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WEST CENTRAL REGION

July 12, 1999

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Dear Vince, Ed and Robert:

As you know, re-suspended road dust has been identified as a highly significant source of inhalable particulate in the Hamilton Wentworth area. Inhalable particulate was also identified by the Hamilton Wentworth Air Quality Initiative as the most important pollutant causing health impacts.

A study was set up to examine different methods of road cleaning to see which would be most effective in reducing inhalable particulate generation.

I have attached the report of this study, so that this information can now be used in Hamilton-Wentworth Region.

In summary, air quality monitors situated at Burlington Street showed that road sweeping/flushing or vacuuming alone does not reduce inhalable particulate pollution. In fact sweeping or vacuuming alone with increased frequency actually worsens the amount of inhalable particulate coming from the road.

However, a combination of frequent (three times per week), sweeping/flushing and vacuuming on Burlington Street, showed a distinct improvement in the immediate vicinity of the road.

The study group hypothesizes that sweeping/flushing alone just removes the heavier particles, leaving the smaller particles available for re-suspension, while vacuuming alone removes only the smaller particles leaving the heavier particles to be ground up and re-suspended by vehicle tires. The combination of sweeping/flushing/vacuuming removes all of the available particulate .

Not unexpectedly, the study did not show an overall improvement in ambient levels of inhalable particles in the industrial area. The study group feels that this result was due to the large number of other sources impacting on the study area and the limited scope of the study.

The study group recommends that an enhanced street cleaning regime of frequent sweeping/flushing/vacuuming be implemented in the area identified by the Hamilton Air Quality Initiative maps as having high levels of inhalable particulate in the air. This area comprises Wentworth St. to Parkdale Ave. and Barton St to Burlington St., but certain streets north of Burlington, particularly Strathearne Ave, should be included as well.

Thank you,

Denis J. Corr
On behalf of the Road Cleaning Study Group

c:
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R. Foulds, Regional Municipality of Hamilton-Wentworth
R. Lane, Stelco
M. Girard, Columbian Chemicals
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REGION OF HAMILTON-WENTWORTH AIR QUALITY PROGRAM

STREET CLEANING INITIATIVE

Ministry of the Environment
Technical Support Section
Air, Pesticides and Environmental Planning
F. Dobroff
West Central Region

June 8,1999

REGION OF HAMILTON-WENTWORTH AIR QUALITY PROGRAM
STREET CLEANING INITIATIVE

Introduction

The Hamilton Air Quality Initiative identified inhalable and respirable particulates as the leading priority pollutant affecting human health. Transportation sources were identified as major contributors of particulates, probably from direct tailpipe emissions as well as road dust re-entrainment. Enhanced street cleaning to minimize re-entrainment was proposed as one strategy to improve airborne particulate levels. This report outlines the research study that was employed to examine the effect of street cleaning on ambient particulate measurements.

Acknowledgments

The author of this report would like to acknowledge the significant contributions to this study by:

- Dr. Denis Corr and Neil Buonocore of the Ministry of the Environment for study conception, design and project management.
- Bill Branch, Carmen Desson and Bill Sparks of the Ministry of the Environment for installation and operation of air monitoring equipment.
- Rosemary Foulds and Sonya Kapusin of the Regional Municipality of Hamilton-Wentworth for project design and management.
- Vince Zingaro and Charles Guthro of the Regional Municipality of Hamilton-Wentworth for management and procurement of equipment for the street cleaning program.
- Dr. Brian McCarry of McMaster University for project design, data analysis and analysis of hivol filters.
- Doug Johnson and Jamie Walker of Ortech Corporation for operation of one continuous monitoring station.
- Rick Lane of Stelco, Ed Cocchiarella of Dofasco and Marc Girard of Slater Steel for study support and use of property for monitoring stations.
- Paul Daszko of Rotek Environmental for help in hivol sampling.

Previous Studies

Street cleaning by mechanical sweepers and vacuums was studied in downtown Hamilton in 1979 as part of the overall study known as the "Hamilton Road Dust Study"[1]. Concentrations of suspended particulates (by high volume sampling methodology) were compared during twice daily mechanical sweeping and vacuum sweeping periods to a baseline period. The main experimental site on Cannon St. (located immediately adjacent to the street) recorded a 7% decrease in TSP levels during the vacuum cleaning period, but an increase in the mechanical cleaning period. The latter methodology was considered ineffective.

The 7% decrease during the vacuum sweeping was marginally statistically significant, however, evaluation of data for specific sets of conditions expected to provide a more sensitive test of the impact of the re-entrained road dust, showed no difference between the experimental site and a control site. Receptor modeling results showed a small but significant decrease in the relative contribution of the road dust component during vacuum sweeping. Dispersion modeling indicated that a substantial reduction (~30%) in the road dust contribution would have to be realized in order to result in the 7% observed reduction. In other words, road dust accounted for about 25% of the TSP burden at the Cannon St station. Thus, although an increased frequency of vacuum sweeping may have resulted in a TSP decrease, it was concluded that sweeping alone would be ineffective to control airborne particulate matter in most urban areas unless undertaken as part of a comprehensive program which addresses all significant sources.

The Road Dust Study report also made reference to several other street cleaning studies done in U.S. cities in the 1970s. Various modes of cleaning (flushing, vacuum, mechanical sweeping) were found to yield variable, inconclusive results. Thus, other sources would need to be controlled in addition to road dust to achieve major improvements to ambient air.

Study Area

An area in the Hamilton northeast industrial zone was chosen for the study. Airborne particulate levels exceed guidelines most frequently there and traffic contributions may be significant. Road cleaning efforts could have the greatest benefit in such conditions. The area was also different from that previously studied in 1979.

An area bounded by Wentworth St. in the west, Burlington St./ Industrial Dr. in the north, Ottawa St. in the east and Barton St. in the south was chosen (Figure 1).

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[1] "An Assessment of Street Dust and Other Sources of Airborne Particulate Matter in Hamilton, Ontario" Ontario Research Foundation, March 1982

Air Monitoring Program

PM_{10}

Inhalable particulates were monitored continuously, yielding hourly data at four stations:

1) MOE station 29011- Burlington/Leeds. Located on a short dead end street approximately 30 metres south of Burlington St. Monitoring from August 7 to December 21.

2)Burlington/Gage, to be referred to as "Stelco site". Located adjacent to the main Stelco entrance, approximately 20 metres north of Burlington St, 40 metres east of Gage. Monitoring from September 10 to December 15.

3)Sherman Ave, on Slater Steel property about 4 metres west of Sherman, 10 metres north of CNR rail line. Monitoring from July 31 to December 31.

4)MOE station 29025- Barton/Sanford. Located approximately 15 metres north of Barton St. Monitoring from October 1 to December 21.

Suspended Particulates

Suspended particulates were measured by high volume (hi-vol) samplers for 24 hour periods (generally 10am to 10 am) at the above sites plus one additional:

5)Ottawa/Beach Rd. on Dofasco property about 5 metres east of Ottawa.

The Stelco hivol site was located approximately 50 metres east of the PM_{10} monitor, on the guardhouse roof within the Stelco parking lot.

Hivol monitoring went from August 20 to November 28, two or three times per week.

The monitoring stations are shown in Figure 1. Meteorological data (wind speed and direction) were gathered from MOE station 29531 on Hillyard St at the harbour's edge, just outside the study area, and from a separate monitor at the Stelco PM_{10} site.

Street Cleaning Program

The major streets in the study area, including Barton, Wentworth, Sherman, Gage, Burlington etc. were cleaned by combinations mechanical sweeping/flushing and vacuum sweeping according to the following schedule:

August 31 - September 13	Mechanical sweeping and flushing 1x/week
September 14 - 27	Mechanical sweeping and flushing 3x/week
September 28 - October	Vacuum sweeping 1x/week
October 12 - 25	Vacuum sweeping 3x/week
October 26 - November 8	Mechanical and vacuum sweeping/flushing 3x/week

Additional streets to be cleaned within the study area were left to the discretion of staff of the City of Hamilton Roads Department.

ANALYSIS OF HOURLY PM_{10} DATA

Pollution Roses

A pollution rose is a cross-tabulation of hourly pollutant data with wind direction classes. Pollutant concentrations are subdivided and averaged by the wind direction classes (north, northeast etc.) which existed during each hour. The peaks in the rose diagrams point to the sources of the pollutant.

Previous PM_{10} monitoring data in Hamilton has shown wide daily variations in concentrations at continuous monitoring stations, particularly in the Hamilton industrial area. Concentrations tend to be much higher during daytime hours when more activity, particularly vehicle activity is present. Figure 2 shows this variation at the industrial Hillyard station, and lesser variation at downtown AQI station 29000.

Similar observations are apparent for weekdays versus weekends, and as a result pollution roses were calculated for the four PM_{10} stations for weekday daytime hours, weekday night hours and weekend/holiday hours. Since data at the Stelco site only commenced on September 10, the roses were calculated using that date as a starting point to make the roses as equal as possible and use as much data as possible. It should be noted however, that the Barton station's data commenced on October 1.

Results

Figure 3 illustrates the daytime roses. Concentrations can be seen to be clearly highest at the Leeds and Stelco sites. Highest levels at Leeds (about 48-58 $\mu g/m^3$) came from the northeast and east directions. The Stelco site located about 250 metres from Leeds on the opposite side of Burlington St, showed its highest levels for directions from the adjacent roadways - Burlington St. and Gage Ave. Levels from the northeast (from the Stelco mill) were the lowest at less than 30 $\mu g/m^3$. Numerous elevated concentrations at Stelco occurred during morning rush hours coinciding with west or northwest winds. This points to the heavy traffic entering the mill for the day shift. Thus it is evident that vehicle and/or roadway emissions were the dominant influence on inhalable particulate levels in this area, although some significant industrial influence could have caused the elevated levels from the east at both Stelco and Leeds.

