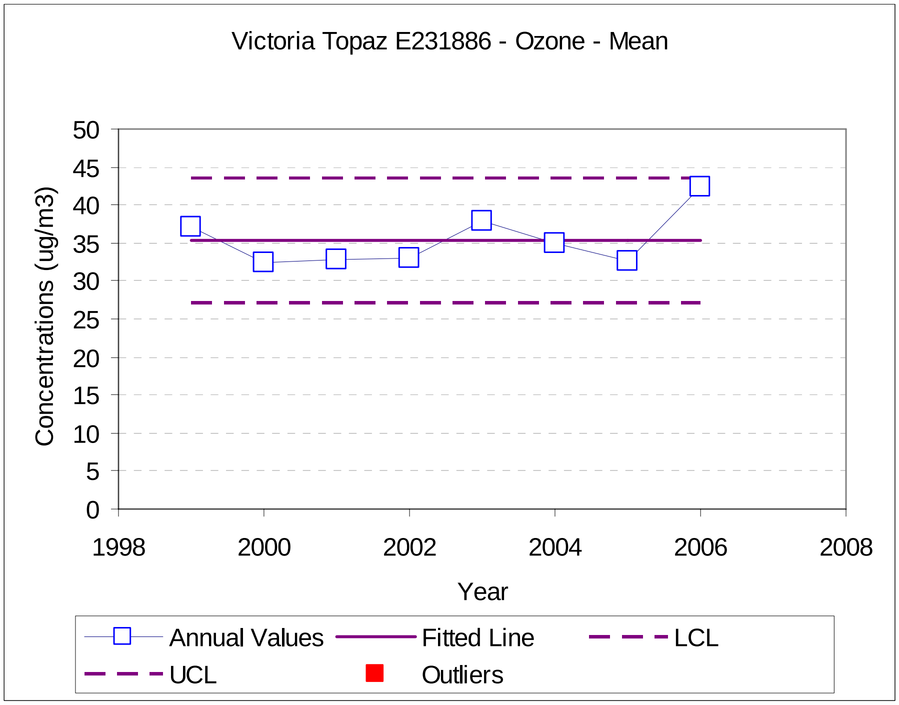


Figure 5.4
O_3 Trend at Victoria Topaz



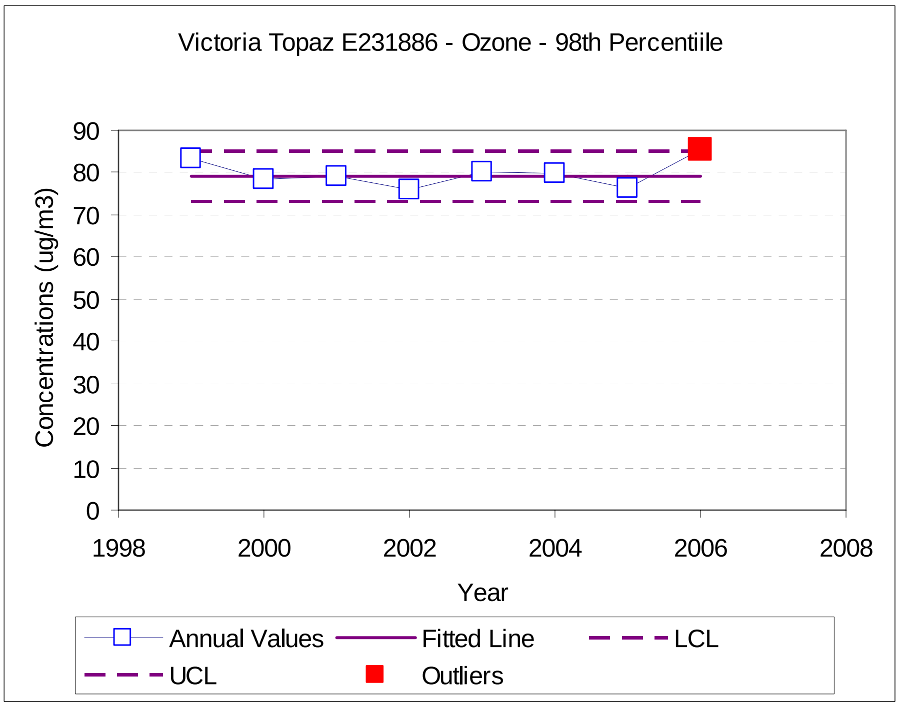
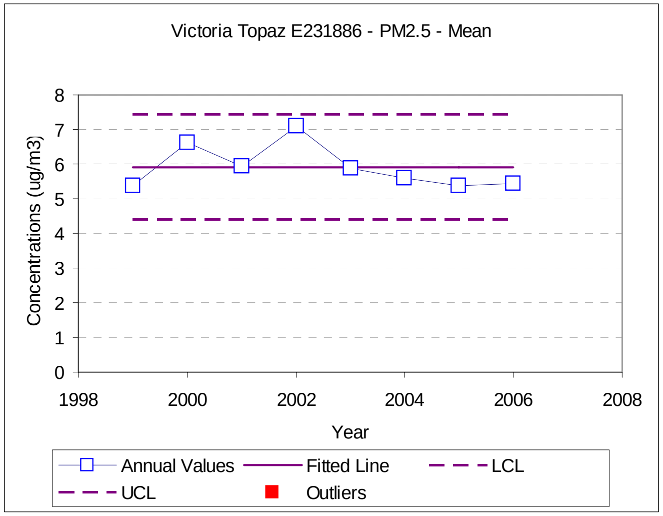
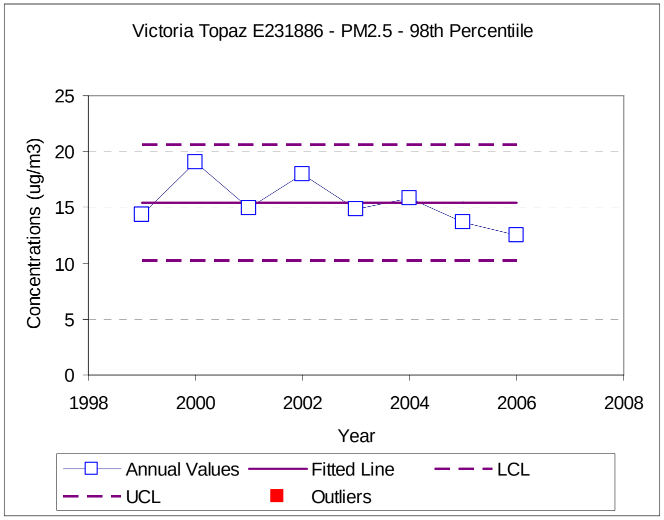


