Health-Impacting Air Pollutants:

A Mobile Monitoring Study to

Identify and Rank Sources in Hamilton, Ontario

Phases 2/3

Performed by

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For

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1. Executive Summary

In Phase 1, a mobile air quality monitoring study was undertaken to identify the transient levels of air pollutants in Hamilton, Ontario. The study generated considerable interest from stakeholders, focused attention on actions required to improve local air quality and provided data for use in air quality models.

To support ongoing air quality improvement actions, Phase 2 of the study refined and extended the Phase 1 results, addressing inversion/smog days, traffic impacts, vehicle idling, drive throughs, road dust resuspension and better air quality modelling. Phase 3 was then initiated to study highway effects, including noise barriers, GTA comparisons and develop procedures to estimate the aggregated health impacts of air pollutants, including those due to traffic, across the urban area.

In Phases 2/3 we have:

- Disseminated the results and recommendations of Phase 1 with a series of presentations;
- Upgraded the mobile unit data collection system;
- Organized a monitoring/modelling workshop at McMaster University incorporating these results;
- Redesigned the areal city wide sampling on the basis of the additional analysis and air quality modeling results;
- Assisted with and presented at the Fugitive Dust Control Workshop;
- Performed follow up monitoring to determine air quality improvements due to the Workshop;
- Performed city wide sampling on an inversion days;
- Sampled pollution emissions from drive throughs, both fast food and coffee shops;
- Studied the downwind impacts of intersections and heavily traveled highways;
- Discovered the beneficial effects of noise barriers on pollutant concentrations downwind of a highway;
- Coordinated with the Spatial Analysis Laboratory at McMaster to perform more sophisticated data analyses, including interpolation maps of individual pollutant distributions across the city;
- Developed a methodology for computing and displaying in map format the aggregated health impacts of pollutants across the city.

Recommendations include rerouting transport to rail and ship where possible, use of vegetation to reduce air pollution impacts of heavily traveled roadways, purchase of electric vehicles, warning cardiac/respiratory compromised individuals to avoid heavy truck routes and updating the Air Quality Health Index to an <u>enhanced</u> (colour coded area wide mapping/more pollutants) and <u>active</u> (automated notification and cutbacks) system for reduction of high pollutant levels during inversions.

Acknowledgements: We gratefully acknowledge the input and assistance of the staff of Rotek Environmental, the City of Hamilton, the Centre for Spatial Analysis, the Ontario Ministry of the Environment, Environment Canada, Dr. Brian McCarry, Mr. Brian Montgomery, Dr. Pavlos Kanaroglou, Dr. Julie Wallace, Mr. Tom Dann, Mr. Pat DeLuca, Mr. Carl Slater, Mr. Barry Duffey, Mr. Bill Sparks, Mr. Larry Howarth, Mr. Frank Dobroff, Mr. Terry Slobodian, Mr. Paul Daszko, Mr. Bill Branch, Mr. Ralph Frisina, Mr. Justin Buonocore, Ms. Anna Corr and Mr. Jordan Bowman.

This study was funded by The City of Hamilton, Clean Air Hamilton, the Ontario Ministry of the Environment and Environment Canada.

2. Introduction and Background

In 2005/2006, Phase 1 of a mobile air quality monitoring study was undertaken to identify the transient levels of air pollutants in Hamilton, Ontario. Historical fixed-site air monitoring data and National Pollutant Release Inventory data for Hamilton were used to develop a target list of sources of health impacting air pollutants.

Mobile scans for NO_x (Oxides of Nitrogen), SO_2 (Sulphur Dioxide), PM (Airborne Particulate Matter) and CO (Carbon Monoxide) were performed in traverses across the city, at selected industrial areas, at traffic intersections and at a school during student pickup and drop-off times. Highest pollutant concentrations were observed near major road intersections and along heavily used roads affected by dirt track-out in the industrial sectors of the city. These high levels were attributed to the impacts of city traffic emissions and the industrial transportation sector, respectively. Industrial point sources still made significant contributions, particularly for SO_2.

Fourteen track-out locations were identified in need of cleanup and an additional fifteen point sources were ranked in order of peak ambient impacts. Point source impacts did not always agree with NPRI emissions data.
The short duration of the study resulted in a limited number of sampling times so that smog/inversion days could not be sampled. Relatively simple GIS techniques proved very useful but it was clear that a more sophisticated GIS analysis of the data would be worthwhile. Modifications to the mobile sampling system would also give a benefit in terms of enhanced spatial analysis capability.

3. Study Objectives

Phase 2 of the study was therefore funded to:

- upgrade the monitoring system,
- refine and further disseminate the Phase 1 results to stimulate air quality improvement actions,
- perform advanced GIS analysis of the data,
- integrate with air quality modeling programs,
- support the Fugitive Dust Control Initiative;
- perform enhanced traffic monitoring,
- cover additional areas of the city;
- sample drive throughs;
- measure smog/inversion day impacts.

Additional items were added (Phase 3) as the study progressed, including traffic model calibrations; studying highway levels of air pollutants; effects of noise barriers; the development of methodology for displaying aggregated health impacts in map format; the application of this technology to intersections and highways; and beginning to extend the mobile monitoring to the GTA for comparison purposes .

4. Mobile Sampling Unit

Since the mobile sampling unit had been decommissioned at the end of Phase 1 and the instruments used in other studies, the pollution monitoring instruments had to be reinstalled and recalibrated. The Ontario Ministry of the Environment had loaned their mobile command post as the mobile platform for Phase 1 and graciously agreed to provide the unit again for Phases 2/3. A battery pack/inverter system was installed by the Ministry which allowed instrument operation for greater than four hours at a time without having to use the gasoline electrical generator, thus reducing potential exhaust interferences.

The data logging collection system was upgraded from the older EMC unit to a Campbell 23X , then a CR1000 data logger which has the capability of simultaneously collecting pollutant and GPS data in an integrated data base for spatial analysis of the monitoring data. An upgraded GPS detector was also installed in the mobile unit. The Grimm particulate monitoring module required reprogramming for use with the upgraded data collection system and this was accomplished successfully.

Figure 1 – Mobile Command Centre

5. Monitoring/Modelling Workshop

A Monitoring/Modelling Workshop was organized for November 22nd, 2006 at the Spatial Analysis Laboratories at McMaster to bring together GIS, modelling, monitoring and government staff to discuss cooperative use of data and models. Representatives of the Geography, Chemistry and Engineering Physics Depts., Rotek Environmental, Ontario Ministry of the Environment, City of Hamilton and Golder Associates attended and participated in discussions. Appendix 1 contains the agenda and Appendix 2 the minutes of the workshop. Discussions were fruitful and it was agreed to continue to share data and refine monitoring target areas and times through use of advanced models.

6. GIS/Modelling Evaluation of Previous Data

The Phase 1 mobile survey data contained several distinctly different types of data, or mini surveys, i.e., downwind of point sources, road dust resuspension, traffic intersections, city wide areal surveys, school dropoff vehicle idling. The data therefore had to be disaggregated into subsets for use in city wide models, as well as cleaned up from obvious interferences such as self sampling during mobile unit reversing or electrical generator self sampling.

After data stratification, the resources of the Centre for Spatial Analysis were used to first provide spatial visualizations of the data. Area wide data were then used to calibrate existing traffic models.

Industrial area point source visualizations of SO_2 downwind for SW and NE winds are shown below.

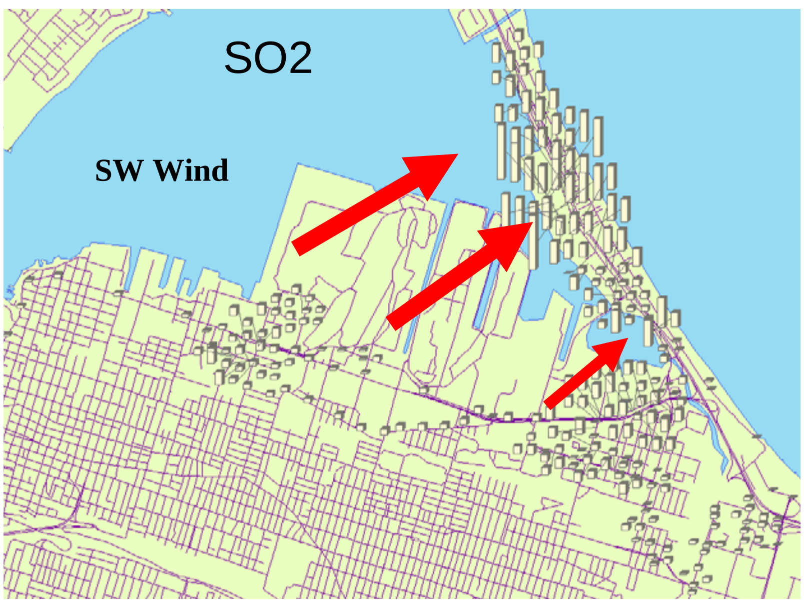


Figure 2. Point sources SW winds

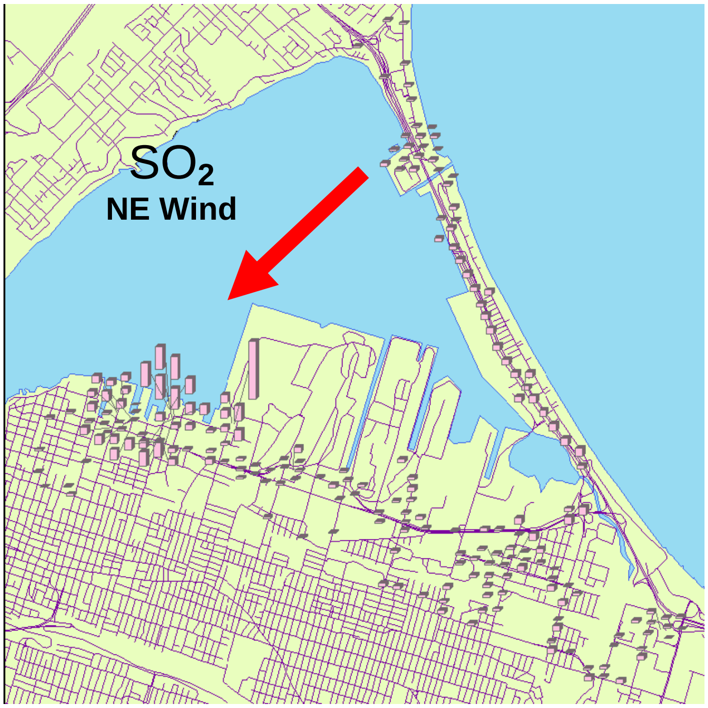


Figure 3. Point sources NE winds.

Area values of different pollutants were sorted into different wind directions, 0 to 90, 90 to 180, 180 to 270 and 270 to 360 degrees. Note wind direction is always <u>from</u> the direction indicated.

Below are examples of area wide measurements when winds were from 0 to 90 degrees, i.e. north east to south west.

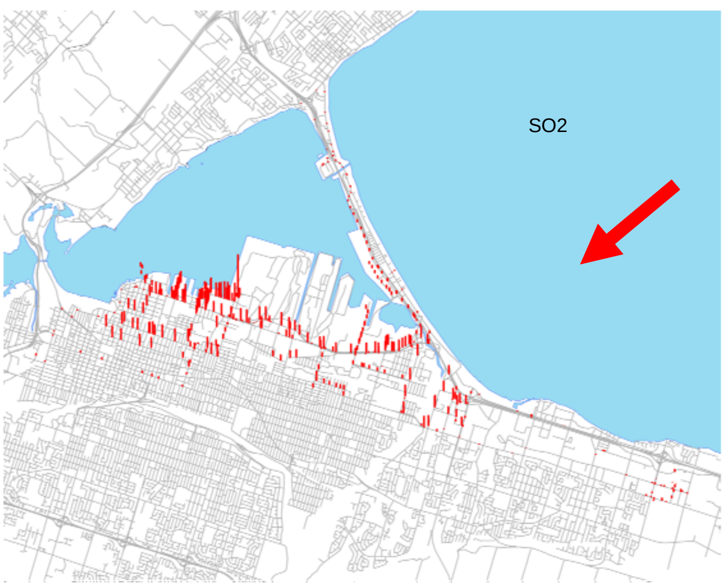


Figure 4. Area SO_2 measurements, winds 0 to 90 degrees, from between North and East.

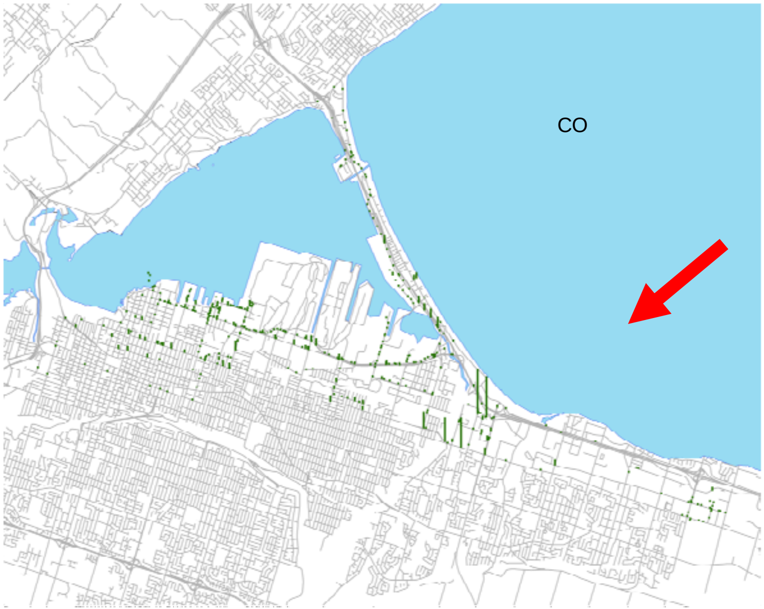


Figure 5. Area CO measurements, winds 0 to 90 degrees, from between North and East.

Figure 6. Area NO measurements, winds 0 to 90 degrees, from between North and East.

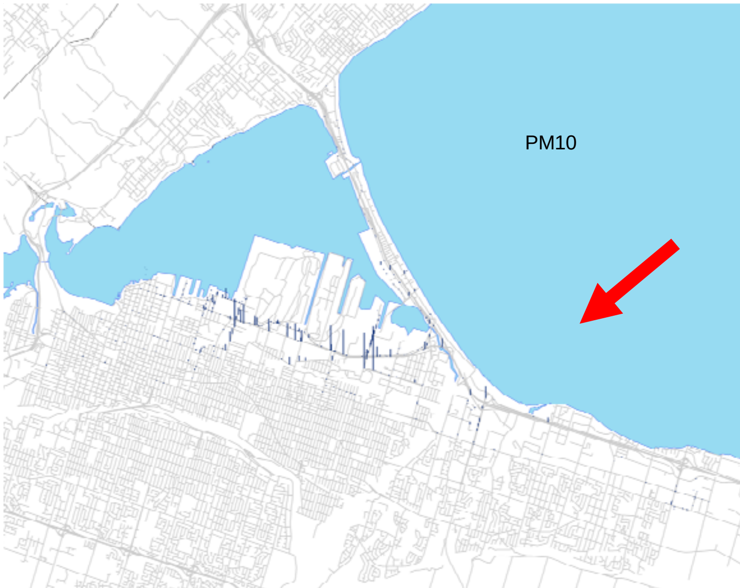


Figure 7. Area PM_{10} measurements, winds 0 to 90 degrees, from between North and East.

