GARDINER EXPRESSWAY AND LAKE SHORE BOULEVARD EAST RECONFIGURATION ENVIRONMENTAL ASSESSMENT

Air Quality and Greenhouse Gas Impact Assessment Report

November 2016

WATERFRONToronto

TORONTO

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Attention: Mr. Paul Martin, Supervisor
Air Pesticides and Environmental Planning

Technical Support Selection Comments – Gardiner Expressway and Lakeshore Boulevard Reconfiguration

Dear Mr. Martin:

This letter is being provided in response to comments received in regards to the air quality and greenhouse gas assessment performed by Dillon Consulting Limited as a part of the Gardiner Expressway and Lakeshore Boulevard Reconfiguration Project. Comments were received from the Ministry of the Environment and Climate Change on November 14th, 2016. For clarity, responses to the individual questions posed are presented in the following table. This letter is being provided with an accompanying updated report to satisfy the Ministry's request. The responses in the following table have been incorporated into the updated AQAI Report which is provided with this letter.

Comment #	MOECC Comment & Rationale	Proponent Response/Proposed Solution
1	Table 1 in Section 3 summarizes the background air quality levels used in this project. It is recommended to attach the technical memorandum dated August 22nd, 2013 prepared by Dillon Consulting to the AQAI report as an attachment so that the selection of stations is documented.	The technical memorandum has been included with the updated report provided with this letter.

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Dillon Consulting Limited

Comment #	MOECC Comment & Rationale	Proponent Response/Proposed Solution
2	The AQAI Report lists the contaminants of concern in Section 3 which follows the scope of work under the Terms of Reference (TOR), however there were only three contaminants of the list selected for the assessment and a rationale was not provided. In addition, the BAP emission factors are expressed as a fraction of particulate matter emissions. However, beyond Section3, BAP emissions were not presented and this should be clarified.	The analysis was performed as a comparison between alternatives where the roadway already exists. As there are already impacts from the roadway, net changes between the scenarios were considered. As such, the analysis focussed on three representative contaminants which are indicative of the impact of transportation infrastructure. NO_x, $PM_{2.5}$, and VOCs are representative of the most significant vehicular emissions and are suitable for benchmarking proposed alternatives. BAP emissions were not presented after section 3 as $PM_{2.5}$ emissions are representative of BAP and provide a suitable assessment for comparative purposes.
3	The Ontario 2011 emissions were applied in the burden analysis which is not appropriate since the Gardiner emissions should be compared to the Region to the study boundaries as shown in Figure 1 "Terms of Reference Study Areas for GELBR" and not the entire province. Please provide a rationale for selecting the provincial totals as opposed to the study area emissions for the burden analysis in the AQAI Report.	This analysis has been performed as a comparison between alternatives where the roadway already exists. The results are presented as a comparison between scenarios, not against provincial standards. The results are not presented in reference to an air quality standard or guideline. As such, the background data selected for the burden analysis do not impact the results.

Comment #	MOECC Comment & Rationale	Proponent Response/Proposed Solution
4	Within the burden analysis, the ranking of alternatives (Maintain, Improve, Replace and Remove) was done without considering the variability of speeds or the changes of traffic patterns. The average speed, as it was employed in this study, does not account for idling emissions since the emission factor for idling is different compared to the free flow emission factors. For these reasons, the proponent should consider to qualitatively explain the differences between alternatives with respect to the traffic volumes and traffic patterns, such as the case when the number of lanes is reduced for both Gardiner and Lakeshore Boulevard in the Improve Scenario.	The assessment was done using the impact of the entire road network including arterial roads within the study area. Additionally, each roadway was represented by small (typically 100 m – 300 m) links which were modelled with the average speed within that section. This resulted in an assessment of over 1,400 individual links. The modelling approach was used to approximate the impact of idling emissions in a way that was feasible within the model. Adding additional idling links throughout the study area would significantly increase the complexity of the model and was determined to not be feasible for an undertaking of this scale.
5	The fleet distribution (% light duty versus heavy duty vehicle) employed in this study was not provided and this should be discussed in the AQAI report.	A 88%/12% light duty/heavy duty split was applied in the modelling. This has been indicated in the updated report provided with this letter.
6	A sample calculation should be provided for the estimated hourly emissions summarized in Table 7. In addition, the AQAI Report should also summarize the traffic volumes used in the Gardiner and Lakeshore modelling. It is not clear for the removal of the Gardiner scenario if additional cars were added to the current volumes at Lakeshore Boulevard. Please clarify in the AQAI Report.	The AQAI Report has been updated to include this sample calculation. Sample traffic volumes have also been included for the removal scenario for comparison with the baseline scenario.
7	A rationale should be provided as to why 2012 was used as the meteorological data set for the local air quality assessment.	The meteorological data selected (2012) was compared to the five-year dataset from 2008-2012. The report showed that 2012 was representative of the five-year dataset. It is important that a meteorological set is representative of the study area; however, as this assessment was performed as a comparison between scenarios, variations in meteorological data between years will have only a very small impact on the results.

Comment #	MOECC Comment & Rationale	Proponent Response/Proposed Solution
8	The AQIA report did not provide the incremental differences for each of the alternatives nor the combined concentrations (background plus predicted) for the preferred alternative nor how these compare to the criteria presented in Section 3. At a minimum, this comparison should be presented and discussed in the AQAI report.	Cumulative results were not compared to criteria for two reasons. Primarily, the existing Gardiner emissions are significant, and would be included in background measured concentrations which results in over-predicted cumulative concentrations. Additionally, the model was overly conservative as discussed in the report. For example, peak hourly vehicle volumes were modelled as occurring for the whole year. Given this level of conservatism, the results were not compared to the criteria as it would depict the alternatives as having significantly greater impacts than realistically expected.
9	It is recommended to compare $PM_{2.5}$ data with the Canadian Ambient Air Quality Standards (CAAQS) criterion of 28 $\mu g/m^3$, which is in effect since 2015.	This updated standard has been included in the revised AQAI Report provided with this letter.
10	Lastly, there is no discussion of the TOR in the AQAI report. The ministry is aware that the proponent conducted monitoring as required by the TOR, but those monitoring results could not be used due to the limitations of the monitoring equipment employed. For these reasons, background air quality concentrations were based on the nearest representative NAPS and AQI stations. This should also be documented in the AQAI Report.	The following discussion has been added to the revised AQAI Report: Due to the limitations of the monitoring equipment which was deployed, in discussion with the MOECC it was determined that NAPS and MOECC monitored data would be used to represent ambient concentrations.

We trust these responses satisfy the Ministry's request. Please don't hesitate to contact us for anything further.

Sincerely,

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1.0 Introduction

On November 30, 2009, the Ministry of the Environment and Climate Change (MOECC) approved the Terms of Reference (ToR) for the Gardiner Expressway and Lakeshore Boulevard Reconfiguration (GELBR) Environmental Assessment (EA) that was submitted jointly by Waterfront Toronto and the City of Toronto. The approved ToR includes a high-level work plan for the Air Quality component of the EA (i.e., the Air Quality Impact Assessment (AQIA)). As a part of the AQIA, Dillon established the background ambient air quality levels for use in the EA, using an approach and data sources approved by the MOECC.

The air quality and greenhouse gas (GHG) impact assessment generally followed the methodologies described within the Ontario Ministry of Transportation's document "*Environmental Guide for Assessing and Mitigating the Air Quality Impacts and Greenhouse Gas Emissions of Provincial Transportation Projects*" (January 2012) [the Guide]. The assessment was conducted in two phases. The first phase was completed in 2014 and evaluated four alternative solutions (Maintain, Improve, Replace and Remove). The preferred alternative from the Phase 1 assessment was carried forward into the Phase 2 assessment. The Phase 2 assessment was performed for two alternative solutions (Boulevard and Hybrid). This document describes how regional air quality, local air quality impact and GHG emissions impact was evaluated for both the phases of assessment.

1.1 Study Area

Two study areas have been specified in the EA ToR, as shown in Figure 1:

- Urban Design and Environmental Effects Study Area – including lands south of King Street to the waterfront, and from Lower Jarvis Street to Logan Avenue.
- Transportation System Study Area – including lands extending from Dundas Street to Lake Ontario and from Spadina Avenue to Woodbine Avenue.

The section of the Gardiner and Lake Shore Boulevard (LSB) that has been examined for reconfiguration is approximately 2.4 km and extends from lower Jarvis Street to just east of the DVP at Logan Avenue.

