Border Air Quality Study – An Ambient Air Quality Overview for Southwestern Ontario (Summer 2007)

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Acknowledgements

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1. Introduction

Smog levels are generally highest in southwestern Ontario, and decrease as you travel northward and eastward across the province. Based on the air quality index data for 2005 and 2006, on average, the Windsor-Essex-Chatham-Kent air quality forecast region recorded more days with air quality in the poor category than the other areas of the province. Port Stanley, which recorded the most exceedances of Ontario's one-hour Ambient Air Quality Criterion (AAQC) for ozone of 80 parts per billion (ppb) in both 2005 and 2006, is also located in southwestern Ontario, along the northern shore of Lake Erie. The higher incidences of poor air quality and the fact that these regions are in a transboundary area of the lower Great Lakes and in close proximity to industrial states of the U.S., led to this major field study campaign called the Border Air Quality and Meteorology Study (BAQS-Met). The study was conducted in the summer of 2007.

BAQS-Met is a collaborative effort of both federal and provincial governments, as well as the University of Toronto, York University, the University of Western Ontario, and the University of Windsor. It is designed to improve understanding of the airshed in the US-Canada border region of southwestern Ontario. The study also aims to gain insight into the sources of air pollution, as well as the impacts of the transboundary flow of pollutants, and lake effects during smog episodes in southwestern Ontario. This intensive field study took place during the period of June 20 to July 10, 2007.

During the study period, the ministry set up temporary air monitoring stations at Agriculture Canada in Harrow, on the airport property of Pelee Island, and at the University of Guelph's Ridgetown campus. Air quality data collected at these sites, together with data from the Ontario Ministry of the Environment permanent ambient air quality monitoring sites at Windsor Downtown, Windsor West, Essex, Chatham, Sarnia, Port Stanley, Grand Bend, London, and Simcoe are used for comparison in this report. Figure 1 shows the location of these sites, and Appendix 1 provides details on the pollutants monitored at each site.

This report provides an overview of the meteorological conditions, air quality data collected by the Ontario Ministry of the Environment, and data analysis of smog episodes during the BAQS-Met monitoring period.

2. Meteorology

The meteorological conditions varied significantly throughout the study period. Table 1 is a summary of some of the meteorological conditions recorded by Environment Canada at the Windsor airport during each day of the study. Sky conditions, maximum and minimum air temperatures, and average wind direction and speed are shown.

Generally speaking, clear skies dominated the beginning of the study period from June 20 – July 2, while mostly cloudy skies were reported almost every day from July 3-10. There was very little precipitation throughout the study, with the only significant accumulation of rain reported on June 27 as a result of afternoon thunderstorms. Maximum temperatures ranged from 21.6°C to 35.6°C throughout the entire study period, with higher temperatures generally recorded on days with south or southwesterly winds.

Table 1: Meteorological Conditions in Windsor, June 20 – July 10, 2007

Date	Sky Conditions	Max Temp (°C)	Min Temp (°C)	Average Wind Direction / Speed (km/h)
June 20	Mainly Clear	27.6	16.2	West / 12
June 21	Mostly Cloudy	28.6	16.2	West-Southwest / 19
June 22	Increasing Cloudiness	24.1	14.6	East-Southeast / 11
June 23	Mostly Cloudy	24.4	13.0	Southeast / 8
June 24	Mainly Clear	26.9	13.5	South-Southeast / 11
June 25	Mainly Clear with Haze	30.9	19.1	Southeast / 7
June 26	Mainly Clear with Haze	33.0	21.1	South / 11
June 27	Increasing Cloudiness/Thunderstorms	31.5	21.4	South West / 15
June 28	Mostly Cloudy	25.9	15.5	East / 17
June 29	Mainly Clear	23.8	13.6	East-Southeast / 13
June 30	Mainly Clear	25.3	14.2	East / 10
July 01	Mainly Clear	21.6	12.9	East / 20
July 02	Mainly Clear	23.1	11.6	East / 9
July 03	Mostly Cloudy	26.5	16.9	Southeast / 10
July 04	Mostly Cloudy with Showers	28.8	17.9	Southwest / 12
July 05	Partly Cloudy	30.4	18.7	Southwest / 10
July 06	Partly Cloudy	28.7	18.1	South / 7
July 07	Mainly Clear	31.4	19.0	West-Southwest / 12
July 08	Mostly Cloudy	35.6	22.9	Southwest / 20
July 09	Mostly Cloudy	35.2	23.7	Southwest / 19
July 10	Mostly Cloudy	33.5	21.7	South-Southwest / 20

3. Criteria Pollutants

The criteria pollutants monitored during the study period were: ozone (O_3), fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO). Ozone and $PM_{2.5}$ were the main pollutants of interest during the study period, because in many cases, the concentrations measured either reached, or exceeded the air quality standards and/or set reference levels. The provincial AAQCs for NO_2, SO_2, and CO were not exceeded at any ambient air quality monitoring site in Ontario during the study period.

<u>Ozone</u>

Figures 2 and 3 show box plots for stations in the study area, as well as surrounding sites, for one-hour average and eight-hour running average ozone

levels measured during the study period. The maximum one-hour and eight-hour ozone concentrations were found at stations located generally along the north shore of Lake Erie, and the southern shores of Lake Huron. The highest one-hour and eight-hour ozone concentrations of 131 ppb and 96 ppb, respectively, were recorded at Grand Bend on June 25. London, the site located furthest inland, recorded the lowest maximum concentration for both one-hour and eight-hour ozone, 76 ppb and 68 ppb respectively. The two highest median concentrations occurred at the southernmost stations, Pelee Island, located in Lake Erie, and Harrow, located on the north shore of Lake Erie. Pelee Island recorded the highest minimum concentration for both one-hour, and eight-hour ozone, as ozone concentrations there remained higher overnight, than at the other stations. Pelee Island, located in the middle of Lake Erie, should be subjected to less dry deposition of ozone than at mainland sites as referenced in *Brook et. al, 1999*. Less overnight titration of ozone occurs in rural areas with lower NO_X concentrations due to the lack of traffic emissions. Land surfaces are also far rougher than lake surfaces, and the extra friction can cause mixing of the pollutants at the mainland sites that would not be experienced over the water at Pelee Island. In addition, the water temperature during the summer months is usually lower than the air temperature. This causes stable conditions over the lake, further reducing the amount of mixing.

Figure 4 displays the geographical distribution of the number of exceedances of Ontario's one-hour AAQC for ozone of 80 ppb, and the eight-hour CWS reference level for ozone of 65 ppb. All sites recorded exceedances for both one-hour and eight-hour ozone, with the exception of London, which exceeded only the eight-hour reference level. The number of exceedances was generally higher at stations located on the shores of Lake Huron and Lake Erie, such as Grand Bend, Harrow, and Port Stanley, as well as on Pelee Island. Pelee Island recorded the most number of exceedances for eight-hour ozone. This site also reported the most number of days with eight-hour ozone concentrations greater than the CWS reference level; 11 out of the 21 days. Harrow recorded the most number of days (5) with at least one hour greater than Ontario's one-hour AAQC for ozone.

$\underline{PM_{2.5}}$

Figures 5 and 6 display box plots for three-hour running average $PM_{2.5}$, and 24-hour average $PM_{2.5}$. The maximum three-hour concentration (55 $\mu g/m^3$) was measured at Grand Bend, and the maximum 24-hour concentration (36 $\mu g/m^3$) was measured at both Windsor Downtown and Sarnia. These concentrations were all measured on June 25. In general, median $PM_{2.5}$ concentrations were higher at urban sites due to the addition of local $PM_{2.5}$ to the background concentration, and were also generally higher at sites in close proximity to the U.S.-Canadian border. This is apparent from the fact that the highest three-hour and 24-hour $PM_{2.5}$ median concentrations were measured at Windsor Downtown and Sarnia, respectively.

In comparison to ozone, there were few occurrences of $PM_{2.5}$ greater than Ontario's benchmark of 45 $\mu g/m^3$ (based on a three-hour running average), and the CWS reference level of 30 $\mu g/m^3$ (based on a 24-hour average). Six of the 11 ambient air monitoring sites exceeded the 24-hour reference level: Windsor Downtown, Windsor West, Sarnia, Grand Bend, Port Stanley, and Simcoe. Only four sites exceeded Ontario's three-hour benchmark: Windsor Downtown, Sarnia, Grand Bend, and Simcoe.

Nitrogen Dioxide

Summary statistics for one-hour NO_2 concentrations during the study period are shown in Figure 7. The highest one-hour concentration measured was 51 ppb, which occurred on June 25 at Windsor West. Statistics for 24-hour NO_2 are displayed in appendix 2, with the maximum 24-hour concentration of 22 ppb measured at Windsor Downtown on June 27. NO produced by vehicles reacts with O_3 to produce NO_2, causing higher NO_2 concentrations in the high-traffic urban areas, such as Windsor, Sarnia, and London. In the rural areas, NO_2 values were much lower, with maximums generally ranging from 15-20 ppb. The maximum concentrations measured were well below the one-hour and 24-hour AAQC for NO_2 of 200 ppb and 100 ppb, respectively.

Carbon Monoxide

CO concentrations, as shown in Figure 8, were generally quite low at all sites during the study period, with a maximum one-hour concentration of 1.01 parts per million (ppm). As shown in appendix 2, the maximum eight-hour CO concentration was 0.49 ppm. Both maximums were measured at Windsor Downtown, with the highest one-hour concentration measured on June 27, and the highest eight-hour concentration measured on June 30. The provincial AAQC for one-hour and eight-hour CO is 30 ppm, and 13 ppm, respectively. The maximum concentrations recorded during the study period were well below these levels. The median CO concentration of 0.07 ppm at London was quite low in comparison to those recorded at other urban sites such as Windsor Downtown (0.12 ppm) and Chatham (0.17 ppm).

Sulphur Dioxide

Figure 9 shows the maximum one-hour average concentrations of SO_2 measured at sites in the study area and surrounding sites. The highest one-hour concentration of 134 ppb was measured on July 10 at Sarnia, during a period of southwesterly winds. Although this concentration was the highest recorded during the study period, it is well below the Ontario AAQC for SO_2 of 250 ppb. High concentrations found in Sarnia are generally due to emissions from the utilities and petroleum-based industries located near the station, both major sources of SO_2 as referenced in *Air Quality in Ontario 2006*. Relatively high

concentrations were also recorded at Windsor Downtown, Windsor West, and Essex, indicating that they were also influenced by industrial sources in the Windsor/Detroit airshed. Figure 10 shows SO_2 pollution roses during the study period for Windsor West and Sarnia. At Windsor West, higher concentrations were generally recorded during periods with southwesterly winds. Similar to Windsor West, Sarnia showed higher SO_2 concentrations with south to southwesterly winds.

Smog Episodes

The Ontario Ministry of the Environment issues a Smog Advisory when there is a strong likelihood that elevated smog levels and poor air quality (poor air quality is defined as AQI values exceeding 49) are forecast within the next 24 hours (www.airqualityontario.com). If widespread, poor AQI readings occur, and weather conditions conducive to the persistence of such levels are expected to continue for several hours, then a smog advisory can also be issued immediately. During the study period, two smog advisories were issued. The first was of three day duration, from June 25 to 27, and the other lasted two days, July 9 to 10. Smog episode days here are defined as days with elevated ozone and fine particulate matter concentrations. As such, the smog advisory days, along with June 24, will be included in this analysis, as the pollutant concentrations began to increase across the study area a day before the first smog advisory was issued. Figure 11 shows the daily maximum 8-hour ozone and 24-hour $PM_{2.5}$ concentrations at Chatham, a centrally located site in the study area. It is apparent from this figure that although elevated ozone and $PM_{2.5}$ concentrations were measured during both episodes, the second episode was driven mainly by ozone.

Figure 12 displays 48-hour back trajectories at 500 m into Chatham at 13:00 Eastern Daylight Time (EDT) on each of the episode days (June 24-27 and July 9-10). In general, each trajectory indicates a southwesterly wind flow. June 24 is an exception as it was the beginning of the episode. The trajectory began with northwesterly flow out of Ontario, and then the winds shifted to southeasterly towards southwestern Ontario on the evening of June 23. The air parcel tracked across Cleveland, a large U.S. city with heavy traffic and industry. As such, pollutants were most likely brought into Ontario from this area.

Figures 13 and 14 show one-hour ozone concentrations at both urban and rural sites during the first smog episode of the study period. Urban and rural sites recorded similar ozone concentrations during this episode. The urban sites, however, generally measured lower ozone concentrations at night, as the higher amounts of NO, caused more titration of ozone.

Grand Bend recorded the highest one-hour concentration of ozone for both urban and rural sites on June 25, a maximum of 131 ppb. This concentration was recorded only one hour earlier than when Sarnia recorded the highest

concentration of the urban sites, 101 ppb. Figure 15 shows 48-hour back trajectories at 500 m into Grand Bend and Chatham at 13:00 EDT on June 25. The air parcel arriving at Grand Bend, started out in central Ohio and travelled up through eastern Michigan, accumulating pollutants along the way. It then moved over the stable layer above Lake Huron where the pollutants reacted in the sunlight over the lake, generating high ozone concentrations before reaching Grand Bend. Elevated ozone concentrations were thus recorded at both Grand Bend and Sarnia. Port Huron, a site located on the southwestern shore of Lake Huron in Michigan, also recorded elevated ozone concentrations, reaching a maximum of 104 ppb on June 25.

Figures 16 and 17 display three-hour $PM_{2.5}$ at both urban and rural sites during the first episode. The flow on June 25 also resulted in elevated $PM_{2.5}$ concentrations at Grand Bend and Sarnia, as concentrations were elevated at a similar time to those of ozone. These figures also show that the highest $PM_{2.5}$ concentrations were measured during the middle of the episode, June 25 and 26, at both the urban and rural sites. As the airmass aged, particulate matter was able to build up. The trajectory into Chatham on June 27, as shown in Figure 12, was significantly longer that the previous days, which implies stronger winds. As a result, conditions were conducive to better mixing and dilution of pollutants, and $PM_{2.5}$ concentrations began to decrease. During this episode, the rural sites, with the exception of spikes at Grand Bend, Port Stanley, and Simcoe, were generally lower than the urban sites. The higher concentrations at the urban sites were due to the contribution of local $PM_{2.5}$ emissions to the regional background.

The second episode, driven mainly by ozone, occurred on July 9 and 10. Figures 18-21 show the one-hour ozone concentrations and three-hour $PM_{2.5}$ concentrations at both urban and rural sites during the second episode. $PM_{2.5}$ concentrations were generally lower in the second episode than in the first episode. Trajectories for July 9 and 10, shown in Figure 12, were both southwesterly, and traveled across the major U.S. city of Chicago. The flow was uniformly southwesterly across the region. As a result, there were no outliers in the second episode similar to Grand Bend in the first episode.

Pollution roses for ozone and $PM_{2.5}$ for the first episode are displayed in Figure 22, and for the second episode in Figure 23. The predominant wind direction was southerly for the first episode, and southwesterly for the second episode. During the first episode, ozone exceedances were measured at Windsor West with winds in the south-southeasterly direction. Concentrations above Ontario's benchmark for three-hour running average $PM_{2.5}$ were recorded at Port Stanley, when winds were south to southwesterly. The pollution roses also show greater ozone concentrations during the second episode, with ozone exceedances measured at Pelee Island, with southwesterly winds, and Port Stanley, with south to southwesterly winds. $PM_{2.5}$ concentrations did not exceed Ontario's

benchmark for three-hour running average $PM_{2.5}$ at any of the sites in the study area during the second episode.

AQI

Ontario's Air Quality Index (AQI) is based on pollutants that have adverse effects on human health and the environment (www.airqualityontario.com). The pollutants are ozone (O_3), fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), and total reduced sulphur compounds (TRS). At the end of each hour, the concentration of each pollutant measured at each site is converted into a number ranging from zero upwards using a common scale or index. The calculated number for each pollutant is referred to as a sub-index. At a given site, the highest sub-index for any given hour becomes the AQI reading for that hour. The AQI is based on air quality standards, and typically O_3 and $PM_{2.5}$ are the main pollutants that result in AQI values in the poor category.