These data were then incorporated in traffic models to refine calculations for city wide traffic impacts. These models estimated that higher levels of traffic related pollution would be expected in the west end as well as the east end of the city and on the mountain accesses. This "high pollution triangle" is joined together by the highway network. see below, Figures courtesy of Dr. Juliet Wallace, Centre for Spatial Analysis.

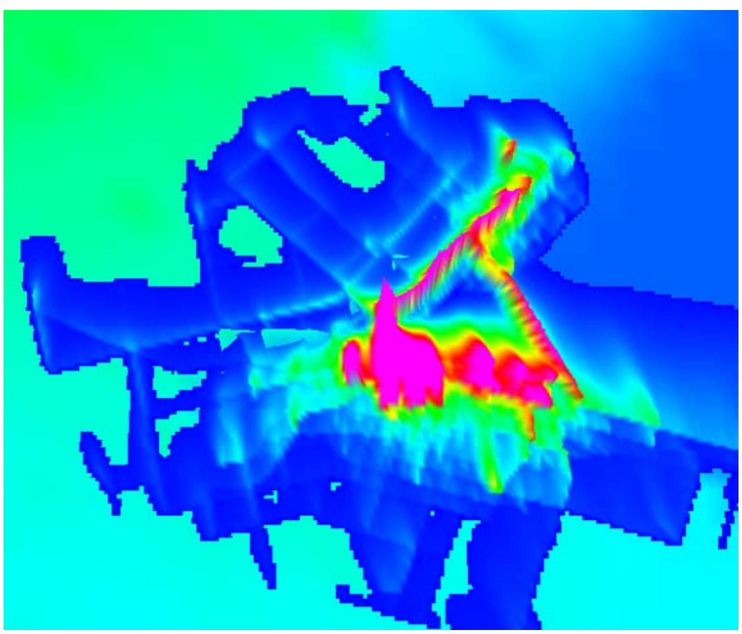


Figure 8. High Pollution Triangle, Samples of Modelled Impacts of Traffic Pollutants, (Julie Wallace, Ph.D. Centre for Spatial Analysis, McMaster University)

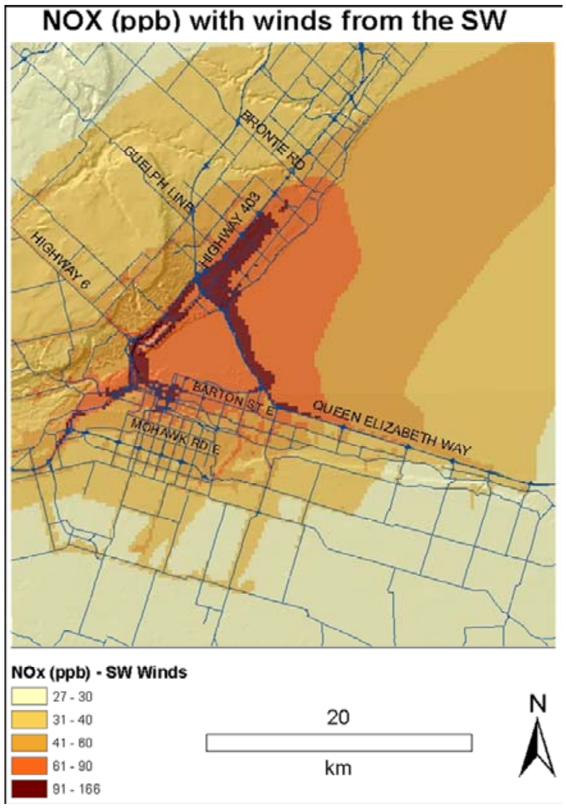
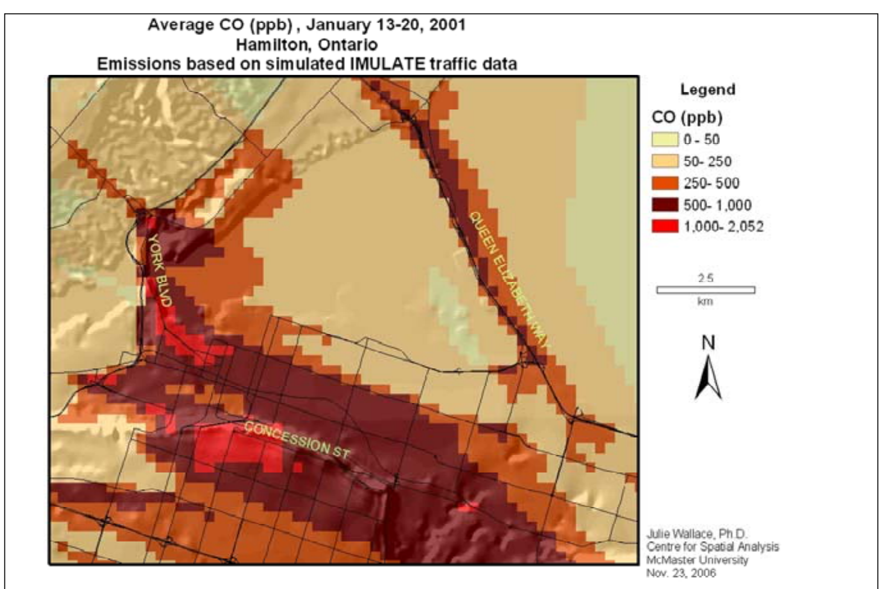


Figure 9. NO_x with SW Winds, Samples of Modelled Impacts of Traffic Pollutants, (Julie Wallace, Ph.D. Centre for Spatial Analysis, McMaster University)

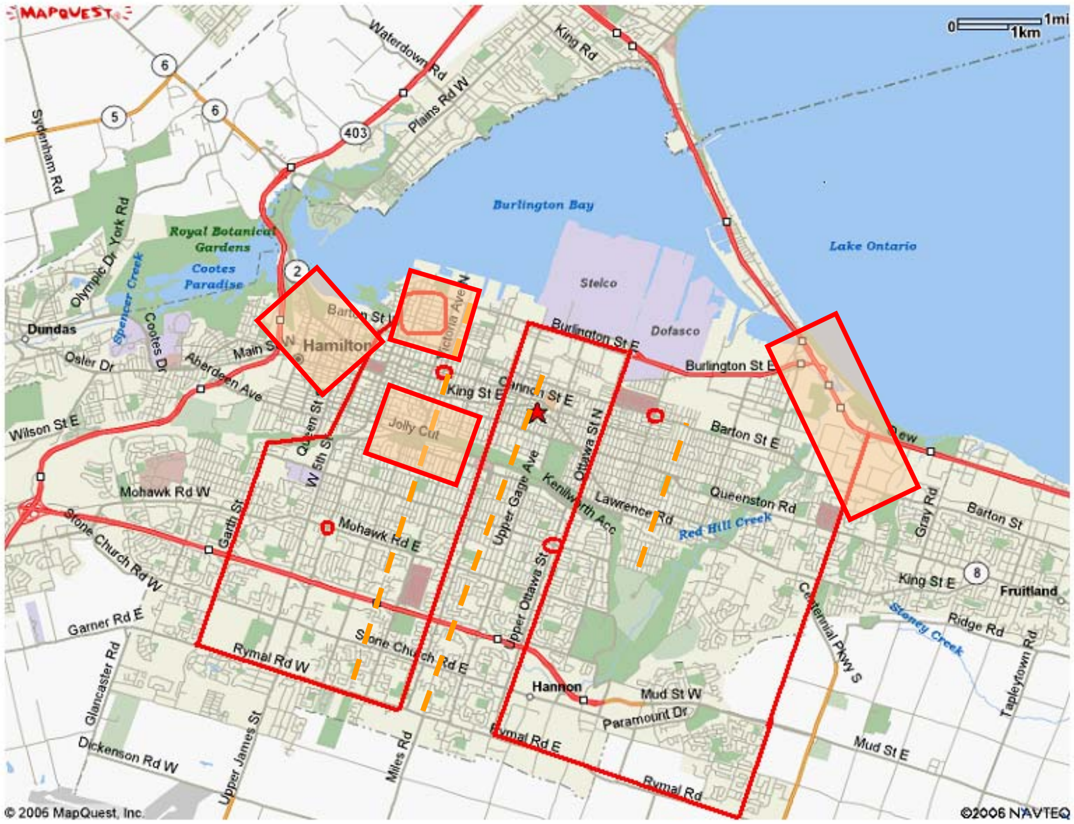


Centre for Spatial Analysis

Figure 10. CO Average, Jan 13-20, 2001, Samples of Modelled Impacts of Traffic Pollutants, (Julie Wallace, Ph.D. Centre for Spatial Analysis, McMaster University)

7. Redirection of Area Sampling Focus Areas.

As a result of these calculations, the proposed city wide area sampling was modified and extended to cover additional target areas, specifically the southwest 403/Main/King/York, northeast QEW/Centennial and the escarpment access high traffic locations, see below.



Main Road Sampling Track

Residential Road Sampling Track

Area of Interest

Figure 11. Additional Sampling Areas

8. High Pollution Triangle Sampling Results

Modelling had indicated that higher pollution incidences would be expected in the east end of the City around the QEW/Hwy 20 intersection, on the Claremont mountain access complex and in the west end around the Hwy 403/ King/Main/Aberdeen intersections. Special sampling runs were conducted over a number of days and under different meteorological conditions to evaluate these results and compare the levels of pollutants in these three areas, see Figure 12.

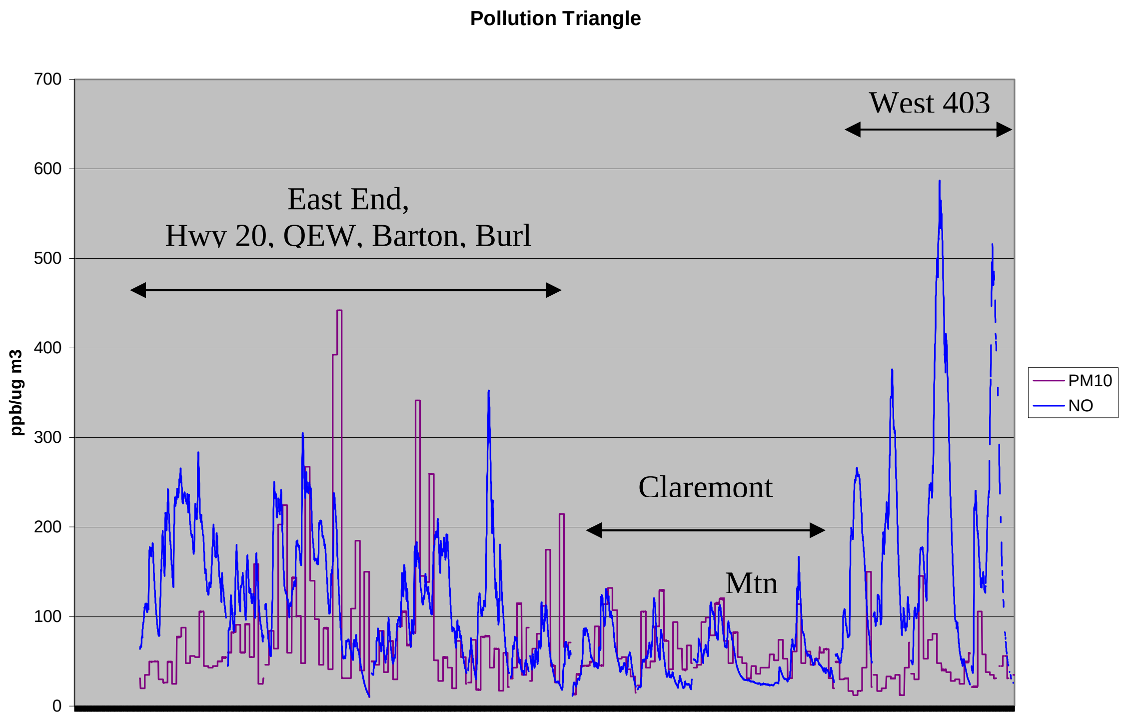


Figure 12. Sampling in High Pollution Triangle, Compilation of 6 Sampling Days

The Claremont Access and Joly Cut mountain accesses did not show pollutant levels significantly different from other well traveled roadways, peaking at 132 ug/m^3 for PM_{10} and 158 ppb for NO. However, these concentrations are still well above the residential levels on the mountain of 26 ug/m3 PM_{10} and 12 ppb NO.

In the 403 Highway valley in the west and on the 403 Ancaster hill, very high levels of NO were detected, reaching a peak of 586 ppb. These are in fact the highest NO levels measured to date in Hamilton, higher than industrial source impacts around major steel companies. The maximum value for NO_x (NO + NO_2) was 660 ppb.

A comparison to MOE standards is of interest, however different averaging times make this comparison difficult. The monitoring unit had to move with the traffic flow so that long averaging times were not possible. For air quality assessments such as this (e.g. annual air quality reports and special study reports) NO_2, not NOx, is the reference contaminant. The NO_2 1-hour average target Ambient Air Quality Criterion (AAQC) is 200 ppb and the maximum one minute average measured here for NO_2 was 110.5 ppb, well within the standard. This does not mean that there are no adverse effects. It is now generally accepted that air pollutants have deleterious effects below the standard levels and that health effects will vary linearly with pollutant concentrations down to low levels.

Although these measured levels are maximum values only, it is also worth pointing out that the MOE half hour standard for NO_x (NO + NO_2) is 500 ppb compared to the peak value of 660 ppb measured.

The interim Ambient Air Quality Criterion for PM_{10} is 50ug/m^3 over a 24hr average time period, with the caution "provided as a guide for decision making (with no conversion to other averaging times)."

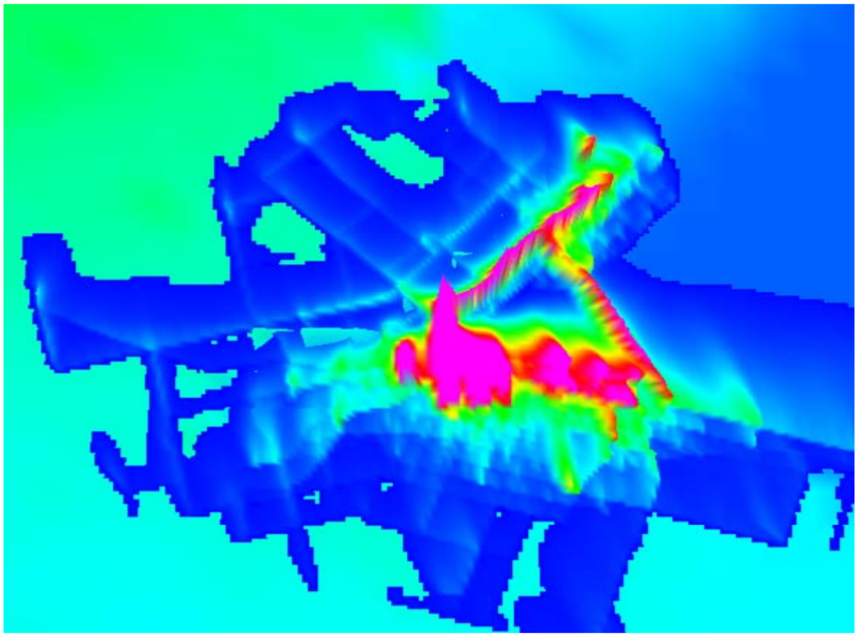
Details of Ontario Ministry of Environment Ambient Air Quality Criteria can be found at http://www.ene.gov.on.ca/en/air/ministry/index.php#stan

PM_{10} values in this west end highway area were also elevated with a peak of 150 ug/m^3, however these values are not so elevated as compared to normal roadways as the NO results.