As described above, both phases of the assessments include a regional air quality, local air quality and GHG emissions impact evaluation. In order to maintain consistency with the ToR study areas and to allow for consideration of the unique features of AQIA the study areas that have been identified for the AQIA include:

1. Regional Study Area (RSA): for the regional air quality assessment and GHG emissions impact evaluation.
2. Local Study Area (LSA): for the local air quality evaluation.

The RSA is defined as the Transportation System Study Area which are the lands extending from Dundas Street to Lake Ontario and from Spadina Avenue to Woodbine Avenue.

The LSA is designated as the study area bounded by King Street in the north, the lakefront in the south, Spadina Avenue in the west and Woodbine Avenue in the east.

Traffic data from the Expressway, arterial roads and collector roads have been included in the AQIA and so these roads have been defined within the RSA and LSA.

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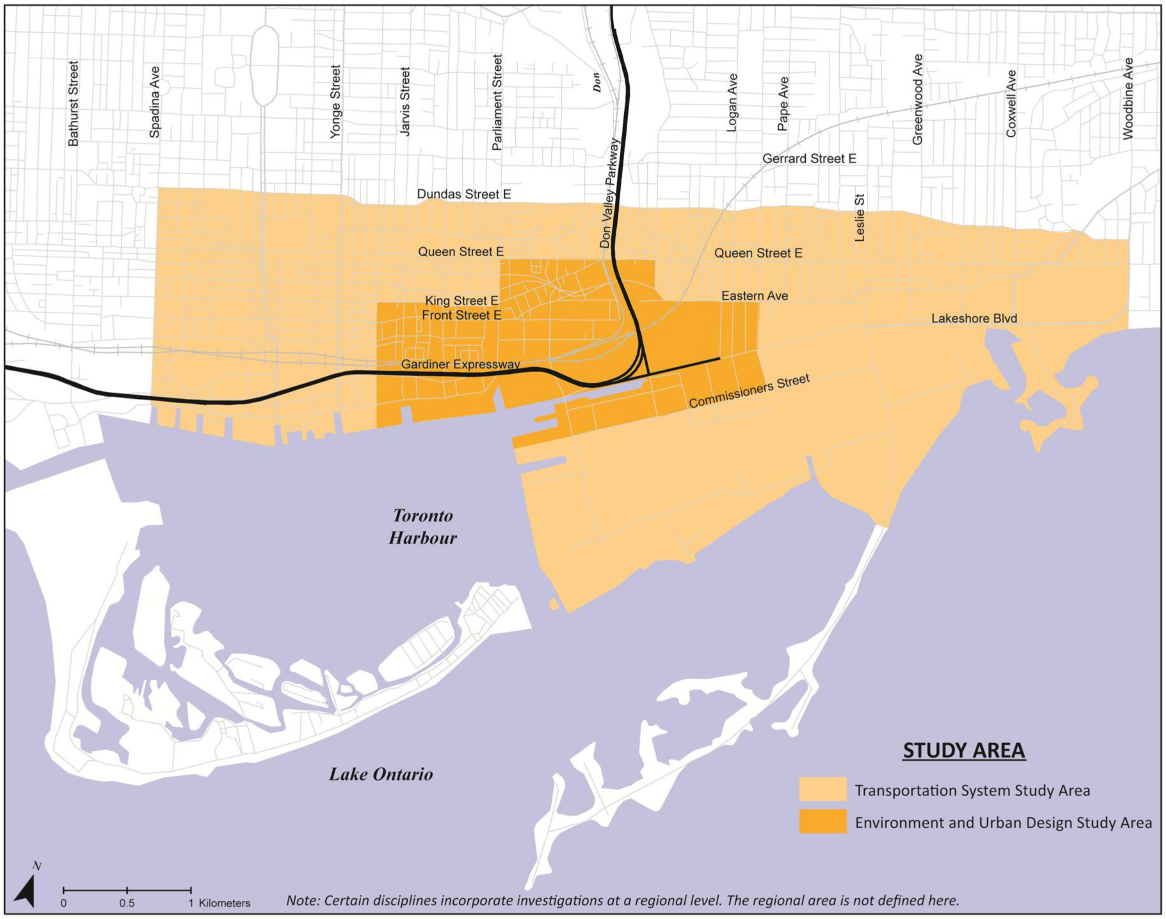

Figure 1: Terms of Reference Study Areas for GELBR

1.2 Receptors

Receptors need to be defined for the local air quality assessment. The Guide recommends that the local air quality impacts be studied within a distance of 500 m from the transportation facility, in each direction and at both sensitive (residences) and critical receptors (hospitals, retirement homes, childcare centers, etc.). For this evaluation, the receptors include:

1. Uniform Cartesian receptor grid with 100-m spacing within LSA at a default height of 1.8 m above ground, with receptors on railways and water removed;
2. Critical receptors at a default height of 1.8 m above ground, identified based on current land use as provided by the City;
3. Elevated receptors at heights of 1.8, 6 and 10 m above ground on both sides of the Gardiner with a spacing of 20 m between Yonge Street and DVP and 50 m between Yonge Street and Spadina Avenue.

Vehicular emissions are typically emitted close to ground level and modelling of transportation corridors generally yields maximum concentrations at ground level. However, some of the existing Gardiner sections are elevated. Therefore elevated receptors were also placed on both sides of the Gardiner. As the CAL3QHC/CAL3QHCR model allows the maximum release height of 10 m, the elevated receptors were placed at 10 m above the ground.

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2.0 ALTERNATIVE SOLUTIONS

2.1 Phase 1 Assessment Alternatives

The alternative solutions evaluated during initial phase were Maintain, Improve, Replace and Remove as described below.

Maintain – the Maintain option represents the future base case (2031) or "do nothing" alternative. As this is a 2031 base case, the option also includes:

1. Full deck replacement and rehabilitation of the Gardiner as per the City's current rehab plans.
2. Build out of the current approved development applications within the study area (as per City's planning information), and the build out of West Don Lands, East Bayfront and Lower Don Lands as per the current precinct plans.
3. The realignment of Lake Shore Boulevard (LSB) between the Don River and Cherry Street as per the Keating Precinct Plan.

Improve – the Improve alternative is to improve the Gardiner between lower Jarvis and the Don Valley Parkway (DVP) and includes:

1. Maintain the same number of ramps.
2. Reduce the number of lanes for both Gardiner and LSB between lower Jarvis and Parliament.
3. Assume realignment of LSB between Don River and Cheery Street as per the Keating Plan.

Replace – the Replace alternative defines a scenario whereby the Gardiner between Yonge Street and DVP is replaced with another elevated expressway. This alternative includes:

1. Elevate the Gardiner by 5 m from lower Jarvis to the DVP.
2. Shift Gardiner between Don River and Cherry Street to the realigned LSB as per the Keating Precinct Plan.
3. Build a transitional section between Yonge Street and Jarvis Street.

Remove – the Remove alternative incorporates the removal of the Gardiner between lower Jarvis Street and the DVP and expands the LSB to 4-lanes in both directions. This alternative includes:

1. Remove all of the 2.4 km elevated expressway east of approximately Jarvis Street, including removal of about 750 m (EB lanes) and 850 m (WB lanes) of the existing Logan on/off ramps;
2. Rebuild the corridor with a new at-grade 8-lane tree lined Lake Shore Boulevard, west of the Don River and a new 6-lane at-grade boulevard east of Don River;
3. Develop new public realm space within the corridor;
4. Remove all road infrastructure along Keating Channel;
5. Build new DVP ramp connection at east end of the Keating Precinct (2 lanes each direction);
6. Build new Gardiner ramps west of Jarvis Street (3 lanes each direction); and
7. Build new multi-use pathway along north side of Lake Shore Boulevard to extend to Yonge Street.

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2.2 Phase 2 Assessment Alternatives

The alternative solutions evaluated during the second phase were Boulevard and Hybrid as described below.

Boulevard – The Remove alternative (renamed to "Remove (Boulevard)" to clarify the changes that are proposed under this alternative). Similar to the Remove alternative in the Phase 1 assessment, modifications to the corridor under this alternative includes:

1. Remove all of the 2.4 km elevated expressway east of approximately Jarvis Street, including removal of about 750 m (EB lanes) and 850 m (WB lanes) of the existing Logan on/off ramps;
2. Rebuild the corridor with a new at-grade 8-lane tree lined Lake Shore Boulevard, west of the Don River and a new 6-lane at-grade boulevard east of Don River;
3. Develop new public realm space within the corridor;
4. Remove all road infrastructure along Keating Channel;
5. Build new DVP ramp connection at east end of the Keating Precinct (2 lanes each direction);
6. Build new Gardiner ramps west of Jarvis Street (3 lanes each direction); and
7. Build new multi-use pathway along north side of Lake Shore Boulevard to extend to Yonge Street.

