APPENDIX A - AIR QUALITY ASSESSMENT REPORT

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Air Quality Assessment
for the

Proposed
Eglinton Crosstown LRT

A Report to

Transit City Group

Prepared by

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Executive Summary

This Air Quality Assessment document examines the potential changes in both local and regional air quality that would result from the construction and operation of the Eglinton LRT as a replacement for diesel bus services that currently use the corridor between Kennedy Road in the east and Renforth Road in the west. The assessment focuses on the impacts of the common contaminants released from both vehicular traffic and construction activities.

While the report discussed available air quality data from different areas of the City of Toronto to put things into perspective, there is no available data that measures current levels in the corridor. However, it is noted that residents within 100 m of heavily travelled roadways may be exposed to two to three times the levels of fine particulate matter measured at general regional air quality monitoring locations.

The report identifies that proceeding with the project will result in the reduction in local emissions, but these will be offset to some extent by emissions associated with the production of the electricity used to power the LRT vehicles. The report identifies net reductions in oxides of nitrogen, volatile organics and particulate matter emissions in southern Ontario, but the local reductions are much more significant than the number indicate because the buses are removed locally and the power is generated some distance away from the corridor. Overall the project will result in the reduction of 52 Mg of conventional contaminants annually. A major reduction in greenhouse gas emissions, over 865 Mg/year, will occur after the system goes into operation. While not quantified, the report notes that any measures that lead to private vehicle owners increasing their use of public transit due to the development of the LRT line will provide more emission reductions as fewer vehicles are on the road. The construction and operation of three new bus terminals along the route will not cause any significant impacts on local air quality around these locations.

The report notes that construction related air emissions will occur. Two major types of emissions are likely, those of dust from various material handling operations, and combustion emissions from construction equipment which is typically powered by diesel engines. Such emissions will be of a temporary nature and the impact is not predicted to move far from the immediate vicinity of the construction activities. Indeed, mitigation measures to control dust releases around the construction sites are listed in the report as are recommendations for minimizing the potential of combustion emissions from construction equipment. Chief among the latter category of recommendations is that tunnel boring machines be powered by electricity from the grid. Wheel washing, tarping and dust suppression measures are recommended to control fugitive dust emissions.

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1.0 Introduction

This report provides an assessment of Air Quality for the Environment Assessment of the Eglinton Crosstown LRT project.

1.1 Eglinton LRT Project Description and Study Area

The Eglinton LRT Project is planned to run along Eglinton Avenue from Kennedy Road in the east to a Pearson Airport in the west. A total of 33 km in length, this line will be on a dedicated right of way when on th surface or underground.

The Eglinton Crosstown LRT includes the following key design components:

- LRT at surface from Pearson International Airport to east of Black Creek Drive, underground from east of Black Creek Drive to east of Brentcliffe Road, then at surface from east of Brentcliffe Road to Kennedy Road including a short underground section at Don Mills Road;
- 28 surface stops and 13 underground stations;
- left turn prohibitions crossing the surface LRT right-of-way, except for signalized intersections;
- left turn prohibitions from Eglinton Avenue to Martin Grove Road, Kipling Avenue, Islington Avenue, Royal York Road, Scarlett Road, Jane Street, Victoria Park Avenue, Pharmacy Avenue and Birchmount Road.
- left turn prohibitions from Jane Street and Pharmacy Avenue to Eglinton Avenue.
- new bridge over Highway 401 to connect Convair Drive to Commerce Boulevard;
- widening of several bridges such as those associated with Mimico Creek, Black Creek, West Don River, and East Don River, and a culvert extension at Wilson Brook;
- traction power substations;
- provision of special track work, emergency exit buildings and ventilation shafts in underground sections; and,
- landscaping, streetscaping and associated amenities.

Two separate study areas were adopted for the Eglinton Crosstown LRT. The first area consists of the section of the Eglinton Crosstown LRT located along Eglinton Avenue, encompassing 500 metres to the north and to the south of the centerline from just west of Renforth Drive in the west to just east of Kennedy Road in the east. A second area (Airport Link) was developed to investigate the connection to Pearson International Airport. This area is bounded by Dixon Road to the north, inside Pearson International Airport lands to the west, Eglinton Avenue to the south and Martin Grove Road to the east. Two major corridors were considered originally for the Airport Link including Highway 27 – Dixon Road and Commerce Boulevard/Renforth Drive – Silver Dart Drive.

1.2 Air Quality Assessment Approach

Overall, the Eglinton LRT would provide an alternative travel mode for commuters living along the route. It would replace some of the surface bus routes currently operating along Eglinton leading to a reduction in emissions of engine exhaust on that route. The design description above suggests that there will be numerous construction sites located along the route. Each construction site will have air emissions associated with the specific operations at those site. The Air Quality Assessment addresses the question, how will the project affect air quality?

This report provides a brief review of existing air quality issues in the City of Toronto to put into perspective the air quality impacts that might be associated with the proposed development of the Eglinton Crosstown LRT system.

2.0 Air Quality in the City of Toronto

2.1 Climate and Meteorology

Toronto has a continental climate where the four seasons bring with them varying temperature and precipitation patterns. Being located on the edge of Lake Ontario, Toronto, like other communities around the lakes, has climatic effects moderated by the influence of large water bodies[1]. The lakes tend to have a cooling effect throughout most of the warmer parts of the year, and to some extent moderate extreme cold periods while they delay the coming of spring and prolong warmer weather in the fall.

In land form, Toronto sits on a plain that slopes down towards the lake with a drop in elevation of nearly 125 m from about 200 m ASL at York University on Steeles Avenue to 75 m ASL at the lake. The plain is intersected by several river valleys the most notable being the Don River in the east and the Humber in the west. As such, the higher land to the north and west tends to minimize the occurrence of fog and frosts because they have a warming effect on winds and set up conditions favourable for breezes down the slope when the land gives off heat during the night.

Toronto is in a latitude subject to winds from the west. However, it comes under the influence of the Great Lakes when winds come from all directions except the north-northwest and east-northeast quadrants. The lake influences local air quality when lake breezes, air flow off the lake unto land caused by local heat island effects and the cooler air over the lake, set up recirculating air flows that trap contaminants in the near shore regions and lead to smog events. Such lake breezes have been seen to have a non-uniform effect on smog levels along the shore line[2]. Observations have shown marked increases in NO$_x$ or ozone levels in different locations, suggesting that the source of the pollutants, and the nature of the air mass over the lake strongly influences the air quality impacts of lake breeze situations.

2.2 Regional Air Quality

Air flows coming into the Toronto area frequently pass over the Ohio Valley and other heavily industrialized areas of the United States and southern Ontario. This contributes as much as 50% of the air pollution burden seen in communities[3]. Other contributors include local industrial operations, fossil fuelled power generation facilities, and the high numbers of vehicles using roads in and around the city. In the middle of the Windsor-Quebec transportation corridor, Toronto is a hub of one of the most

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[1] Shenfeld, Louis, and D.F.A. Slater, 1960. The Climate of Toronto. A publication of the Meteorological Branch, Department of Transport, Canada. CIR-3352, TEC-327, June.

[2] Lin, Hong, Q. Li, D. Sills, J. Brook, L. Alexander and P. King. 2007. Lake Breeze Effects on Air Quality in Southern Ontario. A presentation at the AMS 9th Conference on Atmospheric Chemistry, January.

[3] Ontario MMAH, 20004. Building Strong Communities: Municipal Strategies for Cleaner Air. Available at: http://www.mah.gov.on.ca/Page1307.aspx

heavily travelled corridors in North America.

While trans-boundary air pollution and regional transportation corridors contribute to regional air quality, heavy industry has its own effects, typically using tall stacks to allow emissions to be dispersed and carried downwind. Another factor that can influence regional air quality are large concentrations of asphalt and urban development which gives rise to the "urban heat island" effect. Higher temperatures associated with urban areas, increase the potential for smog formation from the air emissions. In turn, higher temperatures prompt the use of more air conditioning and this leads to higher air emissions from fossil fuelled power generation facilities.

Overall, compared to other communities in southern Ontario, the Toronto area has less frequent poor air quality than Windsor, London or Waterloo; however, as pointed out by the MMAH report cited above, with its higher population Toronto has more people affected by poor air quality.

2.3 Pollutants of Concern

A number of common air pollutants are addressed in this study:

- particulate matter [PM] and the inhalable fraction [PM$_{10}$] and respirable fraction [PM$_{2.5}$];
- oxides of nitrogen [NO$_x$];
- sulphur oxides [SO$_2$];
- carbon monoxide [CO];
- volatile organic compounds [VOC]; and,
- ozone [O$_3$].

The first four categories on the above list are typically referred to as Criteria Pollutants, or common air pollutants. They are classed as "criteria" pollutants because their emissions are regulated based upon human health-based and/or environmentally-based criteria (science-based guidelines) for permissible levels. The set of limits based on human health is called primary standards. A secondary set of standards limit emissions to prevent environmental and property damage.

Ozone would typically be categorized as a Criteria Pollutant because of its health effects, however, it is seldom released from sources, rather at ground level it is created by a chemical reaction between oxides of nitrogen and volatile organic compounds in the presence of sunlight. Ground-level ozone is the primary constituent of smog. Generally, ozone levels are higher in the summer when sunlight and hot weather increase the reaction rate between the chemical constituents. As noted above, these influences are exacerbated by elevated temperatures in large urban areas. Much of the ozone measured in southern Ontario is attributed to sources hundreds of kilometres upwind, but there is a large contribution from vehicular traffic.

The list above is by no means all inclusive of contaminants that can be released into the atmosphere. There are a class of contaminants, frequently referred to as Air Toxics, that include a range of organic pollutants and metallic compounds. Many of these compounds can have health effects if humans are exposed to high concentrations and for this reason they frequently receive attention from public health officials. In a report on the relationship between illness and traffic in Toronto[4] the authors list nine specific compounds associated with vehicle emissions:

- chromium;
- benzene;
- polyaromatic hydrocarbons, [PAHs];
- 1,3-butadiene;
- formaldehyde;
- acrolein;
- acetaldehyde;
- nickel; and,
- manganese.

These compounds are on the short list of compounds that California identified as of concern from diesel engine exhaust[5]. One of the main reason for addressing diesel engine emissions was that diesel particulate matter [DPM] emissions were determined to be at least 20 times higher than particulate emissions from gasoline engines on an equivalent energy basis. The DPM was characterised as agglomerated spherical carbon particles coated with inorganic and organic substances. The inorganic fraction consisted of very fine particles 0.01 to 0.08 microns in diameter. The organic fraction consisted of soluble compounds and PAH and PAH-derivatives that have been identified as mutagens or carcinogens. All diesel exhaust particles are in the less than 10 micron size range, with 92% of the mass being less than 1 micron in diameter. These are particles that can be inhaled and trapped in the bronchial and alveolar regions of the lung.[6]

Within the context of this study, the potential to reduce the emissions of these "toxic contaminants" is small compared to the impacts that are made through the reduction of criteria pollutants. For this reason these contaminants are not explicitly addressed in terms of air quality benefits of the project.