The AQI reached the poor category on six days, June 25, 26, July 6, 7, 9, and 10 (Figures 24-29). On June 25, Figure 24, the maximum AQI was driven by ozone at all sites, and reached the poor category at Windsor Downtown, Windsor West, and Sarnia. On June 26, Figure 25, Sarnia and Windsor Downtown again recorded poor AQI, as did Simcoe. On this day, however, the AQI was driven by $PM_{2.5}$ at Sarnia. On July 6, Figure 26, Essex and Pelee Island recorded AQI values in the poor category, reaching maximums of 51 and 59, respectively. Pelee Island was the only station with a maximum AQI in the poor category on July 7, Figure 27. On both July 6 and 7, poor AQI was not widespread, and therefore no smog advisory was called. On July 9, Figure 28, there were four stations that recorded AQI values in the poor category, Pelee Island, Chatham, Ridgetown, and Simcoe. Poor AQI was again recorded on July 10, Figure 29, however, this time at Windsor Downtown, Sarnia, and Simcoe.

Figure 30 displays the number of hours that the AQI value reached the poor category (AQI > 49) at each station during the study period. The number of hours in the poor AQI category was generally higher at stations located on the shores of Lake Huron and Lake Erie, such as Grand Bend, Sarnia, and Port Stanley, as well as on Pelee Island. London was the only station that did not record any hours in the poor category.

4. $PM_{2.5}$ Speciation

During the study period, black carbon (BC) was measured at three sites: Windsor West, Pelee Island, and Ridgetown. BC is composed of elemental carbon and is released from combustion of fuels (most notably diesel), and biomass burning including forest fires.

Figure 31 shows hourly $PM_{2.5}$ and BC concentrations at Windsor West from June 20-July 10, 2007. In general, BC and $PM_{2.5}$ track closely on a number of days, and thus, it can be inferred that BC is a minor component of the $PM_{2.5}$.

When comparing the BC measurements at all three sites, as shown in Figure 32, it is evident that highest BC concentrations were recorded at the Windsor West site. Pelee Island and Ridgetown are both rural sites, and therefore report the transported BC levels in the airmass. The Windsor West site, however, is in an urban area surrounded by industrial sources in the Windsor/Detroit airshed. As a result, there is a local contribution to the transported levels of BC, and thus, higher concentrations are measured in this location.

Table 2 displays the 24-hour BC concentrations at each site throughout the study period of June 20 – July 10. All of the concentrations recorded were well below the provincial AAQC for BC of 10 $\mu g/m^3$ over a 24-hour period. The highest 24-hour concentration of 1.9 $\mu g/m^3$ was recorded at Windsor West. This was approximately three times greater than the highest concentration measured at the rural sites.

Table 2: 24-Hour BC Concentrations

Date	Concentration ($\mu g/m^3$)		
	Windsor West	**Pelee Island**	**Ridgetown**
June 20	1.3	0.3	0.3
June 21	1.2	0.5	0.4
June 22	0.9	0.1	0.1
June 23	0.9	0.1	0.2
June 24	1.3	0.6	0.4
June 25	1.8	0.7	0.6
June 26	1.5	0.8	0.6
June 27	1.2	0.4	0.4
June 28	0.8	0.3	0.2
June 29	0.9	0.1	0.2
June 30	1.7	0.2	0.3
July 01	0.4	0.1	0.1
July 02	0.6	0.1	0.1
July 03	0.7	0.3	0.2
July 04	1.3	0.6	0.7
July 05	1.7	0.4	0.5
July 06	1.9	0.7	0.6
July 07	1.2	0.7	0.4
July 08	0.9	0.6	0.4
July 09	1.1	0.6	0.4
July 10	1.0	0.5	0.4

5. Volatile Organic Compounds

Ambient levels of selected volatile organic compounds (VOCs) were measured during the study period near the rural ambient air monitoring stations at Harrow, Pelee Island, and Ridgetown. Twenty-one one-hour samples were collected, two in Harrow, three in Pelee Island, and 16 in Ridgetown. These samples were collected on July 5, 6, 9, 10, and 11, and were analyzed through gas chromatography and tandem mass spectrometry on July 16 and 17. They were analyzed for 50 target VOCs (shown in appendix 3), however only 10 of the 50 VOCs were detected. The 10 VOCs that were detected are shown in Table 3.

The average total VOC concentration was 0.83 $\mu g/m^3$, with the total VOC concentration in most samples less than 1 $\mu g/m^3$. One sample with a total VOC concentration of 5.42 $\mu g/m^3$ was abnormally high due to emissions from a vehicle in close proximity to the sampling location. Toluene was detected in 90 per cent of the samples, and isoprene was measured in 76 per cent of the samples. The highest measured concentrations were 1.87 $\mu g/m^3$ for toluene, and 1.01 $\mu g/m^3$ for isoprene. Benzene and ethylbenzene were detected in several samples and xylenes were measured in only a few samples. Overall, the measured VOCs were more than 1000 times lower than any applicable Ontario AAQC. The VOC concentrations measured during the study period were generally representative of typical rural ambient air.

6. Summary

The Ontario Ministry of the Environment collected measurements of criteria pollutants, meteorological parameters, BC, and VOCs in southwestern Ontario as part of the BAQS-Met from June 20 – July 10, 2007. The measurements were collected at eight of the ministry's permanent ambient air monitoring sites, as well as three temporary sites set up specifically for the study. There were two smog episodes that occurred during the study period, June 24-27, and July 9-10. Ozone concentrations exceeded Ontario's one-hour AAQC at all sites, with the exception of London. Ontario's benchmark for $PM_{2.5}$ (based on a three-hour running average) was exceeded at only four of the 11 sites. Smog advisories were issued on June 25-27, and July 9-10. Four of the six days with AQI in the poor category occurred on smog advisory days. NO_2, SO_2, and CO concentrations did not exceed their AAQC at any site during the study period. BC was measured at one urban site (Windsor Downtown), and two rural sites (Pelee Island and Ridgetown). It was found to be a fraction of the $PM_{2.5}$, and was also found to be higher at the urban location. VOC concentrations measured during the study period were generally representative of typical rural ambient air.

Table 3: VOC Cartridge Air Samples from Ridgetown, Harrow, and Pelee Island (July, 2007)													
Sample Date	Location	Sampling Time	Isoprene	Benzene	12-Dichloropropane	12-Dichloroethane	Trichloroethylene	Toluene	112-Trichloroethane	Ethylbenzene	m-p-xylene	o-xylene	**Total Concentration**
July 04	Ridgetown	13:30-14:30	nd	nd	0.09	nd	nd	0.05	nd	nd	nd	nd	0.14
July 04	Ridgetown	14:30-15:30	nd	nd	nd	nd	nd	0.08	nd	nd	nd	nd	0.08
July 05	Ridgetown	11:00-12:00	0.10	0.07	0.05	nd	0.08	0.41	0.16	0.06	nd	nd	0.93
July 05	Ridgetown	12:00-13:00	0.09	0.08	0.07	nd	0.06	0.23	nd	0.03	nd	nd	0.55
July 09	Ridgetown	12:30-13:30	0.82	0.08	nd	0.05	0.10	1.87	1.15	0.45	0.38	0.52	5.42
July 09	Ridgetown	13:30-14:30	0.89	nd	0.12	nd	0.06	0.11	nd	nd	nd	nd	1.17
July 10	Ridgetown	07:30-08:30	nd	nd	0.05	nd	nd	0.08	nd	nd	nd	nd	0.13
July 10	Ridgetown	08:30-09:30	nd	nd	0.11	nd	nd	0.03	nd	nd	nd	nd	0.14
July 10	Ridgetown	09:30-10:30	nd	nd	nd	nd	nd	0.02	nd	nd	nd	nd	0.02
July 10	Ridgetown	10:30-11:30	0.11	nd	nd	0.08	0.14	0.14	nd	0.04	nd	nd	0.51
July 10	Ridgetown	11:40-12:40	0.11	nd	0.10	nd	nd	nd	nd	nd	nd	nd	0.21
July 10	Ridgetown	12:40-13:40	0.14	nd	nd	nd	nd	0.04	nd	0.03	nd	nd	0.20
July 10	Ridgetown	13:40-14:40	0.26	nd	0.07	0.08	0.15	0.31	0.22	0.06	nd	0.07	1.23
July 11	Ridgetown	08:00-09:00	0.06	nd	nd	nd	nd	0.08	nd	0.02	nd	nd	0.16
July 11	Ridgetown	09:00-10:00	0.07	0.10	nd	nd	nd	0.09	nd	0.02	nd	nd	0.28
July 11	Ridgetown	10:00-11:00	0.05	0.18	nd	nd	nd	0.10	nd	0.03	nd	nd	0.36
July 09	Harrow	11:37-12:37	0.80	0.57	0.08	0.13	0.26	0.47	0.35	0.07	nd	0.05	2.77
July 09	Harrow	12:37-13:37	1.01	0.45	0.07	nd	0.08	0.43	0.27	0.07	nd	0.06	2.44
July 10	Pelee island	09:57-10:57	nd	nd	nd	nd	nd	0.08	nd	nd	nd	nd	0.08
July 10	Pelee island	10:57-11:57	0.05	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.05
July 10	Pelee island	12:00-13:00	0.15	nd	0.06	nd	nd	0.20	0.15	0.02	nd	nd	0.59
Maximum			1.01	0.57	0.12	0.13	0.26	1.87	1.15	0.45	0.38	0.52	

7. References

1. Environment Ontario. 2007. *Air Quality in Ontario 2006 – A Concise Report on the State of Air Quality in the Province of Ontario.*

2. Brook, J.R., Zhang, L., Li, Y., and D. Johnson. 1999. *Description and Evaluation of a Model of Deposition Velocities for Routine Estimates of Dry Deposition Over North America. Part II: Review of Past Measurements and Model Results.* Atmospheric Environment, Vol. 33, No. 30, pp. 5053-5070

3. Fraser, D., Yap, D., Kiely, P., DeBrou, G., Dong, W., and J. Debosz. 1997. *Daily and Continuous Monitoring of $PM_{10}/PM_{2.5}$ in Ontario, Canada.* Presented at the 90th Air and Waste Management Association Annual Conference, Toronto, Ontario, June 1997.

Figure 1
2007 Border Air Quality Study and Surrounding MOE Monitoring Sites

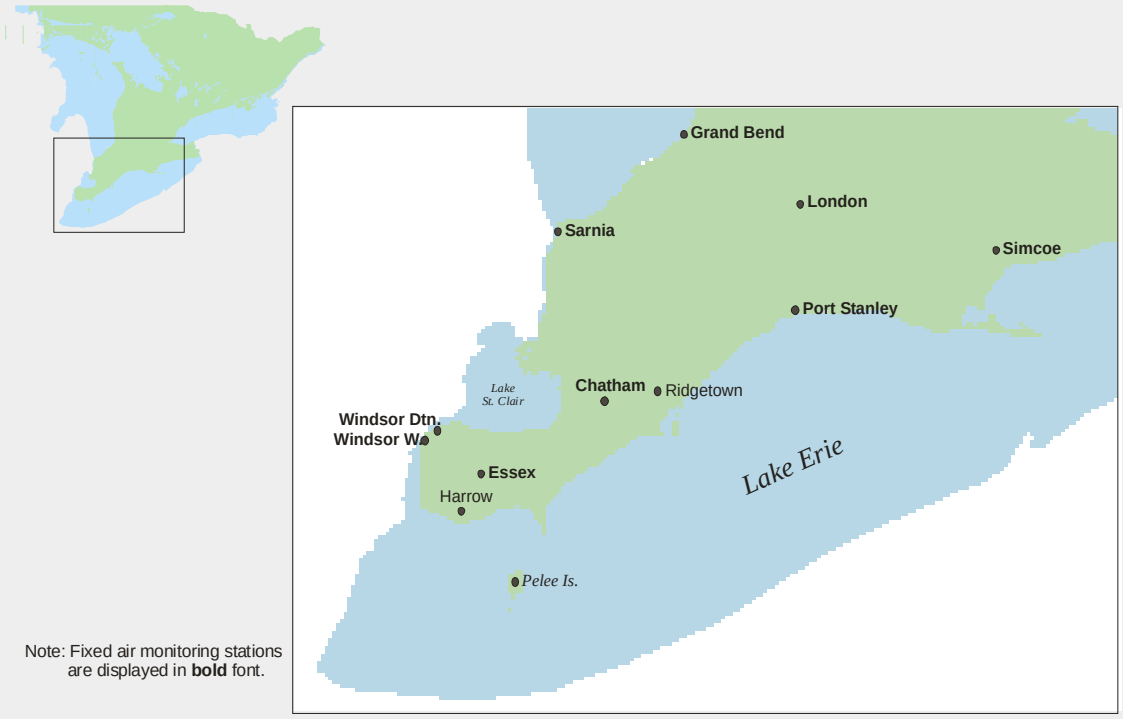


Figure 2
Summary Statistics for One-Hour Ozone
at MOE Sites Across Southwestern Ontario During the Study Period
June 20 - July 10, 2007

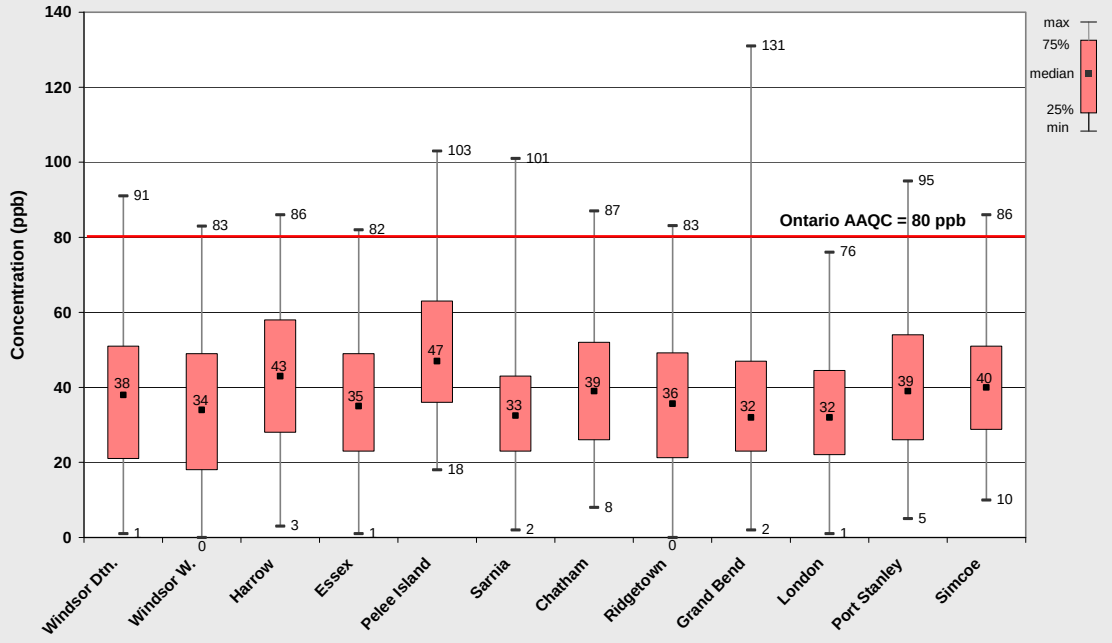


Figure 3
Summary Statistics for Eight-Hour Running Average O_3
at MOE Sites Across Southwestern Ontario During the Study Period
June 20 - July 10, 2007

