APPENDIX A

$PM_{2.5}$ CONSERVATISM ASSESSMENT

APPENDIX A: $PM_{2.5}$ CONSERVATISM ASSESSMENT

The Practical Alternatives report used a very conservative silt loading factor to calculate impacts of $PM_{2.5}$. During the assessment of the Practical Alternatives it was noticed that the silt loading used for $PM_{2.5}$ may have been overly conservative relative to published data in the literature. However, this conservatism was most notable within close proximity to the roadway. Rather than re-modelling all alternatives and re-publishing the data with all alternatives for a lower silt loading, the conservative silt loading was maintained in the Practical Alternatives report as the conservatism increased the contribution from the road and magnified the differences in the impact of the different alternatives.

Between the publication of the Practical Alternatives and of the TEPA, further work was carried out to investigate this matter further:

- A literature review of published studies on $PM_{2.5}$ for roadway assessments;
- A comparison of the MOE and DRIC monitoring data.

This section documents the results of these investigations and discusses how the conclusions were generated.

LITERATURE REVIEW OF PUBLISHED STUDIES ON $PM_{2.5}$ FOR ROADWAY ASSESSMENTS

Several studies have been published that attempt to quantify the impact of traffic on $PM_{2.5}$ levels. Two studies are specific to Windsor and include the MOE Preliminary Air Quality Assessment Related to Traffic Congestion at Windsor's Ambassador Bridge (MOE 2004) and the MOE Modelling Traffic Influences on Particulate Concentration (MOE 2005a). In addition, another particularly relevant study is the MOE Air Quality Assessment Related to Traffic Congestion at Sarnia's Blue Water Bridge (MOE 2005b). All three of these studies conclude that

- During free-flow conditions the average increase in particulate matter adjacent to the roadways is minimal;
- Traffic congestion increases $PM_{2.5}$ concentrations.

Specifics for these studies include:

- Modelled incremental (the difference between traffic and background impacts) maximum hourly $PM_{2.5}$ concentrations from transportation sources for Windsor approached 20 $\mu g/m^3$ within 50 m of the roadways during truck queuing but were lower than 6 $\mu g/m^3$ under free flow conditions (MOE 2005a).
- Measured incremental hourly concentrations from transportation sources in Windsor showed lower concentrations than modelled concentrations and were typically less

than 5 µg/m^3 under freeflow conditions but up to 15 µg/m^3 during truck traffic queuing (MOE 2005a)

- $PM_{2.5}$ concentrations from transportation sources in Sarnia showed a maximum incremental concentration of approximately 7 µg/m^3 within 25 m of the roadway for one hour averaging times during times of significant truck idling. The highest concentrations were at lowest wind speeds (MOE 2005b).

While these studies were limited in scope, they provide a sense on the range of $PM_{2.5}$ concentrations generated by traffic and the difference in impact during freeflow and traffic congestion.

Several other studies appear to support these range in values. One study for busy Montreal roadways (Smargiassi, 2005) recorded transportation related maximum 24 hour concentrations of approximately 6 µg/m^3 within 10 m of an expressway and busy roadway. The combined traffic in this area was 150,000 vehicles per day, or approximately 3 times that predicted for the DRIC study. A study in Los Angeles (Phuleria 2007) records hourly average increments of approximately 3 µg/m^3 within 3 m of the roadway with traffic volumes of 240,000 vehicles per day and 17% diesel trucks. In Birmingham, England (Harrison 2004), roadside 24 hour average increments were between 7 – 11 µg/m^3 for curbside monitors at busy intersections. Traffic conditions for these monitors ranged between 27,000 to 104,000 vehicles per day with up to 40% diesel trucks and buses.

While the values reported for these studies are average values, most studies also report the standard deviations which provides an indication of the variability of the values. Both the background and the road portion of the concentrations demonstrate similarly high standard deviations.

Therefore, the maximum increments reported for free flowing traffic according to published studies appear to be in the range of 5-10 µg/m^3 within close proximity (<25 m) to the roadways. It is important to note that these increments are maximum and would not be typical of concentrations experienced throughout the year.

ASSESSMENT OF DRIC MONITORING DATA

DRIC established two monitoring stations that measured $PM_{2.5}$ for 13 months. This data was compared to the MOE monitoring stations and then assessed for incorporation into the report.

$PM_{2.5}$ maximum concentrations were similar between the MOE and DRIC stations; however both the average and the 90^{th} percentile concentrations for the DRIC stations are higher by 10 µg/m^3 for the DRIC stations as is shown in Table A.1. One potential difference is that the

$PM_{2.5}$ concentrations were measured with two different technologies (the MOE stations used Tapered Element Oscillating Microbalance (TEOMs) and the DRIC station used Beta Attenuation Monitors (BAMs)).

One of the obvious differences in the data is the minimum concentrations. The DRIC data recorded approximately 100 hours of less than 5 µg/m^3 over the course of the monitoring regime. The MOE data recorded over 5000 hours of concentrations less than 5 µg/m^3.

A study conducted by the Mid-Atlantic Regional Air management Association (MARAMA 2005) in the US suggests that BAMs measure **higher** levels of particulate than the Federal Reference Method (the method considered to be most accurate in the US) with concentrations differences of up to 30% higher. Conversely, TEOMs appear to be seasonally dependent and can read up to 40% **lower** than the Federal Reference Method. A New Brunswick Air Study published in 2005 states that BAMs and TEOMs *"provide useful results but may not be directly comparable"*.

Table A.1 Comparison of BAMs and TEOMs monitoring results in Windsor

Pollutant		DRIC OPHL	DRIC SCC	Average of 2 Stations	MOE Monitoring Stations
$PM_{2.5}$ (24-hr), µg/m^3	Max	48	46	47	45
	Min	8	7	8	1
	Average	20	21	21	10
	90th Percentile	32	33	33	21

The DRIC data was examined in greater detail to determine whether the results were indicative of traffic impacts. One of the analyses performed was to determine whether there was a correlation with wind direction to monitor results. It would be expected that when the monitor was downwind of the corridor it would record a higher value than when the monitor was upwind.

The measured differences with time should show positive differences, based on the prevailing wind direction, with some scatter in intensity based on corridor release rates and atmospheric dispersion. The dispersion should be fairly uniform throughout the measurement period with some variation by season depending seasonal variability in the emission rates and the atmospheric dispersion.

Figure A.1 and Figure A.2 show the pattern of median measured differences in $PM_{2.5}$ and NO_x for runs of four consecutive hours of wind direction or greater between the hours of 7 a.m. and 5 p.m (the period of greatest traffic). The colour of the dots indicates the wind direction. With

$PM_{2.5}$ there are a large number of data points that show negative or very slightly positive values. NO_x follows more the expected trends and appears to indicate that the monitors are impacted by the traffic.

Figure A.1 Measured Differences in $PM_{2.5}$ vs. Time

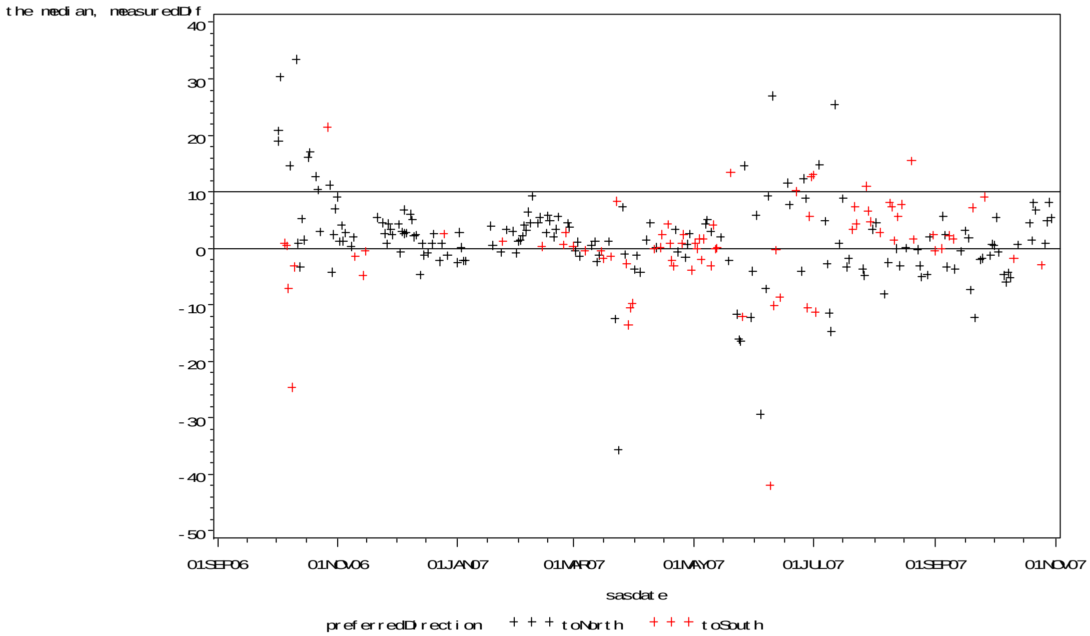
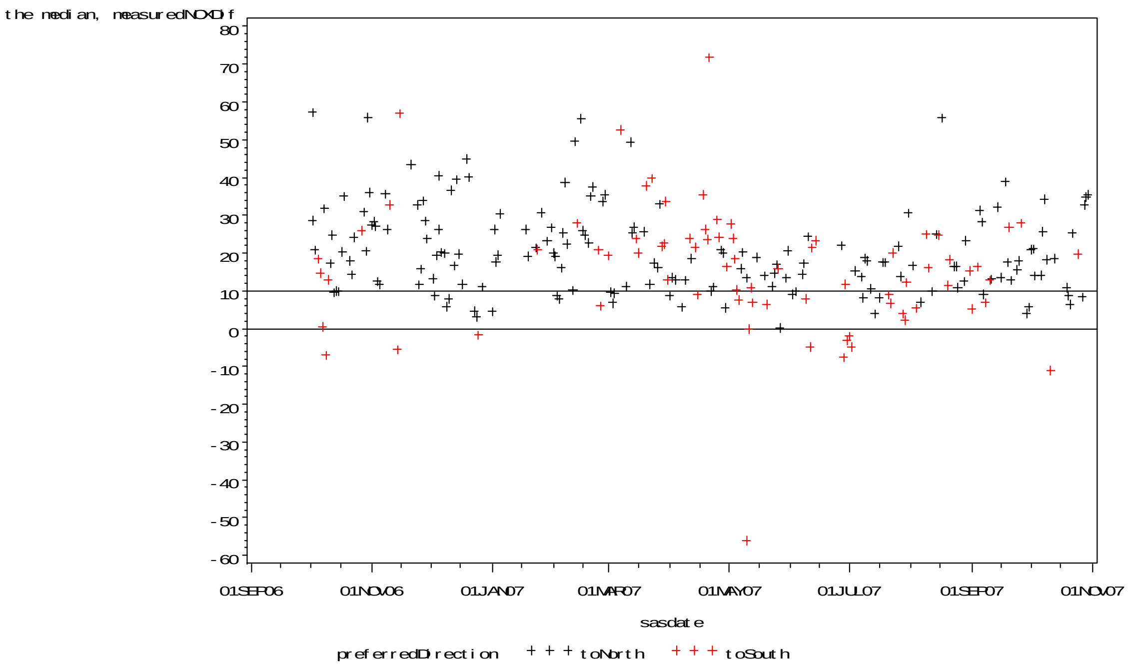


Figure A.2 Measured Differences in NO_x vs. Time



The comparison between the $PM_{2.5}$ and NO_x measurements indicates that the variability is present when comparing between the two DRIC monitors for the $PM_{2.5}$ and that NO_x is closer to the expected pattern. This suggests that the $PM_{2.5}$ readings may not be correlated to traffic impacts and that there may be additional sources of $PM_{2.5}$ that are impacting the monitors.

Windsor has several industries that also emit large amounts of $PM_{2.5}$. According to the National Pollutant Release Inventory, Windsor industries released 256 tonnes of $PM_{2.5}$ in 2007.

In addition, MOE Air Quality reports released for 2000-2004 also present Detroit data. The Detroit data for $PM_{2.5}$ is typically 5 µg/m^3 higher than the Windsor air quality data using similar measurement technologies suggesting that when winds blow from Detroit towards Windsor, somewhat higher $PM_{2.5}$ levels might be expected.,

Roadway contribution of $PM_{2.5}$ cannot be ignored but it is difficult to say that the $PM_{2.5}$ difference between the MOE monitors and the DRIC monitors is due solely to the roadway contribution, particularly given the difference in monitoring technologies and confounding factors such as those noted above.

COMPARISON OF MAXIMUM PREDICTED CONCENTRATIONS USING SILT LOADINGS

As previously noted, a very conservative road surface silt loading was used in the Alternatives report and a more realistic silt estimate in the TEPA report. The TEPA estimate uses the same EPA methods concerning silt loading that was used by the City's consultant.

Table A.2 presents maximum predicted concentrations at distances various distances within close proximity of the road for the Parkway using the two silt loading factors. As can be seen from the table, the conservative silt loading yields results that are significantly higher with the Practical Alternatives report with contributions from road sources predicted to be up to 40 µg/m^3 using the conservative silt loading factor. While it may be possible to achieve these levels under stop and go and heavy idling conditions, it is extremely unlikely based on published literature that these levels would occur under free-flow conditions.

Limited data appears to be available for the difference in $PM_{2.5}$ generated using similar traffic counts but different idling conditions (i.e., a busy road under freeflow conditions vs. a busy road under constant stop and go conditions). The U.S. EPA AP-42 methodology indicates that higher traffic volumes reduce silt loading, however speed does not get considered in the equation. It would seem likely that similar traffic volumes under stop and go conditions would generate more $PM_{2.5}$ than traffic volumes moving at free-flow conditions. Therefore it is possible that the TEPA approach underestimates the concentrations predicted for No Build and that the potential improvements after implementation of the TEPA would be larger than currently estimated.

Table A.2 Comparison of Silt Loading Impacts for the Parkway

		Incremental concentration (background removed), µg/m^3	
Receptor number	**Distance to roadway, m**	**TEPA**	**Alternatives**
Birmingham, England	Curbside	7-11	
714	9	8	41
Montreal	10	6	
707	13	7	35
66	13	8	41
793	21	7	35
MOE – Windsor	25	6	
697	35	2	16
193	40	3	8
63	50	3	17
706	70	2	10

Based on this assessment and due to the inability to determine a correlation to traffic with the DRIC monitoring results it was decided to use the conventional AP 42 emission factors for silt loading in the TEPA analysis. Based on Table A.2, the TEPA data more accurately reflect conditions presented in the literature, including the MOE data.

Using the revised silt loading reduces the predicted number of exceedances. As previously stated, exceedances are driven by the variability in background concentrations. Also as previously stated, a 90th percentile background was chosen for assessment. Thus, while in concept, total (road +background) concentrations could be under-predicted by up to 36 days of the year, the maximum concentrations and exceedances are primarily driven by the background concentrations for these 36 days and not by the traffic. The increment relating to traffic would not change. In fact, a transboundary pollution study by the MOE indicates air quality episodes in Windsor are driven by transboundary pollution rather than by local sources (MOE 2005).