Hybrid – The hybrid alternative is a combination of a few alternatives from the Phase 1 assessment. This alternative includes:

1. Rehabilitation of the Gardiner deck east of Cherry Street;
2. West of Cherry Street, retention of the existing Gardiner structure/ramps;
3. Retention of the existing Gardiner-DVP on/off ramps;
4. Removal of the existing Logan on/off ramps (about 750 m of EB lanes and 850 m of WB lanes);
5. Rebuilding of Lake Shore Boulevard east of the Don River as a new six-lane landscaped boulevard including planned Broadview extension intersection;
6. Construction of one new westbound Gardiner on-ramp and one new eastbound Gardiner off-ramp (each two lanes, about 450 m in length) at Cherry Street (in Keating Channel Precinct);
7. Construction of new approach roads to the new on/off Gardiner ramps that run under/north of the Gardiner through the Keating Channel Precinct (within footprint of current westbound Lake Shore Boulevard lanes);
8. Extension of Queens Quay east of Cherry Street as a one-lane eastbound roadway;
9. Building of new Lake Shore Boulevard/Queens Quay intersection (under DVP ramps);
10. Realignment of Lake Shore Boulevard as per the Keating Channel Precinct Plan;
11. Extend multi-use pathway along north side of Lake Shore Boulevard; and
12. Improvements to some of the existing Lake Shore Boulevard intersections west of Cherry Street.

3.0 BACKGROUND AIR QUALITY

The Contaminants of Concern (COCs) evaluated in the air quality component for both phases of assessment are listed below and were identified in consultation with the MOECC (Dillon technical memo dated August 22nd, 2013). Table 1 identifies the background concentrations used for each COC in the air quality component of the assessments.

- Carbon monoxide (CO);
- Nitrogen oxides (NO_X (focus on NO and NO_2));
- Total suspended particulate (TSP);
- Particulate matter with aerodynamic diameter <10µm (PM_{10});
- Particulate matter with aerodynamic diameter <2.5µm ($PM_{2.5}$);
- Benzene;
- 1,3-Butadiene;
- Formaldehyde;
- Acetaldehyde;
- Acrolein; and
- Benzo(a)pyrene (BaP).

As shown in Table 1, all of the background concentrations at both 70th percentile and 90th percentile were below their respective criteria except Benzene and BaP. For Benzene, the 90th percentile annual concentration was 153% of its criterion. The 90th percentile concentrations for BaP were 186% and 800% of its corresponding 24-hour and annual criteria. The selection of stations is documented in the technical memorandum included with this report, prepared by Dillon Consulting, dated August 22nd, 2013.

This assessment considers the changes in air quality due to proposed alternative solutions for the Gardiner Expressway. As the roadway is already existing, net changes in pollutant impacts between the scenarios are assessed instead of comparing predicted concentrations to provincial standards. For this comparative assessment, three contaminants were chosen as representative of the project impacts. NO_x was chosen as representative of CO and NO_x. $PM_{2.5}$ emissions are directly related to PM_{10}, TSP and BaP emissions. Lastly, total VOCs were modelled to represent acetaldehyde, acrolein, benzene, 1,3-butadiene and formaldehyde.

Monitoring was performed by Dillon to characterize the ambient contaminant concentrations in the study area. However, due to limitations of the monitoring equipment which was deployed, in discussion with the MOECC it was determined that NAPS and MOECC monitored data would be used to represent ambient concentrations.

Table 1: Background Concentrations for AQIA

Pollutant	Averaging Period	Data Period	70th Percentile (µg/m³)	90th Percentile (µg/m³)	Criteria (µg/m³)	
$PM_{2.5}$	24-hour	2010-2012	7	12	28	Canada-Wide Standard; Ontario AAQC
PM_{10}	24-hour	2010-2012	12	21	50	Ontario AAQC
NO_2	24-hour	2010-2012	32	43	200	Ontario AAQC
	1-hour	2010-2012	32	51	400	Ontario AAQC
CO	8-hour	2008-2010	259	356	15700	Ontario AAQC
	1-hour	2008-2010	252	366	36200	Ontario AAQC
Benzene	Annual	2009-2012	0.69	0.69	0.45	Ontario AAQC
	24-hour	2009-2012	0.80	1.08	2.3	Ontario AAQC
Acrolein	24-hour	2008-2010	0.04	0.07	0.4	Ontario AAQC
	1-hour	2008-2010	0.10	0.18	4.5	Ontario AAQC
1,3 Butadiene	Annual	2009-2012	0.07	0.07	2	Ontario AAQC
	24-hour	2009-2012	0.08	0.12	10	Ontario AAQC
Formaldehyde	24-hour	2008-2010	1.46	2.51	65	Ontario AAQC
Acetaldehyde	24-hour	2008-2010	3.48	5.12	500	Ontario AAQC
	½ hour	2008-2010	10.31	15.16	500	Ontario AAQC
BaP	Annual	2008-2010	0.000088	0.000089	0.00001	Ontario AAQC
	24-hour	2008-2010	0.000093	0.000153	0.00005	Ontario AAQC

4.0 EMISSION FACTOR DEVELOPMENT

The air quality and GHG emissions assessments require that emissions (mass per unit of distance or time) of the COCs mentioned above as well as carbon dioxide equivalents (CO_2e) be estimated. Emissions are typically estimated by multiplying established emission factors by corresponding vehicle fleet size and kilometers of distanced travelled or idling durations. The most common emission factor model for mobile source emissions in Canada is the US EPA's MOBILE 6.2 model. This model predicts fleet-average emission factors. For these assessments, the Canadian version of the MOBILE 6.2 model (MOBILE6.2C, Version 6.2.3), which integrates the unique Canadian climate and fuel compositions, has be used.

Inputs and assumptions used within the MOBILE6.2C model followed the methodology recommended within the Guide and included use of:

- the month of July for the evaluation;
- diurnal patterns in temperature and relative humidity that were derived using measured data at Environment Canada's Toronto Island Airport station from 2008 – 2012 as inputs to MOBILE6.2C;
- the default vehicle characteristics (age distribution, annual mileage accumulation rates, and diesel fractions for the 16 vehicle classes) built into MOBILE6.2C;
- vehicle miles travelled (VMT) fractions by vehicle class that are derived from the field vehicle counts;
- VMT fractions by hour that are created based on the diurnal pattern in traffic volumes field counts;
- Ontario's drive clean program limit for the sulphur content of diesel of 15 ppm (note, the emission reductions due to Ontario's Emissions Inspection and Maintenance (I/M) Program have not been considered and this represents conservatism within the assessment);
- the road types: Freeway, Ramp and Arterial to simulate the average speeds that were used; and
- fuel composition and properties that are representative of those used in Ontario.

As all traffic volumes for the alternative solutions in both phases of assessment are projected to 2031, the emissions were estimated for 2031. The emission factors used were calculated by MOBILE6.2C for NO_x, $PM_{2.5}$, volatile organic compounds (VOCs, a surrogate of air toxics) and carbon dioxide equivalent (CO_2e). NO_x, $PM_{2.5}$, and total VOCs were chosen as representative contaminants to assess the local air quality impacts of each of the alternatives. The MOBILE6.2C output emission factors are shown in Tables 2 to 5.

In addition to exhaust, tire wear, brake and evaporative emissions, the re-entrainment of road dust is considered as a particulate matter emission source from vehicles travelling over a paved road. Emissions resulting from travel on paved roads were quantified using the US EPA AP-42 data (Chapter 13.2.1), as shown in Table 6. This is the recommended method within the Guide for the prediction of road dust emissions.

The emission factors for BaP specific to the Great Lakes Region, derived by the Great Lakes Commission for on-road vehicles are expressed as a fraction of particulate matter (PM) emissions from various types of vehicles including: LDGV, HDGV, LDGT, motorcycle, LDDV, LDDT and HDDV. Therefore, as a conservative assumption, $PM_{2.5}$ was used a surrogate to represent BaP in the evaluation. An average 12% heavy duty vehicle percentage was modelled for the study area.