Figure 5.5
$PM_{2.5}$ Trend at Victoria Topaz





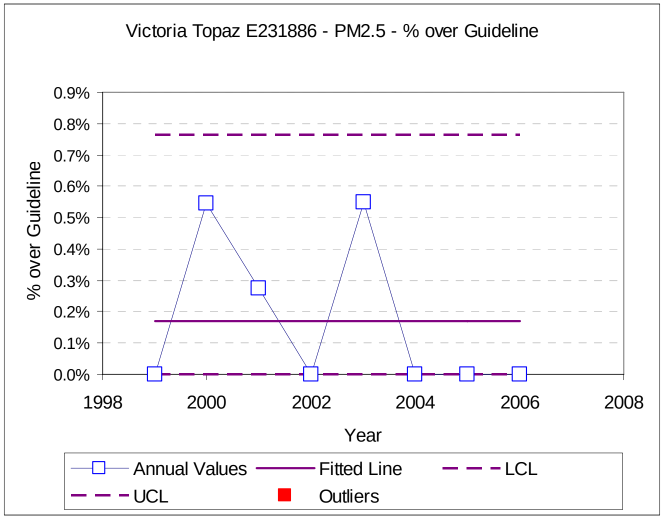


Figure 5.6
PM_{10} Trend at Victoria Topaz

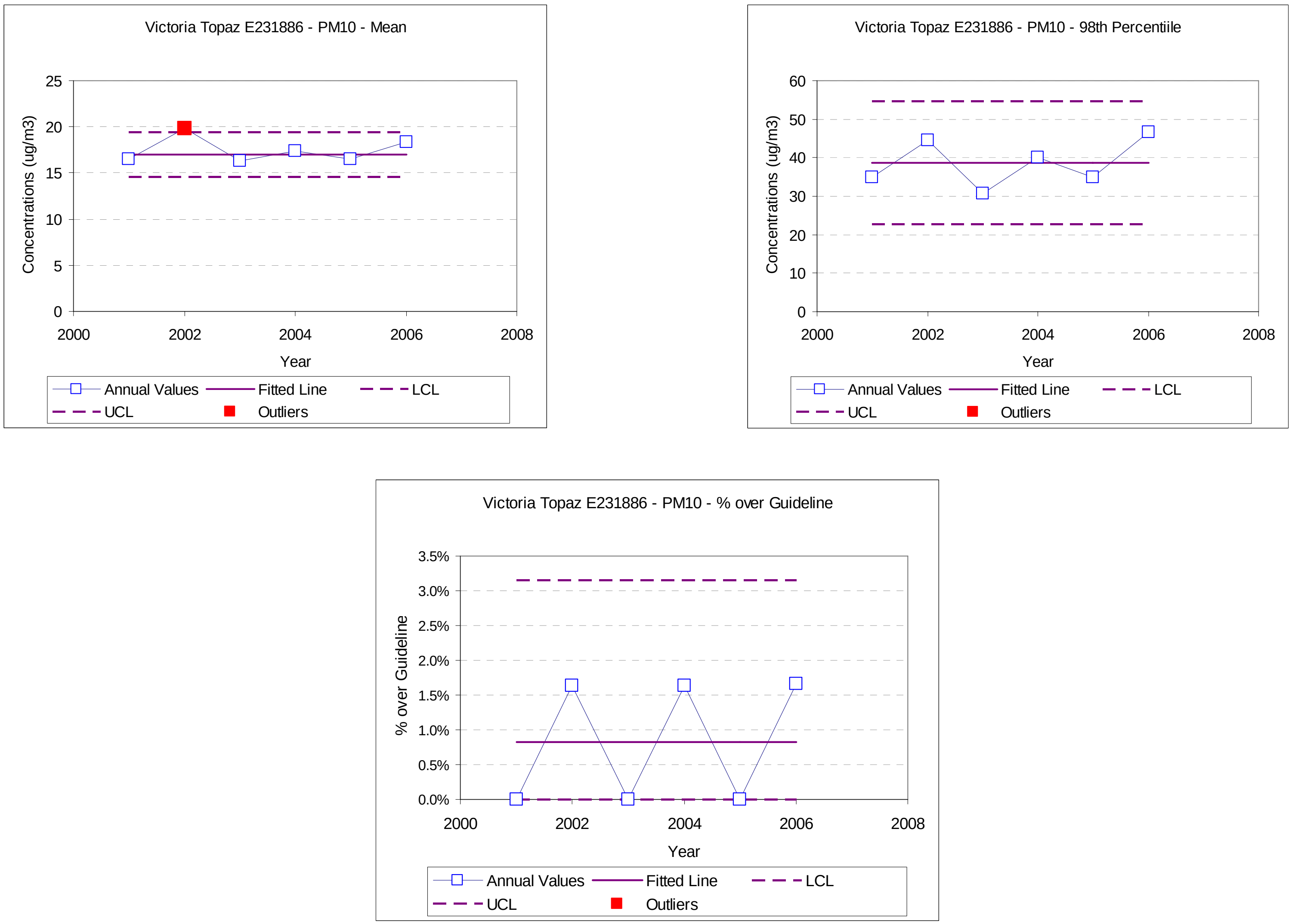
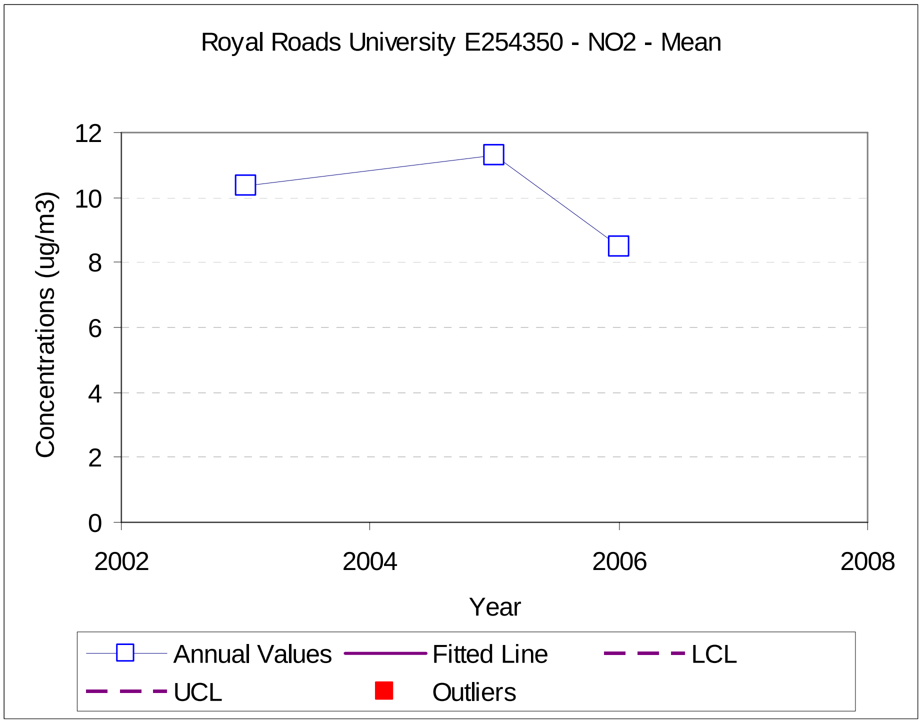


