

**TECHNICAL APPENDIX
AIR QUALITY IMPACT ASSESSMENT
OF THE
HIGHWAY 7 CORRIDOR PUBLIC TRANSIT
IMPROVEMENTS ENVIRONMENTAL ASSESSMENT**

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EXECUTIVE SUMMARY

This study examines existing air quality in an area bounded by Steeles Avenue on the South, 19th Avenue on the North, Highway 50 on the West and the York/Durham line on the east. Within this area, the York Region Rapid Transit Plan has identified a number of rapid transit projects. This report examines the Highway 7 key corridor.

The study shows, through monitoring and modelling, that the existing air quality in the area meets provincial requirements most of the time.

It also identifies that the future air quality will be better than the existing air quality, primarily as a result of improvements in vehicle engine technology and fuels except for PM which will largely be driven by fugitive emissions from the road surfaces.

The impact of BRT on this new future can be summarized as:

- bus rapid transit (BRT) will create a small additional improvement for all pollutants except PM;
- for PM, the BRT will slow the rate of “*business as usual*” PM increases; and
- the introduction of BRT will result in a small net decrease in greenhouse gas emissions.

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1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

The York Region Rapid Transit Plan (YRTP) has its origins in the York Region Transportation Master Plan (TMP) approved by York Region Council in June 2002. The TMP identified a program of rapid transit projects to form a rapid transit network in York Region with intermodal connections to other Regions in the Greater Toronto Area (GTA). The key corridors of this proposed rapid transit network include Yonge Street, Highway 7, Vaughan Corporate Centre-York University/Spadina subway, and Markham Centre-Don Mills subway station/Sheppard subway. Three of the four corridors have inter-regional connections to the Toronto Transit Commission (TTC) subway system.

As part of its implementation strategy for rapid transit, York Region established a public-private partnership with York Consortium 2002. The initial agreement with the Consortium is to complete the environmental assessment (EA) studies required for the four key corridors.

The YRTP implementation strategy is based on three phases:

- Phase 1 – Quick Start program [to create high occupancy vehicle (HOV) lanes, bus lanes signal priority, transit centres, stations and stops];
- Phase 2 – Full Rapid Transit Network (will include execution of agreement with both TTC and GO Transit to integrate services); and
- Phase 3 – Growth Related Expansion.

As part of the EA process, SENES Consultants Limited (SENES) was retained by York Consortium 2002 to assess the Phase 2 and 3 air quality impacts of the YRTP on the Highway 7 Corridor.

If development and population growth continues (“*business as usual*”), the transportation system in York Region by 2021 will have to run at a higher capacity. From an air quality point of view, this would mean increasing emissions. Luckily, as a result of improved engine technologies, tailpipe emissions from vehicles are expected to drop dramatically over the next 10 years. However, for particulate matter, while tailpipe emissions will reduce, resuspended particulate from increased traffic on roads (thrown up by the action of tires on the roadway) will continue to increase.

It is within this context, that a future case with and without BRT on Highway 7 is examined.

1.2 STUDY AREA

The study area nominally includes the area bounded by Steeles Avenue on the South, 19th Avenue on the North, Highway 50 on the west and the York/Durham Line on the east. For air quality studies, however, geographical boundaries do not affect the dispersion and impact of air pollutants. As a result, the air quality boundaries are expanded or contracted to study particular aspects of any project. Where possible, the project boundaries are used.

In the Highway 7 Corridor between Highway 50 and the York-Durham Line, the preferred surface rapid transit route comprises a dedicated transitway mostly in the median of Highway 7 except for diversions along Centre and Bathurst Streets and through the planned Markham Regional Centre between Warden Avenue and Kennedy Road. At certain constrained locations the rapid transit service will operate in mixed traffic. The route also includes the Vaughan North-South Link which will initially consist of surface rapid transit along Jane and Keele Streets from Highway 7 to Steeles Avenue and ultimately, an extension of the Spadina Subway to Highway 7 on an alignment west of Jane Street.

1.3 AIR QUALITY IMPACTS OF PROJECT ON THE ENVIRONMENT

Air quality manifests itself in two broad ways – through pollutant concentrations and through deposition of pollutants to various surfaces. Air quality is usually assessed through the examination of the pollutants that are linked with a particular project. In this case, the pollutants of concern are:

- dust (particles of sizes smaller than 44 microns): three specific size ranges are important – Total Suspended Particulate (TSP), which are those particles 44 microns in diameter and smaller, PM₁₀, which are those particles 10 microns in diameter and smaller and PM_{2.5}, which are those particles 2.5 microns in diameter and smaller. Dust is blown up into the air by the wind, by the action of the wheels of a vehicle on road surfaces and directly from the exhaust of the engines;
- sulphur dioxide (SO₂): a gas formed by the combustion of sulphur impurities in the fuel. It is emitted in vehicle exhaust;
- carbon monoxide (CO): a gas formed by the incomplete combustion of carbon-based fuels. It is emitted in vehicle exhaust;
- nitrogen dioxide (NO₂): a gas formed when anything is burned in air. It is emitted in vehicle exhaust; and
- carbon dioxide (CO₂): a gas formed by the complete combustion of carbon-based fuels, and is emitted from the exhaust pipes of all vehicles.

2.0 EXISTING ENVIRONMENTAL CONDITIONS

2.1 CLIMATE AND METEOROLOGICAL DATA

2.1.1 Introduction

Throughout the lower atmosphere (the troposphere), the weather varies widely in both time and space. The heat balance at the surface is disturbed when a single cloud moves across the sun.

Meteorology (weather) is the key to understanding air quality. The essential relationship between meteorology and atmospheric dispersion involves the wind in the broadest sense of the term. Wind fluctuations over a very wide range of time and space scales accomplish dispersion and strongly influence other processes associated with it.

In general, the wind flow over the earth is induced by the large-scale pressure variations commonly shown on synoptic weather charts. The intensity of these pressure systems and their normal positions, or trajectories determines the general distribution of winds over a given area. Within this large-scale framework, there are many factors that influence the details of air movement in both the vertical and horizontal directions. For most air quality problems, it is the combination of the broad and the detailed patterns that is important.

These patterns dictate the location and distance from a source that the pollutants will travel. The characterization of the existing climatological conditions in the vicinity of a source of pollutants is, therefore, a critical aspect of assessing air quality.

The key parameters that must be taken into account are wind, temperature and atmospheric structure. The importance of these parameters is outlined below.

2.1.2 Wind

Wind has two significant components – direction and speed.

Direction

Wind direction is reported as the direction **from** which the wind blows and is based on surface (10 m) observations. Over the course of a year, wind usually blows in all directions, but with varying frequencies. Certain directions occur more frequently than others. These are known as the prevailing wind directions.

Figure 2.1 presents a wind rose for Pearson International Airport for the years 1996 - 2001. Wind direction in the area varies considerably over the period. The prevailing winds are from the north and the west, with winds blowing from these sectors approximately 45 percent of the time. Due to the complexity of the models used for this project, a single year of meteorology (2001) was used. The year 2001 was used because it was the base year for the study. Both the 6-year average and 2001 data are presented in Figure 2.1. While the best match for the period is 1997, SENES Consultants Limited used 2001 data because 2001 is the base year for the study, and 2001 traffic counts were used for the emissions calculations.

Speed

The distribution of average wind speed at the Pearson International Airport station is also presented in Figure 2.1. The average wind speed, based on the 1996-2001 period, is 4.0 m/s, with calms (i.e. wind speeds less than 1 m/s) occurring approximately 5% of the time.

The concentration of dust in the air decreases with increasing wind speed, as a result of dilution. When wind speeds are high, there is good dispersion of gases and particles throughout the atmosphere, but more potential for re-suspension of surface dust. When wind speeds are near zero, local circulation can lead to very high pollutant concentrations near the surface. Wind speed also increases with height as surface friction decreases. This leads to better dispersion from smokestacks since the wind speed is higher aloft. The lower speeds near the ground are the driving force behind the transport of pollutants from vehicles.

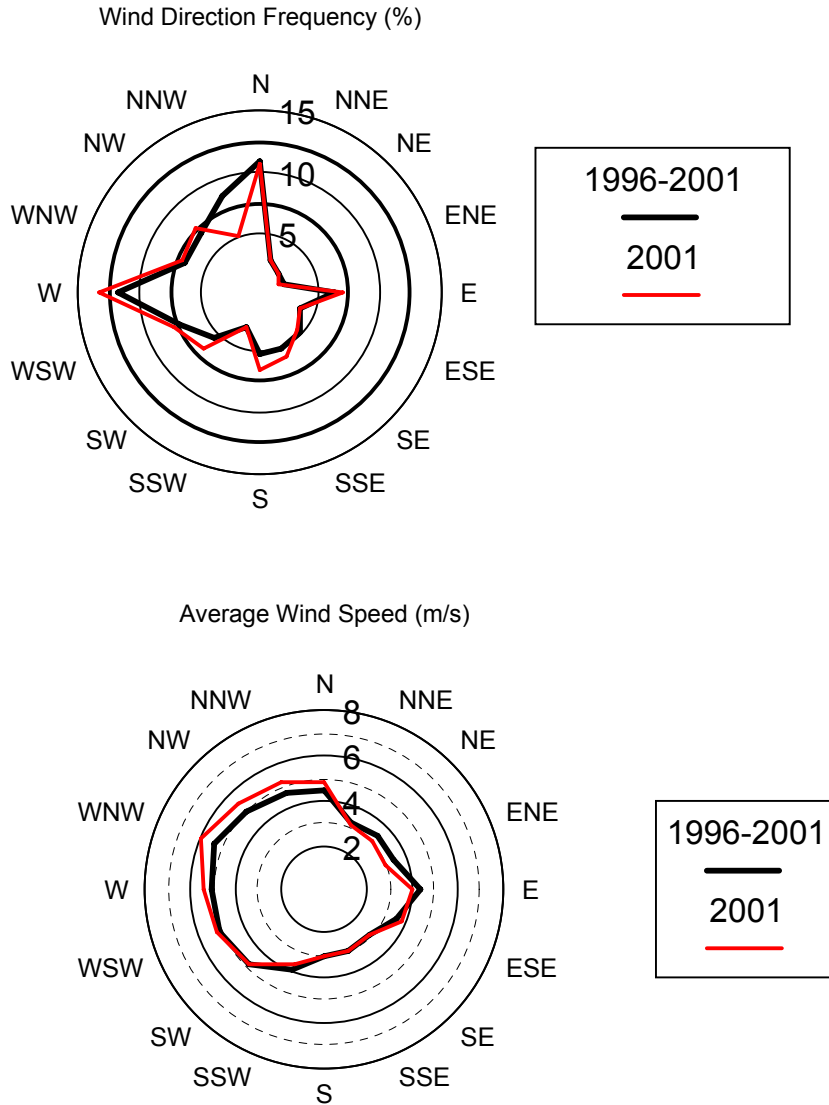
2.1.3 Temperature

There are two key temperature effects that influence air quality – temperature near the surface and temperature aloft.

Temperature near the Surface

Temperature near the surface can greatly affect the dispersion of particulate matter. When it is hot, the surface can dry out, making particulate matter available to be picked up by the wind. Cool temperatures, on the other hand, enable the surface to retain moisture longer, thereby reducing windblown dust. The project location is typical of the Southern Ontario lakes region with relatively cool spring and fall seasons, hot humid summers and cold, wet winters.

FIGURE 2.1
WIND ROSE – TORONTO PEARSON INTERNATIONAL AIRPORT 1996-2001



Temperature Aloft

The change in temperature vertically is the key controlling parameter in the dispersion of gases and particles.

Atmospheric stability is an inherent feature of the vertical temperature structure. It is a measure of the amount of vertical motion in the atmosphere, and hence the atmosphere's ability to mix pollutants. A stable atmosphere has little vertical motion (is less turbulent) and cannot disperse pollutants as well as a more turbulent, unstable atmosphere. A number of classification schemes have been developed for describing stability classes.

An atmospheric stability classification scheme, developed by Pasquill-Gifford and modified by Turner, is now widely used. Six atmospheric stability classes, A through F, are defined using commonly measured meteorological parameters including wind speed, temperature, lapse rate (rate of change of temperature with height), degree of solar insolation (the strength of the sun at a particular time of day) and the amount of cloud cover.

Class A is the least stable class, while class F is the most stable. The intermediate Class D is described as a neutral atmosphere. Classes E and F represent progressively more stable conditions, and Classes C, B and A progressively more unstable conditions, respectively. A statistical summary of the atmospheric stability using the Turner method, based on the results of the PCRAMMET Model (U.S. EPA regulatory meteorological pre-processor) is presented in Table 2.1. This table outlines the distribution of stability classes for Pearson International Airport for the 1996 to 2001 period. Stable conditions can produce higher concentrations near the ground because of reduced vertical mixing. These conditions occur approximately 30% of the time.

**TABLE 2.1
STABILITY CLASS DISTRIBUTION 1996-2001 IN PERCENT
TORONTO PEARSON INT'L AIRPORT**

Stability	1996	1997	1998	1999	2000	2001	Period Average
A	0.7	0.7	0.7	0.3	0.4	0.3	0.5
B	4.5	4.5	4.8	4.3	4.0	4.1	4.4
C	9.6	10.3	11.4	11.5	10.5	10.4	10.6
D	54.5	55.7	51.8	53.2	58.3	58.3	55.3
E	13.5	13.2	14.5	14.5	13.7	13.7	13.9
F	17.2	15.6	16.9	16.2	13.2	13.2	15.4

2.1.4 Atmospheric Structure

The structure of the atmosphere is also defined by the vertical temperature change in another fundamental way – by setting a limit on the vertical dimension through which pollutants can mix.

This vertical extent through which a plume of pollutants can be mixed is called the “mixing height”. With a higher mixing height there is a larger volume of air available within which the pollutants can mix, producing lower concentrations. With a lower mixing height, the plume may become trapped close to the ground, resulting in higher concentrations.

The concept of mixing height is founded on the principle that heat transferred to the atmosphere at the earth's surface results in convection (vigorous vertical mixing) and the establishment of a dry-adiabatic lapse rate (Holzworth 1967). In general, mixing height does not have much effect on modelled annual and 24-hour average ground level concentrations (Young and Radonjic, 1993). For 1-hour concentrations, however, mixing height can be very important. The use of variable mixing heights, that are as close as possible to the actual conditions, improves the ability of the model to accurately predict downwind concentrations.

Mixing height is calculated from the vertical temperature profile measured by weather balloon ascents. The distance between stations that release weather balloons is approximately 300 kilometres. The closest upper air station to Toronto is Buffalo, NY. Because mixing height is a regional parameter, the data measured in Buffalo is representative of conditions over Toronto.

The surface values and the twice-daily upper air measurements are processed through the U.S. EPA meteorological pre-processor (PCRAMMET) to combine surface and upper air measurements into the hourly mixing heights, which are required by the model. Mixing heights calculated to be less than 10 m, were set to 10 m.

2.2 AIR QUALITY STANDARDS

Several measures are used to describe airborne dust impacts from roadways. Those used in this assessment are as follows:

- Total Suspended Particulate (TSP);
- Fine Particulate Matter less than 10 and 2.5 microns in diameter (PM₁₀ and PM_{2.5});
- Dustfall;
- Sulphur Dioxide (SO₂);
- Nitrogen Oxides (NO_x);
- Ozone (O₃); and
- Carbon Monoxide (CO).