In the east end, the area covered by Hwy 20, QEW, Barton and Burlington Streets also showed significantly elevated levels of pollutants. In this area the NO peaks at 348 ppb were not as high as in the west end, however PM_{10} values were very elevated with a maximum of 442 ug/m^3.

These new sampling data were then compared to the improved model results generated by the earlier sampling. Remarkably good agreement was obtained, see Figures 13 and 14 below.

Traffic Modelling
Julie Wallace, CSPA, McMaster



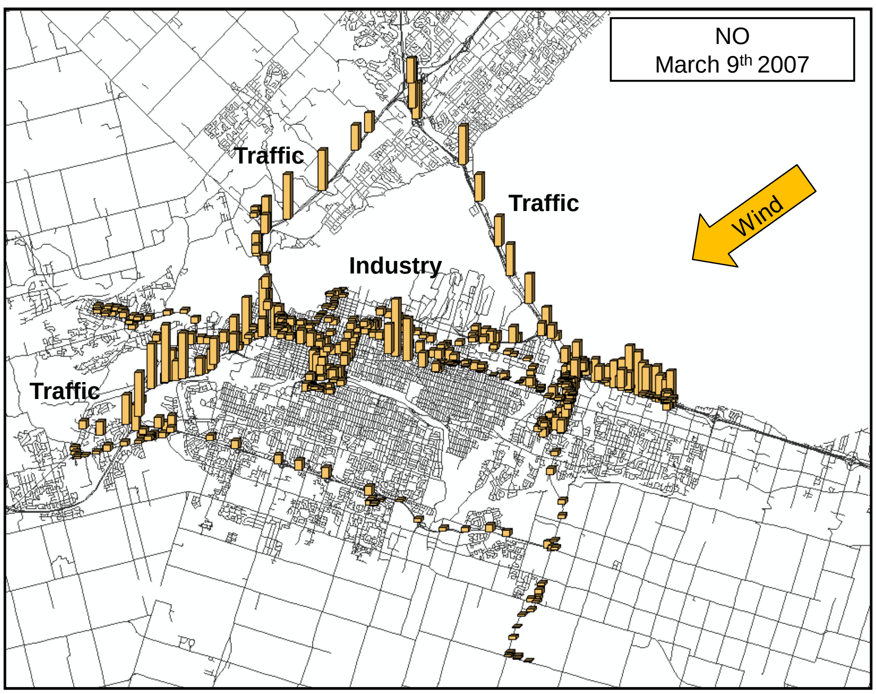


Figure13: Nitric Oxide Traffic Model Predictions and Mobile Monitoring Data, NE Wind.

This figure also shows the relative contributions of Nitric Oxide from traffic and industry with traffic contributing relatively high levels of contaminants.

Figure 14 below shows the excellent correspondence between modelling and monitoring for traffic emissions.

McMaster Model – Rotek Mobile Data
Monitoring/Modeling Interaction

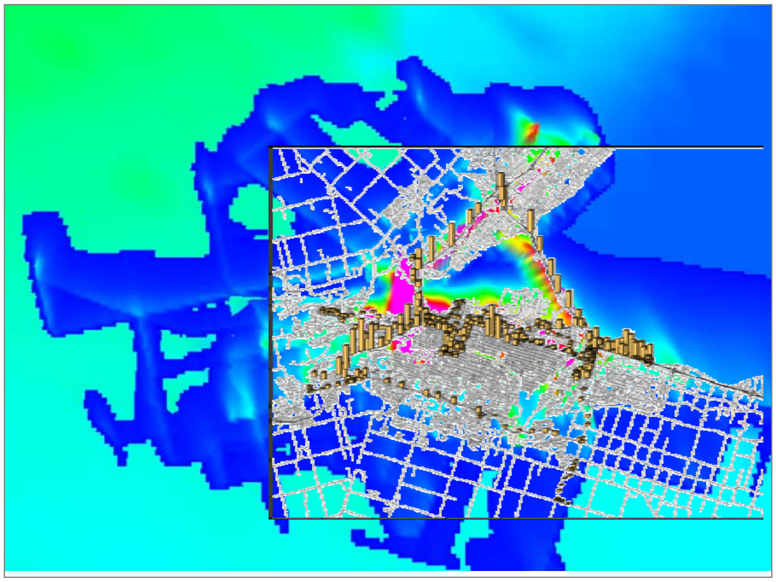


Figure 14: Correspondence of Modelling and Monitoring for traffic related NO.

9. Inversion Day Sampling Results

Although NE winds/inversions occur regularly in the Hamilton airshed and cause elevated levels of air pollution, the areal extent of these conditions has not been previously measured, i.e., air sampling has not previously been conducted in several parts of the city, to our knowledge.
Eight NE wind/inversion days were sampled in Phase 2 to the end of 2007. As an example, on November 15, 2006, pollutant data were collected in a traverse across the industrial area of the city, then Wellington Street to the escarpment, east across the escarpment, then down Highway 20 to the QEW. Particulate data were limited by the existing software (now updated) to one measurement each 5 minutes.

Data scans are shown below. "Int" stands for intersection. "Train" is a peak due to idling trucks near a rail intersection with a passing train.

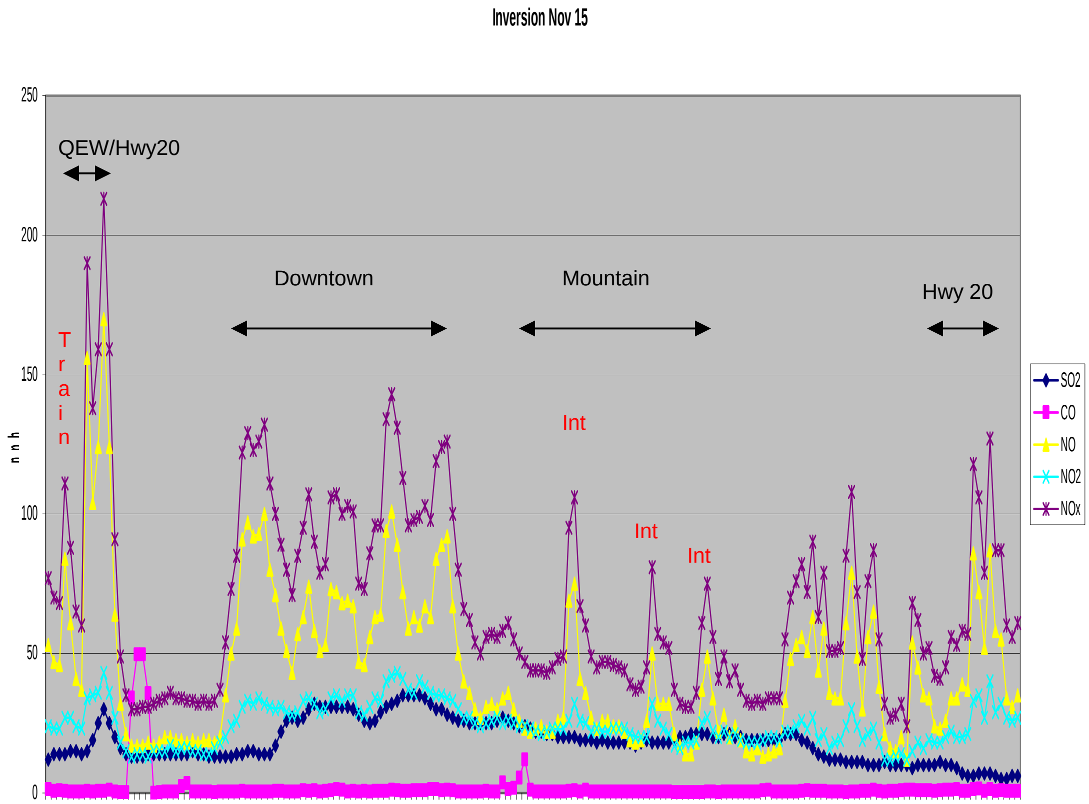


Figure 15. Inversion Day Sampling, November 15, 2006

These data show that inversion impacts (elevated SO_2) spread well beyond downtown towards the south west of the city, including the mountain area. NO_x values downtown are still more than double those on the mountain. The mountain data also show clearly the effects of road intersections. SO_2 values are elevated across the downtown area at 30 ppb and on the mountain at 20 ppb.

March 9, 2007 was also an inversion day with light winds from the east.

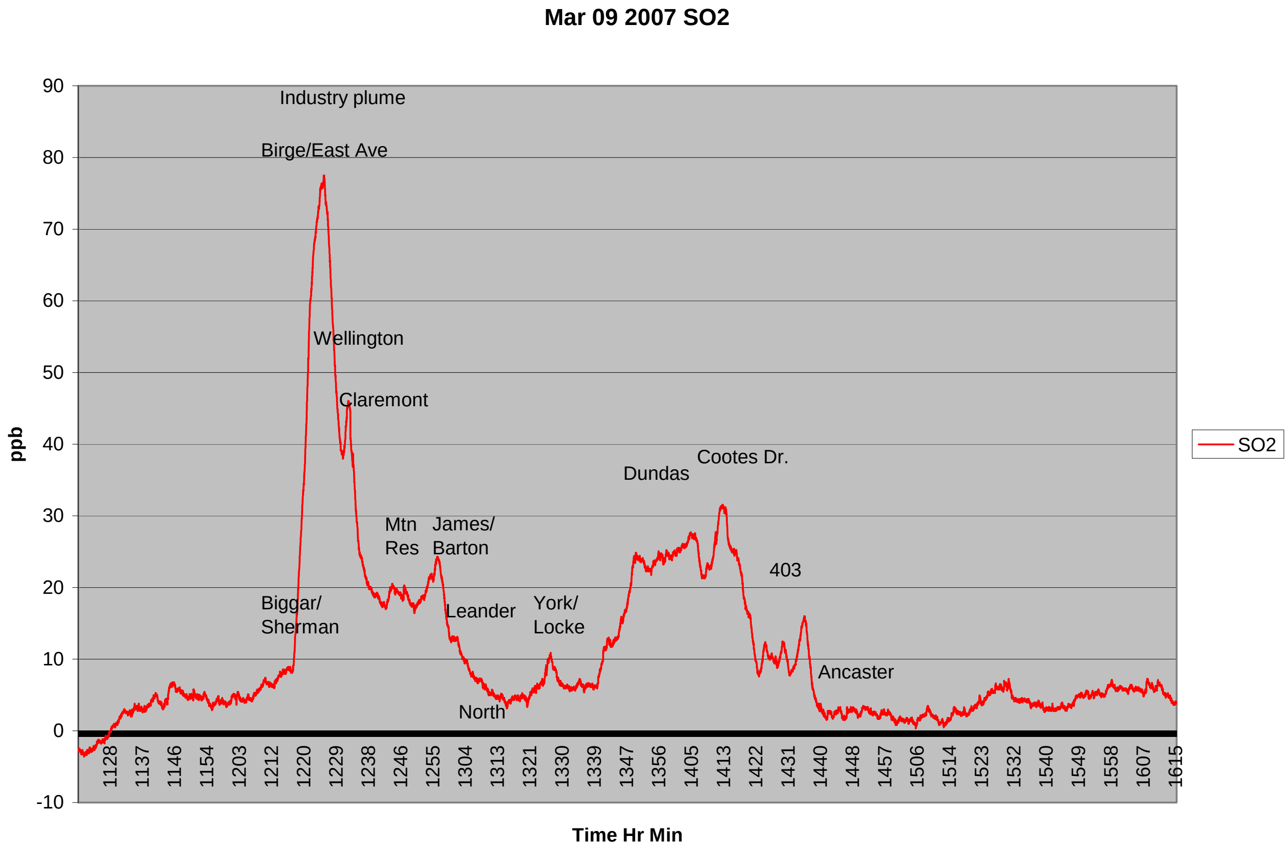


Figure 16. SO_2 Inversion Day Sampling, March 9, 2007

On March 9, 2007, the areal extent of inversion impacts to the west was investigated when a plume from the industrial sector moved across the city under the influence of the light winds from the east. SO_2 comes mainly from industry, so elevated levels of SO_2 are a tracer for industrial impacts. Highest SO_2 levels measured in the downtown area were 77 ppb in the neighbourhood of the Claremont Access, and the plume was clearly detectable throughout Dundas at 27 ppb. Ancaster was not impacted.

Since SO_2 is mainly an industrial emission and can be used as an indicator of inversion day industrial impacts across the City, when other contaminants are also elevated, it is probable that these too are sourced from the same area. The correlation coefficients of SO_2 data with different contaminant data were evaluated, see below.
Due to the large local impacts of roads emissions on NO and particulate, the data for the east end QEW/Hwy 20 and west end 403 traverses were removed from the data set.

Pollutant	PM_1	$PM_{2.5}$	PM_{10}	CO	NO	NO_2	NO_X
SO_2 Correlation	0.53	0.57	0.38	0.53	0.42	0.64	0.50

Table 1. Correlation of Different Contaminants in Inversion Plume with SO_2.

Interestingly, the highest correlation was with NO_2. This may be due to direct industrial emissions but more likely because NO emissions have been oxidized to NO_2 during the atmospheric dwell time in the plume of pollutants. The importance of this is that NO_2 is considerably more toxic than NO.
Finer particles, $PM_{2.5}$ and PM_1 are also more highly correlated with SO_2 data. These finer particles are considered to be more toxic than PM_{10}. In other words the airborne contaminants due to inversion conditions are more problematic. More extensive inversion day sampling will be conducted in Phase 3 of this study.