Figure 5.7
NO_2 Trend at Royal Roads



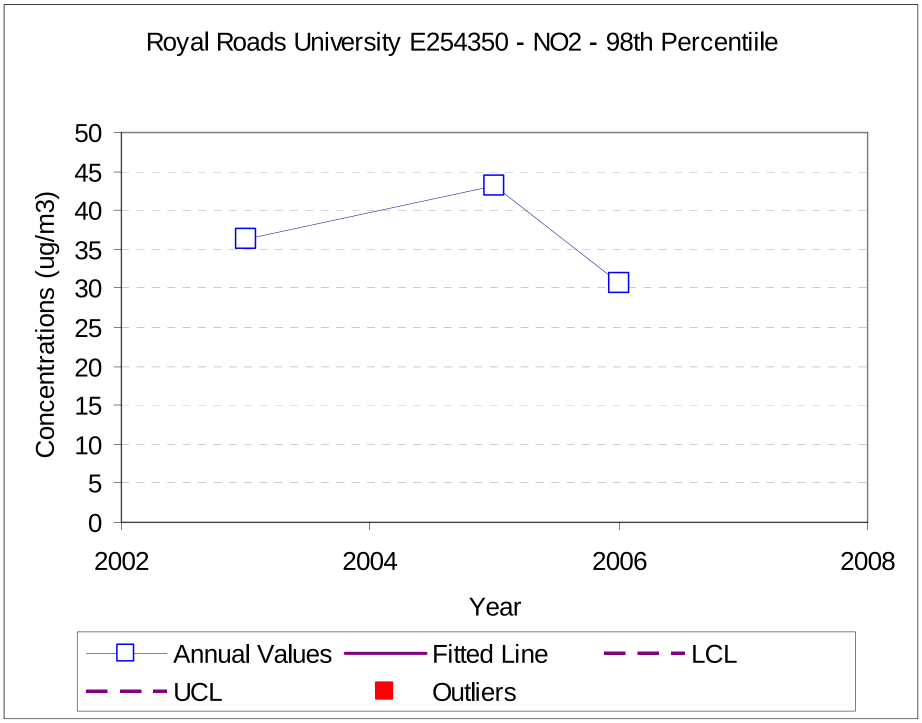
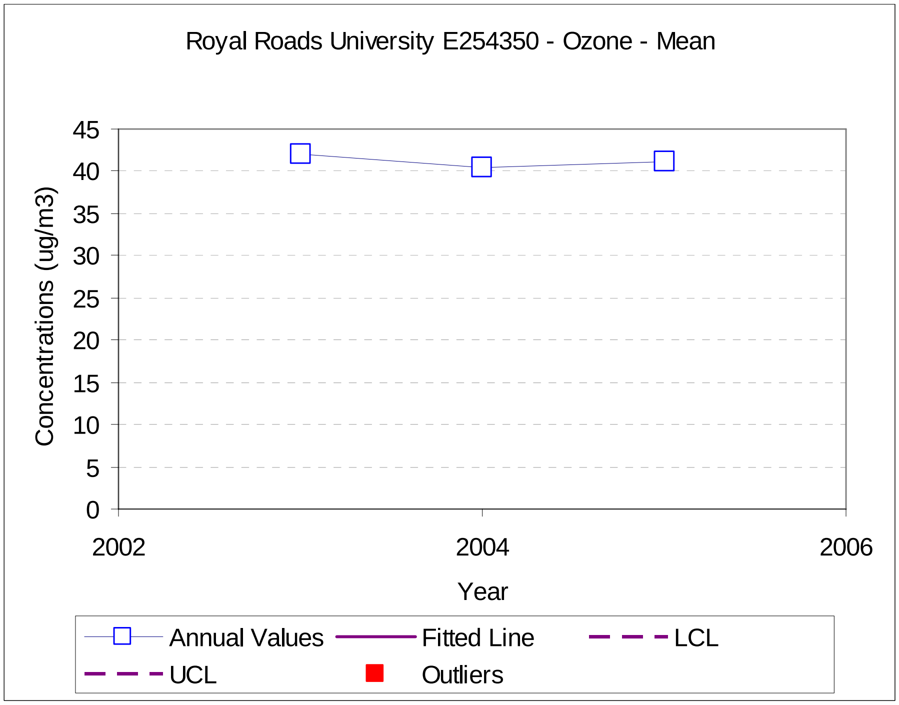


Figure 5.8
O_3 Trend at Royal Roads



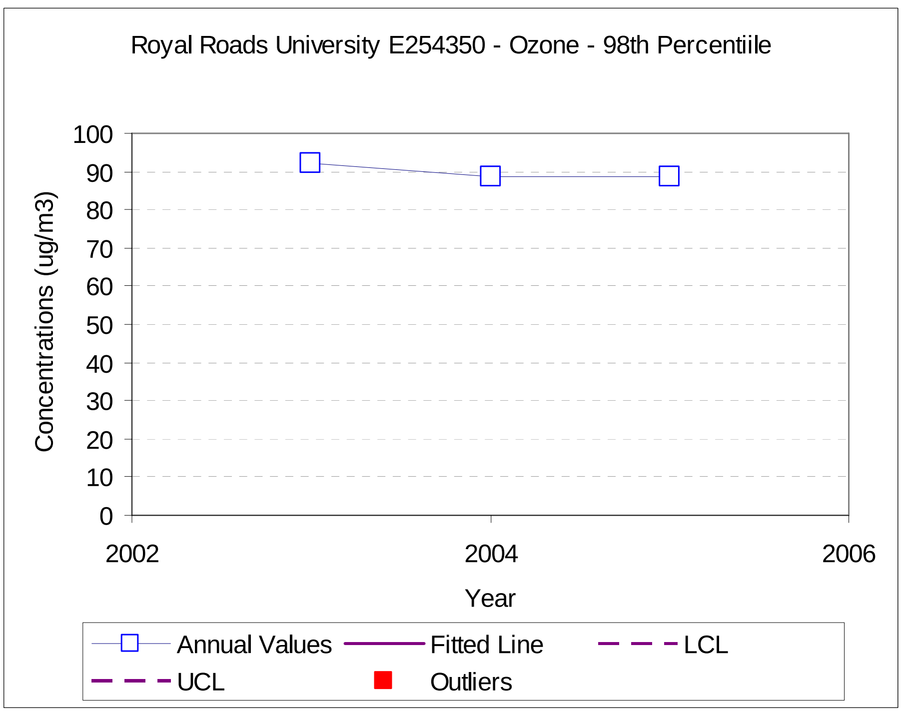
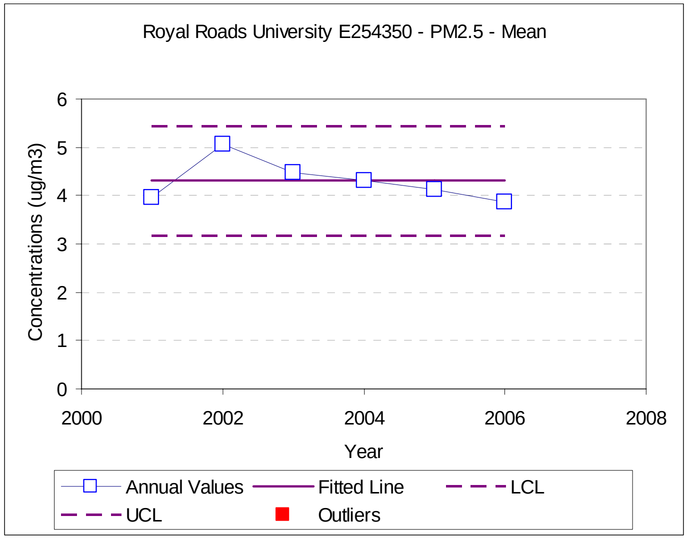
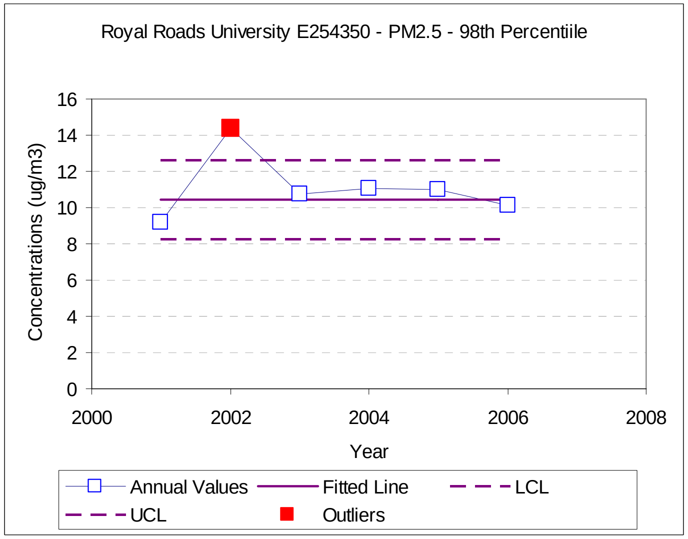