Table 2: 2031 Emission Factors (g/mile) for NOx

Road Type	Speed (mph)	2.5	5	10	15	20	25	30	35	40	45	50	55	60	65	Ramp
Arterial	24-Hour	0.557	0.487	0.398	0.342	0.314	0.297	0.285	0.281	0.285	0.292	0.299	0.308	0.319	0.333	--
	AM Peak	0.561	0.490	0.400	0.344	0.316	0.298	0.287	0.282	0.286	0.293	0.300	0.309	0.320	0.332	--
	PM Peak	0.562	0.490	0.400	0.344	0.315	0.298	0.287	0.282	0.286	0.292	0.299	0.308	0.318	0.330	--
Arterial with Streetcars	24-Hour	0.551	0.482	0.394	0.339	0.311	0.294	0.283	0.279	0.283	0.289	0.297	0.306	0.317	0.330	--
	AM Peak	0.554	0.484	0.396	0.341	0.313	0.296	0.284	0.280	0.284	0.291	0.298	0.307	0.318	0.331	--
	PM Peak	0.554	0.484	0.395	0.340	0.312	0.295	0.284	0.279	0.283	0.289	0.296	0.305	0.314	0.326	--
Freeway with Ramps Combined	24-Hour	0.558	0.488	0.352	0.285	0.285	0.284	0.284	0.283	0.288	0.295	0.303	0.314	0.327	0.343	0.329
	AM Peak	0.560	0.490	0.353	0.286	0.285	0.285	0.285	0.284	0.288	0.295	0.303	0.314	0.326	0.342	0.329
	PM Peak	0.558	0.488	0.349	0.282	0.283	0.283	0.283	0.282	0.287	0.293	0.301	0.310	0.321	0.334	0.329
Freeway with Ramps Inbound	24-Hour	0.558	0.489	0.352	0.285	0.285	0.284	0.284	0.283	0.288	0.295	0.303	0.314	0.327	0.343	0.329
	AM Peak	0.542	0.491	0.353	0.286	0.285	0.285	0.285	0.284	0.288	0.295	0.303	0.314	0.326	0.343	0.330
	PM Peak	0.559	0.489	0.349	0.282	0.283	0.283	0.283	0.282	0.287	0.293	0.301	0.310	0.321	0.334	0.329
Freeway with Ramps Outbound	24-Hour	0.557	0.488	0.352	0.285	0.285	0.284	0.284	0.283	0.288	0.295	0.303	0.313	0.327	0.343	0.328
	AM Peak	0.559	0.490	0.352	0.285	0.285	0.284	0.284	0.284	0.288	0.295	0.303	0.314	0.326	0.342	0.330
	PM Peak	0.558	0.488	0.349	0.282	0.282	0.283	0.283	0.282	0.286	0.293	0.300	0.310	0.321	0.334	
Lakeshore Combined	24-Hour	0.568	0.498	0.408	0.351	0.321	0.304	0.292	0.288	0.292	0.300	0.309	0.321	0.336	0.355	--
	AM Peak	0.564	0.494	0.404	0.348	0.319	0.301	0.290	0.286	0.290	0.297	0.318	0.306	0.332	0.350	--
	PM Peak	0.565	0.494	0.403	0.347	0.318	0.300	0.289	0.284	0.288	0.295	0.302	0.312	0.323	0.337	--
Lakeshore Eastbound	24-Hour	0.568	0.498	0.407	0.351	0.321	0.303	0.292	0.288	0.292	0.299	0.309	0.320	0.335	0.355	--
	AM Peak	0.563	0.493	0.404	0.348	0.319	0.301	0.290	0.286	0.290	0.297	0.306	0.318	0.332	0.350	--
	PM Peak	0.564	0.493	0.403	0.347	0.318	0.300	0.288	0.284	0.288	0.295	0.302	0.312	0.323	0.337	--
Lakeshore Westbound	24-Hour	0.569	0.499	0.408	0.352	0.322	0.304	0.292	0.288	0.292	0.300	0.309	0.321	0.336	0.355	--
	AM Peak	0.565	0.495	0.405	0.349	0.319	0.302	0.290	0.286	0.290	0.298	0.306	0.318	0.332	0.350	--
	PM Peak	0.566	0.495	0.404	0.347	0.318	0.300	0.289	0.284	0.288	0.295	0.303	0.312	0.323	0.337	--

Table 3: 2031 Emission Factors (g/mile) for $PM_{2.5}$

Road Type	Speed (mph)	2.5	5	10	15	20	25	30	35	40	45	50	55	60	65	Ramp
Arterial	24-Hour	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--
	AM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--
	PM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--
Arterial with Streetcars	24-Hour	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--
	AM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--
	PM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--
Freeway with Ramps Combined	24-Hour	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
	AM Peak	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
	PM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Freeway with Ramps Inbound	24-Hour	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
	AM Peak	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
	PM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Freeway with Ramps Outbound	24-Hour	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
	AM Peak	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
	PM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Lakeshore Combined	24-Hour	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	--
	AM Peak	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	--
	PM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--
Lakeshore Eastbound	24-Hour	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	--
	AM Peak	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	--
	PM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--
Lakeshore Westbound	24-Hour	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	--
	AM Peak	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	--
	PM Peak	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	--

Table 4: 2031 Emission Factors (g/mile) for VOCs

Road Type	Speed (mph)	2.5	5	10	15	20	25	30	35	40	45	50	55	60	65	Ramp
Arterial	24-Hour	2.939	1.186	0.677	0.522	0.427	0.388	0.363	0.344	0.332	0.322	0.314	0.012	0.302	0.298	--
	AM Peak	2.956	1.191	0.679	0.524	0.429	0.389	0.365	0.346	0.334	0.325	0.316	0.012	0.304	0.300	--
	PM Peak	2.969	1.194	0.680	0.525	0.429	0.390	0.366	0.347	0.335	0.326	0.317	0.012	0.305	0.301	--
Arterial with Streetcars	24-Hour	2.934	1.184	0.676	0.522	0.427	0.387	0.362	0.343	0.331	0.321	0.313	0.012	0.301	0.297	--
	AM Peak	2.943	1.187	0.677	0.523	0.428	0.388	0.363	0.344	0.332	0.323	0.314	0.012	0.302	0.298	--
	PM Peak	2.967	1.194	0.680	0.524	0.429	0.390	0.365	0.346	0.335	0.325	0.316	0.012	0.304	0.300	--
Freeway with Ramps Combined	24-Hour	2.888	1.174	0.648	0.489	0.411	0.381	0.360	0.342	0.330	0.320	0.311	0.013	0.299	0.296	--
	AM Peak	2.899	1.177	0.649	0.490	0.412	0.382	0.361	0.343	0.331	0.321	0.312	0.013	0.300	0.297	0.364
	PM Peak	2.936	1.186	0.651	0.491	0.414	0.384	0.364	0.345	0.334	0.324	0.316	0.012	0.304	0.300	0.368
Freeway with Ramps Inbound	24-Hour	2.889	1.174	0.648	0.489	0.412	0.381	0.360	0.342	0.330	0.320	0.311	0.013	0.299	0.296	0.364
	AM Peak	2.695	1.177	0.649	0.490	0.412	0.382	0.361	0.343	0.331	0.321	0.312	0.013	0.300	0.297	0.365
	PM Peak	2.937	1.187	0.651	0.491	0.414	0.384	0.364	0.345	0.334	0.324	0.316	0.012	0.304	0.300	0.368
Freeway with Ramps Outbound	24-Hour	2.887	1.173	0.648	0.489	0.411	0.381	0.360	0.342	0.330	0.320	0.311	0.013	0.299	0.296	0.364
	AM Peak	2.897	1.176	0.649	0.490	0.412	0.382	0.361	0.343	0.331	0.321	0.312	0.013	0.300	0.297	0.297
	PM Peak	2.935	1.186	0.651	0.491	0.414	0.384	0.364	0.345	0.334	0.324	0.316	0.012	0.304	0.300	0.368
Lakeshore Combined	24-Hour	2.865	1.169	0.673	0.520	0.425	0.385	0.359	0.340	0.328	0.318	0.309	0.013	0.297	0.293	--
	AM Peak	2.874	1.171	0.673	0.520	0.425	0.385	0.360	0.340	0.328	0.318	0.302	0.013	0.297	0.294	--
	PM Peak	2.946	1.190	0.680	0.524	0.429	0.390	0.365	0.346	0.334	0.324	0.316	0.012	0.304	0.300	--
Lakeshore Eastbound	24-Hour	2.862	1.168	0.672	0.519	0.425	0.385	0.359	0.340	0.328	0.318	0.309	0.013	0.297	0.293	--
	AM Peak	2.871	1.170	0.673	0.520	0.425	0.385	0.360	0.340	0.328	0.318	0.309	0.013	0.297	0.294	--
	PM Peak	2.943	1.189	0.679	0.524	0.429	0.390	0.365	0.346	0.334	0.324	0.316	0.012	0.304	0.300	--
Lakeshore Westbound	24-Hour	2.869	1.171	0.673	0.520	0.425	0.385	0.360	0.340	0.328	0.318	0.309	0.013	0.297	0.293	--
	AM Peak	2.878	1.173	0.674	0.520	0.425	0.385	0.360	0.340	0.328	0.318	0.309	0.013	0.297	0.294	--
	PM Peak	2.950	1.191	0.680	0.525	0.429	0.390	0.365	0.346	0.334	0.324	0.316	0.012	0.304	0.300	--