10. Drive Thrus

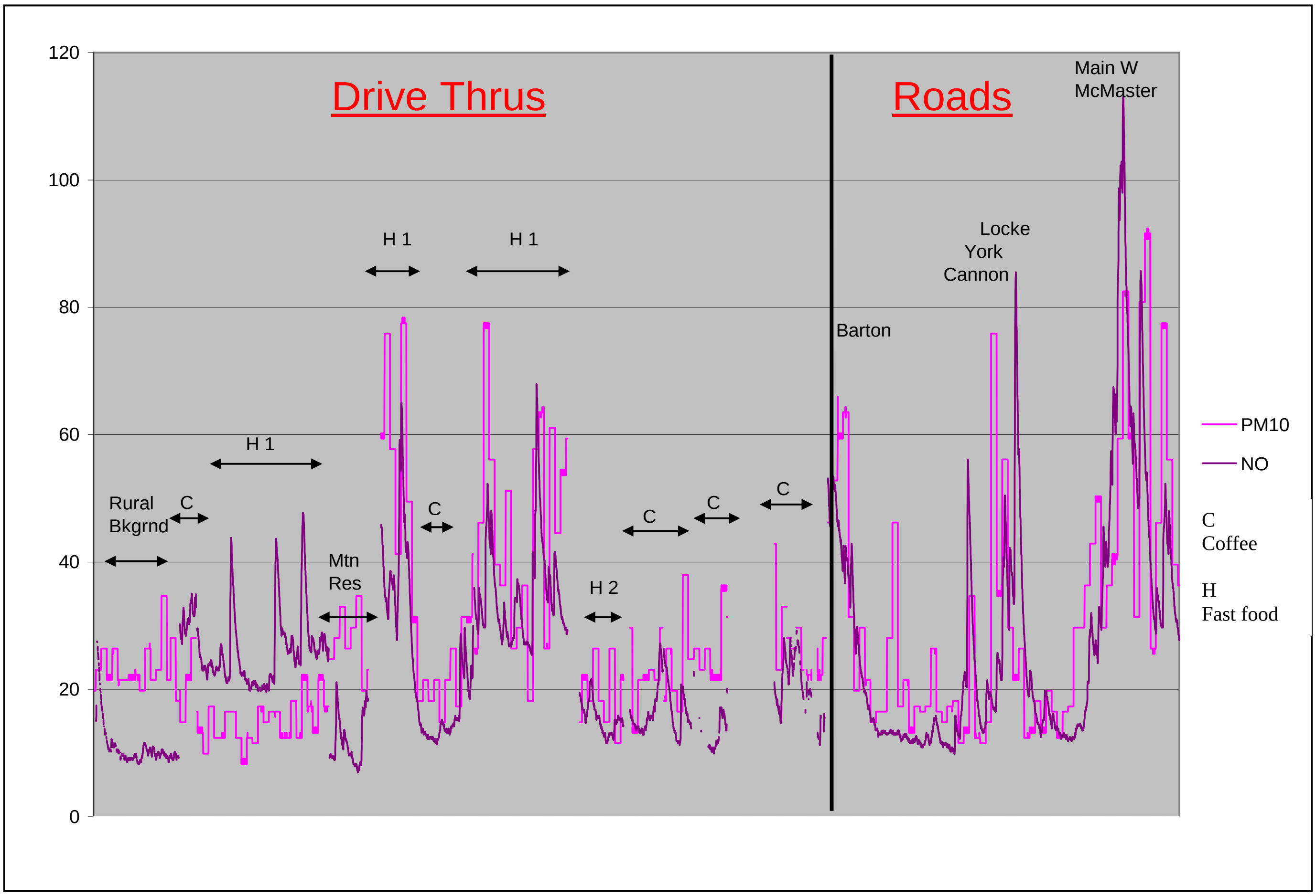


Figure 18. NO and PM_{10} values in the vicinity of drive thrus.

Concern has been expressed about the impacts of idling vehicles at fast food drive-thrus. Preliminary data from Phase 2 of the mobile monitoring survey show that, while there are definite effects, there do not appear to be unusually large pollutant exposures downwind of drive-thrus, see Figure 18. For example, the levels of NO downwind of drive-thrus reach peaks of 70 ppb, while NO levels on Main Street West reached 110 ppb and on Highway 403 reached almost 600 ppb. In fact it was difficult to sample downwind of these facilities without interferences from roadway generated pollutants. Pollutant levels while actually in a drive thru line up were not measured because these are private property and the sampling vehicle would have been too large to fit. It is reasonable to expect, however, that pollutant levels would be high due to the proximity of the other idling vehicles.

11. Road Dust Trend

After the Fugitive Dust Control Workshop was held in December of 2006, additional monitoring was performed in high dust areas to check if measurable improvements occurred due to control actions.
Figures 19 and 20 show the very high levels of PM_{10} originally monitored across the city in 2005/06 with highest levels at 2000 ug/m^{3}and 14 problem locations. Figures 21 and 22 show the levels measured in 2007 after workshop related actions had taken place including enhanced street cleaning, trackout reduction and more enforcement.
Clearly there have been very significant improvements, since the earlier data showed 14 problem locations and the 2007 data showed only two problem locations. Even these were measured at 500 -1500 ug/m^3, lower than the > 2000 ug/m^3 measured earlier. Preliminary data from 2008 maintained this improvement, although summer 2008 was characterized by heavy rainfall events which would also have contributed to cleaning streets and lowering dust levels.

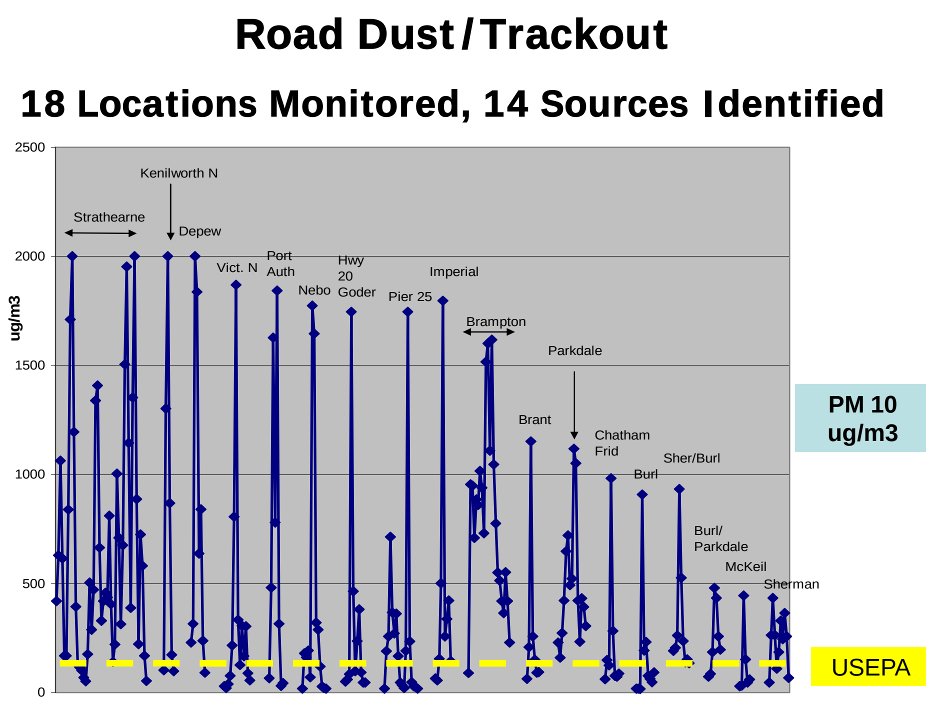


Figure 19. Fourteen high locations for fugitive dust 2005/06.

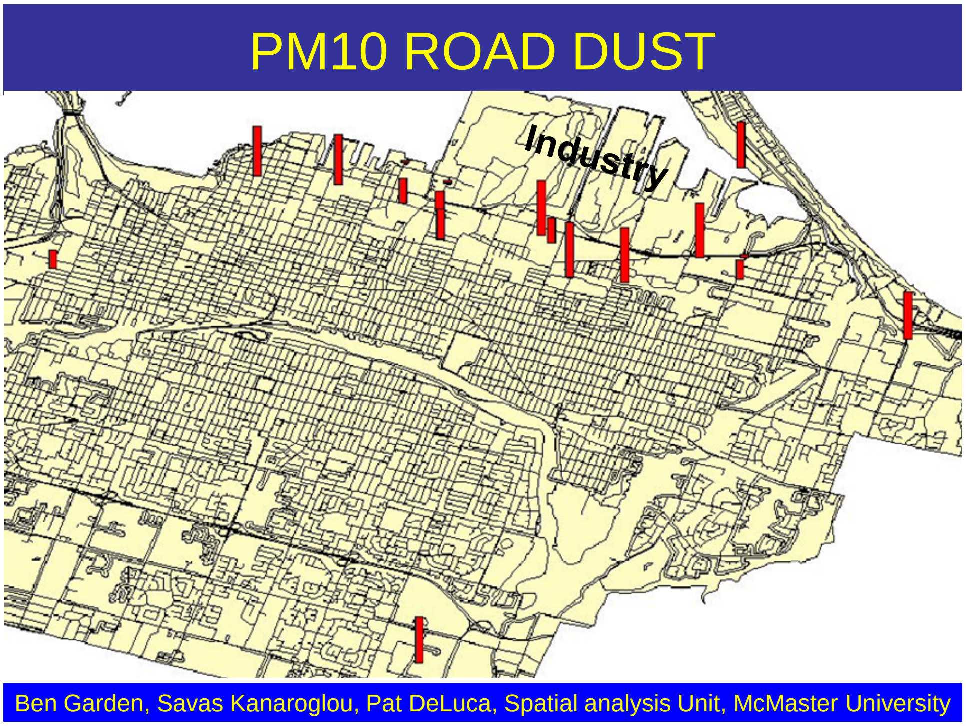


Figure 20. GIS map of fourteen high locations for fugitive dust 2005/06.

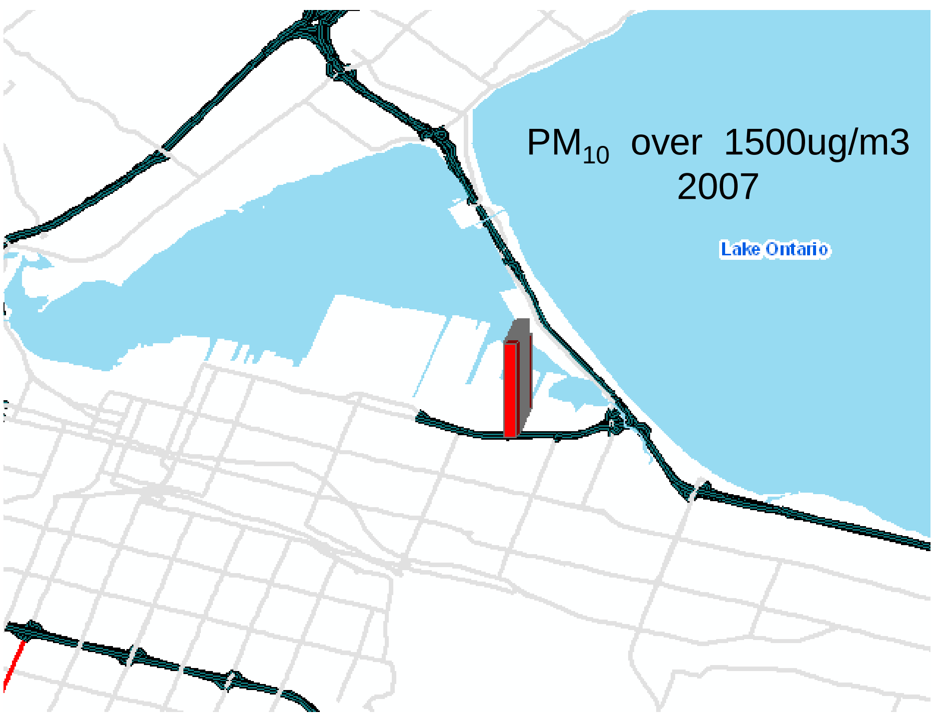


Figure 21. GIS map of one high location (over 1500) for fugitive dust in 2007.

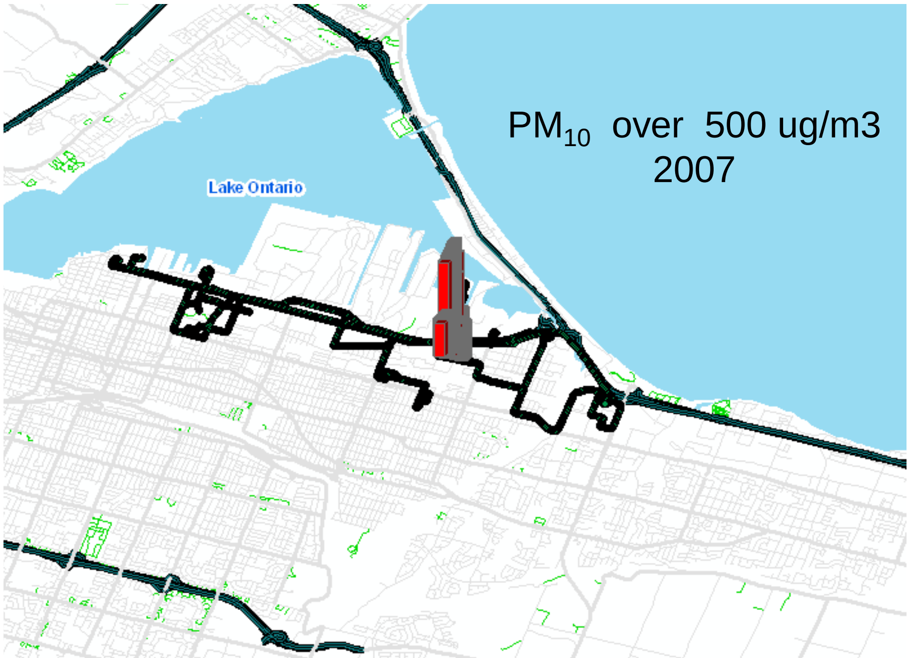


Figure 22. GIS map of two high locations (over 500) for fugitive dust in 2007.

12. Highway Downwind Impacts and Noise Barrier Protective Effects:

Some of the highest levels of air pollutants in the Hamilton area were measured on local highways, the QEW and the 403, so it was of interest to determine the downwind impacts of these roads on surrounding areas. Surprisingly, noise barriers were found to mitigate the levels of air pollutants as well as noise.

Pollutant levels were measured under steady wind conditions both upwind and downwind of the Queen Elizabeth Way highway. Levels were also measured on a transect at different distances downwind from the highway to assess downwind impacts. Figure 23 shows the sampling track.