These contaminants are discussed in some detail in the remainder of this section.

Total Suspended Particulate (TSP)

Total Suspended Particulate (TSP), is often used to characterize air quality near a dust source. TSP is measured with a high-volume (Hi-Vol) sampler over 24 hours and consists of particles less than 44 µm in diameter. An annual average is calculated as the geometric mean of these samples measured every six days.

Under Ontario Regulation 337, an ambient air quality criterion is set for TSP. The ambient air quality criterion for TSP is 120 µg/m³ averaged over 24 hours, and the annual geometric mean of the 24-hour samples is 60 µg/m³.

The air quality criteria for TSP are summarized in Table 2.2.

TABLE 2.2
PROVINCIAL AIR QUALITY CRITERIA FOR TSP

Provincial: Ontario Ministry of the Environment		
Pollutant	Averaging Period	Ambient Air Quality Criteria
Total Suspended Particulates (TSP)	24 hours	120 µg/m ³
	1 year*	60 µg/m ³

Source: MOE (2001a)

* Geometric Mean

The ambient TSP standards and criteria were set to prevent a reduction in visibility. Particles suspended in the atmosphere reduce visibility or the visual range by reducing the contrast between an object being viewed and its background. This reduction is a result of particles scattering or absorbing light coming from both the object and its background, and from particles scattering light into the line of sight (Robinson, 1977). Particles with a radius of 0.1 to 1.0 µm are most effective at reducing visibility. In a rural area where TSP levels are on the order of 30 µg/m³, the visibility would be about 40 km. At 150 µg/m³, a common urban concentration, the range would be reduced to about 8 km. The MOE 24-hour criterion of 120 µg/m³ is based on a visual range of about 10 km.

While visual range can be important, SENES made the decision that the assessment of impact should focus on health impacts (primarily driven by PM₁₀ and PM_{2.5}) and has not considered TSP any further in this report.

Fine Particulate Matter PM₁₀ and PM_{2.5}

Many studies over the past few years have indicated that fine particulate matter (PM₁₀ and PM_{2.5}) in the air is associated with various adverse health effects in people who already have compromised respiratory systems and suffer from asthma, chronic pneumonia and cardiovascular problems. However, the available studies have not been able to link the adverse health effects in such people to any one component of the pollution mix. Fine particulate matter is a mixture of chemically and physically diverse dusts and droplets, and some of these components may be important in determining the effects of PM₁₀ and PM_{2.5} on health.

The current 24-hour regulatory limits for fine particulate matter are presented in Table 2.3 as follows:

**TABLE 2.3
AIR QUALITY CRITERIA FOR PM₁₀ AND PM_{2.5}**

Provincial: Ontario Ministry of the Environment			
Pollutant	Averaging Period	Guideline Level	Ambient Air Quality Criteria
PM ₁₀	24 hours	Ontario Interim	50 µg/m ³
PM _{2.5}	24 hours	Canada-Wide Standard	30 µg/m ³

Dustfall

In developing an Ambient Air Quality Criterion (AAQC) for dustfall of 7 g/m²/30 days, the MOE used soiling data (e.g. surface build-up of dust) from various Ontario towns between 1951 and 1955, which indicated areas of relatively low soiling (11 to 15 g/m²/30 days), relatively moderate soiling (17 to 24 g/m²/30 days) and relatively heavy soiling (26 to 34 g/m²/30 days) (WHO, 1961). The air quality criteria for dustfall are summarized in Table 2.4.

**TABLE 2.4
AIR QUALITY CRITERIA FOR DUSTFALL**

Provincial: Ontario Ministry of the Environment		
Pollutant	Averaging Period	Ambient Air Quality Criteria
Dustfall	1 month	7.0 g/m ² /30 days
	1 year+	4.6 g/m ² /30 days

Source: MOE (2001a)
+ Arithmetic Average

Criteria Air Contaminants (NO_x, SO₂, CO, O₃)

Criteria Air Contaminants (CACs), including nitrogen oxides, sulphur oxides and carbon monoxide are common air pollutants released into the air typically by activities such as the combustion of fossil fuels. Nitrogen dioxide (NO₂) is a reddish brown, highly reactive gas that is formed in the atmosphere through the oxidation of nitric oxide (NO). Nitrogen oxides (NO_x), the term used to describe the sum of NO, NO₂ and other oxides of nitrogen, play a major role in the formation of ozone (O₃). Sulphur dioxide (SO₂) is a colourless gas that smells like burnt matches. It can be oxidized to sulphur trioxide, which, in the presence of water vapour, is readily transformed to sulphuric acid mist. SO₂ can be oxidized to form acid aerosols. SO₂ is a precursor to sulphates, which are one of the main components of respirable particles in the atmosphere. Carbon monoxide (CO) is a colourless, odourless, and at high levels a poisonous gas, formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust, which contributes about 60 percent of all CO emissions nationwide. High concentrations of CO generally occur in areas with heavy traffic congestion. Ozone (O₃) is formed via a complex, non-linear chain of photochemical reactions involving reactive species of VOCs, NO_x and the hydroxyl radical (OH). The amount of O₃ formed depends on the strength of the sunlight, the concentrations of NO_x and the availability of OH radicals to drive the reaction mechanisms. O₃ toxicity occurs in a continuum in which higher concentrations, longer exposure duration, and greater activity levels during exposure cause greater effects. Short-term acute effects include pulmonary function changes, increased airway responsiveness and airway inflammation, and other symptoms.

A recent study shows that 21% and 58% of the SO₂ and NO_x emissions from the City of Toronto are due to transportation sources (RWDI, 2001).

The MOE AAQCs for NO_x, SO_x, CO and O₃ are shown in Table 2.5

**TABLE 2.5
MOE AMBIENT AIR QUALITY CRITERIA FOR CRITERIA AIR CONTAMINANTS**

Compound	CAS No	Ambient Air Quality Criteria (AAQC)			
		Annual (µg/m ³)	24-hour (µg/m ³)	8-hour (µg/m ³)	1-hour (µg/m ³)
Nitrogen Oxides	10102-44-0	NS	200	NS	400
Sulphur Dioxide	7446-09-5	5	275	NS	690
Carbon Monoxide	630-08-0	NS	NS	15,700	36,200
Ozone	10028-15-6	NS	NS	134*	165

NS – No Standard
* Canada-Wide Standard.

Since Ozone (O₃) is largely driven by regional emissions, it has not been considered further in this report as any impact from the small BRT increment will be hidden within the error in the larger change to the future baseline.

2.3 EXISTING AIR QUALITY

2.3.1 Historical Ambient Monitoring Data

Table 2.6 outlines the measurement history at the MOE monitoring locations in, or near, the study area, and presents a summary of the parameters monitored. When there is no MOE criterion for a given averaging period, an equivalent standard for that averaging period was calculated using the standard peak-to-mean ratio approach (MOE, 1996). The table shows that historically SO₂, NO_x and CO have been well within the accepted standards, while O₃ and PM₁₀ concentrations have been observed at values about 50% higher than the standard occasionally. PM_{2.5} has exceeded the standard from time to time by as much as double the allowable concentration.

**TABLE 2.6
HISTORICAL AIR QUALITY DATA**

Pollutant	Averaging Time	Sampling Period	MOE criteria	Location #1 - Stouffville Works Yard (48002)		Location #2 - Yonge and Hendon (34020)	
				Min	Max	Min	Max
SO ₂	24-hr (mg/m ³)	1998 - 1999	275	ND	ND	3	45
	% of Standard		100%			1%	16%
O ₃	24-hr (mg/m ³)*	1998 - 2000	82	17	161	19	124
	% of Standard		100%	21%	196%	23%	151%
NO _x	24-hr (mg/m ³)	1998 - 2000	200	7	258	14	377
	% of Standard		100%	4%	129%	7%	189%
CO	1-hr (mg/m ³)	1998 - 1999	36,200	ND	ND	0	7615
	% of Standard		100%			0%	21%
	8-hr (mg/m ³)	1998	15,700	ND	ND	0	3495
	% of Standard		100%			0%	22%
PM ₁₀	24-hr (mg/m ³)	1998 - 2000	50	5	65	ND	ND
	% of Standard		100%	10%	130%		
PM _{2.5}	24-hr (mg/m ³)	1998 - 2000	30	ND	ND	4	58
	% of Standard		100%			13%	193%

* calculated equivalent 24-hour standard based on 1-hour standard of 165.

ND = No Data

2.3.2 SENES Measurement Program

Figure 2.2 presents the location of the existing MOE, as well as the study initiated, air quality monitoring locations. These locations were used to characterize the existing air quality in the study area by dividing the study area into four zones. These zones are defined as follows:

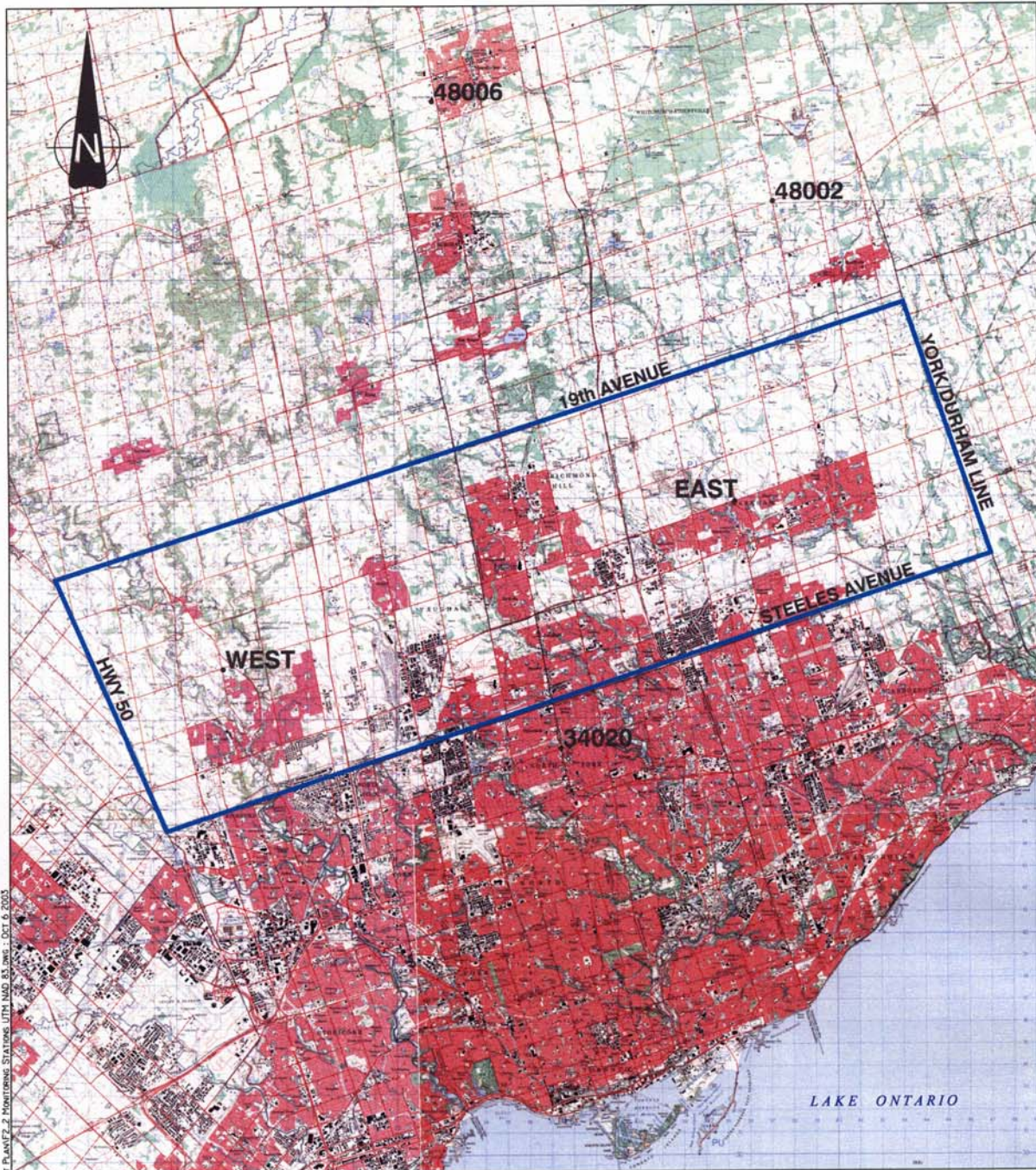
1. The Stouffville Works Yard Monitoring Location, where the MOE currently has an Ozone (O₃) and Weather Monitoring Station (Station 48002), is representative of the area between Highway 48 and York/Durham Line;
2. The Yonge and Hendon Monitoring Location was co-located with the MOE Station (Station 34020) that measures Sulphur Dioxide (SO₂), Ozone (O₃), Oxides of Nitrogen (NO_x), Carbon Monoxide (CO) and Fine Particulate (PM₁₀). Measurements at this station will be representative of the air quality along the Yonge Street Corridor from Highway 400 to Highway 404;
3. The #2 Aitken Circle Monitoring Location was sited near the intersection of 16th Avenue and Kennedy Road and will be representative of the air quality from Highway 404 to Highway 48; and
4. The Woodbine Centre Monitoring Location was sited in the snow removal works yard near the intersection of Highway 27 and Rexdale Boulevard. This location will be representative of the air quality between Highway 50 and Highway 400.

Table 2.7 summarizes the number of valid observations that were made as part of the sampling program for this project. The measurements were made in May 2003. The extra sampling was carried out in order to fill in spatial gaps in the existing MOE coverage. The data are not meant to be statistically valid but rather to show that the existing MOE stations represent the air quality in the area.

**TABLE 2.7
SUMMARY OF NUMBER OF VALID SAMPLES
SENES MEASUREMENT PROGRAM**

Station Name	*Passive SO ₂		*Passive O ₃		*Passive NO _x		CO	PM ₁₀	PM _{2.5}	Dustfall
	24-hr	30-day	24-hr	30-day	24-hr	30-day	10-min	24-hr	24-hr	30-d
#1 - Stouffville Yard	3	3	3	3	3	3	3	0	0	0
#2 - Yonge & Hendon	3	3	3	3	3	3	2	0	0	0
#3 - EAST - 1th & Kennedy	6	3	6	3	6	3	13	10	9	1
#4 - WEST - Woodbine	6	3	6	3	6	2	13	10	7	1
TOTALS	18	12	18	12	18	11	31	20	16	2

* passives sampling was done in triplicate so that 3 samples are equivalent to one period of sampling



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FIGURE 2.2

MONITORING STATIONS

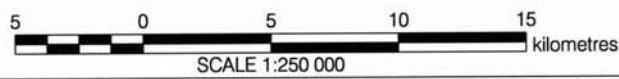


Table 2.8 presents a summary of the data from the project sampling stations in terms of average, maximum, minimum and percentage of the Ambient Air Quality Criteria (AAQC) set by the Province of Ontario. This table confirms the historical data, with SO₂ and CO well within the applicable standards. It also shows that PM can be up to 3 times the standard from time to time. This is further confirmed by the dustfall results that show, for the period of sampling, loadings over double the applicable standard. Daily average NO_x concentrations during the monitoring period were mostly below the standard. The daily average O₃ data was confirmed to be above the standard from time-to-time at all locations. The data also show, for the Highway 7 Corridor, that NO_x levels are equivalent to those near other corridors.