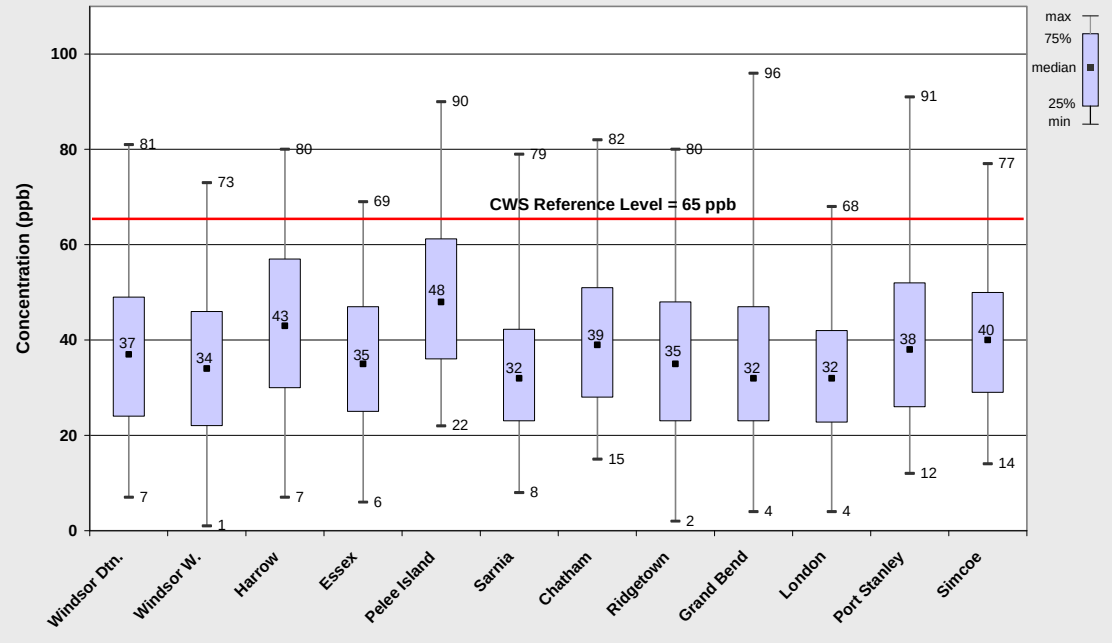
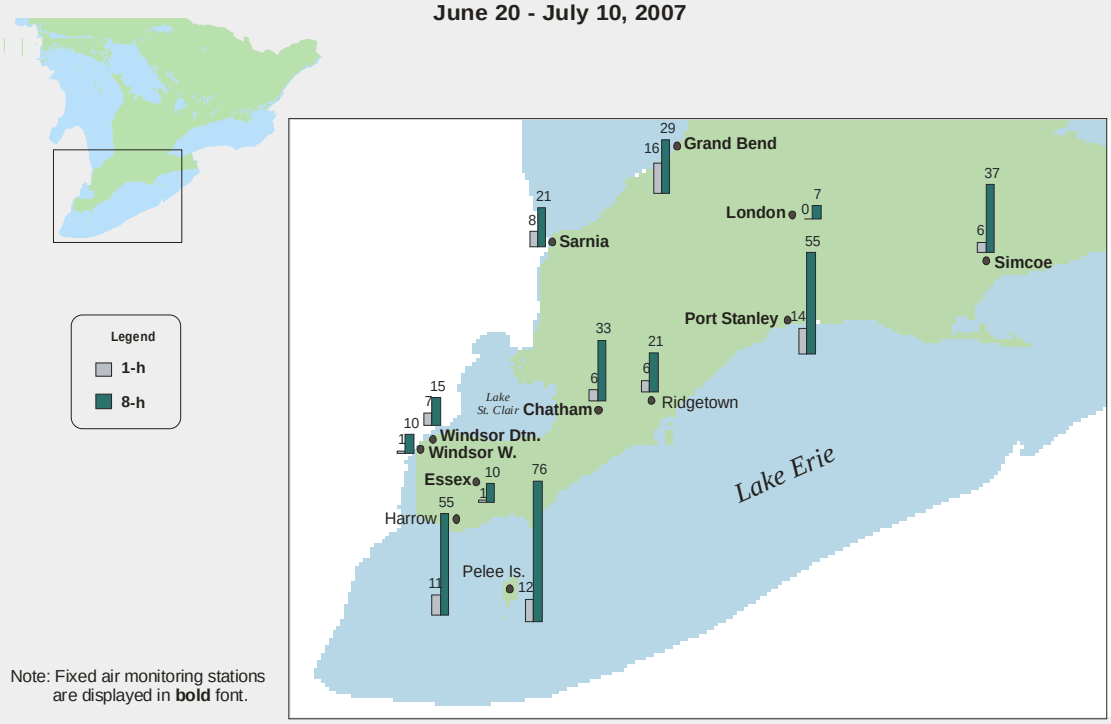


Figure 4
Number of One-Hour Ozone Exceedances, and Number of Hours above the Eight-Hour Running Average CWS Reference Level During the Study Period June 20 - July 10, 2007



Note: Fixed air monitoring stations are displayed in **bold** font.

Figure 5
Summary Statistics for Three-Hour Running Average Fine Particulate Matter at MOE Sites Across Southwestern Ontario During the Study Period June 20 - July 10, 2007

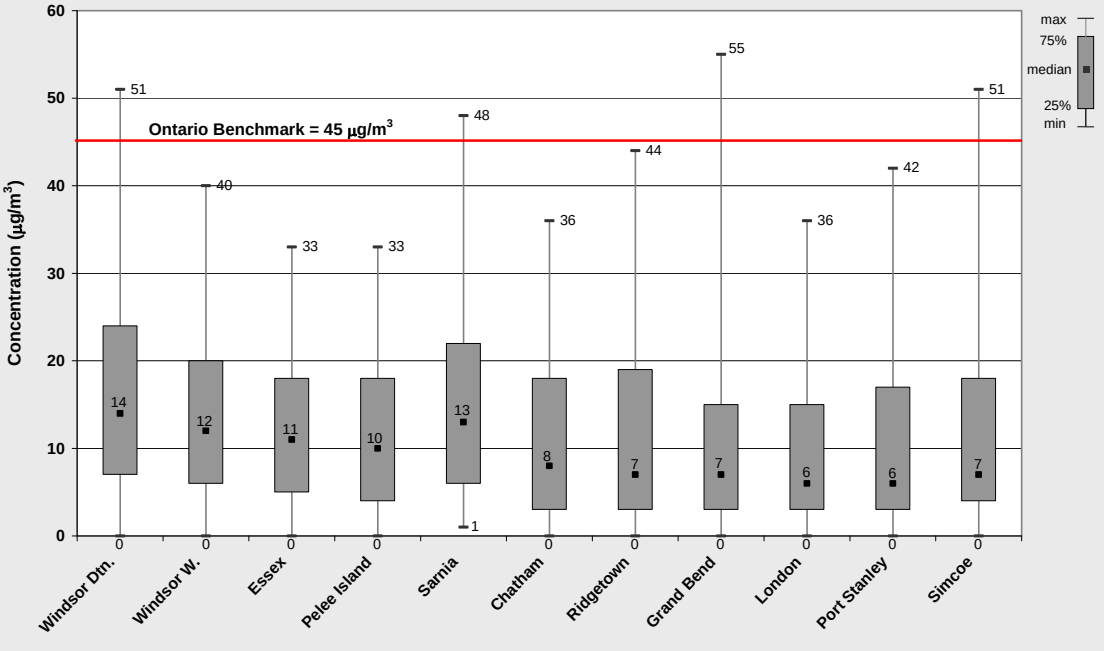


Figure 6
Summary Statistics for 24-Hour Average Fine Particulate Matter
at MOE Sites Across Southwestern Ontario During the Study Period
June 20 - July 10, 2007

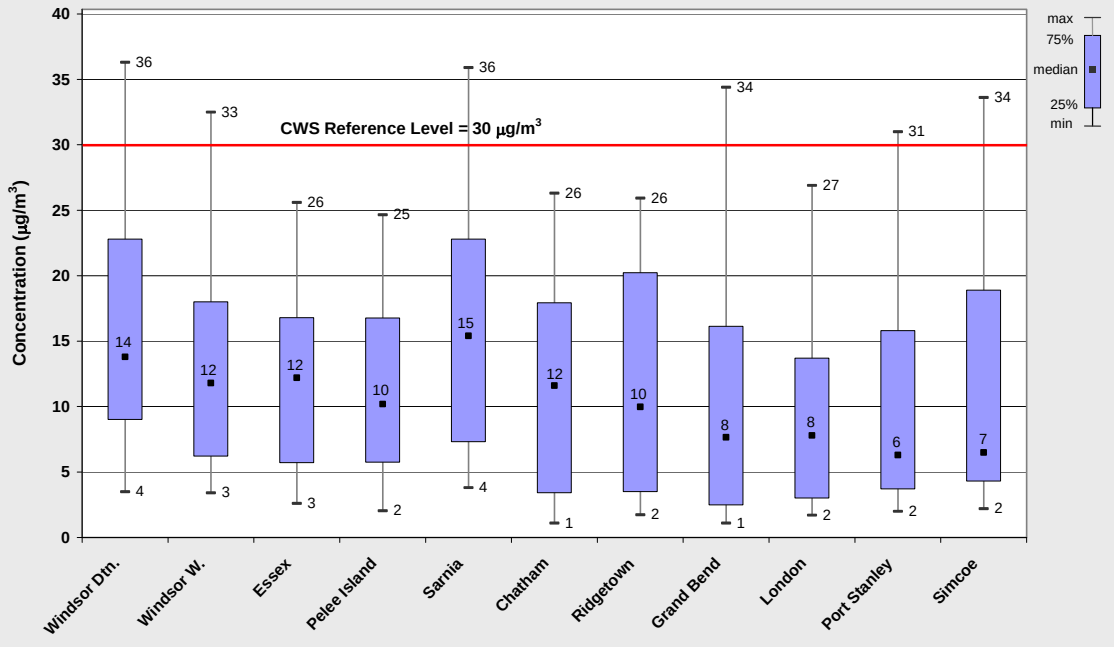


Figure 7
Summary Statistics for One-Hour Nitrogen Dioxide
at MOE Sites Across Southwestern Ontario During the Study Period
June 20 - July 10, 2007

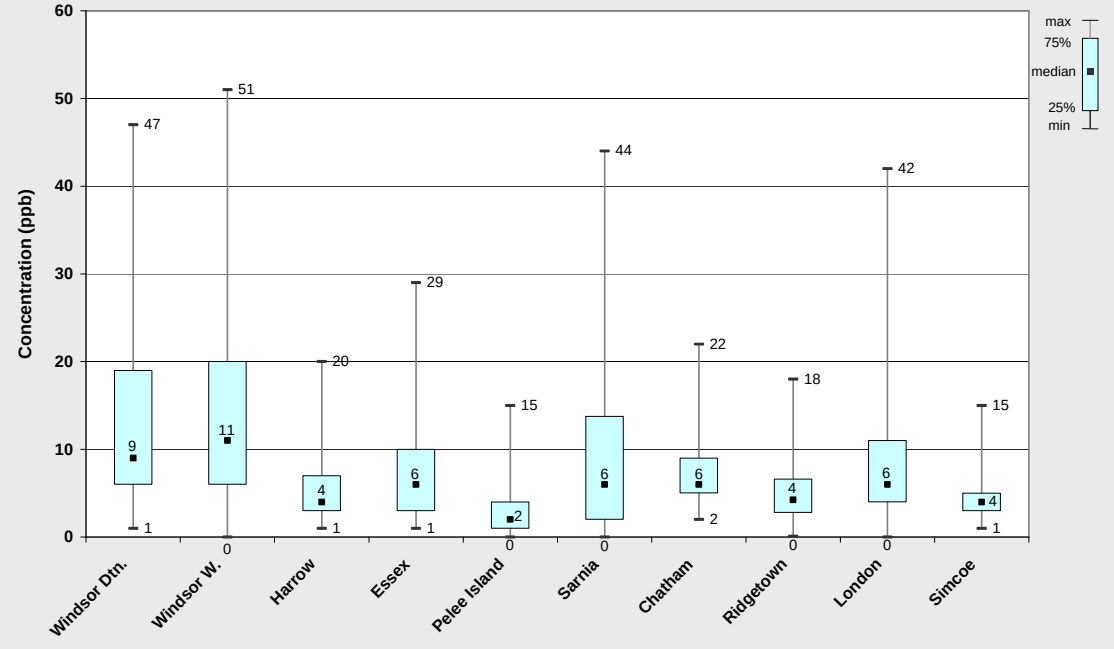


Figure 8
Summary Statistics for One-Hour Carbon Monoxide
at MOE Sites Across Southwestern Ontario During the Study Period
June 20 - July 10, 2007

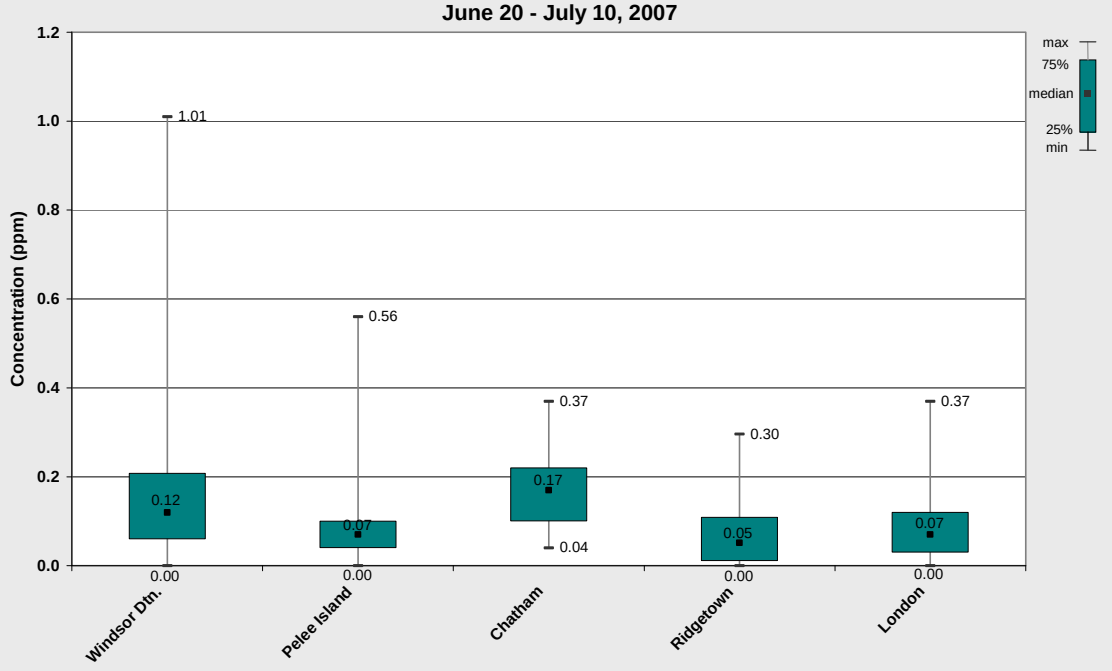


Figure 9
Maximum One-Hour Sulphur Dioxide Concentrations
at MOE Sites Across Southwestern Ontario During the Study Period
June 20 - July 10, 2007