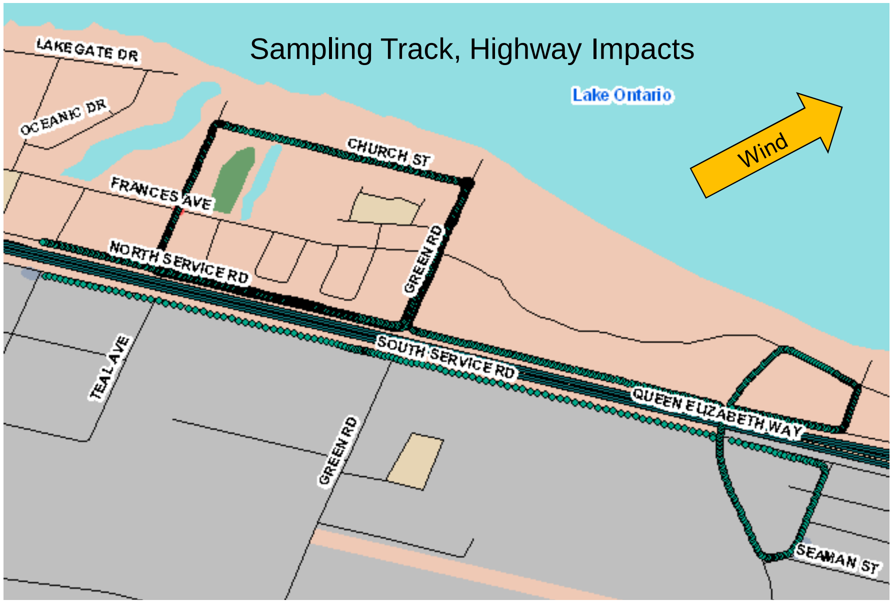


Figure 23. QEW Highway, Land Use Patterns (Residential Pink), Sampling Locations (Green/BlackLine)

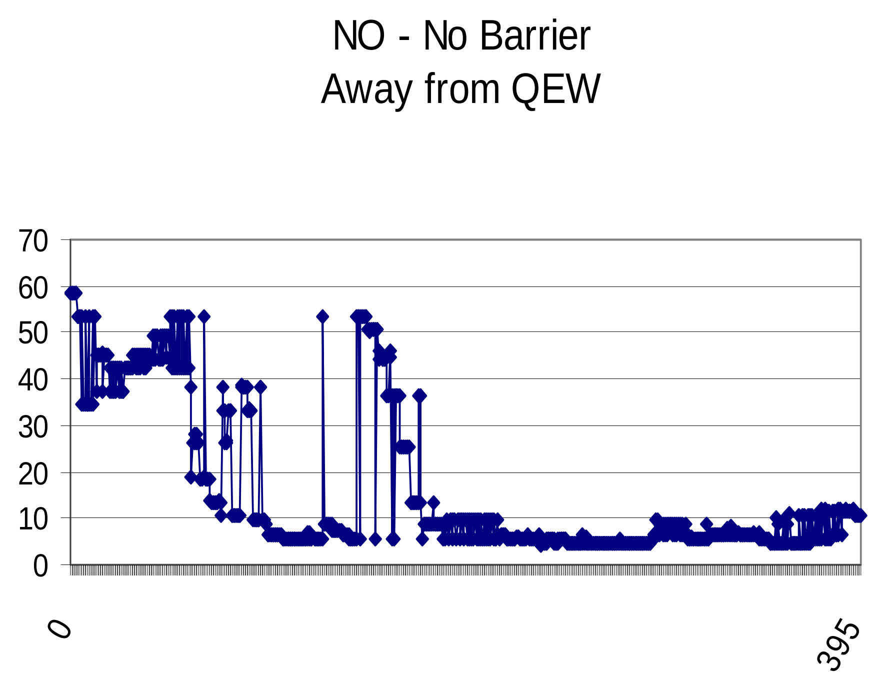


Figure 24. NO concentrations at different distances in metres downwind of highway.

Using NO as a tracer for vehicle emissions, Figure 24 shows there are significant downwind impacts up to approximately 200 metres downwind of the highway.

While gathering data parallel to highway on the downwind side, at one point there was a sudden drop in measured values of vehicle related air pollutants. It was realized that the reason was the sheltering effect of a high noise barrier (Figure 25) on the residential side of the QEW. Further scans confirmed these significant reductions in pollutant levels, see Figures 26, 27 and 28.

Figure 25. Noise Barrier on North (residential side) of Highway

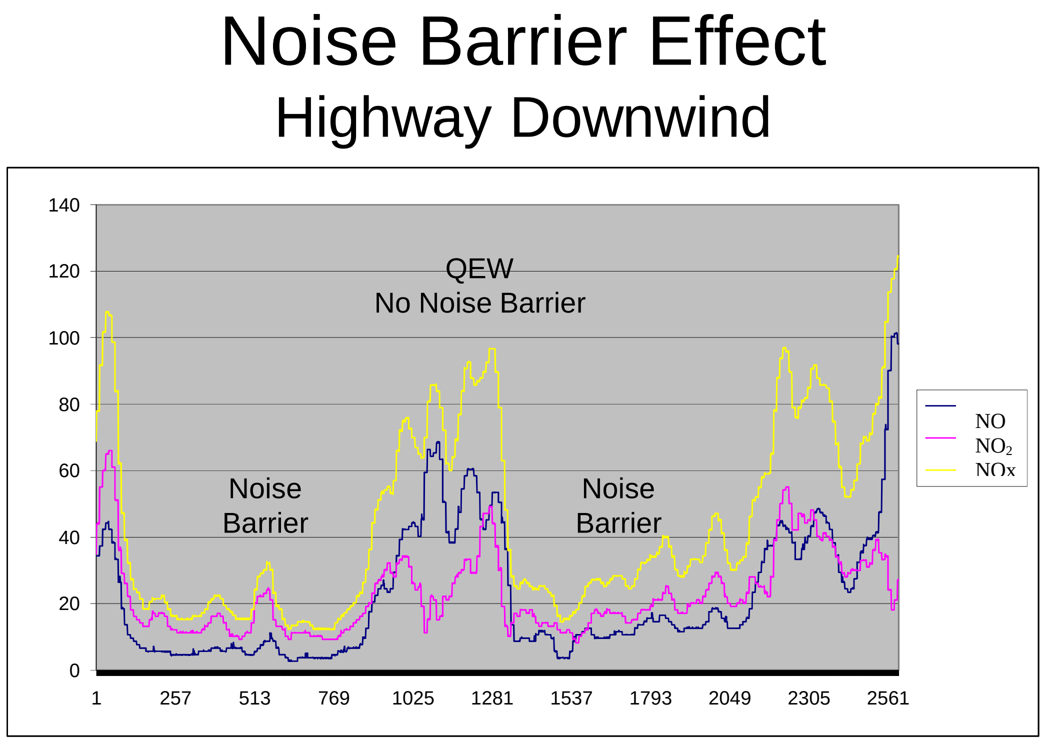


Figure 26. Noise Barrier Effect, NO, NO_2 and NO_x with and without Noise Barrier.

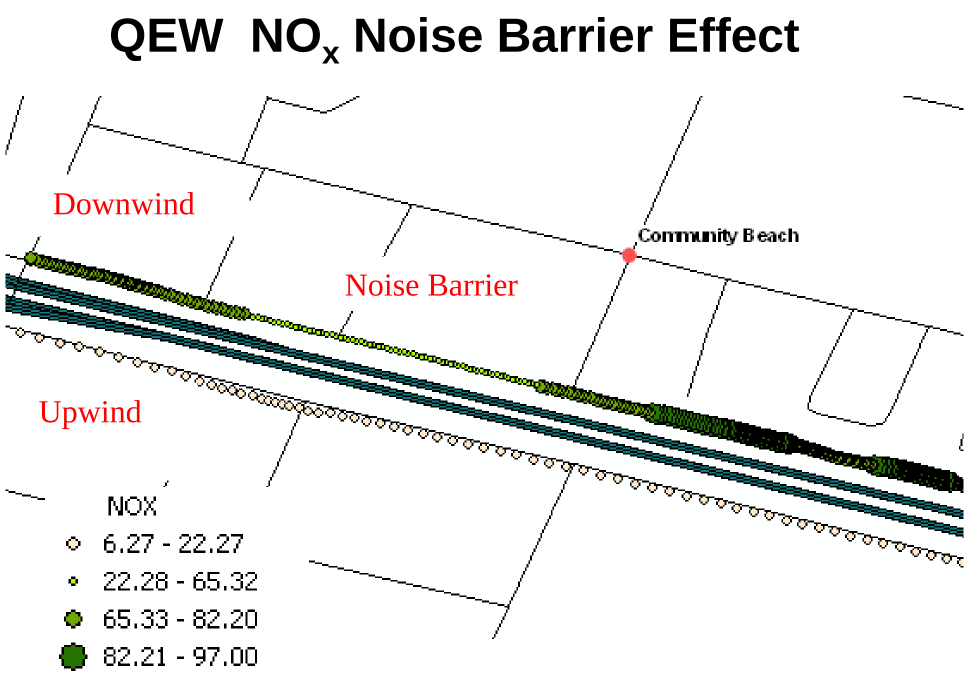
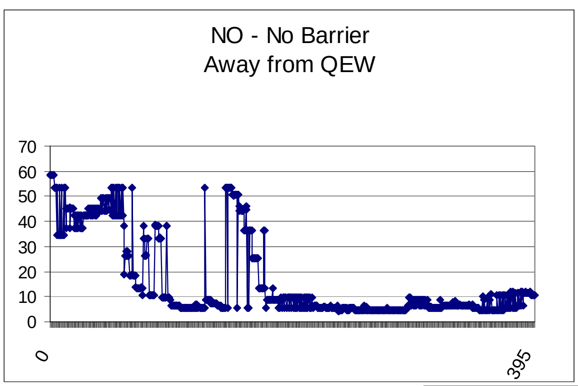


Figure 27. GIS plot of QEW NOx Upwind and Downwind and Noise Barrier Effect.



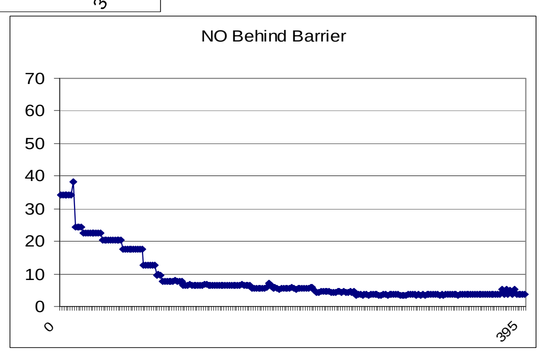


Figure 28. NO Downwind of Highway With and Without Noise Barrier Effect.

13. Aggregated Health Impacts of Air Pollutants .

Previously, the impacts of individual pollutants had been examined, using different compounds as tracers for impact, e.g., SO_2 for industry and NO for traffic. Although we continued to use this technique we also developed an innovative GIS analysis for the total health effects of the pollutants measured. The pollutant effect metrics used were those determined by Jerrett and Sahsorovglou in their May 2003 report to Clean Air Hamilton "A Public Health Assessment of Mortality and Hospital Admissions Attributable to Air Pollution in Hamilton" (School of Geography and Geology and McMaster Institute of Environment and Health), Table 2.

McMaster Institute of Environment and Health
A Public Health Assessment ofMortality and Hospital Admissions
Attributable to Air Pollution in Hamilton
Prepared by:Talar Sahsuvaroglu, PhD and Michael Jerrett, PhD
School of Geography and Geology
May, 2003

Table 1. Summary of Percent Changes per 10 Units of Pollutant: Low, Mean, High, and 42% Adjusted Mean Estimates of Calculated Values

Pollutant	NT mortality[a] (change per 10 units pollutant) range of estimates				Respiratory admissions[b] (change per 10 units pollutant) range of estimates				CV admissions[b] (change per 10 units pollutant) range of estimates			
	low	mean	high	adj mean	low	mean	high	adj mean	low	mean	high	adj mean
PM_{10} ($\mu g/m^3$)	0.43	0.76	1.07	0.44	0.7	2.1	3.5	1.22	0.5	1.4	2.3	0.8
$PM_{2.5}$ (μ/m^3)	1.68	2.88	4.46	1.67								
SO_2 (ppb)	0.84	2	3.89	1.16	1.3	3.7	6.1	2.15	0.2	1.1	2.1	0.6
NO_2 (ppb)	1.5	1.9	2.3	1.10	1	4.9	9	2.84	4.4	6.55	8.7	3.8
CO (1 ppm)	2	3.68	4.95	2.13					0.4	1.95	2.5	1.1
O_3 (ppb)	0.94	1.38	1.7	0.80	1.5	2.8	4.9	1.62	1.6	4.5	7.5	2.6

NT= Non-traumatic; CV = cardiovascular;
[a] = Mortality values were calculated on the basis of 2 or 3 estimates
[b] = Morbidity values were calculated on the basis of 1 or 2 estimates; in the case of one estimate, 95% confidence intervals were used as the low and high range of estimates
adj mean = Mean estimate adjusted for 42% overestimate

Table 2. Percent Changes in Mortality Attributable to Air Pollution per Unit Change in Pollutant.

Although the health effects displayed in this report are percentage increases in mortality, Figure 29 displays graphically that mortality is the only the tip of the iceberg in terms of health impacts. In fact there are increasing numbers of less severe effects as one moves down the pyramid.

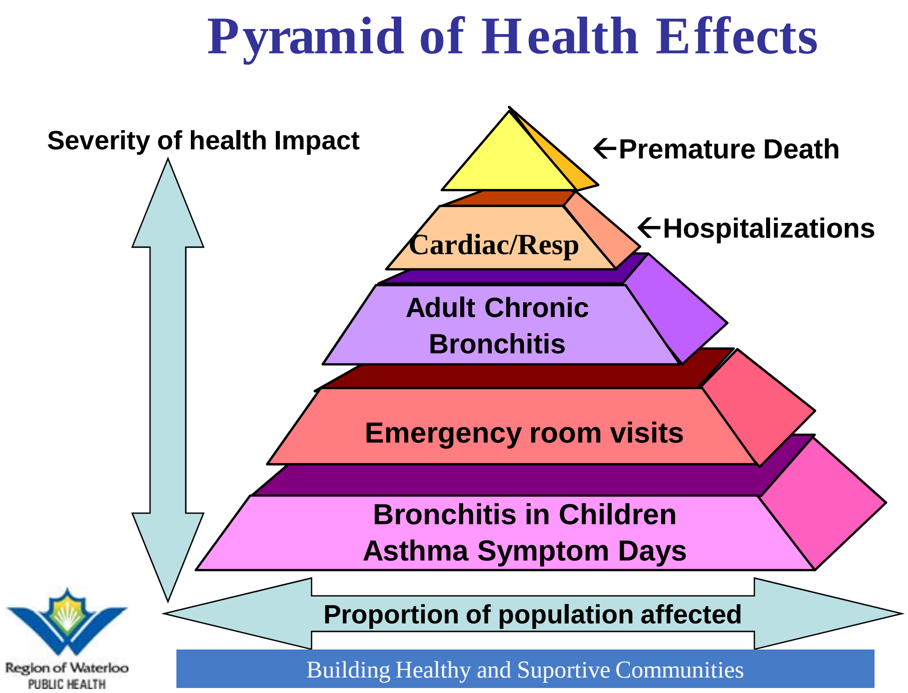
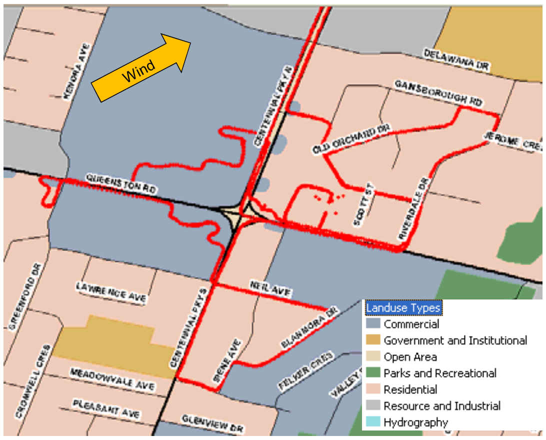


Figure 29. Pyramid of Health Effects Attributable to Air Pollution.