These data are used as part of the model characterization of the existing and future scenarios.

TABLE 2.8
SUMMARY OF PROJECT AIR QUALITY MONITORING

Pollutant	Averaging Time	MOE criteria	Location #1 - Works Yard Stouffville			Location #2 - Yonge and Hendon			Location #3 - 16th & Kennedy			Location #4 - Woodbine Centre		
			Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
SO ₂	24-hr (µg/m ³)	275	11	7	9	6	2	4	9	4	5	4	4	4
	% of Standard	100%	4%	3%	3%	2%	1%	1%	3%	1%	2%	1%	1%	1%
	equivalent 24-hr based on 30-day sample		14	12	13	24	23	23	18	15	16	30	29	30
	% of Standard		5%	4%	5%	9%	8%	8%	7%	5%	6%	11%	10%	11%
O ₃	24-hr (µg/m ³)*	82	19	10	15	17	7	11	16	3	8	35	3	16
	% of Standard	100%	24%	12%	19%	21%	9%	13%	19%	3%	10%	43%	3%	20%
	equivalent 24-hr based on 30-day sample		294	276	286	243	213	223	243	216	228	228	218	224
	% of Standard		359%	336%	349%	297%	260%	272%	297%	263%	279%	278%	266%	273%
NO _x	24-hr (µg/m ³)	200	53	49	51	150	140	145	77	18	42	107	21	62
	% of Standard	100%	26%	24%	25%	75%	70%	73%	39%	9%	21%	53%	10%	31%
	equivalent 24-hr based on 30-day sample		74	69	72	242	216	231	157	153	155	272	0	173
	% of Standard		37%	35%	36%	121%	108%	115%	79%	76%	77%	136%	0%	87%
CO	1-hr (µg/m ³)	36,200	406	406	406	813	418	447	1626	406	424	813	406	427
	% of Standard	100%	1%	1%	1%	2%	1%	1%	4%	1%	1%	2%	1%	1%
PM ₁₀	24-hr (µg/m ³)	50	ND	ND	ND	ND	ND	ND	130	14	44	101	14	52
	% of Standard	100%							259%	28%	89%	202%	29%	103%
PM _{2.5}	24-hr (µg/m ³)	30	ND	ND	ND	ND	ND	ND	58	7	27	88	15	44
	% of Standard	100%							194%	24%	89%	293%	48%	146%
Dustfall (inorganic fraction)	30-day (g/m ²)	7	ND	ND	ND	ND	ND	ND	ND	ND	16	ND	ND	11
	% of Standard	100%									228%			164%

* calculated equivalent 24-hour standard based on the 1-hour average of 165.

ND = No Data

3.0 ATMOSPHERIC EMISSIONS

3.1 Vehicle Emissions Estimation

Traffic Volumes

The rate of contaminant emissions from a section of road is proportional to the number and type of vehicles travelling along that road. Hourly traffic flows for Highway 7 were calculated based on the known ratios of hourly-to-peak traffic flows. The York Consortium 2002 provided peak morning, peak afternoon and maximum 8-hour traffic volumes for the various sections of Highway 7 for the Year 2001. For the large-scale modelling approach, the annual average daily traffic (AADT) counts are used for emission calculations for each of the 372 different links shown in Figure 3.1.

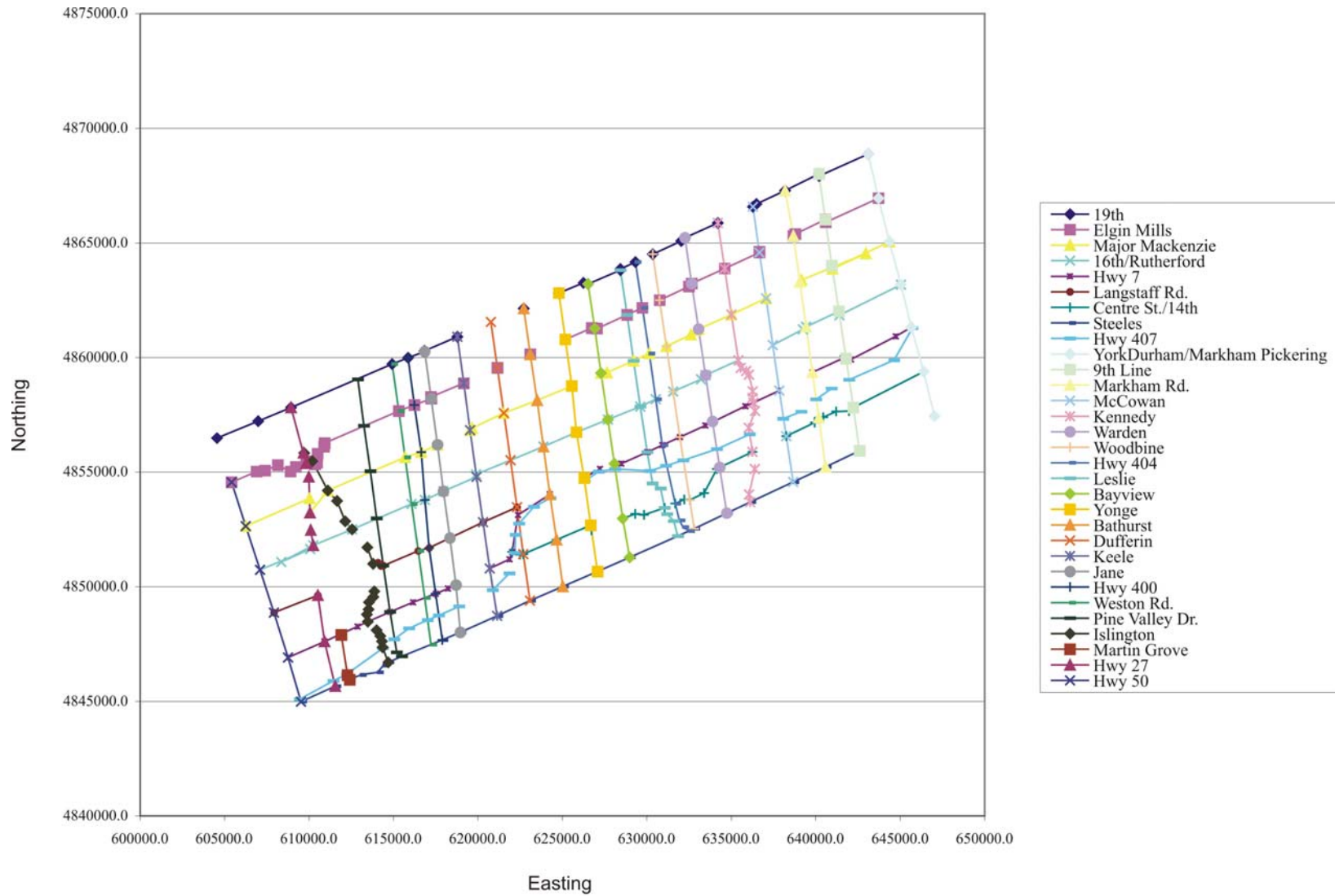
Vehicle Emissions

Tailpipe emissions from vehicles are a function of many variables. Some of the more important parameters are listed below.

- age of the vehicle (newer vehicles emit less);
- number of kilometres which the vehicle has driven;
- emission control equipment that may have been tampered with;
- type of fuel (gasoline, diesel);
- Reid Vapour Pressure (RVP) of gasoline used (adjusted seasonally);
- ambient air temperature;
- vehicle speed;
- rate of acceleration;
- time spent idling;
- type of vehicle (automobile, light truck, heavy truck, bus, etc.); and
- cold or hot start mode.

Vehicular emissions are generally estimated from emission factors in units of mass of contaminant emitted per vehicle, per distance travelled. To obtain a mass emission rate for a particular road section, the length of the road section is multiplied by the number of vehicles using that section.

FIGURE 3.1
ROAD NETWORK FOR DISPERSION MODELLING



SENES Consultants Limited and Air Improvement Resources, Inc. produced for Environment Canada the “*Updated Estimate of Canadian On-road Vehicle Emissions for the Years 1995 – 2020*”, that was completed in December 2001 and then updated in October 2002. This work used the MOBILE6 and the PART5 emissions models, adjusted for the Canadian fleet. Vehicular emissions predicted by these models are expressed in terms of mass emitted per distance travelled per vehicle.

The vehicular emission rates were estimated for 2001, for vehicles travelling at an appropriate speed for a given link. Emission factors have been developed for two major road types – highways (used for 407) and major roads (used for other links). Vehicle registration distributions (which give the distribution of vehicle ages represented in the traffic flow in Ontario) were used in the development of the emission factors (SENES/AIR, 2002). This state-of-the-art reference material was used to prepare the original report of emissions. The fleet average emission factors were used for the large-scale simulation in this assessment.

Table 3.1 summarizes the emission factors used in the base and future scenario years, for the average Ontario fleet travelling on major roads (32.8 km/hr) and highways (66.6 km/hr).

**TABLE 3.1
TAILPIPE EMISSION FACTORS FOR VEHICLES**

Pollutant	Emission factor (g/km)			
	Base year (2001)		Future year (2021)	
	street	highway	street	highway
CO	13.12	6.25	4.45	1.94
SO ₂	0.0825	0.0825	0.0189	0.0189
NO _x	1.537	1.569	0.76	0.75
PM ₁₀	0.0744	0.0744	0.0351	0.0351

SENES has assumed that future traffic speeds on all links will be about the same as they are today or that there will not be any significant deterioration in vehicle speeds as a result of continued improvements.

In addition to PM₁₀ emissions from the tailpipes of vehicles, the U.S. EPA provides an emission factor (U.S.EPA 2003) to estimate the amount of dust suspended by vehicles on the road, according to the following equation:

$$E = k \left(\frac{sL}{2} \right)^{0.65} \times \left(\frac{W}{3} \right)^{1.5} - C$$

where:

E = particulate emission factor g/VKT

k = particle size multiplier – 4.6 g/VKT for PM₁₀

sL = silt loading (g/m²) = 0.4 for Low ADT Roads (<5000 vehicles per day)
= 0.1 for High ADT Roads (>5000 vehicles per day)

W = weight of fleet (tons/vehicle) = 2.73

C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear

VKT = vehicle kilometres travelled

ADT = average daily traffic

E = 1.269 g/VKT for Low ADT Roads and 0.437 g/VKT for High ADT Roads

The simulation of the large-scale patterns around the road network in York Region for the existing conditions was completed. The details of the dispersion modelling are presented in Chapter 4.

As there is very little information about PM_{2.5} emissions from vehicles and roadways, the ratio method was used. The modelling of PM₁₀ assumes a particle size distribution as depicted in Figure 3.2 below. This figure was developed using data measured for the U.S. EPA at Iron & Steel Plants (Iron & Steel Plant Open Sources Fugitive Emission Control – EPA 800/2-83-110), using the “average heavy unpaved road data” (memo to Baynes, Young, Coutts from T. Van der Vooran, 22 June 93 for the Peel Landfill Project). The figure shows that about 18.5% of the dust from roads is PM_{2.5}. The graph also shows that 59.8% of the dust is PM₁₀. This gives a ratio of PM_{2.5}/PM₁₀ = 0.3095. This fraction was used to calculate both the emissions as well as the concentrations from the PM₁₀ data.

3.1.1 Large Scale Modelling

The large scale modelling was undertaken to put the project into perspective over its lifetime. For this modelling all of the mobile sources in the study area were assessed. The assessment covered three different scenarios: the existing base case, the future base case and the future case with bus rapid transit (BRT).

The “existing base case” looks at the current road network and its use by a fleet of vehicles. Using information about emissions from this fleet and the numbers of vehicles on each road link an emission inventory was created. This inventory was then put into the Industrial Source Complex version 3 (ISC3) atmospheric dispersion model and the distribution of maximum pollutant concentrations throughout the study area was calculated based on the hourly meteorological data.

The “future base case” assumes that the road network will not change much but that the fleet will adjust to the newer engine technologies and fuels. This technology change would result in emission reductions if the volume of traffic remained the same as at present. However, traffic will increase in response to population growth. A new emission inventory was developed for this future base case and the impacts of these emissions were simulated using the same dispersion model and meteorological data.

The “future case with BRT” was handled in the same way except that part of the vehicle increase was replaced with bus transit. Again emissions from the vehicles were calculated and dispersed throughout the study area.

Tables 3.2 to 3.4 present the cases outlined above for the pollutants commonly associated with vehicular travel.

FIGURE 3.2

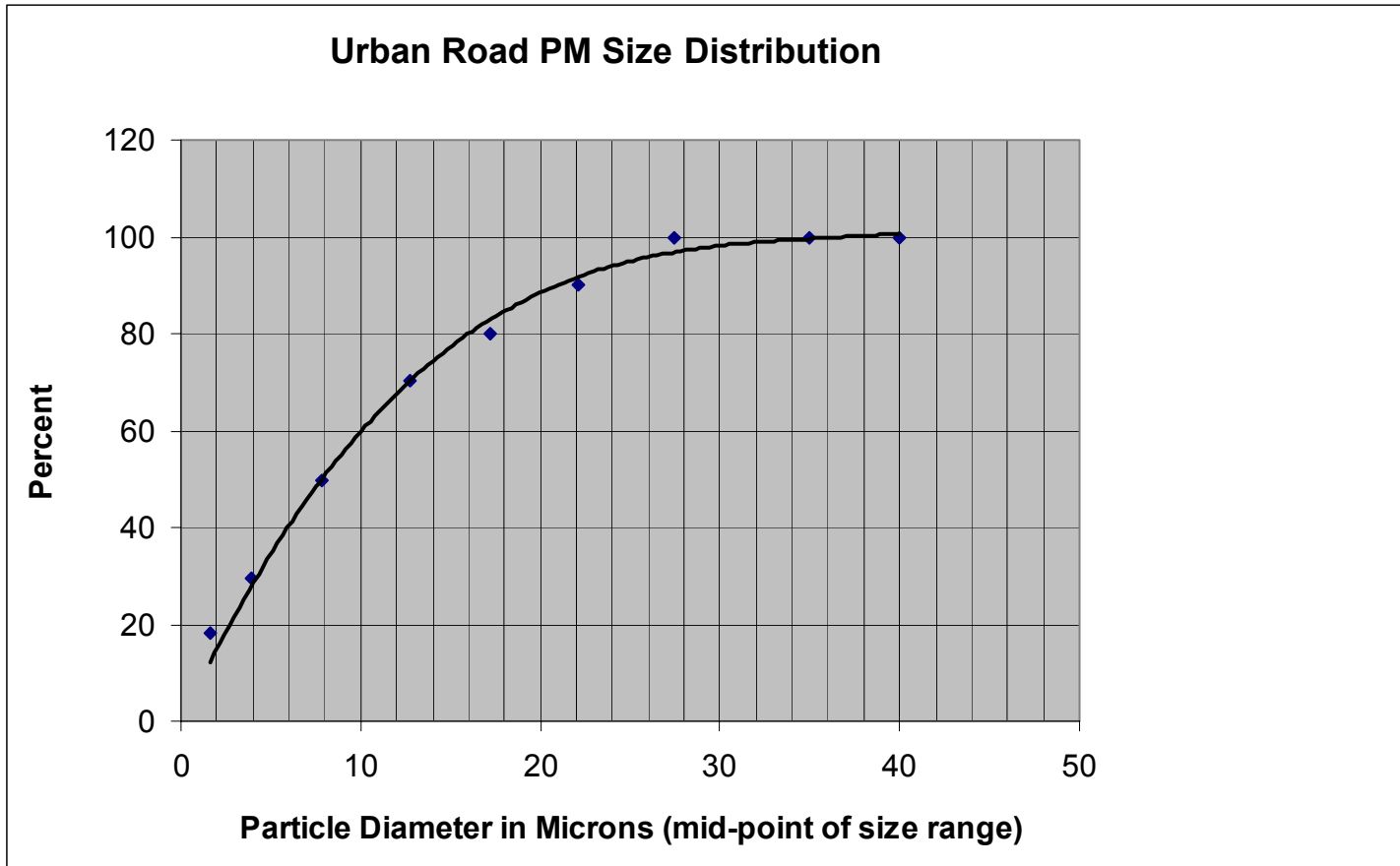


Table 3.2 presents the emissions for the “existing base case” for the year 2000 for PM₁₀, NO_x, SO₂ and CO for all major north-south and east-west links in the study area. For input into the model, the roads were broken down into smaller links but for the sake of this presentation these smaller links have been aggregated by major road. Table 3.2 presents the emission rates used in the computer model by major link. For example, the emissions of NO_x from the current traffic on Highway 7 are approximately 24 g/s. For all of the N-S links, the total NO_x emissions are approximately 117 g/s, and for the E-W links 137 g/s, for a grand total of 254 g/s over the study area. By using the ratio method, the “existing base case” PM_{2.5} emissions are 29.57 g/s.