Figure 5.9
$PM_{2.5}$ Trend at Royal Roads





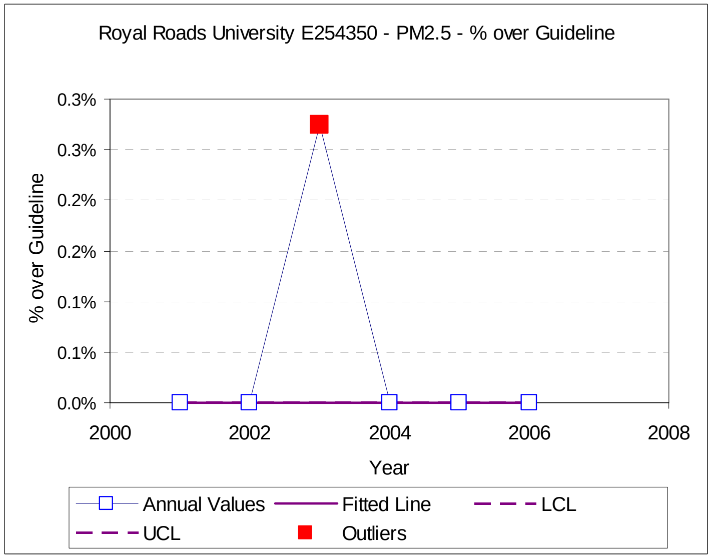
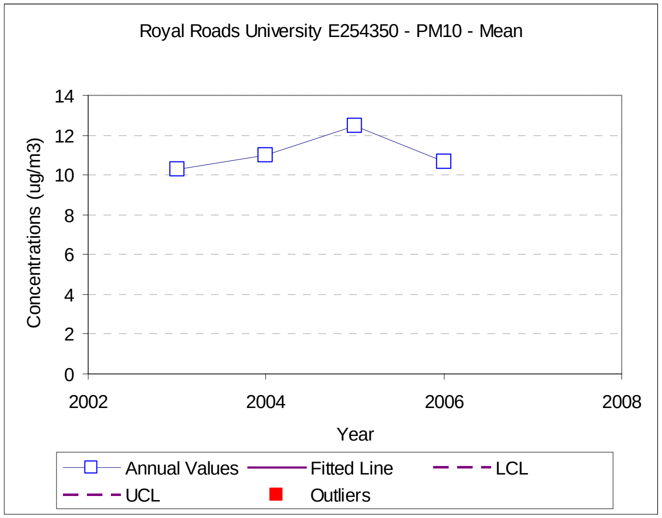
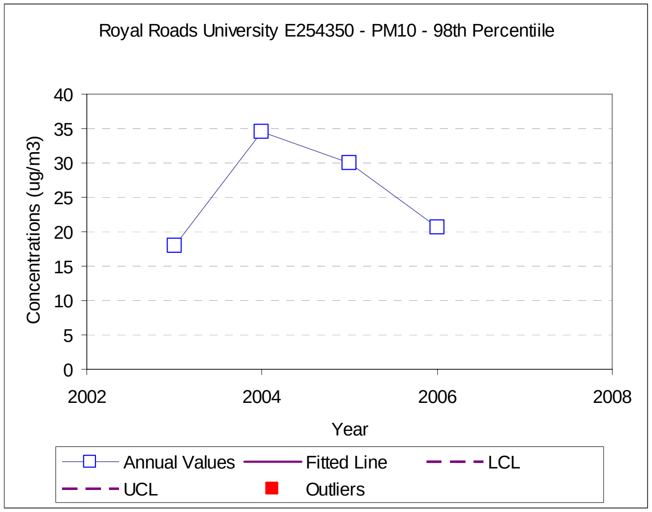


Figure 5.10
PM_{10} Trend at Royal Roads





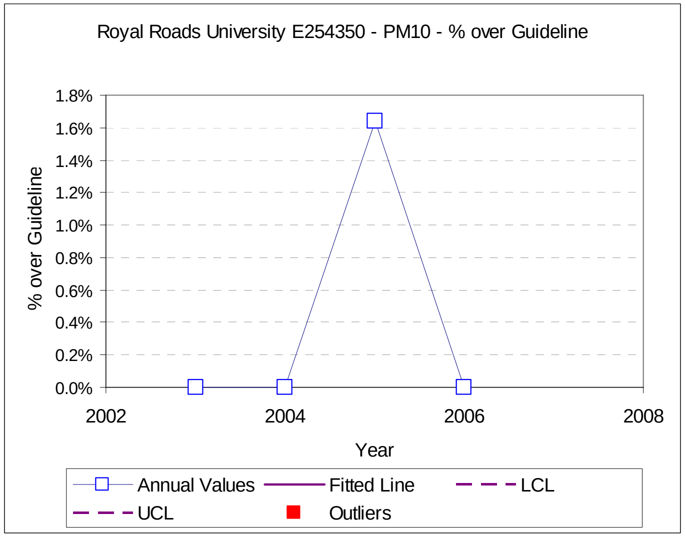
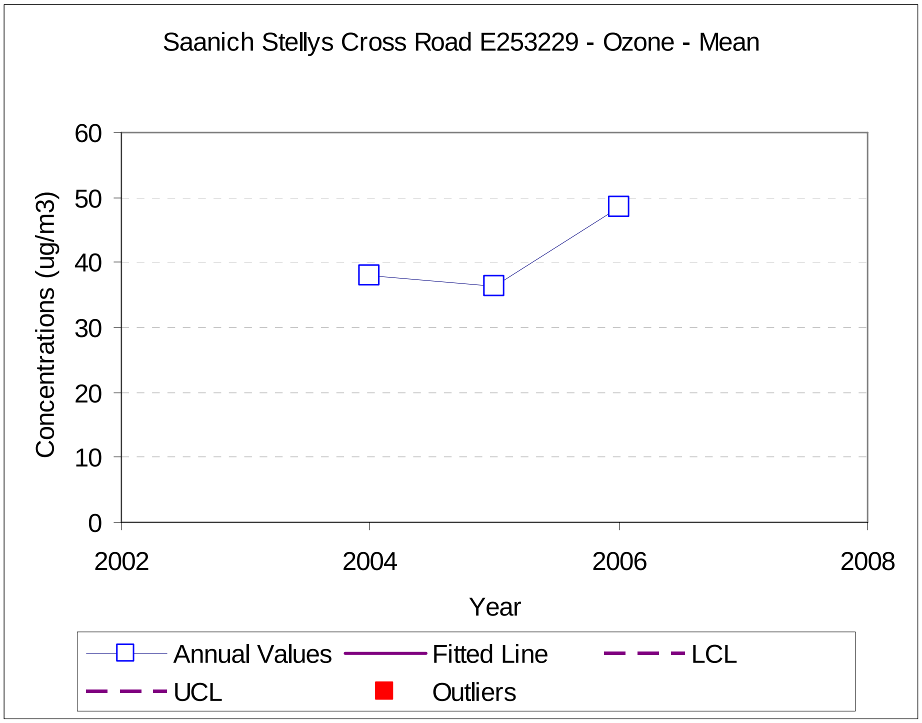