Table 5: 2031 Emission Factors (g/mile) for CO_2e

Road Type	Speed (mph)	2.5	5	10	15	20	25	30	35	40	45	50	55	60	65	Ramp
Arterial	24-Hour	524.8	524.8	524.8	524.8	524.8	524.8	524.8	524.8	524.8	524.8	524.8	524.8	524.8	524.8	--
	AM Peak	518.0	518.0	518.0	518.0	518.0	518.0	518.0	518.0	518.0	518.0	518.0	518.0	518.0	518.0	--
	PM Peak	512.4	512.4	512.4	512.4	512.4	512.4	512.4	512.4	512.4	512.4	512.4	512.4	512.4	512.4	--
Arterial with Streetcars	24-Hour	523.8	523.8	523.8	523.8	523.8	523.8	523.8	523.8	523.8	523.8	523.8	523.8	523.8	523.8	--
	AM Peak	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	519.9	--
	PM Peak	507.8	507.8	507.8	507.8	507.8	507.8	507.8	507.8	507.8	507.8	507.8	507.8	507.8	507.8	--
Freeway with Ramps Combined	24-Hour	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2
	AM Peak	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0
	PM Peak	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2
Freeway with Ramps Inbound	24-Hour	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2
	AM Peak	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0
	PM Peak	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2
Freeway with Ramps Outbound	24-Hour	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2	542.2
	AM Peak	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0	537.0
	PM Peak	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	519.2	
Lakeshore Combined	24-Hour	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	--
	AM Peak	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	--
	PM Peak	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	--
Lakeshore Eastbound	24-Hour	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	--
	AM Peak	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	--
	PM Peak	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	--
Lakeshore Westbound	24-Hour	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	--
	AM Peak	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	556.7	--
	PM Peak	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	522.0	--

Table 6: Re-entrained Road Dust Emission Factors

Road Type	$PM_{2.5}$ Emission Factor (g/mile)
Gardiner/DVP/ Ramps	0.02030
Lakeshore	0.02232
Arterial	0.01788

5.0 REGIONAL AIR QUALITY ASSESSMENT

Regional air quality is commonly described in terms of the concentrations of air pollutants that are important at a regional scale. Current knowledge on health and environmental effects clearly identifies ground level ozone (O_3) and fine particulate matter ($PM_{2.5}$) as the two pollutants of greatest regional importance. They are the major constituents of smog and are produced by numerous complex physical and chemical processes that usually take place over a large geographic area. Ground level O_3 and most $PM_{2.5}$ are secondary pollutants that are produced by precursors such as NOx, CO and VOCs.

There are various approaches to assess the impact of a project on regional air quality ranging from advanced (data intensive) modelling techniques to a qualitative discussion. Two common approaches referenced in the Guide are an empirical source-receptor model and regional air pollution burden analysis.

The empirical source-receptor model postulates a linear relationship between relative changes in concentrations and emissions of primary pollutants. However, the relationships for $PM_{2.5}$ and O_3, which are the major elements/drivers for regional air quality, are non-linear and highly variable. Thus, this empirical source-receptor approach is not relevant for broad assimilation and routine application.

The regional air pollution burden analysis entails a quantitative assessment of the net increase or decrease in pollutant emissions attributable to the project and the net effect of the project on regional emissions of relevant primary pollutants. The burden analysis is the preferred approach in many air quality impact assessments to look at the regional air quality implications of individual projects and has been used in both the assessment phases. The burden analysis is also the recommended approach for assessment of regional air quality impacts within the Guide.

Within a burden analysis, the vehicular emissions are typically calculated for both the free flow and idling conditions. For this evaluation, emissions were calculated based on the average travelling speed (free flow and idling) of vehicles within each road segment (link). Emissions were calculated based on an average 12% heavy-duty vehicle percentage within the study area. The emission rate for each link was calculated as:

$$ERF\left(\frac{g}{hr}\right) = EFF\left(\frac{g}{vehicle\ mile}\right) VPH\left(\frac{vehicle}{hr}\right) D(miles) \qquad (1)$$

where ERF: Emission rate in g/hr;

EFF: Composite emission factor in g/vehicle/mile;

VPH: Traffic volume in vehicle/hr

D: Length of the road in miles.

Hourly emissions of each contaminant for each link were calculated using Equation (1). The regional hourly emissions for each contaminant were estimated by summing the emissions associated with all links within the RSA.

5.1 Phase 1 Assessment

Table 7 shows the Phase 1 estimated AM peak hourly emissions for NOx, $PM_{2.5}$ and VOCs.

The AM peak hourly emissions of NOx, $PM_{2.5}$ and VOCs for the four alternatives were then divided by the corresponding total Ontario hourly emissions derived from 2011 annual emissions. The Ontario hourly numbers were derived by dividing the annual numbers by 365 days, 24 hours per day (i.e., the percent of the 2011 Ontario emissions) to represent the burden

To evaluate the four alternatives within the burden analysis, three ranking schemes were used:

1. Total hourly emissions – the alternative with the lowest annual emissions is the most preferred (highest ranking). As indicated in Table 7, the Remove alternative is the most preferred and Maintain is the least preferred in terms of both NOx and $PM_{2.5}$ emissions. However, the Maintain alternative is the most preferred in terms of VOCs emissions.
2. Burden analysis – the lowest burden represents the least contribution to the regional emissions. The Remove alternative is the most preferred in terms of NOx and $PM_{2.5}$ emissions. The Improve and Maintain alternatives are the most preferred in terms of VOC emissions.
3. Burden weighted ranking –total hourly emissions ranking is weighted by the burden to combined all three contaminants together (i.e., the highest value is the most preferred). This allows for consideration of the fact that individual contaminants may have different significance within the burden analysis (e.g., VOCs have a higher predicted burden and may therefore be considered to be more important than $PM_{2.5}$ and NOx as indicator compounds). As shown in Table 7, the Remove alternative (0.008) is the most preferred while the Replace alternative (0.005) is the least preferred.

Based on the above three schemes it can be concluded that the Remove option is most preferred and Replace is marginally the least preferred, as shown in Tables 7 and 8. The estimated emissions presented in Tables 7 and 8 were calculated following the methodology below which shows the calculation of NO_x from the 'Maintain' scenario:

$$ERF\left(\frac{t}{hr}\right) = EFF\left(\frac{t}{vehicle\ mile}\right) VPH\left(\frac{vehicle}{hr}\right) D(miles) \qquad (1)$$

where ERF: Emission rate in t/hr;

EFF: Composite emission factor in g/vehicle/mile;

VPH: Traffic volume in vehicle/hr

D: Length of the road in miles.

$$ERF\left(\frac{t}{hr}\right) = 3.3E-07\left(\frac{t}{vehicle\ mile}\right) * 115{,}670\ \frac{vehicle\ miles}{hr}$$

$$ERF\left(\frac{t}{hr}\right) = 0.038$$

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Table 7: Estimated Hourly Emissions and Burden Analysis for Phase 1 Assessment

Estimated Hourly Emissions					Notes
Scenario	NOx (t/hr)	VOC (t/hr)	PM2.5 (t/hr)		
Maintain	0.038	0.048	0.004		AM Peak expressed as emissions for peak hour
Improve	0.036	0.050	0.003		
Replace	0.036	0.052	0.003		
Remove	0.034	0.052	0.003		
2011 Ontario	40	46	7		(2011 Ontario emissions/365 days/year)/24 hours a day
Ranking Based on Emissions					Notes
Scenario	NOx	VOC	PM2.5	Total	Lower emission has higher ranking; higher number is better (preferred)
Maintain	1	4	1	6	
Improve	2	3	2	7	
Replace	3	1	3	7	
Remove	4	2	4	10	
Burden					Notes
Scenario	NOx	VOC	PM2.5	Total	Lower number is better (preferred)
Maintain	0.095%	0.104%	0.054%	0.253%	
Improve	0.089%	0.108%	0.050%	0.247%	
Replace	0.089%	0.113%	0.048%	0.250%	
Remove	0.085%	0.113%	0.045%	0.243%	
Burden					Notes
Scenario	NOx	VOC	PM2.5	Total	Higher number is better (preferred)
Maintain	1	4	1	6	
Improve	2	3	2	7	
Replace	3	1	3	7	
Remove	4	2	4	10	
Burden Weighted Ranking					Notes
Scenario	NOx	VOC	PM2.5	Total	Higher number is better (preferred)
Maintain	0.10%	0.42%	0.05%	0.0057	
Improve	0.18%	0.33%	0.10%	0.0060	
Replace	0.27%	0.11%	0.14%	0.0052	
Remove	0.34%	0.23%	0.18%	0.0075	

Table 8: Phase 1 Evaluation Matrix Based on Regional Air Quality Assessment

Scenario	Evaluation Matrix for Regional Air Quality
Maintain	Moderately Preferred
Improve	Moderately Preferred
Replace	Least Preferred
Remove	Most Preferred

5.2 Phase 2 Assessment

Table 9 shows the Phase 2 estimated AM peak hourly emissions for NOx, $PM_{2.5}$ and VOCs.