REFERENCES

Harrison et al (Harrison 2004). Field study of the influence of meteorological factors and traffic volumes upon suspended particle mass at urban roadside sites of differing geometries. Atmospheric Environment 38 (2004) 6361-6369.

Mid-Atlantic Regional Air Management Association (MARAMA 2005). Correlating Federal Reference Method and Continuous $PM_{2.5}$ Monitors in the MARAMA Region.

New Brunswick Air Quality Monitoring Results (NB 2005) http://www.gnb.ca/0009/0355/0017/0003-e.pdf

Ontario Ministry of the Environment (MOE 2005b). Air Quality in Ontario, various years, Queen's Printer for Ontario, 2004.

Ontario Ministry of the Environment (MOE 2004). Preliminary Air Quality Assessment Related to Traffic Congestion at Windsor's Ambassador Bridge.

Ontario Ministry of the Environment (MOE 2004). Air Quality Assessment Related to Traffic Congestion at Sarnia's Blue Water Bridge.

Ontario Ministry of the Environment (MOE 2005a) Modelling Traffic Influences on Particulate Concentration.

Ontario Ministry of the Environment (MOE 2005). Transboundary Air Pollution in Ontario June.

Phuleria et al (Phuleria 2007) Roadside measurements of size-segregated particulate organic compounds near gasoline and diesel-dominated freeways in Los Angeles, CA. Atmospheric Environment 41 (2007) 4653-4671.

Smargiassi et al (Smargiassi 2005). Small-scale spatial variability of particle concentrations and traffic levels in Montreal: a pilot study. Science of the Total Environment 338 (2005) 243-251.

APPENDIX B

SAMPLE CALCULATIONS AND INPUT FILES

TRAFFIC PROFILE CALCULATIONS

This table illustrates how the AADTs are converted to hourly rates for Mon-Friday Traffic in 2035 for sample links.

AADT is multiplied by the different percentages for traffic profiles for each hour.

Profile 3 is for all roads south of EC Row

Profile 4 is for non arterial-roads N of EC Row

Table B.1 AADT to Hourly Traffic Sample Calculations

			Link Number	151	327	591	665	1036	1037	744	745	746	747
		Link Info	**Link Name**	ECR - Matchette to Ojibway 1	Dorchester - HC to Felix 1	S SERVICE RD - Pulford to Todd/Cabana 1	BEECH-EB-4	7BHC Rd/401 NB Off Ram-Ojibway/401 NB Off Ram-11NB	Ojibway/401 NB Off Ramp-Ojibway/401 NB On Ramp-1NB	TUNNEL-CON PLB-At Labelle NB-1NB	TUNNEL-CON PLB-At Labelle NB-2NB	TUNNEL-CON PLB-At Labelle SB-1SB	TUNNEL-CON PLB-At Labelle SB-2SB
			Profile	3	3	3	4	3	3	3	3	3	3
			Domestic Car Traffic (veh/day)	26,963	1,368	8,703	56	2,232	0	13,607	13,607	14,465	14,465
			US Car Traffic (veh/day)	360	24	0	1	2,087	2,373	12,727	12,727	13,434	13,434
			Domestic Truck Traffic (veh/day)	532	26	17	1	66	0	405	405	831	831
			US Truck Traffic (veh/day)	0	0	0	0	6,818	6,407	41,572	41,572	39,582	39,582
Hour	Profile 3	Profile 4	**Total AADT**	27,855	1,419	8,720	58	11,203	8,780	68,312	68,312	68,312	68,312
1	**0.7%**	**1.6%**	**Domestic Car Traffic (veh/hr)**	187	10	60	1	15	0	94	94	100	100
			US Car Traffic (veh/hr)	3	0	0	0	14	16	88	88	93	93
			Domestic Truck Traffic (veh/hr)	4	0	0	0	0	0	3	3	6	6
			US Truck Traffic (veh/hr)	0	0	0	0	47	44	289	289	275	275
2	**0.3%**	**1.3%**	**Domestic Car Traffic (veh/hr)**	78	4	25	1	6	0	39	39	42	42
			US Car Traffic (veh/hr)	1	0	0	0	6	7	37	37	39	39
			Domestic Truck Traffic (veh/hr)	2	0	0	0	0	0	1	1	2	2
			US Truck Traffic (veh/hr)	0	0	0	0	20	19	121	121	115	115
3	**0.2%**	**1.2%**	**Domestic Car Traffic (veh/hr)**	62	3	20	1	5	0	31	31	33	33
			US Car Traffic (veh/hr)	1	0	0	0	5	5	29	29	31	31
			Domestic Truck Traffic (veh/hr)	1	0	0	0	0	0	1	1	2	2
			US Truck Traffic (veh/hr)	0	0	0	0	16	15	95	95	91	91
7	**2.0%**	**4.4%**	**Domestic Car Traffic (veh/hr)**	538	27	174	2	45	0	271	271	289	289
			US Car Traffic (veh/hr)	7	0	0	0	42	47	254	254	268	268
			Domestic Truck Traffic (veh/hr)	11	1	0	0	1	0	8	8	17	17
			US Truck Traffic (veh/hr)	0	0	0	0	136	128	829	829	790	790
8	**3.7%**	**5.9%**	**Domestic Car Traffic (veh/hr)**	1007	51	325	3	83	0	508	508	540	540
			US Car Traffic (veh/hr)	13	1	0	0	78	89	475	475	502	502
			Domestic Truck Traffic (veh/hr)	20	1	1	0	2	0	15	15	31	31
			US Truck Traffic (veh/hr)	0	0	0	0	255	239	1552	1552	1478	1478
9	**6.8%**	**6.1%**	**Domestic Car Traffic (veh/hr)**	1824	93	589	3	151	0	920	920	978	978
			US Car Traffic (veh/hr)	24	2	0	0	141	160	861	861	909	909
			Domestic Truck Traffic (veh/hr)	36	2	1	0	4	0	27	27	56	56
			US Truck Traffic (veh/hr)	0	0	0	0	461	433	2811	2811	2677	2677
15	**6.9%**	**5.6%**	**Domestic Car Traffic (veh/hr)**	1856	94	599	3	154	0	937	937	996	996
			US Car Traffic (veh/hr)	25	2	0	0	144	163	876	876	925	925
			Domestic Truck Traffic (veh/hr)	37	2	1	0	5	0	28	28	57	57
			US Truck Traffic (veh/hr)	0	0	0	0	469	441	2862	2862	2725	2725
16	**7.8%**	**6.4%**	**Domestic Car Traffic (veh/hr)**	2113	107	682	4	175	0	1066	1066	1134	1134
			US Car Traffic (veh/hr)	28	2	0	0	164	186	997	997	1053	1053
			Domestic Truck Traffic (veh/hr)	42	2	1	0	5	0	32	32	65	65
			US Truck Traffic (veh/hr)	0	0	0	0	534	502	3258	3258	3102	3102
17	**8.0%**	**6.3%**	**Domestic Car Traffic (veh/hr)**	2152	109	695	4	178	0	1086	1086	1155	1155
			US Car Traffic (veh/hr)	29	2	0	0	167	189	1016	1016	1072	1072
			Domestic Truck Traffic (veh/hr)	42	2	1	0	5	0	32	32	66	66
			US Truck Traffic (veh/hr)	0	0	0	0	544	511	3318	3318	3160	3160
18	**8.0%**	**6.5%**	**Domestic Car Traffic (veh/hr)**	2161	110	698	4	179	0	1091	1091	1159	1159
			US Car Traffic (veh/hr)	29	2	0	0	167	190	1020	1020	1077	1077
			Domestic Truck Traffic (veh/hr)	43	2	1	0	5	0	32	32	67	67
			US Truck Traffic (veh/hr)	0	0	0	0	546	514	3332	3332	3173	3173
24	**1.4%**	**2.3%**	**Domestic Car Traffic (veh/hr)**	390	20	126	1	32	0	197	197	209	209
			US Car Traffic (veh/hr)	5	0	0	0	30	34	184	184	194	194
			Domestic Truck Traffic (veh/hr)	8	0	0	0	1	0	6	6	12	12
			US Truck Traffic (veh/hr)	0	0	0	0	99	93	602	602	573	573

SAMPLE LINK PM_{10} CALCULATIONS.

Weighted average vehicle weight for AADT is used for all hours. Tail pipe and road dust hourly emission factors are calculated using AADT volumes. Emission factors in g/veh-mil are therefore constant for 24 hour period. The final model concentration is dependent on traffic.

Emissions within TEPA tunnels set to 0 and traffic adjusted at ends of tunnels in separate links. See Appendix C of TEPA and Practical Alternatives report for discussion on how emissions are calculated from tunnels.

Table B.2 AADT to Hourly Traffic Sample Calculations

Tail Pipe Emission Factors, g/vkt				
Speed (km/	Dom Car	Dom Truck	US Car	US Truck
Idle	0.0139	0.04581	0.01385	0.04581
25	0.00343	0.01139	0.00341	0.01139
50	0.00344	0.01139	0.00343	0.01139
75	0.00344	0.01139	0.00343	0.01139
100	0.00344	0.01139	0.00343	0.01139

Road Dust Emission Factors		
	AADT	Silt Loading
Silt Loading	<500	0.6
	500-5000	0.2
	5000-10000	0.06
	>10000	0.03
Other	k (g/VKT)	4.6
	C (g/VKT)	0.1317

Link Information	**Link Number**	151	327	591	665	1036	1037	744	745	746	747	738	731
	Road Elevation	AG	AG	BR	AG	BR	BR	DP	DP	DP	DP	DP	DP
	Link Name	ECR - Matchette to Ojibway 1	Dorchester - HC to Felix 1	S SERVICE RD - Pulford to Todd/Cabana 1	BEECH-EB-4	7BHC Rd/401 NB Off Ram-Ojibway/401 NB Off Ram-11NB	Ojibway/401 NB Off Ramp-Ojibway/401 NB On Ramp-1NB	TUNNEL-CON PLB-At Labelle NB-1NB	TUNNEL-CON PLB-At Labelle NB-2NB	TUNNEL-CON PLB-At Labelle SB-1SB	TUNNEL-CON PLB-At Labelle SB-2SB	401 to EC SB Off Ramp-HC Rd/401 SB On Ramp-7SB	7BHC Rd/401 NB Off Ramp-Ojibway/401 NB Off Ram-4NB
	X1	329,164	330,296	331,840	328,782	329,091	328,881	331,383	331,229	331,195	331,353	331,215	331,369
	Y1	4,682,408	4,683,757	4,680,371	4,682,129	4,682,240	4,682,194	4,681,227	4,681,452	4,681,462	4,681,244	4,681,439	4,681,253
	X2	329,042	330,276	331,890	328,803	328,881	328,590	331,369	331,209	331,215	331,368	331,353	331,229
	Y2	4,682,447	4,683,745	4,680,234	4,682,183	4,682,194	4,682,156	4,681,253	4,681,473	4,681,439	4,681,218	4,681,244	4,681,452
	Elevation, m	0	0	2	0	10	13	-3	-3	-4	-7	-4	-3
	Mixing Zone Width	13.295	10.385	13	10	21	21	21	21	17	17	17	21
	Road Speed	100	50	75	50	100	100	100	100	100	100	100	100
Total	**Domestic Car Traffic (veh/day)**	26,963	1,368	8,703	56	2,232	0	13,607	13,607	14,465	14,465	0	0
	US Car Traffic (veh/day)	360	24	0	1	2,087	2,373	12,727	12,727	13,434	13,434	0	0
	Domestic Truck Traffic (veh/day)	532	26	17	1	66	0	405	405	831	831	0	0
	US Truck Traffic (veh/day)	0	0	0	0	6,818	6,407	41,572	41,572	39,582	39,582	0	0
	Total AADT	27,855	1,419	8,720	58	11,203	8,780	68,312	68,312	68,312	68,312	0	0
	Average vehicle weight, tons	3.8	3.8	3.5	3.9	13.6	15.5	13.6	13.6	13.3	13.3		
	Tailpipe Emission Factor, g/vkt	0.004	0.004	0.003	0.004	0.008	0.009	0.008	0.008	0.008	0.008		
	Road Dust Emission Factor, g/vkt	0.299	1.340	0.470	2.945	2.777	5.420	2.777	2.777	2.657	2.657		
	Total emission factor, g/vkt	0.302	1.344	0.473	2.949	2.785	5.429	2.785	2.785	2.665	2.665		
	Total emission factor, g/veh-mi	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289		
Hour 1	**Domestic Car Traffic (veh/hr)**	187	10	60	0	15	0	94	94	100	100	0	0
	US Car Traffic (veh/hr)	3	0	0	0	14	16	88	88	93	93	0	0
	Domestic Truck Traffic (veh/hr)	4	0	0	0	0	0	3	3	6	6	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	47	44	289	289	275	275	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 2	**Domestic Car Traffic (veh/hr)**	78	4	25	0	6	0	39	39	42	42	0	0
	US Car Traffic (veh/hr)	1	0	0	0	6	7	37	37	39	39	0	0
	Domestic Truck Traffic (veh/hr)	2	0	0	0	0	0	1	1	2	2	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	20	19	121	121	115	115	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 3	**Domestic Car Traffic (veh/hr)**	62	3	20	0	5	0	31	31	33	33	0	0
	US Car Traffic (veh/hr)	1	0	0	0	5	5	29	29	31	31	0	0
	Domestic Truck Traffic (veh/hr)	1	0	0	0	0	0	1	1	2	2	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	16	15	95	95	91	91	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 7	**Domestic Car Traffic (veh/hr)**	538	27	174	1	45	0	271	271	289	289	0	0
	US Car Traffic (veh/hr)	7	0	0	0	42	47	254	254	268	268	0	0
	Domestic Truck Traffic (veh/hr)	11	1	0	0	1	0	8	8	17	17	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	136	128	829	829	790	790	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 8	**Domestic Car Traffic (veh/hr)**	1007	51	325	2	83	0	508	508	540	540	0	0
	US Car Traffic (veh/hr)	13	1	0	0	78	89	475	475	502	502	0	0
	Domestic Truck Traffic (veh/hr)	20	1	1	0	2	0	15	15	31	31	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	255	239	1552	1552	1478	1478	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 9	**Domestic Car Traffic (veh/hr)**	1824	93	589	4	151	0	920	920	978	978	0	0
	US Car Traffic (veh/hr)	24	2	0	0	141	160	861	861	909	909	0	0
	Domestic Truck Traffic (veh/hr)	36	2	1	0	4	0	27	27	56	56	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	461	433	2811	2811	2677	2677	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 15	**Domestic Car Traffic (veh/hr)**	1856	94	599	4	154	0	937	937	996	996	0	0
	US Car Traffic (veh/hr)	25	2	0	0	144	163	876	876	925	925	0	0
	Domestic Truck Traffic (veh/hr)	37	2	1	0	5	0	28	28	57	57	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	469	441	2862	2862	2725	2725	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 16	**Domestic Car Traffic (veh/hr)**	2113	107	682	4	175	0	1066	1066	1134	1134	0	0
	US Car Traffic (veh/hr)	28	2	0	0	164	186	997	997	1053	1053	0	0
	Domestic Truck Traffic (veh/hr)	42	2	1	0	5	0	32	32	65	65	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	534	502	3258	3258	3102	3102	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 17	**Domestic Car Traffic (veh/hr)**	2152	109	695	4	178	0	1086	1086	1155	1155	0	0
	US Car Traffic (veh/hr)	29	2	0	0	167	189	1016	1016	1072	1072	0	0
	Domestic Truck Traffic (veh/hr)	42	2	1	0	5	0	32	32	66	66	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	544	511	3318	3318	3160	3160	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 18	**Domestic Car Traffic (veh/hr)**	2161	110	698	4	179	0	1091	1091	1159	1159	0	0
	US Car Traffic (veh/hr)	29	2	0	0	167	190	1020	1020	1077	1077	0	0
	Domestic Truck Traffic (veh/hr)	43	2	1	0	5	0	32	32	67	67	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	546	514	3332	3332	3173	3173	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0
Hour 24	**Domestic Car Traffic (veh/hr)**	390	20	126	1	32	0	197	197	209	209	0	0
	US Car Traffic (veh/hr)	5	0	0	0	30	34	184	184	194	194	0	0
	Domestic Truck Traffic (veh/hr)	8	0	0	0	1	0	6	6	12	12	0	0
	US Truck Traffic (veh/hr)	0	0	0	0	99	93	602	602	573	573	0	0
	Emission Factor (g/veh-mi)	0.486	2.162	0.762	4.746	4.483	8.737	4.483	4.483	4.289	4.289	0	0