The Sherman rose shows its highest average levels from the northern directions, (slightly more than 30 $\mu g/m^3$), while Barton was highest during east and south winds, but less than 30 $\mu g/m^3$. Industrial contributions are unclear for these sites, but roadway contributions are apparent. Sherman's roadway contribution becomes clearer in the following analysis.

Figure 4 illustrates the nighttime roses. Concentrations are clearly much lower than the daytime ones, with one exception. The Sherman site recorded its highest levels at night. Highest average levels were from the northwest through to northeast up to 58 $\mu g/m^3$. It is suspected that truck traffic from the Slater Steel driveway off Sherman leading into the plant may be a significant contributor, although it is not clear why levels would be higher at night. Industrial contributions from unknown localized sources are possible. The Slater driveway was about 25 metres north of the monitor.

The other three stations showed similar patterns to daytime, except levels were lower. On average Stelco was 40% lower, Leeds 50% lower and Barton 10% lower.

Figure 5 illustrates the weekend roses. The southerly and southeasterly directional averages in these roses are somewhat suspect due to very small sample sizes. Generally similar patterns emerge as per the other roses. The weekend data were similar to the weekday nighttime data.

The suggested smaller industrial particulate contributions and larger traffic contributions indicated by the Stelco/Leeds stations runs counter to previous monitoring data at other industrial zone stations, and will require further monitoring and analysis to resolve.

Comparison of PM_{10} During Cleaning Cycles

Upwind/Downwind at Stelco and Leeds

Because of the potential influence of other sources in the neighbourhood on ambient particulate levels, a feature of the study design was to install a pair of stations (Stelco and Leeds) on each side of Burlington St. to examine upwind/downwind differences across the road. The two stations were located close enough together (250 metres apart) on either side of a cleaned Burlington St., to compare paired hourly concentrations during specific wind regimes during each cleaning phase. Paired hourly concentrations were averaged for specific sectors of wind direction, which placed one station upwind of the road and the other downwind. The two specific sectors or wind regimes are shown in Figures 6 and 7. This analysis makes external contributions irrelevant as only the downwind difference is important, making possible to measure the immediate impact of the cleaning.

The summary statistics for this analysis are given in Table 1 and the key statistics are displayed graphically in Figures 8 and 9. The numeric results in the table show the calculated differences between the upwind/downwind hours for the two wind regimes. The upwind/downwind differences for each cleaning phase should be compared to the Phase 1 difference which can be considered as baseline, because a normal status quo cleaning cycle (mechanical sweep/flush 1x) was performed on Burlington St. during that time. The Stelco site only started on September 10, missing the August baseline period.

The pattern which emerged in Figures 8 and 9 was that either vacuum or mechanical sweeping alone does not reduce road dust contribution to PM_{10}, however, a relatively frequent combination of both with flushing results in air quality improvements.

The paired differences were compared for statistical significance at the 95% confidence level, and due to small sample sizes, none of the differences were significant. However, the two wind regimes were composed of completely independent data, with largely different sample sizes and still showed about the same pattern of results, with the exception of the post cleaning phase.

This indicates that the final cleaning cycle appeared to have a positive impact of reducing downwind PM_{10} in the immediate vicinity of the road by 2 or 3 $\mu g/m^3$.

Overall PM_{10} Changes During Cleaning Cycles

The hourly PM_{10} data during the five bi-weekly cleaning cycles were compared to baseline conditions to determine if the cleaning had a positive impact on reducing overall ambient particulate concentrations, apart from the micro-setting near the road, discussed in the previous section.

The impact of long range transport is significant on urban PM_{10} levels. In Hamilton, sources from outside the city account for 50-80% of measured levels. Thus, this contribution needs to be accounted for in the analysis of the monitoring data. Respirable particulates $PM_{2.5}$ were measured in downtown Hamilton and other locations in Southern Ontario during the study. (Unfortunately, PM_{10} was not). This data was used to determine a "correction" in the average levels during each cleaning phase. $PM_{2.5}$ data from downtown Hamilton (MOE station 29000) and rural Simcoe (MOE station 22071) were employed for this purpose. Figure 10 illustrates the trend in $PM_{2.5}$ levels during the various phases of the survey at the two stations, and show remarkably similar concentrations at urban and rural sites, indicating the consistency of long range transport effects.

Table 2 shows the data from the two stations for each phase and compares it to the baseline periods. The absolute magnitude of the differences (the average between the two stations) from the baseline became the "correction" needed for the study station data. Further, since $PM_{2.5}$ comprises about 60% of PM_{10}, the data had to divided by 0.6 to simulate PM_{10}. This "correction" factor was then subtracted from the study averages at each station.

Secondly, the station data themselves were subdivided by wind direction classes; when winds were from the nearby major roadway and when not. Figures 11 and 12 show the wind angles employed for the three stations for this analysis - Stelco, Leeds and Sherman. The Barton/Sanford monitor only started collecting valid data on October 1st, in the midst of the cleaning effort and thus could not undergo this particular analysis.

The Stelco and Leeds survey sites both commenced monitoring in August, well before the cleaning program began. Thus an August baseline could be employed. The Stelco site only started on September 10, after the cleaning program had started, and thus, the post-cleaning period in November and December had to be used as the baseline for this station.

Figure 13 shows the actual measured averages for the various cleaning phases, for the "wind from the road" and "wind not from the road" cases. These data are also given in Table 3 alongside the "predicted" value based on the regional correction calculated in Table 2. Examples of the comparisons of "predicted vs actual" are displayed graphically in Figures 14 and 15, and all comparisons are shown numerically in Table 3.

For both Leeds and Sherman which employed the August baseline, the actual measured readings were all higher than the predicted values. In other words, the cleaning program did not result in concentrations as low as could be reasonably expected based on overall particulate impacts. There are too many other influences on the area for the cleaning effect to be observable.

The Stelco site's data (which used the November/December baseline) did show slightly lower actual levels than predicted for the "wind from the road" case, but by an equal amount (2 $\mu g/m^3$) for all cleaning phases. When winds were not from the road, there was greater variability. The mechanical/flushing 3 times/week cycle showed the greatest drop from the predicted (39 vs 50 $\mu g/m^3$).

To determine if the use of the November/December baseline could change the outcomes of the Leeds and Sherman results, those data were re-analyzed and shown in the bottom section of Table 3. The Leeds results show a significantly lesser actual level than predicted for the mechanical/flushing 3 times/week cycle (14 $\mu g/m^3$), almost duplicating the results for the "wind not from the road" case at Stelco. This suggests that drop was due to other factors besides the road cleaning. The final two major cleaning cycles (vacuuming 3x and mechanical/vacuum 3 x) also showed significant drops from the predicted (5-7 $\mu g/m^3$).

The use of the November/December baseline for Sherman is also shown in Table 3, but in all cases the actual levels were all significantly higher than the predicted levels, duplicating the results of using the August baseline. As shown by the pollution roses, other sources besides the road significantly affected this station.

Overall Effects During Daytime Hours

Since particulate levels in the study area are generally higher during daytime hours, a similar background correction was calculated for individual hours of the day, from 0800 to 1900. The Simcoe and downtown Hamilton stations measuring $PM_{2.5}$ were again employed. Hourly averages were calculated for each cleaning phase, corrected for the changes from baseline observed at Simcoe and downtown Hamilton and compared to the actual measured averages using the same procedures as done earlier, except there was no subdivision of data by wind direction.

The differences between measured and predicted values for each hour and phase are displayed in one example, Figure 16.

The analyses by this method essentially duplicated those above, indicating the use of specific times of day did not alter the outcomes.

The overall impressions of these analyses indicate inconclusive results. The results of the cleaning appear to be too small to be observable except in a few limited cases. There are so many other impacts, that the attempt to correct for long range transport effects was insufficient to show a clear picture. All sources, including road dust will need to be controlled to effect air quality improvement.

SUSPENDED PARTICULATE ANALYSIS

Suspended particulates (TSP) are comprised of a larger size range of particles than PM_{10} (up to about 50 microns) and were studied to determine if larger particle ambient concentrations were reduced by the street cleaning.

TSP concentration showed a steep gradient of concentrations when moving from west to east. Lowest levels were measured at Barton/Sanford averaging 56 $\mu g/m^3$ and highest levels were at the Ottawa St/Beach Rd station averaging 122 $\mu g/m^3$.

Data are presented in Table 4 which shows the data alongside the wind direction frequencies on each sampling date.

Table 4 segregates the August and November baselines, but the cleaning data were compared to only August where possible. Three stations- Barton, Leeds and Ottawa, showed large drops from this baseline while Sherman was higher. Only the Barton difference was marginally statistically significant. Stelco could only be compared to the November post-clean baseline and was much higher than it.

It should be stated that the wind frequency statistics for the cleaning period and baselines were fairly similar, so that at least this factor was constant and should not have played a large role in causing variation between data sets. As well, rainfall during the survey was mostly negligible and was also not a factor. No attempt was made on regional TSP corrections as for PM_{10} because TSP mostly includes locally generated primary particles with a small background component, which would have only a small effect.

The results of the suspended particulate data must be considered as inconclusive, due to small sample sizes, but do not show any great tendency toward a significant impact of the cleaning.

CONCLUSIONS

Inhalable particulates (PM_{10}) - upwind/downwind analysis across Burlington St. showed that frequent applications of a combination of vacuuming/sweeping and flushing led to a reduction in PM_{10} contributions in the immediate vicinity of the roadway . Infrequent sweeping or vacuuming alone actually increased PM_{10} coming from the road.

Due to the large number of other influences in the study area, and the short duration of the study, there was no clear evidence that the street cleaning program had a measurable impact on overall concentrations within the wider study area. The other sources (vehicle exhaust, industrial sources and long range transport) masked any impact of the street cleaning.

Suspended particulates (TSP)- results of the suspended particulate data were inconclusive, due to small sample sizes, but do not show any great tendency to showing a significant impact of the street cleaning. The 1979 Hamilton Road Dust Study did show a 7% reduction in TSP.