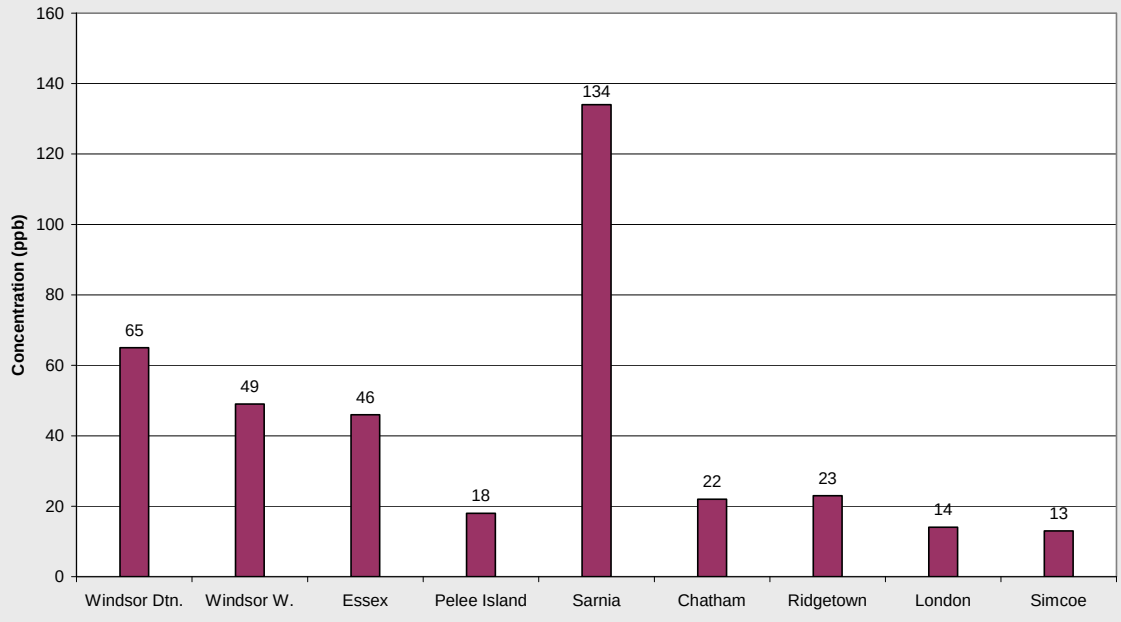
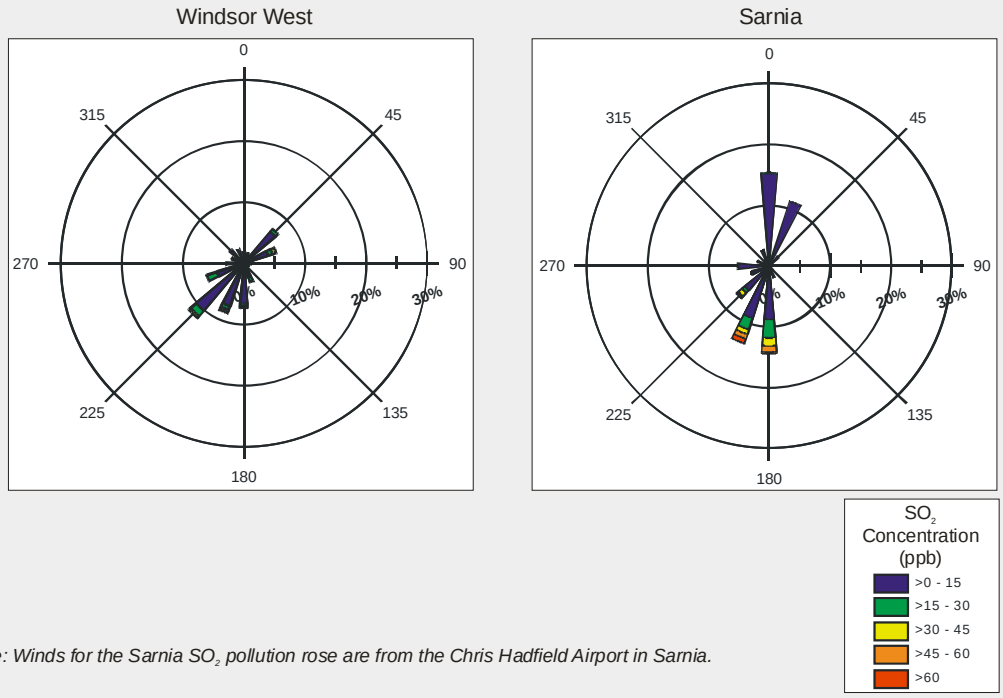


Figure 10
SO_2 Pollution Roses at Windsor West and Sarnia During the Study Period
June 20 - July 10, 2007



Note: Winds for the Sarnia SO_2 pollution rose are from the Chris Hadfield Airport in Sarnia.

Figure 11
Daily Maximum Eight-Hour Ozone and 24-Hour $PM_{2.5}$ Concentrations at Chatham During the Study Period
June 20 - July 10, 2007

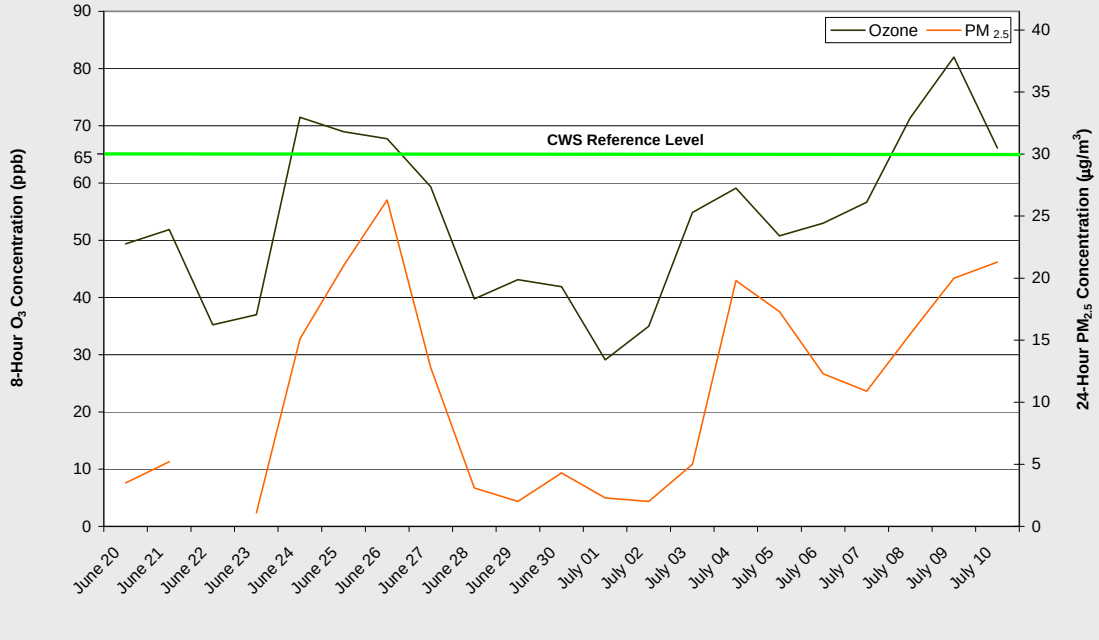


Figure 12
48-Hour Back Trajectories at 500m Arriving at Chatham, Ontario
at 1300 EDT on Smog Episode Days During the BAQS in 2007

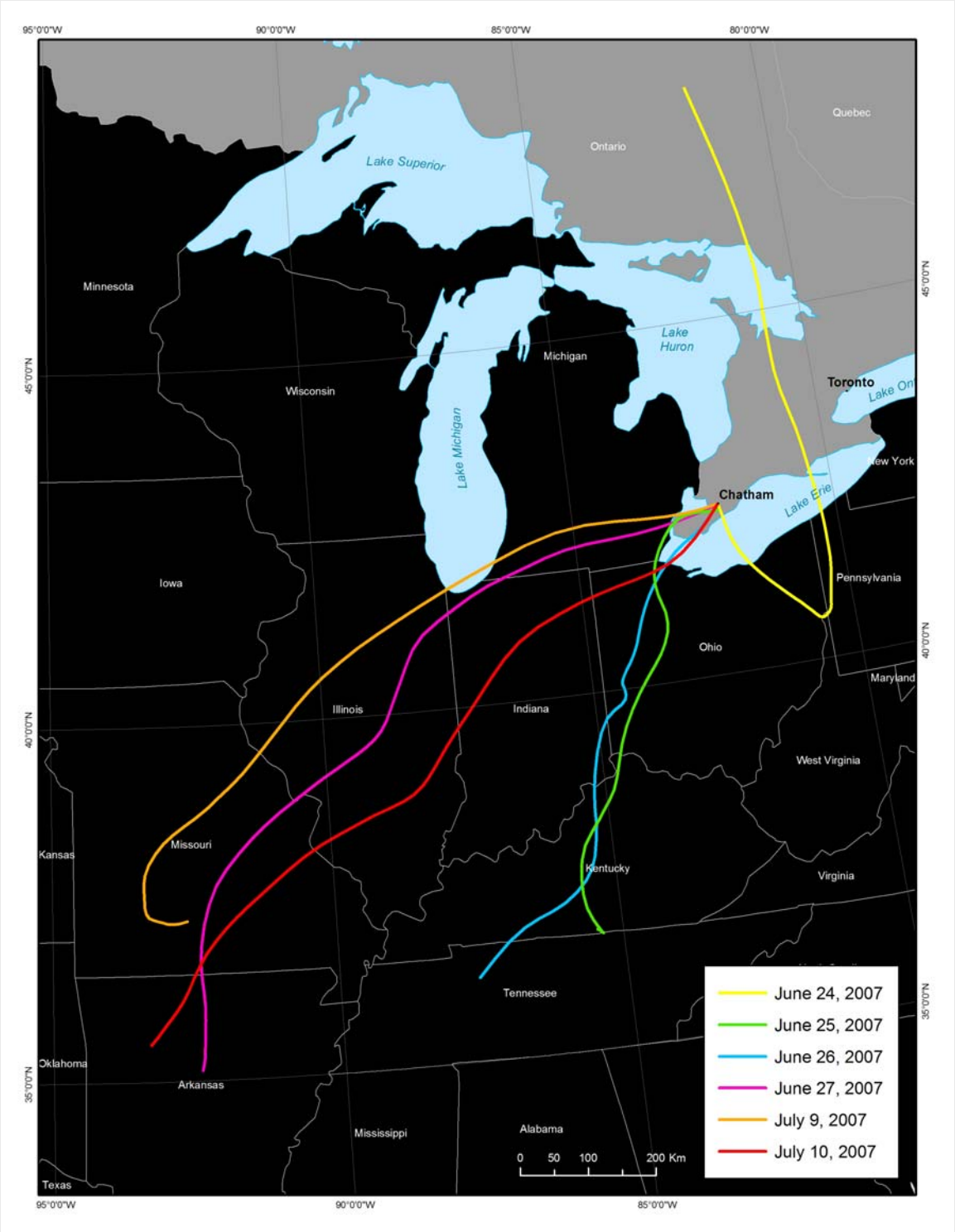


Figure 13
One-Hour Ozone Concentrations at MOE Urban Sites
in Southwestern Ontario During the Smog Episode
June 24-27, 2007

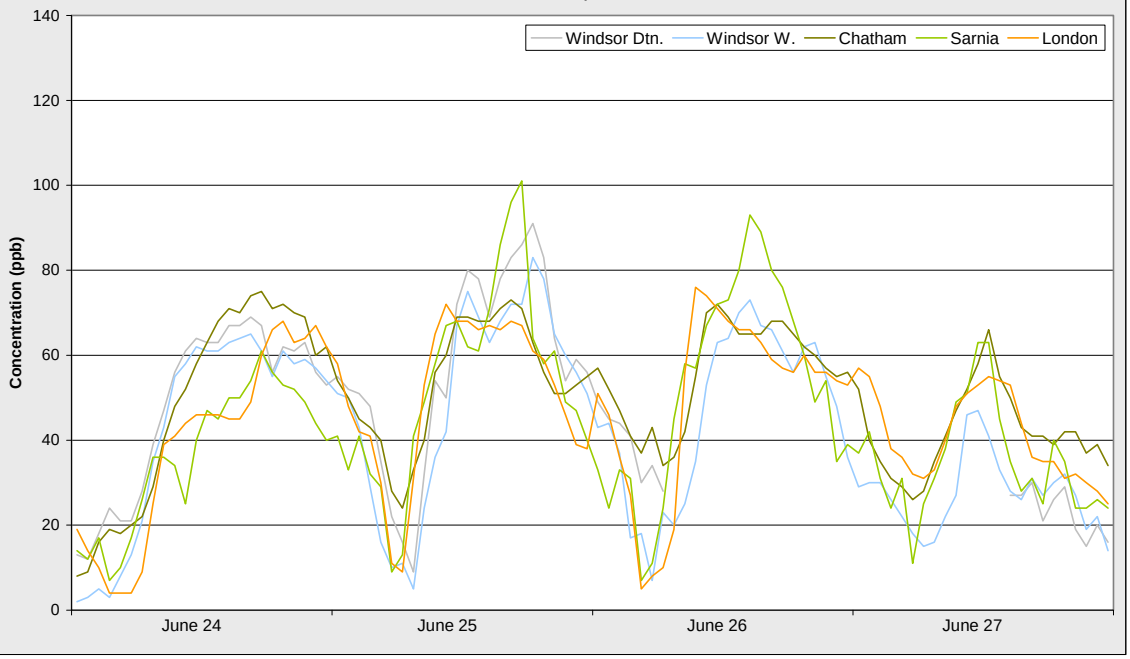


Figure 14
One-Hour Ozone Concentrations at MOE Rural Sites
in Southwestern Ontario During the Smog Episode
June 24-27, 2007

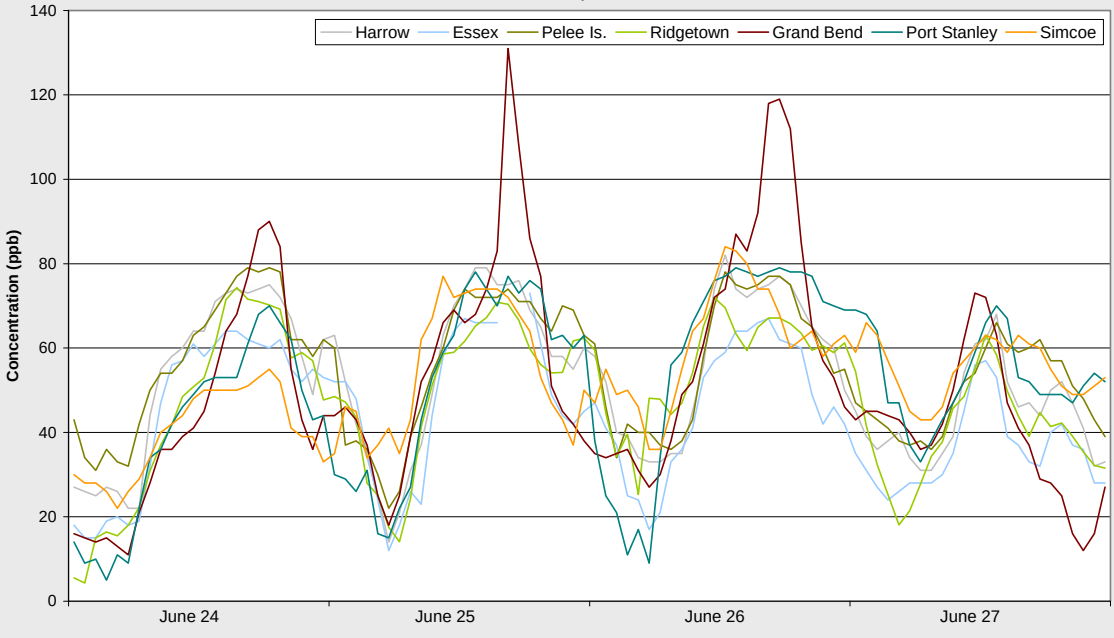


Figure 15
48-Hour Back Trajectories at 500m Arriving at
Grand Bend and Chatham Ontario
at 1300 EDT on June 25, 2007