SAMPLE LINES FROM INPUT FILES

Header

```
'DRIC 2035 Pkwy 110708 1 3 PM10'   60.0
108.0   0.3   0.3   2484   1.0   0
01 01 95   12 31 95
61395   95   4830   95
0   1   'U'
```

Receptors

```
'R1'   329573.1   4685495.7   2.0
'R2'   329515.1   4685622.6   2.0
…
'R2484'   331641.2   4680930.5   2.0
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Freeflow Link Geographic Description

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4684983.0   0.0   18.2
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5   1
…
'FF1104'   'AG'   330203.5   4682503.1
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16   2
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Queue Link Geographic Description

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4686162.9   0.0   7.2  2
35   2
'Q35'   'AG'   329254.9   4686106.4   329180.1
4686005.6   0.0   3.4  1
15   2
…
```

Hour 1, Pattern 1 Emission Factors, Free Flow

```
1   0.0
1   46   0.858
2   23   1.882
3   23   1.882
4   23   1.882
…
1103   46   1.571
1104   51   2.722
```

Hour 1, Pattern 1 Emission Factors, Queue Link

```
16   76   52   1.0   48   0.015   1561   3   5
40   76   26   1.0   50   0.014   1691   3   5
35   76   26   1.0   27   0.014   1728   3   5
…
```

Hour 8, Pattern 1 Emission Factors, Free Flow

```
1   248   0.858
2   125   1.882
3   125   1.882
…
693   2227   2.186
694   2227   2.186
695   2227   3.043
696   2227   3.043
…
1102   434   0.513
1103   243   1.489
1104   270   2.63
```

Hour 24, Pattern 2 Emission Factors, Free Flow

```
1   110   0.811
2   67   1.882
3   67   1.882
4   67   1.882
5   44   1.882
6   44   1.882
…
747   329   0.496
748   596   0.431
749   461   0.45
750   365   0.462
…
1102   232   0.778
1103   125   2.5
1104   125   3.309
```

Hour 24, Pattern 2 Emission Factors, Queue Lin

```
16   76   52   1.0   140   0.014   1561   3
5
40   76   26   1.0   145   0.014   1691   3
5
35   76   26   1.0   82   0.014   1728   3   5
15   76   39   1.0   117   0.014   1686   3
5
```

APPENDIX C

MODELLING LINE SOURCES (ROADS) USING CAL3QHCR, ISCST3, AERMOD AND CALPUFF

Appendix C: Modelling Line Sources (Roads) Using CAL3QHCR, ISCST3, AERMOD and CALPUFF

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ABSTRACT

Inter-comparison of the CAL3QHCR, ISCST3, AERMOD and CALPUFF models has been found quite useful for road impact assessments, especially for situations in which the road impact is combined with sources of differing configurations (landfills, quarries, mines) area, volume and point sources.

This paper demonstrates practical applications and limitations of using a long-area source (as a line source) in the ISCST3 and AERMOD models, as well as the buoyant line source in the CALPUFF model, for simulations of the long segments of roads. The CAL3QHCR model is used as the reference model for the road assessments because it has been widely validated against real observations around road sources.

Based on the inter-comparison of the models with ground based area source releases, it is clear that the ISCST3 model can be used for road simulations with an "adjustment factor" in the emissions. "Adjusted" or "equivalent" emissions should be reduced by a factor 2-3 for ISCST3 run in the rural mode and no adjustments are necessary for ISCST3 run in the urban mode for 24-hour averages and annual averages. AERMOD applications are possible, but AERMOD is much more conservative in the predicted concentrations by up to a factor 4-6 (depending on the surface roughness and other site characteristics) compared to CAL3QHCR. The CALPUFF buoyant line source algorithm can also be used for road simulations with a careful calculation of the initial buoyancy parameters. Different examples and model comparisons are demonstrated in the paper.

In performing these model comparisons, it was observed that the air concentrations predicted with AERMOD can be sensitive to the source of meteorological data and surface characteristics used in preparing the meteorological data. Since AERMOD is becoming an increasingly important regulatory tool, a few comments on this issue are also provided.

1.0 INTRODUCTION

Many air dispersion model applications involve the assessment of impacts from roadways. Such applications require a reliable line source algorithm to properly assess the roads. For example, evaluations of the development or expansion of landfills involving (on-site and off-site) roads, emissions due to changes in traffic volume around the landfill have often been found to have a greater impact on the environment than emissions from within the landfill itself. A significant portion of the overall particulate matter (PM) emissions from quarry operations is also derived from on-site and possibly off-site roads. Another example includes traffic studies, where it is necessary to evaluate the changes due to traffic volume in a portion of a city or changes due to highway re-alignment. For complex industrial facilities with large properties (e.g., cement plants, mining properties), the fugitive dust emissions from on-site roads may constitute a significant of the total PM emissions from the facility. Consequently, the evaluation of road impacts is an important aspect in the assessment of the potential impact of a facility on the environment.

In all applications with mixed source types (stacks, areas, roads) in which the modelling of line sources can be important, it is much easier from a data management and quality control perspective to use a single model rather than combing results from two or more models. For example, in the past, SENES has used CAL3QHCR for roads and combined the results with those from other model runs using ISCST3, AERMOD (which do not contain a line source algorithm) or CALPUFF for other sources (e.g., area sources). The model run times for using more than one model can be prohibitive, not to mention the increased time required to set up more than one model and process the output data from multiple models into a cohesive data set. Another consideration in combining data from different models is that different physics is used in each model, consequently the combined results may be less defensible.

Although the ISCST3 and AERMOD manuals indicate that line sources can be simulated as a series of volume sources. The computer runs can quickly become unmanageable with long road lengths because the road must be subdivided into a large number of segments. The ISC3 manual also recommends that line sources be simulated as area sources as long as the 1:10 width vs. length ratio is not exceeded. Simulating these sources as volume sources will also quickly lead to unmanageable model runs. As an alternative, Roger W. Brode (PES Inc.; personal communication) has suggested that area sources with a larger width to length ratio can actually be used in ISCST3 and AERMOD. This approach was explored further in this paper.

This study presents several practical examples to demonstrate the applicability of using long area sources (greater than the 1:10 ratio) to simulate road sources for different environmental settings. Four models are evaluated (CAL3QHCR, ISCST3, AERMOD and CALPUFF) to model a generic road length of 1000 m having two 20 m wide lanes.

Because CAL3QHCR was developed specifically for such road source applications, it was used as the reference model for the simulations presented here. CAL3QHCR has been validated against observations adjacent to roadways. This model has a line source algorithm where the initial dispersion parameters (σ_z) are modified to match initial mixing from the roads caused by traffic movements. All validations for this model were based on hourly data. For the purposes of this paper, it was assumed that CAL3QHCR also provides reliable predictions of the maximum 24-hour and annual average concentrations.

To evaluate the differences in the model predictions between the different models, model simulations for equivalent source definitions with the ISCST3, AERMOD and CALPUFF models are compared with predictions using CAL3QHCR. For this assessment, a long area source is used in each model to simulate a line source. In addition, a buoyant line source in

CALPUFF is compared to CAL3QHCR. For each model, both urban and rural settings are investigated for the maximum 1-hour, maximum 24-hour and annual average time frames.

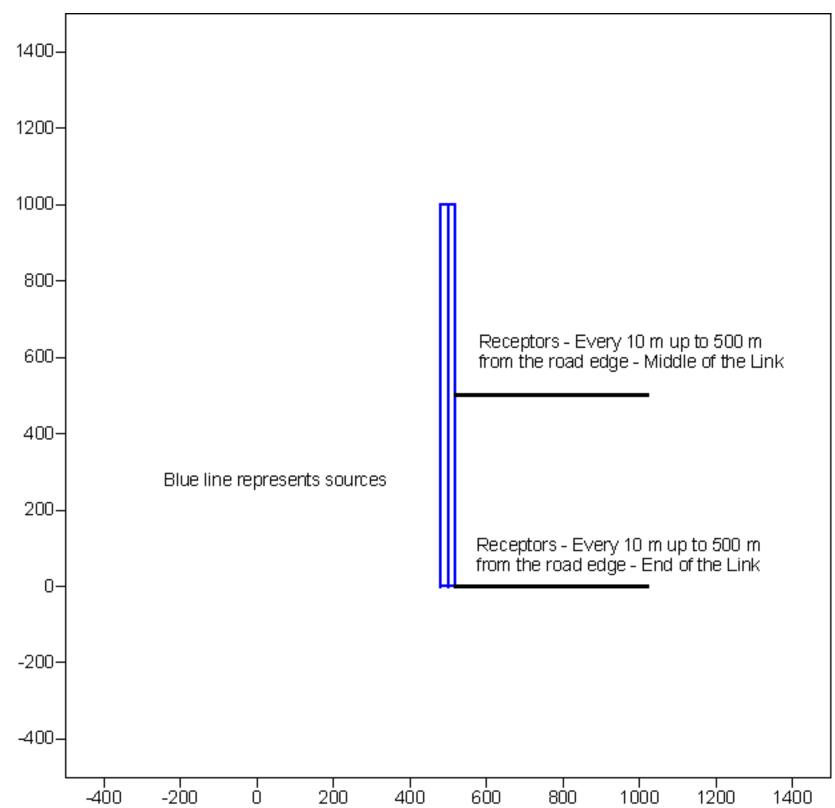
In order to prepare the meteorological data required by AERMOD, AERMET requires surface characteristics such as surface roughness, albedo and Bowen Ratio as input. The impact of surface roughness on the metrological dataset is discussed in this paper.

The source of meteorological data was also found to have a significant impact on the predicted concentrations. This study presents the differences in reported wind speeds that depend on the time averaging methodology used by the meteorological stations and the exposure of the station.

2.0 SOURCE DESCRIPTION

In CAL3QHCR, a line source (road), oriented south-north with two lanes of 20 m in 1000 m length, was modelled for a traffic volume of 1500 cars per hour in each direction and an emission rate corresponding to 0.5 g/s for each lane, or 1 g/s for the modelled road. For the ISC3ST, AERMOD and CALPUFF models, equivalent area sources were used in the simulation. Receptors used in the modelling exercise were oriented perpendicular to the road in the east-west direction, at 10 m intervals, extending out to 500 m from the road edge. Also, to compare the spatial concentration distribution around the source, a detailed 20 m by 20 m grid out to a distance of 2 km was used. Figure 1 illustrates the source configuration used in the modelling.

Figure 1. Modelling Domain with the Receptors Used In Air dispersion Modelling



3.0 METEOROLOGY

Hourly observations from the Toronto Pearson International Airport combined with Upper Air data from Buffalo, NY for 2001 were used in this study. The PCRAMMET meteorological processor was used to prepare meteorological input for ISCST3 and CALPUFF (run with ISCST3 hourly meteorology). AERMET (02222) was used to process data for the AERMOD (02222) simulation. The wind rose for Toronto Pearson International Airport (2001) is presented in Figure 2. The stability class distribution for this meteorological data set is provided in Table 1 for the different meteorological processors.

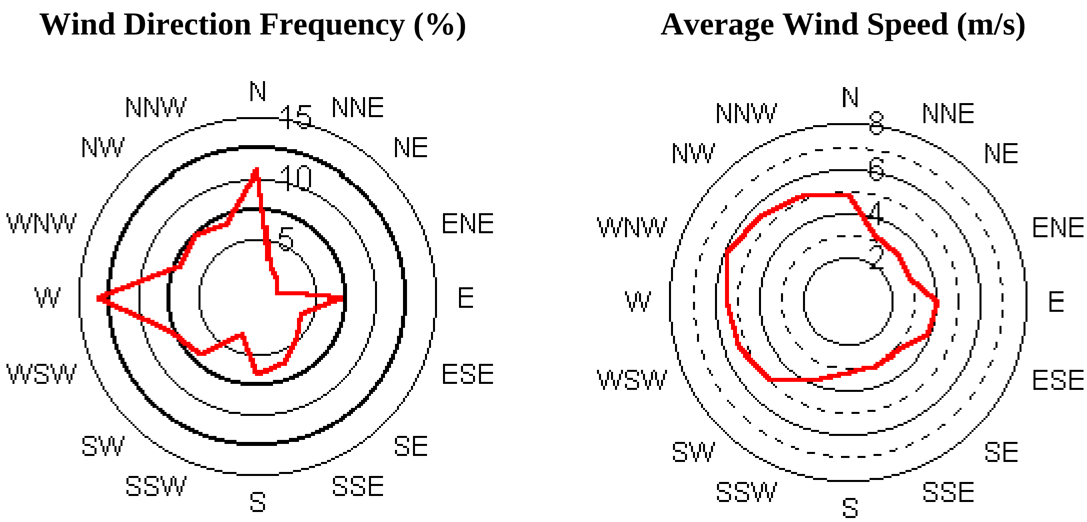
The initial physical parameters chosen for AERMET to define surface characteristics (i.e. surface roughness, albedo and Bowen Ratio), can significantly impact the AERMET output and consequently concentrations predicted with the AERMOD model. The AERMET manual currently does not provide guidance on whether these parameters should be assigned for the location of the meteorological station or the model domain. To illustrate the impact of using different parameters, an evaluation of surface roughness was conducted. Changing the surface roughness (S.R.) in AERMET from the higher (urban) to lower (rural) values causes a change in the stability class distribution, with a higher frequency of stable conditions in the rural mode. The stability class distribution for the AERMET pre-processor was derived based on Monin-Obukhov length and the relationship developed by D. Golder (1972). The PCRAMMET stability class distribution is based on the Pasquil-Gifford distribution for stability.

