Georgian Bay Air Quality Study 2000

Environmental Monitoring and Reporting Branch
Ontario Ministry of the Environment

March 2001

Ontario

GEORGIAN BAY AIR QUALITY STUDY 2000

Summary

From July 17th to July 27th, 2000, the Ministry of Environment measured hourly pollutant concentrations around the shores of Georgian Bay using their state-of-the-art Mobile Air Quality Index (AQI) Unit. The pollutants measured were ambient ozone (O_3), inhalable particles (PM_{10}), nitrogen dioxide (NO_2), mercury (Hg), and sulphur dioxide (SO_2). The measurements taken around the Georgian Bay area by the Mobile AQI Unit were compared to the levels of pollutants recorded at various fixed air quality monitoring sites in the north, as well as sites located further south in Tiverton, Grand Bend and Toronto, over the same time period.

The daily maximum values of ozone measured by the Mobile AQI Unit and the fixed air monitoring sites showed reasonably good agreement throughout the study. However, for average hourly concentrations, the correlation was somewhat lower.

Comparisons of pollutants measured along the shores of Georgian Bay with those measured in Toronto, both downtown and in the west end showed that, in general, the pollutant concentrations in the Georgian Bay area were significantly less than those in Toronto.

In summary,

- On most days, ozone levels at the Georgian Bay area sites were lower than corresponding levels recorded at the Toronto Downtown site.

- On the majority of days, 24-hour average inhalable particle levels in the Georgian Bay area were lower than levels in the Toronto area.

- Daily average nitrogen dioxide levels measured in the Georgian Bay area were typically orders of magnitude lower than levels in Toronto.

- Daily average mercury levels in the Georgian Bay area were significantly lower than at the Toronto West site where levels were typically two times the measured Georgian Bay area values.

- Daily average sulphur dioxide levels, on average, were comparable with those measured in Toronto.

- During the period of study, there were no exceedances of any of the provincial ambient air quality criteria in the Georgian Bay area.

Introduction

The purpose of this study was to examine the spatial variation in concentrations of key air pollutants along the shores of Georgian Bay, to identify the role of trans-boundary and long range transport of pollutants into the region and, to determine the representativeness of existing sites located in the vicinity of Georgian Bay. The study was partially initiated on the request of the Georgian Bay Cottage Association.

From July 17th to 27th, 2000, the Mobile AQI Unit of the Air Monitoring Section, Environmental Monitoring and Reporting Branch of the Ontario Ministry of the Environment, monitored air pollutant concentrations at 7 different locations along the shores of Georgian Bay. These sites, in chronological order, were Parry Sound, Pointe au Baril, Honey Harbour, Britt, Providence Bay, Killarney, and Killbear Provincial Park, (Figure 1).

At each location, the following pollutants were monitored: ozone (O_3), inhalable particles (PM_{10}), nitrogen dioxide (NO_2), mercury (Hg), and sulphur dioxide (SO_2). Meteorological conditions, such as temperature, wind speed and wind direction, were also monitored by the Mobile AQI Unit.

Measurements made in the Georgian Bay area by the Mobile AQI Unit were compared with measurements taken at fixed air monitoring stations around the area. The location of the fixed air monitoring stations around Georgian Bay are Sault Ste. Marie, Sudbury Science North, Haliburton (Dorset), and Georgian Bay South, (Figure 2). Stations at Tiverton, Grand Bend and in the City of Toronto were also included in the study to ascertain how the air quality in the Georgian Bay area compared with that in Toronto, a major urban centre, and also with that at the Tiverton and Grand Bend stations, which are strongly impacted by trans-boundary sources.

Table 1 is a record of the meteorological conditions recorded in the Georgian Bay area during each day of the study. Sky conditions, precipitation, maximum and minimum air temperatures and average wind direction and speed are shown.

Table 1: Meteorological Conditions in the Georgian Bay Area, July 17th to 27th, 2000

Date	Sky Conditions	Max. / Min. Temp (^oC)	Wind dir / speed (km/h)
July 17	Partly cloudy with light rain	24.6 / 18.5	West / 14
July 18	Partly cloudy with light rain	18.2 / 14.7	West / 17
July 19	Partly cloudy	20.5 / 11.4	Southwest / 12
July 20	Partly cloudy with light rain	23.7 / 12.4	Southwest / 10
July 21	Mainly cloudy with rain	19.8 / 15.1	Southwest / 10
July 22	Partly cloudy	20.5 / 14.5	Northwest / 21
July 23	Partly cloudy	21.1 / 12.7	South / 11
July 24	Partly cloudy	24.8 / 13.9	South / 17
July 25	Mainly clear	24.3 / 12.4	South / 13
July 26	Mainly clear	23.4 / 11.0	Southeast / 12
July 27	Mainly clear	31.0 / 20.3	Southwest / 11

Correlation Analysis Results

Correlation studies were carried out between the data collected by the Mobile AQI Unit and the fixed air monitoring sites around Georgian Bay. Data from each fixed site was compared to the Mobile AQI Unit data when the Unit was, geographically, closest to that fixed station. Correlation analysis essentially shows if there is any association between the data collected at various locations.

Although the air monitoring sites around Georgian Bay primarily measure ozone, the Mobile AQI Unit was able to measure concentrations of ozone, inhalable particles (PM_{10}), nitrogen dioxide, mercury, and sulphur dioxide. Thus, concentrations of these pollutants, including ozone, were compared with concentrations measured in Toronto, to give some perspective on the concentration levels of these pollutants in the Georgian Bay area.