In conclusion, enhanced street cleaning (mechanical sweeping/vacuuming and flushing) has a role to play in reducing inhalable particulate levels, however, other sources will also need to be addressed.

TABLE 1

UPWIND VS DOWNWIND AT STELCO/LEEDS

CONTINUOUS PM10 ug/m3

	hrs	245-285 deg Leeds upwind	Stelco downwind	Downwind difference	Statistically Significant?
Phase 1	26	46.0	47.8	1.8	No
MechFlush3x	57	49.1	54.9	5.8	No
Vac1x	36	24.6	30.8	6.2	No
Vac3x	133	34.0	38.4	4.4	No
MFV3x	***42***	***35.8***	***34.6***	***-1.2***	No
Post clean	322	25.7	32.9	7.2	Yes
		70-100 deg Stelco upwind	Leeds downwind	Downwind difference	
Phase 1	10	49.9	50.8	0.9	No
MechFlus3x	22	52.0	64.5	12.5	No
Vac1x	32	33.7	39.4	5.7	No
Vac3x	16	35.5	48.0	12.5	No
MFV3x	***6***	***78.2***	***76.1***	***-2.1***	**No**
Post clean	15	47.1	44.9	-2.2	No

TABLE 2

DETERMINATION OF LONG RANGE TRANSPORT "CORRECTION" FACTOR

USING THE AUGUST BASELINE FOR SLATER & LEEDS

	Elgin/Kelly		Simcoe		Average subtraction
	29000 PM2.5	29000 (Base-Phase)/60% PM10 Simulation	22071 PM2.5	22071 (Base-Phase)/60% PM10 Simulation	22071/29000 (Base-Phase)/60% PM10 Simulation
August Baseline	23.4		23.4		
Phase 1	12.9	17.5	14.9	14.2	15.8
MechFlus3x	21.4	3.3	19.3	6.8	5.1
Vac1x	9.0	24.0	8.7	24.5	24.3
Vac3x	11.9	19.2	10.9	20.8	20.0
MFV3x	8.5	24.8	9.3	23.5	24.2

USING THE POST CLEAN PERIOD NOV 9-DEC 15 FOR BASELINE FOR STELCO

	Elgin/Kelly		Simcoe		Average subtraction
	29000 PM2.5	29000 (Base-Phase)/60% PM10 Simulation	22071 PM2.5	22071 (Base-Phase)/60% PM10 Simulation	22071/29000 (Base-Phase)/60% PM10 Simulation
Phase 1	12.9	-4.8	14.9	-10.3	-7.6
MechFlus3x	21.4	-19.0	19.3	-17.7	-18.3
Vac1x	9.0	1.7	8.7	0.0	0.8
Vac3x	11.9	-3.2	10.9	-3.7	-3.4
MFV3x	8.5	2.5	9.3	-1.0	0.7
Postclean BASELINE	10.0		8.7		

TABLE 3

ACTUAL MEASURED PM10 VS BASELINE CORRECTIONS

USING 29000/22071 SUBTRACTION & AUGUST BASELINE

ug/m3

Leeds

	Wind from road Actual	Wind from road Baseline corrected for Regional changes	Wind NOTfrom road Actual	Wind NOTfrom road Baseline corrected for Regional changes
Baseline	40.8		42.5	
Phase 1	35.4	25.0	35.0	26.7
MechFlus3x	38.4	35.7	51.0	37.4
Vac1x	33.6	16.5	28.5	18.2
Vac3x	32.7	20.8	34.1	22.5
MFV3x	26.7	17.3	32.6	19.0

Sherman

	Wind from road Actual	Wind from road Baseline corrected for Regional changes	Wind NOTfrom road Actual	Wind NOTfrom road Baseline corrected for Regional changes
Baseline	54.3		33.9	
Phase 1	36.7	38.5	36.0	18.1
MechFlus3x	56.6	49.2	37.8	28.8
Vac1x	34.1	30.0	22.5	9.6
Vac3x	41.1	34.3	26.6	13.9
MFV3x	41.6	30.8	31.1	10.4

USING 29000/22071 SUBTRACTION & NOV/DEC BASELINE

Stelco

	Wind from road Actual	Wind from road Baseline corrected for Regional changes	Wind NOTfrom road Actual	Wind NOTfrom road Baseline corrected for Regional changes
MechFlus3x	49.7	51.5	38.8	50.1
Vac1x	29.5	32.4	29.8	31.0
Vac3x	34.9	36.6	40.0	35.2
MFV3x	30.0	32.5	28.7	31.1
Postclean	33.2		31.8	

USING 29000/22071 SUBTRACTION & NOVEMBER (POST CLEAN) BASELINE

ug/m3

Leeds (uses data to Dec 15)

	Wind from road Actual	Wind from road Baseline corrected for Regional changes	Wind NOTfrom road Actual	Wind NOTfrom road Baseline corrected for Regional changes
Phase 1	35.4	41.7	35.0	33.6
MechFlus3x	38.4	52.4	51.0	44.3
Vac1x	33.6	33.3	28.5	25.2
Vac3x	32.7	37.5	34.1	29.4
MFV3x	26.7	33.4	32.6	25.3
Post clean	34.1		26.0	

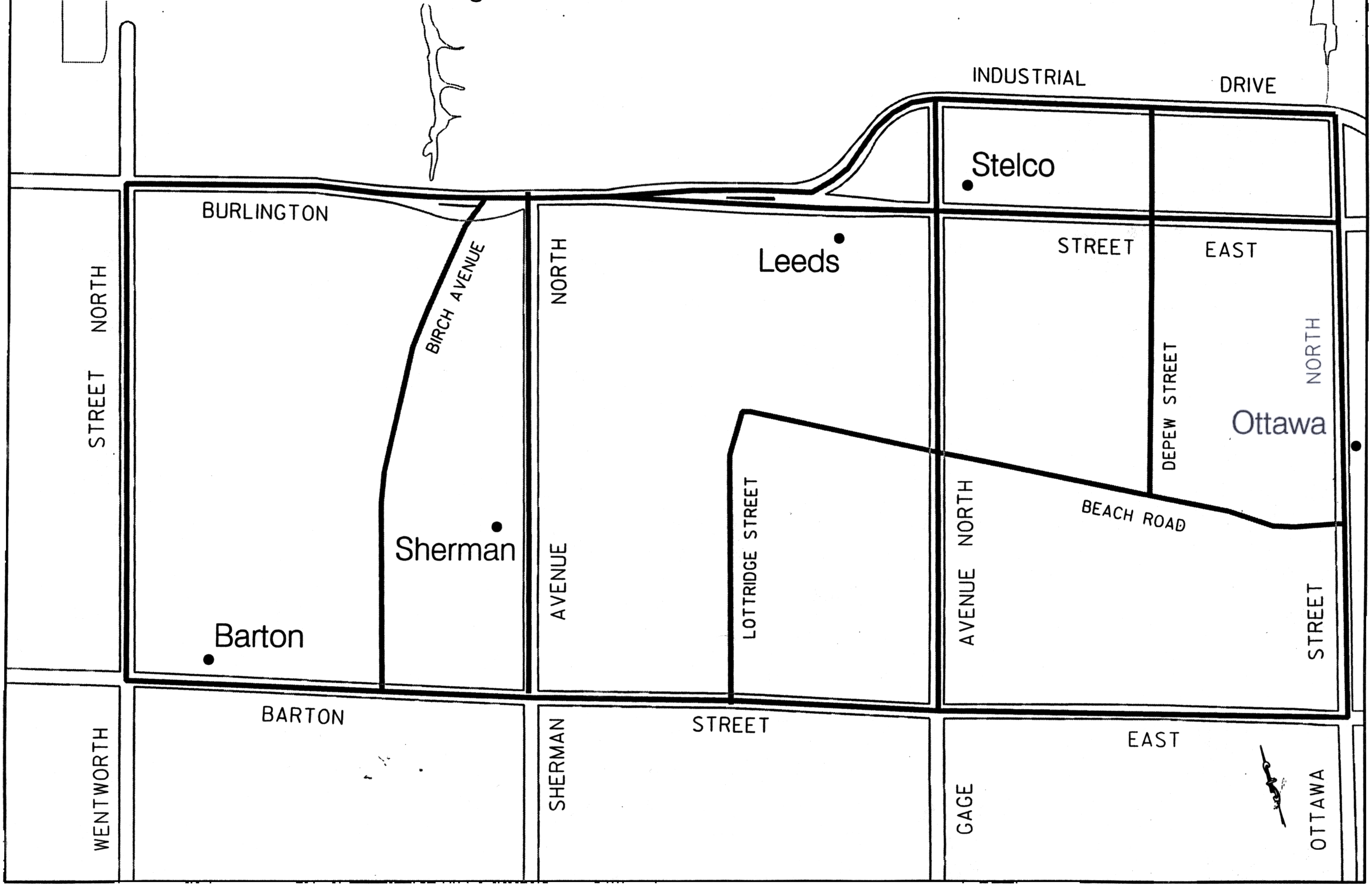
Sherman (uses data to Dec 15)