Table 1. Stability Class Distribution for PCRAMMET and AERMET (Urban and Rural) Settings for Different Surface Roughness

Stability	PCRAMMET	AERMET			
		Urban		Rural	
		S.R.=1 m	S.R.=0.5 m	S.R.= 0.1 m	S.R.= 0.05 m
Unstable	4.41	6.01	6.28	5.38	6.84
Neutral	68.68	57.25	52.39	49.19	44.34
Stable	26.89	36.74	41.31	45.42	48.82

S.R. – Surface Roughness

Figure 2. Wind Rose, Toronto Pearson International Airport, 2001



Note: Percentage Calms = 2.86%

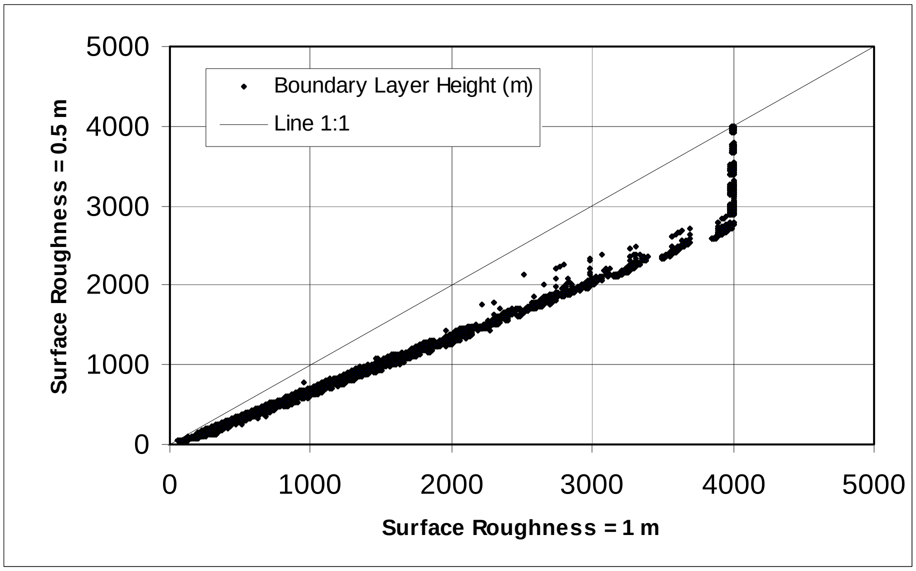
Table 1 illustrates that the Pasquill-Gifford distribution compares most closely with the AERMET stability class distribution for a surface roughness of 1.0 m. The AERMET pre-processor also shifts to a greater frequency of stable conditions as the surface roughness decreases. The frequency of unstable conditions is approximately the same in all cases. These observations are consistent with boundary layer physics.

URBAN ENVIRONMENT

For the AERMET pre-processor, urban conditions were represented by a surface roughness of 1.0 m and 0.5 m with Albedo of 0.2 and Bowen Ratio of 1.63 averaged over the year. As illustrated above, the stability class distribution shifts to a greater frequency of stable conditions with decreasing surface roughness. The surface roughness assumed for processing the meteorological data using AERMET significantly affects the results of the meteorological data sets produced by AERMET; in particular, the height of the mechanically generated boundary layer, the Monin-Obukhov length and the sensible heat flux are affected. Figures 3, 4 and 5 illustrate the difference between a surface roughness of 0.5 m and 1.0 m, for each of these meteorological parameters.

Figure 3 shows that the height of boundary layer based on a surface roughness of 1.0 m is approximately 50% larger than the heights based on a surface roughness of 0.5 m. A similar difference is illustrated for the Monin-Obukhov length presented in Figure 4.

Figure 3. Height of the Mechanically Generated Boundary Layer (AERMET) – Urban Conditions Toronto Pearson Airport (2001)



The change in heat flux has a direct effect on daytime turbulence calculations in AERMET. Heat flux is also used by AERMET to calculate the hourly growth of mixing height throughout the day. At night, the change in outgoing (negative) heat flux affects stability calculations, which directly affects nighttime dispersion. Figure 5 illustrates the difference in the sensible heat flux between the two surface roughness lengths for the nighttime heat flux. Daytime heat flux was found to be in good agreement for the different surface roughness values considered.

Figure 4 Monin-Obukhov Length (m) (AERMET) – Urban Conditions Toronto Pearson International Airport (2001)

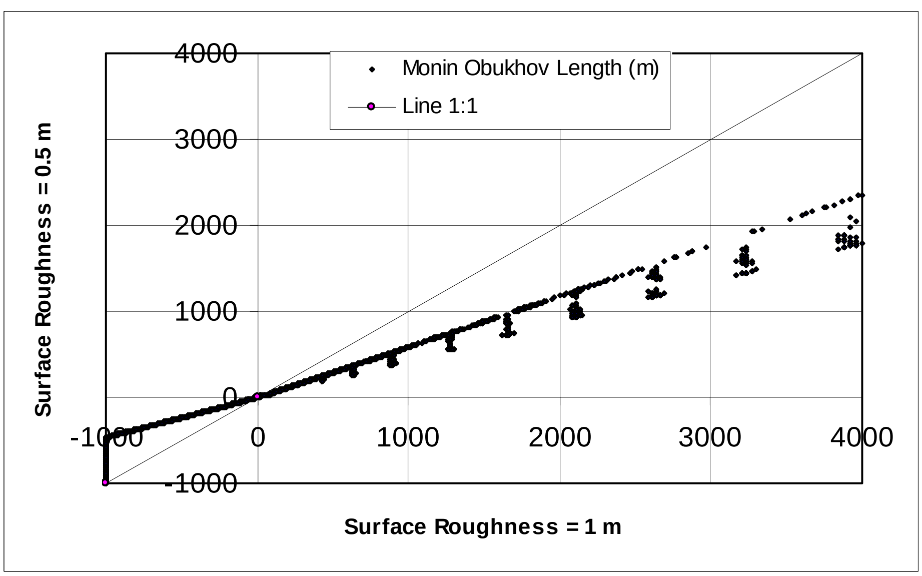
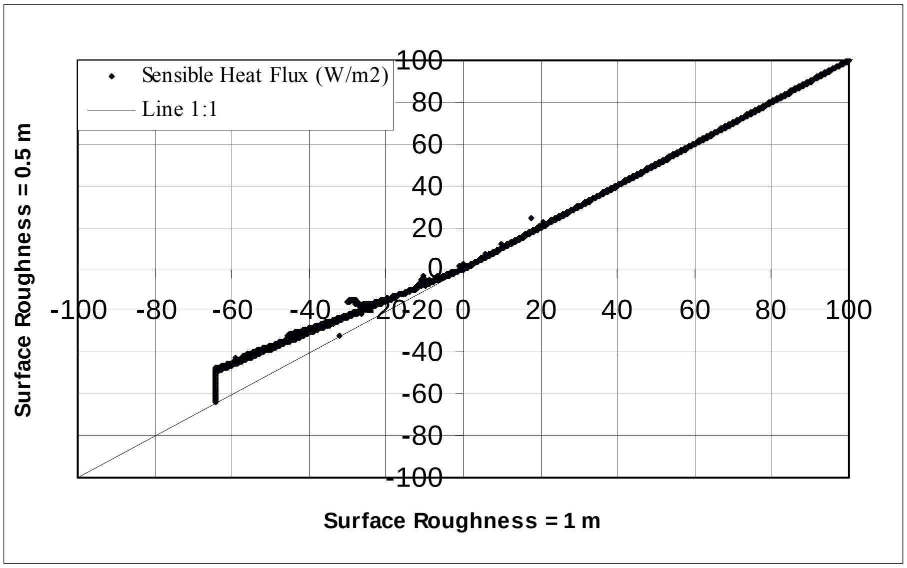


Figure 5. Sensible Heat Flux (W/m^2) (AERMET) – Urban Conditions
Toronto Pearson International Airport (2001)



These differences in the meteorological data affect the model predictions for this application.

RURAL ENVIRONMENT

As per AERMET User's Guide (1998), surface roughness values of 0.1 m and 0.05 m with Albedo of 0.28 and Bowen Ratio of 0.74 (averaged over the year) were used to represent rural conditions. As for urban conditions, decreasing the surface roughness increases the frequency of stable conditions. The annual average parameter values derived by AERMET are presented in Table 2 for the Urban and Rural conditions.

Table 2. Annual Average AERMET Parameters Based on Hourly Toronto Pearson Airport (2001)

Parameter	Urban		Rural	
Surface Roughness	1 m	0.5 m	0.1 m	0.05 m
Stable Boundary Layer	1603.2	1143.3	584.6	466.5
Monin-Obukhov Length	446.24	446.20	414.35	414.36
Sensible Heat Flux	5.05	9.04	-4.04	-2.02

Based on all AERMET analyses, it is evident that changes in surface characteristics and determined parameters correspond to trends reflecting the changes in the corresponding physical processes.

The following discussion evaluates the relative changes in predicted downwind concentrations for a simulated line source considering these different parameters.

4.0 MODEL SET-UP

CAL3QHCR

The primary CAL3QHCR modelling assumptions are: urban dispersion coefficients having a surface roughness of 0.5 m, and rural dispersion coefficients having a surface roughness of 0.1 m. These two modes were used as reference runs against which to compare all other results. It is important to note that the CAL3QHC model is sensitive to surface roughness for wind directions which run parallel to the line source, whereas for wind directions crossing the line source, predicted concentrations are more influenced by initial vertical mixing within the mixing zone, which is independent of surface roughness. For this reason, the predicted concentrations at receptors located at greater distances from the source are only slightly sensitive to changes in the surface roughness.

For the purpose of model comparison, air concentrations were predicted at different distances from the edge of the road ranging from10 m to 500 m (at 10 m intervals) at both the mid-point and end of the length of the source (Figure 1).

ISCST3

ISCST3 was used in both the urban and rural modes. Two initial vertical dispersion coefficients (σ_z) were evaluated; namely, 1) σ_z was set to 4.65 m to account for the initial vertical dispersion along roadways and 2) set to zero to evaluate the effect of this parameter. Based on the recommendation of Roger W. Brode (personal communication), area sources with a larger width to length ratio than the 10:1 ratio provided in the model guidance can actually be used in ISCST3 and AERMOD. This road source was modelled as two area sources, each having a width of 20 m and a length of 1000 m (ratio of 50:1).

AERMOD

AERMOD was set-up equivalent to ISCST3.

CALPUFF

CALPUFF modelling was performed using “screening level meteorology” (i.e. single point meteorology). The same hourly meteorological data set used for the ISCST3, AERMOD and CAL3QHCR model simulations was used in this CALPUFF application. This ensures a common point of comparison between the different models. The model settings, urban or rural, were changed through the land use data used to characterize the site. A land use category of 10 (urban), and surface roughness of 0.5 m were used for an urban setting and land use category of 30 (rangeland) and surface roughness of 0.1 m were used to defined a rural setting. Table 3 provides a summary of the different parameters used for each model.

Table 3. Summary of Model Set-Up Parameters

	CAL3QHCR	ISCST3	AERMOD	CALPUFF
Source Type	Line	Area (50:1 length : width ratio)	Area (50:1 length : width ratio)	Buoyant Line Source F_b=50 m^4/s^3 and 100 m^4/s^3
Urban Dispersion	Surface Roughness = 0.5 m	Urban Setting σ_z = 4.65 and 0.0	AERMET Parameters: Surface Roughness = 0.5-1.0 Albedo = 0.2 Bowen Ratio = 1.63	Land Use Category (urban) – 10; Surface Roughness = 0.5
Rural Dispersion	Surface Roughness = 0.1 m	Rural Setting σ_z = 4.65 and 0.0	AERMET Parameters: Surface Roughness = 0.05-0.1 Albedo = 0.28 Bowen Ratio = 0.74	Land Use Category (rangeland) – 30; Surface Roughness = 0.1

5.0 RESULTS OF MODEL COMPARISON

Summary graphs illustrating the predicted concentrations with distance from the road source for all four models, for both urban and rural settings, are provided in Figures 6, 7 and 8 for maximum 1-hour average, maximum 24-hour average and annual averages, respectively. As can be seen from these graphs, for the maximum predicted 1-hour and 24-hour average concentrations, the CALPUFF (buoyant line source) best approximates the CAL3QHCR model, especially close to the source (<100 m). ISCST3 tends to over predict compared to CAL3QHCR. However, within approximately 100-200 m, the ISCST3 model predictions approach the CAL3QHCR model predictions. It is apparent from these graphs that the AERMOD model predictions are significantly higher than the CAL3QHCR model predictions, and higher than either ISCST3 or CALPUFF.