Particularly pertinent to this study are the priority contaminants, ozone and $PM_{2.5}$ because these have been associated with mortality, respiratory effects and cardiovascular effects according to the reviews in Campbell et al. The health concerns raised by these contaminants resulted in them being targeted by the CCME CWS for Particulate Matter and Ozone[7].

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[4] Campbell, Monica, K. Bassil, C. Morgan, M, Lalani, R. Macfarlane, and M. Bienefeld, 2007. Air Pollution Burden of Illness from Traffic in Toronto, Problems and Solutions. Published by Dr. David McKeown, Medical Officer of Health, Toronto Public Health. Available at: http://www.toronto.ca/health/hphe.

[5] California Air Resources Board, 1998. Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant Part A Exposure Assessment. Approved by the Scientific Review Panel on April 22, 1998. Available at http://www.arb.ca.gov/toxics/dieseltac/part_a.pdf

[6] California Air Resources Board, 1998. Executive Summary for the "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant". April, 1998. Avaiable at: http://www.arb.ca.gov/toxics/dieseltac/finexsum.pdf

[7] CCME, 2000. CANADA-WIDE STANDARDS for PARTICULATE MATTER (PM) and OZONE http://www.ccme.ca/assets/pdf/pmozone_standard_e.pdf

The Ontario Ministry of the Environment operate a network of air quality monitoring stations in the Toronto area and data from these locations can be used to track trends in both the temporal and spatial variations in contaminant levels in the atmosphere. For this study the 2006 data from the locations listed in Table 1 will be used as the baseline.

Table 1 Toronto Area Air Monitoring Stations

Location	Nearest Intersection	Station #	Description of Station				
			O_3	$PM_{2.5}$	NO_2	CO	SO_2
Downtown	Bay/Wellesley	31103	x	x	x	x	x
East	Kennedy/Lawrence	33003	x	x	x		
North	Yonge/Hendon	34020	x	x	x		
West	Resources Road/Islington near 401	35125	x	x	x		
Etobicoke West	Elmcrest Road/Centennial Park	35003	x	x	x		
Etobicoke South	Judson/Islington	35033	x	x	x	x	x

2.3.1 Fine Particulate Matter

Particulate matter as defined above included all particles that could remain suspended in the air for any length of time, but those of most interest are the respirable fraction that are less than 2.5 um (micrometers or microns) in size and designated at $PM_{2.5}$. These particles have a diameter that are approximately 30 times smaller than the average diameter of a human hair. Their size means they can have significant effects on health because they enter the lungs and are not always removed through normal breathing. As noted above, these fine particles can consist of compounds that have varying effects from those on respiratory systems to cancer causing agents. Still thought to be important, but not targeted by the CWS are particles that are inhalable, $PM_{10.}$

The $PM_{2.5}$ in the atmosphere comes from two sources: primary emissions of fine particles and secondary formation through chemical reactions after they enter the atmosphere. Primary particulate matter in the atmosphere includes those particles emitted directly from a source be it re-suspended road dust, or emissions from internal combustion engines, space heating, or other combustion sources, as well as those from industrial processes. Recognizing that industrial processes have an impact on particulate matter emissions under the CWS national multi-pollutant emission reduction strategies were implemented for the following sectors:

- Pulp and Paper
- Lumber and Allied Wood Products
- Electric Power
- Iron and Steel
- Base Metals Smelting
- Concrete Batch Mix Plants
- Asphalt Mix Plants

Combustion sources emit $PM_{2.5}$ and vehicle emissions are a major contributor. Secondary particulate matter are largely ammonium nitrate and ammonium sulphate particles. They are created when acids formed from gaseous sulphur and nitrogen oxides emissions react with ammonia in the atmosphere to create very fine solid particles. Such fine particulate matter effectively scatter light and can result in a reduction of visibility.

Since the implementation of the CWS, provincial agencies have increased the level of $PM_{2.5}$ monitoring that is undertaken. The CWS requires daily 24 hour averages be calculated from hourly values recorded by the instruments. Meeting the CWS standard of 30 ug/m^3 requires evaluation of the 98th percentile of the 24 hour averages recorded over the last 3 years. In essence, to meet this standard, no more than 7 daily averages in any year can be in excess of the 30 ug/m^3 criteria level [2% x 365]. In 2006 there were six monitoring stations located in the Toronto area. The data for the monitoring sites: the mean 24-hour average, the maximum 24 hour average as well as the 90 percentile level for the 24 hour average, the level that 90% of all the readings were below, and the number of day in the year when the 24 hour average exceeded 30 ug/m^3 are shown in Table 2.

Table 2 Summary of Toronto Area 2006 $PM_{2.5}$ [ug/m^3] Data[8]

Location	24-hr Mean	24-hr 90th Percentile	Maximum 24 Hour	Number of Days Value > 30 ug/m^3
Downtown	7.3	16	35	4
East	7.6	17	37	5
North	7.6	17	36	2
West	8.2	18	35	3
Etobicoke West	8.3	18	34	4
Etobicoke South	8.8	19	38	6

The 90th percentile is generally accepted as a reasonable estimate of background levels in an area, while the mean provides an average over the year and the maximum is the peak value. These values will vary depending upon both regional and local influences but the hourly values provide some indication of local variations.

The Annual Air Quality report also provides a comparison of the $PM_{2.5}$ data for 2004 - 2006 against the CWS standard of the 98th percentile over 3 years that should be below 30 ug/m^3. In addressing this standard, the report addresses concentrations in an area to provide a general picture of the ambient levels of $PM_{2.5}$. Averaging the Toronto East, North, Downtown and West values for the three year period produced a value just above 30 ug/m^3, but the average was lower than reported in the 2005 report[9].

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[8] MoE, 2007. Air Quality in Ontario, 2006 Report. Available at http://www.ene.gov.on.ca/publications/6552e.pdf

The 2005 report clearly suggests that trans-boundary pollution is a factor in $PM_{2.5}$ concentrations measured. That report illustrates the fact that high levels recorded in September 2005 corresponded to a period when the predominant wind directions across the province were from the south and southwest. A backward trajectory examination of smog days in 2006 confirms that high levels are associated with winds that have travelled over the heavily industrialized areas of the United States.

2.3.2 Ozone

While not directly released from combustion sources, ozone levels can be influenced by releases of VOC and NO_x to the atmosphere. The MoE Air Quality report notes that both the formation and the transport of ground-level ozone are strongly dependent on meteorological conditions. As noted in the discussion on trans-boundary pollution and the effect of lake breezes earlier, short-term and year-to-year differences in ozone concentrations are attributable to causes beyond emissions in the air shed. In most areas where ozone levels are notable, elevated concentrations of ground-level ozone are generally recorded on hot and sunny days. In Ontario, these occur between May and September. Furthermore, there is a diurnal variation in levels which tend to peak in the afternoon and early evening period.

Vehicular traffic is responsible for a large portion of the NO_x released into the atmosphere. While oxides of nitrogen, NO_x, is a general term for nitrogen compounds released to the atmosphere, they are defined to be the sum of nitrogen dioxide [NO_2] and nitric oxide [NO]. Emissions of NO_x from internal combustion engines consist mainly of NO, with some NO_2. When released, NO emissions convert to NO_2 which has adverse health effects at a lower level than NO. One of the chemicals that NO reacts with to form NO_2 is ozone present in the atmosphere. Thus, vehicular emissions in the morning rush hour can result in a decrease in ambient ozone levels as the NO scavenges the ozone from the atmosphere. The production of ground level ozone continues throughout the day peaking in midafternoon when the sunlight is at its most intense level. The diurnal cycle shows levels starting to decrease after the sun sets.

The daily and seasonal variations in ozone levels must then be taken into account when reviewing ozone monitoring data. The MoE reports mean hourly data for the year for ozone at monitoring stations as well as computing the maximum 1 hour and 24 hour averages. When considering the results for the province, the MoE looks at trends in the annual average of the maximum one hour values from year to year, as well as considering changes in the average of the maximum 1 hour readings on a seasonal basis.

Table 3 provides the results for Toronto area monitoring locations for 2006. It is worthwhile noting that the MoE report shows that the Toronto West station had one of the lower maximum 1 hour value of all the locations where this contaminant is monitored. Some rural areas were significantly higher, a fact

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[9] MoE, 2006. Air Quality in Ontario, 2005 Report. Available at http://www.ene.gov.on.ca/en/publications/air/6041e.pdf

the MoE attributes to the scavenging effect of NO releases in the urban environment. The MoE suggest that across the province the average of the maximum 1 hour values for all sites has dropped 15% since 1988. Two thirds of this drop has occurred in the last 10 years, and the annual average of 1 hour maximum has dropped significantly since 2004. Contrary to behaviour of the maximum 1 hour values, the means of all the data, plotted on a seasonal basis show the summer mean to be higher than the winter, but both have been on an increasing trend since 1988. Thus while the peaks have decreased, ozone levels have risen over the period. The MoE attributes some of this to a drop in NO_x emissions, and thus less scavenging effects, and a rise in global ground level ozone levels. While recognizing that the contribution of long range transport is a factor in summer levels, this is not quantified.

Looking at trends in the Toronto data, the Campbell et al. report cited earlier graphs a general increasing trend in the provincial mean data from 1992 to the present.

Table 3 Summary of Toronto Area 2006 Ozone [ppb] Data[10]

Location	Annual Mean	1-hr 90th Percentile	Maximum 1 Hour	Number of Hours Value > 80 ppb
Downtown	22.6	42	92	15
East	22	41	88	14
North	23.3	43	96	6
West	19	40	94	9
Etobicoke West	21.4	43	91	13
Etobicoke South	19.1	38	98	5

As noted in the discussion of $PM_{2.5}$ the Canada Wide Standard $PM_{2.5}$ also contains a numerical target for ozone. In this case the standard is based upon the average of the 4th highest 8 hour rolling average value of ozone for each of the last three years. The criteria value is 65 ppb. The MoE shows that the Toronto average level based upon taking the 4th highest annual value and averaging the results from the downtown, north, east and west sites was approximately 75 ppb, or about 10 ppb over the standard. No discussion is available in the MoE report to assess the contribution of long range transport to this reported average, but it is important to recognize that the numerical target in Part 1 of the CWS provides specific provisions related to transboundary flow of ozone.

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[10] MoE, 2007. Air Quality in Ontario, 2006 Report. Available at http://www.ene.gov.on.ca/publications/6552e.pdf

2.3.3 Other Pollutants

Trends in the concentrations of other criteria air pollutants in the Toronto area are presented in the Campbell et al. report. These were based upon the MoE annual report data since 1980. The report suggests that CO and SO_2 concentrations in the city have declined in recent years while TSP levels show little change. The MoE suggest that provincially the CO levels have decreased consistently since 1971, being down nearly 90% on average. Mean SO_2 levels in the province have declined gradually over the last 8 years.

Tables 4 - 6 provide monitoring data for CO, NO_x and SO_2 at the various monitoring stations. These tables show that there were no occurrences of measured values exceeding the applicable criteria levels.