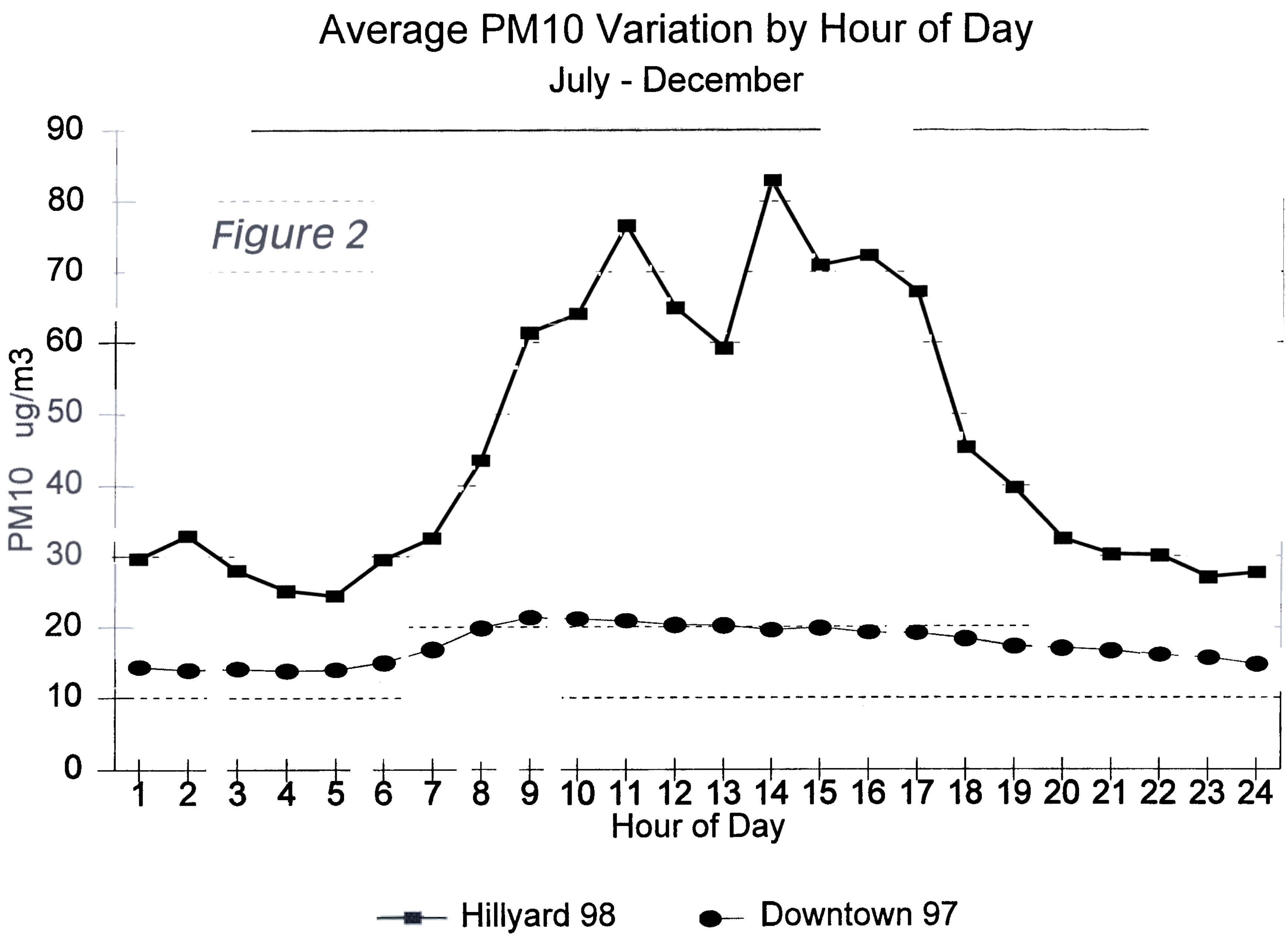
	Wind from road Actual	Wind from road Baseline corrected for Regional changes	Wind NOTfrom road Actual	Wind NOTfrom road Baseline corrected for Regional changes
Phase 1	36.7	36.5	36.0	22.5
MechFlus3x	56.6	47.3	37.8	33.3
Vac1x	34.1	28.1	22.5	14.1
Vac3x	41.1	32.4	26.6	18.4
MFV3x	41.6	28.2	31.1	14.2
Post clean	31.1		17.1	

TABLE 4
SUSPENDED PARTICULATES
STREET SWEEPING STUDY

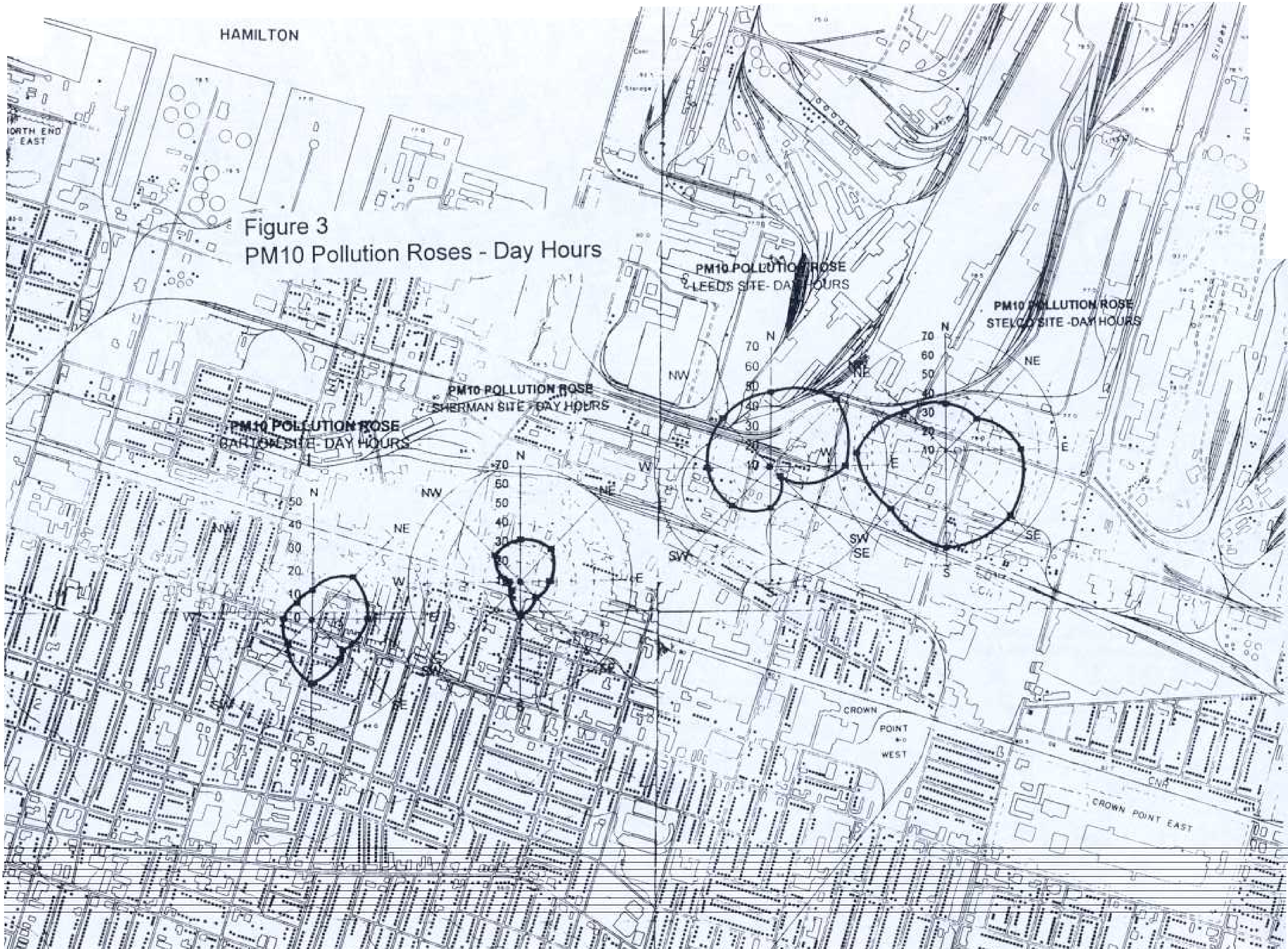
	10AM-10AM "ON" DATE	HOURS OF WIND/DAY HILLYARD ST. N	NE	E	SE	S	SW	W	NW	CALM	AVG SPEED km/hr	TSP - ug/m3 Barton	Sherman	Leeds	Stelco	Ottawa	
	AUG 31	0	0	0	0	0	0	11	13	0	9	26	87	121	80	196	
	SEP 2	0	0	0	0	0	5	16	3	0	9	54	43	138	115	85	
Phase 1	5	0	0	0	0	0	23	1	0	0	13	63		73	68	102	
	9	1	0	0	0	0	1	12	10	0	12	40	115	87	93	138	
	12	3	13	2	0	0	1	2	3	0	9	71	113	83	64	136	
	15	6	5	0	0	0	8	3	2	0	13	63	113	119	98	142	
	17	2	5	4	0	0	3	8	2	0	5	124	145	158	172	209	
MF3x	19	4	5	1	0	0	2	9	3	0	4	114	120	107	110	138	
	21	3	0	0	0	0	0	10	11	0	11	37	96	125	92	164	
	23	1	2	1	0	0	2	14	4	0	5	33	67	92	93	110	
	25	0	0	0	0	0	11	13	0	0	7	65	69	104	87	114	
	30	0	0	0	0	1	3	14	6	0	10	34	52	78	58	94	
VAC1x	OCT 5	0	11	13	0	0	0	0	0	0	19	75	77	99		172	
	8	19	5	0	0	0	0	0	0	0	14	33	74	91	80	226	
	10	4	8	0	0	0	9	2	1	0	5	38	12	53	65	63	
	14	0	0	0	0	0	0	13	11	0	12	8	71	49	10	106	
	16	1	10	2	0	0	4	5	1	1	6	108	106	138	113	142	
VAC3x	19	0	0	0	0	0	15	9	0	0	14	12	29	48	34	84	
	21	0	0	0	0	0	0	6	18	0	14	7	67	68	40	70	
	23	0	0	1	0	0	16	7	0	0	19	69	71	149	102		
	26	2	18	0	0	0	0	0	2	2	8	95	107	131	70	159	
	29	2	9	2	0	1	6	3	0	1	5	41	59	71	63	158	
MFV3x	31	6	1	0	0	0	1	11	5	0	7		34		51	58	
	NOV 2	17	0	0	0	0	0	1	6	0	11	35	133	120	129	171	
	4	0	0	0	0	0	1	16	7	0	8	98	9	85	50	74	
	7	0	0	0	0	0	1	12	11	0	8	13	37	88	34	78	
	Total hours	**71**	**92**	**26**	**0**	**2**	**112**	**198**	**119**	**4**	**624**	**54**	**76**	**99**	**79**	**128**	AVG
	%	11.4	14.7	4.2	0.0	0.3	17.9	31.7	19.1	0.6		33.1	36.3	30.4	34.3	46.0	STD DEV
												25	25	25	25	25	N
	AUG 20	0	1	0	0	0	14	9	0	0	10	73	31	107		120	
Baseline	24	0	0	0	0	0	21	2	1	0	15	75	54	102		154	
	26	4	7	0	0	0	0	9	3	1	6	102	86			185	
	28	2	8	2	0	0	1	9	2	0	9	105	102	121	111		
	Total hours	**6**	**16**	**2**	**0**	**0**	**36**	**29**	**6**	**1**	**96**	**89**	**68**	**110**	**111**	**153**	AVG
	%	6.3	16.7	2.1	0.0	0.0	37.5	30.2	6.3	1.0		14.8	27.6	8.0	0.0	26.5	STD DEV
												4	4	3	1	3	N
Post	NOV 9	0	0	10	0	2	6	3	1	2	6	59	64	60	68	88	
Clean	12	0	0	0	0	0	8	14	2	0	14	32	32	88	63	113	
	14	0	2	0	0	0	11	11	0	0	15	29	44	46	27	60	
	16	2	14	7	0	0	1	0	0	0	16	16	31	21	13	20	
	18	1	8	6	2	1	5	0	1	0	6	74	54	111	148	137	
	20	0	0	0	0	0	10	14	0	0	14	33	22	81	60	84	
	24	1	0	0	0	0	1	17	4	1	8	43	79	107	75	114	
	26	0	0	0	0	0	3	21	0	0	14	104	21	63			
	28	4	12	0	0	0	6	2	0	0	8	35	72	86		129	
	Total hours	**8**	**36**	**23**	**2**	**3**	**51**	**82**	**8**	**3**	**216**	**47**	**47**	**74**	**65**	**93**	AVG
	%	3.7	16.7	10.6	0.9	1.4	23.6	38.0	3.7	1.4		25.8	20.5	27.4	40.0	36.4	STD DEV
												9	9	9	7	8	N