Figure 6. Maximum 1 Hour Average Concentrations– Model Comparison

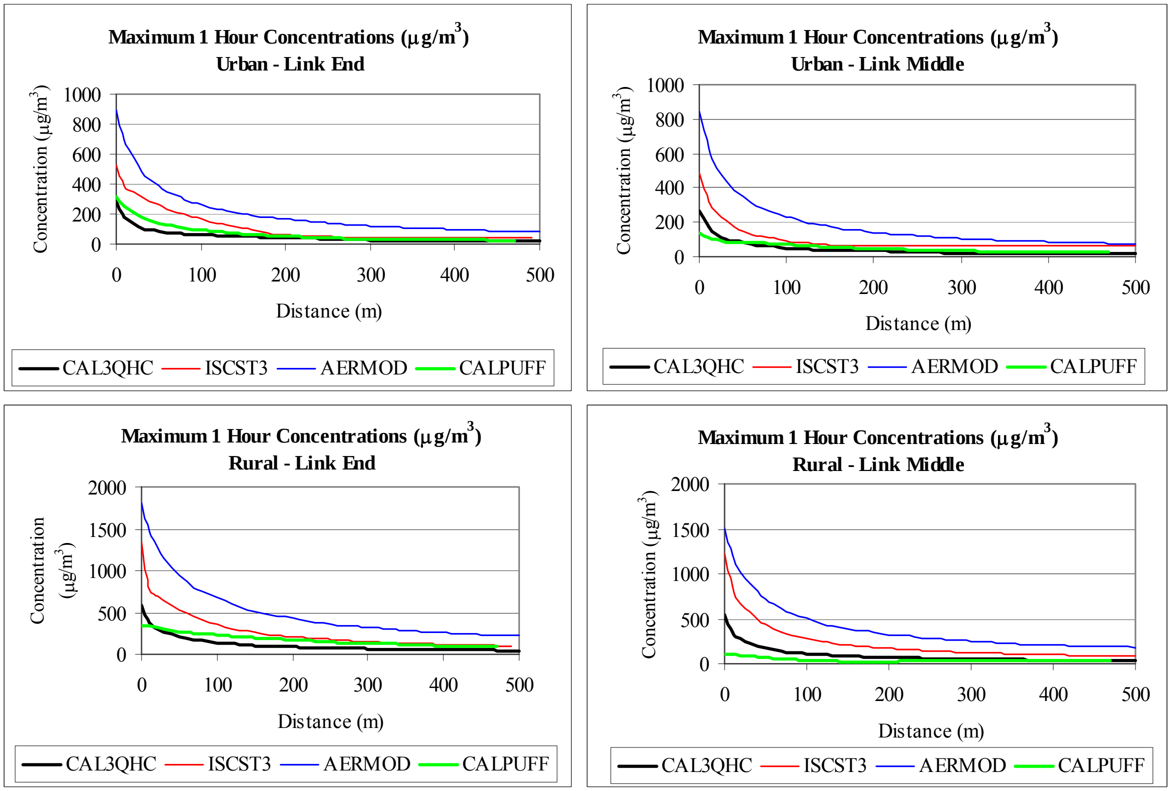


Figure 7. Maximum 24 Hour Average Concentrations– Model Comparison

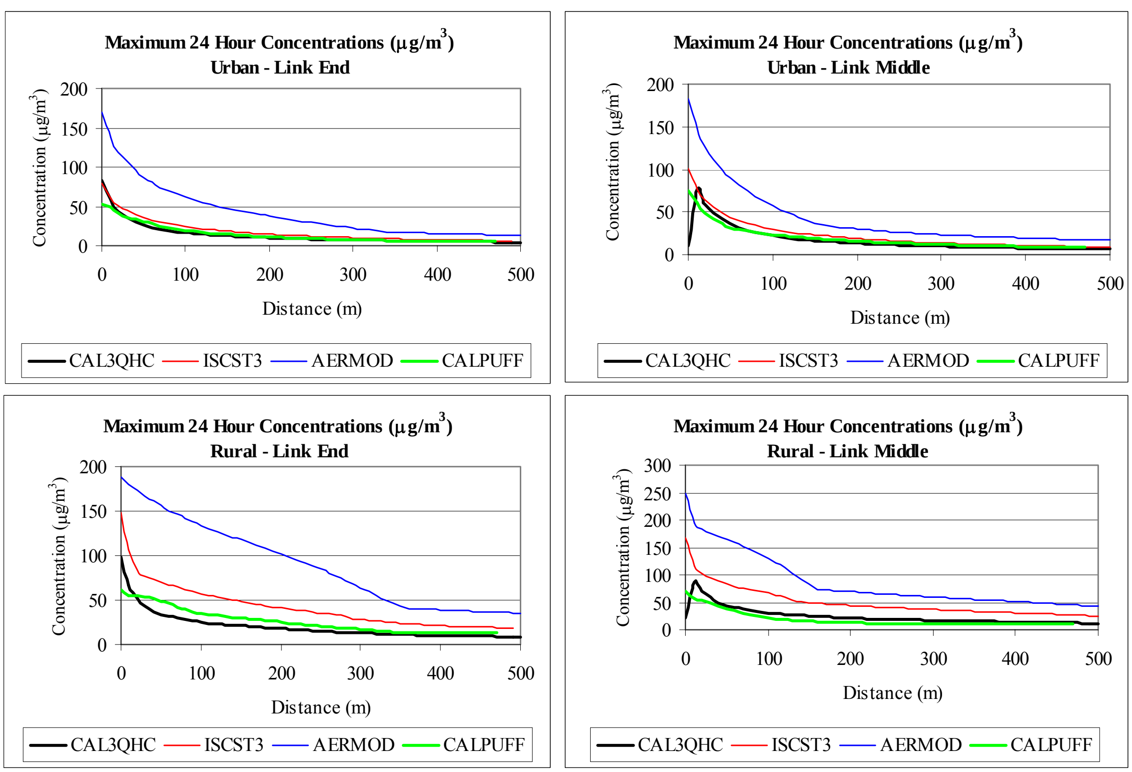
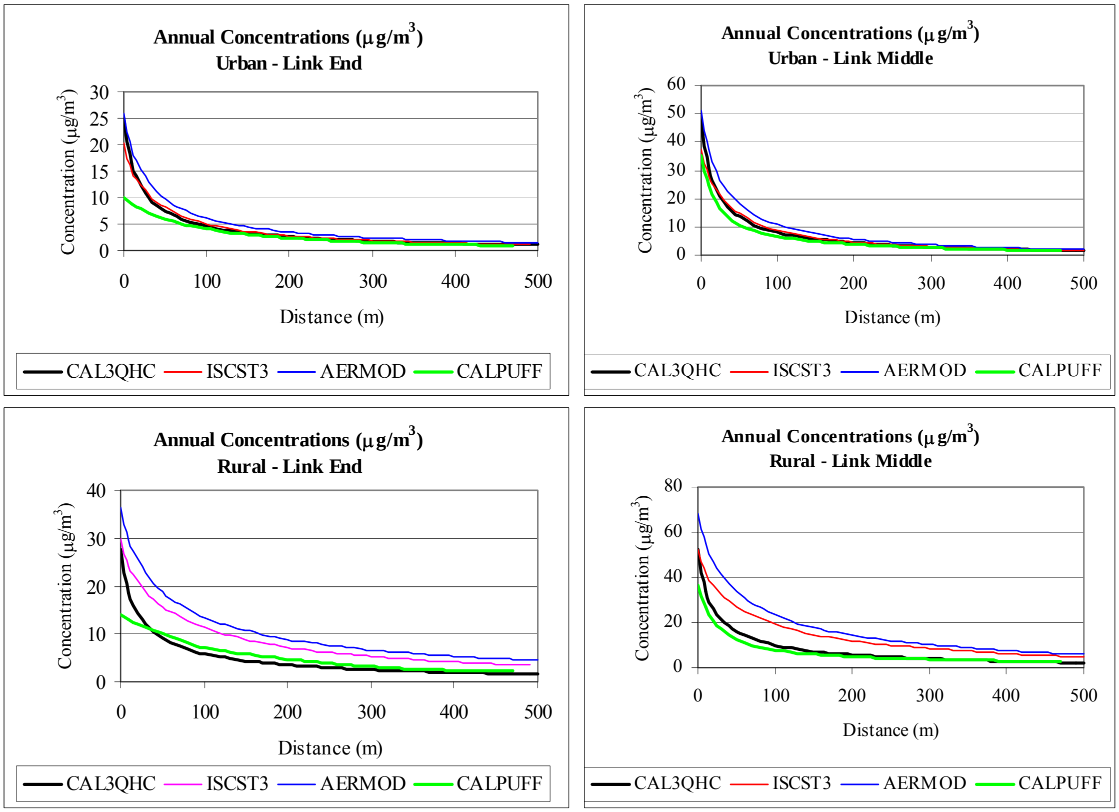


Figure 8. Annual Average Concentrations – Model Comparison



On an annual basis, the different models have much better agreement. However, the same overall trend is evident as for the shorter averaging periods: CALPUFF buoyant source best approximates CAL3QHCR, ISCST3 provides the next best approximation and AERMOD tends to over predict compared to CAL3QHCR.

Tables 4 and 5 provide, for each model, the ratio of the predicted concentration vs. the CAL3QHCR predicted concentration for different distances at the mid-point and end of the road source, respectively.

Table 4. Predicted Concentration Ratios (Compared to CAL3QHCR) for Mid-Point Along Line Source

Settings	Averaging Period	Distance from Source (m)	ISCST3		AERMOD		CALPUFF	
			σ_z (m)=4.3	σ_z (m)=0.0	Surface Roughness = 1 m	Surface Roughness = 0.5 m	Fb(m^4/s^3)= 50	Fb(m^4/s^3)= 100
Urban	Maximum 1 Hour	100	1.88	2.02	4.30	6.00	1.07	0.76
		200	1.88	1.90	4.66	6.69	1.50	1.26
		>200	3.28	3.28	4.75	6.87	1.49	1.39
		overall	**2.34**	**2.40**	**4.57**	**6.52**	**1.35**	**1.14**
	Maximum 24 Hour	100	1.21	1.45	2.44	3.42	0.92	0.71
		200	1.40	1.47	2.33	3.44	1.14	0.95
		>200	1.39	1.41	2.50	3.71	1.21	1.11
		overall	**1.33**	**1.45**	**2.43**	**3.53**	**1.09**	**0.93**
	Annual	100	1.05	1.20	1.32	1.78	0.81	0.70
		200	1.07	1.10	1.32	1.94	0.86	0.77
		>200	1.03	1.04	1.27	1.97	0.91	0.84
		overall	**1.05**	**1.11**	**1.30**	**1.89**	**0.86**	**0.77**
Rural	Maximum 1 Hour	100	2.52	3.14	4.15	4.47	0.44	0.34
		200	2.46	2.87	4.62	5.01	0.68	0.31
		>200	2.97	2.63	4.84	5.34	1.20	0.65
		overall	**2.65**	**2.88**	**4.54**	**4.94**	**0.77**	**0.43**
	Maximum 24 Hour	100	1.85	2.58	3.58	3.72	0.94	0.80
		200	2.03	2.61	3.47	3.76	0.85	0.62
		>200	2.15	2.49	3.54	4.04	1.25	0.74
		overall	**2.01**	**2.56**	**3.53**	**3.84**	**1.01**	**0.72**
	Annual	100	1.66	2.29	2.07	2.23	0.99	0.78
		200	2.03	2.00	2.45	2.74	1.13	0.82
		>200	2.15	2.34	2.61	3.05	1.40	0.99
		overall	**1.95**	**2.21**	**2.38**	**2.67**	**1.17**	**0.86**

Note: Shaded values are recommended factors.

Table 5. Predicted Concentration Ratios Compared to CAL3QHCR for End-Point of Line Source

Settings	Averaging Period	Distance from Source (m)	ISCST3		AERMOD		CALPUFF	
			σ_z (m)=4.3	σ_z (m)=0.0	Surface Roughness = 1 m	Surface Roughness = 0.5 m	Fb(m^4/s^3)= 50	Fb(m^4/s^3)= 100
Urban	Maximum 1 Hour	100	2.80	2.79	4.30	6.33	1.59	1.53
		200	1.94	1.94	3.97	5.88	1.30	1.28
		>200	1.88	1.89	4.85	7.24	1.39	1.37
		overall	**2.21**	**2.20**	**4.37**	**6.48**	**1.43**	**1.39**
	Maximum 24 Hour	100	1.34	1.54	3.29	4.58	1.12	1.06
		200	1.45	1.47	3.81	5.85	1.14	1.11
		>200	1.39	1.41	3.06	4.73	1.04	1.00
		overall	**1.39**	**1.48**	**3.39**	**5.05**	**1.10**	**1.06**
	Annual	100	1.06	1.20	1.29	1.75	0.77	0.73
		200	1.08	1.11	1.34	1.97	0.90	0.85
		>200	1.05	1.08	1.38	2.12	0.85	0.81
		overall	**1.06**	**1.13**	**1.33**	**1.95**	**0.84**	**0.79**
Rural	Maximum 1 Hour	100	2.43	2.88	4.46	4.98	1.49	1.30
		200	2.44	2.66	4.93	5.59	2.03	1.87
		>200	2.02	2.43	4.94	5.64	2.08	1.97
		overall	**2.30**	**2.65**	**4.78**	**5.41**	**1.87**	**1.72**
	Maximum 24 Hour	100	2.00	2.72	4.42	4.55	1.52	1.30
		200	2.29	2.62	5.61	6.16	1.57	1.41
		>200	2.17	2.40	4.48	5.10	1.48	1.31
		overall	**2.15**	**2.58**	**4.84**	**5.27**	**1.53**	**1.34**
	Annual	100	1.70	2.29	2.04	2.22	1.26	1.05
		200	2.03	2.00	2.45	2.76	1.57	1.31
		>200	2.12	2.31	2.71	3.06	1.53	1.27
		overall	**1.95**	**2.20**	**2.40**	**2.68**	**1.45**	**1.21**

Note: Shaded values are recommended factors.

ISCST3

Urban Mode

For the annual average concentrations, it was found that the ratio of the predicted concentrations from ISCST3 and from CAL3QHCR is approximately equal. For the 24-hour average concentrations, the ISCST3 model predicts only slightly higher values than CAL3QHCR. For the 1-hour average values, however, it was found that the ISCST3 model predicts approximately 2.2 times higher than CAL3QHCR.

Rural Mode

The results are slightly different for the rural mode. For the 1-hour average, the ISCST3 model predicts higher concentrations than the CAL3QHCR model by a factor of approximately 2.4. For 24-hour and annual average concentrations, the ratio is approximately 2.0.

Recommendation: In order to avoid combining the results from two models (CAL3QHCR and ISCST3) for applications involving both line source emissions and emissions from area or point sources, the line source emissions can be well simulated in ISCST3 by applying a source correction factor to the emissions from road sources. In this case, for urban mode simulations, a correction factor of 2.2 is appropriate for maximum 1-hour average simulations. For maximum 24-hour average and annual concentrations, no correction factor is recommended. This will result in maximum 24-hour average model predictions that are conservative by approximately 35-40%. For rural mode simulations, an emission correction factor of approximately 2.0 would be appropriate for all averaging times.

AERMOD

The ratio of predicted concentrations from AERMOD and CAL3QHCR varies considerably depending on the surface roughness and for different averaging times. The predicted 1-hour average concentration ratio between AERMOD and CAL3QHCR is as high as 6.5 in urban mode for a surface roughness of 0.5. A surface roughness of 1.0 results in concentration ratios of approximately 4.5 for the maximum 1-hour average concentrations, ratios of 2.4-4.8 for the maximum 24-hour average concentrations, and 1.3 to 2.5 for annual average concentrations. Inconsistencies in the AERMOD/CAL3QHCR ratios between averaging periods may indicate that AERMOD significantly over predicts or under predicts in the shorter term averaging periods (maximum 1-hour and maximum 24-hour averages).

Recommendation: AERMOD is not considered the best option for this type of application, however, with the use of appropriate “adjustment” factors (Tables 4 and 5), may result in predicted concentrations that more closely approach the CAL3QHCR model predictions.

CALPUFF

Different initial buoyancies were investigated for the CALPUFF model runs. For the scenarios considered here, the best agreement, between CALPUFF and CAL3QHCR was achieved with the initial buoyancy of F_b=50 m^4/s^3 in both urban and rural modes. In the urban mode, the maximum predicted 1-hour average concentrations using CALPUFF are approximately 35% higher for urban simulations and 23% lower for rural simulations compared to CAL3QHCR. Maximum predicted 24-hour average concentrations agree quite well in both rural and urban modes. Annual concentrations are less than CAL3QHCR by approximately 14% in urban mode and 17% higher in rural mode.

The CALPUFF area source algorithm was also tested; however, the results did not provide good agreement compared with CAL3QHCR. Therefore, these results are not presented.

Recommendation: The CALPUFF buoyant line source was found to provide the best approximation of the CAL3QHCR model results.

CAL3QHCR

Recommendation: Because there are many parameters, which can influence model predictions, it is recommended that, for any particular application, the chosen model be tested against CAL3QHCR for each application to ensure that appropriate model parameters are used and correction factors are applied.

6.0 WIND SPEED DIFFERENCES FROM AIRPORT OBSERVATIONS AND ON-SITE AUTOMATIC STATIONS

The preceding analysis indicated that AERMOD was not the best option for approximating CAL3QHCR model calculations. AERMOD model predictions were found to be significantly more variable than ISCST3 or CALPUFF. In carrying out the model comparisons, it was noted that AERMOD is quite sensitive to the source of the meteorological data used in the model. This aspect is briefly discussed in this section.

The Ontario Ministry of the Environment (MOE) is moving toward adopting AERMOD as its future regulatory model. SENES has concerns with the adoption of this model for regulatory purposes, given the variability observed in model predictions. In Ontario, the MOE regulates emission sources based on meeting a ½ hour average Point of Impingement (POI) criterion at the location of maximum concentration along the property line or off property. Given the potential implications in using AERMOD as a regulatory model in Ontario, and the variability in model predictions compared to other models, a better understanding of the reasons behind the variability in AERMOD's predictions compared to other models is considered imperative.