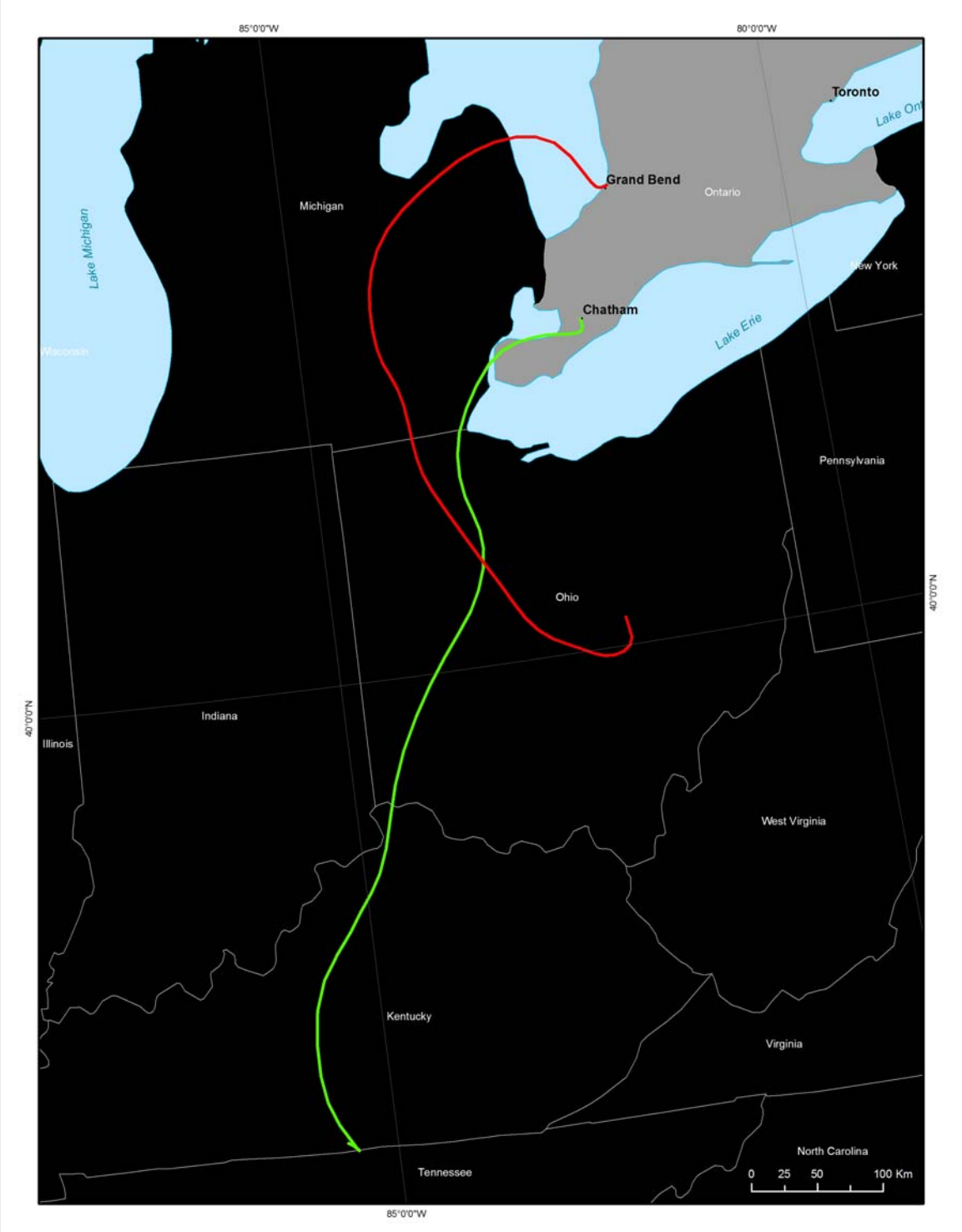


Figure 16
Three-Hour $PM_{2.5}$ Concentrations at MOE Urban Sites in Southwestern Ontario During the Smog Episode June 24-27, 2007

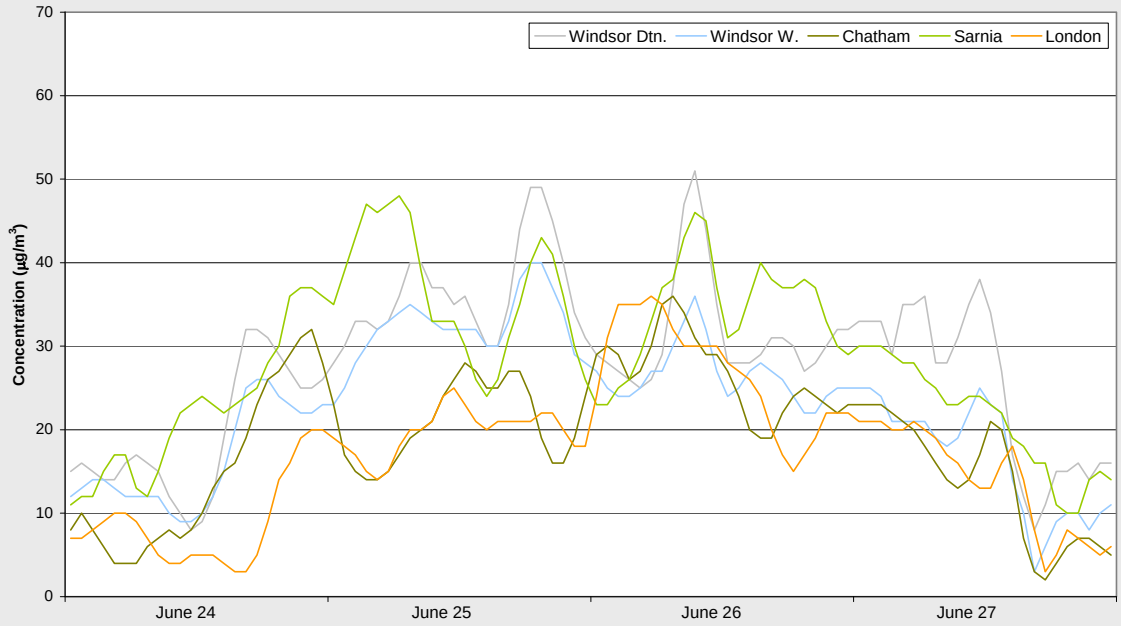


Figure 17
Three-Hour $PM_{2.5}$ Concentrations at MOE Rural Sites in Southwestern Ontario During the Smog Episode June 24-27, 2007

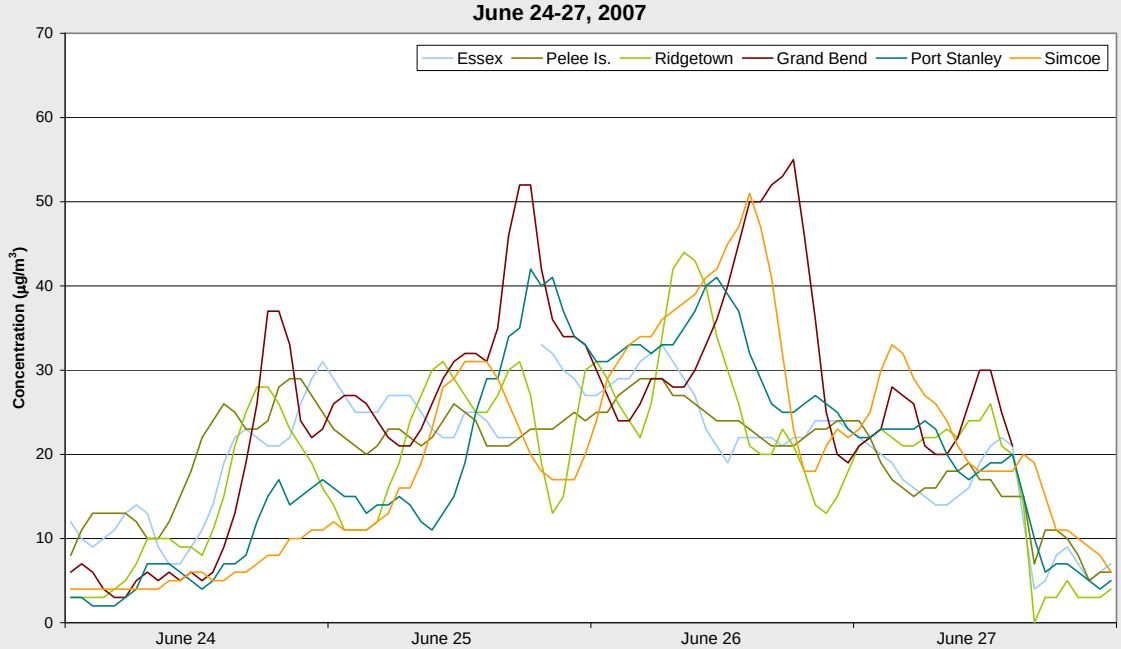


Figure 18
One-Hour Ozone Concentrations at MOE Urban Sites
in Southwestern Ontario During the Smog Episode
July 9-10, 2007

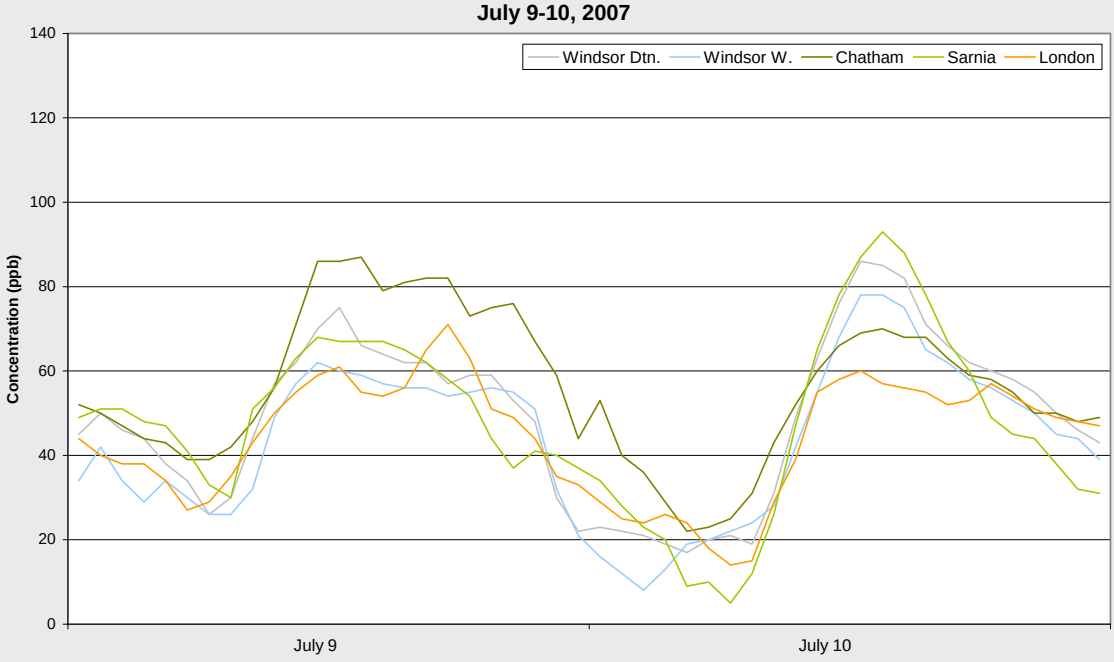


Figure 19
One-Hour Ozone Concentrations at MOE Rural Sites
in Southwestern Ontario During the Smog Episode
July 9-10, 2007

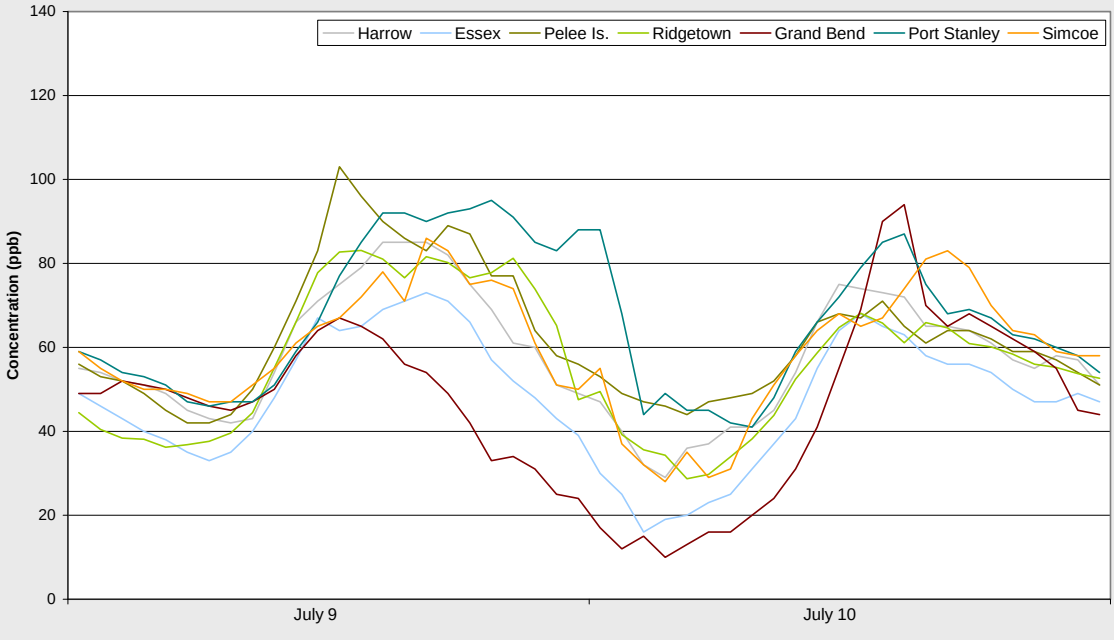


Figure 20
Three-Hour $PM_{2.5}$ Concentrations at MOE Urban Sites in Southwestern Ontario During the Smog Episode
July 9-10, 2007

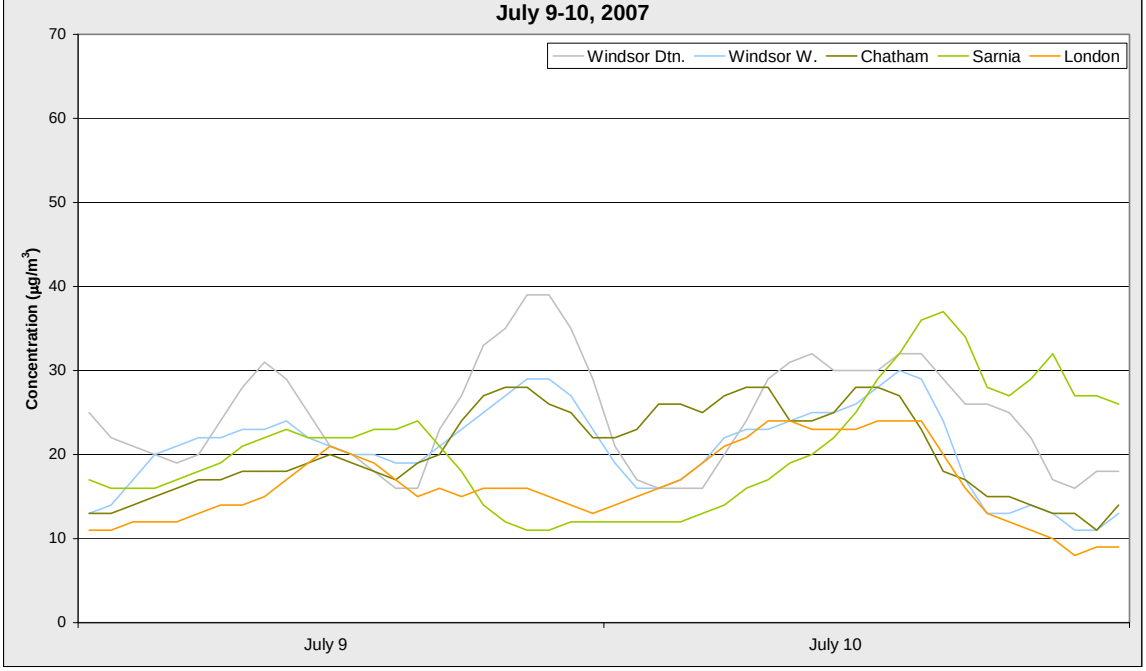


Figure 21
Three-Hour $PM_{2.5}$ Concentrations at MOE Rural Sites in Southwestern Ontario During the Smog Episode
July 9-10, 2007