The AM peak hourly emissions of NOx, $PM_{2.5}$ and VOCs for the two alternatives were then divided by the corresponding total Ontario hourly emissions derived from 2011 annual emissions. The Ontario hourly numbers were derived by dividing the annual numbers by 365 days, 24 hours per day (i.e., the percent of the 2011 Ontario emissions) to represent the burden

To evaluate the two alternatives within the burden analysis, three ranking schemes were used:

1. Total hourly emissions – the alternative with the lowest hourly emissions is the most preferred (highest ranking). As indicated in Table 9, the Boulevard alternative is the most preferred in terms of both NOx and $PM_{2.5}$ emissions. However, the Hybrid alternative is the most preferred in terms of VOCs emissions.
2. Burden analysis – the lowest burden represents the least contribution to the regional emissions. The Boulevard alternative is the most preferred in terms of NOx and $PM_{2.5}$ emissions. The Hybrid alternative is the most preferred in terms of VOC emissions.
3. Burden weighted ranking –total hourly emissions ranking is weighted by the burden to combined all three contaminants together (i.e., the highest value is the most preferred). This allows for consideration of the fact that individual contaminants may have different significance within the burden analysis (e.g., VOCs have a higher predicted burden and may therefore be considered to be more important than $PM_{2.5}$ and NOx as indicator compounds). As shown in Table 9, there is no significant difference between the Boulevard alternative and the Hybrid alternative.

Based on the above three schemes it can be concluded that the Boulevard alternative and the Hybrid alternative are similar, as shown in Tables 9 and 10.

Table 9: Estimated Hourly Emissions and Burden Analysis for Phase 2 Assessment

Estimated Hourly Emissions					Notes
Scenario	NOx (t/hr)	VOC (t/hr)	PM2.5 (t/hr)		AM Peak expressed as emissions for peak hour
Boulevard	0.035	0.053	0.003		
Hybrid	0.038	0.051	0.004		
2011 Ontario	40	46	7		(2011 Ontario emissions/365 days/year)/24 hours a day
Ranking Based on Emissions					Notes
Scenario	NOx	VOC	PM2.5	Total	Lower emission has higher ranking; higher number is better (preferred)
Boulevard	2	1	2	5	
Hybrid	1	2	1	4	
Burden					Notes
Scenario	NOx	VOC	PM2.5	Total	Lower number is better (preferred)
Boulevard	0.087%	0.116%	0.047%	0.249%	
Hybrid	0.094%	0.112%	0.053%	0.259%	
Burden					Notes
Scenario	NOx	VOC	PM2.5	Total	Higher number is better (preferred)
Boulevard	2	1	2	5	
Hybrid	1	2	1	4	
Burden Weighted Ranking					Notes
Scenario	NOx	VOC	PM2.5	Total	Higher number is better (preferred)
Boulevard	0.26%	0.12%	0.14%	0.0052	
Hybrid	0.19%	0.22%	0.11%	0.0052	

Table 10: Phase 2 Evaluation Matrix Based on Regional Air Quality Assessment

Scenario	Evaluation Matrix for Regional Air Quality
Boulevard	Moderately Preferred*
Hybrid	Moderate Preferred*

6.0 LOCAL AIR QUALITY ASSESSMENT

As described in Appendix 3 of the Guide, the local air quality assessment can be carried out by using either a credible worst-case analysis or a comprehensive analysis. The credible worst-case analysis is based on the concept that a project is acceptable under all conditions if it is accepted under a credible worst-case condition.

Further, the credible worst-case condition assumes that the weekday morning or afternoon traffic conditions occur all the time under an unfavorable dispersion condition (i.e., wind speed at 1 m/s; wind direction at 5 degree off the mainline highway axis, to the right or to the left off the axis; stability class of D for urban regions). This type of analysis is likely to reflect an overly conservative prediction of potential impacts.

The comprehensive analysis addresses the variability of traffic and meteorological conditions from hour to hour, thus representing a more realistic prediction of potential impacts.

The US EPA CAL3QHC and CAL3QHCR models are widely used to predict the maximum air quality concentrations at receptors from transportation projects like GELBR. These two models are also recommended by the MTO in its Guide. CAL3QHC is most suited to predict concentrations for a single set of meteorological conditions. Hence, it is the preferred model for the credible worst-case analysis. CAL3QHCR, on the other hand, can process 1-year of meteorological data in a single model run. This makes it most suited for the full-year comprehensive analysis.

Within the LSA, over 1400 links have to be included for the assessment while the CAL3QHC model allows a maximum of 600 links. Therefore, the CAL3QHCR model, which allows simulating up to 5000 links, was used in these evaluations. The use of the refined model allowed for links to be representative of a very small area (typically 100 m - 300 m), providing a detailed assessment of the local variations in vehicle speed and traffic volumes. For instance, a congested segment of a roadway would be captured by the link resolution used in the model.

Vehicle volumes and average link speeds for each scenario were projected using traffic forecasting simulations. The projected volumes account for the additional or reduced burden on a roadway due to the scenario evaluated. For example, the Remove scenario resulted in an additional traffic burden being placed on surrounding arterial roads.

6.1 Phase 1 Assessment

The meteorological data from the Environment Canada Toronto Island Airport meteorological station was provided by the MOECC for use in the study. Figure 2 shows the wind rose for the period 2008 – 2012 and Figure 4 shows the wind rose during 2012. The two wind roses are very similar, demonstrating that conditions in 2012 were representative of the 5 year period of 2008 to 2012. Therefore, the CAL3QHCR model was run using the 2012 meteorological data. As this is a comparative assessment between alternatives, a single year of representative meteorological data is suitable to evaluate the differences between the proposed scenarios.

Figure 4 is an isopleth plot of maximum concentrations predicted for one alternative. The maximum concentrations occur along the Gardiner Expressway and DVP and dissipate very quickly with distance away from these expressways.

Figure 2: Wind Rose at Toronto Island Airport (2008 – 2012)

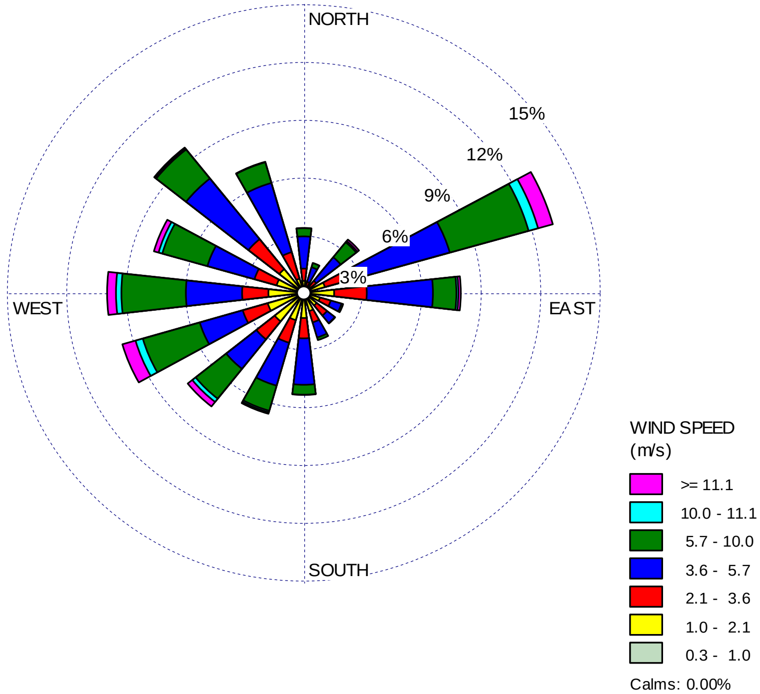


Figure 3: Wind Rose at Toronto Island Airport (2012)