Comparison of Ozone Concentrations between the Mobile AQI Unit and Fixed Air Monitoring Stations Surrounding Georgian Bay

Table 2 shows the correlation coefficient (r) and coefficient of determination (r^2) for the hourly ozone concentrations measured at each site closest to the Mobile AQI Unit during each day of the study. Correlation between the fixed air monitoring sites and the Mobile AQI Unit was generally good.

However, the correlation between the Mobile AQI Unit measurements at Honey Harbour and those measured at the Georgian Bay South site (the closest fixed site) was quite low. On July 21st mainly cloudy conditions with rain prevailed over the Georgian Bay area and these conditions could have affected the ozone measurements.

Table 2: Correlation Coefficients of Hourly Ozone Concentrations
Mobile AQI Unit vs. Fixed Air Monitoring Sites, July 17th to 27th, 2000

Date	Mobile AQI Unit Location	Closest Fixed Station	r	r^2
July 17-19	Parry Sound	Haliburton	0.75	0.57
July 20	Point au Baril	Sudbury	0.69	0.48
July 21	Honey Harbour	Georgian Bay South	0.37	0.14
July 22-23	Parry Sound	Haliburton	0.79	0.62
July 24	Britt	Sudbury	0.80	0.64
July 25	Providence Bay	Sudbury	0.87	0.76
July 26	Killarney	Sudbury	0.52	0.27
July 27	Killbear Prov. Park	Haliburton	0.85	0.72

r - correlation coefficient
r^2 - coefficient of determination

Table 3 shows the correlation coefficient (r) and coefficient of determination (r^2) between the daily maximum 1-hour ozone concentrations at each fixed air monitoring site, as compared to the maximum levels measured by the Mobile AQI Unit. With the exception of Tiverton, the daily maximum ozone levels measured show very high correlation, with the sites closest to Georgian Bay (Haliburton, Sudbury and Georgian Bay South) having correlation coefficients in the range 0.92 to 0.95. Tiverton is much further in distance from Georgian Bay than the other fixed air quality monitoring stations. This might explain why the correlation coefficient between data from the Mobile AQI Unit and Tiverton is lower than those determined with sites in closer proximity to the Georgian Bay area.

Table 3: Correlation Coefficients of Daily Maximum 1-hour Ozone Concentrations Mobile AQI Unit vs. Fixed Air Monitoring Stations, July 17th to 27th, 2000

Fixed Monitoring Station	r	r^2
Tiverton	0.77	0.59
Sudbury	0.92	0.84
Georgian Bay South	0.94	0.88
Haliburton	0.95	0.90
Sudbury	0.94	0.89

r - correlation coefficient
r^2 - coefficient of determination

Figure 3 compares the daily 1-hour maximum ozone concentrations for the Mobile AQI Unit and the fixed air monitoring stations. (The site closest to the Mobile AQI Unit on a particular day is marked with an asterisk.) The maximum value seen at Tiverton on the 20th of July, which was not reflected at any of the other sites around Georgian Bay or the Mobile AQI Unit, was likely caused by local transport related to a slow moving weather system with light winds, and near stagnant conditions over Lake Huron. Daily maximum 1-hour concentrations of ozone in mid-eastern Michigan and at the Grand Bend monitoring station read between 76 ppb (Flint and Otisville) to 89 ppb (Grand Bend). Forty-eight hour airflow over Tiverton, on July 20th shows the winds originated from northeastern Michigan and over Lake Huron, (Figure 4). This slow movement of the air over the lake did not allow for transport of these relatively high levels of ozone into the Georgian Bay area.

Comparison of Ozone Concentrations between the Georgian Bay Area and the Toronto Downtown Air Monitoring Site

Figure 5 is a comparison of the daily maximum 1-hour ozone concentration measured around Georgian Bay, versus the corresponding ozone concentration recorded at the Toronto Downtown site, for each day of the study. On most days, daily maximum ozone levels recorded at air monitoring sites (including the Mobile AQI Unit) in the Georgian Bay area were lower than the levels recorded at the Toronto Downtown air monitoring site. On July 26th, the maximum 1-hour ozone concentration reached 76 ppb in the Georgian Bay area, while the maximum 1-hour ozone concentration recorded at the Toronto Downtown air monitoring site was 84 ppb. Across most of southern Ontario, maximum ozone levels on July 26th were typically in the range 74 ppb to 91 ppb for a 1-hour average.

High concentrations of ozone, in Ontario, are produced in summer with sunny, warm conditions, and southerly winds. Since cloudy conditions with showers prevailed over southern Ontario on July 27th, ozone levels were low. In contrast to the Georgian Bay area where the wind was southerly, the sky was mainly clear, and temperatures reached a maximum of 31° C. Under these conditions relatively high levels of ozone were produced. Thus, the daily maximum 1-hour ozone concentration recorded in the Georgian Bay area (74 ppb) was higher than the level recorded at the Toronto Downtown air monitoring site (62 ppb). However, the maximum ozone level recorded in Georgian Bay area was below the Ontario 1-hour criterion for ozone (80 ppb). In fact, during the study period ozone levels recorded in the Georgian Bay area did not exceed the Ontario ozone criterion.