14. Aggregated Health Impacts of Air Pollutants Downwind of Intersections.

Figure 30 shows the land use patterns, including residential use, around a major intersection in East Hamilton and the sampling track used to obtain upwind and directly downwind measurements as well as the concentrations in the residential area.



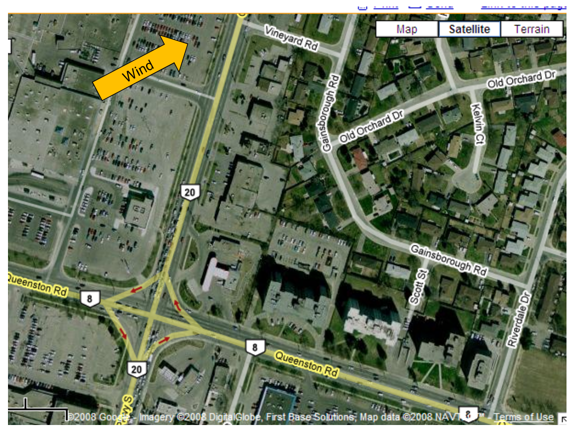


Figure 30. Queenston Road and Centennial Parkway Intersection, Land Use Patterns and Sampling Locations (Red Line).

Figure 31 displays the upwind vs downwind characteristic intersection pattern of idling traffic causing up to twenty five times the NOx impact compared to upwind, with lower levels when the traffic is moving, while Figures 32 and 33 show the aggregated health impact downwind of the intersection on a residential area, both in GIS mapping and line graph format.

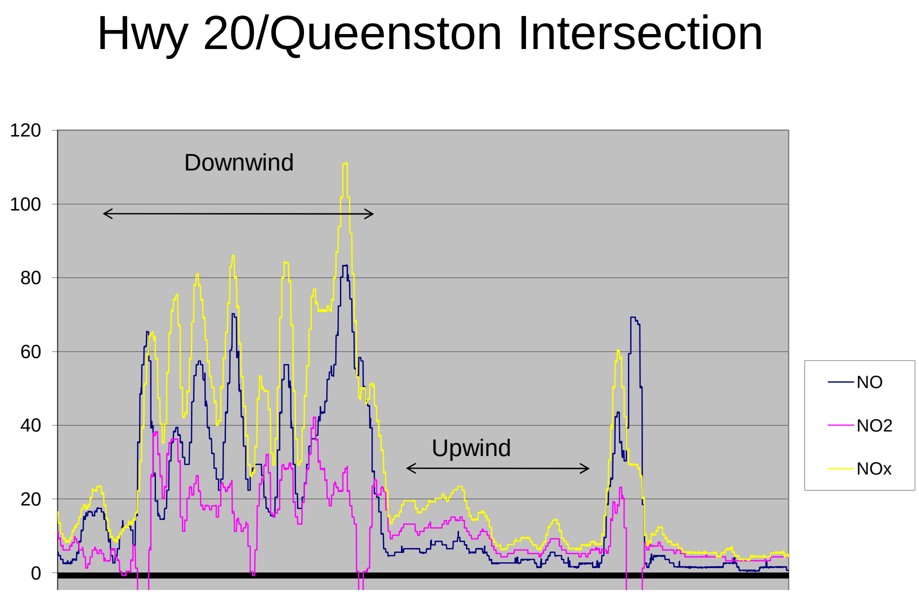
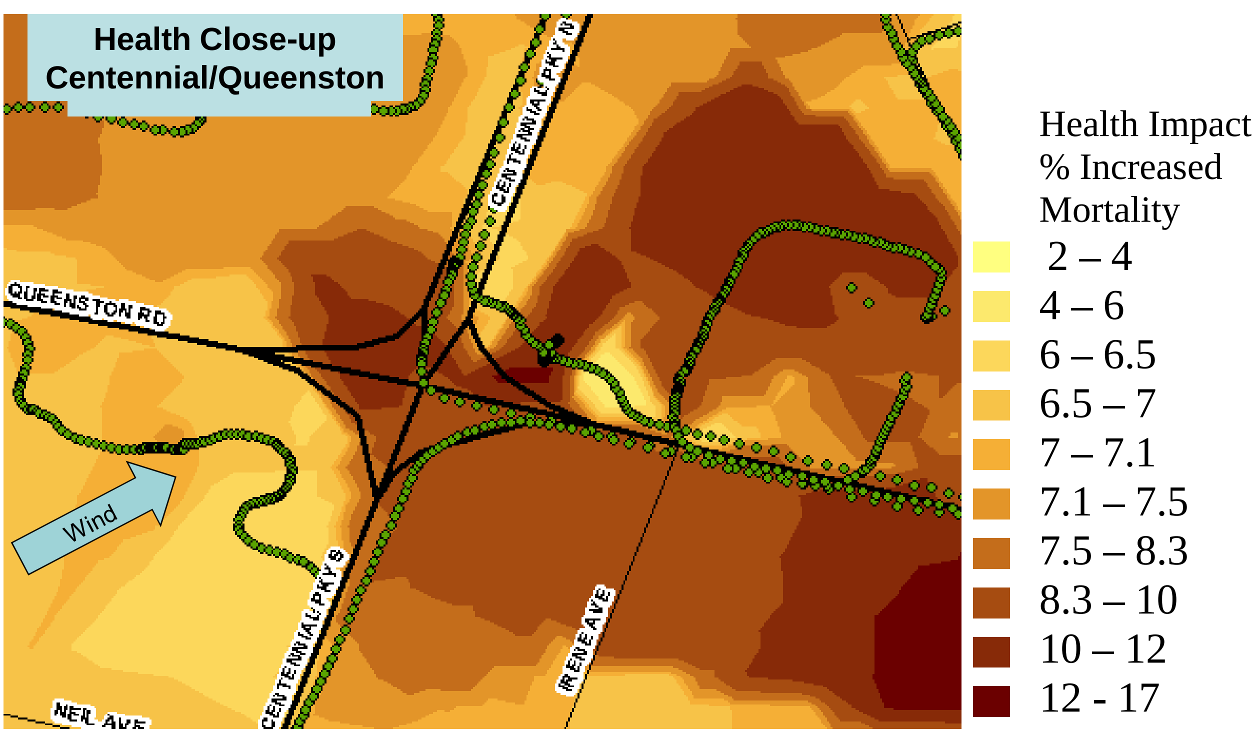


Figure 31. Queenston Road and Centennial Parkway Intersection, Upwind/Downwind, NOx.



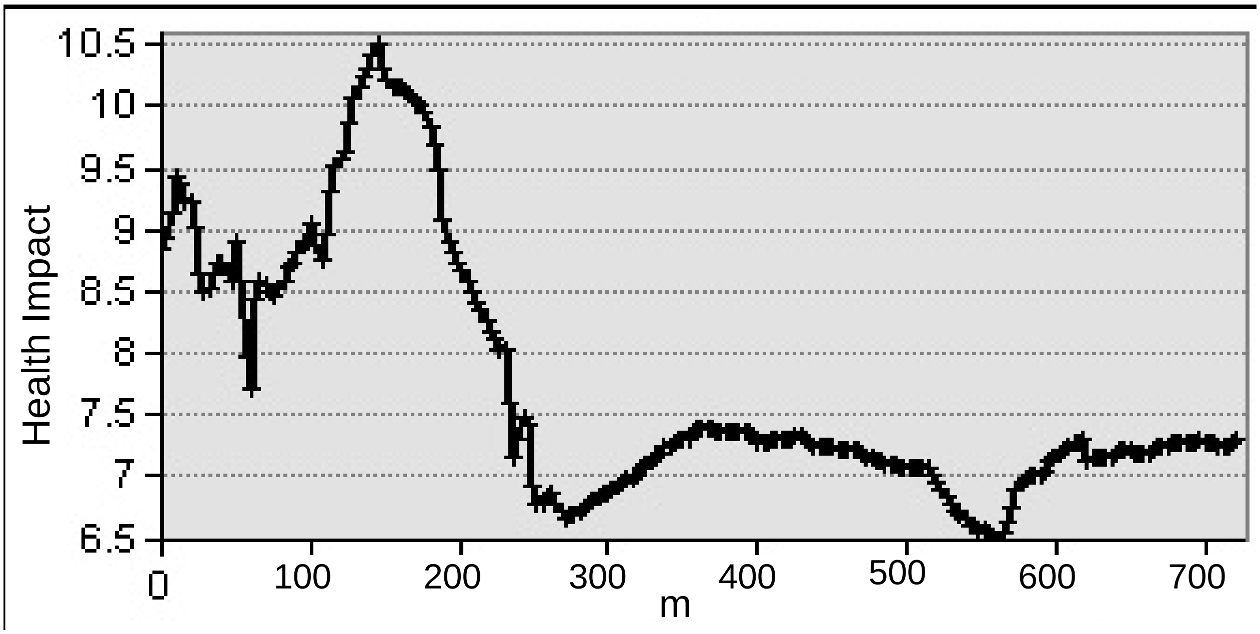


Figure 32. Health Impacts by Percentage Downwind from Intersection.

15. Aggregated Health Impacts of Air Pollutants City Wide on Prevailing Wind (SW) and NE Wind/Inversion Days.

These GIS interpolation and visualization techniques were also applied to the city wide sampling surveys for both prevailing wind conditions (winds from the south west) and for inversion/northeast wind conditions when more poor air quality impacts are anticipated. It is cautioned that these are interpolations and not city wide models and thus at the edges may extrapolate from monitored data to higher levels than warranted. The main portions of the figures should be essentially accurate, however, particularly along highways and in the main portion of the figures. Figures 33, 34 and 35 display inversion/NE wind conditions for SO_2, NO and total health effects by annual percentage increase in mortality. Although heavy industry clearly impacts the lower and upper city, highway effects are also very significant, adding to the NO and health impacts out through the Dundas Valley.