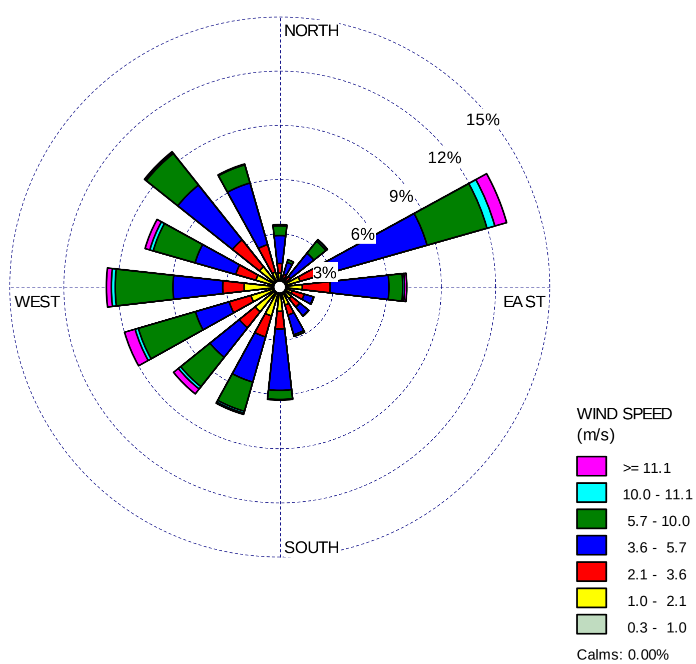
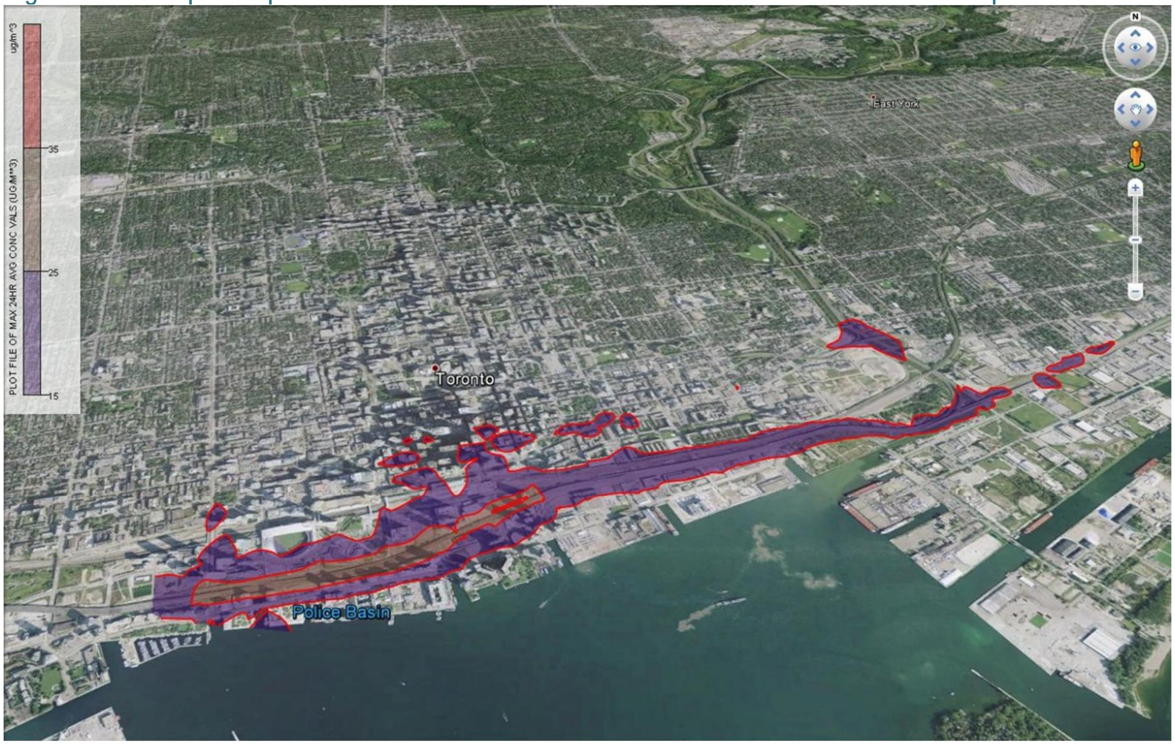


Figure 4: Example Isopleth Plot of Predicted Maximum Concentrations for the Improve Alternative



In order to evaluate the alternatives with regards to local air quality, the distributions of the predicted air quality concentrations (i.e., the maximum predicted concentrations, 90^{th} percentile, 80^{th} percentile) were developed.

Figures 5 and 6 show the predicted concentration distributions for three contaminants using the AM peak traffic data, for 1-hour and 24-hour averaging periods, respectively.

Related to local air quality, the more preferable alternatives are the ones that yield lower concentration distributions. As can be seen in Figure 5 and 6, the Remove and Replace alternatives can be identified as the most preferred while the Maintain alternative is the least preferred, for NO_x and $PM_{2.5}$ concentrations. For VOCs concentrations the Replace alternative is the most preferred.

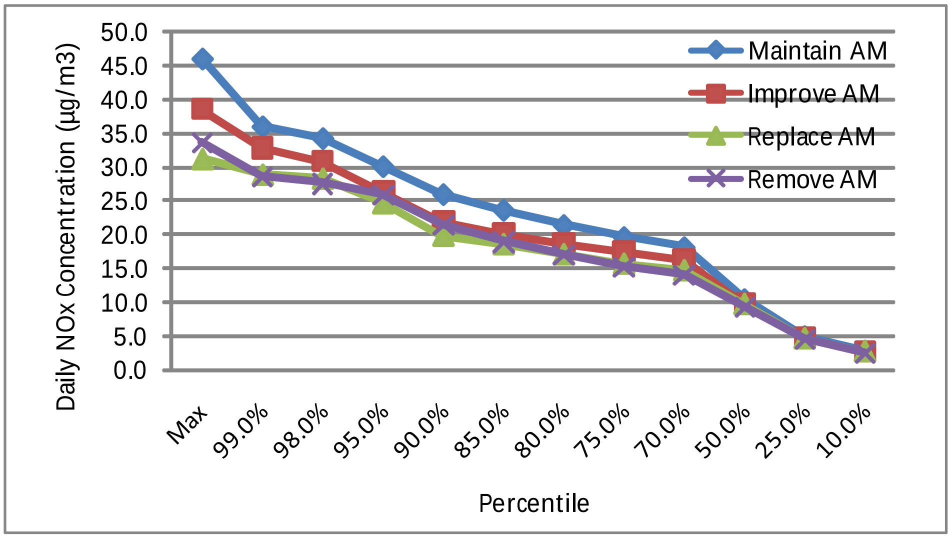
As discussed in Section 4, the primary drivers for characterizing local air quality are Benzene and BaP which can be represented by VOCs and $PM_{2.5}$, respectively. With no significant difference in VOC profiles for the 4 alternatives and more clear differences in profiles for $PM_{2.5}$, the Remove alternative emerges as the most preferred and the Maintain alternative is the least preferred.

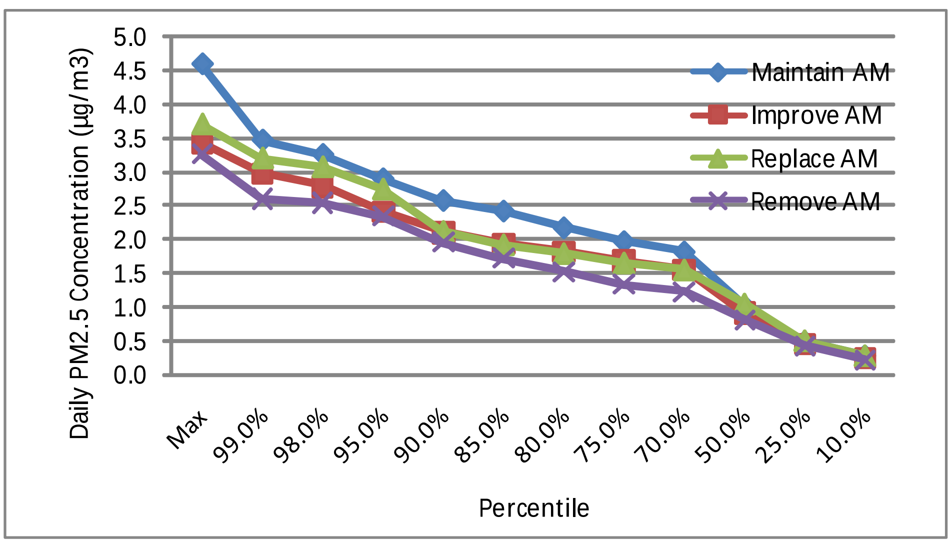
Predicted contaminant concentrations have not been assessed against provincial standards because this is a comparative assessment. The roadway already exists, and does not represent a new source of contaminants. Therefore, the alternatives were evaluated on their net impacts in order to recommend a preferred alternative. Additionally, cumulative concentrations were not included in this assessment as the roadway already exists and the results are focused on selecting an alternative not assessing the impact of the roadway itself on local air quality and/or against provincial air quality criteria.