The Campbell report suggests that while annual average NO_x levels in Toronto have decreased for the last 8 years, they are only now getting back to where they were in 1981. It is not clear how much the averages are influenced by the extremes that are reported at the Toronto West location. Located adjacent to the 401 just east of Islington where the 409 merges with the 401, this site reported the highest annual mean in the province in both 2005 and 2006. The Toronto West average was 33% higher than the next highest Toronto average in 2005, and 15% higher in 2006. In Ontario as a whole, the composite annual mean NO_x concentration has decreased 33% over the last 32 years, and 20% over the last decade. Urban areas seldom show this level of decline because traffic volumes continue to increase year over year. Indeed, in the Vancouver area NO_x levels showed little change for the period from 1999 to 2004[11].

Overall, the rate of decline of most airborne contaminants is slowing, with, as noted above, some species increasing in concentration. If the trends of increasing population bring with it more vehicular traffic it is doubtful if these trends can be maintained, despite measures to reduce vehicular emissions. Clearly, other emission reduction strategies, such as increased use of public transport in large urban areas can only benefit the environment and those living in the city.

Table 4 Summary of Toronto Area 2006 Carbon Monoxide [ppm] Data[12]

Location	Annual Mean	1-hr 90th Percentile	Maximum 1 Hour	Number of Times 1 hour Maximum Value > 30 ppm	Maximum 8 hour Average	Number of Times 8 hour Average Value > 13 ppm
Downtown	0.33	0.51	1.46	0	1.02	0
West	0.35	0.55	2.98	0	2.98	0

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[11] Global Change Strategies International, 2003. Air Quality and Greenhouse Gas Emission Benefits of the Richmond Airport Vancouver Rapid Transit Project. A report prepared for the Richmond Airport Vancouver Rapid Transit Project. May.

[12] MoE, 2007. Air Quality in Ontario, 2006 Report. Available at http://www.ene.gov.on.ca/publications/6552e.pdf

Table 5 Summary of Toronto Area 2006 SO_2 [ppb] Data[12]

Location	Annual Mean	1-hr 90th Percentile	1 hour Average		24 hour Average	
			Maximum	Times >250 ppb	Maximum	Times >250 ppb
Downtown	1.9	5	38	0	13	0
West	2.0	5	27	0	9	0

Table 6 Summary of Toronto Area 2006 NO_2 [ppb] Data[12]

Location	Annual Mean	1-hr 90th Percentile	1 hour Average		24 hour Average	
			Maximum	Times >200 ppb	Maximum	Times >100 ppb
Downtown	19.1	33	75	0	45	0
East	17.4	31	68	0	45	0
North	17.4	34	70	0	42	0
West	22.3	37	73	0	43	0
Etobicoke West	INS	29	74	0	41	0
Etobicoke South	24	43	89	0	53	0

INS insufficient data for average

2.4 Emissions Inventory

An emission inventory provides information on the sources of air pollution within a region. A detailed emissions inventory for both criteria air contaminants and greenhouse gas emissions based upon 2004 data was prepared for the City of Toronto[13]. These data are used by the Toronto Environment Office in air quality models that provide insight into potential trends and factors that can affect air quality in the City. Such information identifies the sources of particular types of air contaminants and provides some understanding for the potential beneficial impacts that would be associated with the proposed development.

2.4.1 Criteria Air Contaminants

Air contaminants included in the City of Toronto emission inventory that is used for the Air Quality Model [AQM] are summarized by source category in Table 7.

As explained in the ICF report, the natural gas combustion and mobile source related emissions were calculated from basic data. In the case of natural gas, gas sales by postal code were used to develop emission numbers and assign them by building type, as the nature of the exhaust influences the impact of the emissions in the local area. Mobile data were developed from an approximation of the operating fleet data from traffic counts adjusted for known fleets operating in the City, TTC, GO and school buses, and emission factors developed by the federal environment agency, which in turn used US EPA mobile emission data. Mobile data include the contribution of road dust re-suspension that is typically included in area source calculations. Area source data were adjusted by removing the contribution of sources quantified specifically by the City, such as natural gas combustion and road dust. Area sources include: industrial fugitive emissions; residential and commercial fuel combustion (not including natural gas); residential wood fuel combustion; utility emissions not included elsewhere; dry cleaning; fuel marketing; general solvent use; pesticides and fertilizer applications; printing; structural fires; surface coating (painting); meat cooking and human emissions including smoking. Specifically excluded from the City's inventory at the time it was created were construction related emissions. These tend to be localized and variable and while economic activity in this sector might provide an overall emission estimate, to apportion it across the city was not possible so it was excluded.

Point source data relate mainly to industrial facilities that file emission information to the National Pollutant Release Inventory. These data include emission rates, and the characteristics of the stacks which can be entered into the City's AQM. Industrial releases that cannot be assigned to specific stacks are removed from the site emissions and introduced into the AQM as part of the Area source emissions.

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[13] ICF International, 2007. Greenhouse Gases and Air Pollutants in the City of Toronto: Towards a Harmonized Strategy for Reducing Emissions. Prepared in collaboration with Toronto Atmospheric Fund and Toronto Environment Office. June. Available at http://www.toronto.ca/taf/pdf/ghginventory_jun07.pdf

Table 7 Summary of Toronto's Annual Emissions [Mg/year] as Used in the City's AQM[14]

Contaminant	Natural Gas Combustion			Other Sources			Total	Mobile [%]
	Short	Medium	Tall	Mobile	Area	Point		
CO	2,344	896	914	306,174	47,573	435	358,336	85
NO_x	3,858	1,264	1,562	27,434	3,740	1,749	39,607	69
PM_{10}	304	98	123	7,432	10,848	470	19,275	39
$PM_{2.5}$	304	98	123	1,576	7,305	408	9,814	16
SO_2	24	8	10	117	8,531	304	8,993	1
VOC	220	71	89	25,003	562,053	1,273	588,709	4

The table shows the contribution of mobile traffic to air quality in the City. A review of the basis for the $PM_{2.5}$ emission estimates shows that there appears to be little difference between the emission factors for $PM_{2.5}$ between expressway, arterial or residential roads. This is because only the diesel bus and motorcycle emissions in terms of grams released per vehicle kilometre travelled alter between the three types of roads. It is not immediately apparent how these distinctions were made. It is interesting to note that there are data to suggest that the rate of $PM_{2.5}$ emissions is related to the speed and acceleration on any particular section of road[15]. This suggests that the split between PM_{10} and $PM_{2.5}$ deserves more attention particularly since there is evidence that the finer particles can have greater health impacts. The 2006 MoE provincial inventory for $PM_{2.5}$ suggests that transportation sources could account for 20% of provincial emissions of this contaminant. In Vancouver, 2002 data identified transportation sources as contributing 45% of the fine particulate matter released to the atmosphere, and this excluded the contribution of road dust.

The apparent deficiency in the existing Toronto $PM_{2.5}$ inventory lends credence to the thought that removing traffic from the roads might have a greater local impact than would be suggested simply by a proportional reduction in vehicle traffic. Reducing congestion by removing light duty passenger vehicles from the streets will also reduce $PM_{2.5}$ emissions due to start and stop traffic situations.

2.4.2 Greenhouse Gas Emissions

The ICF report provides an inventory of greenhouse gases [GHG] for 2004. The overall emissions and sources are summarized in Table 8. Mobile sources, road vehicles, account for 35% of the GHG

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[14] Morgan, Christopher, 2007. Appendix B - The City of Toronto's Air Quality Model. Part of ICF International, 2007.

[15] Soliman, Ahmed S. and R.B. Jacko, 2008. A Quantitative Approach to the Traffic Air Quality Program: The Traffic Air Quality Index. JAWMA, 58:641-646. May.

emissions in 2004. Not included in the inventory are emissions from aircraft and trains operating in the Toronto area and carrying passengers who live in Toronto or environs. Of the transportation total, 74% of the emissions were estimated to arise from passenger and other light vehicles.

Table 8 Toronto Greenhouse Gas Emissions [Gg eCO_2/year]

Source	Sub-Category	eCO_2	Percentage by Source Type
Residential		6	25
Commercial & Industrial	Small	6.88	28
	Large	2	8
Transportation	Cars & Light Trucks	6.37	26
	Trucks	2.19	9
Waste Management		0.98	4
TOTAL		24.42	

2.5 Emissions Forecast

Toronto published a forecast of GHG emission growth if the current emission trends continue[16] as part of its initiative to reduce air emissions through 2020. It is projected that GHG emissions could grow by 17% by that time if steps are not taken to reduce emissions. Similar projections for the criteria air contaminants addressed in this report are not supplied in the report, however, the report suggests that various reductions in emissions should be achieved between 2007 and 2012 and 2020. The report goes on to list initiatives that could be helpful in achieving the desired reductions and included in the list is improving public transit to reduce the number of passenger vehicles on the roads.

The Campbell report shows that between 1985 and 2006 traffic inbound to the city in the morning rush hour has increased 75% while at the same time traffic leaving the city has increased 79%. There was a steady increase in traffic between 2001 and 2006 and the result is that travel in off-peak hours has increased as well.

Trends in air quality in another large Canadian city help in assessing potential trends for emissions[17].

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[16] Toronto Environment Office, 2007. Change is in the Air: Toronto's Commitment to an Environmentally Sustainable Future. Available at: http://www.toronto.ca/legdocs/mmis/2007/ex/bgrd/backgroundfile-2428.pdf

[17] Metro Vancouver, 2007. 2005 Lower Fraser Valley Air Emissions Inventory & Forecast and Backcast Executive Summary. December. Available at: http://www.gvrd.bc.ca/air/pdfs/ExecSummary_2005_LFV.pdf

The Vancouver report shows NO_x emissions declining from 1990 to 2020. This is attributed to improved vehicle emission standards and active vehicle inspection programs in the area. Cars and light trucks dominate NO_x emissions until 2010. Unlike the Toronto situation, Vancouver has large marine terminals and by 2015 it is projected that marine vessels will become the dominant source of NO_x emissions, largely because emission controls are not coming as fast in this industry.

The emissions of $PM_{2.5}$ have been decreasing in Vancouver since 1990 mainly due to reductions in industrial activity including petroleum refinery and wood product sector closings. Vehicular related emissions have also declined. By 2010 though the emissions are projected to start increasing due largely to population growth and the need to heat spaces occupied by the residents. Interestingly, the report notes that if particulate matter emissions associated with road dust resuspension are included in the dust emission estimates it is the major source. The amount of road dust is anticipated to rise throughout the study period as the number of vehicles on the road increases. Road dust tends to release larger sized particles, whereas $PM_{2.5}$ emissions are dominated by combustion sources.

Carbon monoxide emissions appear to follow the same trends as $PM_{2.5}$, declining until 2005 and then increasing in later years. The decline is attributed to the reduction of vehicular emissions, but increases in heating and passenger vehicles after 2005 are associated with increasing emissions.

Marine vessels will result in increased SO_2 emissions after 2010. Up until that time, the inventory suggests that emissions have been reducing, the result of lowering the sulphur content of vehicle fuels. VOC emission trends suggest that levels will decrease until 2015 due to improved controls on vehicles and stay steady for a period of time as older vehicles continue to be retired and other initiatives are implemented. The surface coating industry starts to dominate the emissions by 2015 and as population continues to grow, emissions from that sector are estimated to grow despite federal government programs to reduce solvent evaporation.