Investigating the source of the variability in the model predictions led to an investigation of the source of the meteorological data, specifically related to wind speed. Our understanding is that AERMOD and other model validations are based on on-site meteorological data that represents hourly averages derived from 1-second sampling periods. The hourly average data from airport stations are based on 2-minute averages of the 53^{rd} and 54^{th} minute in each hour.

On an annual basis, these different averaging methods result in very similar annual average wind speeds. Therefore, it is not surprising that the annual average predictions using AERMOD generally are in good agreement with the annual average predictions from other models such as ISCST3. For shorter time periods AERMOD predictions are more variable. Comparison of wind speed averages of the shorter time frame found that they can vary significantly (by approximately a factor of 2).

In addition to recording the average wind speed from the two minutes before each hour, the U.S. ASOS stations keep a database of 1-minute average wind speeds. Using this data, hourly averages can be developed based on 60 readings from the past hour that will correspond to hourly average from on-site stations used in model validation. In Canada, new automatic airport stations are record hourly averages as 2-minute averages. Unfortunately, the 1-minute averages are not saved.

To confirm the difference between hourly and 2-min averages, data from Buffalo's Niagara International Airport (14733) for 2001 was analyzed. The annual average wind speed from Buffalo's Airport based on 2-minute averages is: 4.55 m/s, while the annual average wind speed based on 1 minute averages is 4.51 m/s. It is important to underline that different methods of wind speed averaging do not result in differences in wind speed based on an annual average basis. However, the difference can be more than a factor of 2 if the comparison is done on an hourly basis (airport method vs. on-site method).

It was also found that meteorological stations located in close proximity may record significantly different wind speeds. This is dependant on both the station exposure and the averaging method. The Ontario Ministry of the Environment Station (MOE) (Evans Avenue) was used for comparison with Toronto Pearson International Airport. For 2001, after processing through AERMET, the annual average wind speed from MOE's station is 2.33 m/s while the Toronto Pearson International Airport annual average wind speed is 4.44 m/s. Toronto Pearson International Airport is located on the west side of Toronto and approximately 12.5 km NW from the nearest shoreline of Lake Ontario. The MOE Evans Avenue station is located 2.5 km from Lake Ontario and approximately 10 km from the Toronto Pearson International Airport station in a flat terrain setting and similar open exposures.

Based on this analysis, the sensitivity of the four models to wind speed differences of a factor of 2 was conducted to represent the possible difference in recorded wind speeds. For present purposes, all models were evaluated with the same Toronto Pearson Airport data, with original wind speed and with wind speed reduced by a factor of 2 to simulate wind speed differences caused by different averaging methods or different station exposure.

A first comparison was done for the PCRAMMET and AERMET results as a function of two different wind speeds on the stability classes. The results are presented in Table 6.

Table 6. Stability Class Comparison

Stability	**PCRAMMET**		**AERMET**	
	Measured Wind Speed	**½ Measured Wind Speed**	**Measured Wind Speed**	**½ Measured Wind Speed**
Unstable	4.41	17.56	6.28	19.96
Neutral	68.68	31.01	52.39	25.64
Stable	26.89	51.41	41.31	54.39

A decrease of a factor of 2 in wind speed resulted in an increase in both unstable and stable conditions and a reduction in neutral conditions of about 38% in PCRAMMET and about 27 % in AERMET. The following comparison concentrates on the "generic" source. Results from all four models, shown as a ratio of predicted concentrations in relation to reduced wind speed (factor of 2), are presented in Table 7.

Table 7. Influence of Wind Speed on Predicted Concentrations from the Generic Source: Concentration Ratios (Simulated Automatic Station Meteorological Data /Airport Station Meteorological Data)

Averaging Period	CAL3QHC			ISCST3			AERMOD			CALPUFF		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Maximum 1 Hour Average	0.94	1.56	1.16	1.03	1.5	1.44	0.94	1.27	1.17	0.99	1.18	1.06
Maximum 24 Hour Average	1.38	1.63	1.5	1.49	1.93	1.58	0.82	1.24	1.13	1.15	1.84	1.55
Annual Average	1.59	1.64	1.62	1.75	1.86	1.84	1.04	1.47	1.35	1.47	1.8	1.74

CAL3QHC

The sensitivity analysis for CAL3QHCR shows that a reduction in wind speed results in a 16% increase in maximum 1-hour average concentrations, a 50% increase in maximum 24-hour average concentrations, and a 62% increase in annual averages.

ISCST3

The ISCST3 predicted concentrations are more sensitive to wind speed than the CAL3QHC predictions. For ISCST3, maximum 1-hour average predictions increased by about 44% with lower wind speeds. Factors of 1.58 for maximum 24-hour average concentrations and 1.84 annual concentrations are predicted. The increase in predicted annual average concentrations is inversely proportional to the reduction in wind speed reduction.

AERMOD

Based on these results, it is suggested that, with lower wind speed recorded at automatic on-site stations, average hourly concentrations may be as much as 17% higher for AERMOD when running in urban mode than those derived from the use of meteorological data measured at airports. Maximum 24-hour average concentrations are about 13% higher for AERMOD and annual average concentrations are about 35% higher. The difference in concentration predictions from ground base area sources using automatic (on-site) stations (hourly average wind speed) and airport wind speed (2-minute average) is not significant. For the area source case presented here, the annual average AERMOD concentrations are only 35% higher using wind speed reduced by a factor of two, compared to the other models in which the concentrations increase by 60-80%. There are indications, however, that the difference in wind speed from these two averaging methods causes much larger concentration differences for stack releases - the subject of future work.

ISCST3 VS. AERMOD FOR AREA SOURCES

A comparison of the predictions between ISCST3 and AERMOD with reduced wind speeds was conducted for the urban mode. The results are presented in Table 8. Based on average ratios, AERMOD predicts higher than the ISCST3 model by factors of about 2.5, 2.2 and 1.38 for maximum 1-hour, maximum 24-hour and annual averages, respectively. It is evident based on all these comparisons that the AERMOD area source algorithm has a tendency towards over prediction when compared with models such as ISCST3 and CALPUFF.

Table 8. Ratio of Predicted Concentrations AERMOD/ISCST3 using Automatic Station Wind Speed Data

Averaging Period	Min	Max	Avg
Maximum 1 Hour Average	1.33	4.44	2.50
Maximum 24 Hour Average	1.04	3.30	2.20
Annual Average	0.90	1.65	1.38

CALPUFF

For CALPUFF, the influence of wind speed differences on predicted concentrations is quite similar to that with ISCST3. Results in Table 7 show that with reduced wind speed, CALPUFF (buoyant line source algorithm) will predict higher concentrations by factors of 1.55 and 1.74 for maximum 24-hour average and annual average concentrations, respectively, compared with 1.58 and 1.84 for ISCST3. However, ISCST3 predicts higher 1-hour average concentrations than CALPUFF.

7.0 CONCLUSIONS

This work confirms that a line source algorithm should be incorporated in the other Regulatory models (such as ISCST3 and AERMOD), not only to make modelling easier but also to make results more reliable.

While every approach has a challenge, it is concluded that models such as ISCST3, AERMOD and CALPUFF can be successfully applied to buoyant line sources with the use of appropriate correction factors to mimic results that would be derived from CAL3QHCR.

In the case presented here, it was found that CALPUFF model with buoyant line source algorithm could be used without any adjustment factors and reproduces the CAL3QHCR results quite well.

ISCST3 can be used in the rural mode without corrections for estimating maximum 24-hour average concentrations and annual averages; however, in the case presented here a "correction" factor of 2.3 is needed for maximum 1-hour averages. In the rural mode, for this case a correction factor of 2.2 can be applied to all averaging periods. In our opinion, the ISCST3 model can be used with long narrow area sources for modelling roads.

AERMOD needs different correction factors for every averaging period. AERMOD applications with the area source approach cause large over-estimations in predicted concentrations for maximum 1-hour and maximum 24-hour predicted concentrations compared with CAL3QHCR. Annual average concentrations are over-predicted for about 30% in the urban mode, using a surface roughness that is twice the value used in the CAL3QHCR run. For the same surface roughness, the AERMOD model over-predicts annual averages by about 90%.

In the rural mode, AERMOD over predicts annual averages by about a factor of 2.38 for the matching surface roughness. Over prediction factors for shorter averaging periods are quite a bit larger than annual factors. Overall, to use of AERMOD with this approach will require re-running the model for every averaging period.

AERMOD is also sensitive to the surface roughness in the urban mode. Reducing surface roughness from 1.0 to 0.5 m results in an increase in predicted concentrations of about 50%. In the range of lower surface roughness lengths (rural), the concentration change is smaller. Changing surface roughness from 0.1 m to 0.05 m causes concentrations to change in the range of 10 – 14%. It should be emphasized that all these sensitivity and model comparisons were done with standard airport meteorological observations (hourly wind speed recorded represented by 2-minute average wind speed before the hour of observation).

Regardless of which model is used, thorough testing against CAL3QHCR is necessary to ensure appropriate model parameters are used and correction factors determined.

Models such as CAL3QHC3, ISCST3 and CALPUFF show similar factor increases in concentrations with respect to reduced wind speed as a result of hourly averaging of wind speed at automatic on-site monitoring stations. Sensitivity analysis of AERMOD to wind speed differences from automatic (on-site) stations versus airport data for area sources did not show significant variability. Predicted annual concentrations using on-site data were a factor of 1.35 times higher compared to the other three models had about a factor 2 increase in predicted concentrations for a factor 2 reduction in wind speed.

It is important for Regulatory Agencies to be aware of the sensitivity of the AERMOD model to the wind speed (much larger for point sources) and to develop a modelling Guidance on the use of ASOS – airport data in model applications for regulatory use. One of the suggestions for the U.S. ASOS data would be to use 1-minute averages and developed hourly averages based on those observations. In Canada, in the case of lack of on-site monitoring data or MOE meteorological stations perhaps a relationship between airport and automatic station data could be developed or alternatively, specific modelling guidelines to deal with this discrepancy could be developed. This will ensure that the appropriate meteorological data is used for modelling.

REFERENCES

1. Addendum to the *User's Guide to CAL3QHC Version 2.0 (CAL3QHCR Users Guide).* Eckhoff, P.; Braverman, T. U.S. Environmental Protection Agency. U.S. Government Printing Office: Washington, D.C, 1995.

2. Benson, P. *CALINE3 – A Versatile Dispersion Model for Predicting Air Pollutant Levels Near Highways and Arterial Streets, California Department of Transportation, Sacramento,* 1979, FHWA/CA/TL-79/23.

3. Golder, D., *Boundary-Layer Meteorology*1972,3, 47-58.

4. *Meteorological Monitoring Guidance for Regulatory Modeling Applications.* Environmental Protection Agency. U.S. Government Printing Office: Washington, D.C. 2000, EPA-454/R-99-005.

5. *Revised Draft User's Guide for the AMS/EPA Regulatory Model – AERMOD,* U.S. Environmental Protection Agency. U.S. Government Printing Office: Washington, D.C. 2002.

6. *Revised Draft User's Guide for the AMS/EPA Regulatory Model – AERMET,* U.S. Environmental Protection Agency. U.S. Government Printing Office: Washington, D.C. 1998 (Addendum, August, 2002).

7. Scire, J.; Robe, M. Ferunau, M.; Yamartino R. *A User's Guide for the CALMET Meteorological Model (Version 5).* Earth Tech, Inc, Concord, MA. 2000.

8. Scire, J.; Strimaitis, D.; Yamartino R. *A User's Guide for the CALPUFF Dispersion Model (Version 5* Earth Tech, Inc, Concord, MA. 2000.

9. *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models (Volume I).* Environmental Protection Agency. U.S. Government Printing Office: Washington, D.C. 1995, EPA-454/B-95-003a.

Key Words

AERMOD
AERMET
ISC3
CAL3QHC
Line Sources
Emissions

APPENDIX D

ASSESSMENT OF $PM_{10}/PM_{2.5}$ RATIO

APPENDIX D: CALCULATION OF $PM_{10}/PM_{2.5}$ RATIO

To calculate PM_{10} concentrations on a daily basis for 2003 (the meteorological year used in the TEPA and Practical Alternatives analysis), the $PM_{2.5}$ daily concentrations were adjusted by the average ratio of PM_{10} to $PM_{2.5}$ from monitor results for Windsor West and Windsor Downtown for 2006 and 2007. The adjustment factor is 2.3 with these values as shown in Table D.1. Table D.2 shows the differences in ratios based on $PM_{2.5}$ concentration ranges for 2006/2007 Windsor West and Windsor Downtown monitoring stations.

As a quality check, the $PM_{10}/PM_{2.5}$ ratios were checked for concentration ranges to determine if there was a correlation with maximum $PM_{2.5}$ concentrations. In general, the ratios are highest at lower concentrations. While this may be based on limited data, it does indicate that the ratios are between a factor of 1.5 to 5 and that 2.3 may be a reasonable pairing value. At the lower concentrations, multiplying by a factor of five increases the predicted PM_{10} concentrations but would not likely change the number of exceedances.

Figure D.1 illustrates the variability in predicted background by applying both a factor of 2.3 to the $PM_{2.5}$ concentrations and by adjusting the concentrations relative to the ratio predicted by the concentration range. As can be seen in the figure, adjusting by a factor of 2.3 generally results in higher maximum concentrations but results in lower PM_{10} concentrations when PM_{10} concentrations are lower. There are 24 exceedances predicted by using the 2.3 factor and 16 exceedances predicted when using the range specific ratios.