Figure 5.11
O_3 Trend at Stellys



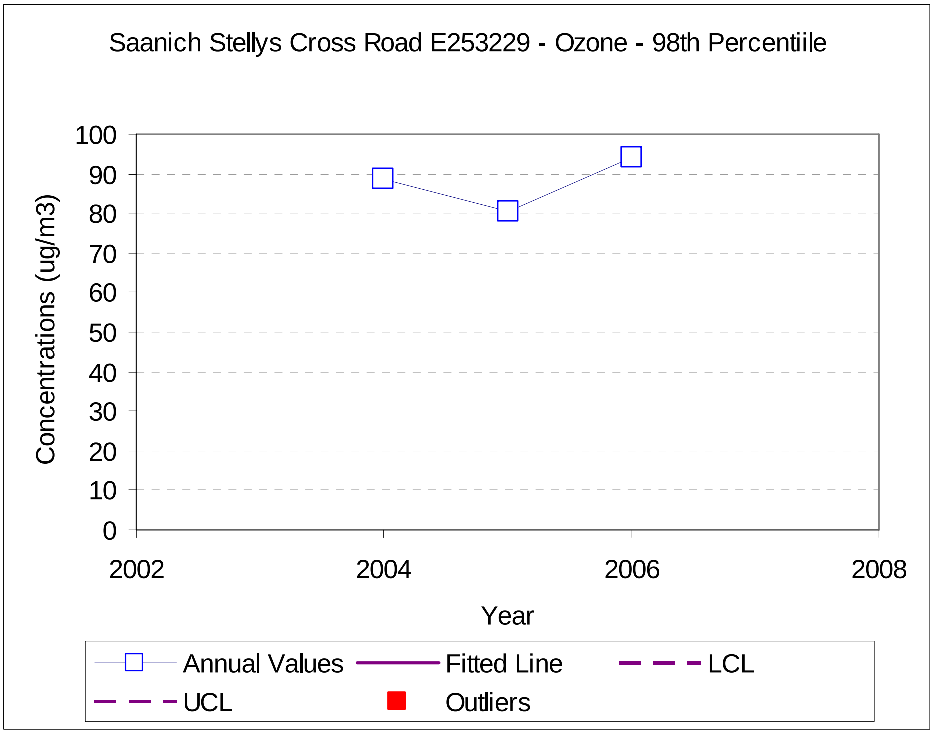
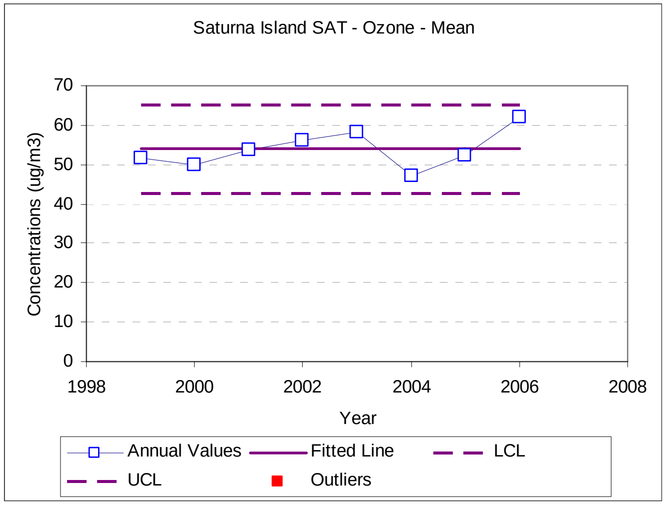
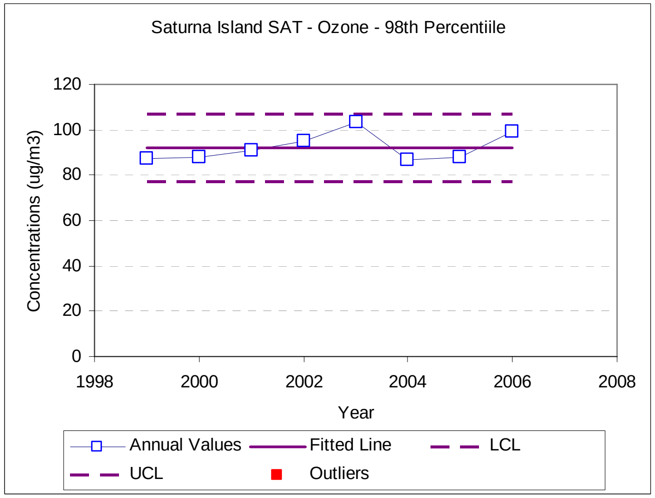


Figure 5.12
O_3 Trend at Saturna Island





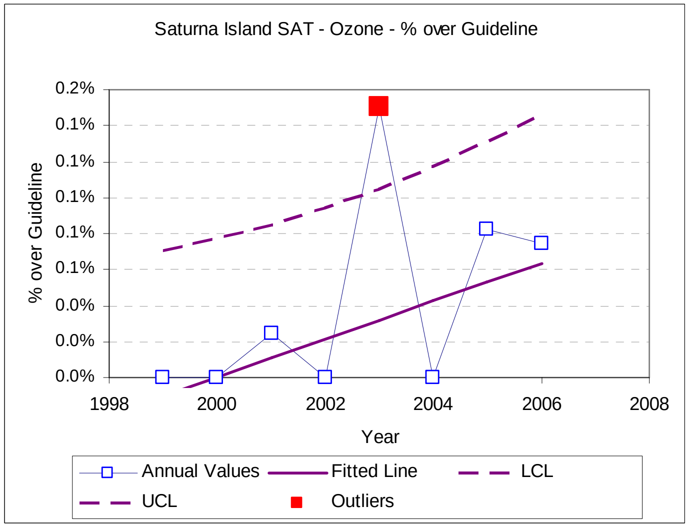
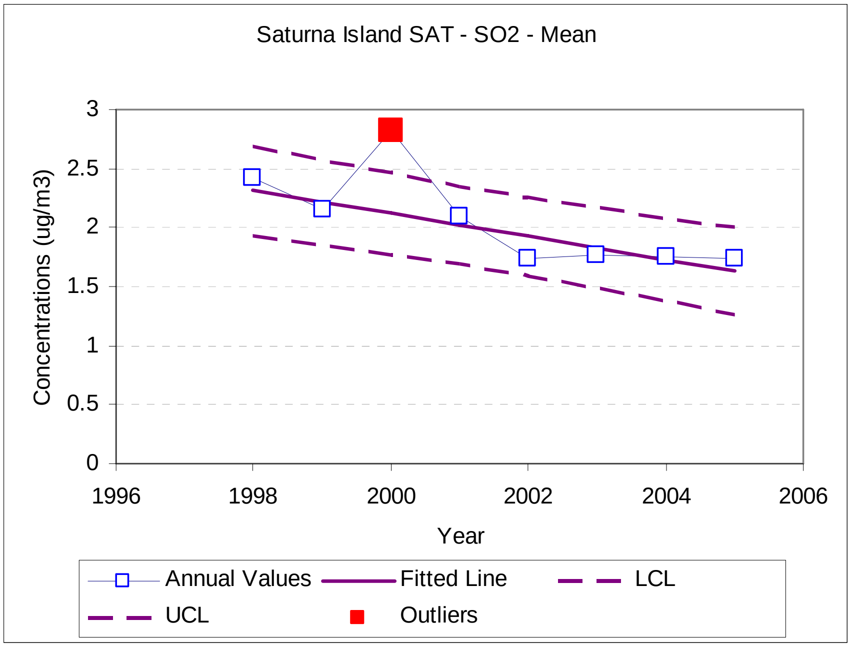
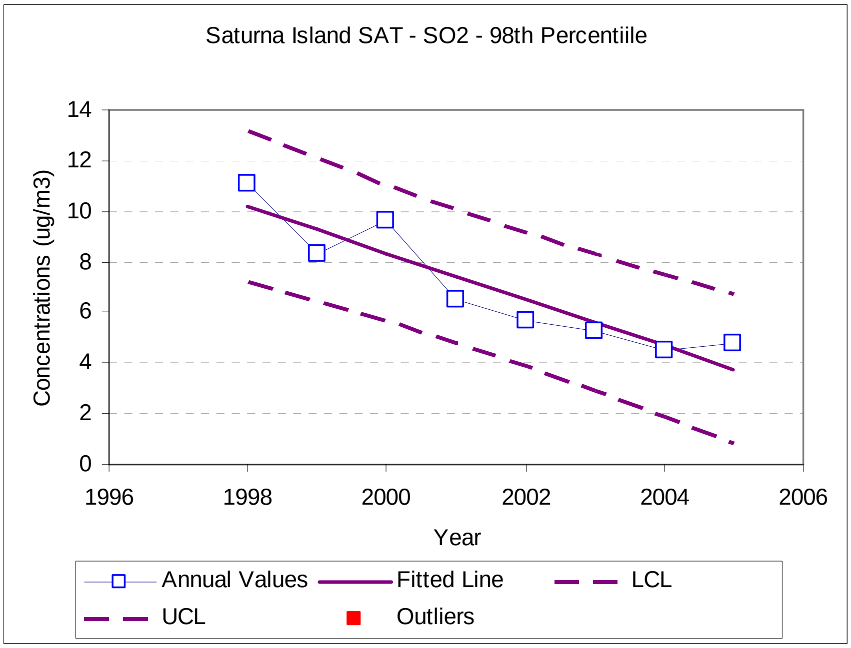