The report looks at smog forming pollutant emissions including $PM_{2.5}$, VOC, NO_x, SO_2 and ammonia from the agricultural industry in the valley. As might be expected from the foregoing materials, the emission rate of these materials is expected to decrease until 2020 at which point they begin to rise. Dominated up until 2000 by vehicular emissions, by 2030 solvent evaporation will be the biggest contributor to this category.

With the exception of the emissions associated with marine operations in Vancouver's harbour, it would be anticipated that if emissions in Toronto were forecast for the period from 2005 to 2030 they would follow the same trends, unless interventions were promoted.

2.6 Ambient Air Quality Criteria and Monitoring Results

The monitoring data discussed earlier in this report can be judged against a number of criteria or standards. While the Canada Wide Standards for Ozone and $PM_{2.5}$ have already been presented, a number of other criteria are summarized in Table 9.

In all cases these criteria are set to protect the general community. Monitoring locations do not always reflect the average seen in the community as they tend to be located in areas which, while they might have been reflective of the community in the 1970s when the site was established, are now heavily influenced by traffic on nearby roads. Should air quality around these highly exposed stations meet the criteria levels it would be anticipated that much of the community further removed from the heavy traffic areas would experience lower levels.

It is anticipated that implementing the Eglinton LRT will result in emission reductions for those air contaminants associated with vehicular traffic. With this reduction, it would be anticipated that local air quality along the route and on other connecting transportation routes will be improved. This will also reduce total emissions within the city. Such reductions preclude the need for a detailed analysis of the impacts with respect to air quality objectives.

2.7 Health and Visibility Impacts of Air Pollution

The Campbell report referenced earlier identifies the factors important in illness associated with air pollution, and in particular the burden imposed by traffic in Toronto. Using the emissions inventory for the city, the Air Quality Model and the Air Quality Benefits Assessment Tool developed by Health Canada, the report provides predictions of the contribution of traffic to mortality and morbidity of the residents in the city. There are a range of anticipated health outcomes associated with air pollution. Short term exposures to high levels can lead to mortality as can long term exposures to somewhat lower levels of air pollutants. Cardiac patients, both the elderly and others, can be admitted to hospitals as the result of exposure to air pollutants, or simply need to visit emergency rooms. Respiratory emergency room visits followed by chronic bronchitis attacks in adults and then children represent the next level of effects. Asthma symptoms and the number of acute respiratory symptom days reported increases with air pollution levels. At the bottom of the list are restricted activity days when the effects of air pollution reduce the ability of residents to undertake their normal activities. In total the Assessment tool defines 13 health endpoints.

Table 9 Ambient Air Quality Objectives

NO_x [ug/m^3]	**Level**	**1-Hour**	**24-Hour**	**Annual**
National	Maximum Desirable	-	-	60
	Maximum Acceptable	400	200	100
	Maximum Tolerable	1100	300	-
Provincial		400 [200 ppb]	200 [100 ppb]	
World Health Organization	Proposed Guideline	200		
CO [mg/m^3]	**Level**	**1-Hour**	**8-Hour**	
National	Maximum Desirable	15	6	
	Maximum Acceptable	35	15	
	Maximum Tolerable	-	20	
Provincial		36 [30 ppm]	16 [13 ppm]	
World Health Organization	Proposed Guideline	30	10	
Particulate Matter [ug/m^3]	**Level**		**24-Hour**	**Annual**
National [TSP total]	Maximum Desirable		-	
	Maximum Acceptable		120	
	Maximum Tolerable		400	
CWS $PM_{2.5}$	National Target		30	
Provincial [SPM <44 um]	AAQC		120	60
	PM_{10} Target Interim		50	
Ozone [ppb]	**Level**	**1-Hour**	**24-Hour**	**Annual**
National	Maximum Desirable	100	30	
	Maximum Acceptable	100	50	30
			4th Highest 8-Hour Avg.	
CWS Ozone National Target			65	
Provincial CWS Adopted			65	

The outcome of the modelling shows that as one goes down the scale of responses the number of incidents is predicted to increase. Traffic in the city is estimated to result in 440 mortalities; 1,700 hospitalizations; 1.200 acute bronchitis attacks for children; 67,000 acute respiratory symptom days; 68,000 asthma symptom days; and 200,000 restricted activity days. It is estimated that the economic cost of traffic associated air pollution is 2.2 billion dollars, and every 10% reduction in traffic emissions would reduce premature deaths by 63 and save $300 million. Clearly, the estimated 10 - 20% reduction in vehicle use that could be realized from implementing enhancements to the public transit system would make a major improvement in the life of the citizens of the province.

3.0 Evaluation of Air Quality Impacts of Proposed Project

To evaluate the air quality impacts of the project it is necessary to estimate changes that might occur in air pollutants and greenhouse gas emissions during the operational phase of the project. IBI Group undertook an evaluation of the traffic on Eglinton. The result of this analysis was a table showing annual average daily traffic, AADT, for various segments of LRT route. AADT is determined by dividing the total volume of vehicle traffic of a road for a year by 365 days. Thus, AADT is a useful and simple measurement of how busy a road is and it assists transportation planners and engineers in defining the impact of changes along the route. The AADT data provided by IBI Group was based upon a number of assumptions, including the most important one, that the route was currently at capacity and there was a very limited ability to add more traffic to the road. Indeed, the evaluation assumed that there would be no change in the number of light, medium and heavy trucks on the various segments. There are two noticeable changes: the addition of up to 600 cars per day on some segments of the route, and the removal of buses from the route as they are replaced by the LRT.

3.1 Operating Emissions

3.1.1 Assumed Service Changes

The TTC Service Summary[18] shows all the transit routes operational in the city. It identifies the origin and destination of each route, provides the total route length and the number of vehicles servicing the route at different times of the day on both weekday and weekends. This formed the basis of Table 6 which shows the routes that currently service Eglinton Avenue, or use Eglinton Avenue to get to their destination. The actual number of buses operating on the various segments along Eglinton were taken from the TTC schedule information[19] with the counts of departures each day from the originating station defining the AADT in both directions. The weekend departures were counted and the ratio of Saturday and Sunday departures to the weekday departures was summed to determine the AADT for the weekends. To determine the distance these vehicles travel on Eglinton at present, the distance from the originating station to the end point of the route along the LRT line was determined from Google Earth. A description of the proposed realignment of routes, as the LRT replaces all or a portion of the route, is shown in the extreme right hand column. The appropriate distance is listed in the table and this is multiplied by the number of buses on the route each weekday or weekend to determine the total distances buses travel on Eglinton in a year.

It is estimated that the installation of the LRT will replace 4.91 million kilometres of bus traffic on Eglinton between Kennedy and Renforth. At capacity, the LRT will operate 280 trips in each direction over the whole route each day. This is a total of 18,480 km/day. Assuming the level of service drops to 60% on the weekends, the weekly total would be 114,576 km/week, or 5.96 million kilometres per year

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[18] http://www3.ttc.ca/PDF/Transit_Planning/Service_Summary_2009_10_18.pdf

[19] http://www3.ttc.ca/Routes/Buses.jsp

Table 10 Summary of Buses Operating on Eglinton Avenue that will be replaced by LRT

Route	Description	Start/End Station	Route Overlaps LRT to:	Distance on Eglinton	AADT East	AADT West	Total Travelled Daily	Total Travelled Weekdays	Total Travelled Weekends	Total Travelled Annually	Potential Re-Alignment
				[Km]			[Km]	[Km]	[Km]	[Km]	
Existing Routes to be Altered											
5	Avenue Road	Eglinton	Oriole Pkwy	0.6	53	53	64	318	102	21,828	Combine with 61- run through Avenue Rd Stn
32	Eglinton W	Eglinton	Renforth	16.13	16	16	516	2581	625	166,678	Discontinue
32	Eglinton W A	Eglinton	Renforth	16.13	78	78	2516	12581	3045	812,557	Discontinue
32	Eglinton W B	Eglinton	Renforth	16.13	37	37	1194	5968	1444	385,444	Discontinue
32	Eglinton W C	Eglinton	Keele	6.4	143	143	1830	9152	2215	591,073	Terminate at Trethewey (Keele & Eglinton Stn)
32	Eglinton W D	Eglinton W	Keele	3.3	137	137	904	4521	502	261,175	Terminate at Trethewey (Keele & Eglinton Stn)
34	Eglinton E	Eglinton	Kennedy	11.5	192	192	4416	22080	5566	1,437,592	Discontinue
51	Leslie	Eglinton	Leslie	4.1	59	59	484	2419	599	156,915	Combine with 56 along Eglinton to Laird
54	Lawrence E	Eglinton	Leslie	4.1	195	195	1599	7995	1919	515,518	Terminate at Don Mills & Eglinton Station
56	Leaside	Eglinton	Laird	2.8	51	51	286	1428	414	95,805	Combine with 51 along Eglinton to Leslie
61	Avenue Road N	Eglinton	Avenue Rd	2.4	80	80	384	1920	427	122,054	Combine with 5 - run through Avenue Rd Stn
100	Flemington	Eglinton	Don Mills	5.1	113	113	1153	5763	1510	378,175	Terminate at Don Mills & Eglinton from east via Wynford to Donlands Stn
103	Mt. Pleasant N	Eglinton	Mt. Pleasant	0.6	71	71	85	426	137	29,266	Loop at Eglinton with 74 Mt. Pleasant to St. Clair
						Reduced Route Traffic Total	15430	77152	18503	4,974,080	
Additional Traffic on Eglinton											
47	Lansdowne	Lansdowne	Caledonia	0.3	80	80	48	240	65	15,881	New loop added to east of CN Line
51/56	Leslie/Leaside	Donlands	Laird to Leslie	1.25	59	59	148	737.5	214	49,479	New route for Leslie bus along Eglinton to Laird
						Added Route Traffic Total	196	978	279	65,360	
						Net Change in Total Distance	15235	76175	18224	4,908,720	

for the LRT.

3.1.2 Emission Changes Associated with Service Changes

As noted in Chapter 2.4, inventories of emissions in the City of Toronto have been created. The factors used in developing that inventory can be used to estimate the changes in emissions that will occur by replacing diesel powered buses with the LRT.

It should be noted that the emission factors used for the buses in the ICF report is dated. The report suggests that the electricity factors reflect 2004 data, and it is anticipated that the vehicular emission factors are of the same vintage. As such these emission factors are probably conservative, ie bus emissions on average have probably dropped since the numbers were established.

Emission levels for diesel bus engines are regulated. For both PM and NO_x regulations have resulted in a decrease in specific emissions over the last 13 years as reflected in the US EPA regulatory levels changes shown in Table 11. Note, the CO emission regulations have remained constant over that period.

Table 11 Summary of Allowable Emissions US EPA [g/bhp-hr]

Year of Manufacture	Carbon Monoxide	Oxides of Nitrogen	Particulate Matter
1997			0.1
>1998	15.5	6	
1998-2004	15.5	4	
2004-2007	15.5	2.5	
2007	15.5		0.01
2007-2010	15.5	1.2	
2010	15.5	0.2	

Since the emission factors reflect the year of manufacture of the vehicles newer buses would be expected to have lower emission factors. A review of the equipment used on most of the routes in Table 6 suggests that the buses are typically Orion VII units and nothing in that portion of the TTC fleet is older than 2002. Some of the Orion units are the Next Generation Hybrid Electric Vehicles which are among the newest equipment in the fleet and have smaller engines and better emission characteristics.