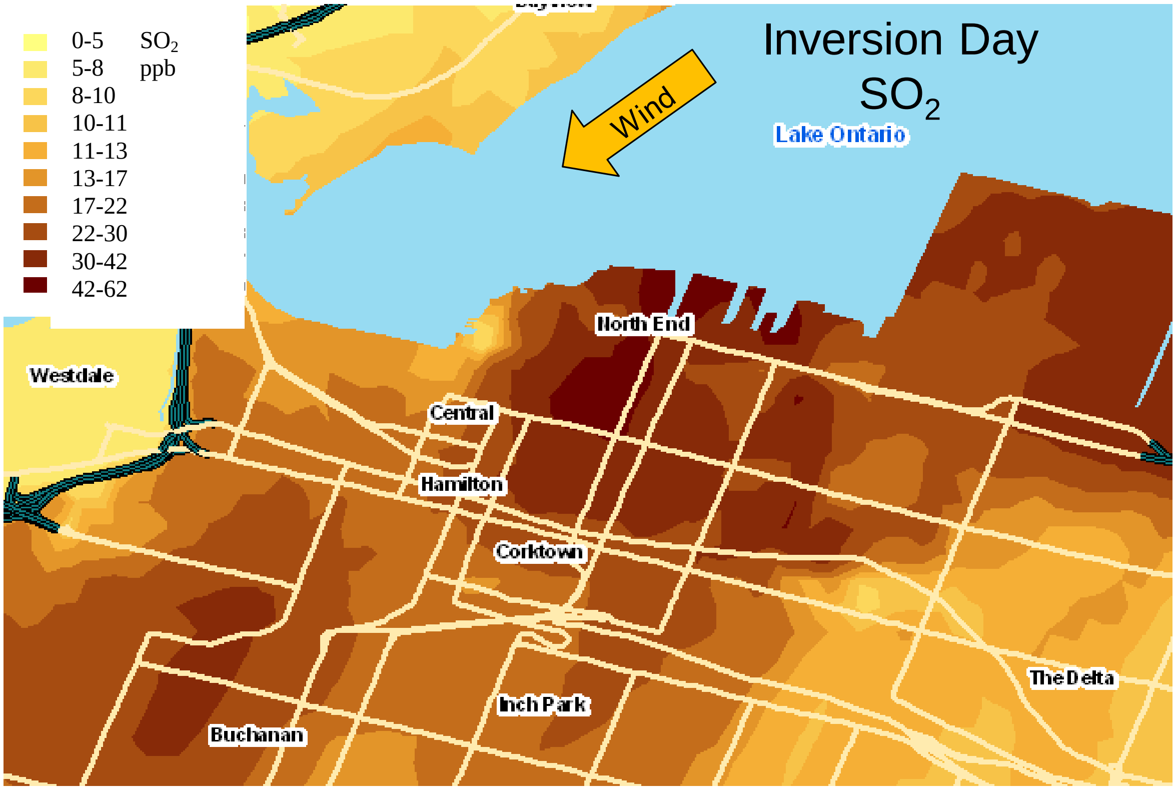


Figure 33. Inversion Day SO_2 Impacts Across the City

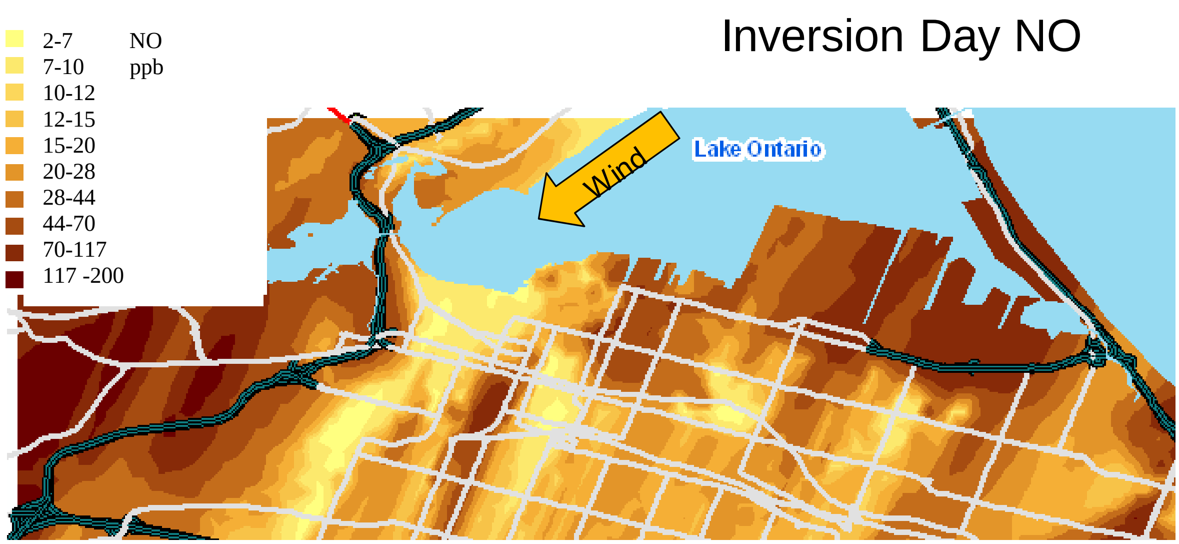


Figure 34. Inversion Day NO impacts across the City

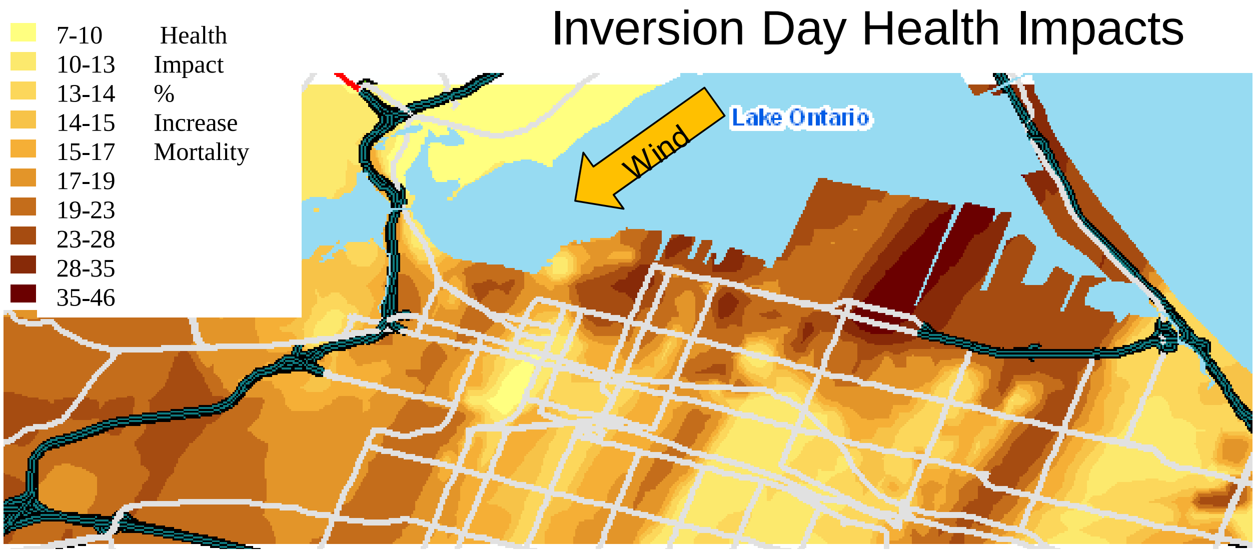


Figure 35. Inversion Day Aggregated Health Impacts across the City

The above figures showed the relationship between industrial, traffic and health impacts on one inversion day. The next figures, 36 and 37, demonstrate some average pollutant effects and health impacts on prevailing wind (SW) days for all days sampled in the years 2005 -2007. The first figure shows industrial impacts traced by SO_2. Figure 37 shows how the highways add health impacts (particulate levels higher than 500 ug/m^3 have been removed in order to remove very localized effects of resuspended dusts).

Please note again that these pictures are interpolation surfaces and not the result of detailed models. As a result, they need to be interpreted with caution, particularly at the edges where little or no sampling data are currently available, e.g. Burlington. In these cases the program may extrapolate to higher pollutant levels than actually exist and additional measurements would need to be made.

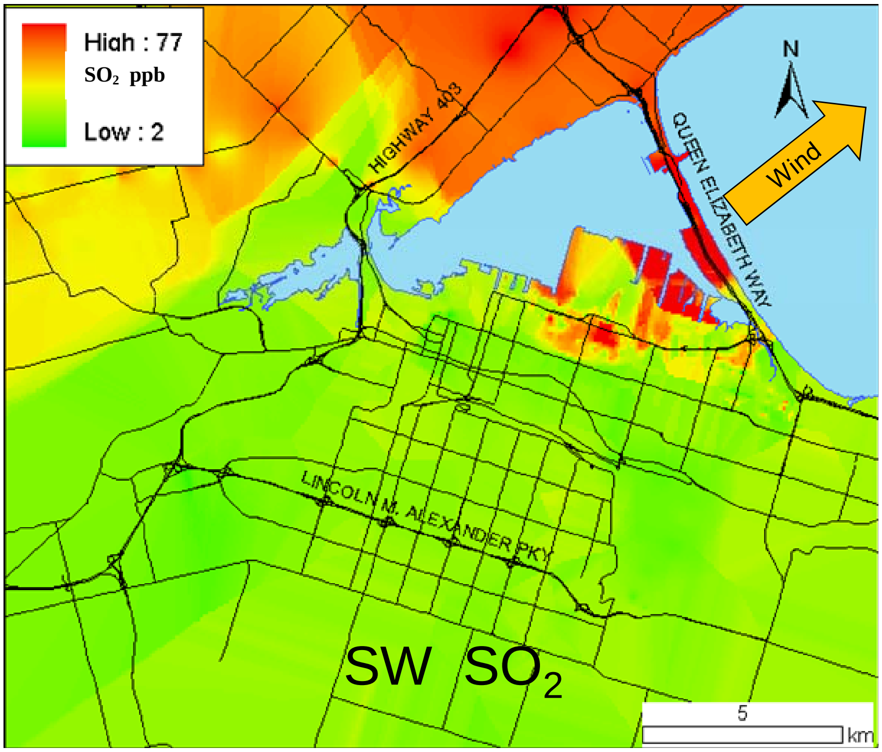


Figure 36. Prevailing SW Wind, Average SO_2 Impacts Across the City

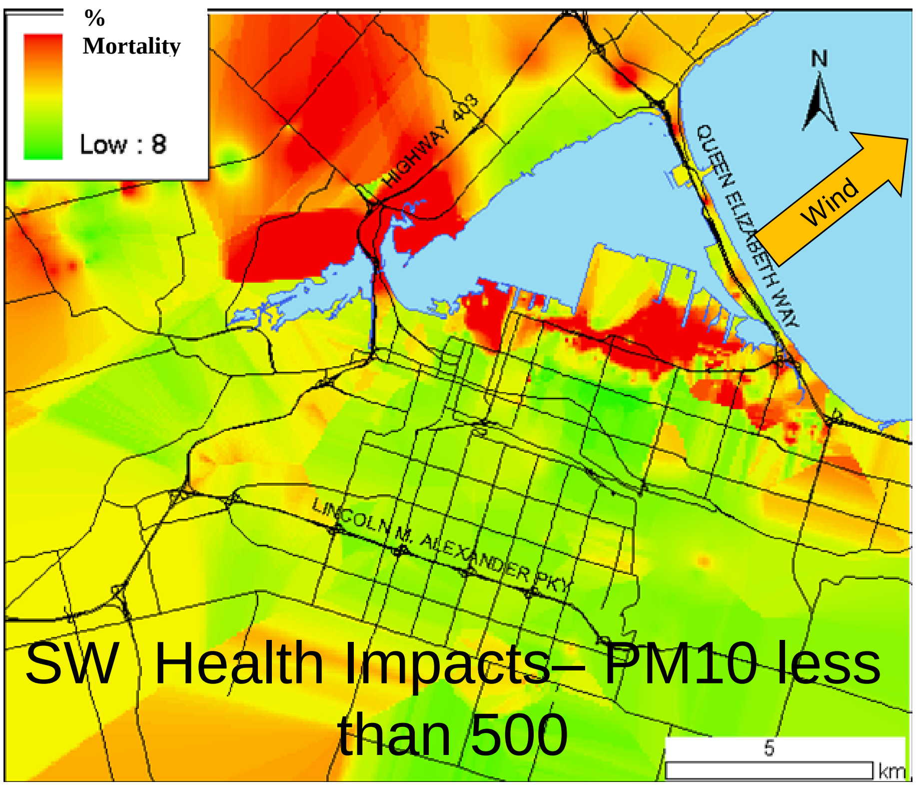


Figure 37. Prevailing SW Winds, 2005-2007, Average Health Impacts Across the City, excluding PM_{10} higher than 500 ug/m^3

Figure 38 shows the average health impacts on NE wind/inversion days for days sampled in the years 2005 -2007. Clearly, during these conditions, there are significant impacts on much greater numbers of citizens and at higher health impact levels over wider areas. This also shows that both traffic and industry effects are significant under these atmospheric conditions and all available means should be taken to reduce these effects. Note the relatively low levels of health impact on the Lincoln Alexander Parkway, compared to the 403 Highway, despite the presence of numerous sections on the Linc with high berms at the roadside and presumably low dispersion. This is probably due to the low frequency of large truck traffic on the Lincoln Alexander, compared to the very heavy truck traffic on the 403. All these measurements were taken before the Red Hill Creek Expressway opened. In addition the 403 incorporates a steep grade so that diesels are under extra load. The Clean Air Task Force in the U.S. has published a series of videos on the internet which dramatically illustrate the localized air pollution impacts of different vehicles, particularly large diesels, see http://www.catf.us/projects/diesel/noescape/videos.php

NE – Aggregated Health Impact

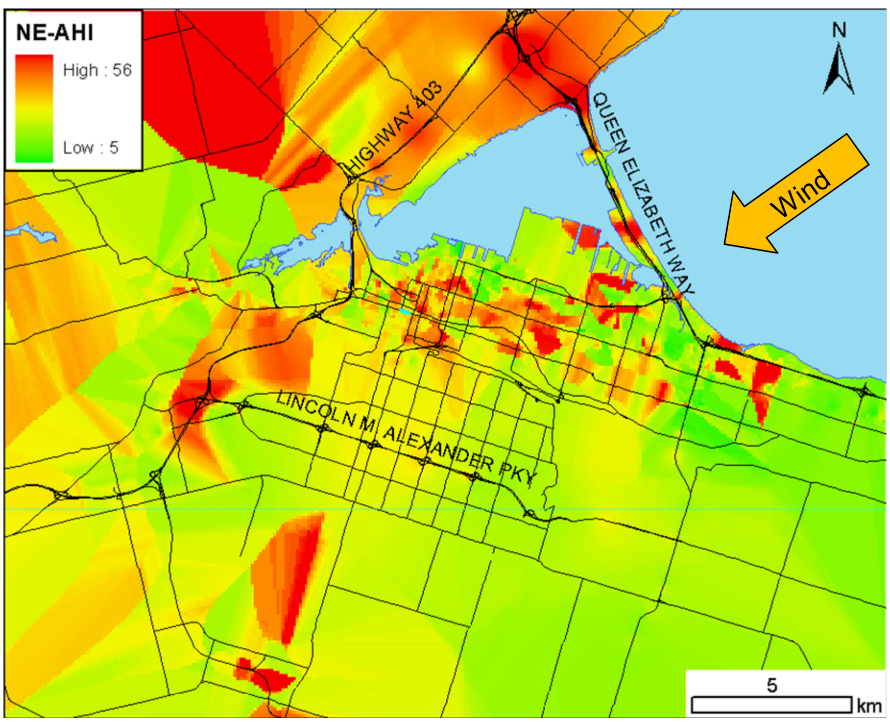


Figure 38. NE Wind and Inversion Days, 2005 -2007, Average Health Impacts Across the City.

16. Presentations

Mobile Monitoring data and recommendations have been presented to Clean Air Hamilton, the Planning and Economic Development Committee (PECD) and the Committee of the Whole of Hamilton City Council, the Upwind Downwind Conference, the Hamilton Industrial Environmental Association, several Commuter Challenge kickoff events, the McMaster University Spatial Analysis and Occupational Health Seminar series, the Fugitive Dust Control Initiative, Ministry of Environment and City of Hamilton staff and the GTA Clean Air Committee.

Aldermen, decision makers and stakeholders have expressed a very high level of interest in the results. The City of Hamilton's PECD Committee referred the report to the Health Department for feedback and the report was presented to a full Council meeting on August 2nd, 2006 along with the Health Department response.

17. Conclusions and Recommendations

The majority of direct air pollution exposures of Hamilton citizens are due to vehicles, although under NE wind/inversion conditions significant industrial impacts also occur . Road intersections, highways and any accumulation of idling vehicles exacerbate these exposures.

Data from Phase 1 of the study were further analyzed using the GIS resources of the Spatial Analysis Laboratory at McMaster University, allowing better visualization of pollution impacts. The data were also used to improve existing traffic pollution models for international use. A monitoring/modeling workshop was held at McMaster University to assist both monitoring and modeling initiatives. The models were used to estimate traffic impacts across Hamilton, resulting in a refocusing of monitoring efforts to include projected high impact areas in the west end and mountain accesses.

In this Phase 2 study, the highest air pollution levels measured by far are on highways and heavily traveled arterial roads, particularly where truck traffic is frequent, i.e. QEW, Hwy 20, 403, Burlington Street. If the emissions are confined in a valley or between banks, or trucks have to drive up a hill (403 west), then the ambient levels rise sharply. These high pollutant levels do seem to be mainly confined to the roadway and immediate vicinity.

NO roadway concentrations are highest in the west end, peaking at 586 ppb. These values are higher than those downwind of heavy industry in the City. Roadway pollutant levels in the east end are more heavily influenced by particulate, with PM_{10} levels as high as 442 ug/m^3.

These results bear out the modeling projections with regard to major highway/arterial road intersections, however the mountain access measurements were more reflective of normal arterial road concentrations. The Claremont Access and Joly Cut mountain accesses peaked at 132 ug/m^3 for PM_{10} and 158 ppb for NO.

Concern had been expressed about the effects of drive thrus, so monitoring was conducted in the vicinity of a number of both coffee shop and fast food drive thrus. Downwind pollution levels were comparable to nearby roads. This is unsurprising, given that the same vehicles are involved. These concentrations, of course, are still elevated compared to residential values. No measurements were made within the drive thru line ups and higher values might well be expected there.

Inversions have been a factor in higher pollution incidences in Hamilton for many years. Stagnant conditions cause pollution buildups, then the lake breeze effect generates light east to north east winds which blow accumulated industrial and vehicle related pollution back across the City. Although these conditions can occur at any time of the year, they are more pronounced in the spring due to the greater temperature differences between the cold lake water and the warmer City.

To our knowledge, the areal extent of inversion related pollution has never been measured before in Hamilton. In this study, measurements were made on several inversion days and showed that plumes from the industrial area can reach across the City and up through the Dundas valley. Ancaster was also surveyed and showed no elevated pollution levels.

Health impacts for most of the pollutants measured in this study vary linearly on an individual exposure basis. This can lead to the conclusion that all pollution reductions are important, whether at high or low levels. Under inversion conditions, however, there are much higher aggregate exposures to air pollution, because of the greater exposure area and greater numbers of exposed citizens in addition to the higher air pollution concentrations. As noted earlier, the content of pollutant mixtures in inversions is a more toxic mix than in normal conditions, making the situation worse yet again. A further consideration is that there is a wide of range of bronchial reactivity (asthma sensitivity) and cardiac status in the population, so that reducing these higher pollution levels could bring relief to a sizeable fraction of asthma sufferers and cardiac patients.

Some recommendations arising from these data are that:

- since barriers can cause significant downwind reductions of air pollutants from roadways, intensive tree plantings, preferably dense evergreens, should be considered along highways and arterial roads.

- frequent diesel truck emission testing and enforcement, e.g., at MTO highway weigh stations would aid in fine particulate and NO_x reductions.