Comparison of Inhalable Particulate Matter (PM_{10}) Concentrations between the Mobile AQI Unit and the Toronto West Air Monitoring Site

Over the period of the study, daily (24-hour) average concentrations of inhalable particles (PM_{10}) measured in the Georgian Bay area were found to be fairly constant between 9 and 10 micrograms per cubic metre ($\mu g/m^3$), and were approximately half the concentrations measured at Toronto West over the same period, (Table 4). On July 26th relatively high levels of PM_{10} were recorded in the Toronto area, with a 24-hour average concentration of 40.8 $\mu g/m^3$ being measured at Toronto West. On July 27th, however, PM_{10} levels in the Georgian Bay area exceeded those in Toronto (where the weather was cloudy with showers). On this day, the Mobile AQI Unit measured a 24-hour average concentration of 28.3 $\mu g/m^3$, compared to 19.3 $\mu g/m^3$ at the Toronto West site, approximately 45% higher.

On both July 26th and 27th wind flow was southerly and therefore, the relatively high level of PM_{10} measured in the Georgian Bay area on July 27th was likely due to transport of PM_{10} into the area, (Figure 6). The 24-hour average PM_{10} levels measured in the Georgian Bay area, however, were below the Ministry's interim 24-hour criterion of 50 µg/m^3 on all days of the study.

Table 4: Daily Average Inhalable Particulate Matter (PM_{10}) Concentrations (µg/m^3), July 17th to 27th, 2000

Date	Location	Mobile AQI Unit	Toronto West
July 17	Parry Sound	-	22.6
July 18	Parry Sound	7.3	11.0
July 19	Parry Sound	9.6	14.9
July 20	Point au Baril	9.9	25.3
July 21	Honey Harbour	9.5	15.3
July 22	Parry Sound	9.2	10.5
July 23	Parry Sound	10.5	13.0
July 24	Britt	10.1	23.5
July 25	Providence Bay	-	30.4
July 26	Killarney	-	40.8
July 27	Killbear Prov. Park	28.3	19.3

- insufficient data measured to compute a valid daily average.

Comparison of Nitrogen Dioxide Concentrations between the Mobile AQI Unit and Toronto Downtown Air Monitoring Site

Table 5 shows the daily (24-hour) average nitrogen dioxide concentrations measured by the Mobile AQI Unit and those at Toronto Downtown, for the 11 days of the study. The daily average NO_2 concentrations measured by the Mobile AQI Unit ranged from 0.8 to 11.0 ppb. These levels were significantly lower (typically by several orders of magnitude) than concentrations recorded at the Toronto Downtown air monitoring site. Throughout the study period, NO_2 levels recorded in the Georgian Bay area and also across Ontario, were below the 24-hour criterion of 100 ppb.

Comparison of Mercury Concentrations between the Mobile AQI Unit and the Toronto West Air Monitoring Site

For the period of the study, daily (24-hour) average mercury (Hg) concentrations measured by the Mobile AQI Unit along the shores of Georgian Bay ranged between 1.1 and 1.3 nanograms per cubic metre (ng/m^3), (Table 6). These concentrations were compared with the daily average Hg concentrations from the fixed air monitoring station at Toronto West, which measured between 2.1 and 3.1 ng/m^3 for the same time period. Mercury levels recorded around the Georgian Bay area were approximately half the concentrations measured in the Toronto area, nonetheless, mercury levels did not exceed Ontario's 24-hour provincial criterion of 2000 ng/m^3.

Table 5: Daily Average Nitrogen Dioxide (NO_2) Concentrations (ppb), July 17th to 27th, 2000

Date	Location	Mobile AQI Unit	Toronto Downtown
July 17	Parry Sound	-	20.5
July 18	Parry Sound	0.8	12.3
July 19	Parry Sound	2.7	17.9
July 20	Point au Baril	7.4	24.9
July 21	Honey Harbour	4.4	18.9
July 22	Parry Sound	1.5	13.0
July 23	Parry Sound	3.6	14.5
July 24	Britt	6.1	21.3
July 25	Providence Bay	-	28.1
July 26	Killarney	-	20.7
July 27	Killbear Prov. Park	11.0	14.8

- insufficient data measured to compute a valid daily average.

Table 6: Daily Average Mercury (Hg) Concentrations (ng/m^3), July 17th to 27th, 2000

Date	Location	Mobile AQI Unit	Toronto West
July 17	Parry Sound	-	3.0
July 18	Parry Sound	1.3	2.4
July 19	Parry Sound	1.2	2.4
July 20	Point au Baril	1.1	2.5
July 21	Honey Harbour	1.2	2.2
July 22	Parry Sound	1.1	2.1
July 23	Parry Sound	1.1	2.3
July 24	Britt	1.1	2.2
July 25	Providence Bay	-	2.4
July 26	Killarney	-	3.0
July 27	Killbear Prov. Park	1.2	2.5

- insufficient data measured to compute a valid daily average.

Comparison of Sulphur Dioxide Concentrations between the Mobile AQI Unit and the Sudbury Science North and Etobicoke South (in Toronto) Air Monitoring Sites

The daily (24-hour) average sulphur dioxide (SO_2) concentrations measured by the Mobile AQI Unit were compared with values measured at the Sudbury Science North and at the Etobicoke South air monitoring sites, (Table 7). Sulphur dioxide levels in the Georgian Bay area were more or less the same as those measured at the Etobicoke South air monitoring site, apart from the 18th and 19th of July, when air flow was from the northwest, (Figure 7). On these days, Sudbury's SO_2 emissions were being transported southeast, into the Georgian Bay area. During the period of study, the daily average concentrations of SO_2 measured at the Sudbury site were between 8.8 ppb and 15.5 ppb. These concentrations were higher than those measured by the Mobile AQI Unit and the Etobicoke South air monitoring site. Sulphur dioxide levels recorded in the Georgian Bay area and across Ontario were all well below the provincial 24-hour criterion of 100 ppb.