Figure 1:
Survey Area and Location of Monitoring Stations





Average PM10 Variation by Hour of Day
July - December
Figure 2
PM10 ug/m3
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day
Hillyard 98
Downtown 97


HAMILTON
Figure 3
PM10 Pollution Roses - Day Hours
PM10 POLLUTION ROSE
LEEDS SITE- DAY HOURS
PM10 POLLUTION ROSE
STELCO SITE -DAY HOURS
PM10 POLLUTION ROSE
SHERMAN SITE - DAY HOURS
PM10 POLLUTION ROSE
BARTON SITE- DAY HOURS
CROWN POINT WEST
CROWN POINT EAST

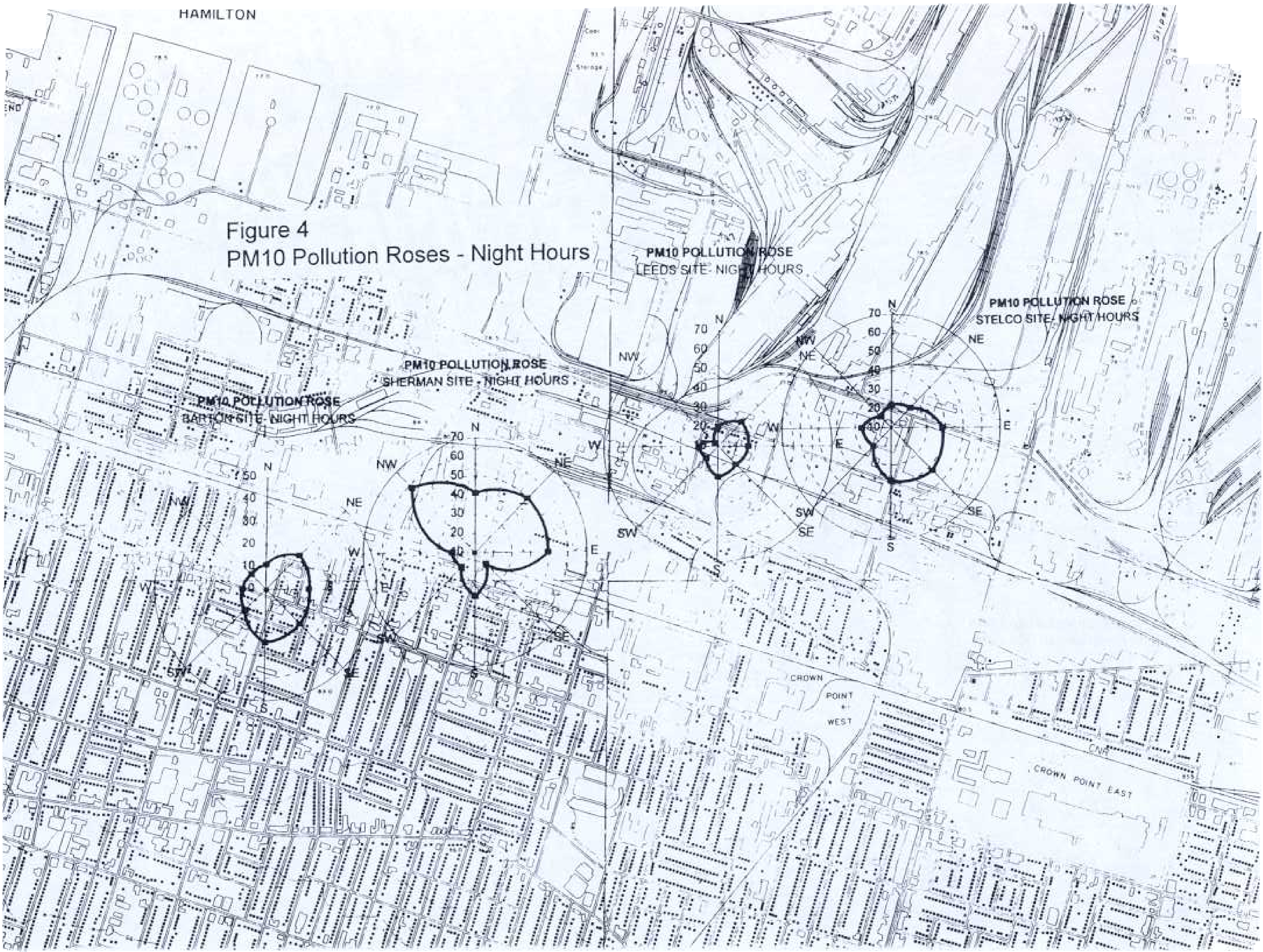


Figure 4
PM10 Pollution Roses - Night Hours

Figure 5
PM10 Pollution Roses - Weekend Hours

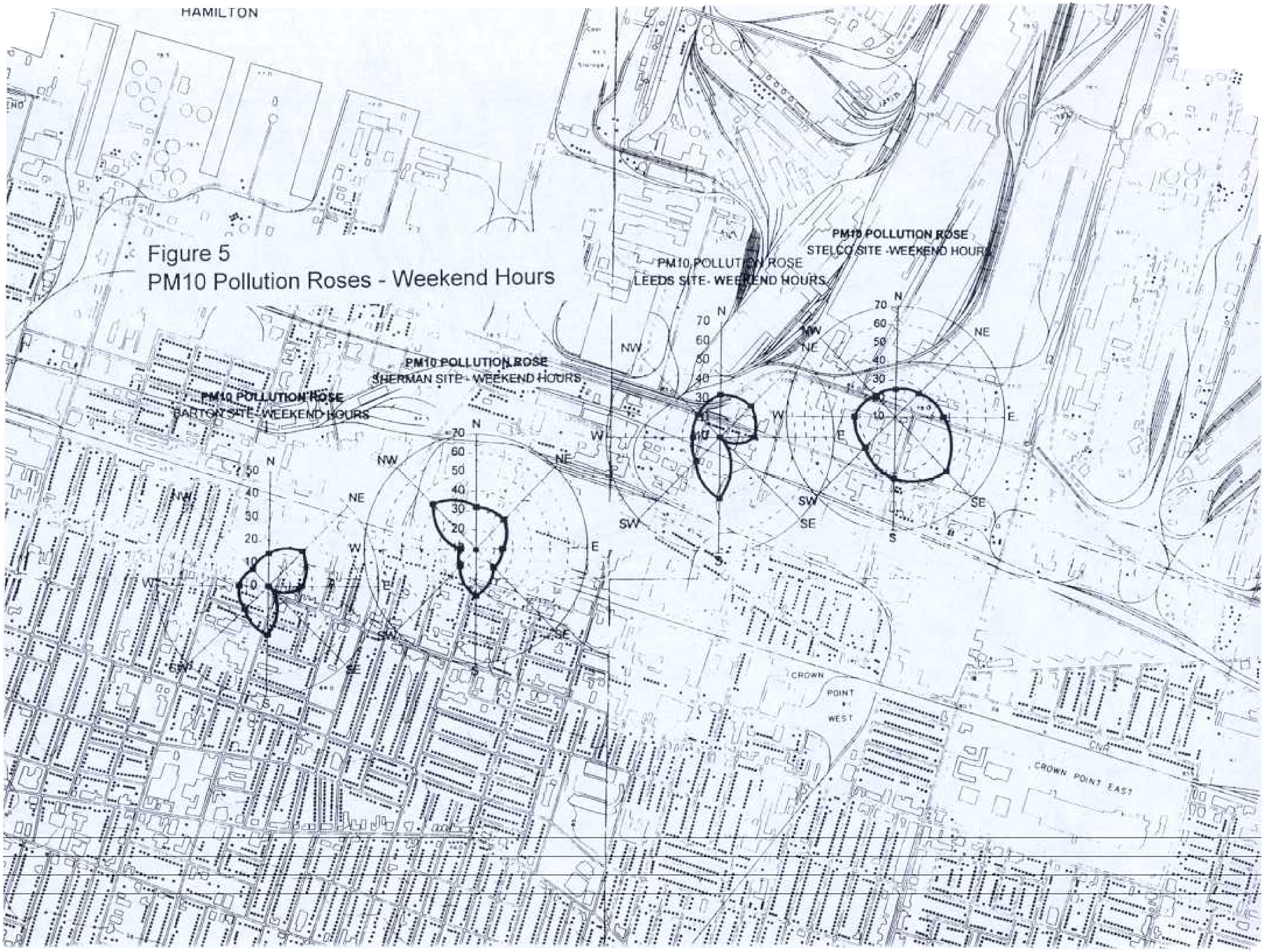
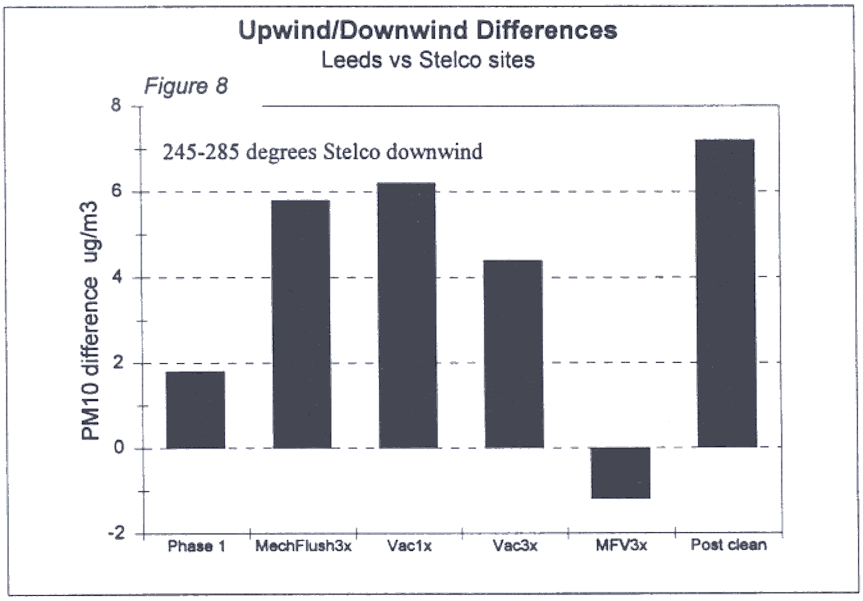