The allowable emission limits do not translate directly to emissions per vehicle mile travelled, and some means needed to be found to predict realistic operating emissions for in service vehicles. Typically such analyses are done with detailed emission projection algorithms such as MOBILE6 developed by the US EPA and adjusted for use in Canada where the latest version is MOBILE6.3C. This algorithm develops a detailed estimate of emissions from vehicles of different years based upon typical emission performance of engines manufactured in that year, and the operating conditions for that vehicles which can be expressed as a fuel efficiency, ie how much fuel is burned under different operating conditions. These data are then included in air dispersion models that require traffic flow numbers to complete the input parameters. Unfortunately, for full traffic modelling one must make various assumptions about the mix of vehicles, their operating regime, and age of the vehicle. As pointed out in the City of Toronto's assessment of air pollutants referenced earlier as ICF, 2007 there are significant limitations in the level of data necessary to accurately project the emissions. That report chose to used the basic data from MOBILE6.3C but extracted the emission factors for different classes of vehicles, amongst which were diesel transit buses. Those data were used for this study.

The Toronto report's authors chose to aggregate the complete diesel transit bus fleet operating in Toronto and apply a single emission factor for various pollutants. This ignored the age of the vehicles, the size of the engine in the bus, and the operating conditions, but serves as a reasonable estimate for this study. It is presumed that the aggregate number used in the 2007 assessment was reflective of the fleet in service at that time, and it would be expected that with the addition of newer vehicles to the TTC fleet, the emissions may be marginally lower now than when that study was undertaken but since the overall fleet continues to grow older vehicles can still be expected to be present.

The data from the Toronto report, for emissions from diesel buses, is shown in the top section of Table 12. These emission factors are expressed as gram of pollutant released per vehicle kilometre travelled. Estimating the mileage the fleet travels on a specific route in a year allows one to estimate annual emissions for buses on that route.

For the LRT the emissions are expressed as grams per kilowatt hour of power consumed based upon factors from the Toronto report. These are the emission factors associated with the average kilowatt-hour of electricity used in Ontario. The electricity emission factors need to be converted to allow LRT consumption based emission estimates to be produced.

The emission factors related to the LRT reflect emissions associated with electricity generation and are expressed on the basis of the amount of electricity produced. Transmission losses have been included in the electricity related emissions but it is necessary to determine how much electricity must be generated to support LRT operation. Lacking any specific data for the LRT vehicles the TTC will be using, a default value of 4.2 kWh/km[20] was used. This value is taken from data in an assessment of a similar light rail transit system in Vancouver.

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[20] RWDI, Air Quality Assessment, Environmental Assessment Certificate Application for the Richmond•Airport•Vancouver Rapid Transit Project available at: http://www.eao.gov.bc.ca/epic/output/documents/p208/d19462/1102717279615_494bf0b1bf6a4bffa19de1d5c32 0ab0a.pdf

Table 12 Annual Emissions Eglinton Transportation Route

Vehicle Type	Units	NO_x	VOC	TPM (total)	TPM (Exhaust)	CO	SO_2	GHG (eCO_2)
Emission Factors as per ICF, 2007[12] Table 7								
Bus	[g/vkt]	12.39	0.41	0.509	0.49	3.16	0.3	1420
LRT	[g/kWh]	0.348	0.005	0.102	NA	0.83	0.063	244
Annual Distance								
Bus	[km]	4,908,720	4,908,720	4,908,720	4,908,720	4,908,720	4,908,720	4,908,720
LRT	[km]	5,957,952	5,957,952	5,957,952	5,957,952	5,957,952	5,957,952	5,957,952
Annual Emissions								
Bus	[Mg/year]	60.82	2.01	2.50	2.41	15.51	1.47	6970
LRT	[Mg/year]	8.71	0.13	2.55	0.00	20.77	1.58	6106
Difference	[Mg/year]	-52.11	-1.89	0.05	-2.41	5.26	0.10	-865

The Toronto report[21] provides a GHG emission factor for diesel emissions of 73 kg eCO_2/GJ of input. To convert this to g/vkt, assumptions must be made about fuel consumption in diesel buses. The Vancouver report[20] suggests that the average fuel consumption for a 40 foot long transit vehicle is 0.5L/km, which is about 25% lower than the number quoted for Toronto, however it is likely more reflective of the newer fleet used along the Eglinton corridor. Assuming that diesel fuel has a density of 0.854 kg/L and an energy value of 45.566 MJ/kg, the specific emission rate is (73* 0.5* 0.845* 45.566) = 1420 g CO_2/km as shown in Table 12. Using the higher fuel consumption rate assumed by the Toronto report would increase this value to 1775 g CO_2/km.

Two different factors for particulate matter are provided. One based upon exhaust emissions, the other reflecting the amount of particulate matter resuspended from the roadway as vehicles pass. The road dust is a combination of dirt tracked onto roads from unpaved surfaces, dropped onto the roads from haulage vehicles, and dust created by the wear of brakes and tires on the vehicles on the road. These is a difference between the nature of the two dust components. Diesel emissions tend to be comprised of predominantly fine particles, less than 2.5 um and even less than 1 um in size, whereas some road dust fractions include materials that have settled to the ground and are as large as 40 um in size. The drop in emissions of exhaust related particulate matter is particularly important given the size of these materials and their potential impacts on human health.

The second part of Table 12 lists the respective distances travelled by the two modes of transport. For buses it is the net change in distances from Table 10. For the LRT the number represents the 33 km of the route, assuming 280 traverses in each direction each day.

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[21] ICF International, 2007. Greenhouse Gases and Air Pollutants in the City of Toronto: Towards a Harmonized Strategy for Reducing Emissions. Prepared in collaboration with Toronto Atmospheric Fund and Toronto Environment Office. June. Available at http://www.toronto.ca/taf/pdf/ghginventory_jun07

The emissions in the bottom section of Table 8 suggest that replacing the diesel buses with the LRT will result in a decrease in emissions of most of the contaminants listed, however, CO and SO_2 are estimated to rise marginally based upon the electricity emission factors used. While the reductions, and for that matter the increases in emissions do not appear to be significant compared to the emission inventory summary in Table 3 and Table 4, the impact will be much more significant. Electricity is generated outside the City of Toronto and thus the new emissions associated with the production will be seen regionally in southern Ontario's atmosphere, however the reductions from removing the buses will occur locally along the LRT route. Numerous studies[20, 22] have identified that the impacts from traffic routes that occur within 100 m of the centerline of the road are two to three times more severe so any reduction in these areas will be very beneficial.

With respect to Greenhouse Gas Emissions the operation of the LRT will result in a regional decrease in CO_2 equivalents of over 865 tonnes/year.

It should be noted that these estimates of the changes in emissions reflect activity along Eglinton. The traffic study suggests that traffic volumes will not change on this route due to the introduction of the LRT. Similarly, this study makes no attempt to estimate the changes in traffic that will occur in other parts of the city due to this project. Most notable might be the decrease in passenger vehicle traffic to Pearson International airport. Any other traffic that is replaced by the introduction of the LRT will increase the reduction in all emissions.

3.1.3 New Off-Street Terminal Impacts

Operating emissions will be reduced by removing buses from the routes as a whole, however, the underground stations on the LRT line create a need to provide convenient transfer facilities for passengers. In many cases access from surface routes to the LRT will simply mean passengers making their way to the surface route stop in a manner similar to transfer points between the Yonge and Spadina subways to surface routes or indeed transfers currently occurring between east/west bound routes and north/south bound routes. In other cases, where there could be more than one surface route involved, or where the surface transfer process could be difficult due to road configuration, a bus loop may be required. In this study three such locations are considered: Don Mills & Eglinton Station, the Keele & Eglinton Station at Trethewey, and the Caledonia Station west of Caledonia. The first two stations represent appropriate terminus points for routes currently served out of the Eglinton Station or Eglinton W.

The Don Mills & Eglinton loop will serve as the end point for service on both Route 54 Lawrence East and Route 100 Wynford Drive which currently terminate at the Eglinton Station on the Yonge Street line. The loop will also serve as a transfer point for the north and south bound Don Mills 25 bus route at least until the Don Mills LRT is constructed. As such, 25 route buses that are both north bound and south bound will pull into the terminal each time they cross Eglinton and each must be counted. For the other buses which start or finish their routes at the loop, the arrival of the bus coincides with the departure and the bus waiting time at the terminal only needs to be counted once for each bus in any given hour.

The Caledonia Station is situated some distance west of Caledonia Road in an area off Eglinton. As such, the distance between the station and Caledonia was inconvenient. To improve convenience, the 47 bus will travel along Eglinton in both directions to a new loop to be constructed above the station.

The Keele and Eglinton loop at Trethewey will serve as the end point for the 32C Jane and Lawrence via Trethewey route which currently operates out of the Eglinton Station at Yonge Street and the 32D Jane and Emmett bus that also operates out of Eglinton. The 32C buses currently travel northbound/southbound on Trethewey just west of the planned loop from Eglinton. The 32D bus currently travels east/west through the Trethewey and Eglinton intersection.

Table 13 summarizes the movements on the routes served by the respective loops. The table shows the number of buses that will use the loop each hour at different times during the day: AM and PM rush hour service, mid-day service and evening service. The number in parentheses after the frequency of use is the service interval planned for the buses on the route, or the time between buses. Buses arriving at the loop, discharge passengers, pick-up passengers and leave. On average, it is anticipated that the average time the bus will be in the loop area will be about 2 minutes. To maintain the scheduled service interval, the buses might occasionally wait at the loop for a few more minutes to get back on schedule. The duration of the wait cannot exceed the service interval otherwise additional buses will be in the loop. For the purposes of this evaluation it was assumed that the wait time would not exceed 5 minutes.

While the reduction in distances travelled by the buses was factored into Table 12, Table 13 does not account for the reduction in bus activity that will be associated with the removal of buses from the routes currently served out of the Eglinton and Eglinton West stations.

The operation of buses in these loops will result in emissions from the buses. It should be remembered, that while the discussion on the reduction in emissions in the previous section of this report only addressed the emission reductions, it did state that generally the effects of emissions associated with the operation of vehicular traffic have the most impact within 100 m of the roadway. In light of that, the reductions in emissions associated with the removal of Eglinton bus traffic from routes when the LRT starts operation, with generally affect the zone where the new terminals are proposed. Because the number of buses being removed from Eglinton within 100 m of the loop locations will far exceed the number of vehicles using the terminals the overall emissions in the area will drop.

To determine the potential effects of the emissions in the loop, it is necessary to estimate the emission rate at the various sites and then calculate the resulting concentration of contaminants at various locations around the sites. The average of the 90 percentile values from the ambient air quality data presented in Chapter 2 can be used to estimate the maxima that might be encountered around the terminal areas.