- Industrial emission reductions remain important but even short term reductions would be worthwhile under NE wind/inversion conditions according to a forecast Air Pollution Index. Historically the Ministry of the Environment operated an Air Pollution Index which required additional control of emissions under high pollutant conditions. The current Air Quality Index is for information purposes only. Consideration should be given to reinstating the Air Pollution Index for inversion conditions using current health data, possibly based on the new Environment Canada proposed health based index, combined with air pollution forecasting.

- reductions in heavy truck traffic and materials handling should also be required using similar controls.

- control of both point and area particulate pollution, NO_x and SO_2 emissions remains an ongoing priority.

- air pollution health effect GIS displays have been convincingly demonstrated in this study and could be incorporated in an enhanced GIS map based Air Quality Health Index, available on the web.

- physicians should caution patients with respiratory or cardiac difficulties to avoid areas of higher air pollution, e.g. highways with high levels of diesel truck traffic, particularly under low dispersion conditions, whether weather related or by virtue of valley type effects.

- anti idling measures should be aggressively promoted.

- cycling/walking routes should be separated from heavily travelled roads.

- previously low levels of truck traffic on the Lincoln Alexander Parkway may have increased since the completion of the Red Hill Creek Expressway and the pollutant levels on these highways should be investigated along with Centennial Parkway (to check whether pollutant levels have decreased there).

- GTA highways and city centres should also be monitored for comparison purposes.

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Appendix 1

Air Quality Monitoring/Modelling Workshop

McMaster Centre for Spatial Analysis/Engineering Physics Dept.

Meeting Room, Burke Science Building, 3rd Flr (BSB-236A)

Wednesday, November 22, 2006

Agenda

9.00	Introductions & backgrounds
9.10 – 9.30	Pavlos Kanaroglou, Centre for Spatial Analysis A Policy Related Research Agenda on Urban Air Quality
9.30 – 9.45	Juliet Wallace, Centre for Spatial Analysis TAPM- A Dispersion Model Possibilities of Assessing Air Quality with Remote Sensing
9.45 – 10.05	Denis Corr, Eng Physics Mobile Monitoring Capabilities, Data Availability Phase 1 study, Phase 2 study
10.05 – 10.20	Pat DeLuca, Centre for Spatial Analysis Centre Capabilities- hardware/software, K-line+ Dispersion Model Phase 1 Mobile Study Spatial Analysis
10.20 – 10.35	Dave Stronach, Halton Public Health Proposed Network
10.35 – 10.45	Break
10.45 – 11.30	Anthony Ciccone, Golder Associates Phase 1 and Phase 2 GTA Hamilton Modelling Opportunities for Collaboration
11.30 – 11.50	Frank Dobroff, MOE Regional data/initiatives.
11.50 – 12.10	Rob Bloxam, MOE Provincial data/initiatives
12.10 – 1.00	Light Lunch

1.00 – 2.30 Open Discussion on data sharing, model inputs, opportunities for collaboration

Appendix 2

Centre for Spatial Analysis

McMaster University

Air Quality Monitoring/Modelling Workshop

Wednesday, November 22, 2006 9:00-2:30

MINUTES

Present: Dr. Denis Corr (McMaster), Dr. Anthony Ciccone (Golder Associates), Mr. Patrick DeLuca (McMaster), Dr. Juliet Wallace (McMaster), Mr. Frank Dobroff (MOE), Mr. Brian Montgomery (City of Hamilton), Dr. Brian McCarry (McMaster), Dr. Yorgos Photis (University Aegean), Dr. Pavlos Kanaroglou (McMaster), Mrs. Deane Maynard (McMaster), Ms. Magda Janik (City of Hamilton)

Regrets: Dr. Malcolm Sears (McMaster), Mr. Dave Stronach (Halton Public Health), Mr. Robert Bloxam (MOE)

This workshop was coordinated by Dr. Denis Corr to exchange information and discuss opportunities between modelers, spatial analysts, air monitoring people and government agencies. Each participant was introduced and gave presentations on their current types of research involving air quality with demonstration of their models.

1) Air Quality Research Goals

Discussions between Kanaroglou, Montgomery, Ciccone and Corr indicated the goals of their air quality research included:

- **creation of models for decision-making policies to improve our quality of life**
- **to supply urban areas with planning and direction to sustain cities**
- **to supply urban planners with accurate information and forecasting to take to councils to assist in decision-making.**

2) Group Dynamics and Research

(a) Centre for Spatial Analysis (Dr. Pavlos Kanaroglou, Director, CRC and Professor, Geography, McMaster University)

The attached flowchart best describes the air quality research processes being conducted in the
Centre for Spatial Analysis. Research consists of obtaining data from different sources to assess air pollution concentrations and how they come about. In order to do this, one must understand all levels. For example satellite data, ground concentration and ground observations. Pavlos's research pulls together all of these data (data fusion) to create models for decision-making. Pavlos is also collaborating with Dr, Salim Yusuf in Cardiology who is directing a 50 country study of the health impacts of air pollution. Calibration of satellite measurements here could then be extrapolated to developing countries with little ground based monitoring to examine health effects internationally.

Types of models used:

(a) Dispersion Modelling: Caline + (Gauss model) and TAPM (Euclidean Model)
(b) Land Use Regressions: Land use over space (what's happening spatially)
(c) Location-Allocation: Spatial arrangement of economic activities to identify optimal locations for facilities, etc.

Data fusion is used to create air pollution estimates and models to answer questions such as:
How are health outcomes (such as asthma/cardiac events) related to air pollution?
Air pollution and health = population exposure estimates.
How can we use these techniques and how do they compare to ground data?
Can we take these models and apply them to other countries with limited data?

CSpA's air quality research is focused on transportation emissions and how people make decisions to travel from one place to another.

CSpA has built the following programs:

ITLUM models (Decision-support tool, refer to flow chart for more information)
IMULATE models (morning peak hours)
IPACTS model (beta stage, 24 hour basis)

Land use and transportation models used are then related to emissions modules. Models predict where congestion will occur at certain times of the day.

Actions: *establish web links with MyHamilton.ca for traffic emission/flows, etc. Research the new one-way streets in Hamilton versus the old two-way street information*

Juliet Wallace (Post-doctoral Fellow, Centre for Spatial Analysis, McMaster University)

Expertise in Remote Sensing. Currently investigating:

- TAPM Dispersion Modelling
- Remote Sensing of Atmospheric Pollution possibilities

<u>TAPM</u>

Uses: DEM, Land Use, Vegetation and Soil, Global long-term sea surface temperature and Emissions all at a global scale. Juliet is trying to get it down to a more localized level.

Pollution grid resolution is at 250 m.
Imulate data with TAPM represents peak hours in traffic. TAPM model cycles every 12 hours just as there are 2 peak periods.

400 km x 400 km is what the TAPM program suggests

Customization of the TAPM program should include: meteorological data needs to be changed for wind direction, link with population and health data = policy decisions

<u>IMULATE</u>

Generates data for every 5 years
3-D modeling is based on 1 hour of data only (7:00-8:00 a.m.) This is a snapshot only, it is not dynamic. (250 m grid on 50 m DEM from DMTI)

<u>IMPACTS</u>

Will provide 24-hour data once it is up and running.

<u>Remote Sensing</u>

New satellites are determining how much light passes through the atmosphere. Juliet is using data from ICARUS (University of Aegean).

Limitations of atmospheric satellite observations:

- Currently low spatial resolution
- Does not identify many specific pollutants (mainly O3, aerosol optical depth)
- Orbits near Hamilton only (sits over Guelph)
- Measures a column of air (not across) around 8 km x 5 km
- Doesn't always see because of clouds, etc.

Actions: MOE – DEM terrain file is better. Frank will forward to Juliet, Frank to supply local met data on request by Juliet.

Patrick DeLuca (Centre for Spatial Analysis, McMaster University)

CSpA and GIS Lab administration, teaching and research. Software used: S-Plus, SPSS, ArcGIS, IMULATE, CALINE+.

Sample research includes working with programmer to customize CALINE 3 (to CALINE +) which includes 4000 links and 3500 receptors.

Uses collection of the following data for research:

- DMTI
- Mobile 6 (emission factors)
- IMULATE
- Corr data

Uses CALINE+ and IMULATE

Results for RBG meteorological data versus Burlington Piers – vastly different due to equipment? Sounds like it after some discussion. Identified Hwy 20/ QEW area, Claremont access and West End/Dundurn/403 area as hot spots.

Action: Denis Corr asks CSpA to recommend locations of sampling for Phase II of his study Pavlos would like to run some landuse regressions with Denis's data for windspeed and direction.

(b) **Denis Corr** (Engineering Physics, McMaster University)

Denis's research is part of Clean Air Hamilton, contracted to Rotek Environmental. Clean Air Hamilton has evaluated Health Impacts of Air Pollutants in Hamilton using ground pollution monitors strategically placed throughout the city. One result of the Health evaluation was that cardiac emergency admissions are 3x higher than respiratory admissions.

Clean Air Hamilton's approach consists of:

- Identification of the problem

- Measure and evaluate
- Prioritize risks
- Inform community
- Take co-operative actions

Using Health effect and NPRI data as a starting point, Denis conducted a mobile survey of sources of air pollution in Hamilton, Phase I. Study Objective for Phase I was - Where is the health impacting air pollution coming from?

Results include the following:
From the NPRI data, at CO is largest contaminant emission in Hamilton = 66% transportation, 23% industry and PM10 = 73% open road dust, 18% industry.

From the Mobile Sampling;
Response time of sampling units is 1-2 minute.
Traffic Intersection idling effects are dramatic, e.g. Barton Centennial /Mohawk and Upper James.
Sampling focused on non- rush hour sampling for stability of cross city sampling.
Buildup of pollutants across city quantified.
Residential vs. road concentrations quantified.
Arterial road contribution (Burlington St.) quantified.
Idling outside school has significant contribution.
Road dust trackout/resuspension has major airborne particulate contribution, 14 sources and locations identified
15 Point Source ground level impacts quantified
NPRI point source data have a highly variable relationship to actual ground level measurements.

Outcomes/inputs to other actions to date:
Three presentations to Hamilton City Council, one to GTA Clean Air Committee, one to West Central Region MOE, one to Upwind Downwind Conference, one to Hamilton School Board, one to Commuter Challenge kickoff, McMaster.
Hamilton School Board reviewing need for anti idling program outside schools
Data being incorporated in Hamilton bicycle route planning
MOE abatement taking action against trackout/road dust offending industry
Hamilton City staff reviewing bylaw options for trackout action/ road cleaning options
Fugitive Emission Control Workshop hosted by City, MOE, Clean Air Hamilton, planned for Dec 11, 2006, 100+industries contacted

Actions for Phase II (Trackout/Diesel Trucks)

- *Include rush hour sampling*
- *Perform sampling on major arterial roads at intersections and drive throughs (coffee shops)*
- *Monitor downwind impacts of roads and intersections in residential areas*

- *Photochemical modeling required for more accurate information.*
- *Aerotropolis (airport) modeling (maybe a potential Thesis?)*
- *Harbour marine emissions.*
- *Natural gas consumption (Golder has data)*
- *Raw data to be given to Anthony for Burlington Street area.*
- *CSpA to assist in determining where phase II sampling should occur*
- *Assist in Fugitive Emissions Control Initiative*
- *Test existing models of city wide distribution of air pollution and extend mobile monitoring to fill data gaps across the City, e.g. Dundas, Stoney Creek.*
- *Perform Smog day/Inversion day monitoring, upwind of City and across City to identify Regional and Transboundary impacts and compare to City impacts*

(c) **Anthony Ciccone** (Golder Associates Inc.)

Anthony is principal of Golder which specializes in research in Environmental Engineering (air, water, groundwater)

Recent research for GTA included some air quality monitoring of the Hamilton Airshed (urban canyon modeling).

Used grid and meteorological data to run the following models:

CALPUFF: atmospheric dispersion model
CALMET: meteorological data from the MM5 model; uses NCEP 2005 global data.

Meteorological data spans 1 year (2005), hour by hour throughout. Modelling uses true composite of all emissions from RDIS.

<u>Data Used:</u>
RDIS (Environment Canada's Residual Discharge Information System)
Area, mobile and point emissions

Limitations of RDIS data and MPRI data: lots of missing data so they have to be backfilled.

<u>Spatial aggregates used:</u>
Digital road maps for mobile emissions
Visual land use maps for area emissions

Used MPAC data to categorize, gridded 2 km x 2 km

1 year MODELLED versus 6 MONTHS MONITORED indicate that Golder models are within range with all emission levels.

Anthony supplied the following information about various data:

Mobile 6.2 is not a correct model to use – can't model intersections.
Use Microfact – USEPA (more refined model); intersection model is included therefore can predict CO2 during intersection idling. This software is owned by Golder.
OLANS data – 42 km grid
Use CMAC to further refine chemistry

Golder is interested in the monitoring data and results of remote sensing.

(d) Halton Health Department (Denis Corr spoke on Dave Stronach's behalf)

Halton Health would like to set up an air quality monitoring system with real time web display. They are especially interested in the expressway corridors and the Milton expansion.

Would like to have monitoring stations set up in Milton, outside of Milton, inside Burlington and throughout the expressways.

Halton went to industry for support (103 point sources, 6 sewage, 50 responded, 30 at meeting). Cost is $300,000-$400,000 to run a network. Industry voluntarily came up with 10% and this is now going to the region for decision on funding. Planning committee meets December 12 for decisions. Denis will be unable to attend (due to an operation) but other members of the group would be welcome to give input if they so desire on worth of project.

(e) Frank Dobroff (Ministry of the Environment)

Regulation 419 – new way of regulating/monitoring industry, much tighter, replaces REG 346 – ½ hour concentrations – some chemicals need different time periods to react

New Regulation invokes EPA up to date models, different times, odorous contaminants (10 minute intervals)

3) RECOMMENDATIONS AND NEXT STEPS?

<u>Denis:</u>
Implementation of Phase II
Attending December 11 track/out dust workshop
Take 3 intersections during rush hour and monitor
Work out detailed grid pattern for city
Would like to work with CSpA and Golder for Phase II
Looking to CSpA to assist in determining areas to monitor for Phase II
Write up formal papers.
Hire part-time programmers for telemetry systems for air monitoring systems

Pavlos:
Using Denis's data, he would like to blueprint what it is we are seeing on the ground (spatial interpolation) resulting in improvements of his models.

Anthony:
Interested in land-use regression and how he can use it in the models Golder is using.
Interested in satellite imagery and data (topical – to look at as things are spreading)
Interested in u/g Students for hire. Will send Deane job descriptions to post.
Would like to work with CSpA on satellite imagery (UN environmental stuff)
Would like to use satellite imagery to focus on ozone; new satellites are looking into global climate change.

Juliet:
Would like to see minimum simulation models, MET data

Pavlos and Anthony:
Call for Proposals. Pavlos to coordinate when proposals come up with call for industrial partners.

Frank:
Will provide data for research, DEM and met. To email Deane copies of report for West Mtn area around the Linc.

/November 24, 2006