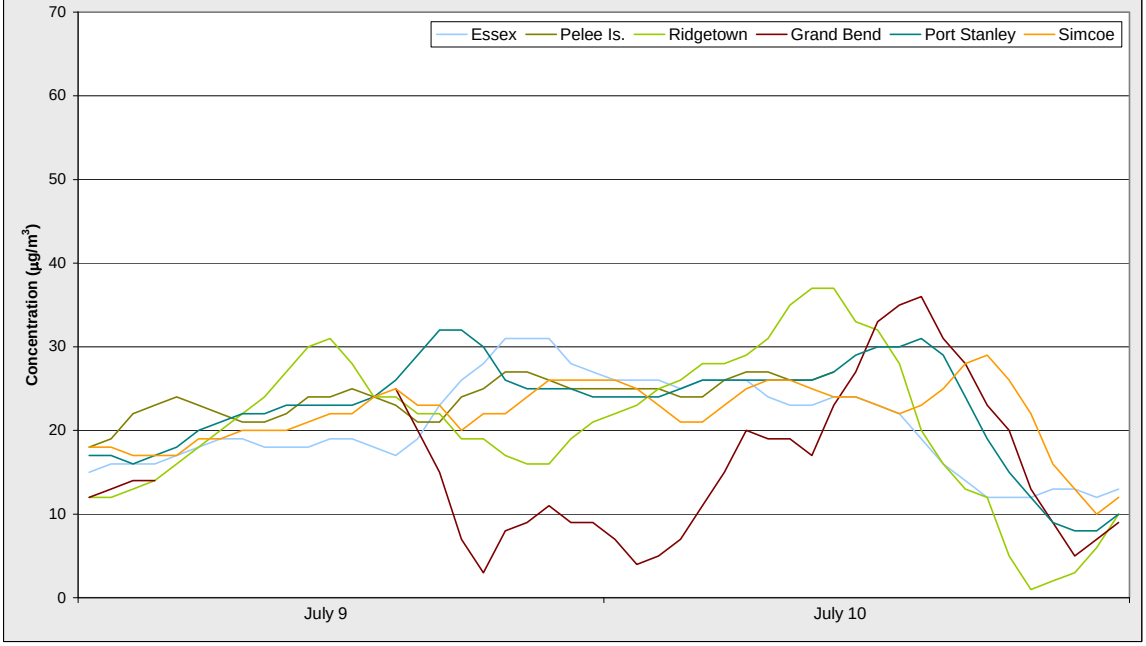
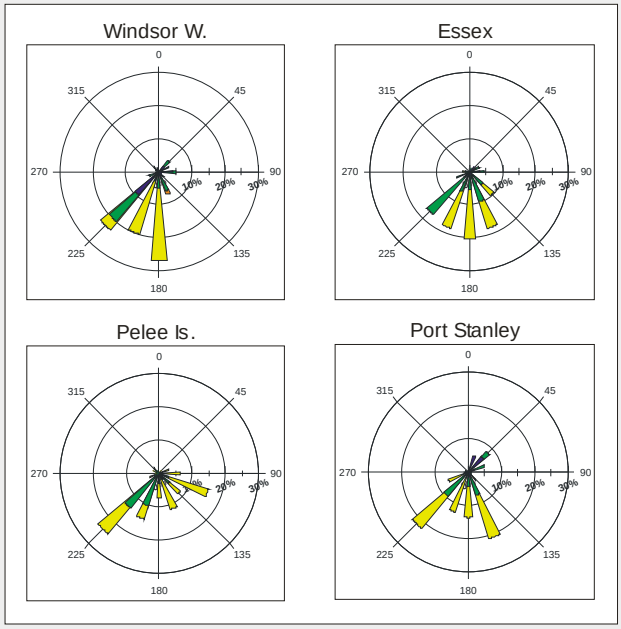
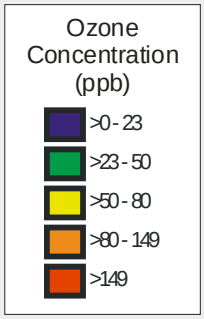


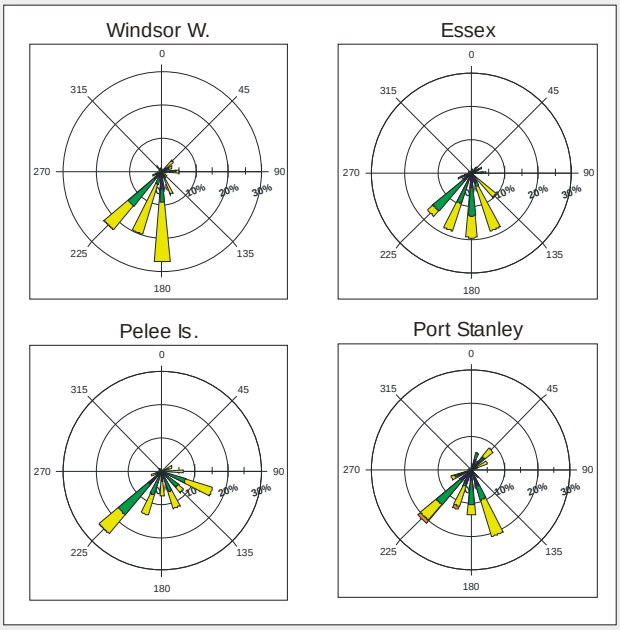
Figure 22
Pollution Rose Figures for the First Smog Episode of the BAQS
June 24-27, 2007

Ozone Pollution Rose Figures





$PM_{2.5}$ Pollution Rose Figures



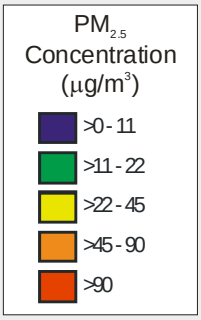
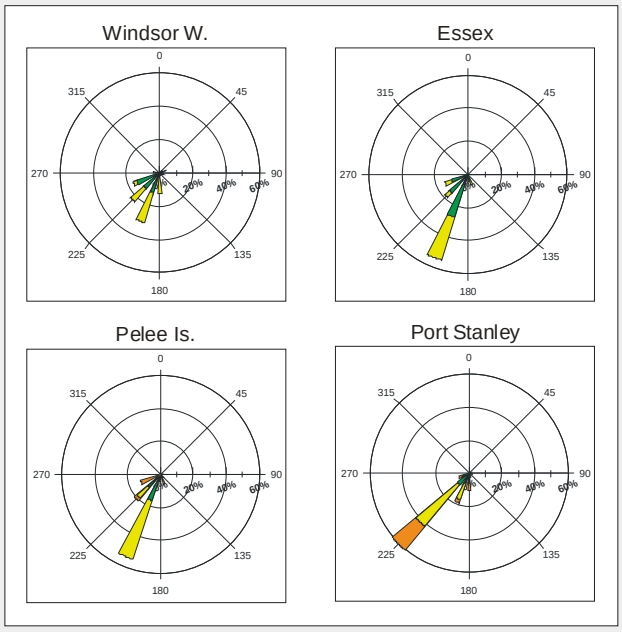
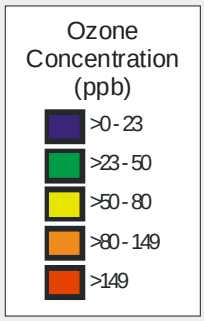


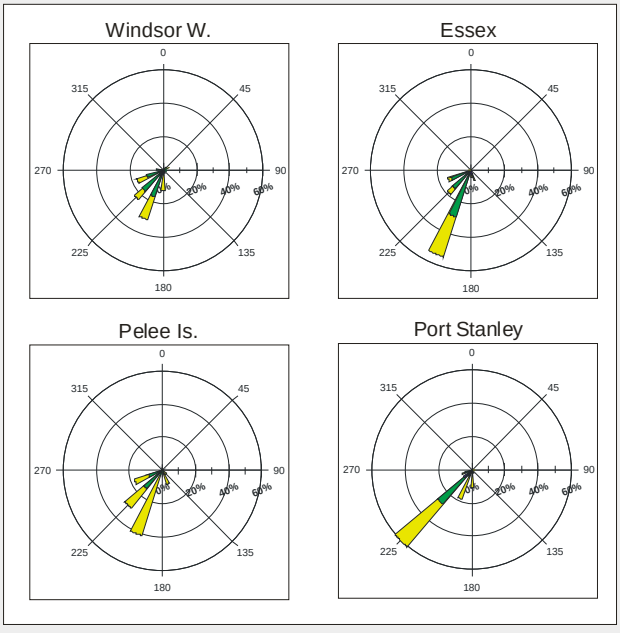
Figure 23
Pollution Rose Figures for the Second Smog Episode of the BAQS
July 9-10, 2007

Ozone Pollution Rose Figures





$PM_{2.5}$ Pollution Rose Figures



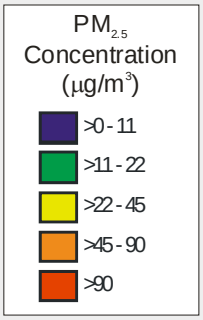


Figure 24
Daily Maximum AQI at MOE Sites Across Southwestern Ontario
June 25, 2007

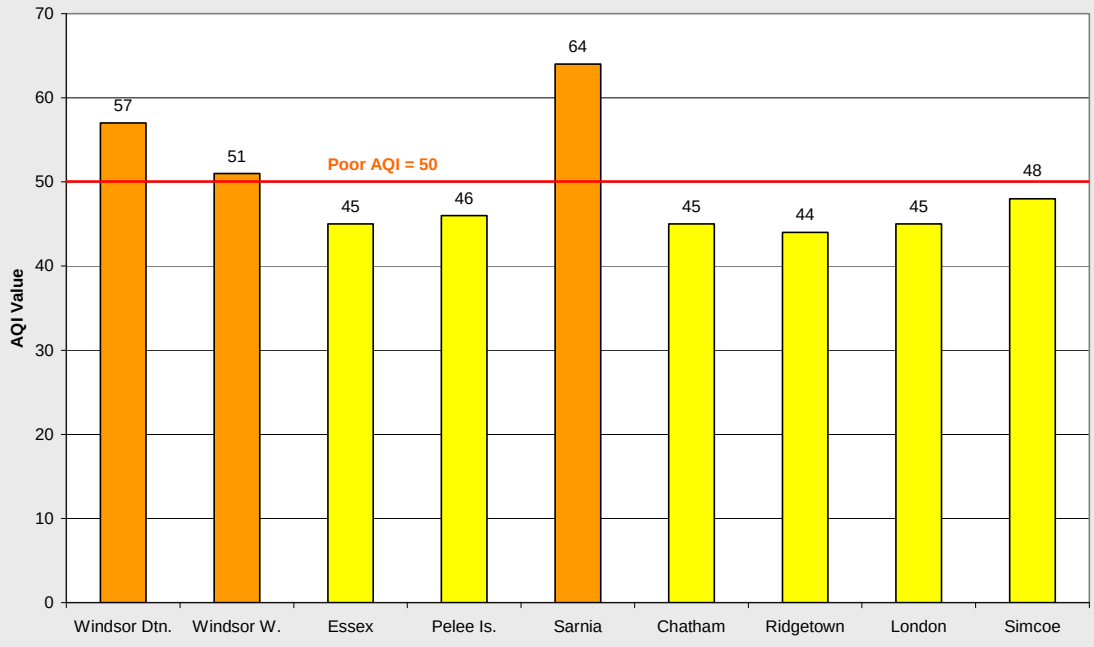


Figure 25
Daily Maximum AQI at MOE Sites Across Southwestern Ontario
June 26, 2007

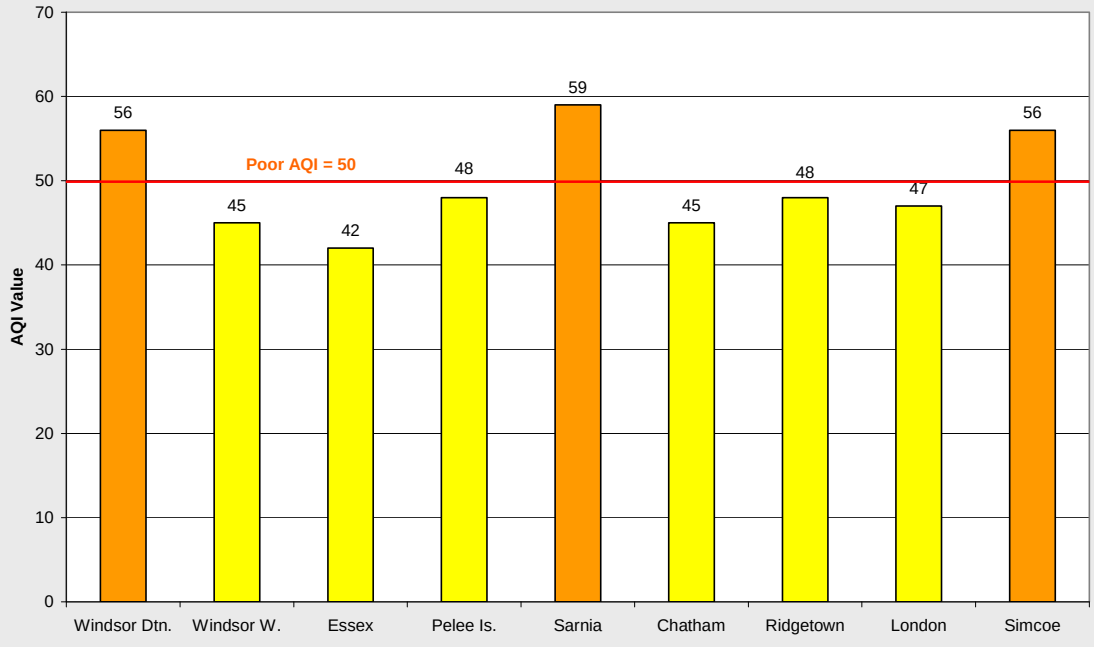


Figure 26
Daily Maximum AQI at MOE Sites Across Southwestern Ontario
July 6, 2007

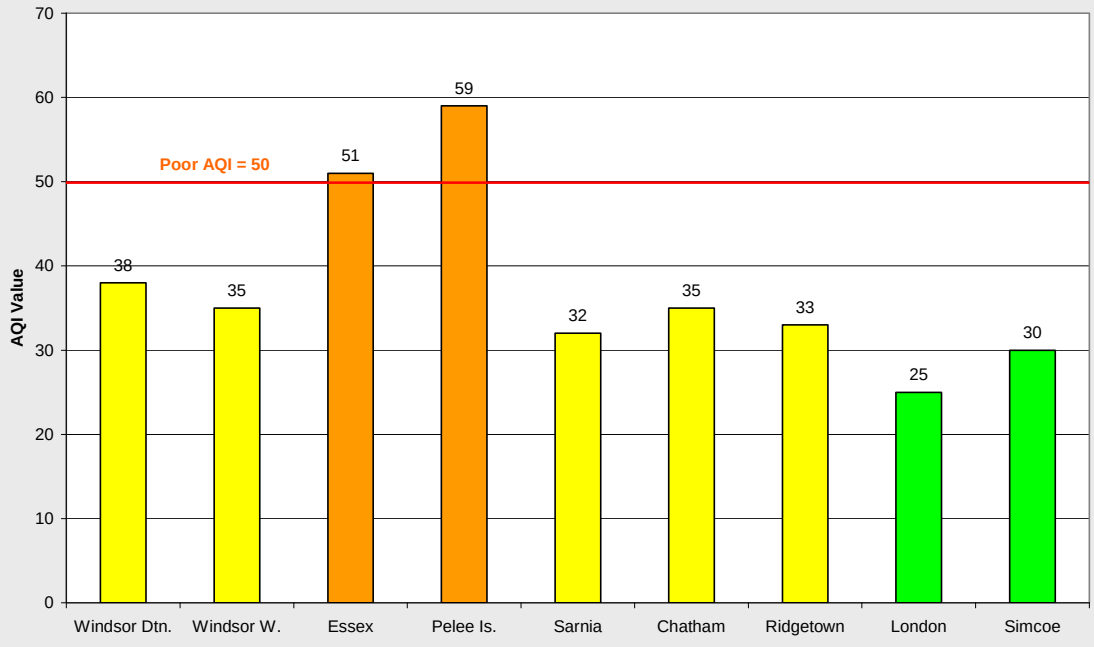


Figure 27
Daily Maximum AQI at MOE Sites Across Southwestern Ontario
July 7, 2007