Table 7: Daily Average Sulphur Dioxide (SO_2) Concentrations (ppb), July 17th to 27th, 2000

Date	Location	Mobile AQI Unit	Etobicoke South	Sudbury Science North
July 17	Parry Sound	-	3.5	12.5
July 18	Parry Sound	8.2	3.0	10.9
July 19	Parry Sound	8.5	3.0	15.5
July 20	Point au Baril	5.1	5.0	9.8
July 21	Honey Harbour	2.1	3.4	14.3
July 22	Parry Sound	3.0	3.2	9.8
July 23	Parry Sound	4.1	3.8	13.3
July 24	Britt	3.5	-	-
July 25	Providence Bay	-	-	-
July 26	Killarney	-	6.0	8.8
July 27	Killbear Prov. Park	1.0	2.8	9.8

- insufficient data measured to compute a valid daily average.

Conclusions and Recommendations

Limited conclusions can be drawn from the air quality data collected by the Mobile AQI unit during the study period of July 17th to 27th, 2000.

Very high correlations were found between the daily maximum concentrations of ozone measured with the Mobile AQI unit and the fixed stations located around the Georgian Bay area. However, the hourly average ozone concentrations did not correlate as well.

The 24-hour average inhalable particle levels measured in the Georgian Bay area were lower than the levels measured in Toronto except on one day when the level recorded in Georgian Bay was approximately 45% higher than that recorded in Toronto.

The daily average nitrogen dioxide levels measured in the Georgian Bay area were lower than levels recorded in Toronto. Throughout the study period, NO_2 concentrations recorded in the Georgian Bay area and also across Ontario were below the Ontario 1-hour criterion (200 ppb).

Daily average mercury levels measured in the Georgian Bay area were one-half the levels measured in Toronto. However, the levels recorded were significantly below the 24-hour provincial criterion for mercury of 2000 ng/m^3.

Daily average sulphur dioxide concentrations in the Georgian Bay area were comparable to the concentrations measured in Toronto, except on two days when the Mobile AQI unit measured concentrations in the Georgian Bay area higher than concentrations in Toronto. These higher levels, based on wind observations, are believed to have been transported into the area from Sudbury.

Overall, none of the pollutants measured in the Georgian Bay area reached or exceeded its provincial criterion during the study period. In fact, only ozone exceeded the provincial criterion in Toronto on one day.

This study will be continued during the smog season of 2001, since the wetter and cooler weather conditions during the summer of 2000 were not conducive for production of very high levels of ozone and inhalable particles. The Mobile AQI Unit should spend longer periods of time at each location, possibly for a week at a time, to monitor air quality under a variety of meteorological conditions. Also, monitoring during smog episodes would allow us to determine more conclusively how the Georgian Bay area is affected during such periods and to ascertain how trans-boundary pollution and long-range transport, impacts the Georgian Bay area.

Figure 1: Mobile AQI Monitoring Sites at Selected Locations Around Georgian Bay, July 17th to 27th, 2000