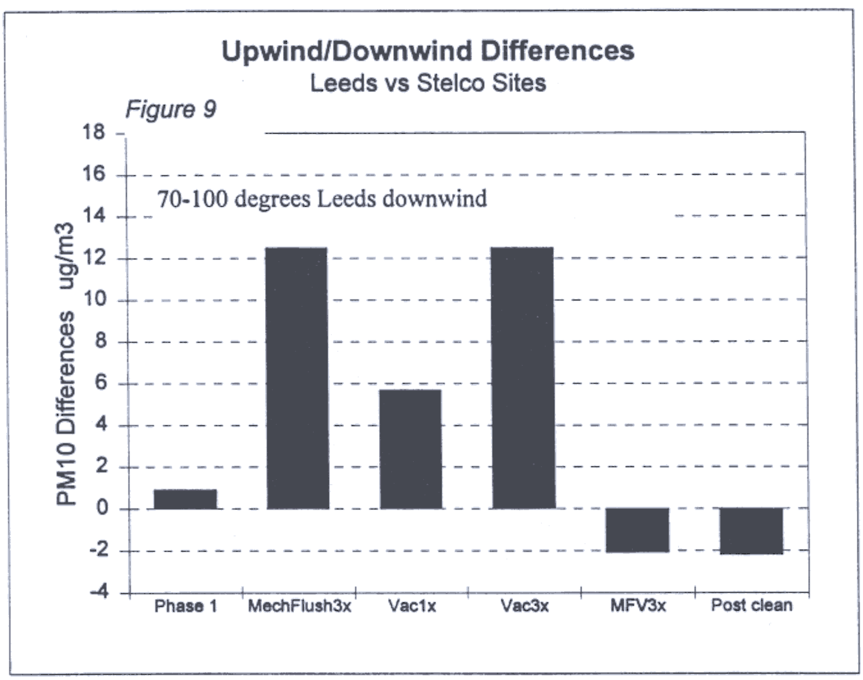
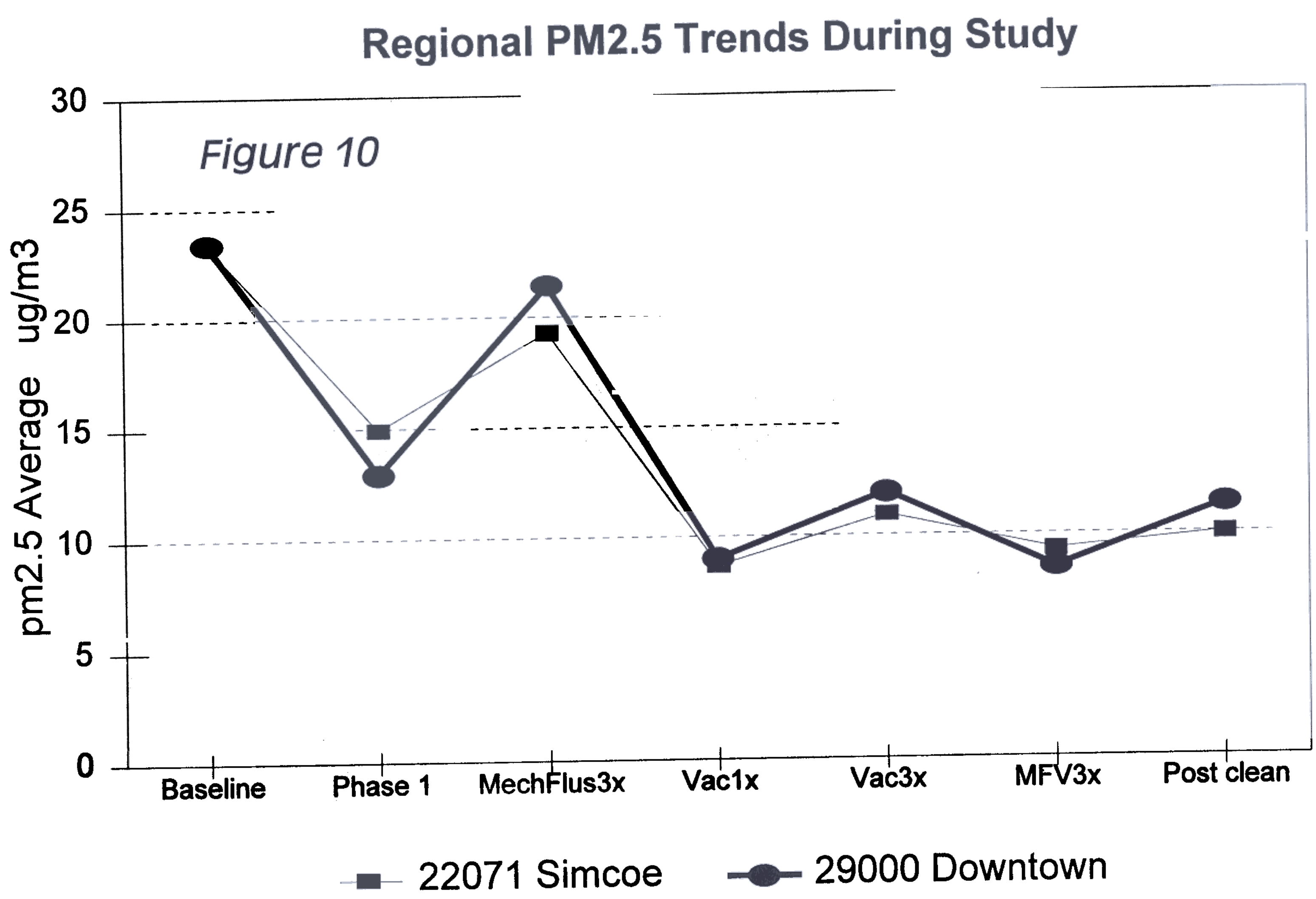


Figure 6
Upwind /Downwind Angles
Leeds Downwind

Figure 7
Upwind /Downwind Angles
Stelco Downwind


Upwind/Downwind Differences
Leeds vs Stelco sites
Figure 8
245-285 degrees Stelco downwind
PM10 difference ug/m3
8
6
4
2
0
-2
Phase 1
MechFlush3x
Vac1x
Vac3x
MFV3x
Post clean


Upwind/Downwind Differences
Leeds vs Stelco Sites
Figure 9
70-100 degrees Leeds downwind
PM10 Differences ug/m3
18
16
14
12
10
8
6
4
2
0
-2
-4
Phase 1
MechFlush3x
Vac1x
Vac3x
MFV3x
Post clean


Regional PM2.5 Trends During Study
Figure 10
pm2.5 Average ug/m3
30
25
20
15
10
5
0
Baseline
Phase 1
MechFlus3x
Vac1x
Vac3x
MFV3x
Post clean
22071 Simcoe
29000 Downtown