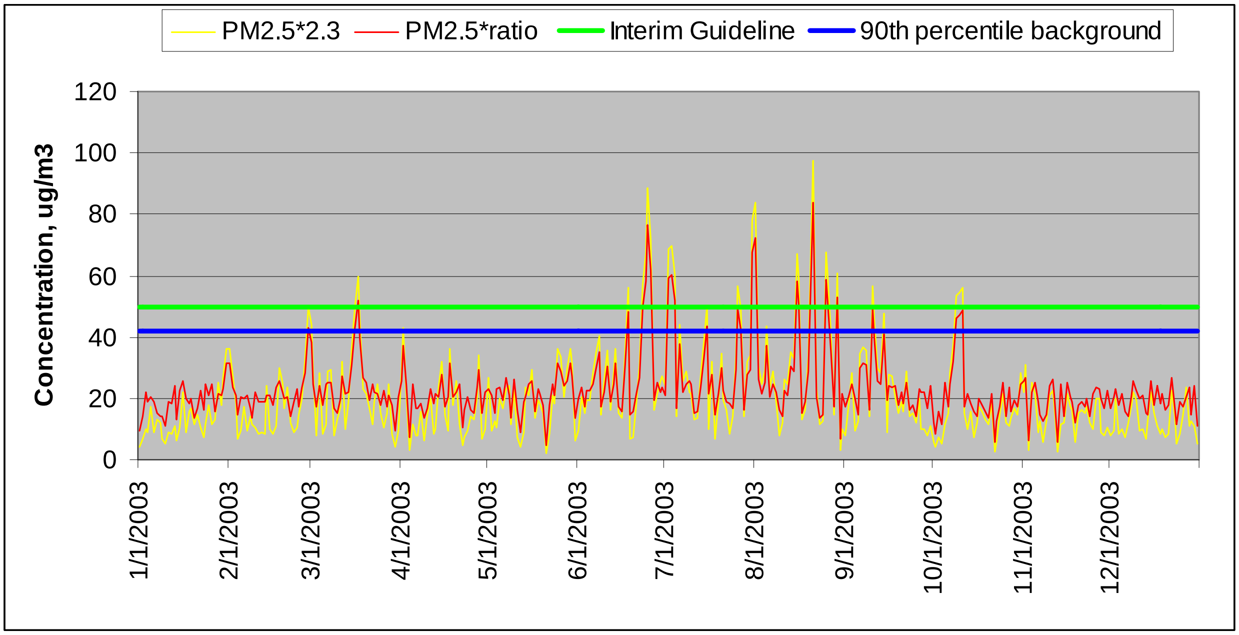
Table D.1 $PM_{10}/PM_{2.5}$ Ratio

	$PM_{10}/PM_{2.5}$	
Year	2006	2007
Windsor West	2.5	2.6
Windsor Downtown	2.1	2.0
Average	2.3	

Table D.2 $PM_{10}/PM_{2.5}$ Ratios by Concentration for Windsor West and Downtown, 2006 and 2007

$PM_{2.5}$ range, µg/m^3	$PM_{10}/PM_{2.5}$
0-5	5.0
5-10	2.7
10-15	2.0
15-20	1.7
>20	1.5

Figure D.1 Daily Background Concentrations of PM_{10}



One other data check was performed by examining PM_{10} and $PM_{2.5}$ ratios for published Air Quality Data for Ontario. Table D.3 shows PM_{10} and $PM_{2.5}$ ratios for Ontario locations that monitored for both PM_{10} and $PM_{2.5}$. The monitoring may have occurred at different stations within the cities indicated, but for the purpose of determining a suitable ambient concentration, the data check is worthwhile to verify the general range of ratios. As can be seen in Table D.3, the typical $PM_{10}/PM_{2.5}$ ratios are somewhere between 2-3 with higher ratios at lower $PM_{2.5}$ concentrations which is consistent with the ratios specific to Windsor shown in Table D.1 and in Table D.2. Accordingly, applying a ratio of 2.3 to the $PM_{2.5}$ daily concentrations can be considered indicative of daily PM_{10} concentrations.

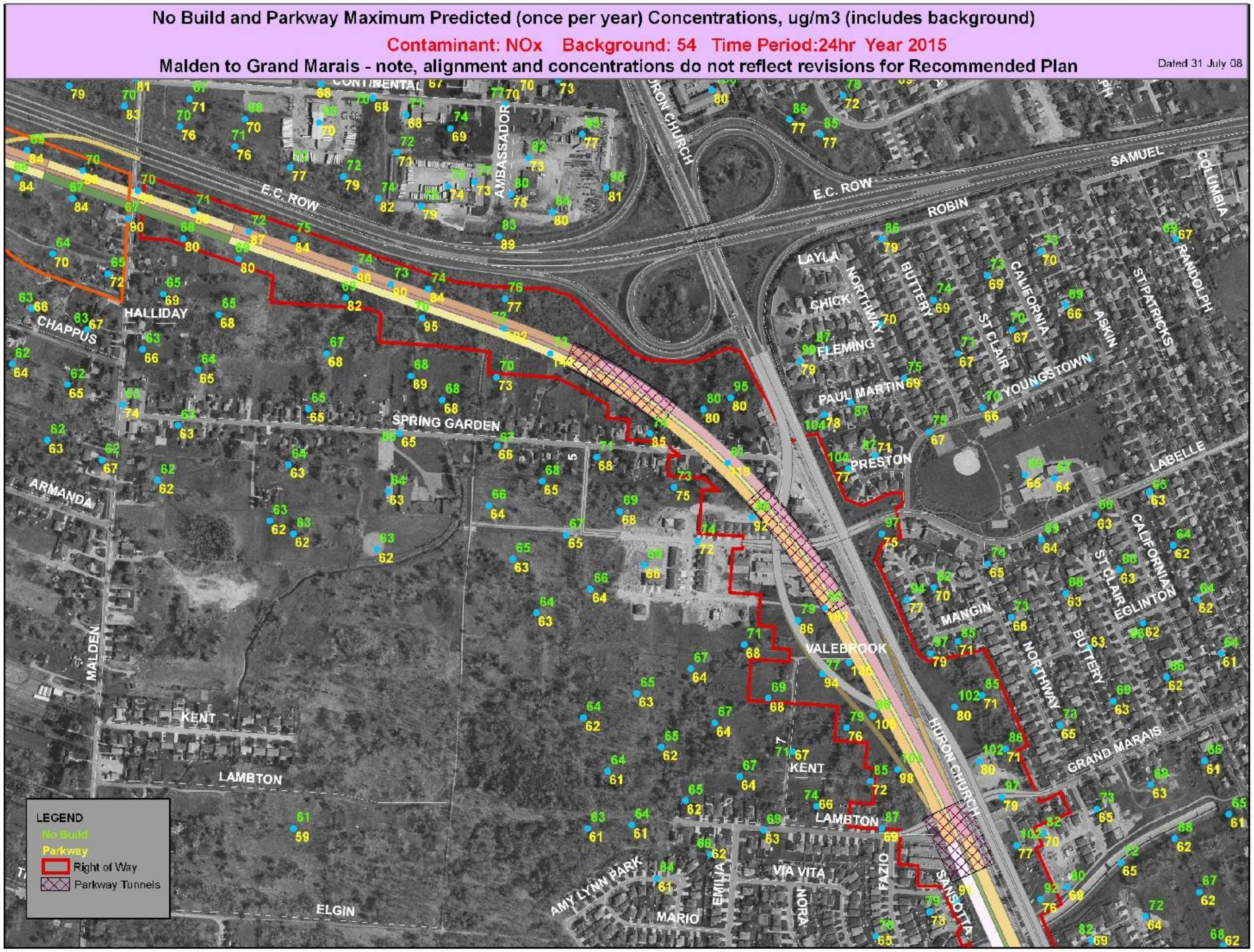
Table D.3 $PM_{10}/PM_{2.5}$ Ratios In Ontario

Ratios		Percentiles ($PM_{2.5}$ concentration range in brackets)							
Year	**City**	**10%** (0-2 µg/m³)	**30%** (2-5 µg/m³)	**50%** (5-8 µg/m³)	**70%** (8-13 µg/m³)	**90%** (13-24 µg/m³)	**99%** (24-44 µg/m³)	**Mean** (11 µg/m³)	**Max 24 h**
1999	Etobicoke	1.6	1.9	1.9	1.7	1.6	1.7	1.7	1.4
2000		8.0	3.5	2.9	2.3	2.1	2.2	2.5	2.3
2001		4.0	2.6	2.4	2.1	2.0	1.8	2.2	1.9
1999	Hamilton	2.0	2.7	3.0	3.3	3.4	6.2	3.6	8.2
2000		4.0	3.1	2.8	2.6	2.8	3.4	2.9	2.6
2001		4.0	3.4	2.7	2.9	2.7	2.8	2.9	2.1
2000	Sarnia	-	3.0	2.3	1.8	1.6	1.5	1.9	1.4
2001		6.0	3.3	2.1	1.9	1.7	1.4	2.0	1.4
2000	Sault Ste. Marie	-	2.7	1.8	1.4	1.3	1.6	1.6	1.4
2000	Toronto	6.5	3.0	2.6	2.1	1.8	1.8	2.2	1.5
2001		4.7	3.3	2.5	2.3	2.0	1.7	2.2	1.4
1999	Windsor	2.3	1.9	1.7	1.6	1.3	1.3	1.5	1.1
2000		9.0	3.5	2.5	2.3	2.1	1.9	2.5	1.9
2001		8.0	3.5	2.7	2.3	2.2	1.8	2.4	1.8
	average	**5.0**	**2.9**	**2.4**	**2.2**	**2.0**	**2.2**	**2.3**	**2.2**

APPENDIX E

ADDITIONAL PLOTS

NO_x


No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (includes background)
Contaminant: NOx Background: 54 Time Period:24hr Year 2015
Malden to Grand Marais - note, alignment and concentrations do not reflect revisions for Recommended Plan
Dated 31 July 08
E.C. ROW
HALLIDAY
CHAPPUS
SPRING GARDEN
ARMANDA
MALDEN
KENT
LAMBTON
ELGIN
AMBASSADOR
VALEBROOK
PRESTON
MANGIN
GRAND MARAIS
LABELLE
YOUNGSTOWN
HURON CHURCH
SAMUEL
ROBIN
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels

No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (includes background)

Contaminant: PM10 Background: 42 Time Period:24hr Year 2035

Grand Marais to Todd/Cabana

Dated 31 July 08


No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (includes background)
Contaminant: NOx Background: 54 Time Period:24hr Year 2015
Todd/Cabana to Cousineau
Dated 31 July 08
CABANA
SANTO
TODD
GOULD
DAYTONA
MARGURIET
VILLA BORGHESE
BORRELLI
ORA
PRAIRIE
SOUTHWINDS
GERAEDTS
AVON
MOUNT CARMEL
LENNON
STRATFORD
MOUNT ROYAL
VILLA MARIA
EDEN
CHURCHILL
MOUNT SINAI
MITCHELL
ASHFIELD
TALBOT
HURON CHURCH LINE
BROOKLYN
NORMANDY
DISPUTED
NORTHWAY
BETTS
ST CLAIR
COUSINEAU
TRILLIUM
HERITAGE
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels

No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (includes background)

Contaminant: NOx Background: 64 Time Period:24hr Year 2015

Cousineau to Howard

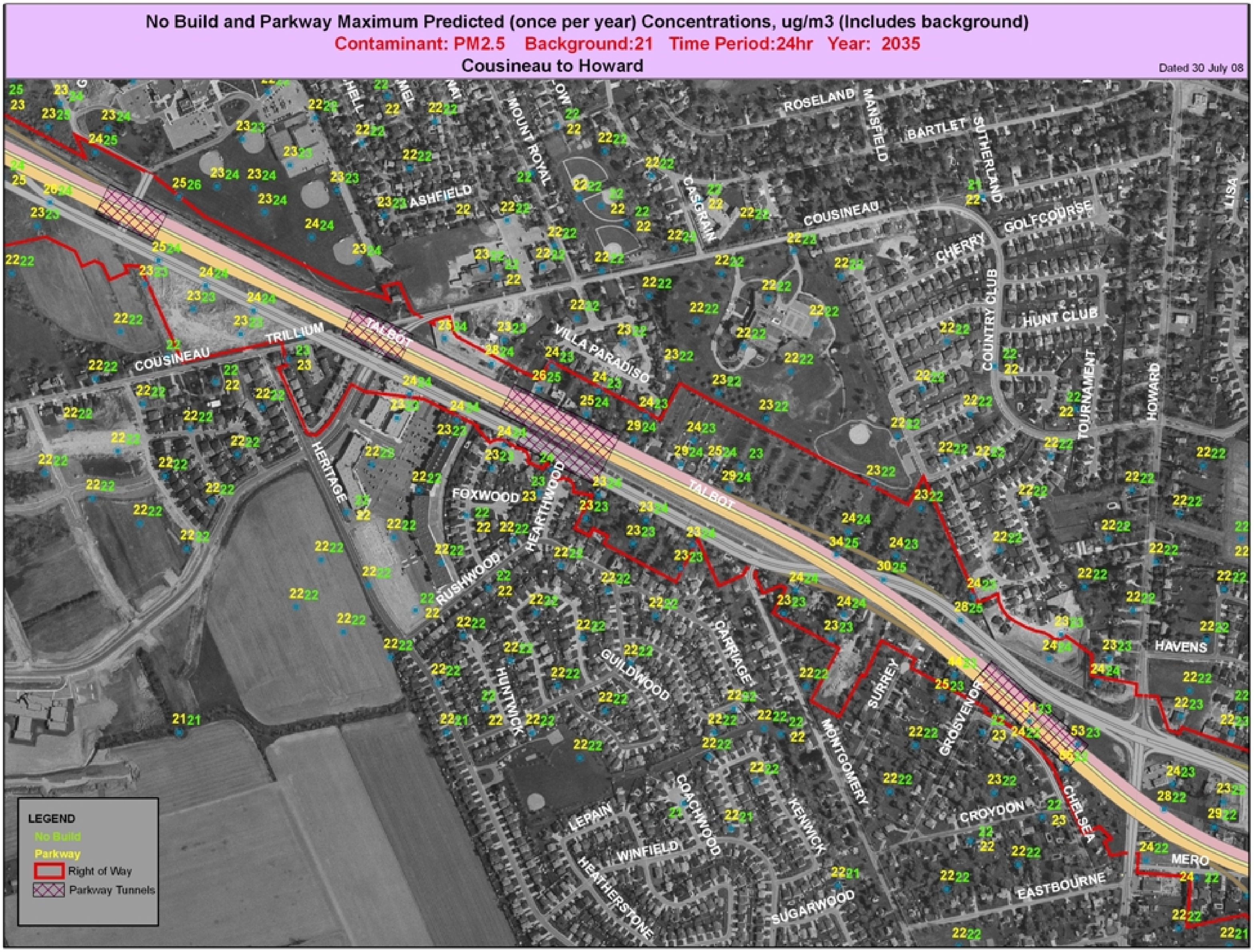
Dated 31 July 08

$PM_{2.5}$


No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes background)
Dated 30 July 08
Contaminant: PM2.5 Background:21 Time Period:24hr Year: 2035
Malden to Grand Marais - Note, alignment and concentrations along Spring Garden does not reflect revised alignment for Recommended Plan
CONTINENTAL
AMBASSADOR
E.C. ROW
SAMUEL
COLUMBIA
SIERRA
ROBIN
LAYLA
CHICK
FLEMING
PAUL MARTIN
PRESTON
BUTTERY
CALIFORNIA
ST CLAIR
YOUNGSTOWN
ASKIN
ST PATRICKS
RANDOLPH
PARTINGTON
JAMAICA
LABELLE
RIVIERA
SKYLINE
HALLIDAY
CHAPPUS
SPRING GARDEN
ARMANDA
MALDEN
KENT
LAMBTON
BRISTOL
ELGIN
HURON CHURCH
MANGIN
VALEBROOK
EGLINTON
NORTHWAY
GRAND MARAIS
BALMORAL
NORFOLK
SANSOTTA
VIA VITA
NORA
EMILIA
MARIO
DONNA
AMY LYNN PARK
FAZIO
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels


No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes background)
Contaminant: PM2.5 Background:21 Time Period:24hr Year: 2035
Grand Marais to Todd/Cabana
Dated 30 July 08
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels
LAMBTON
VIA VITA
SANSOTTA
HURON CHURCH
EMILIA
NORA
MARIO
AMY LYNN PARK
DONNA
FAZIO
GRATIOT
CALIFORNIA
NORFOLK
RANDOLPH
RANKIN
MARK
NORTHWAY
PULFORD
LIBERTY
ST PATRICKS
CHARLEVOIX
ROXBOROUGH
GLENWOOD
BEALS
ASKIN
SPRING
SUMMER
AUTUMN
WINTER
LANSING
REDDOCK
CABANA
BETTS
ST CLAIR
DAYTONA
SANTO
PRAIRIE
SOUTHWINDS
BONDY
HASTINGS
TODD
TALBOT
GOULD
MARGURIET
VILLA BORGHESE
BORRELLI
ORA
CABOT
CANADA
DALTON
OXLEY
BISHOP
BAGLEY
CADY