Figure 5.13
SO_2 Trend at Saturna Island





6.0 CONCLUSION

A summary of comparisons of maximum pollutant concentrations in 2006 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 2006. There were two exceedences of the CRD guideline for PM_{10} and two exceedences of the CRD guideline for ground level ozone. 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 exceedences were localised in the vicinity of a single monitoring location in each case. There were no exceedences of the CRD guidelines for other common air contaminants, and no exceedences of any provincial/federal objectives or standards for any air contaminant over the year. At this time, there is no indication that the Canada Wide Standards (CWS) for ground level ozone and respirable particulate matter ($PM_{2.5}$) will be exceeded at the implementation date (2010).

Table 6.1
Summary of Maximum Pollutant Concentrations (µg/m³) in the CRD for 2006

		Air Quality Criteria		**Monitoring Station**							
Contaminant	Averaging Period	CWS	CRD Guideline	Victoria Topaz	Stellys	Royal Roads	Christopher Point	Oak Bay	Braefoot	Keating	Saturna Island
CO	8-hour*		5500	3071.4	737.5		1450				
NO_2	1-hour*		200	97.5	66.9	53.5	65				
SO_2	24-hour*		125	15.1			8.6				N/A
O_3	8-hour**		120	108.3	113.5	101.6	123.2				**123.5**
PM_{10}	24-hour*		50	**53** (HiVol)	**58** (Partisol)	21 (Hi-Vol)		33 (HiVol)	22 (HiVol)	29 (HiVol)	
$PM_{2.5}$	24-hour*		25	22.8 (TEOM)		15.7 (TEOM)	12.8 (TEOM)				
Canada Wide Standards											
Ozone	8-hour**	127.6[1]		96.7[4]							
$PM_{2.5}$	24-hour*	30[2]		14.4[3]							

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.
3 Compliance determined using data from Victoria Topaz and Royal Roads University. Representative of the year 2006 only.
4 Compliance determined using data from Stellys . Representative of the year 2006 only.
N/A – not yet available

The new long term monitoring site at Christopher Point began operation in September of 2005, and 2006 was the first full year of data analysis for this location. Data collection rates were reasonably good for the year, with some exceptions. Over 60% of the CO and NO_x data were missing for the Stellys station, and almost 40% of the ozone monitoring data were missing from the Royal Roads station record. Almost 25% of the $PM_{2.5}$ monitoring data were missing for the Christopher Point site. As well, all of the $PM_{2.5}$ data and 18% of the PM_{10} data at the Stellys site were missing. This level of missing data is higher than in 2005.

On May 16th, an 8-hour ground-level ozone concentration of 123.2 µg/m³ was recorded at Christopher Point, which is slightly above the guideline value of 120 µg/m³. The exceedence occurred during the spring, when ozone concentrations are typically at the highest levels of the year in the CRD. The exceedence was not experienced throughout the CRD, as two other urban monitoring stations showed levels below the guideline during the same period. A similar ozone level of 123.5 µg/m³ was recorded at Saturna Island on September 3rd, constituting a second exceedence of the CRD guideline value.

One of the two PM_{10} exceedences occurred at the Victoria Topaz monitoring station monitoring station on May 5th of the year, with a 24-hour average concentration of 53 µg/m^3. Concentrations recorded at each of the other PM_{10} stations in the CRD on that date were much lower, indicating that the high PM_{10} concentration was not experienced throughout a large portion of the CRD. The likely cause of the high concentration at the Victoria Topaz site on this date could not be determined. A second PM_{10} exceedence occurred at the Stellys monitoring station on September 2nd. On this same day, PM_{10} concentrations recorded at the other monitoring stations were significantly lower than the Stellys value of 58 µg/m³. This suggests that the level of exposure to the higher PM_{10} concentrations at Stellys was low for the CRD as a whole and likely contained to the area near the monitoring station.

The level of community exposure to the two slight exceedences of the CRD ozone guideline level is uncertain, since the Victoria Topaz, Stellys and Royal Roads stations recorded lower ozone concentrations than that measured at Christopher Point and Saturna Island during the same periods. The number of people that may have been exposed to the higher ozone concentrations at Christopher Point is likely very low. As such, the related health effects to the ozone exceedences cannot be determined within a suitable degree of confidence.

The two PM_{10} exceedences appear to have been representative of localized dust in the air near the Victoria Topaz and Stellys stations. Because of the limited nature of these events, the related health effects to the PM_{10} exceedence cannot be determined within a suitable degree of confidence.

With respect to long term trends in air quality in the CRD, SO_2 concentrations at the Victoria Topaz site are low and have been declining at a rate of about 13-14% per year over the period 1998-2006 in terms of both the mean and peak (98th percentile) concentrations. A similar decline in SO_2 concentrations at the 98th percentile level has also occurred at Saturna Island, although the decline in the mean annual concentration has been lower at 5% per year. There is also a suggestion from the data that these downward trends may have begun to level off after 2002. No other statistically significant trends were identified for any of the other pollutants in the monitoring network, although in most cases the period of record is insufficient to determine such trends. There appears to be a suggestion of a very weak downward trend in $PM_{2.5}$ concentrations at both the Victoria Topaz and Royal Roads University monitoring locations, but these are not statistically significant trends to date.