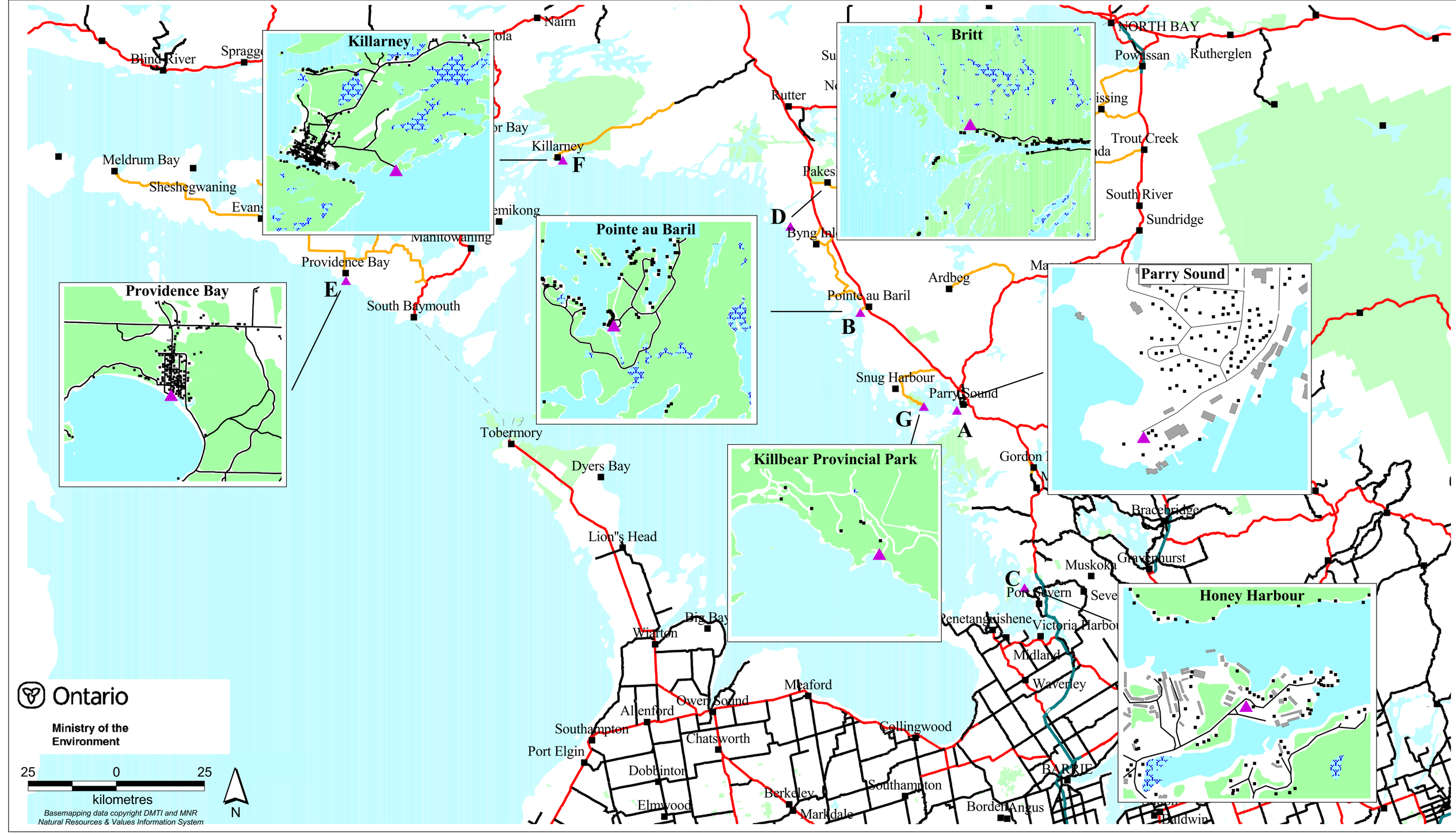


Figure 2: Location of Fixed Air Monitoring Stations for the Georgian Bay Study, July 17th to July 27th, 2000