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[22] Gerald Diamond and Michael Parker, 2004. Preliminary Air Quality Assessment Related to Traffic Congestion at Windsor's Ambassador Bridge. A report prepared by Ontario MoE, PIBS 4624e. Available at: http://www.ene.gov.on.ca/envision/techdocs/4624e.pdf

Table 13 Off-Street Bus Loop Operations

Station	Routes	Total/Hour (Interval between buses minutes)				
		AM	Mid	PM	Evening	Late
Keele & Eglinton	32C	15 (4)	6 (10)	12 (5)	6 (10)	6 (10)
	32D	4 (15)	4 (15)	4 (15)	4 (15)	4 (15)
Don Mills & Eglinton	25S	19 (3)	10 (6)	17 (4)	9 (6)	5 (12)
	25N	18 (3)	10 (6)	17 (4)	9 (6)	6 (10)
	54	15 (4)	10 (6)	14 (4)	10 (6)	10 (6)
	100	14 (4)	8 (7)	10 (6)	7 (4)	6 (10)
Caledonia	47 N	4 (15)	4 (15)	4 (15)	4 (15)	4 (15)
	47 S	4 (15)	4 (15)	4 (15)	4 (15)	4 (15)

3.1.3.1 Emission Estimates

Diesel engines release products of combustion during operation. The quantity of contaminants released is a function of the load on the diesel engine and thus the fuel feed rate during operation. Typically diesel engine emission factors are expressed as g/bhp-hr, that is an emission rate that is a function of the horsepower being generated by the engine at any time. Such an emission factor suggests that emissions would vary directly relative to the load on the engine.

At the bus loops the majority of the emissions will occur when the buses are idling. There is only limited data on idling emissions from diesel vehicles. The main contaminants that are measured in most studies are the regulated species,.

McCormick[23] reports CO, PM, and NO_x data from idling bus engines along with total hydrocarbons [THC]; the volatile organic fraction of the particulate matter emissions [VOF], and aldehydes. These data were collected within 20 minutes of the vehicle being tested on a chassis dynamometer, meaning that any auxiliary equipment typically used on buses would have been operational for the testing. Thus the data represents the emissions that would come from an operating fleet of buses. These data provide g/minute emission rates for a range of engines. The data are summarized in Table 14. The details provided in the paper include the manufacturing year of the engine along with its manufacturer and specifications.

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[23] McCormick, R.L., M.S. Graboski, T.L. Alleman, J. Yanowitz, 2000. Idle Emissions from Heavy-Duty Diesel and Natural Gas Vehicles at High Altitude. JAWMA 50:1992-1998

Table 14 Emission Data for Buses under Idling Conditions from McCormick, 2000

Vehicle	Model Year	Engine	HP	Engine Family	THC, g/min	CO, g/min	NO x , g/min	PM, g/min	VOF, % of PM	Aldehyde, g/min
Bus 5054	1993	DDC S50, 8.5 L	250	P00085FZK7	0.038	1.740	1.979	0.106	8.2	0.0128
Bus 5021	1993	DDC S50, 8.5 L	250	P00085FZK7	0.030	1.238	2.109	0.047	7.3	0.0092
Bus 1710	1991	DDC 6V92, 9.0 L	330	8067–7B28	0.161	0.785	2.165	0.047	21	0.0064
Bus 1717	1991	DDC 6V92, 9.0 L	330	8067–7B28	0.318	2.156	2.406	0.173	18	0.0053
Bus 1510	1987	DDC 8V92, 12.1 L	370	8067–7AV0	0.181	1.624	2.738	0.031	14	0.0066
Bus 1501	1987	DDC 8V92, 12.1 L	370	8067–7AV0	0.215	0.967	2.767	0.037	2.8	0.0075
Bus 1936	1998	DDC S60, 12.7 L	430	6067GK2B	0.108	0.930	2.698	0.060	7.4	0.0068
Bus 1937	1998	DDC S60, 12.7 L	430	6067GK2B	0.130	1.733	2.352	0.019	35	0.0080
Bus 1009	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA	0.222	2.345	1.147	0.021	32	0.0072
Bus 1010	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA	0.070	0.763	1.030	0.006	–	–
Bus 1011	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA	0.094	1.143	1.743	0.017	32	0.0003
Bus 1012	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA	0.078	0.491	1.051	0.007	–	–
Bus Average					**0.137**	**1.326**	**2.015**	**0.048**	**19**	**0.006**
Maximum Emission Rate according to US Regulations (varies by year of manufacture)						**CO,** g/bhp/h	**NO x ,** g/bhp/h	**PM,** g/bhp/h		
Bus 5054	1993	DDC S50, 8.5 L	250	P00085FZK7		15.5	6	0.25		
Bus 5021	1993	DDC S50, 8.5 L	250	P00085FZK7		15.5	6	0.25		
Bus 1710	1991	DDC 6V92, 9.0 L	330	8067–7B28		15.5	6	0.25		
Bus 1717	1991	DDC 6V92, 9.0 L	330	8067–7B28		15.5	6	0.25		
Bus 1510	1987	DDC 8V92, 12.1 L	370	8067–7AV0		15.5	6	0.6		
Bus 1501	1987	DDC 8V92, 12.1 L	370	8067–7AV0		15.5	6	0.6		
Bus 1936	1998	DDC S60, 12.7 L	430	6067GK2B		15.5	4	0.1		
Bus 1937	1998	DDC S60, 12.7 L	430	6067GK2B		15.5	4	0.1		
Bus 1009	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		15.5	6	0.1		
Bus 1010	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		15.5	6	0.1		
Bus 1011	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		15.5	6	0.1		
Bus 1012	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		15.5	6	0.1		
Bus Average						15.50	5.67	0.23		
Maximum Emission Rate based upon operating at the Standard						**CO,** g/minute	**NO x ,** g/minute	**PM,** g/minute		
Bus 5054	1993	DDC S50, 8.5 L	250	P00085FZK7		64.6	25.0	1.0		
Bus 5021	1993	DDC S50, 8.5 L	250	P00085FZK7		64.6	25.0	1.0		
Bus 1710	1991	DDC 6V92, 9.0 L	330	8067–7B28		85.3	33.0	1.4		
Bus 1717	1991	DDC 6V92, 9.0 L	330	8067–7B28		85.3	33.0	1.4		
Bus 1510	1987	DDC 8V92, 12.1 L	370	8067–7AV0		95.6	37.0	3.7		
Bus 1501	1987	DDC 8V92, 12.1 L	370	8067–7AV0		95.6	37.0	3.7		
Bus 1936	1998	DDC S60, 12.7 L	430	6067GK2B		111.1	28.7	0.7		
Bus 1937	1998	DDC S60, 12.7 L	430	6067GK2B		111.1	28.7	0.7		
Bus 1009	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		45.2	17.5	0.3		
Bus 1010	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		45.2	17.5	0.3		
Bus 1011	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		45.2	17.5	0.3		
Bus 1012	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		45.2	17.5	0.3		
Bus Average						74.49	26.44	1.24		
Idling Emissions as Percentage of Maximum Allowable Emissions						**CO,** % of Max.	**NO x ,** % of Max.	**PM,** % of Max.		
Bus 5054	1993	DDC S50, 8.5 L	250	P00085FZK7		2.69	7.92	10.18		
Bus 5021	1993	DDC S50, 8.5 L	250	P00085FZK7		1.92	8.44	4.51		
Bus 1710	1991	DDC 6V92, 9.0 L	330	8067–7B28		0.92	6.56	3.42		
Bus 1717	1991	DDC 6V92, 9.0 L	330	8067–7B28		2.53	7.29	12.58		
Bus 1510	1987	DDC 8V92, 12.1 L	370	8067–7AV0		1.70	7.40	0.84		
Bus 1501	1987	DDC 8V92, 12.1 L	370	8067–7AV0		1.01	7.48	1.00		
Bus 1936	1998	DDC S60, 12.7 L	430	6067GK2B		0.84	9.41	8.37		
Bus 1937	1998	DDC S60, 12.7 L	430	6067GK2B		1.56	8.20	2.65		
Bus 1009	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		5.19	6.55	7.20		
Bus 1010	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		1.69	5.89	2.06		
Bus 1011	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		2.53	9.96	5.83		
Bus 1012	1997	Cum. ISB, 5.9 L	175	VCE359DJDARA		1.09	6.01	2.40		
Bus Average						1.97	7.59	5.09		

The basic emission data, provided in grams per minute, suggests a relationship to the power of the engine, larger engines produce more emissions. This is in line with the emission factor expression of g/HP-hr. The problem is, how does one translate the idling emission data to the conventional emission factor so it can be used for the this study?

For the purposes of this study, only CO, PM and NO_x from idling will be considered, largely because these are the only contaminants that can be directly related to engines of a given year of manufacture through the emission limits. Using the regulatory emission limit for the year of manufacture, shown in Table 11, and the engine HP for the test engines list in Table 14, the emission rate at full horsepower can be calculated. McCormick's idling emissions can then be expressed as a percentage of the permitted maximum emission rate that the engine was certified to meet. These calculations are shown in the last section of Table 14 for CO, NO_x, and PM. The average idle emission rates as a function of allowable emissions range from 2 to 8%. There are some differences evident in the table where the four 1997 engines tested showed lower emissions. These engines, Cummins ISB 5.9 L engines are more typical of those installed in newer buses and, as noted in various references, newer engines produce less emissions than some older engines.

Assuming that the average emission rate at idle as a function of the maximum permissible emission rates is representative for all engines in a given fleet, the weighted average idling emission rate for the fleet can be calculated by taking the permissible rate for each bus, multiplying it by the average idling percentage of the total, as shown in Table 14, and summing the values over the total fleet. The average for the fleet would then be obtained by dividing by the total number of vehicles in the fleet.

For this study, where the exact buses that might be used on the various routes at various times is not known, several additional, conservative assumptions were made about the buses that will be in the loops. A review of the TTC Service Summary[24] shows that there are currently 1785 buses operating in the city. Of that total, 1206 are Orion VII units purchased between 2002 and the present. A further 120 of these buses are to be delivered in 2010. The Orion VII bus is equipped with an 8.9 L Cummins ISL engine. This engine when used in transit buses typically has a horsepower rating of between 250 and 330 HP. Assuming that, by the time the Eglinton LRT goes into operation, the older buses in the fleet will be replaced, the worst case emission situation will likely be 2002 era Orion VII buses with 330 HP engines. This implies older engines, less stringent emission standards, and higher bus horsepower which results in a higher potential emission rate.

The emissions are shown in Table 15 where the idling factor is the ratio of maximum emissions to idling emissions in the last line of Table 14.

For modelling purposes it is necessary to determine the average emissions that will occur over the model averaging period. For simplicity, this analysis has determined the hourly emissions based upon the maximum number of buses passing through the loop on any day. Table 13 shows that the AM peak hour has the most buses arriving all any of the loops under consideration. Because the buses are on the route, essentially lined up behind each other with a fixed time interval as shown in that table, they can be anticipated to arrive at the terminal at equal intervals. Should traffic be lighter than assumed in the scheduling profile, they could arrive early. For this evaluation, as stated earlier, it has been assumed that they could wait at the terminal for as long as the service interval, or up to 5 minutes in the case of routes with long service intervals.