TABLE 3.2
SUMMARY EMISSIONS BY ROAD LINK AND POLLUTANT (g/s)
EXISTING BASE CASE

LINK	PM ₁₀	NO _x	SO ₂	CO	LINK	PM ₁₀	NO _x	SO ₂	CO
Yonge	2.64	7.16	0.20	49.20	Highway #7	8.81	23.95	0.69	164.45
Bathurst	2.02	5.48	0.16	37.63	Highway #407	17.51	48.36	1.36	147.95
Dufferin	1.44	3.91	0.11	26.87	Langstaff	0.89	2.41	0.07	16.58
Keele	1.37	3.73	0.11	25.64	14th Ave.	2.63	6.85	0.20	47.05
Jane	1.43	3.87	0.11	26.60	Steeles Ave.	9.40	25.56	0.73	175.53
Hwy 400	8.87	24.50	0.69	74.96	16th Ave.	5.45	14.49	0.41	99.50
Weston Rd	1.50	3.84	0.11	26.39	Major Mackenzie	3.81	10.10	0.29	69.39
Pine Valley	0.63	1.54	0.04	10.58	Elgin Mills	2.02	3.76	0.11	25.85
Islington	1.16	3.15	0.09	21.64	19th Ave.	1.72	1.73	0.05	11.86
Martin Grove	0.17	0.46	0.01	3.16					
Hwy.#27	1.33	3.67	0.10	11.23					
Hwy#50	1.30	3.53	0.10	24.23					
Bayview	1.95	5.30	0.15	36.39					
Leslie	1.34	3.65	0.10	25.05					
404/DVP	7.55	20.86	0.59	63.82					
Woodbine	1.45	3.93	0.11	27.02					
Warden Ave.	1.25	3.39	0.10	23.27					
Kennedy	1.38	3.74	0.11	25.70					
McCowan	1.39	3.77	0.11	25.88					
Markham	1.89	5.14	0.15	35.28					
9th Line	0.54	1.48	0.04	10.17					
MPTYDL	0.72	0.73	0.02	5.00					
					Total	52.24	137.22	3.90	758.15
Total	43.30	116.85	3.32	615.70	Grand TOTAL	95.54	254.06	7.22	1373.85

Table 3.3 presents the emissions for the “future base case” for the year 2021 for PM₁₀, NO_x, SO₂ and CO for all major north-south and east-west links in the study area. The table presents the emissions rates used in the computer model by major link. For example, the emissions of NO_x from the future traffic, without additional rapid transit, on Highway 7 would be approximately 18 g/s. For all of the N-S links, the total NO_x emissions are projected to be approximately 96 g/s,

and for the E-W links 114 g/s, for a grand total of 210 g/s over the study area. By using the ratio method, the “future base case” PM_{2.5} emissions are 40.85 g/s.

In summary this table shows a decrease in emissions over the present base case for all pollutants examined, except PM₁₀ and PM_{2.5} as a result of improving vehicle and fuel technology. PM₁₀ and PM_{2.5} increase because of the increase in the number of cars re-suspending road dust. Resuspended dust is at least an order of magnitude larger than dust emitted from engines so this increase in PM from the “present” to the “future” baseline is expected.

**TABLE 3.3
SUMMARY EMISSIONS BY ROAD LINK AND POLLUTANT (g/s)
FUTURE BASE CASE**

LINK	PM ₁₀	NO _x	SO ₂	CO	LINK	PM ₁₀	NO _x	SO ₂	CO
Yonge	3.19	5.13	0.13	30.03	Highway #7	11.25	18.11	0.45	106.04
Bathurst	2.55	4.11	0.10	24.06	Highway #407	22.07	35.08	0.88	97.00
Dufferin	1.89	3.04	0.08	17.81	Langstaff	1.45	2.34	0.06	13.68
Keele	2.04	3.29	0.08	19.25	14th Ave.	3.64	5.64	0.14	33.00
Jane	2.06	3.32	0.08	19.46	Steeles Ave.	12.42	19.98	0.50	116.99
Hwy 400	10.64	16.90	0.43	43.72	16th Ave.	8.96	14.42	0.36	84.42
Weston Rd	2.13	3.43	0.09	20.08	Major Mackenzie	6.14	9.61	0.24	56.28
Pine Valley	0.87	1.40	0.03	8.19	Elgin Mills	3.87	5.07	0.13	29.66
Islington	1.82	2.93	0.07	17.16	19th Ave.	2.43	3.91	0.10	22.89
Martin Grove	0.37	0.59	0.01	3.46					
Hwy.#27	1.88	2.99	0.08	7.72					
Hwy#50	2.12	3.42	0.08	20.00					
Bayview	2.34	3.76	0.09	22.01					
Leslie	1.97	3.16	0.08	18.52					
404/DVP	9.71	15.42	0.39	39.88					
Woodbine	1.81	2.91	0.07	17.07					
Warden Ave.	1.75	2.81	0.07	16.44					
Kennedy	2.47	3.98	0.10	23.30					
McCowan	2.15	3.46	0.09	20.25					
Markham	3.44	5.53	0.14	32.40					
9th Line	2.18	3.51	0.09	20.56					
MPTYDL	0.37	0.60	0.01	3.51					
					Total	72.23	114.15	2.85	559.97
Total	59.75	95.69	2.39	444.88	Grand TOTAL	131.98	209.83	5.24	1004.85

Table 3.4 presents the emissions for the “future BRT case” for the year 2021 for PM₁₀, NO_x, SO₂ and CO for all major north-south and east-west links in the study area. The table presents the emissions rates used in the computer model by major link. For example, the emissions of NO_x from the future traffic, with bus rapid transit, on Highway 7 would be close to 17.5 g/s. For all of the N-S links, the total NO_x emissions are projected to be almost 94 g/s, and for the E-W links

112 g/s, for a grand total of 206 g/s over the study area. By using the ratio method, the “future BRT case” PM_{2.5} emissions are 40.21 g/s.

In summary this table shows a decrease in emissions over the “future base case” for all pollutants examined as a result of the introduction of bus rapid transit. PM₁₀ and PM_{2.5} also decrease because the number of vehicles, and hence the re-suspended road dust, is projected to decrease slightly with the introduction of BRT.

TABLE 3.4
SUMMARY EMISSIONS BY ROAD LINK AND POLLUTANT (g/s)
FUTURE BRT CASE

LINK	PM ₁₀	NO _x	SO ₂	CO	LINK	PM ₁₀	NO _x	SO ₂	CO
Yonge	3.16	5.08	0.13	29.77	Highway #7	10.85	17.46	0.43	102.24
Bathurst	2.58	4.16	0.10	24.35	Highway #407	23.02	36.58	0.92	99.89
Dufferin	1.93	3.10	0.08	18.15	Langstaff	1.68	2.70	0.07	15.80
Keele	2.04	3.29	0.08	19.26	14th Ave.	3.66	5.68	0.14	33.25
Jane	1.96	3.15	0.08	18.43	Steeles Ave.	12.10	19.47	0.48	113.99
Hwy 400	10.73	17.05	0.43	44.10	16th Ave.	8.29	13.14	0.33	76.94
Weston Rd	2.10	3.37	0.08	19.74	Major Mackenzie	5.83	9.20	0.23	53.86
Pine Valley	0.84	1.19	0.03	6.99	Elgin Mills	3.51	4.51	0.11	26.41
Islington	1.61	2.59	0.06	15.18	19th Ave.	2.17	3.14	0.08	18.41
Martin Grove	0.30	0.49	0.01	2.86					
Hwy. #27	1.78	2.82	0.07	7.29					
Hwy#50	2.51	4.04	0.10	23.67					
Bayview	2.32	3.73	0.09	21.82					
Leslie	1.87	3.00	0.07	17.58					
404/DVP	9.82	15.60	0.39	40.34					
Woodbine	1.83	2.94	0.07	17.23					
Warden Ave.	1.65	2.65	0.07	15.53					
Kennedy	1.78	2.86	0.07	16.77					
McCowan	2.07	3.33	0.08	19.48					
Markham	3.35	5.40	0.13	31.61					
9th Line	2.10	3.37	0.08	19.76					
MPTYDL	0.50	0.65	0.02	3.81					
					Total	71.10	111.88	2.79	540.80
Total	58.82	93.87	2.35	433.74	Grand TOTAL	129.92	205.76	5.14	974.54

All else being equal, a slight reduction in emissions will lead to a slight reduction in pollutant concentrations downwind. Comparing Tables 3.3 and 3.4 suggests a slightly improved future situation with the introduction of BRT.

3.2 ODOURS

Odours from diesel exhaust are generally acknowledged to be associated with aldehyde constituents in the exhaust. These are largely comprised of formaldehyde, but acrolein and possibly acetaldehyde may contribute to the odour as well.

Using the fact that diesel odour is associated with formaldehyde (HCHO)¹, and the Internal Combustion Engines Emission Calculation [ICE 2000 Revision B], the ratios between emission factors for PM₁₀, NO_x, CO, SO₂ and HCHO were determined for both gasoline and diesel engines. These ratios are:

	Gasoline Engines	Diesel Engines
HCHO/PM ₁₀	0.011997	0.0037546
HCHO/NO _x	0.000786	0.0002665
HCHO/CO	0.000020	0.0012365
HCHO/SO ₂	0.014636	0.0040293

These ratios were then used to estimate the HCHO emissions based on the emissions of other pollutants. The maximum emission rate calculated was used as representative of the odorous constituents in order to model odour distribution across the study area.

Greenhouse Gas (GhG) Emissions

CEAA has provided draft guidance on incorporating climate change considerations in an Environmental Assessment. With respect to greenhouse gases, the guidance document (CEAA, 2003) outlines a procedure for assessing whether greenhouse gas emissions associated with the project are sufficient to be addressed in greater detail within the EA, and whether greenhouse gas management plans would be required.

The preliminary scoping involves *“identifying whether the project’s greenhouse gas emissions are likely to be of relatively low, medium or high volumes or intensity. If the project’s emissions are likely to be of only low intensity or volume, then there may be no need to conduct further analysis.”*

To determine the intensity of the project’s greenhouse gas emissions, the CO₂ emissions from the vehicle fleet were estimated using the same methodology described for SO₂, NO_x and CO emissions in Section 3.1. The vehicle CO₂ emission factor, for the current conditions, is estimated to be 511.56 g/mile and the CO₂ emission factor, for the future conditions, is estimated

¹ www.catalyticexhaust.ca/products.

to be 556.25 g/mile. The methane and nitrous oxide emissions from vehicle emissions are only a small fraction of the CO₂ emissions (<3% CO₂-equivalent) and are considered insignificant. Therefore the analysis presented here discusses only CO₂ emissions.

The estimated **annual** CO₂ emissions for each scenario are estimated to be:

- existing – 1,906 kilotonnes;
- future Base Case – 2,995 kilotonnes; and
- future BRT – 2,941 kilotonnes.

For comparison, the estimated CO₂-equivalent emissions from the Ontario fleet for 2001 are 49,400 kilotonnes and from all sources, approximately 200,000 kilotonnes. The existing CO₂ emissions are approximately 4% of the Ontario fleet CO₂-equivalent emissions. The introduction of the BRT will result in a net decrease of CO₂ emissions of approximately 54 kilotonnes. Therefore, this project is considered to be of net benefit with respect to Greenhouse Gas emissions, and no further analysis is considered necessary.

4.0 AIR DISPERSION MODELLING APPROACH

4.1 MODELLING METHODOLOGY

In order to assess the future air quality resulting from this project, a two level approach was used. The first level, the large-scale approach, examined concentrations of pollutants over the whole study area to delineate any significant patterns or “hot-spots”. The second level, the small-scale approach, examined an area in more detail if sensitive receptors were found very close to the corridor that might be adversely affected.

Four specific areas were selected for the Highway 7 Corridor. They are:

- Area 1 – Islington;
- Area 2 – Jane/Keele;
- Area 3 – Kennedy Road; and
- Area 4 – Stouffville Hospital.

The measured ambient air concentrations reflect the contribution from both local sources (i.e. traffic in the study area) as well as upwind sources (i.e. traffic from downtown Toronto, fossil fuel fired power stations in Southern Ontario and the United States). To determine the relative contribution of the traffic in the study area to local ambient air quality, a large-scale dispersion modelling approach was used.

4.1.1 Air Dispersion Model – Large Scale Approach

Air quality is a measure of the number of molecules of a chemical in a given volume of air. The typical unit of measurement is micrograms of chemical, or particles, per cubic metre of air ($\mu\text{g}/\text{m}^3$). This is known as the concentration of the chemical constituent at a point in space and time. The concentration will vary from point-to-point and from minute-to-minute in response to the changing atmospheric conditions (wind speed, wind direction, temperature, atmospheric stability and mixing height).

To calculate the concentration at a given location, near an emissions source, an atmospheric dispersion model is used. Such a model takes the emissions from a source and disperses them into the surrounding community typically using at least 1 (one) year of historical meteorological data from a local weather station.

To assess the impact of any change, for a specific project in a given location, the model is run twice – once for the existing conditions and a second time, using the same meteorological conditions, to assess any changes that would occur as a result of the project. The only

differences, between these two computer simulations of air quality, are the amount of emissions released and possibly the number, or location, of sources that are input into the model. In general terms, if the emissions are reduced, the resulting impact in the surrounding community (gas or particulate concentrations) will be reduced. Conversely, if the emissions increase, the impact will increase.