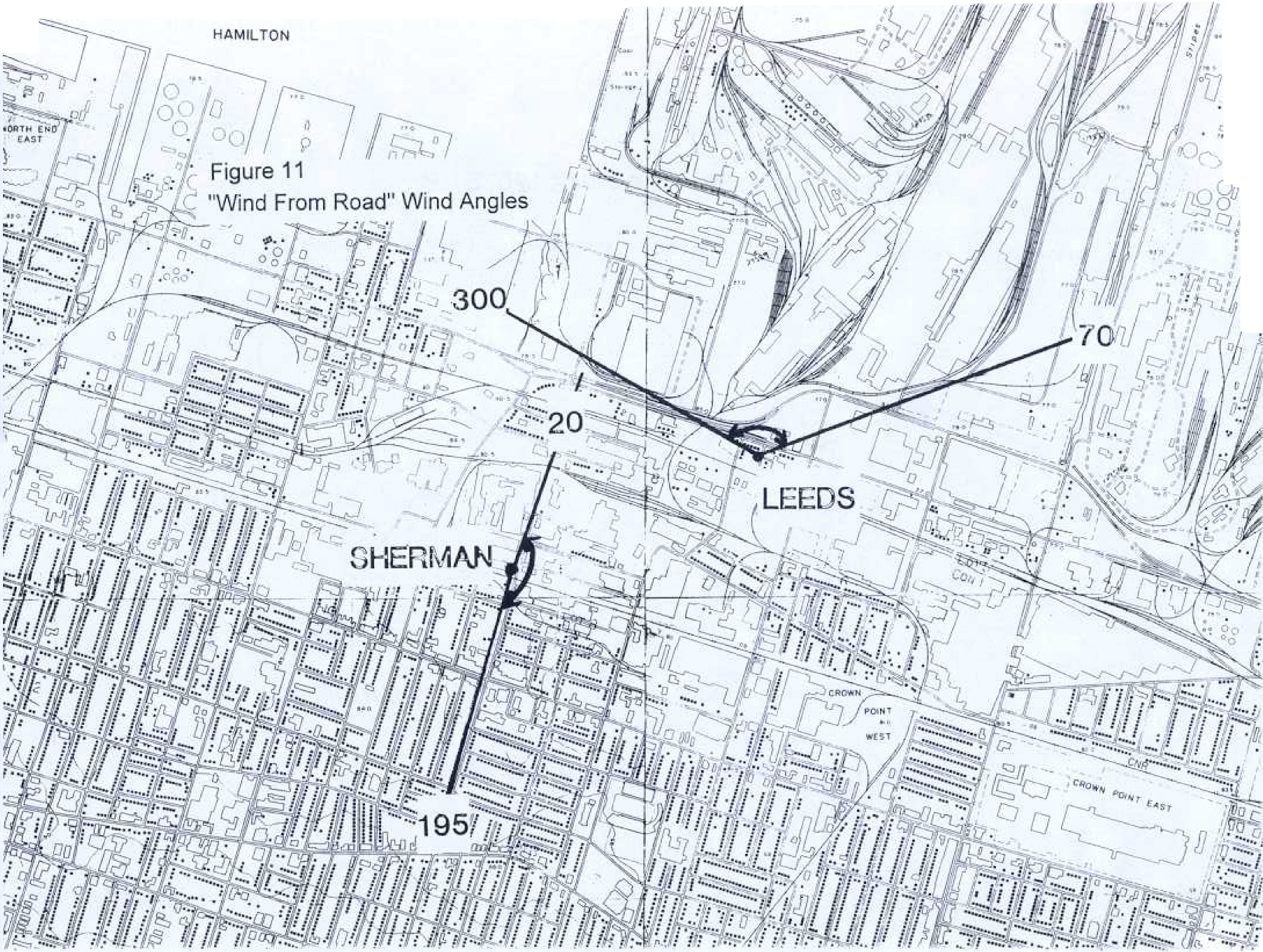
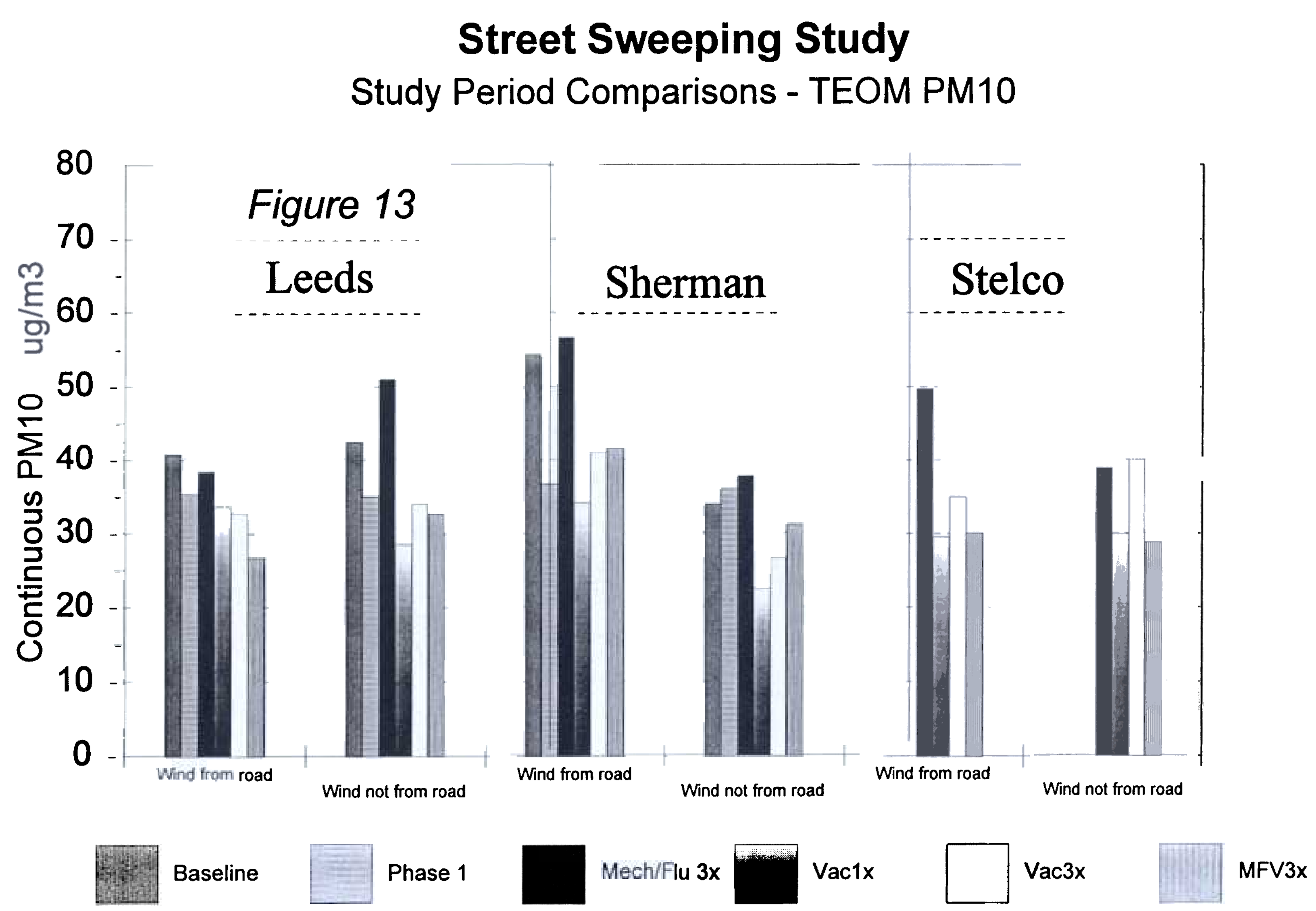
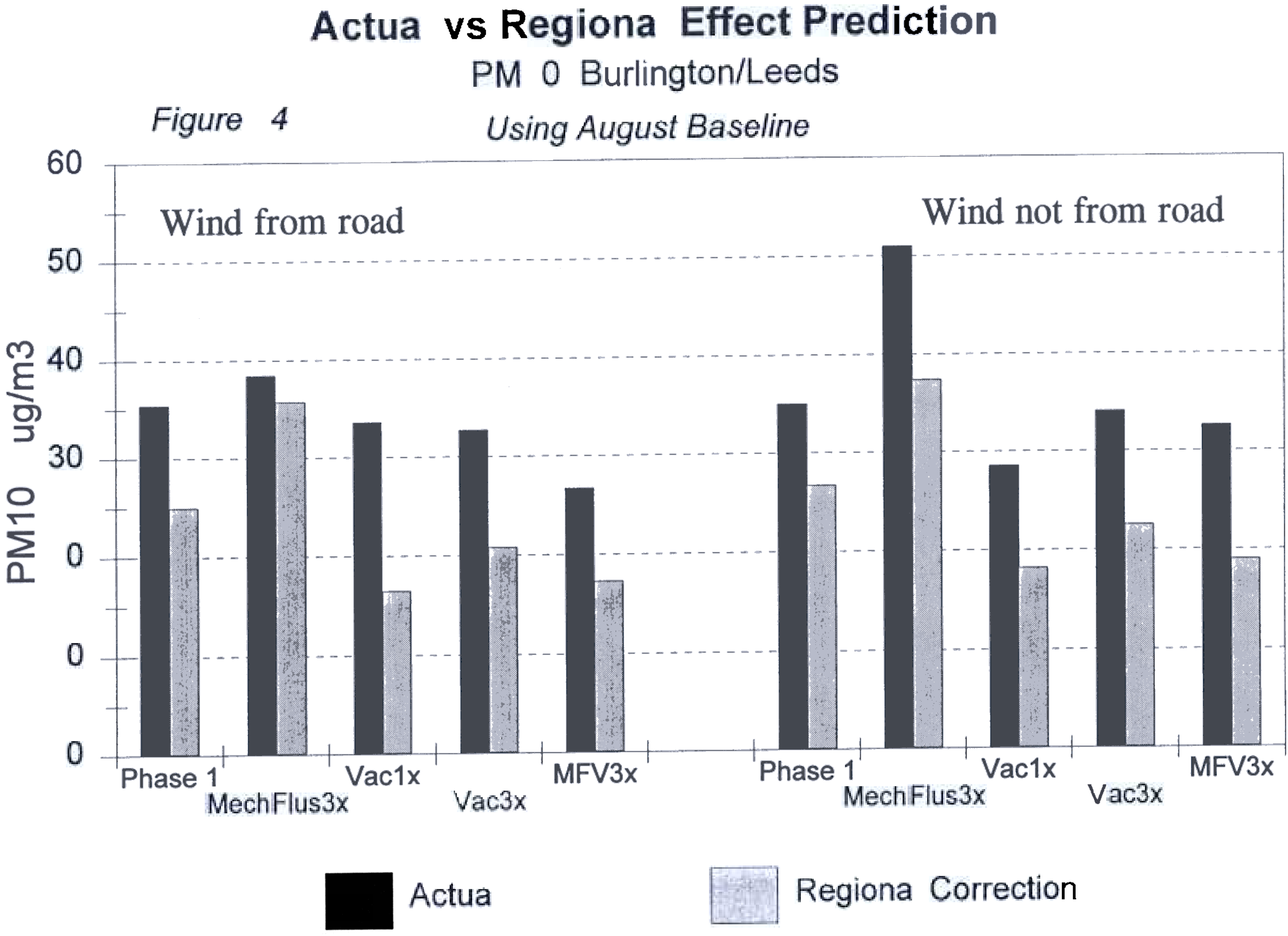