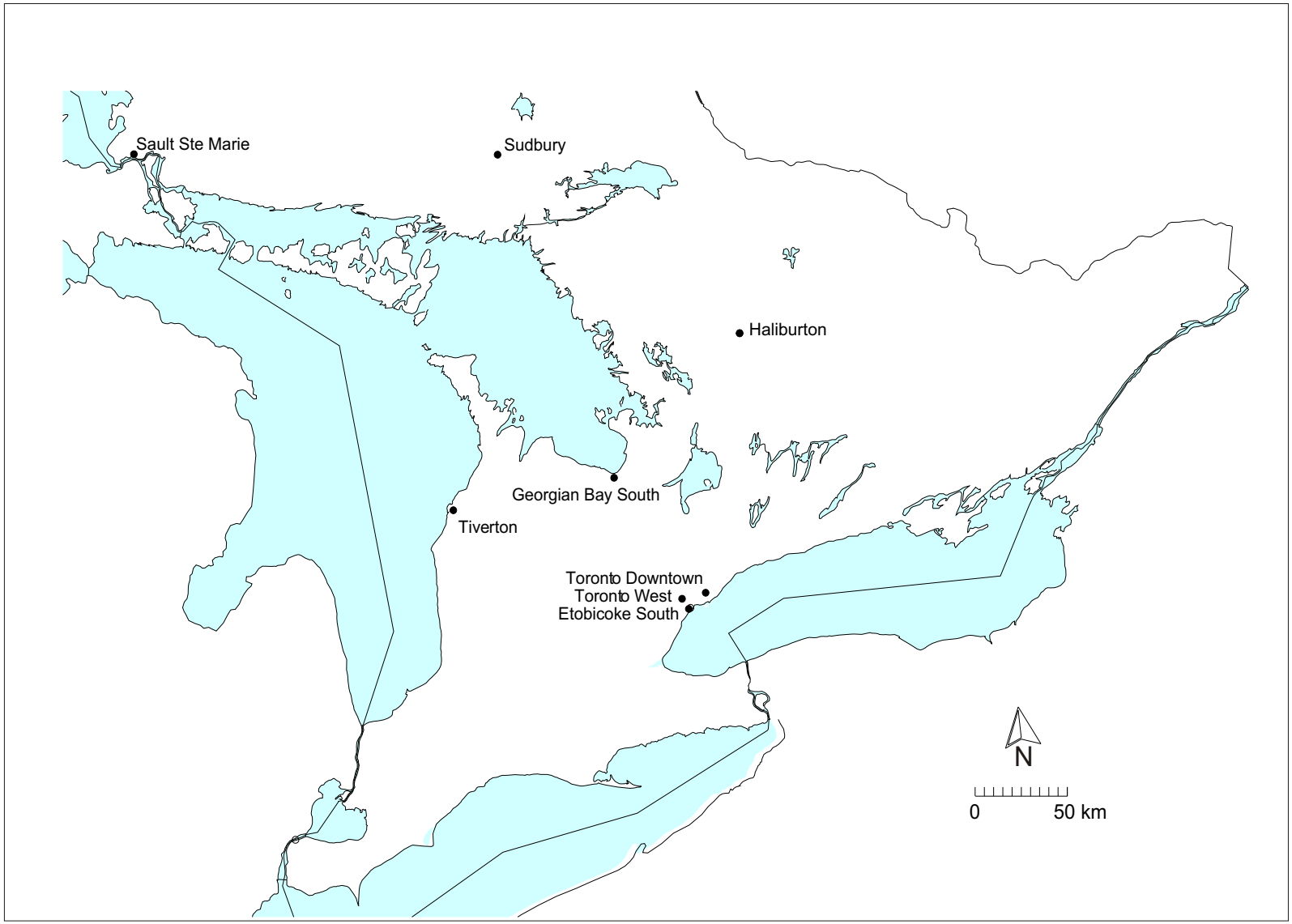
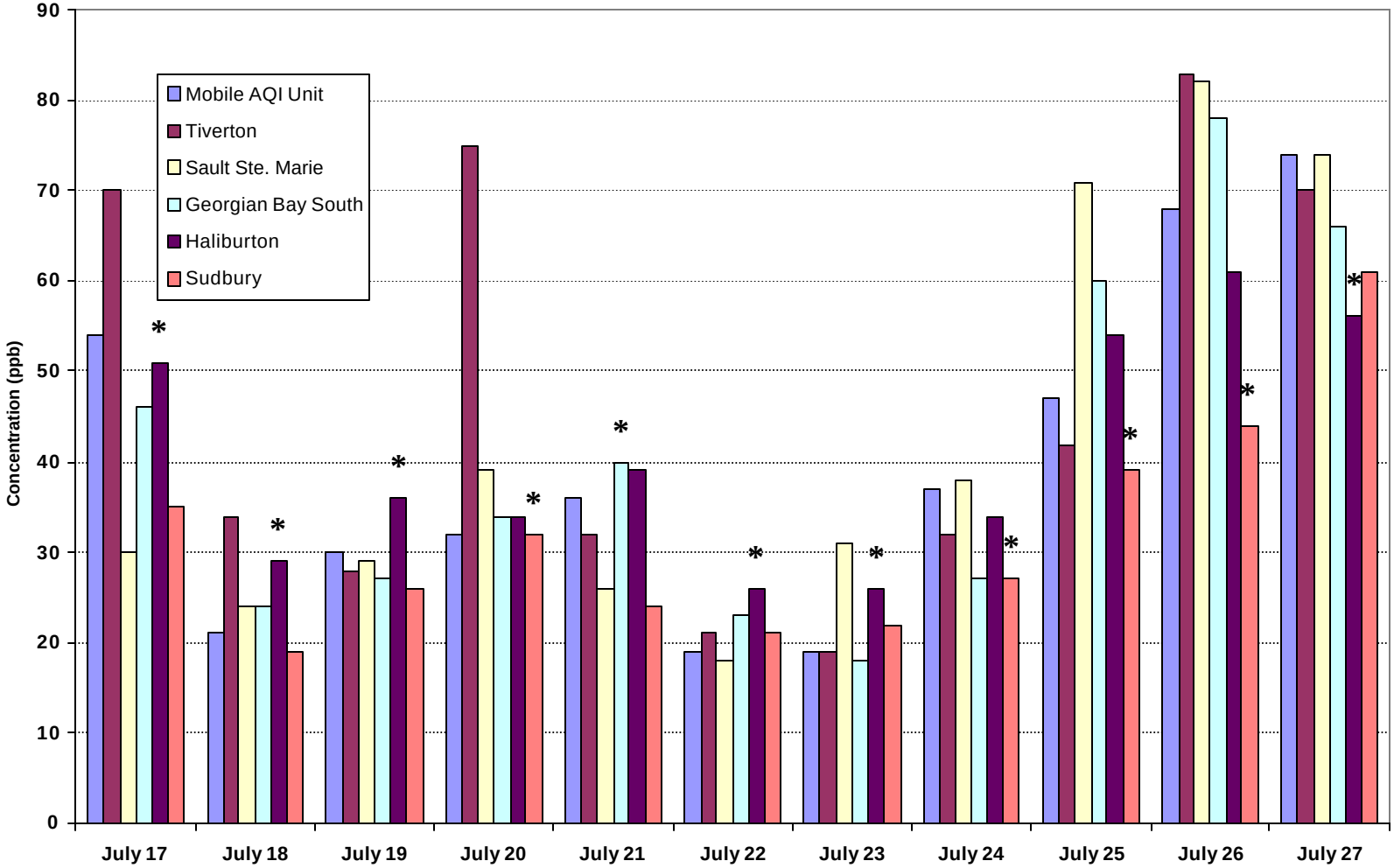


Figure 3: Daily Maximum Ozone Concentrations (ppb) for Mobile AQI Unit and Fixed Air Monitoring Stations, Georgian Bay Study, July 17 to 27, 2000