The general approach chosen was to compare the existing situation to the future situation for the day predicted to have the highest emission rate. Other days would have impacts less than this day. In order to ensure that the worst-case impact was assessed, it was assumed that the emissions from the day, with the highest emission rate, occurred every day for the entire year modelled.

Several atmospheric dispersion models were considered for use in this air quality assessment. They are described briefly below.

4.1.1.1 ISC3

In Ontario and Canada it is accepted practice to evaluate atmospheric impacts through the use of an atmospheric dispersion model. In Ontario the U.S.EPA regulatory atmospheric dispersion models are generally considered the best available tools for these applications. The ISC3 series of dispersion models are considered appropriate for industrial source complex applications in a rural or urban setting, for flat or rolling terrain at distances less than 50 km for continuous emissions from sources to the air.

The Industrial Source Complex Version 3 (ISC3) Model (U.S.EPA 1995a) is the regulatory tool currently recommended for simulating short-term air quality impacts from industrial complexes. The ISC3 model is specifically designed to permit the analysis of emission sources from complex industrial settings (multiple stacks, fugitive emissions, building wake effects, etc.). This model is currently recommended by the U.S. Environmental Protection Agency for compliance modelling, and has been accepted by Canadian regulatory agencies.

The ISC3 model is a steady-state Gaussian Plume model that provides options to model emissions from a wide range of sources. The model accepts hourly meteorological data records to define the conditions for plume rise, transport and dispersion. The model estimates concentration or deposition values for each source-receptor combination, for each hour of input meteorology, and calculates short-term averages, such as one-hour, eight-hour and 24-hour averages. The hourly averages can also be combined into longer averages (monthly, seasonal, annual).

4.1.1.2 AERMOD

AERMOD (U.S. EPA, 1998) was developed from ISC3 and is largely a Gaussian Plume model. The primary difference between AERMOD and ISC3 is that AERMOD uses a non-Gaussian probability density function for the vertical dispersion in the convective boundary layer (for unstable conditions). This is a refinement of the discrete stability classes used by many other models such as ISC3. The stability is described by the Monin-Obukhov (M/O) length. The M/O length is a function of surface parameters (roughness, albedo [reflectivity] and soil moisture content) as well as the upper air data. AERMET is used to combine and format the surface and upper air data. AERMOD processes the meteorological data directly without the need of a further meteorological data pre-processor.

4.1.1.3 CAL3QHCR

CAL3QHCR is a model developed specifically to predict the impacts of vehicle emissions at, and near, roadway intersections (U.S. EPA 1995b). The model combines the CALINE-3 (CSC, 1979) line source dispersion model and a traffic algorithm for estimating vehicular queue lengths at signalized intersections. The CALINE-3 line source dispersion model predicts more realistic concentrations immediately around roads because of the initial mixing in the wake zone of the vehicle. This initial mixing, combined with the traffic algorithm for queuing (added emissions from idling vehicles), provides improved model predictions of vehicle tailpipe emissions adjacent to roadways.

4.1.1.4 ISC3, AERMOD versus CAL3QHCR - Model Assessment

The air quality assessment evaluates the concentrations of vehicle exhaust emissions as well as re-suspended dust from roadways. While the CAL3QHCR model is ideal to assess dispersion from vehicle emissions, it is an extremely detailed model that is best suited to evaluate tailpipe emissions at individual intersections. For this study, the air quality in York Region is being assessed, and the change to the future air quality as a result of implementing the proposed BRT. To assess an area of this scale and to include re-suspended dust emissions from roadways, a broader scale model is required.

SENES evaluated both the ISC3 and AERMOD dispersion models vs. the CAL3QHCR model to determine which broader scale model would best reflect the line dispersion within CAL3QHCR.

To assess the performance of ISC3 and AERMOD vs. CAL3QHCR, one road link along Yonge Street was examined. The link extends in the north-south direction for a distance of 1 km along Yonge south of 16th Avenue. The emissions for this modelling exercise are based on a traffic volume of 1621 vehicles northbound and 1275 vehicles southbound. An overall PM₁₀ tailpipe

emissions factor of 0.117 g/mi/vehicle was assumed for these simulations. The road link was modeled with CAL3QHCR, ISC3 and AERMOD using Toronto Pearson International Airport meteorology for 2001.

The ISC3 model was tested with different source characteristics to evaluate the best approximation of the initial vertical dispersion due to mechanical mixing (due to traffic movement) simulated with the CAL3QHCR model. The source was defined as a ground level area source with both no initial mechanical mixing ($\sigma_z = 0$ m) and with initial mechanical mixing ($\sigma_z = 4.65$ m). For comparison, the AERMOD model was run with an equivalent area source and considering initial mechanical mixing ($\sigma_z = 4.65$ m).

Air concentrations at receptors placed at different distances from the roadway were predicted at the mid-point (500 m) and one end of the 1 km road link. The maximum predicted 24-hour average PM_{10} concentrations for 2001 at each test receptor are illustrated in Figures 4.1 and 4.2 for all three dispersion models. These figures show that the ISC3 dispersion model with the initial vertical dispersion slightly overestimates compared to CAL3QHCR, but is much closer to the CAL3QHCR model results than the AERMOD dispersion model. With no initial vertical dispersion, the ISC3 dispersion model predicts slightly higher concentrations within approximately 50-100 m of the source.

FIGURE 4.1

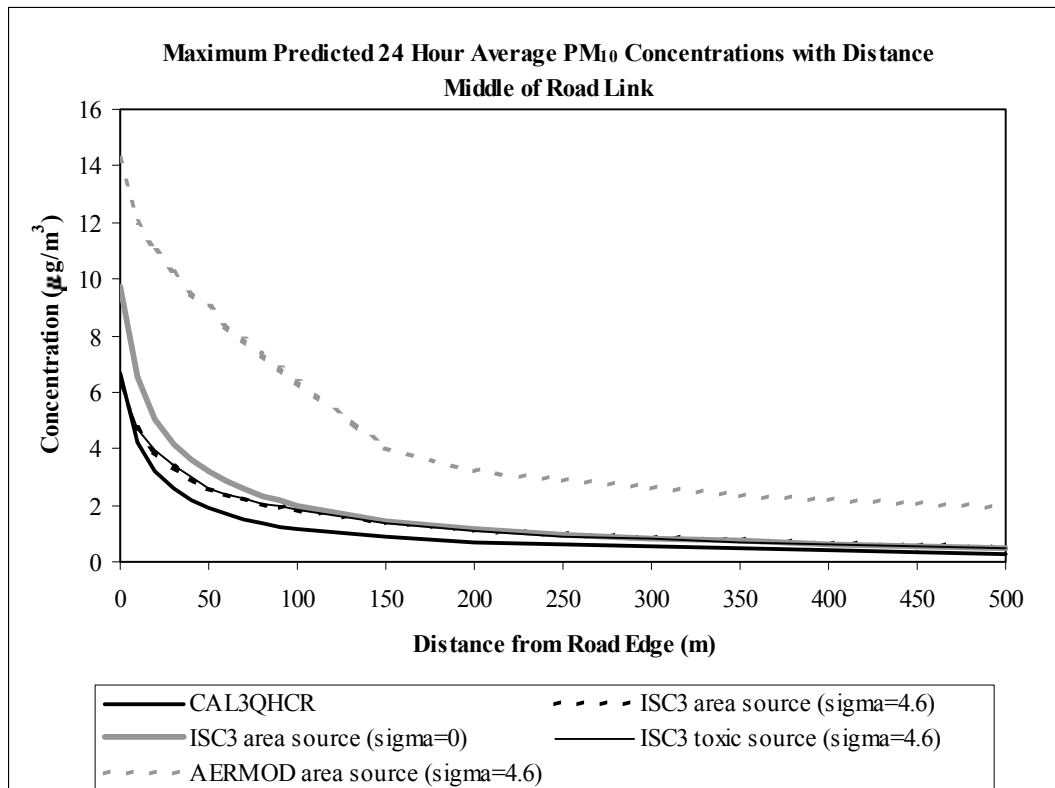
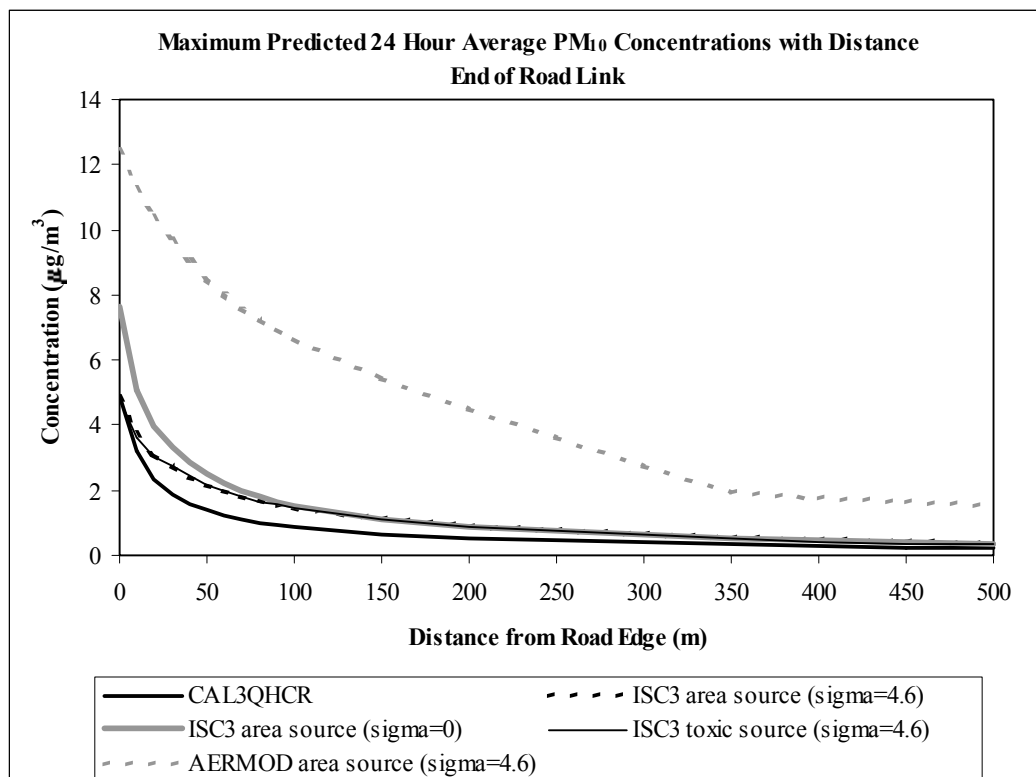


FIGURE 4.2



As expected for this type of source, the predicted PM₁₀ concentrations decrease with increasing distance from the roadway for all models. CAL3QHCR has an improved initial mechanical dispersion algorithm to account for traffic movement over ISC3 or AERMOD and, therefore, predicts slightly lower concentrations than ISC3 and significantly lower than AERMOD.

The U.S.EPA has developed an area source refinement for the ISC3 dispersion model. The TOXICS option optimizes the numerical integration which results in reduced run times. The model predictions between the ISC3 area source using the TOXICS refinement and not using the TOXICS refinement are virtually identical (Figures 4.1 and 4.2).

Because the ISC3 dispersion model compares more favorably with CAL3QHCR for this application, the ISC3 dispersion model was used in the modelling of the emissions from the regional modelling domain illustrated in Figure 4.3. For this application the ISC3 Model was set up on a domain of 44.5 km east-west and 26.0 km south-north with grid spacing of 250 m. The TOXICS refinement option was used to define the sources and optimize the run time. To ensure a conservative assessment, no initial vertical dispersion was assigned to the sources for the Large Scale Model Runs.

4.2 AIR DISPERSION MODEL – SMALL SCALE APPROACH (TRANSIT YARD)

To evaluate the potential impact of the transit yard, which will have a large number of buses idling and moving around the area, generally the same modelling methodology as the large scale modelling approach was used. The results of this are presented in the Technical Appendix – Air Quality Impact Assessment of the Yonge Street Corridor Public Transit Improvement/Environmental Assessment, July 2004.

4.3 METEOROLOGICAL DATA USED FOR DISPERSION MODELLING

For ISC3 modelling, hourly meteorological data are required including: mixing height, temperature, cloud cover, cloud opacity, wind speed and wind direction. For calculating hourly mixing heights, upper air measurements are needed. Using upper air observations (twice daily) morning and afternoon mixing heights are calculated and, based on these measurements, hourly mixing heights are estimated using the U.S. EPA's regulatory meteorological pre-processor PCRAMMET.

Typically, 5 years of hourly meteorological data are used in dispersion modelling calculations, and are recommended by the U.S. EPA, in order to include all of the possible combinations of meteorological conditions expected to occur in the area to be modelled (U.S. EPA 1999). The meteorological data examined for this assessment with conventional modelling included 1996 to 2001 hourly surface meteorological data from Pearson International Airport, and upper air (mixing height) data from the Buffalo International Airport. Due to the complexity of the model runs, one year of data (2001) was used for the simulations. Mixing heights are a regional parameter and do not change significantly over moderate distances. For this reason, upper air meteorological stations are located approximately 300 km apart. Buffalo is the closest upper air meteorological station to Toronto.

5.0 ASSESSMENT OF AIR QUALITY

Within the larger picture of a significant improvement in air quality over the next 10-15 years as a result of technology improvements in vehicle engines, this chapter assesses the small changes that will occur if BRT is introduced to a significantly different “future base case”.

5.1 AIR DISPERSION MODEL – SMALL SCALE APPROACH

Area 1

The predicted maximum PM₁₀ concentrations due to currently existing traffic ranges from 30 – 40 µg/m³ (PM_{2.5}: 9-12 µg/m³) over this area as seen in Figure 5.1a. For the future base case these values have increased to 40 – 60 µg/m³ (PM_{2.5}: 12-19 µg/m³) over this area as seen in Figure 5.1b. The percentage change between these two cases along Highway 7 will be an increase in the maximum PM₁₀ levels of 30-40% over this area as shown in Figure 5.1c. Using BRT will lower emissions (and improve air quality) of all pollutants by about 4% along Highway 7.