No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes background)
Contaminant: PM2.5 Background:21 Time Period:24hr Year: 2035
Todd/Cabana to Cousineau
Dated 30 July 08
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels
TODD
GOULD
CABANA
SANTO
MARGUERIET
VILLA BORGHESE
BORRELLI
ORA
PRAIRIE
SOUTHWINDS
GERAEDTS
AVON
LENNON
MOUNT CARMEL
STRATFORD
VILLA MARIA
EDEN
CHURCHILL
MITCHELL
MOUNT SINAI
MOUNT ROYAL
CASGRAIN
WHITTIER
ASHFIELD
TALBOT
BROOKLYN
NORMANDY
HURON CHURCH LINE
DISPUTED
DAYTONA
NORTHWAY
BETTS
ST CLAIR
COUSINEAU
TRILLIUM
HERITAGE
HOMESTEAD


No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes background)
Contaminant: PM2.5 Background:21 Time Period:24hr Year: 2035
Cousineau to Howard
Dated 30 July 08
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels
ROSELAND
MANSFIELD
BARTLET
SUTHERLAND
MOUNT ROYAL
ASHFIELD
CASGRAIN
COUSINEAU
GOLFCOURSE
CHERRY
COUNTRY CLUB
HUNT CLUB
TOURNAMENT
HOWARD
LISA
TALBOT
TRILLIUM
VILLA PARADISO
HERITAGE
FOXWOOD
HEARTHWOOD
RUSHWOOD
HUNTWICK
GUILDWOOD
CARRIAGE
SURREY
MONTGOMERY
GROSVENOR
HAVENS
CROYDON
CHELSEA
MERO
EASTBOURNE
KENWICK
COACHWOOD
LEPAIN
WINFIELD
HEATHERSTONE
SUGARWOOD

PM_{10} – Concentrations

No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (includes background)

Contaminant: PM10 Background: 42 Time Period:24hr Year 2035

Grand Marais to Todd/Cabana

Dated 31 July 08

No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes 90th Percentile background)

Dated 30 July 08

Contaminant: PM10 Background: 42 Time Period: 24hr Year: 2035

Todd/Cabana to Cousineau


No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes 90th Percentile background)
Dated 30 July 08
Contaminant: PM10 Background: 42 Time Period: 24hr Year: 2035
Cousineau to Howard
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels

PM_{10} – Exceedances


No Build and Parkway Maximum Predicted Exceedances, days (Includes 90th Percentile background)
Contaminant: PM10 Background:42 Time Period:24hr Year: 2035
Grand Marais to Todd
Dated 30 July 08
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels
LAMBTON
VIA VITA
SANSOTTA
EMILIA
NORA
MARIO
DONNA
AMY LYNN PARK
FAZIO
GRATIOT
HURON CHURCH
CALIFORNIA
NORFOLK
NORTHWAY
PULFORD
LANSING
REDDOCK
BONDY
TODD
GOULD
DAYTONA
TALBOT
BETTS
ST CLAIR
CABANA
SANTO
MARGUERITE
BORRELLI
ORA
PRAIRIE
SOUTHWINDS
RANDOLPH
RANKIN
ST PATRICKS
ASKIN
LIBERTY
ROXBOROUGH
GLENWOOD
CHARLEVOIX
BEALS
SPRING
SUMMER
AUTUMN
WINTER
MARK
DALTON
OXLEY
BISHOP
BAGLEY
CADY
WYOMING

No Build and Parkway Maximum Predicted Exceedances, days (Includes 90th Percentile background)

Dated 30 July 08

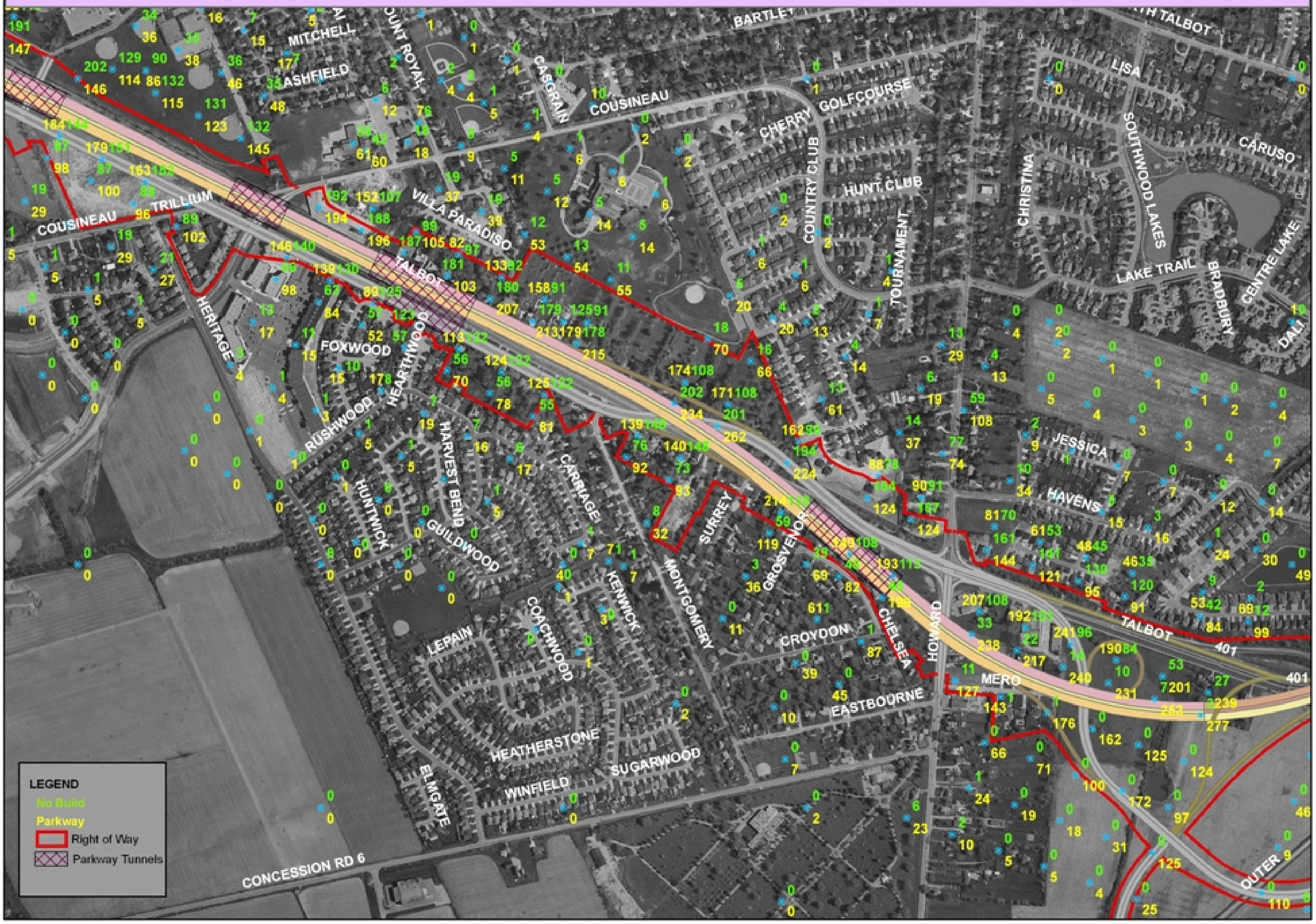
Contaminant: PM10 Background:42 Time Period:24hr Year: 2035

Todd/Cabana to Cousineau

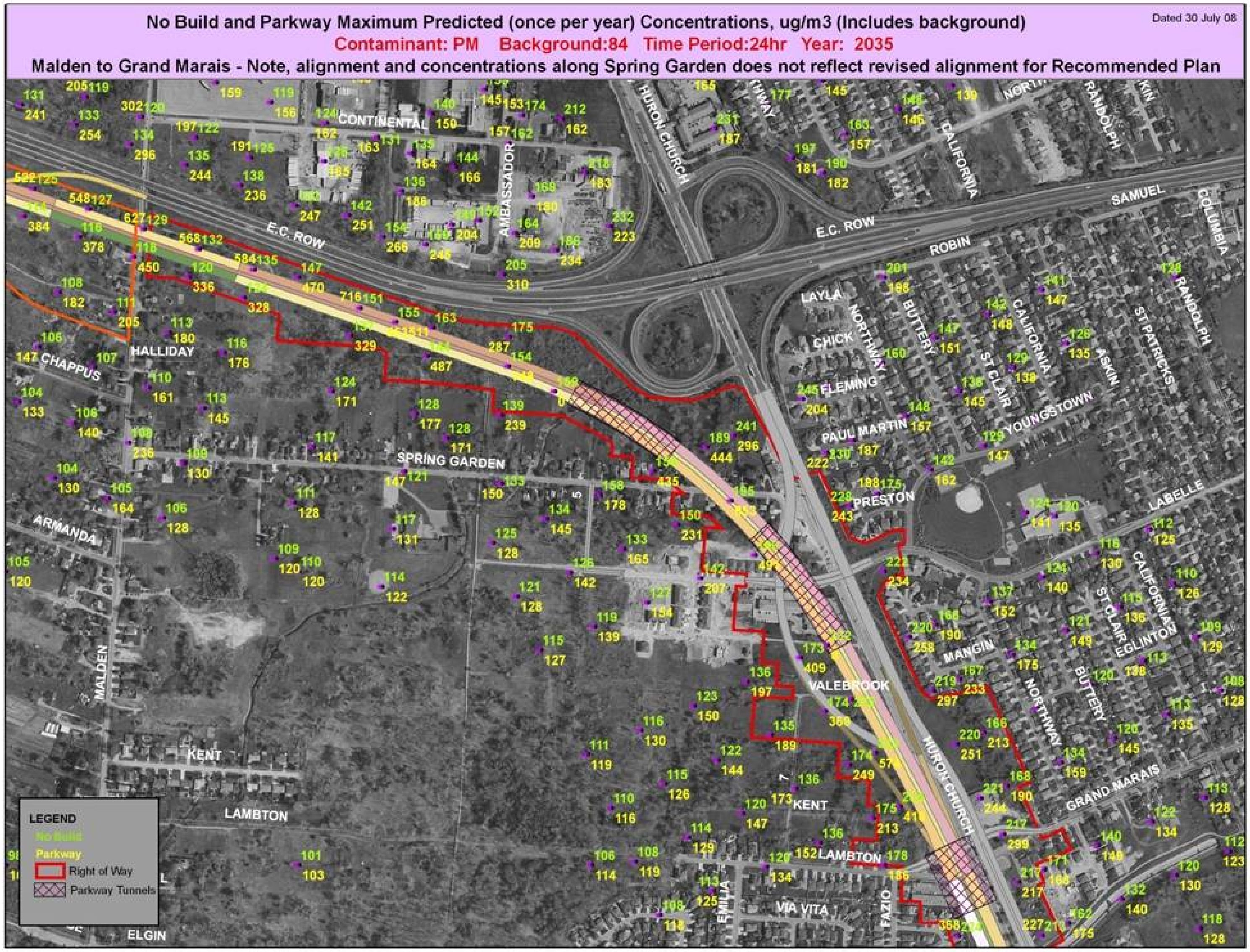
No Build and Parkway Maximum Predicted Exceedances, days (Includes 90th Percentile background)

Contaminant: PM10 Background: 42 Time Period: 24hr Year: 2035

Cousineau to Howard



PM – Concentrations




No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes background)
Dated 30 July 08
Contaminant: PM Background:84 Time Period:24hr Year: 2035
Grand Marais to Todd/Cabana
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels
KENT
LAMBTON
VIA VITA
SANSOTTA
EMILIA
NORA
DONNA
FAZIO
GRATIOT
HURON CHURCH
GRAND MARAIS
BALMORAL
CALIFORNIA
NORFOLK
MASSEY
MARK
EVERTS
CURRY
MCKAY
RICHARDIE
RANDOLPH
RANKIN
ROXBOROUGH
GLENWOOD
LIBERTY
CHARLEVOIX
ST PATRICKS
BEALS
PARKSIDE
NORTHWAY
PULFORD
ASKIN
SPRING
SUMMER
AUTUMN
WINTER
ST GABRIEL
LANSING
REDDOCK
BETTS
ST CLAIR
CABANA
SANTO
PRAIRIE
SOUTHWINDS
DAYTONA
BORRELLI
TALBOT
TODD

No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes background)

Dated 30 July 08

Contaminant: PM Background:84 Time Period:24hr Year: 2035

Todd/Cabana to Cousineau

No Build and Parkway Maximum Predicted (once per year) Concentrations, ug/m3 (Includes background)

Dated 30 July 08

Contaminant: PM Background:84 Time Period:24hr Year: 2035

Cousineau to Howard

PM – Exceedances

No Build and Parkway Maximum Predicted Exceedances, days (Includes 90th Percentile background)

Dated 30 July 08

Contaminant: PM Background:84 Time Period:24hr Year: 2035

Grand Marais to Todd


No Build and Parkway Maximum Predicted Exceedances, days (Includes 90th Percentile background)
Dated 30 July 08
Contaminant: PM Background: 84 Time Period:24hr Year: 2035
Todd to Cousineau
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels
LANSING
REDDOCK
HURON CHURCH
NORTHWAY
BETTS
ST CLAIR
DAYTONA
TODD
GOULD
SANTO
MARGURIET
BORRELLI
ORA
PRAIRIE
SOUTHWINDS
AUTUMN
WINTER
RANDOLPH
CHERRYLAWN
CURRY
AVON
MOUNT CARMEL
LENNON
STRATFORD
LONGFELLOW
CASGRAIN
ROSELAND
CABANA
KENNEDY
VILLA MARIA
CHURCHILL
EDEN
MITCHELL
MOUNT SINAI
MOUNT ROYAL
ASHFIELD
GERAEDTS
TALBOT
BAGLEY
DELMAR
CADY
BRIDGEWAY
BROOKLYN
NORMANDY
HURON CHURCH LINE
DISPUTED
COUSINEAU
TRILLIUM
HERITAGE


No Build and Parkway Maximum Predicted Exceedances, days (Includes 90th Percentile background)
Dated 30 July 08
Contaminant: PM Background: 84 Time Period:24hr Year: 2035
Cousineau to Howard
LEGEND
No Build
Parkway
Right of Way
Parkway Tunnels
TRILLIUM
HERITAGE
HOMESTEAD
HEARTHWOOD
RUSHWOOD
HARVEST BEND
HUNTWICK
GUILDWOOD
CARRIAGE
COACHWOOD
LEPAIN
BLACKTHORN
HEATHERSTONE
WINFIELD
CONCESSION RD 6
SUGARWOOD
KENWICK
MONTGOMERY
SURREY
GROSVENOR
CROYDON
EASTBOURNE
CHELSEA
HOWARD
MERO
ROYAL
VILLA PARADISO
TALBOT
CHERRY
COUNTRY CLUB
HUNT CLUB
CLUBHOUSE
TOURNAMENT
CHRISTINA
SOUTHWOOD LAKES
LAKE TRAIL
JESSICA
HAVENS
ALPENROSE
401