There were five meteorological stations within the CRD that collected data during 2006 that were considered for inclusion to the 2006 air quality report. Data from the Environment Canada station at Saturna Island could not be obtained in timely fashion. Wind speed and direction data were summarised for each station and a separate summary of wind direction was produced to portray the seasonal differences in wind flow for the CRD as a whole. 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 2006 Monthly Climate Data for Victoria International Airport

Month	Mean Max Temp	Mean Temp	Mean Min Temp	Extr Max Temp	Extr Min Temp	Total Rain	Total Snow	Total Precip
	Cº	**Cº**	**Cº**	**Cº**	**Cº**	**mm**	**cm**	**mm**
Jan	9.4	6.5	3.6	13.8	-1.8	222.2	0	222.2
Feb	8.4	4.4	0.4	12.8	-4.5	66.7	0.6	67.3
Mar	10.7	6.6	2.5	14.5	-2.5	35.8	11.8	47.6
Apr	13.7	9.2	4.7	21.5	0.8	42.8	0	42.8
May	17.9	12.7	7.4	25.9	1.1	35.4	0	35.4
Jun	21.1	16.1	11	30.2	7.3	40.6	0	40.6
Jul	23.6	17.8	12	33.4	8.2	6.9	0	6.9
Aug	22.3	16.6	10.9	25.9	9.2	2.4	0	2.4
Sep	20.3	14.8	9.2	29.2	6.1	29.7	0	29.7
Oct	14.8	10.2	5.6	21.3	-2.6	45.6	0	45.6
Nov	8.8	5.7	2.5	17.1	-10.5	310.5	41.7	351.9
Dec								
Sum						**838.6**	**54.1**	**892.4**

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

	Mean Max Temp	Mean Temp	Mean Min Temp	Extr Max Temp	Extr Min Temp	Total Rain	Total Snow	Total Precip
	°C	**°C**	**°C**	**°C**	**°C**	**mm**	**cm**	**mm**
Jan	6.9	3.8	0.7	15.4	-15.6	121.8	15.2	137.0
Feb	8.4	4.9	1.4	18.3	-15.0	98.8	9.0	107.8
Mar	10.5	6.4	2.3	21.4	-10.0	75.8	0.0	75.8
Apr	13.4	8.8	4.1	26.3	-3.9	44.5	0.0	44.5
May	16.6	11.8	6.9	31.5	-1.1	36.5	0.0	36.5
Jun	19.3	14.4	9.3	33.3	2.1	32.0	0.0	32.0
Jul	21.9	16.4	10.8	36.1	4.1	19.5	0.0	19.5
Aug	22.0	16.4	10.8	34.4	4.4	23.9	0.0	23.9
Sep	19.4	14.0	8.4	31.1	-1.1	30.4	0.0	30.4
Oct	14.2	9.8	5.3	27.6	-4.4	75.6	0.2	75.8
Nov	9.5	6.1	2.7	18.3	-13.3	144.4	3.3	147.7
Dec	6.9	4.0	1.0	16.1	-14.4	138.3	13.8	152.1
Sum						**841.5**	**41.5**	**883.0**