FIGURE 5.1a
PREDICTED PM₁₀ CONCENTRATIONS – MAXIMUM 24 HOURS
EXISTING BASE CASE – AREA 1

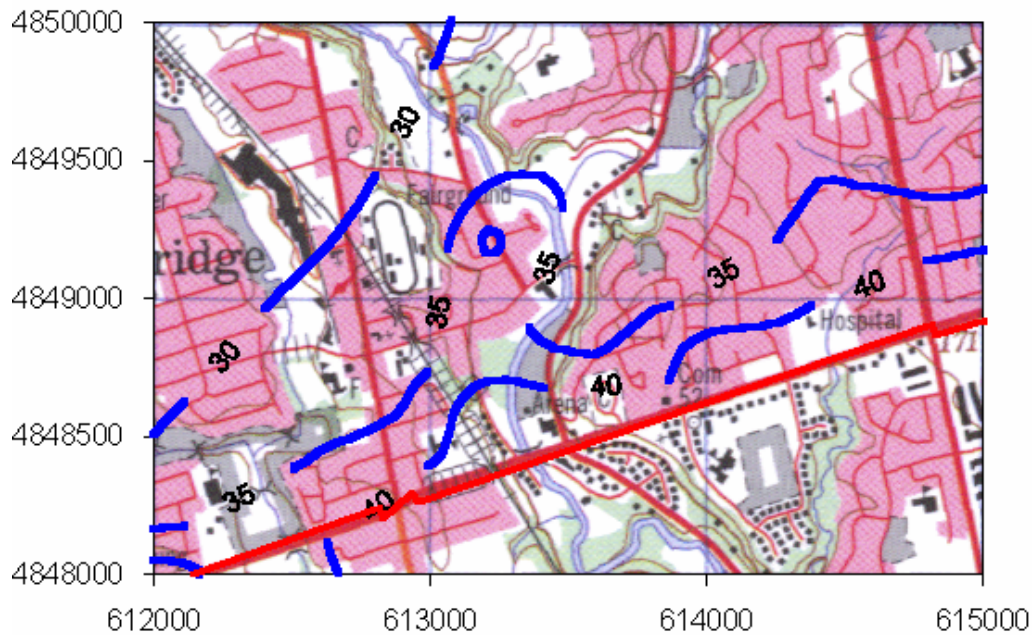


FIGURE 5.1b
PREDICTED PM₁₀ CONCENTRATIONS – MAXIMUM 24 HOURS
FUTURE BASE CASE – AREA 1

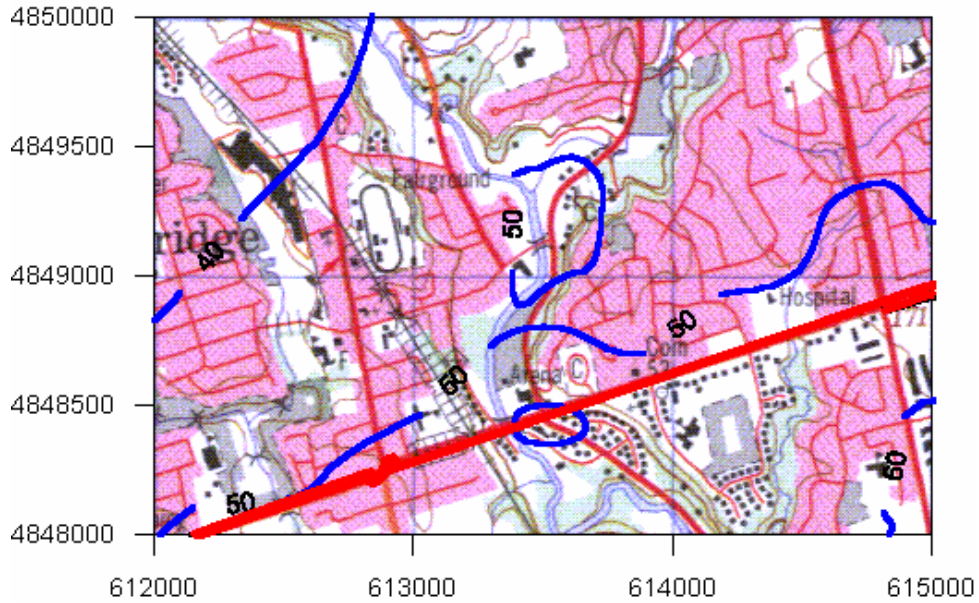
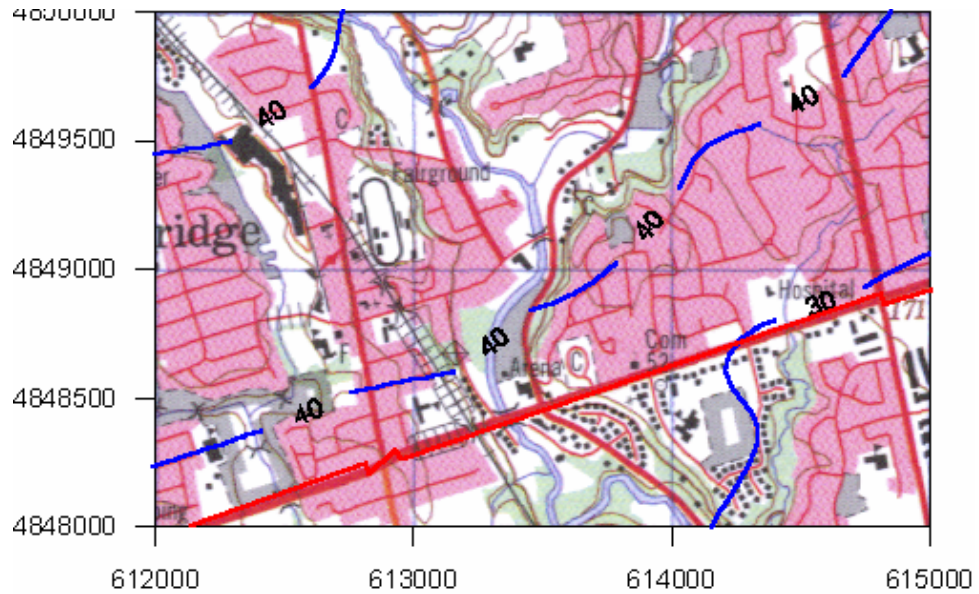


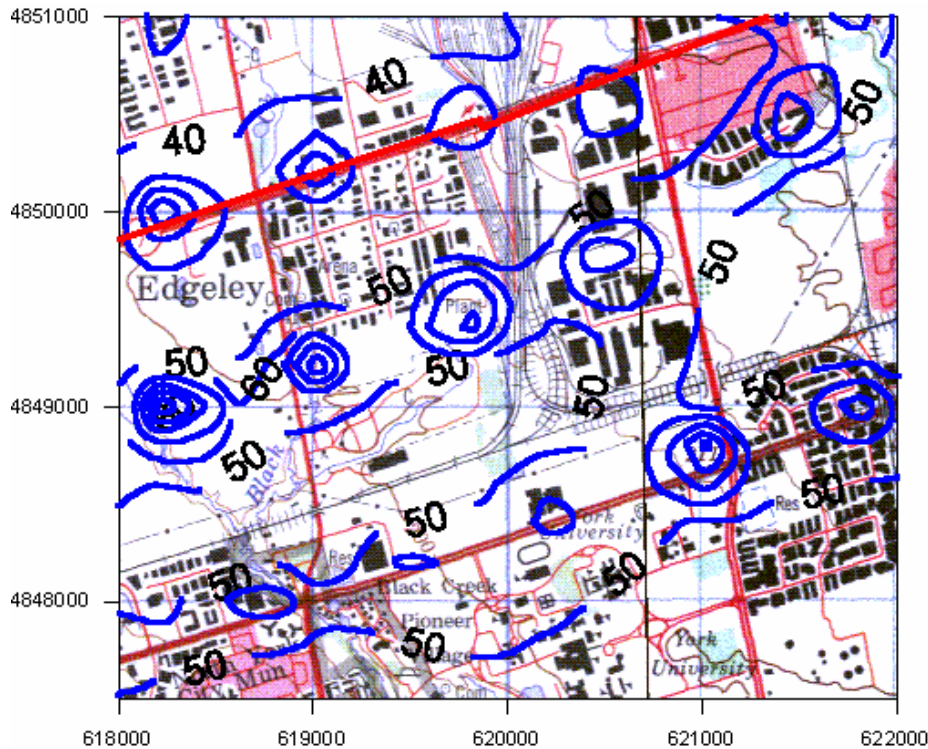
FIGURE 5.1c
PERCENTAGE CHANGE OF MAXIMUM 24 HOUR PM₁₀ CONCENTRATIONS
FUTURE BASE CASE / EXISTING BASE CASE – AREA 1



Area 2

The predicted maximum PM₁₀ concentrations due to currently existing traffic ranges from 40-60 µg/m³ (PM_{2.5}: 12-19 µg/m³) over this area as shown in Figure 5.2a. For the future base case these values have increased to 60 – 70 µg/m³ (PM_{2.5}: 19-22 µg/m³) over this area as shown in Figure 5.2b. The percentage change between these two cases along Highway 7 will be an increase in maximum PM₁₀ levels of 60-70% over this area as shown in Figure 5.2c. Using BRT will lower emissions (and improve air quality) of all pollutants by about 4% along Highway 7.

FIGURE 5.2a
PREDICTED PM₁₀ CONCENTRATIONS – MAXIMUM 24 HOURS
EXISTING BASE CASE - AREA 2



NOTE:

The appearance of what seem to be hot spots on some figures along the road is an artifact of the curve-fitting program SURFER. They do not exist in the model outputs.

FIGURE 5.2b
PREDICTED PM₁₀ CONCENTRATIONS – MAXIMUM 24 HOURS
FUTURE BASE CASE – AREA 2

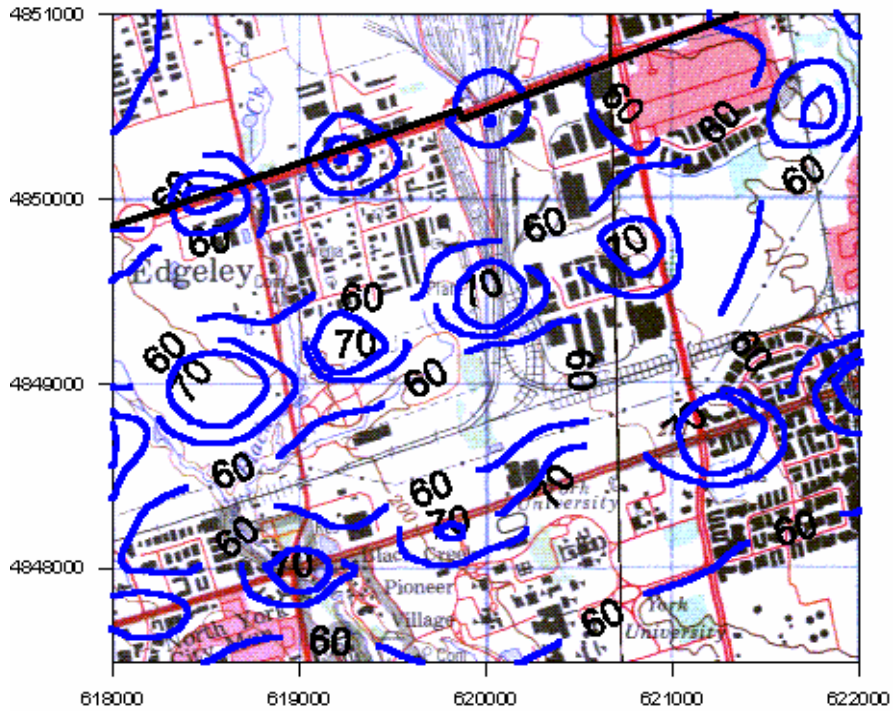
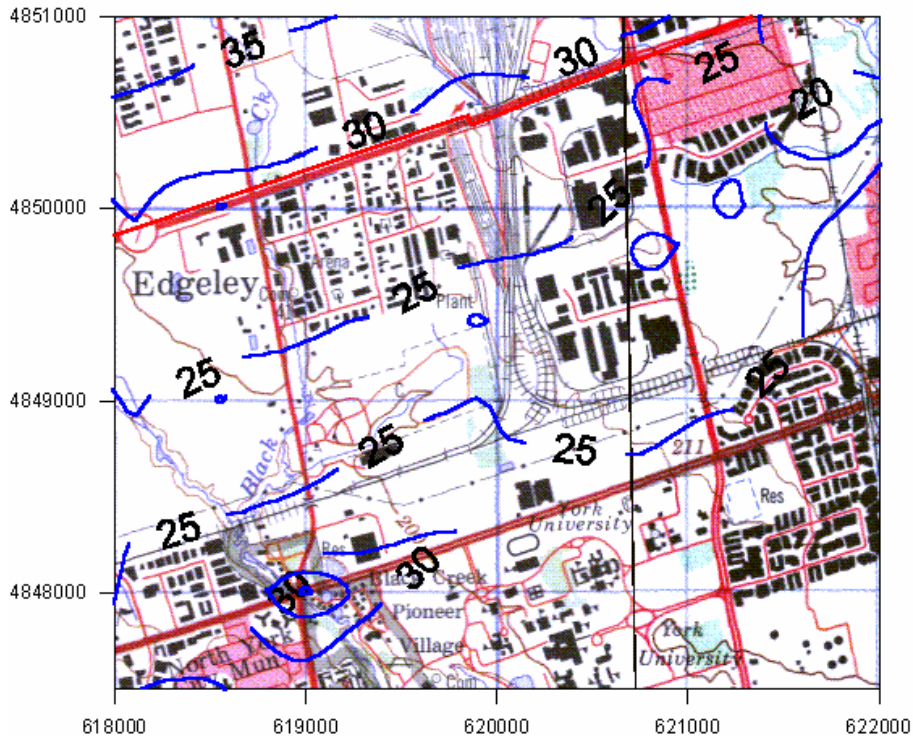


FIGURE 5.2c
PERCENTAGE CHANGE OF MAXIMUM 24 HOUR PM₁₀ CONCENTRATIONS
FUTURE BASE CASE / EXISTING BASE CASE AREA 2



Area 3

The predicted maximum PM₁₀ concentrations due to currently existing traffic ranges from 40-45 µg/m³ (PM_{2.5}: 12-14 µg/m³) over this area as shown in Figure 5.3a. For the future base case these values have increased to 50 – 55 µg/m³ (PM_{2.5}: 15-17 µg/m³) over this area as shown in Figure 5.3b. The percentage change between these two cases along Highway 7 will be an increase in maximum PM₁₀ levels of 20-30% over this area as shown in Figure 5.3c. Using BRT will lower emissions (and improve air quality) of all pollutants by about 4% along Highway 7.