* Site closest to Mobile AQI Unit on that day

Figure 4: Air Flow into the Lake Huron Area, July 20th, 2000

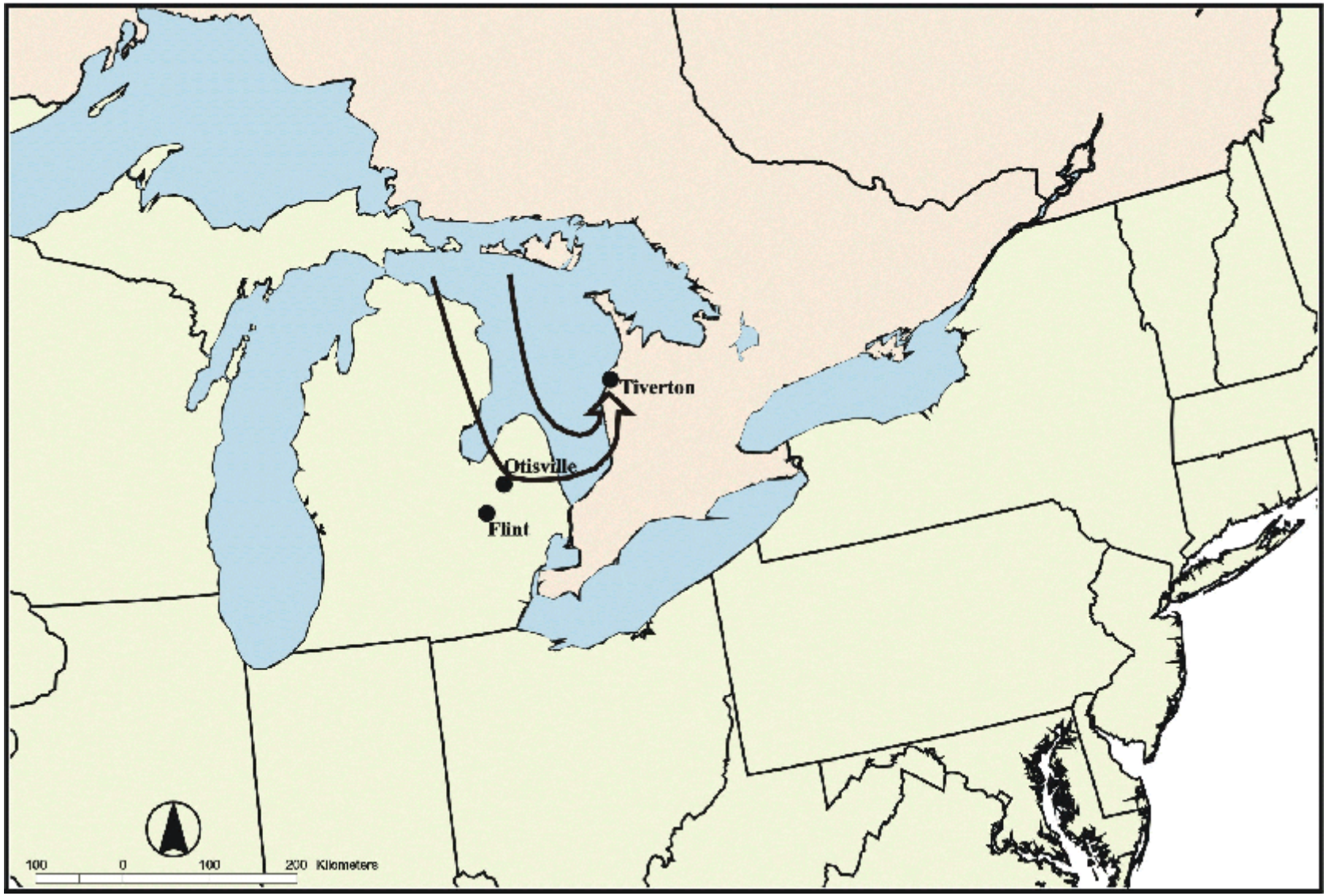


Figure 5: Daily Maximum Ozone Concentrations (ppb) in the Georgian Bay Area and at Toronto Downtown, July 17th to 27th, 2000