Figure 11
"Wind From Road" Wind Angles

Fig re
"Wind F om Road" Wind Angle



Street Sweeping Study
Study Period Comparisons - TEOM PM10
Figure 13
Leeds
Sherman
Stelco
Continuous PM10 ug/m3
80
70
60
50
40
30
20
10
0
Wind from road
Wind not from road
Wind from road
Wind not from road
Wind from road
Wind not from road
Baseline
Phase 1
Mech/Flu 3x
Vac1x
Vac3x
MFV3x


Actua vs Regiona Effect Prediction
PM 0 Burlington/Leeds
Figure 4
Using August Baseline
60
50
40
30
0
0
0
PM10 ug/m3
Wind from road
Wind not from road
Phase 1
MechFlus3x
Vac1x
Vac3x
MFV3x
Phase 1
MechFlus3x
Vac1x
Vac3x
MFV3x
Actua
Regiona Correction

Actual vs Regional Effect Prediction

PM10 Sherman Ave

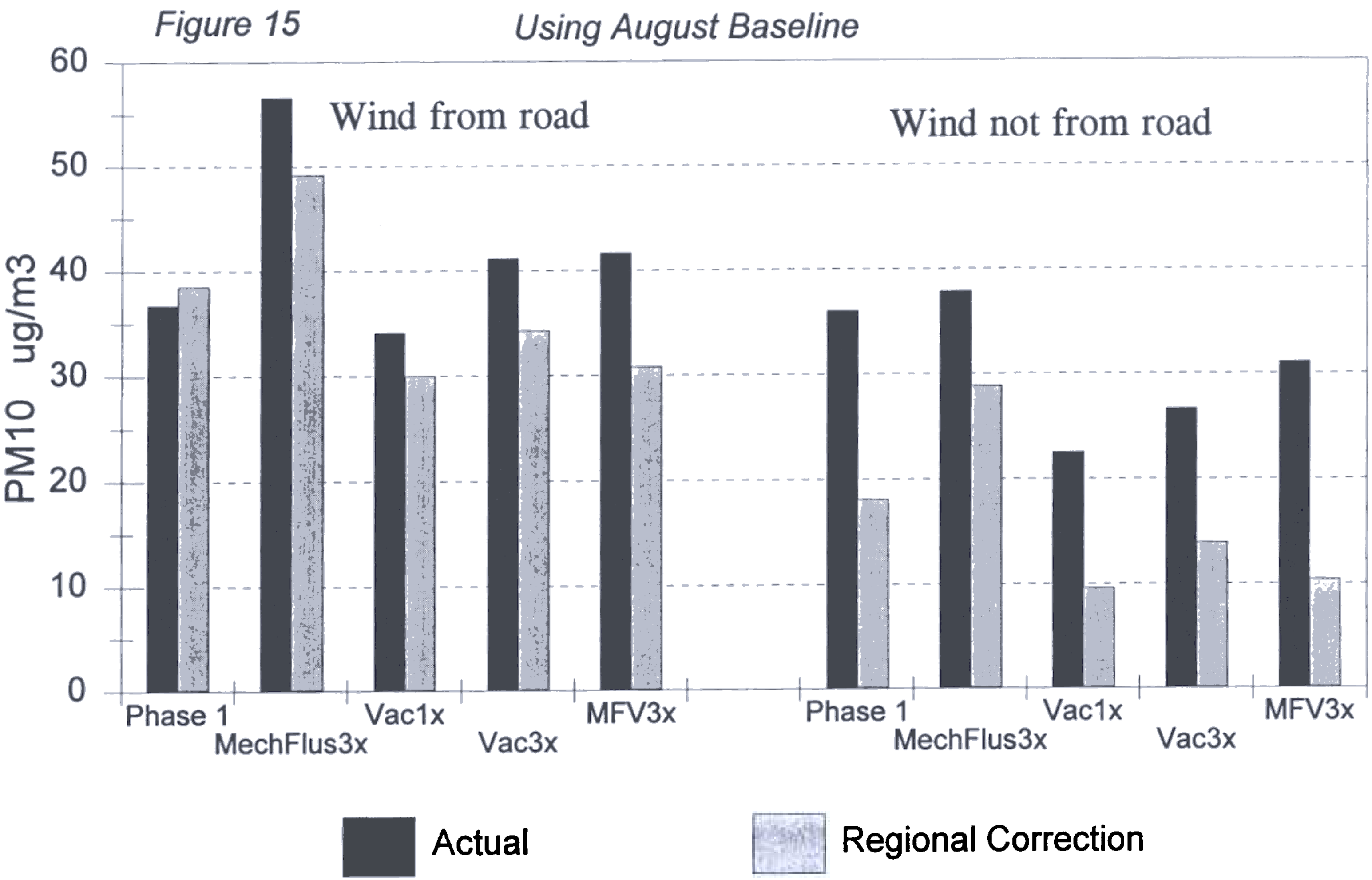
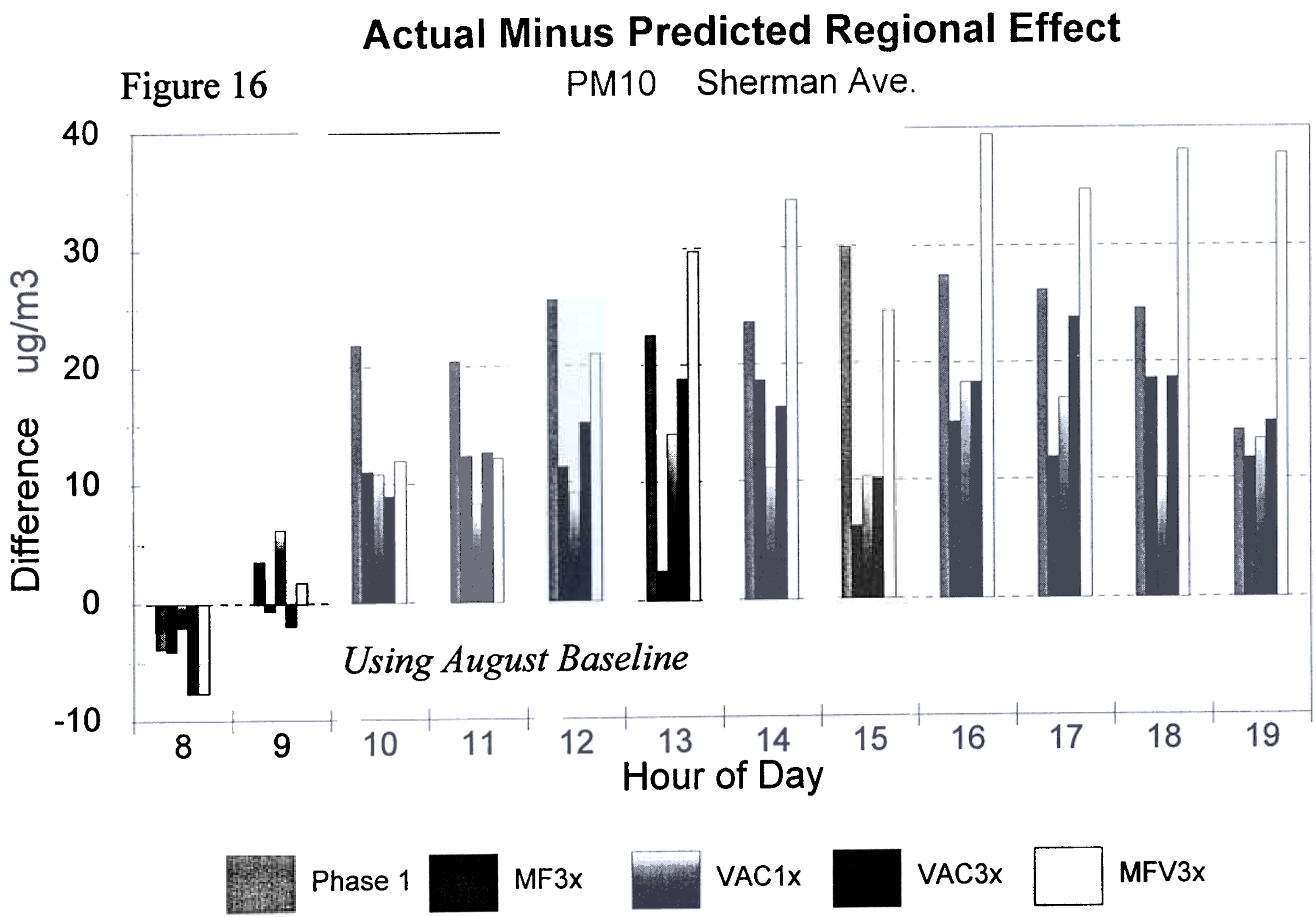


Figure 16


Actual Minus Predicted Regional Effect
PM10 Sherman Ave.
Difference ug/m3
40
30
20
10
0
-10
Using August Baseline
8
9
10
11
12
13
14
15
16
17
18
19
Hour of Day
Phase 1
MF3x
VAC1x
VAC3x
MFV3x