**FIGURE 5.3a
PREDICTED PM₁₀ CONCENTRATIONS – MAXIMUM 24 HOURS
EXISTING BASE CASE – AREA 3**

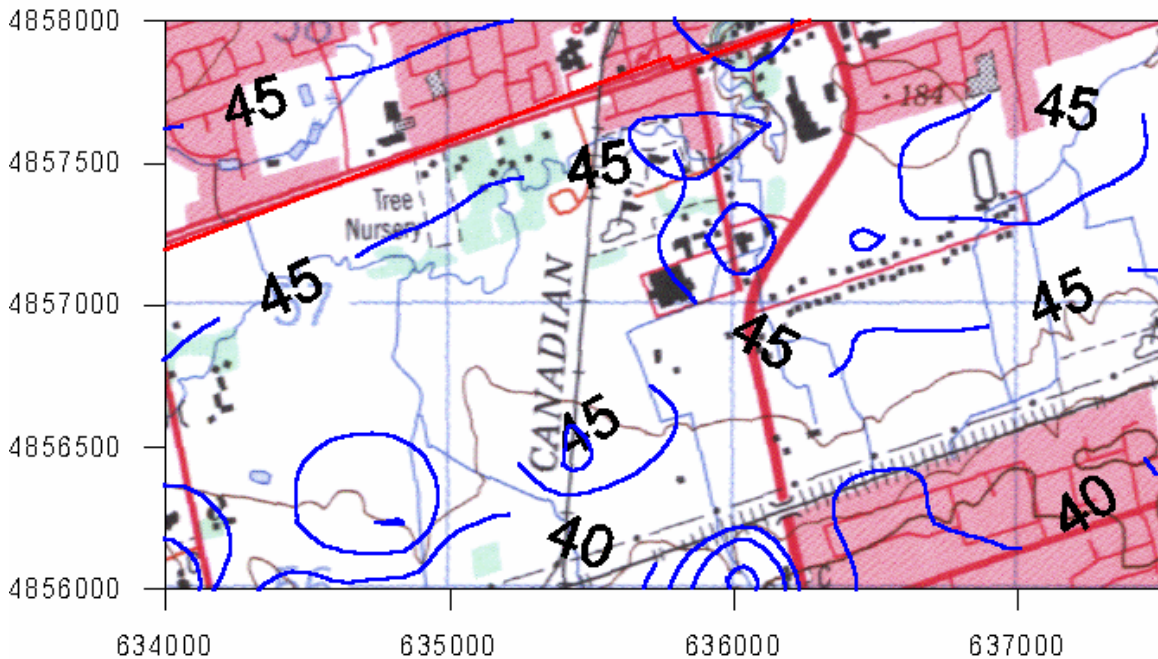


FIGURE 5.3b
PREDICTED MAXIMUM 24 HOUR PM₁₀ CONCENTRATIONS
FUTURE BASE CASE – AREA 3

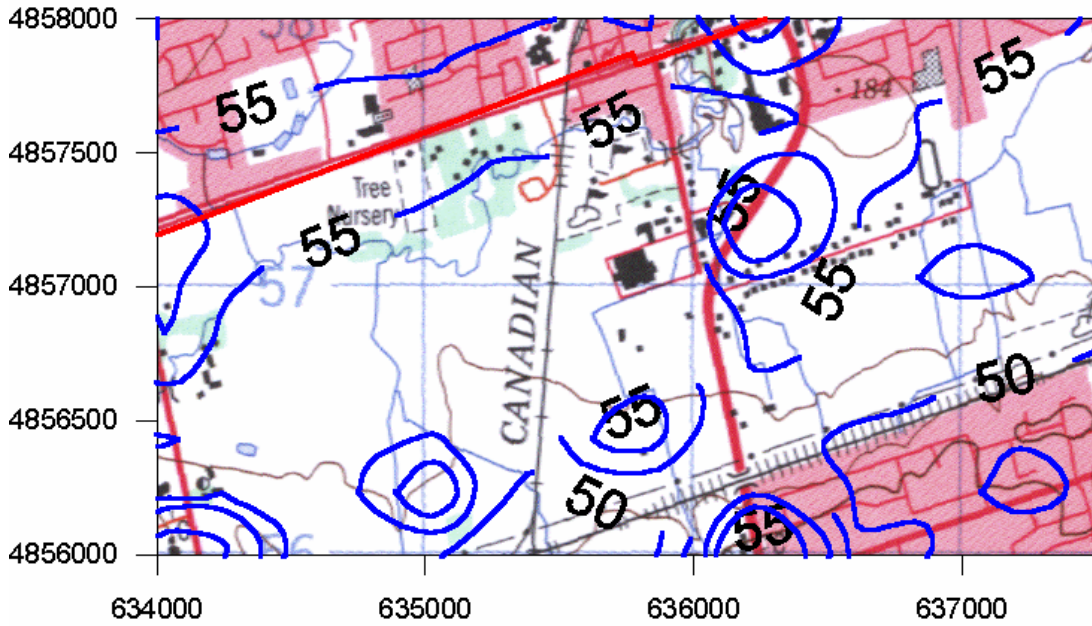
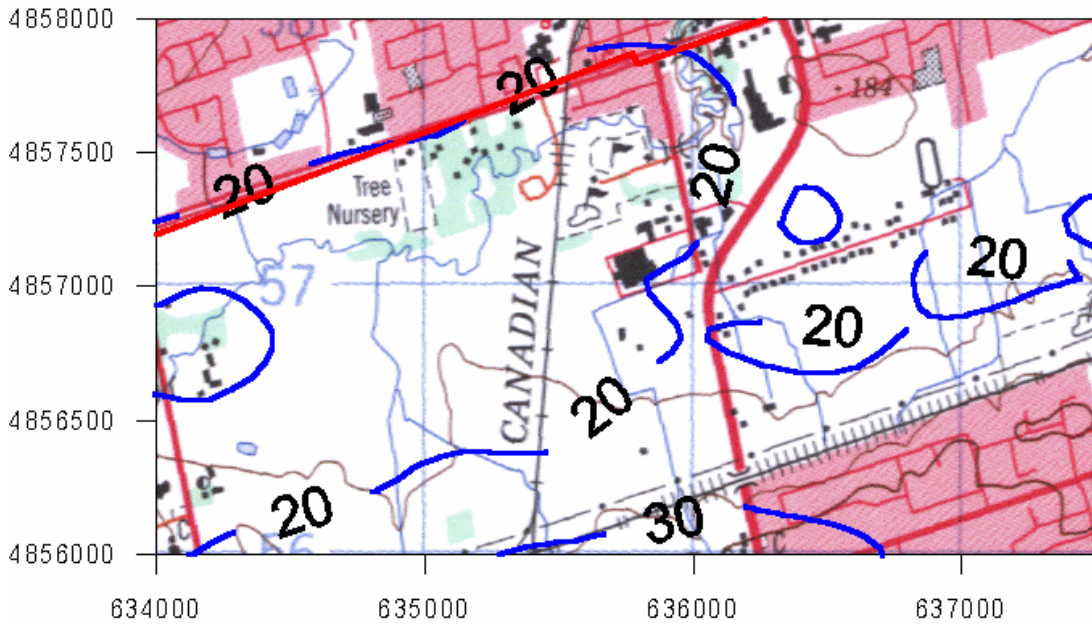


FIGURE 5.3c
PERCENTAGE CHANGE OF MAXIMUM 24 HOUR PM₁₀ CONCENTRATIONS
FUTURE BASE CASE / EXISTING BASE CASE – AREA 3



Area 4

The predicted maximum PM₁₀ concentrations due to currently existing traffic is about 45 µg/m³ (PM_{2.5}: 14 µg/m³) over this area as shown in Figure 5.4a. For the future base case this value has increased to 55 – 60 µg/m³ (PM_{2.5}: 17-19 µg/m³) over this area as shown in Figure 5.4b. The percentage change between these two cases along Highway 7 will be an increase in maximum PM₁₀ levels of about 30% over this area as shown in Figure 5.4c. Using BRT will lower emissions (and improve air quality) of all pollutants by about 4% along Highway 7.

**FIGURE 5.4a
PREDICTED PM₁₀ CONCENTRATIONS – MAXIMUM 24 HOURS
EXISTING BASE CASE – AREA 4**

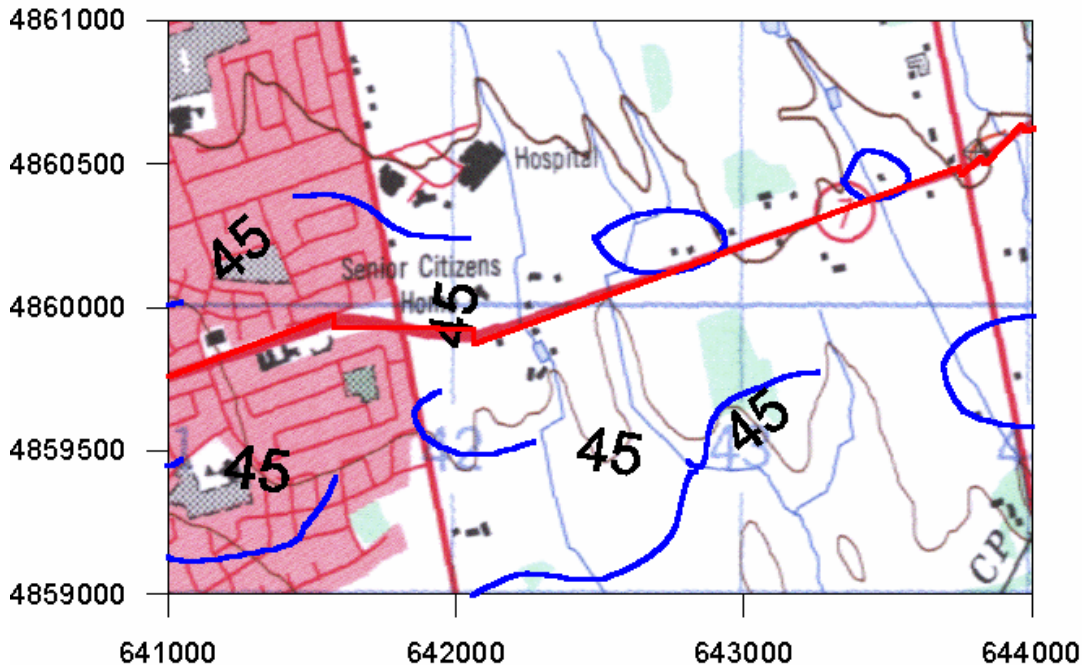


FIGURE 5.4b
PREDICTED MAXIMUM 24 HOUR PM₁₀ CONCENTRATIONS
FUTURE BASE CASE – AREA 4

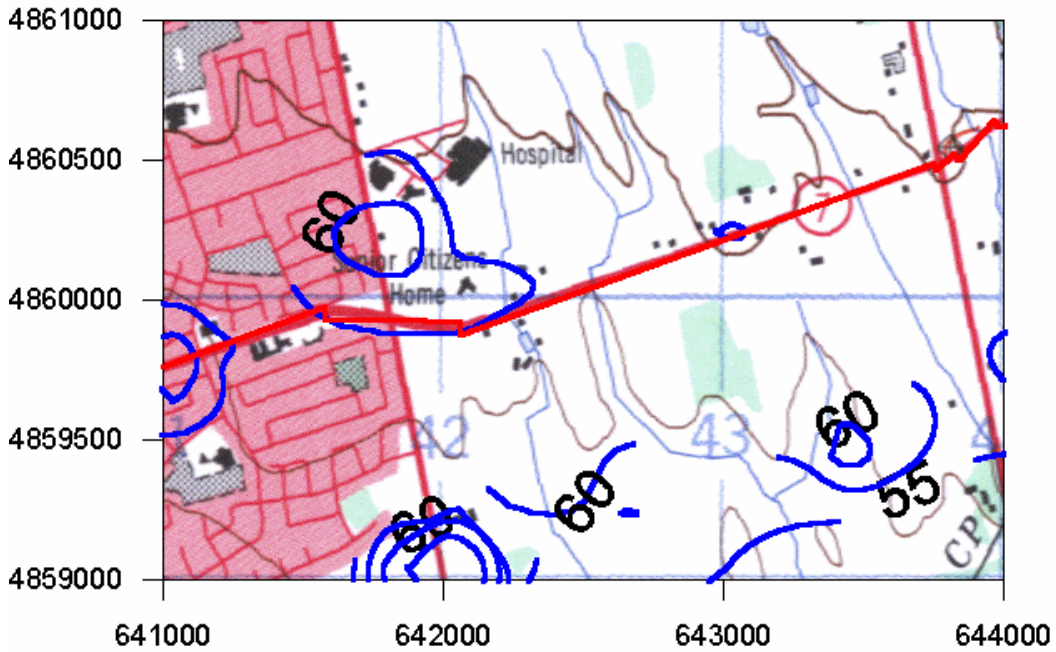
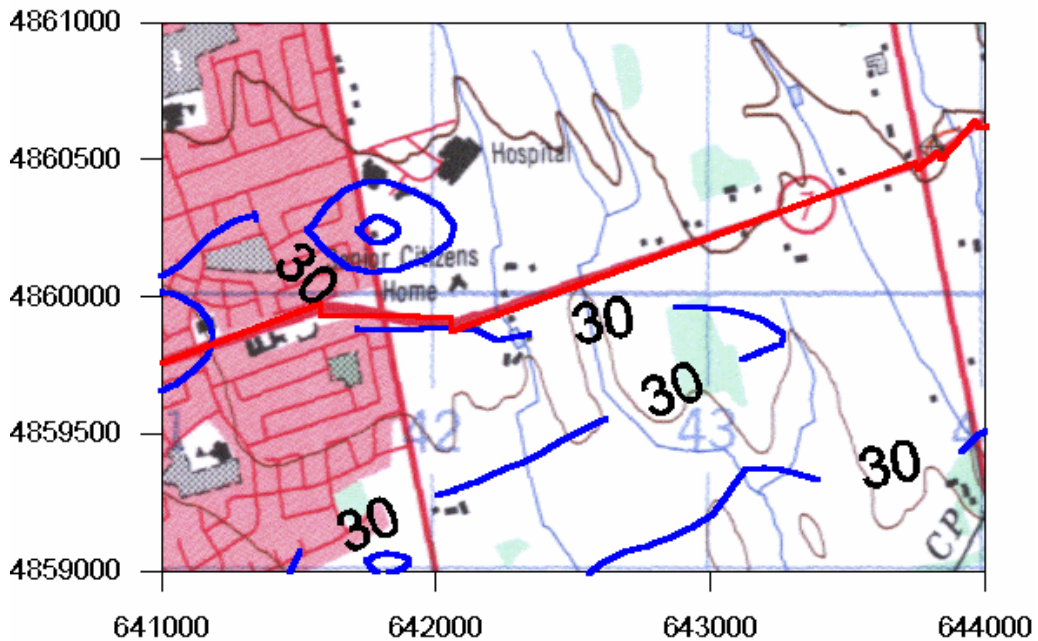


FIGURE 5.4c
PERCENTAGE CHANGE OF MAXIMUM 24 HOUR PM₁₀ CONCENTRATIONS
FUTURE BASE CASE / EXISTING BASE CASE – AREA 4



5.2 MODELLING RESULTS

The model results present the incremental pollutant concentrations resulting from the traffic on the modelled links (372) only. The model predictions do not include pollutants:

- transported into the area from upwind distant sources (long range transport);
- transported into the area from sources just upwind of the study area (short range transport);
- from small roads not included in the study area;
- from industries within the study area; or
- from small sources (from individual house furnaces, for example) within the study area.

Model Predictions at Monitoring Locations

Figure 2.2 illustrates the locations of monitoring sites used in this study. These locations were modelled as discrete receptors in the ISC3 Model.

Table 5.1 presents the base case concentrations due to traffic in the study area at the monitoring locations. There was no data for 2001 for Stations 14016 and 48006 so they have not been included in this analysis.

**TABLE 5.1
PREDICTED INCREMENTAL CONCENTRATIONS AT MONITORING LOCATIONS**

Predicted Maximum 1 Hour Average Concentrations (in $\mu\text{g}/\text{m}^3$)

Station	SO ₂	CO	NO _x	PM ₁₀	Odour*
48002	3	173	100	n/a	0.004
34020	12	1057	412	n/a	0.015
EAST	10	1306	367	n/a	0.015
WEST	10	915	345	n/a	0.015
MOE AAQC	690	36200	400	n/a	1.0

* Odour is a 10 minute average in odour units.

Predicted Maximum 24 Hour Average Concentrations (in $\mu\text{g}/\text{m}^3$)

Station	SO ₂	CO	NO _x	PM ₁₀
48002	1	96	18	9
34020	3	476	89	31
EAST	3	667	120	45
WEST	3	479	88	31
MOE AAQC	275	15700	200	50

* CO is an 8-hour average.