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[24] TTC, 2010. http://www3.ttc.ca/PDF/Transit_Planning/Service_Summary_2010_Jan03-Mar27.pdf

Table 15 Estimated Release Rate from an Individual Bus Idling in a Bus Loop

Contaminant	2002 Emission Limit [g/HP-h]	HP	Maximum Emissions [g/s]	Idling Emission Factor	Idling Emissions [g/s]
CO	15.5	330	1.42	0.0197	0.0280
PM	0.1	330	0.01	0.0509	0.0005
NO_x	4	330	0.37	0.0759	0.0278

Assume the data in Table 13 for each bus route in the AM Peak period is the maximum emission scenario. The total number of emission minutes in the loop from buses on a particular route is the product of the number of buses in the loop in an hour and the duration in the loop which is the lesser of the service interval, or 5 minutes. For the Keele and Eglinton location for Route 32C this calculation results in 15x4=60 minutes in the hour. This is the equivalent of one bus in the loop at all times. Similar calculations for the rest of the routes result in the values in Table 16.

Table 16 Estimate of Average Number of Buses in Loops during Peak AM Hour

Station	Route	Buses Per Hour	Idling Time	Total Idling Minutes	Equivalent Buses per Hour by Route	Equivalent Buses by Loop
Keele & Eglinton	32C	15	4	60	1.00	
	32D	4	5	20	0.33	1.33
Don Mills & Eglinton	25S	19	3	57	0.95	
	25N	18	3	54	0.90	
	54	15	4	60	1.00	
	100	14	4	56	0.93	3.78
Caledonia	47 N	4	5	20	0.33	
	47 S	4	5	20	0.33	0.67

Assuming each bus in the loop emits contaminants at the rate shown in Table 15, the product of the emission rate for each contaminant in Table 14 and the number of buses in loop provides the emission rates for modelling the effect of the loop operation.

Table 17 Emission Rates by Contaminant and Loop

Contaminant	Emission Rate [g/s]	Emission Rate by Loop [g/s]		
		Keele & Eglinton	Don Mills & Eglinton	Caledonia
Equivalent Buses In Loop (Table 16)		1.33	3.78	0.6700
CO	0.0280	0.0372	0.1058	0.0188
PM	0.0005	0.0007	0.0019	0.0003
NO$_x$	0.0278	0.0370	0.1051	0.0186

3.1.3.2 Modelling Emissions in Loops

To evaluate the impact of the emissions in the loops, they must be modelled using algorithms that describe how emissions from the buses might behave after being released to the atmosphere. The two larger loops are anticipated to operate in a manner similar to bus terminals at larger transfer points, buses arrive and unload at one platform before moving to another platform where they load. Thus, the emissions occurring when buses are in the loop will be distributed over the space occupied by the loop. This suggests that the emissions are best modelled as an area source. The size of the area was defined by the bus platform space in the terminal. Based upon preliminary design details the dimensions are listed in Table 18.

Table 18 Active Area of Bus Loops

Loop	Dimensions [m]		Area [m^2]	Effective Emission Rate [g/s-m^2]		
	East/West	North/South		CO	PM	NO$_x$
Keele & Eglinton	30.0	17.0	510.0	7.3e-05	1.4e-06	7.3e-05
Don Mills & Eglinton	80.0	31.5	2520.0	4.2e-05	7.5e-07	4.2e-05
Caledonia	20.0	8.0	160.0	1.2e-04	1.9e-06	1.2e-04

The modelling was conducted utilizing Screen3, a model designed for screening emission impacts to determine if more detailed modelling might be required. Generally more detailed modelling would be done should the emissions result in values close to the criteria levels.

When using the area source approach for modelling, the emission rate is defined to be uniform over the entire area and, as shown in Table 18, is expressed in emissions per square metre per second. The emission rate is calculated by dividing the emission rates in Table 17 by the area in Table 18. The model uses an algorithm that numerically integrates the emissions in the defined source area and thus will predict levels within the area defined as part of the source. Furthermore, for sources with one dimension greater than the other, the concentration calculated will be greater at points of the end of the narrow dimensions than at points on the long side. The model predicts concentrations at various

distances from the centre of the area, and provides the angle that results in the highest concentrations. The model requires that the height of the sources and the height of the receptors be defined. New transit buses typically have exhaust pipes that discharge vertically at the rear of the vehicle. For the purposes of the modelling the height of the area sources were assumed to be roof height of the bus: 3.3 m above grade. The receptors were assumed to be at 2 m above the ground.

The model produces estimates of the maximum concentration generated by the source based upon algorithms that adjust wind speed, wind direction, and stability class. As noted above the maxima will occur along the long axis of the source, however, at the Eglinton and Keele loop the residential properties to the east are at varying distances and orientations from the source. The model was used to provide individual estimates of concentration at the rear of the houses on Keele Street. Maxima only were defined for both the Caledonia and Don Mills loops.

The model was run for the CO/NO$_x$ emission rate only. The results for the PM emissions can be determined simply by multiplying the reported results for NO$_x$ by the ratio of PM emissions to NO$_x$ emissions.

3.1.3.3 Results

Modelling results are expressed as 1-hour concentrations in ug/m^3. These results must be adjusted so they can be added to the 90th percentile monitoring data for the particular contaminant to determine the new level compared to the estimated background level.

Since CO is monitored in ppm the modelling results in ug/m^3 must be converted to the appropriate units. Assuming a standard temperature of 20^{O}C the conversion factor is 1ppm = 1164 ug/m^3.

This analysis assumes that all the particulate emissions from the engines are PM$_{2.5}$ in size. The 1 hour maxima for PM must be converted to a 24-hour average to include monitoring results. To perform this conversion considerations must include the nature of winds over a 24 hour period and variations in the source emission rate that will occur. To compensate for the changes that will occur because of changing winds, the conversion can follow the approach in O.Reg. 419/05 and the maximum value in 1-hour would be reduced by multiplying by 0.4107 to get the 24 hour value. Since the comparison is over 24 hours, it is necessary to adjust the source emission rate to the average over this period. The peak operation used to define 1 hour emission rates is 1.33 buses in the terminal every minute. On average over the 24 hours approximately 6 buses would operate on the 32C route and 4 would operate on 32D which results in an overall average of 0.83 buses in the terminal every minute. The peak 1 hour value used for modelling must first be adjusted by multiplying by 0.624 the ratio of average to peak buses. Then the hourly predicted concentration must be adjusted by 0.4107 to account for wind variations. The resulting adjustment from the peak to 24 hour PM values is 0.26 times the peak 1 hour value.

The comparison of the estimated concentrations of NO$_x$ with the standards requires a conversion of the NO$_x$ results to NO$_2$, the form of oxides of nitrogen used to determine the criteria values. The proportion of NO$_2$ in NO$_x$ varies greatly with location and time according to a number of factors, including the amount of ozone available and the distance from the emission source. There are several approaches to making this conversion. The ambient ratio method converts the modelled NO_x concentrations to NO_2 based upon the ratio of NO_2/NO_x in the ambient modelling data. While the NO_2 data from the MoE's 2006 Air Quality Report are presented in Table 6, the NO_x data are not. The NO_2 and NO_x data are presented in Table 19.

While Table 19 shows the average ratio for the city could be as low as 0.52, the values around the Finch Terminal on the Yonge Street line should be considered most indicative of the type of environment that might be present at various loops on the Eglinton LRT line. Both the Etobicoke monitoring locations and the Toronto West locations are dominated by highway traffic where it would be expected that the NO values could be higher. For this study, the 0.58 value from Hendon and Yonge will be used. To convert ug/m^3 NO_x results to NO_2 in ppb at 20^{O}C, the conversion is NO_x x 0.5229. Thus the modelled NO_x values must be multiplied by 0.3033 to determine the ppb value to be added to the background 90th percentile values so the result can be compared to the criteria.

Table 19 Comparison of 90th Percentile Toronto Area 2006 Oxides of Nitrogen [ppb] Data[12]

Location	NO_2 1-hr 90th Percentile	NO_x 1-hr 90th Percentile	Ratio NO_2/NO_x
Downtown	33	49	0.67
East	31	57	0.54
North	34	59	0.58
West	37	83	0.45
Etobicoke West	29	59	0.49
Etobicoke South	43	103	0.42
Average	34.5	68.33	0.52

The maximum concentration predicted for each loop and each contaminant is shown in Table 20.

In all cases, the maxima were predicted to be approximately 10 m downwind of the area on the long axis of the source. Comparing the estimated concentrations, including the background contribution, to criteria values, the maximum 1-hour concentration for CO from the area sources might double the ambient concentrations but the level would still be only 3% of the standard. For NO_2 the predicted 1 hour maximum values including the background are 73 - 87% of the standard depending upon the location.

Table 20 Maximum Concentrations and Predicted including Background

Loop	Maximum Concentration due to Area Source			Distance from End of Source along Major Axis [m]	Predicted Concentration including Background		
	CO [ppm] 1-hr	PM [ug/m^3] 24-hr	NO_2 [ppb] 1-hr		CO [ppm] 1-hr	PM [ug/m^3] 24-hr	NO_2 [ppb] 1-hr
Keele & Eglinton	0.31	1.68	110.77	11.00	1	20	145
Don Mills & Eglinton	0.40	2.10	138.58	10.00	1	20	173
Caledonia	0.33	1.75	115.13	10.00	1	20	150
Criteria					30		200

The maximum 24-hour $PM_{2.5}$ concentration is estimated to be an order of magnitude (0.1 times) lower than the background levels measured in the city. Given the variation is measured data, this increase is unlikely to be distinguishable in the surrounding areas. Adding this additional contribution to the background levels results in a maximum PM concentration around the loops of 20 ug/m^3. This value is below the guideline value for $PM_{2.5}$ of 30 ug/m^3 that must be met by the 98th percentile measured value from a 3 years of monitoring data.

Before leaving the data it would also be appropriate to consider the situation that occurs at the Eglinton & Keele loop which is projected to be built behind a row of houses on the west side of Keele Street. The houses are between 40 and 65 m from the centre of the area used for modelling at this site. Houses are not that close to either of the other loops. Since NO_2 levels are closer to the criteria levels than CO as shown in Table 20, a calculation of the concentration at each of the houses was undertaken for the maximum hour. It would be expected that the further the house is from the source the lower the concentration. The calculations show that while the maximum on the centerline of the long axis is a maximum 11 m from the edge of the area, at 85 m it has dropped to a third of the maximum and at 185 m is in a tenth of the maximum. Since the houses are aligned perpendicular to the long axis of the area source, the further north the house is, the lower the contribution of the source. Compared to the maximum shown in Table 20, on the back wall of 1858 Keele the estimated concentration is 84% of the maximum. This reduces to 79% at 1860; 58% at 1862; 48% at 1864; and 47% at 1866. These data serve to illustrate that the maxima discussed in this report are indeed higher than would be seen at the nearby homes.

3.2 Construction Impacts

There exists a potential for air quality impacts related to construction activities for the LRT line. The extent and duration of construction related emissions will vary depending upon what needs to be done at any given location on the route. For instance, laying track at grade is similar to road construction work, excavation to lay a foundation and finished concrete work along with mounting the pole line. At any point on the surface such operations should not be of long duration. The underground section of the route will be constructed by boring and cut and cover techniques, which by their nature have different emissions than road construction. This section address the types of emissions possible from these operations:

- dust emissions from non-combustion sources; and,
- exhaust emissions from construction vehicles and stationary combustion sourcres.

The latter emissions are similar to those arising from the diesel vehicle operating on the existing routes. They have the potential to remain airborne and drift further away from where they are generated than will the dust from material handling operations. Each type of source are discussed below.