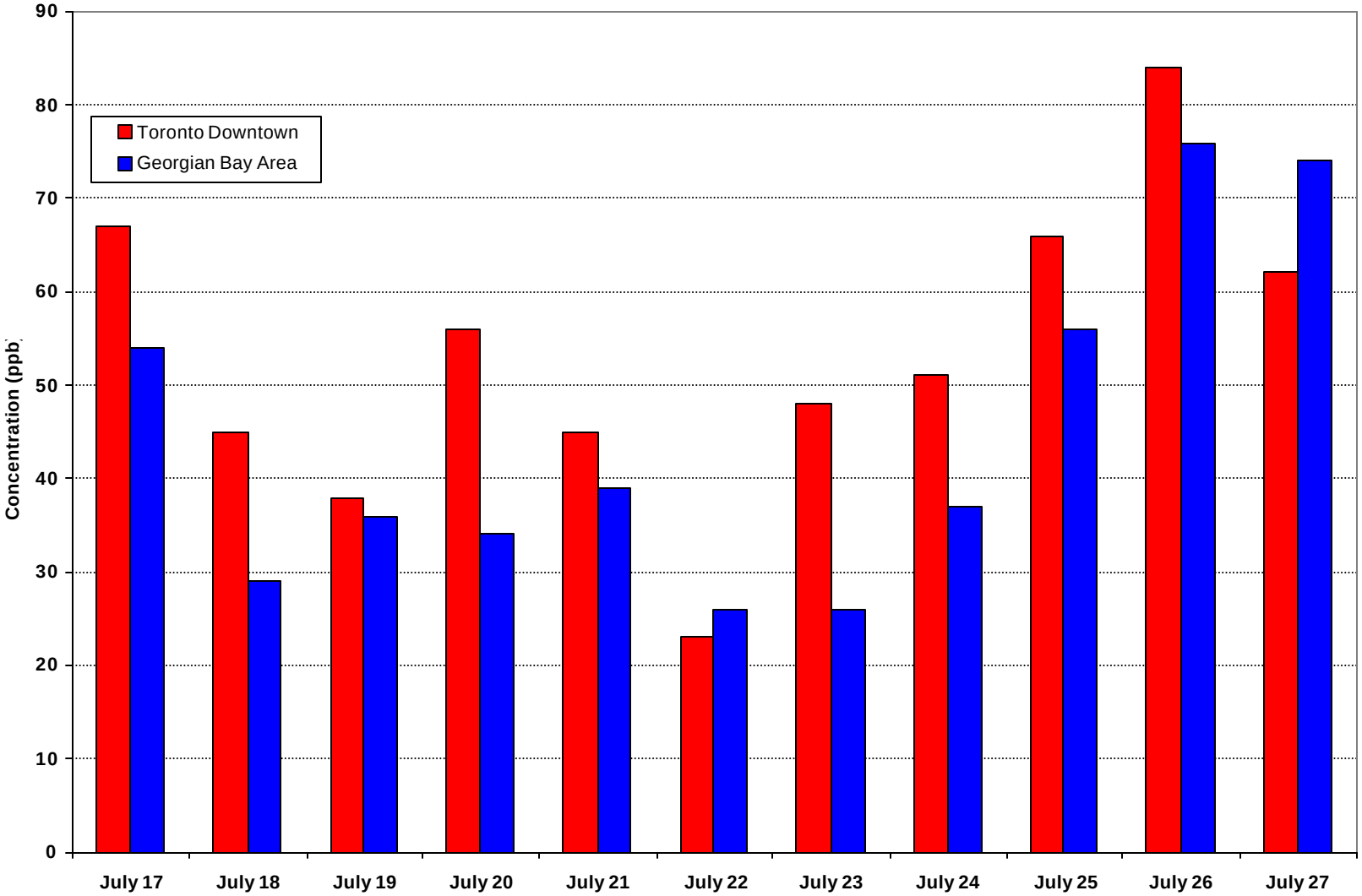


Figure 6: Air Flow into the Georgian Bay Area, July 26th and 27th, 2000

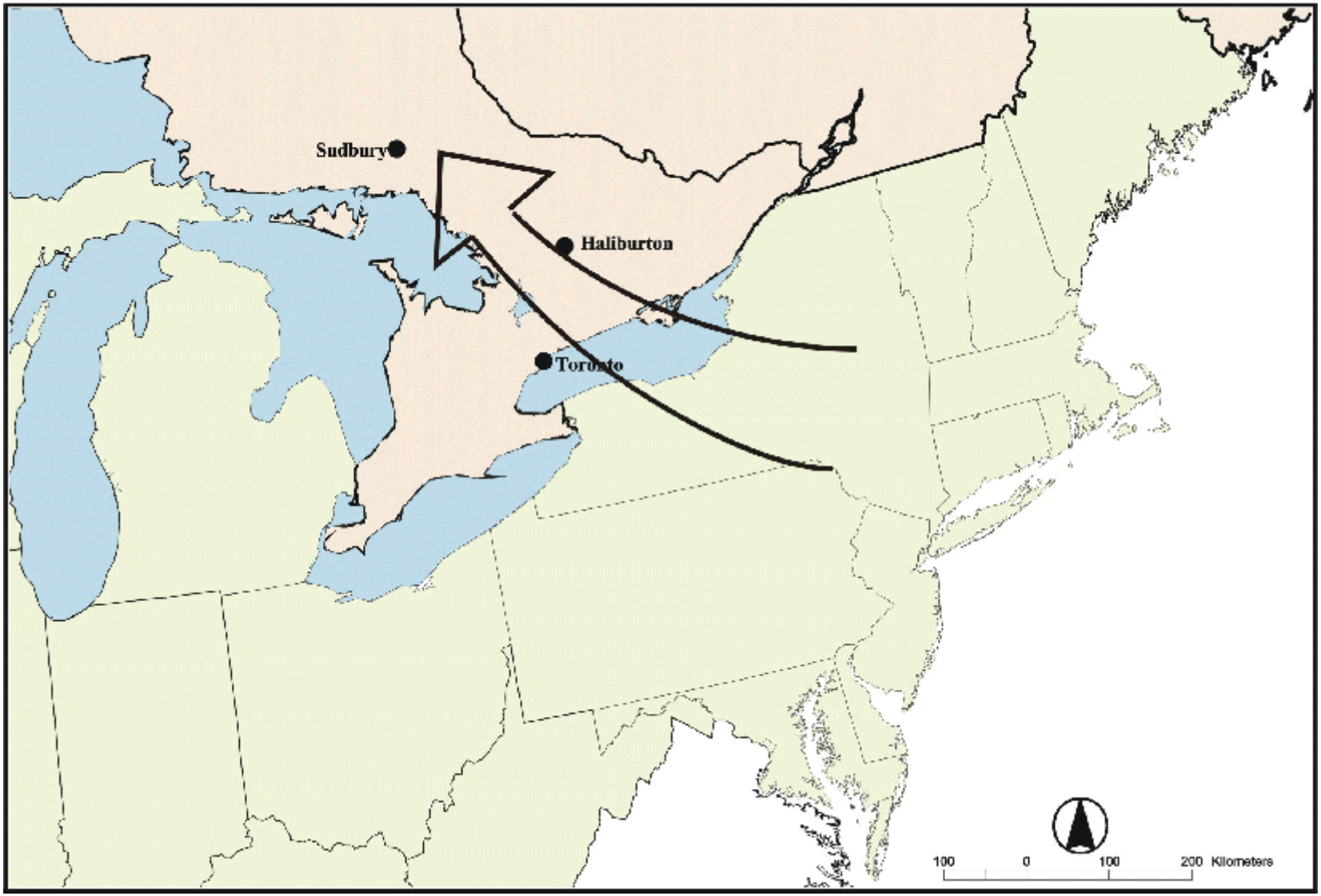


Figure 7: Air Flow into the Georgian Bay Area, July 20th, 2000