Predicted Annual Average Concentrations

Station	SO ₂	CO	NO _x	PM ₁₀
48002	0.04	n/a	1.3	1.1
34020	0.13	n/a	4.7	2.3
EAST	0.19	n/a	6.8	3.1
WEST	0.24	n/a	8.4	2.0
MOE AAQC	55	n/a	n/a	n/a

Table 5.2 compares the predicted maximum 24-hour average concentrations, resulting from the existing traffic in the study area, against the observed maxima at the monitoring stations.

**TABLE 5.2
PREDICTED VS. OBSERVED 24 HOUR AVERAGE CONCENTRATIONS (µg/m³)**

Pollutant		MOE 24-Hour Average AAQC	48002	34020	EAST	WEST
SO ₂	Predicted	275	1	3	3	3
	Observed		11	6	9	4
NO _x	Predicted	200	18	89	120	88
	Observed		53	150	77	107
PM ₁₀	Predicted	50	9	31	45	31
	Observed		ND	ND	130	101

The table shows, in the majority of cases, that the model predicts less than is observed. This is to be expected because the model does not include all of the upwind and in-study-area emissions. For the EAST location the NO_x predicted concentration is higher than the maximum observed concentration. This is not unusual because the monitoring period was limited whereas the model covered the whole year of meteorological conditions. Another factor is the uncertainty in the modeling and emissions inputs. A very small change (<5%) in the traffic numbers will swamp, by an order of magnitude, the improvement suggested by the introduction of the BRT.

SENES Consultants Limited concludes that the model baseline is a reasonable representation of the current contribution by the mobile sources in the study area.

5.2.1 Large Scale Modelling

The model output, in the form of maximum ground level concentrations, shows very little difference among the three scenarios examined for this project. For that reason, the following graphs have been presented by pollutant and as a percentage change from a base case.

Future Base Case

Figures 5.5 through 5.8 present the percentage change from the current base case to the future base case for NO_x, PM₁₀, CO and SO₂, respectively. For NO_x (Figure 5.5), the figure shows from a 20-25% decrease in maximum gas concentrations, along the Highway 7 Corridor, for the “do nothing” case, that is as a result of projected technology and fuel improvements. For reference purposes on the figures, the red line depicts Highway 7. Figures 5.6 through 5.8 show a 20-40% increase in PM₁₀, a 40-50% decrease in CO and a 40-50% decrease in SO₂.

Future Case with BRT

The emission rate estimates between the Future Base Case and the Future BRT scenario are very similar. Therefore, the ratio of predicted air concentrations for the BRT scenario vs. the future base case for NO_x, PM₁₀, CO and SO₂, will be so small that they will not be noticeable if plotted on a figure. For this reason, the assessment of this change is based on the emissions for the Highway 7 corridor (Tables 3.3 and 3.4). The tables show for NO_x, a 3.6% decrease in maximum gas concentrations, along the Highway 7 Corridor, for the “future BRT” case, that is as a result of rapid transit removing passengers from automobiles. The tables also show a 3.6% decrease in PM₁₀, PM_{2.5}, and CO and a 4.4% decrease in SO₂ emissions. Consequently, the change in predicted air concentrations between the future base case and the future BRT are expected to be similar to these changes in emissions.

FIGURE 5.5
PERCENTAGE CHANGE OF MAXIMUM 24-HOUR NO_x CONCENTRATIONS
FUTURE BASE CASE / BASE CASE

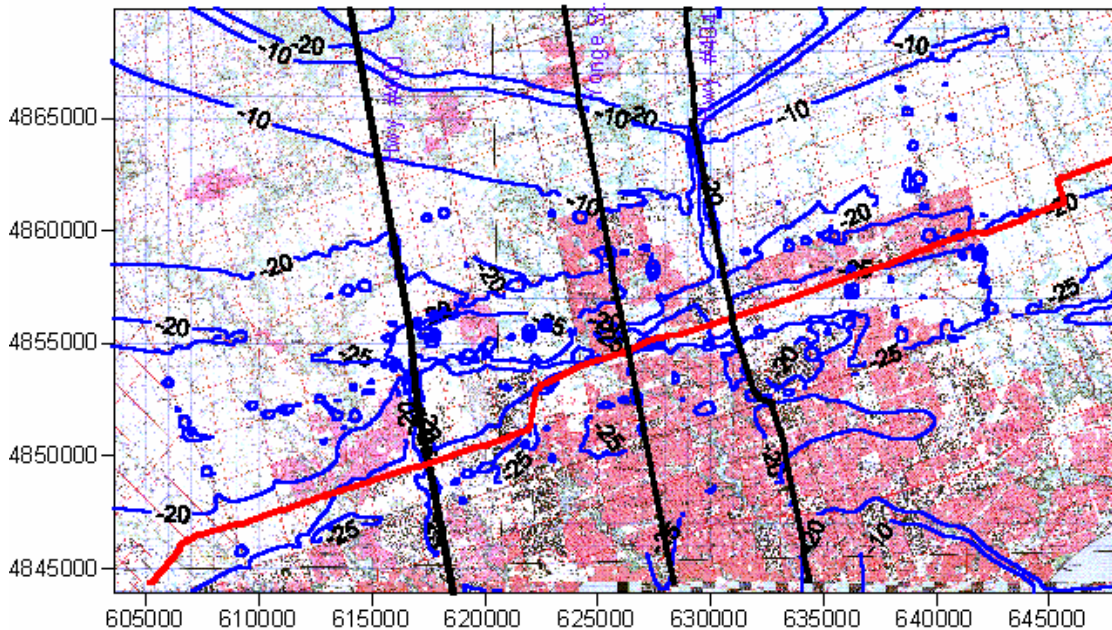


FIGURE 5.6
PERCENTAGE CHANGE OF MAXIMUM 24-HOUR PM₁₀ CONCENTRATIONS
FUTURE BASE CASE / BASE CASE

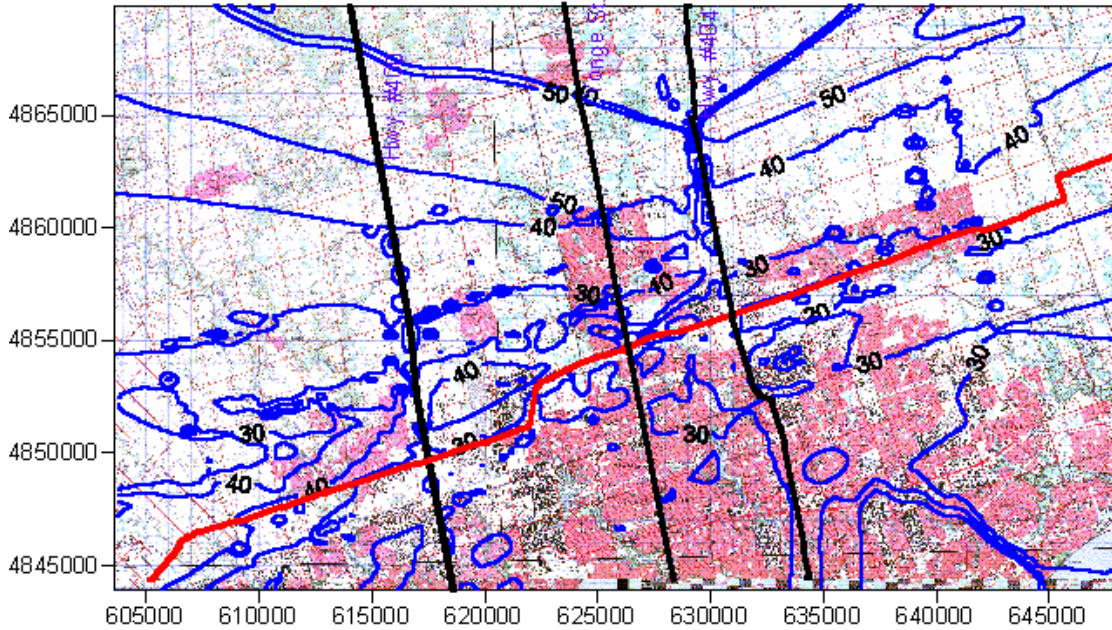


FIGURE 5.7
PERCENTAGE CHANGE OF MAXIMUM 24-HOUR CO CONCENTRATIONS
FUTURE BASE CASE / BASE CASE

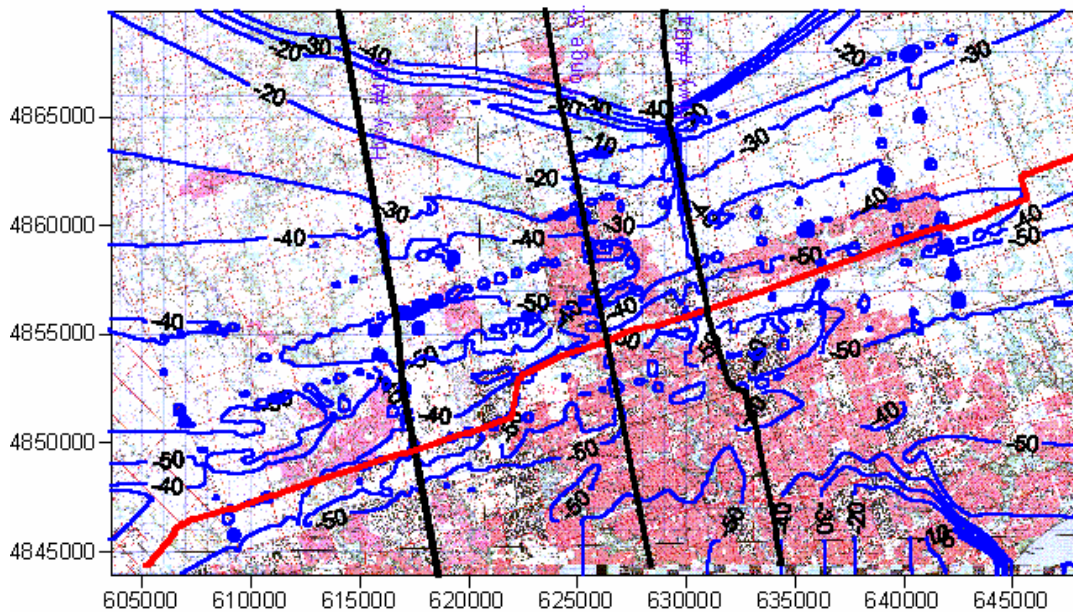
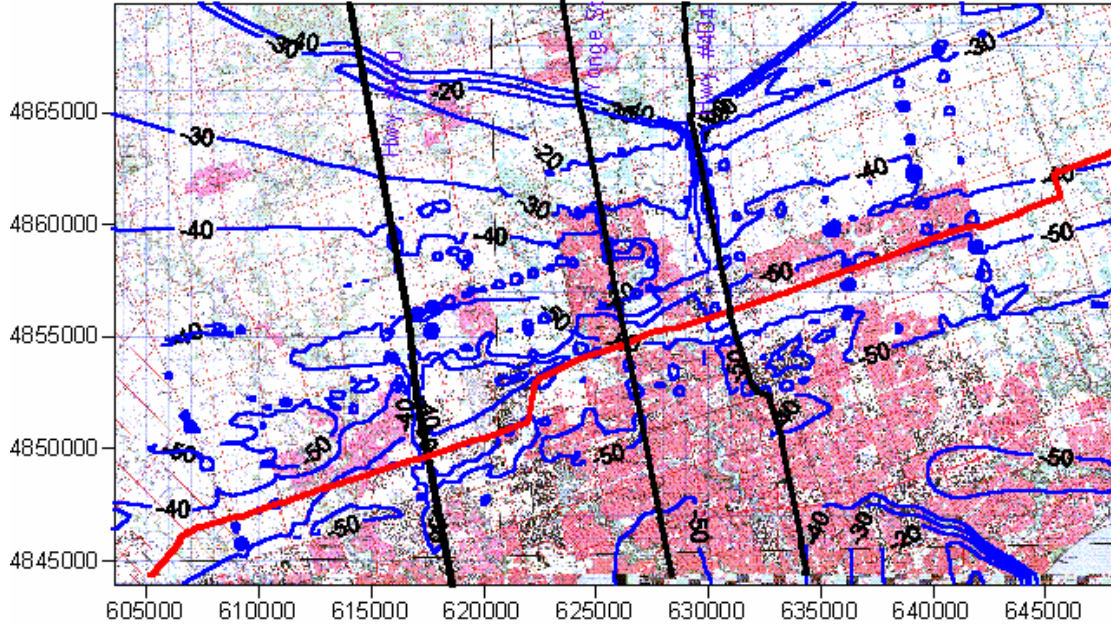


FIGURE 5.8
PERCENTAGE CHANGE OF MAXIMUM 24-HOUR SO₂ CONCENTRATIONS
FUTURE BASE CASE / BASE CASE



6.0 EVOLUTION OF THE SYSTEM

6.1 INTRODUCTION

The role of the Highway 7 Transitway in the planned York Rapid Transit Network, discussed above, is a key factor in the selection of the appropriate technology for the corridor. Studies of potential network configurations (route and technology options) have indicated that the Highway 7 corridor is one in which the rapid transit technology could evolve over time. As growth and development patterns change, increases in demand may justify or even mandate transitions from an initial technology application, such as partially segregated BRT (segregated operation with at-grade intersections), to either light rail or ultimately in the southernmost segment, an extension of Toronto's subway technology.

6.2 IMPACT ON AIR QUALITY

Conversion to partially segregate BRT would leave emissions virtually the same as in the current formulation. Conversion to light rail or subway technology would result in zero emissions locally but an increase in GhG emissions at the point of electricity generation. The size of this increase would depend on the percent of the system converted, where the power was generated and the reduction in GhG emissions locally (due to reduced use of fossil fuel).

7.0 OVERALL ASSESSMENT OF AIR QUALITY

The existing air quality in the area can be described as fairly good because:

- the historical SO₂ and CO concentrations are well within all applicable standards as shown in Table 6.2);
- the historical data (Table 2.6) also shows that PM concentrations can be up to two times the standard from time to time. This was confirmed by project specific sampling (Table 2.7) that found values up to three times the standard;
- daily average NO_x concentrations, measured during the project sampling (Table 2.7), were confirmed to be below the standards,
- historically (Table 2.6) there have been occasional exceedances of the O₃ standard. This was also confirmed by the additional sampling; and
- the estimated CO₂-equivalent emissions from the Ontario vehicle fleet are 49,400 kilotonnes of a total of 200,000 Kt for all sources. The CO₂ emissions from the study area are approximately 4% of the Ontario fleet CO₂-equivalent emissions

The future air quality can be described as better than the existing air quality because:

- improvements in engine technology and fuels will improve air quality for all pollutants over the next 10 years except PM;
- bus rapid transit will provide an additional, albeit small, improvement of about 4% for all pollutants (as shown in Section 5.2.1);
- for PM, which is expected to increase into the future as traffic increases, BRT will slow the rate of increase (as shown in Section 5.2.1); and
- the introduction of the BRT will result in a net decrease of CO₂ emissions of approximately 54 kilotonnes from the current total of 49,400 Kt.

While some fine PM, and all O₃, are formed through chemical reactions in the atmosphere, as result of the mixing of pollutants, the small differences expected from the introduction of BRT to a “future base case” will not be distinguishable against variations in this base. As a result, the 4% figure would be impossible to monitor.

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