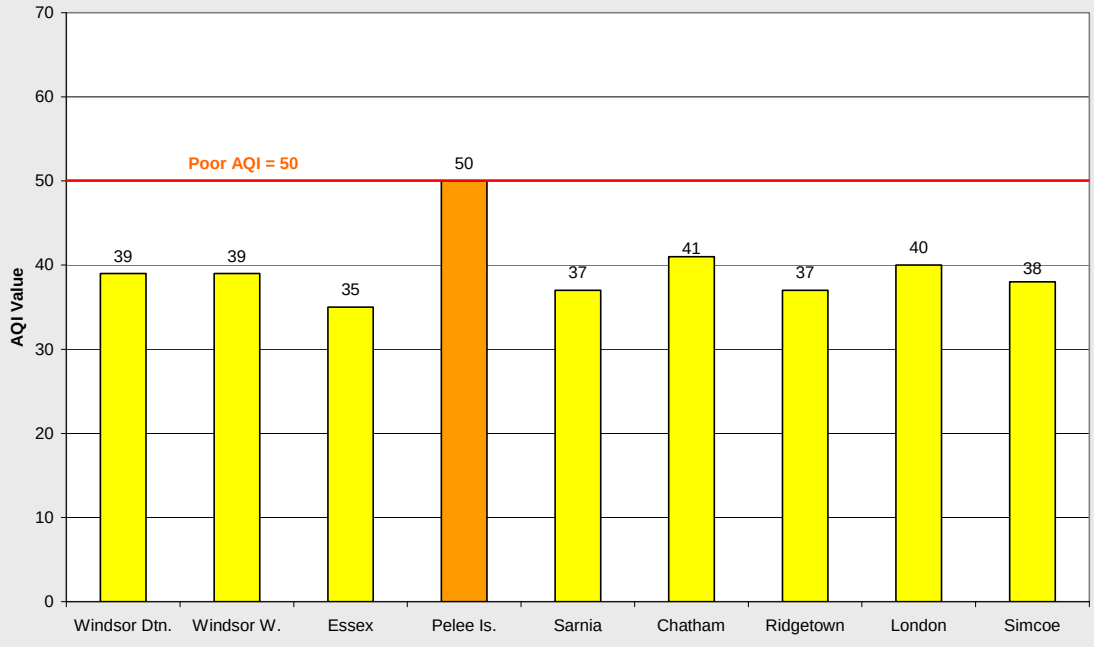


Figure 28
Daily Maximum AQI at MOE Sites Across Southwestern Ontario
July 9, 2007

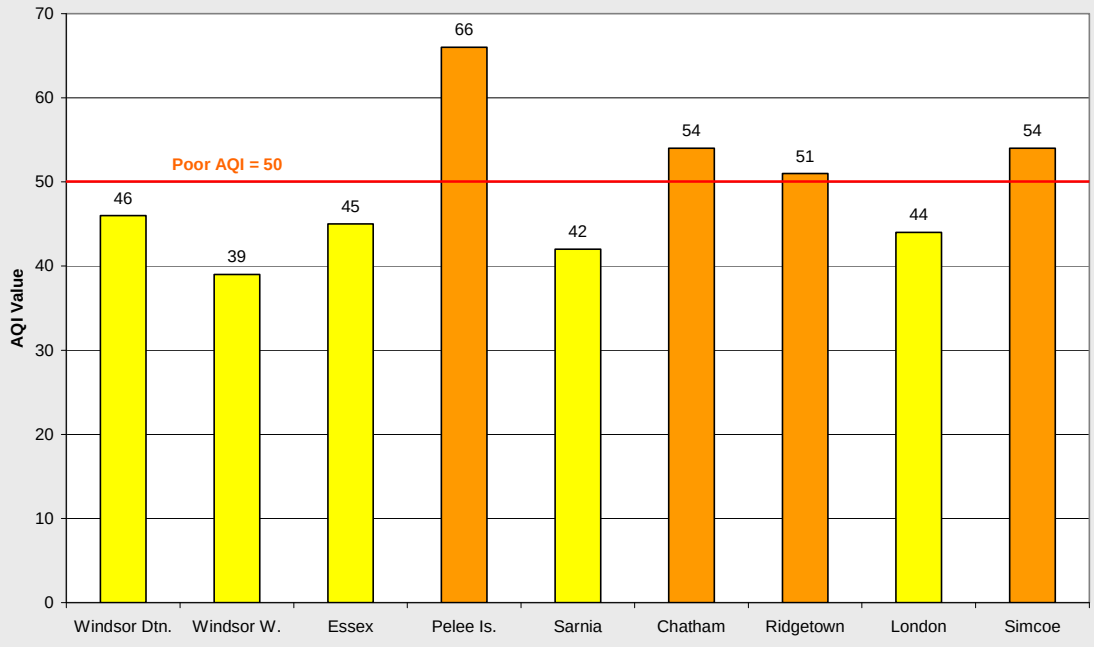


Figure 29
Daily Maximum AQI at MOE Sites Across Southwestern Ontario
July 10, 2007

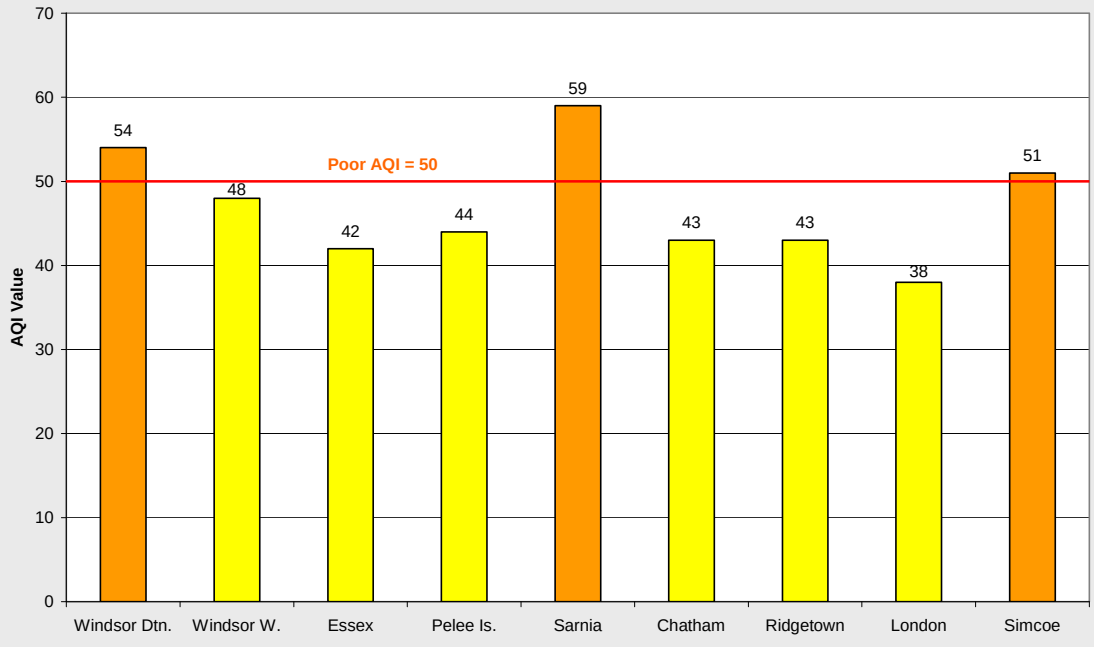


Figure 30
Number of Hours AQI > 49 at MOE Sites Across Southwestern Ontario During the Study Period
June 20 - July 10, 2007

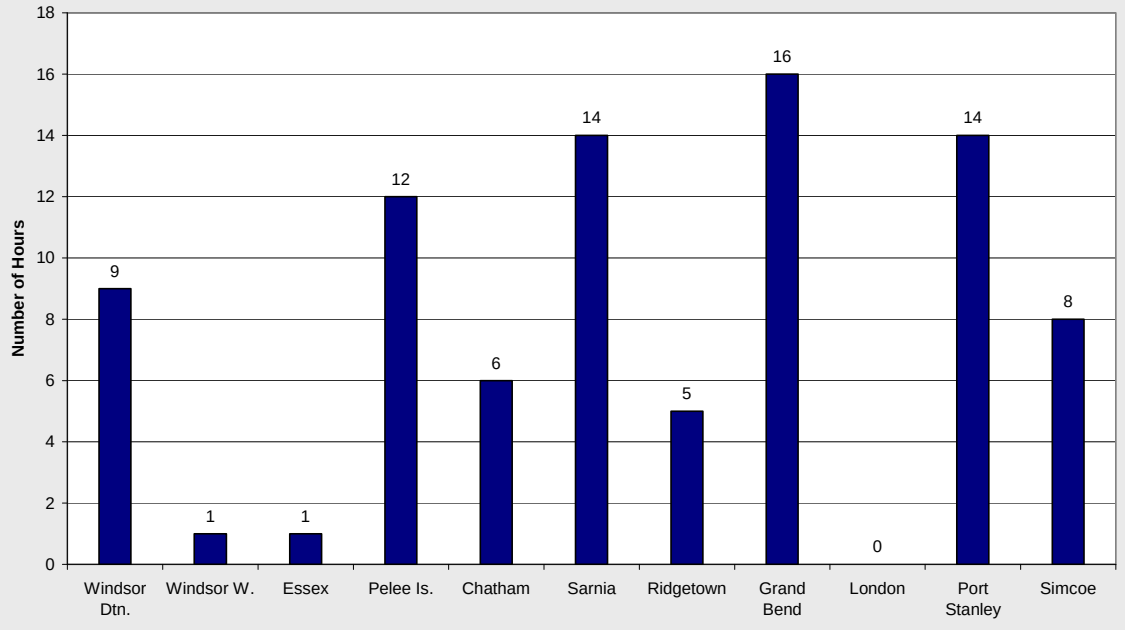


Figure 31
One-Hour BC and $PM_{2.5}$ at Windsor West
June 20 to July 10, 2007

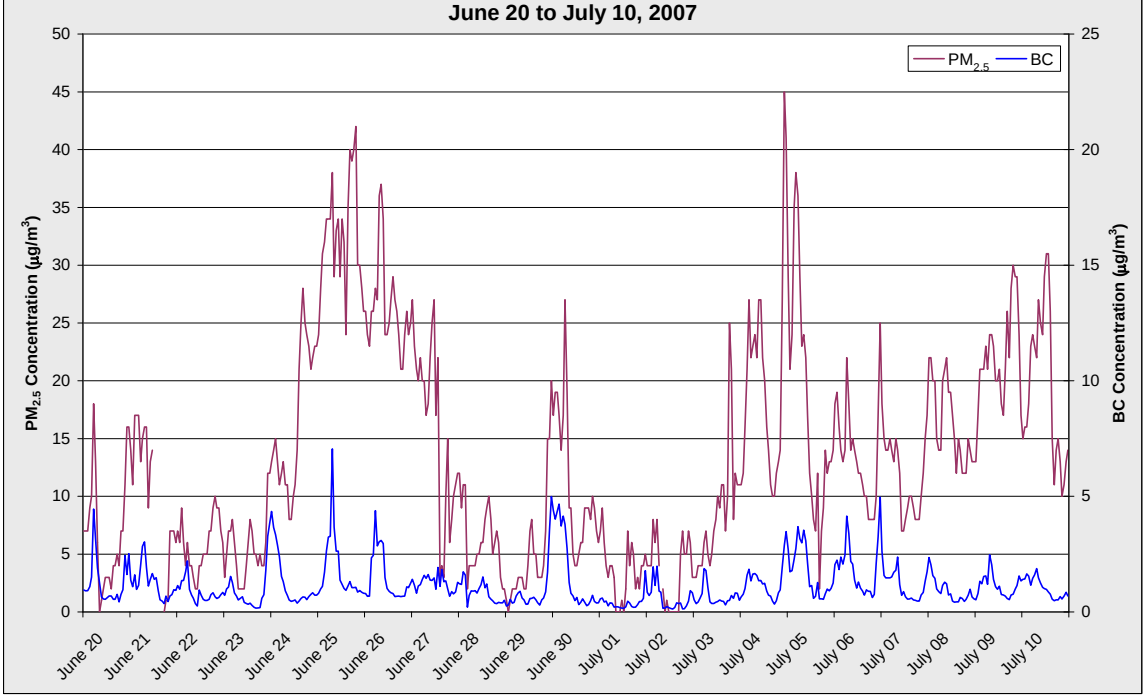
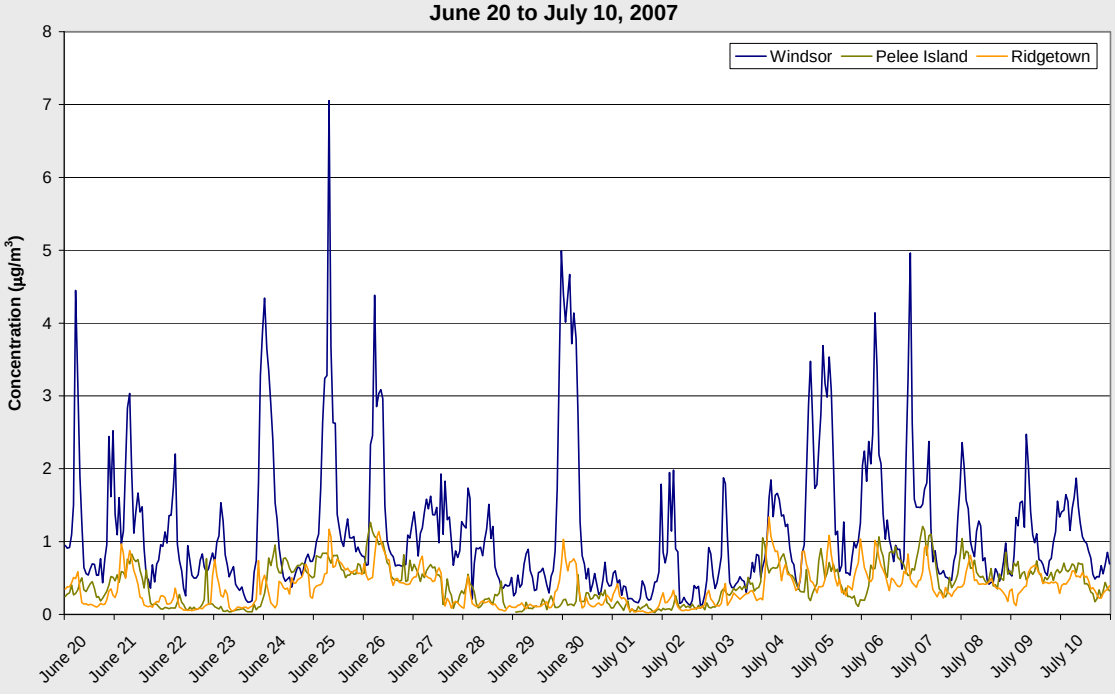


Figure 32
One-Hour BC Concentrations at Windsor West, Ridgetown, and Pelee Island
June 20 to July 10, 2007



Appendix 1
Ontario Ministry of the Environment's BAQS-Met Air Monitoring Stations

MOE ID	NAPS ID	CITY/TOWN	STATION LOCATION	YEAR	LATITUDE	LONGITUDE	AIR INTAKE	TYPE	O_3	$PM_{2.5}$	NO	NO_2	NO_X	CO	SO_2	BC	WS	WD	VOCs
12008	60204	WINDSOR DOWNTOWN	467 UNIVERSITY AVE.	1969	42°18`57``	83°02`38``	8	U	T	T	T	T	T	T	T	.	.	.	.
12016	60211	WINDSOR WEST	COLLEGE AND SOUTH	1975	42°17`34``	83°04`24``	4	U	T	T	T	T	T	.	T	T	T	T	.
n/a	n/a	HARROW	2585 COUNTY RD. # 20, AGRICULTURE CANADA	2007	42°01`59``	82°53`36``	4	R	T	.	T	T	T	.	.	.	.	.	T
12059	65601	ESSEX	360 FAIRVIEW DR. W.	2004	42°09`36``	82°50`00``	5	R	T	T	T	T	T	.	T	.	T	T	.
85135	65135	PELEE ISLAND	CENTRE DYKE RD./ AIRPORT	2007	42°46`46``	82°40`13``	5	R	T	T	T	T	T	T	T	T	T	T	T
13001	65801	CHATHAM	435 GRAND AVE. W.	2005	42°24`12``	82°12`31``	15	U	T	T	T	T	T	T	T	.	T	T	.
14064	61004	SARNIA	FRONT ST./CN TRACKS, CENTENNIAL PARK	1976	42°59`01``	82°24`16``	3	U	T	T	T	T	T	.	T	.	.	.	.
85130	65130	RIDGETOWN	120 MAIN ST. E, UofG RIDGETOWN CAMPUS	2007	42°27`12``	81°53`16``	4	R	T	T	T	T	T	T	T	T	T	T	T
15020	63701	GRAND BEND	WATER TREATMENT PLANT	1991	43°20`02``	81°44`20``	10	R	T	T	.	.	.	.	.	.	.	.	.
15025	60903	LONDON	900 HIGHBURY AVE.	1995	43°00`32``	81°12`34``	4	U	T	T	T	T	T	T	T	.	.	.	.
16015	65301	PORT STANLEY	43665 DEXTER LINE, ELGIN WATER T. PLANT	2002	42°39`36``	81°13`08``	5	R	T	T	.	.	.	.	.	.	T	T	.
22071	62601	SIMCOE	HWY 3/BLUE LINE RD., EXPERIMENTAL FARM	1975	42°51`08``	80°15`50``	4	R	T	T	T	T	T	.	T	.	.	.	.