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

Figure A.1
Monthly Temperatures at Victoria International Airport in 2006

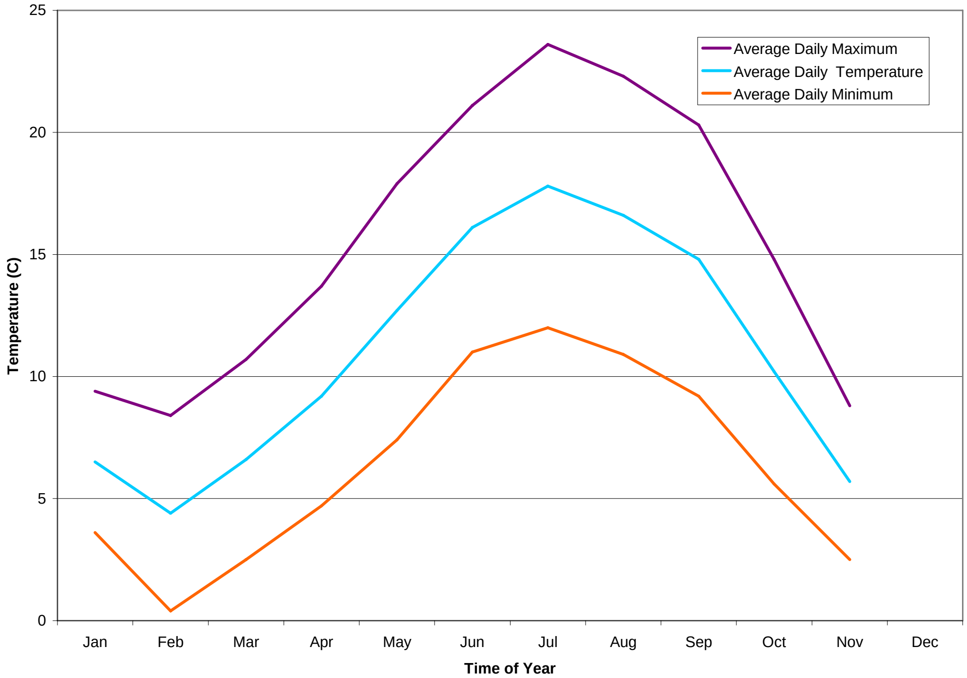


Figure A.2
2006 Wind Rose Diagram for Victoria International Airport

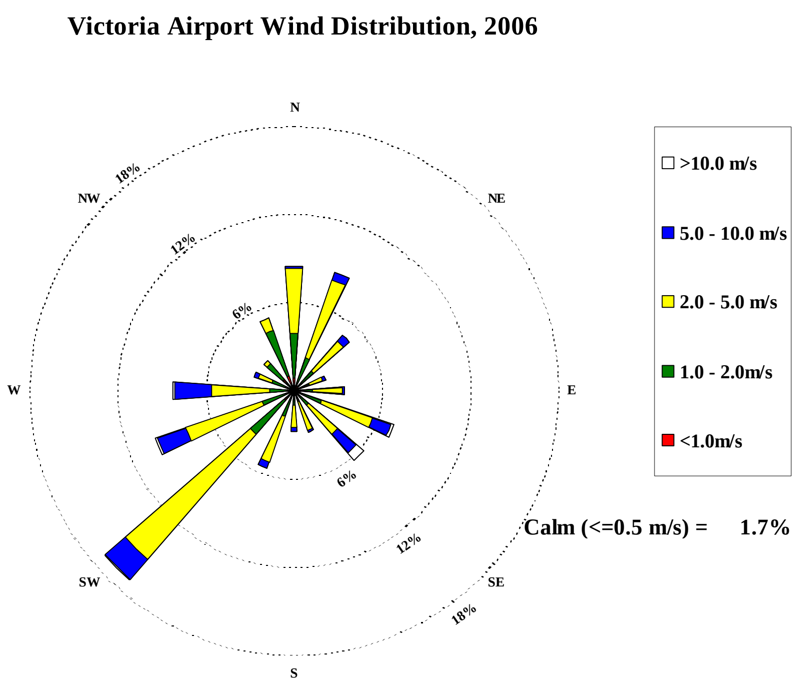


Figure A.3
2006 Wind Rose Diagram for Victoria Topaz

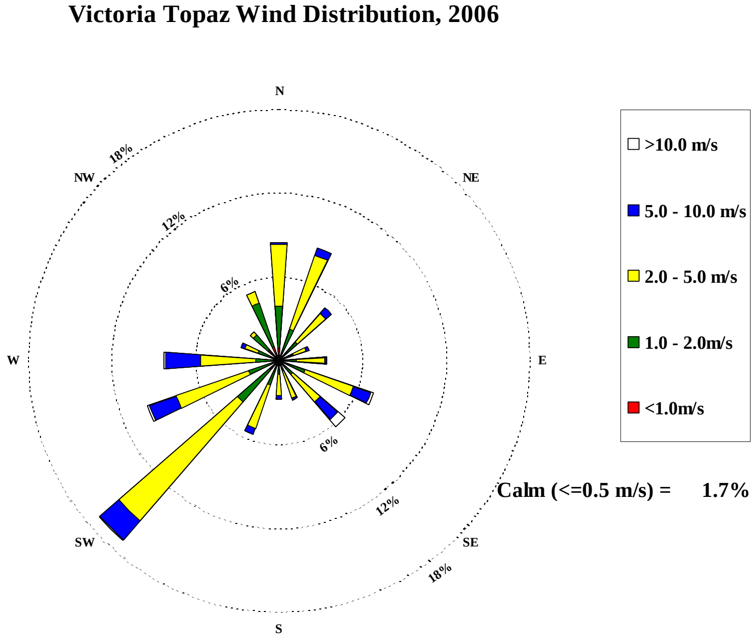


Figure A.4
2006 Wind Rose Diagram for Stellys

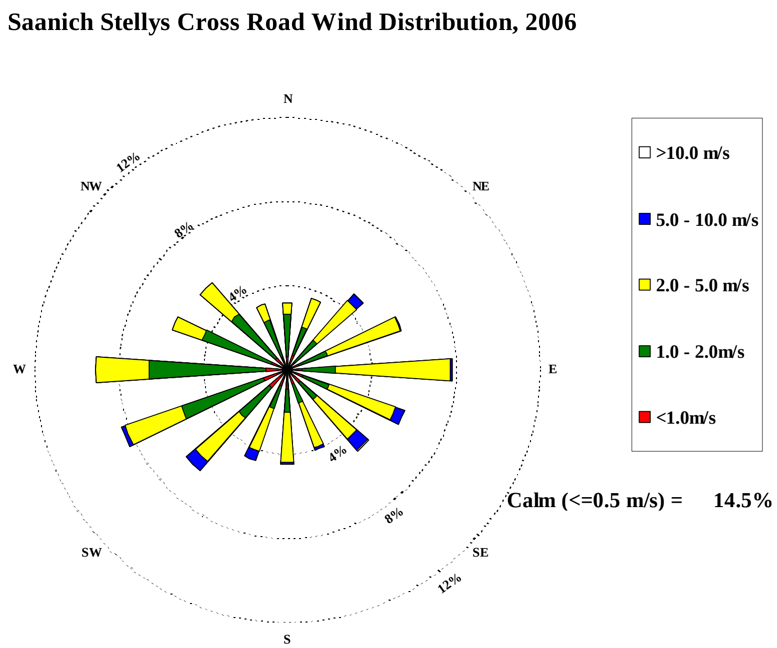


Figure A.5
2006 Wind Rose Diagram for Hartland Landfill

Hartland Landfill Wind Distribution, 2006

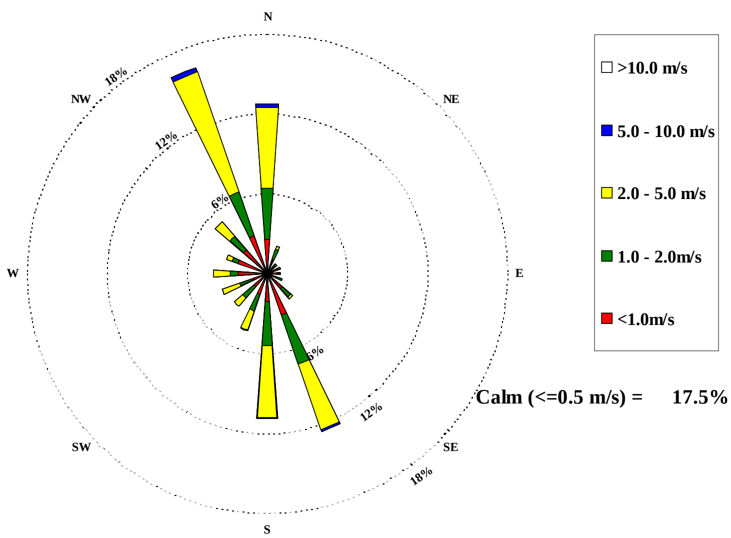
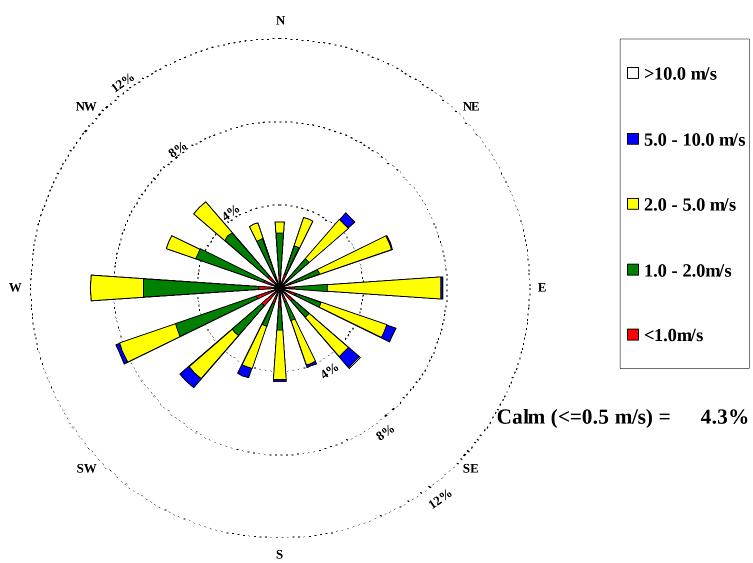


Figure A.6
2006 Wind Rose Diagram for Royal Roads University

Royal Roads University Wind Distribution, 2006



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[10]. 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 2006 are compared with federal and provincial objectives in Table B.3.

[10] 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)[11]

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.**

[11] 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 µg/m^3

Table B.3
Comparison of Maximum Observed Pollutant Concentrations (µg/m^3) in the CRD for 2006 with Provincial and Federal Objectives

Contaminant	Averaging Period*	B.C. or Federal Maximum Acceptable Level	Victoria Topaz	Royal Roads	Stellys	Christopher Point	Oak Bay	Braefoot	Keating	Saturna Island
Carbon Monoxide	1-hour	28000	5100		1600	1600				
	8-hour	11000	3071.4		737.5	1450				
Nitrogen Dioxide	1-hour	400	97.5	53.5	66.9	65				
	24-hour	200	50.2	26.8	25.5	37.9				
	Annual	100	22.9	8.3	N/A	7.5				
Sulphur Dioxide	1-hour	900	77			27				
	24-hour	300	15.1			8.6				N/A
	Annual	60	2.5			1.5				
Ozone	1-hour	160	127.7	111.7	139.7	129.7				144
	24-hour	50	82.8	95.2	102.3	102.3				103.1
	Annual	50	41.5	39.3	27.1	21.4				63
PM_{10}	24-hour	50	53 (HiVol)	21 (Hi-Vol)	58 (Partisol)		33 (HiVol)	22 (HiVol)	29 (HiVol)	

Appendix C: Summary of SO_2 Monitoring Data at Saturna Island 1998-2005

Table C.1
Summary of 24-Hour Average SO_2 Concentrations at Saturna Island 1998-2005

	Concentration (µg/m^3)							
Parameter	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
5th percentile	0.385	0.420	0.572	0.541	0.363	0.327	0.445	0.416
25th percentile	1.070	0.994	1.284	1.151	0.849	0.862	0.996	1.015
50th percentile	1.712	1.611	2.060	1.694	1.475	1.521	1.509	1.479
75th percentile	2.895	2.692	3.642	2.601	2.158	2.282	2.255	2.157
98th percentile	11.055	8.324	9.666	6.539	5.661	5.259	4.478	4.807
99th percentile	11.887	9.861	11.275	7.576	7.280	6.166	5.038	5.375
Maximum	16.674	12.065	17.593	11.240	9.665	6.712	17.118	10.693
Minimum	0.122	0.094	0.259	0.103	0.085	0.075	0.133	-0.126
Mean	2.417	2.151	2.824	2.093	1.731	1.769	1.759	1.738
Standard Deviation	2.378	1.866	2.463	1.486	1.339	1.230	1.324	1.177