The design of the final version of the LRT line is not complete at this time. The general approach, at grade and below grade has been defined and the portal locations for the underground sections are largely determined. The discussion that follows generally discusses the types of sources that could be present. Following the identification of the sources, there is a section that outlines best practices that can be employed to reduce local impacts due to construction activities.

Dust Emission Sources

Large transportation projects such as new highways generally have the potential to create significant dust emissions since they cover a large area and high levels of activity occur to grade, lay foundations and finally pave the new road. In the case of this project, much of the at grade work will entail removing existing pavement to construct the new LRT right-of-way. Sources of dust emissions for these activities include:

- pavement cutting;
- pavement and earth excavation activities;
- vehicle travel on gravel or dusty roads;
- fugitive dust from material transfer operations; and,
- fugitive dust from dump trucks.

There is a potential for these emissions wherever activity occurs however the most likely points for long term dust emissions are:

- openings to tunnel boring sections;
- along lengths where major excavation has occurred such as in sections where the tunnel boring machine will enter or leave the tunnel sections, and areas where excavated materials will be removed from the tunnel;
- transfer activities were excavated materials are loaded onto trucks; and,
- spoils tipping areas.

Combustion Exhaust Emissions

Combustion emissions typically associated with construction activities include:

- diesel exhaust from earth moving equipment and trucks;
- exhaust from stationary combustion equipment including generators, heaters on site and the possibility that off-site construction and fabrication activities, such as concrete-casting sites have similar equipment; and,
- exhaust from tunnel boring machines, either directly, in the case of diesel powered equipment, or indirectly if the tunnel boring machines is electrically powered and the power is generated on site with diesel engines.

Given the location of the tunnel section it is likely that electrically powered boring machines can be connected directly to an electrical sub-station on the grid, thereby avoiding local exhaust emissions.

None of the diesel emissions can be estimated without detail knowledge of how the construction will be done and with what equipment. The important aspect of these emissions is that they are all temporary, and in many cases the duration of such operations will not extend for too long. In all cases the effects of these operations will be localized. It in unlikely that such activities will add to the regional air burden since the equipment would likely be used on other construction sites if it were not being used to build the LRT line.

There will be Greenhouse Gas emissions from the construction equipment but these would not be out of line with those to be expected from other construction projects of the same scale. The two major sources of GHG emissions are:

- direct emissions from fossil fuelled combustion equipment; and,
- indirect emissions from the production of cement used for construction.

The amount of GHG emissions from fossil fuelled combustion is directly linked to the amount of fuel used in the equipment. These are the only direct GHG emissions anticipated from the construction project. In a similar manner the amount of GHG emissions from cement production are directly proportional to the amount of cement used in every tonne of concrete produced. Typical GHG emission rates are 1 Mg eCO_2 per Mg of cement used in the mix. Since some types of concrete can be produced with fly ash and similar materials substituted for cement, there are ways to reduce the indirect GHG emissions for concrete use. Up to 50% of the cement can be substituted with flyash in some cases, but the use of flyash for cement would require careful consideration of the properties of the final product and this should be left to the designers to specify.

4.0 Mitigation of Air Quality Impacts and Greenhouse Gas Emissions

The analysis in the previous section indicates that over the long term the LRT would result in a decrease in localized air quality impacts associated with public transit along Eglinton Avenue. This effect would be enhanced by any large scale move from private automobiles to public transit. The only significant emissions associated with operation of the line would be those from the generation of electricity. Even the creation of additional bus bays at three locations on the Eglinton route will not add significantly to local air quality conditions. There will be short term air quality impacts from construction related to a number of different operations and sources. However, there are measures that can reduce the impact of the project on air quality and GHG emissions. These are described in the following paragraphs.

4.1 During Operation

As noted above, electricity generation related emissions are the only significant ones during operation. The rate of emissions in the province is a function of the mix of sources used for generating electricity. Regardless of the emissions, as noted in Chapter 3, the immediate benefits of reduced diesel bus emissions more that compensates for the electricity related emissions, and should the TTC choose more energy efficient LRT vehicles the net reduction in emissions could increase more than has been shown in this document. Furthermore, as noted elsewhere, any increase in transit passenger volumes that results in a reduction in the use of private vehicles for commuting will further increase the positive benefit.

New bus terminals will be constructed at three locations along the Eglinton route. At the largest of these, the Don Mills & Eglinton terminal, facilities will provide an off road termination for two routes and off road transfer location for the Don Mills Route 25 buses. Since two of these routes already operate through the intersection, this will reduce on road congestion at this busy intersection and will likely result in reduced air quality impacts around the intersection. Even at this terminal the vehicles in the facility are not projected to significantly elevate local levels of air contaminants. Thus, other than ensuring that operational practices designed to limit idling time in the terminal are complied with, no mitigation is necessary for these terminals.

4.2 During Construction

Typically, the TTC include environmental controls practices in their construction contracts. With respect to air contamination these contract documents include measures that are aimed at limiting the amount of dust released during these activities. Contracts can include requirements to undertake air monitoring studies to address issue of particular concern with respect to worker health and safety. Any measures that will be applied during such contracts are to be addressed in an Environmental Controls and Methods Plan that must be developed by the contractor before any construction activities

commence.

Typically, such plans would include dust control measures such as:

- watering to limit dust emissions from surfaces;
- covering of excavated materials or fill materials stored on site; and,
- street cleaning to limit tracking of materials.

They would also include guidelines to minimize the potential for minimizing impacts from diesel powered construction equipment such as:

- locating truck staging zone away from potential receptors; and,
- minimizing idling time for all diesel powered equipment operating on the site.

There are other of measures that can be applied by the contractors and site inspectors to ensure that the impacts of combustion source exhaust and fugitive dust emissions are controlled during construction.

For combustion related emissions and impacts the following measures can be employed:

- **S**electing construction equipment to be used on site based upon low emission factors and high energy efficiency.
- Ensuring that all construction equipment is tuned and maintained in accordance with the manufacturer's specifications.
- Using only ultra low sulphur fuel for diesel engines and ensuring that such equipment is equipped with diesel particulate matter traps to reduce particulate matter emissions.
- Utilizing electric or diesel powered equipment, in lieu of gasoline powered engines, where feasible.
- Ensuring that construction plans include a statement that work crews will shut off equipment when it is not in use.
- During smog alerts (May through October), measures should be taken to ensure that diesel equipment use is optimized to reduce the emissions of smog forming substances.
- Whenever possible, time the construction activities so as to not interfere with peak hour traffic and minimize obstruction of through traffic lanes adjacent to the site; if necessary, a flagperson shall be retained to maintain safety adjacent to existing roadways.
- Support and encourage ride sharing and transit incentives for the construction crew.

There are a number of additional measures that can be employed to reduce the amount of fugitive dust released from construction activities. Generally the objective should be to employ the best available control measures to ensure that such dust does not remain visible in the atmosphere beyond the property line of the emission source. These measures include dust suppression techniques such as:

- water active sites daily.
- all trucks hauling dirt, sand, soil, or other loose materials should be covered.
- all adjacent streets shall be cleaned by the contractor if visible soil materials are present

due to his operations.

- install wheel washers where vehicles enter and exit the work site onto public roads.

The following examples can be applied where appropriate to control dust generated by the construction activities:

- all haul roads can be designed with an appropriate road base to sustain heavy truck traffic.
- during clearing, grading, earth moving, excavation, or transportation of cut or fill materials, water trucks or sprinkler systems can be used to prevent dust from leaving the site and to create a crust after each day's activities cease.
- during construction, water trucks or sprinkler systems can be used to keep all areas of vehicle movement damp enough to prevent dust from leaving the site.
- immediately after clearing, grading, earthmoving, or excavation is completed, the entire area of disturbed soil can be treated until the area is seeded or otherwise developed so that dust generation will not occur.
- soil stockpiled for more than two days can be covered, kept moist, or treated with soil binders to prevent dust generation.

One caution, while it is common practice to use nontoxic chemical soil stabilizers such as calcium chloride to minimize the need for watering uncovered soil surfaces, the use of this material should be kept to a minimum inside the city, and its use should be severely restricted near watercourses. Typically this product is used in areas where graded areas are left inactive for ten days or more and it in unlikely that such situations will exist in many locations along the route.

Regardless of the measures adopted, the TTC and their contractors should establish a procedure for responding to complaints and documenting visual inspections, complaints and responses made.

5.0 Conclusions

Replacing the existing diesel powered buses that serve the Eglinton route, and moving the terminus points for some routes that are currently served from either the Eglington Station on the Yonge Street portion of the subway, or the Eglinton West Station on the Spadina portion of the subway, will result in significant reductions in local air emissions along Eglinton Avenue. These reductions will result in a net benefit to those who reside in close proximity to Eglinton Avenue. Furthermore Greenhouse Gas emissions are estimated to be reduced by this replacement, and that benefit can be extended should the LRT encourage motorists to use the public transit system.

Operation of the LRT will result in significant reductions in emissions of oxides of nitrogen, volatile organic compounds, and carbon monoxide along the LRT route as compared to the existing or “no build” alternative. There is a significant upside potential to further reduce these emissions should the users of private vehicles choose to use public transit. It is unlikely that these users would be swayed away from their vehicles by the existing bus services.

While regional reductions in emissions are not as large as the reductions in the local areas along the proposed LRT route, the report estimates that there will be some reductions for most contaminants addressed in this study.

While there will be three new bus loops constructed as a part of the Eglinton LRT these are not expected to result in significant impacts on the community surrounding their locations. It is possible that the construction of the new terminal at Don Mills and Eglinton could alleviate some road congestion at this intersection and actually improve traffic flow and with it reduce air contaminant levels.

During the construction phase of the project there is a potential for air quality impacts to occur. These will be of short duration, limited to the period where significant excavation and construction activities occur on surface routes, or where cut and cover construction is required for the tunnels. The two major sources of emissions from construction are dust emissions from non-combustion sources, and exhaust emissions from construction vehicles and stationary combustion sources. Regardless of the quantity of emissions that result from construction, all construction locations will be temporary in nature. Emissions from these temporary locations will only have a localized impact.

There will be a need for more electricity to operate the LRT. Even with the increased contaminant releases associated with electricity production, it is estimated that there will be a reduction of 52 Mg/year in common air contaminants released in southern Ontario as a result of implementing the LRT. These reductions could grow if private vehicle users move to the LRT.

Not accounted for in these estimates are the reductions in emissions that will occur with the curtailed use of the Eglinton Station as the terminus for numerous bus routes. With the population density in this area of the route, reduced bus activity will bring noticeable changes in fine particulate and NO_x levels in this area.

The reductions in GHG emission associated with the use of the LRT will far outweigh any short term increase in greenhouse gas emissions that are associated with construction activities. Increased electrical efficiency, changes in the mix of electrical generation modes, and increased diversion of private vehicle users to public transit will all increase the potential for GHG reductions.

The report includes a number of recommendations for reducing emissions associated with construction activities. While the effect these measures has not been quantified, the most significant reduction would be expected to occur if tunnel boring was completed with equipment that was electrically powered and directly connected to the electricity grid as opposed to either diesel powered equipment or electrically powered equipment driven by local diesel generators.