ID - station identfication number
Year - year station began monitoring
Air intake - height of air intake above ground (m)
Type - type of monitoring site: U = urban, R = rural
T - telemetry
O_3 - ground-level ozone
$PM_{2.5}$ - fine particulate matter
NO - nitric oxide
NO_2 - nitrogen dioxide
NO_X - nitrogen oxides
CO - carbon monoxide
SO_2 - sulphur dioxide
BC - black carbon
WS - wind speed (10m)
WD - wind direction (10m)
VOCs - volatile organic compounds

Appendix 2

Ozone (O_3) Statistics During the BAQS

Unit: parts per billion (ppb)
O_3 1-hour AAQC is 80 ppb

				PERCENTILES								Maximum		No. of Times Above Criterion
ID	City	Location	Valid h	10%	30%	50%	70%	90%	99%	Mean	1h	24h	1h
12008	Windsor Downtown	467 University Ave.	473	14	25	38	49	62	83	37.3	91	57	21
12016	Windsor West	College and South	502	9	22	34	46	59	75	34.1	83	50	18
n/a	Harrow	2585 County Rd. # 20, Agriculture Canada	503	21	31	43	55	70	85	43.8	86	62	14
12059	Essex	360 Fairview Dr. W.	502	16	24	35	47	59	71	36.3	82	52	7
85135	Pelee Island	Centre Dyke Rd./ Airport	499	27	37	47	60	72	88	48.8	103	67	31
13001	Chatham	435 Grand Ave. W.	503	18	29	39	50	65	81	40.1	87	53	13
14064	Sarnia	Front St./CN Tracks, Centennial Park	502	14	24	33	41	58	88	34.4	101	63	18
85130	Ridgetown	120 Main St. E, UofG Ridgetown Campus	503	9	25	36	47	61	80	35.8	83	61	10
15020	Grand Bend	Water Treatment Plant	504	13	25	32	43	60	94	35.7	131	62	27
15025	London	900 Highbury Ave.	503	14	24	32	41	57	68	33.6	76	54	0
16015	Port Stanley	43665 Dexter Line, Elgin Water T. Plant	502	16	29	39	51	70	91	41.4	95	71	15
22071	Simcoe	Hwy 3/Blue Line Rd., Experimental Farm	504	20	31	40	49	63	81	41.0	86	62	6

Fine Particulate Matter ($PM_{2.5}$) Statistics During the BAQS

Unit: micrograms per cubic metre ($\mu g/m^3$)

				PERCENTILES								Maximum		No. of Times Above Reference Level
ID	City	Location	Valid h	10%	30%	50%	70%	90%	99%	Mean	1h	24h	24h
12008	Windsor Downtown	467 University Ave.	480	4	8	14	22	31	48	16.2	57	36	2
12016	Windsor West	College and South	484	3	7	11	17	27	39	13.3	45	33	1
12059	Essex	360 Fairview Dr. W.	475	2	5	11	16	24	31	12.0	35	26	0
85135	Pelee Island	Centre Dyke Rd./ Airport	461	2	5	11	17	25	29	11.9	36	25	0
13001	Chatham	435 Grand Ave. W.	441	1	4	9	16	25	33	11.0	40	26	0
14064	Sarnia	Front St./CN Tracks, Centennial Park	490	3	7	13	20	33	47	15.3	52	36	2
85130	Ridgetown	120 Main St. E, UofG Ridgetown Campus	434	0	3	7	16	26	38	11.0	46	26	0
15020	Grand Bend	Water Treatment Plant	431	1	3	7	13	27	51	10.8	63	34	2
15025	London	900 Highbury Ave.	468	1	3	6	12	21	35	9.0	36	27	0
16015	Port Stanley	43665 Dexter Line, Elgin Water T. Plant	466	1	4	6	16	26	41	10.8	48	31	1
22071	Simcoe	Hwy 3/Blue Line Rd., Experimental Farm	471	2	4	7	15	25	41	11.0	52	34	1

Nitric Oxide (NO) Statistics During the BAQS

Unit: parts per billion (ppb)

				PERCENTILES								Maximum	
ID	City	Location	Valid h	10%	30%	50%	70%	90%	99%	Mean	1h	24h
12008	Windsor Downtown	467 University Ave.	340	0	0	1	2	5	22	2.4	83	11
12016	Windsor West	College and South	367	0	1	1	2	7	37	3.1	89	16
n/a	Harrow	2585 County Rd. # 20, Agriculture Canada	101	0	0	0	0	1	4	0.3	6	1
12059	Essex	360 Fairview Dr. W.	230	0	0	0	1	3	16	1.2	54	4
85135	Pelee Island	Centre Dyke Rd./ Airport	107	0	0	0	0	1	2	0.3	12	1
13001	Chatham	435 Grand Ave. W.	503	1	1	1	1	2	3	1.2	6	2
14064	Sarnia	Front St./CN Tracks, Centennial Park	497	1	1	2	2	4	12	2.4	36	6
85130	Ridgetown	120 Main St. E, UofG Ridgetown Campus	454	2	3	3	4	7	15	4.2	21	8
15025	London	900 Highbury Ave.	330	0	0	1	1	3	14	1.4	20	3
22071	Simcoe	Hwy 3/Blue Line Rd., Experimental Farm	94	0	0	0	0	1	2	0.2	3	1

Nitrogen Dioxide (NO_2) Statistics During the BAQS

Unit: parts per billion (ppb)
NO_2 1-hour AAQC is 200 ppb
NO_2 24-hour AAQC is 100 ppb

				PERCENTILES								Maximum		No. of Times Above Criteria	
ID	City	Location	Valid h	10%	30%	50%	70%	90%	99%	Mean	1h	24h	1h	24h
12008	Windsor Downtown	467 University Ave.	503	4	6	9	16	28	40	13.0	47	22	0	0
12016	Windsor West	College and South	502	4	7	11	18	27	42	13.6	51	20	0	0
n/a	Harrow	2585 County Rd. # 20, Agriculture Canada	504	2	3	4	6	10	16	5.4	20	8	0	0
12059	Essex	360 Fairview Dr. W.	502	2	4	6	8	16	24	7.4	29	12	0	0
85135	Pelee Island	Centre Dyke Rd./ Airport	416	0	1	2	3	5	9	2.6	15	4	0	0
13001	Chatham	435 Grand Ave. W.	503	4	5	6	9	12	18	7.5	22	11	0	0
14064	Sarnia	Front St./CN Tracks, Centennial Park	489	1	3	6	12	19	31	8.6	44	17	0	0
85130	Ridgetown	120 Main St. E, UofG Ridgetown Campus	454	2	3	4	6	10	15	5.2	18	7	0	0
15025	London	900 Highbury Ave.	488	2	4	6	10	17	35	8.4	42	17	0	0
22071	Simcoe	Hwy 3/Blue Line Rd., Experimental Farm	504	2	3	4	5	6	10	3.9	15	6	0	0

Nitrogen Oxides (NO_x) Statistics During the BAQS

Unit: parts per billion (ppb)

				PERCENTILES							Maximum	
ID	City	Location	Valid h	10%	30%	50%	70%	90%	99%	Mean	1h	24h
12008	Windsor Downtown	467 University Ave.	503	5	7	11	18	32	58	15.4	123	30
12016	Windsor West	College and South	504	4	8	12	19	34	79	16.7	130	35
n/a	Harrow	2585 County Rd. # 20, Agriculture Canada	504	2	3	4	7	11	18	5.7	25	9
12059	Essex	360 Fairview Dr. W.	502	3	4	6	9	19	37	8.7	79	16
85135	Pelee Island	Centre Dyke Rd./ Airport	433	0	1	2	4	6	11	3.0	28	5
13001	Chatham	435 Grand Ave. W.	503	5	6	8	10	14	20	8.6	24	13
14064	Sarnia	Front St./CN Tracks, Centennial Park	502	3	5	8	14	23	41	11.0	80	23
85130	Ridgetown	120 Main St. E, UofG Ridgetown Campus	454	5	6	8	10	16	26	9.3	38	14
15025	London	900 Highbury Ave.	492	3	6	7	11	19	40	9.9	59	19
22071	Simcoe	Hwy 3/Blue Line Rd., Experimental Farm	504	2	3	4	5	7	12	4.3	16	6

Carbon Monoxide (CO) Statistics During the BAQS

Unit: parts per million (ppm)
CO 1-hour AAQC is 30 ppm
CO 8-hour AAQC is 13 ppm

				PERCENTILES							Maximum		No. of Times Above Criteria	
ID	City	Location	Valid h	10%	30%	50%	70%	90%	99%	Mean	1h	8h	1h	8h
12008	Windsor Downtown	467 University Ave.	473	0.03	0.08	0.12	0.18	0.32	0.81	0.16	1.01	0.49	0	0
85135	Pelee Island	Centre Dyke Rd./ Airport	490	0.02	0.04	0.07	0.09	0.13	0.26	0.08	0.56	0.31	0	0
13001	Chatham	435 Grand Ave. W.	503	0.07	0.11	0.17	0.22	0.26	0.34	0.17	0.37	0.31	0	0
85130	Ridgetown	120 Main St. E, UofG Ridgetown Campus	407	0.00	0.02	0.05	0.10	0.14	0.23	0.06	0.30	0.21	0	0
15025	London	900 Highbury Ave.	438	0.00	0.03	0.07	0.11	0.15	0.24	0.08	0.37	0.22	0	0

Sulphur Dioxide (SO_2) Statistics During the BAQS

Unit: parts per billion (ppb)
SO_2 1-hour AAQC is 250 ppb
SO_2 24-hour AAQC is 100 ppb
SO_2 1-year AAQC is 20 ppb

				PERCENTILES								Maximum		No. of Times Above Criteria		
ID	City	Location	Valid h	10%	30%	50%	70%	90%	99%	Mean	1h	24h	1h	24h	1y
12008	Windsor Downtown	467 University Ave.	474	1	1	2	5	15	42	5.7	65	12	0	0	0
12016	Windsor West	College and South	335	0	0	1	4	13	35	4.7	49	12	0	0	0
12059	Essex	360 Fairview Dr. W.	295	0	0	1	2	7	31	2.9	46	12	0	0	0
85135	Pelee Island	Centre Dyke Rd./ Airport	352	0	1	1	2	6	12	2.1	18	7	0	0	0
13001	Chatham	435 Grand Ave. W.	217	0	0	0	1	4	12	1.4	22	5	0	0	0
14064	Sarnia	Front St./CN Tracks, Centennial Park	407	0	1	1	4	22	66	7.1	134	30	0	0	0
85130	Ridgetown	120 Main St. E, UofG Ridgetown Campus	277	0	0	1	1	4	14	1.5	23	6	0	0	0
15025	London	900 Highbury Ave.	272	0	0	1	1	3	8	1.1	14	5	0	0	0
22071	Simcoe	Hwy 3/Blue Line Rd., Experimental Farm	236	0	0	0	1	3	9	1.0	13	4	0	0	0

Black Carbon (BC) Statistics During the BAQS

Unit: micrograms per cubic metre ($\mu g/m^3$)
BC 24-hour AAQC is 10 $\mu g/m^3$

				PERCENTILES								Maximum		No. of Times Above Criterion
ID	City	Location	Valid h	10%	30%	50%	70%	90%	99%	Mean	1h	24h		24h
12016	Windsor West	College and South	504	0.4	0.6	0.9	1.3	2.4	4.4	1.2	7.1	2.2		0
85135	Pelee Island	Centre Dyke Rd./ Airport	499	0.1	0.2	0.4	0.6	0.8	1.1	0.4	1.3	0.9		0
85130	Ridgetown	120 Main St. E, UofG Ridgetown Campus	504	0.1	0.2	0.3	0.5	0.7	1.1	0.4	1.3	0.7		0

Appendix 3

Volatile Organic Compounds (VOC) and Method Detection Limits (MDL)

No.	VOC	MDL ($\mu g/m^3$)
1	Freon 12	>2.0
2	Freon 114	>2.0
3	Methyl chloride	>2.0
4	Vinyl chloride	>2.0
5	1,3-Butadiene	>0.5
6	Ethyl chloride	>0.5
7	Methyl bromide	>0.5
8	Freon 11	0.10
9	Isoprene	0.05
10	1,1-dichloroethene	0.05
11	Freon 113	0.15
12	Methylene chloride	0.05
13	trans-1,2-dichloroethylene	0.05
14	1,1 dichloroethane	0.05
15	Hexane	0.05
16	cis-1,2-dichloroethylene	0.05
17	Chloroform	0.02
18	Cyclohexane	0.05
19	1,1,1-trichloroethane	0.05
20	Benzene	0.05
21	Carbon tetrachloride	0.05
22	1,2 dichloroethane	0.05
23	1,2 dichloropropane	0.05
24	trichloroethylene	0.05
25	Bromo-dichloromethane	0.10
26	cis-1,3 dichloropropylene	0.02
27	trans-1,3 dichloropropylene	0.02
28	Toluene	0.02
29	1,1,2 trichloroethane	0.15
30	1,2-dibromoethane	0.05
31	tetrachloroethylene	0.05
32	Chlorobenzene	0.05
33	Ethylbenzene	0.02
34/35	m/p-Xylene	0.10
36	Styrene	0.02
37	o-Xylene	0.05
38	1,1,2,2-tetrachloroethane	0.20
39	isopropylbenzene	0.02
40	4-chlorotoluene	0.02
41	Propylbenzene	0.02
42	1,3,5 trimethylbenzene	0.05
43	1,3-dichlorobenzene	0.05
44	1,4-dichlorobenzene	0.10
45	1,2,4-trimethylbenzene	0.05
46	1,2-dichlorobenzene	0.10
47	Butylbenzene	0.05
48	1,2,4-trichlorobenzene	0.15
49	Naphthalene	0.10
50	hexachloro-1,3-butadiene	0.15

Note:

Cartridge air samples analyzed by thermal desorption-gas chromatography-tandem mass spectrometry

Air Monitoring & Reporting Section, Environmental Monitoring & Reporting Branch, Ontarion Ministry of Environment

TD-GC-MS/MS system in TAGA laboratory at 125 Resources Road, West Wing, Toronto