Table 11: Evaluation Matrix Based on Local Air Quality Assessment for Phase 1 Assessment

Scenario	Evaluation Matrix for Local Air Quality
Maintain	Least Preferred
Improve	Moderately Preferred
Replace	Most Preferred
Remove	Most Preferred

Figure 5: Predicted 24-Hour Percentile Concentrations





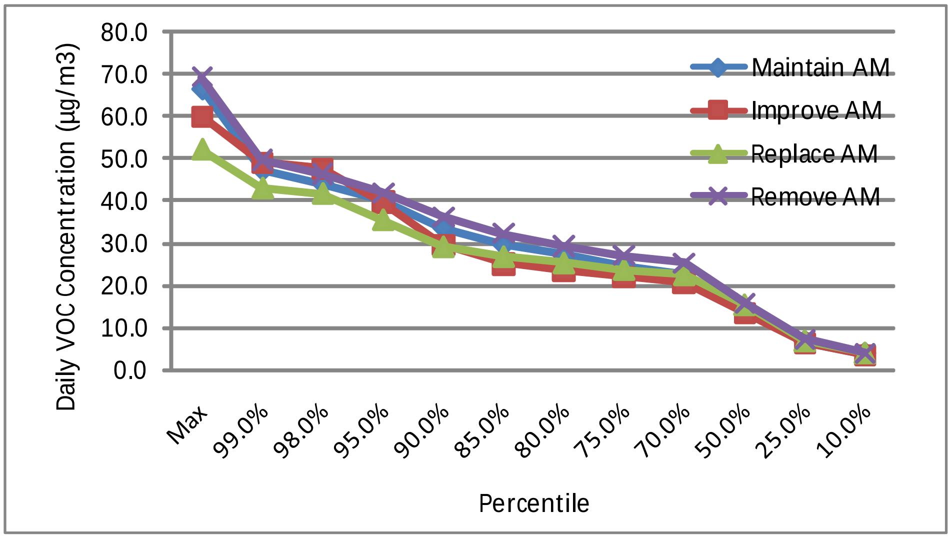
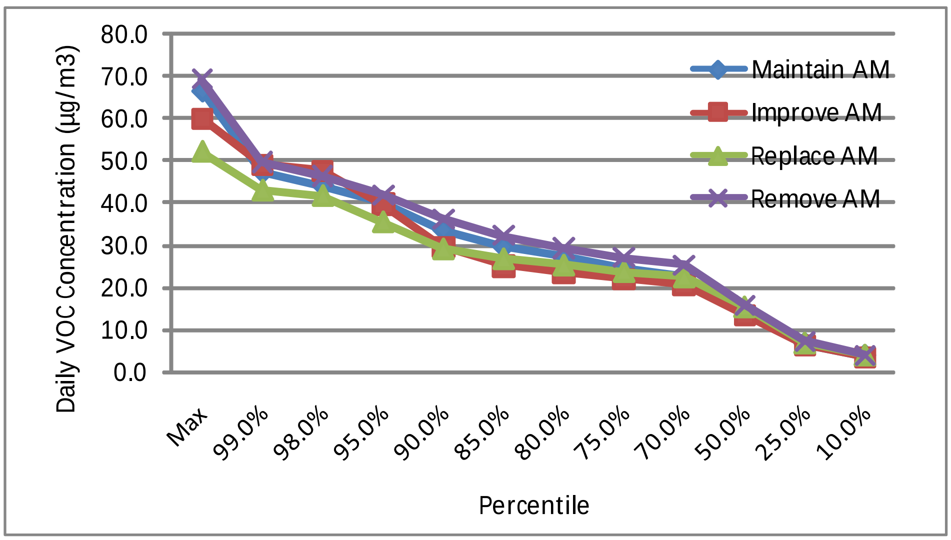
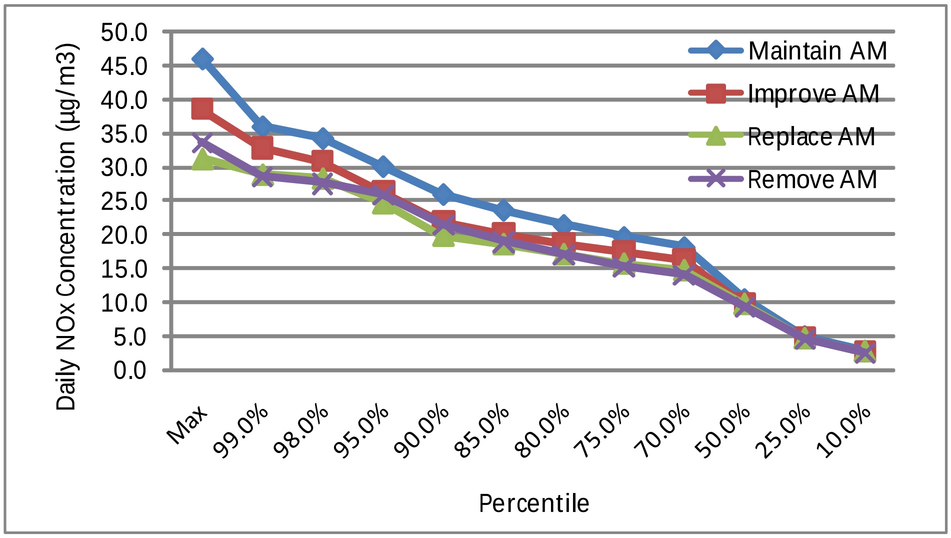
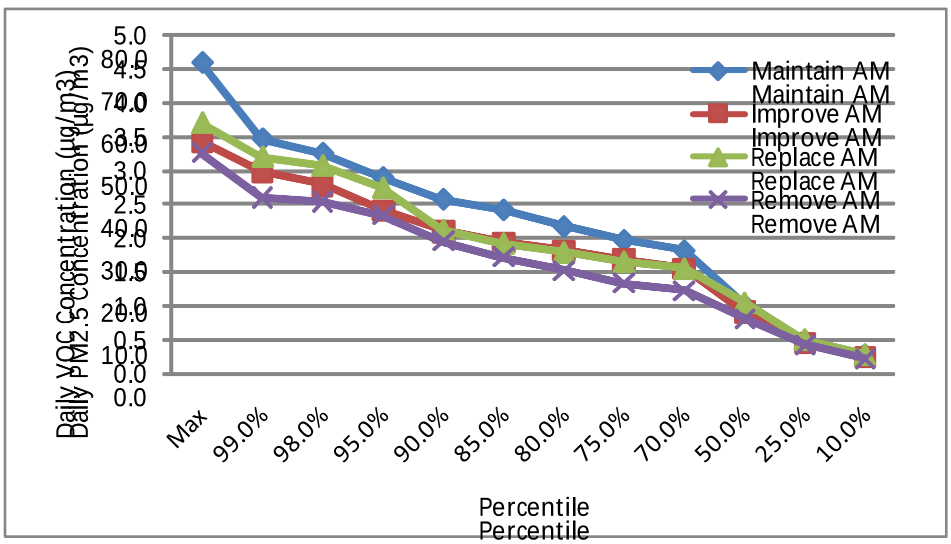


Figure 6: Predicted 24-Hour Percentile Concentrations







6.2 Phase 2 Assessment

The Phase 2 Assessment involves the analysis of the Boulevard option versus the Hybrid option. The Hybrid option represents a combination of the Maintain, Improve and Replace alternatives whereas the Boulevard option is based on the Remove alternative.

From the results of the Phase 1 Assessment, it can be extrapolated that the Boulevard would be preferred over Hybrid within a local air quality assessment, because within the Phase 1 Assessment the Remove option was most preferred.

Boulevard, when compared to Hybrid, represents the lower vehicle kilometers travelled and the lower number of vehicles within the study area.

Based on the above, Boulevard was selected as preferred over Hybrid when considering local air quality.

Table 12: Evaluation Matrix Based on Local Air Quality Assessment for Phase 2 Assessment

Scenario	Evaluation Matrix for Local Air Quality
Boulevard	Hybrid
Hybrid	Boulevard

7.0 GHG EMISSION ASSESSMENT

Transportation sources produce almost one-third of Ontario's total anthropogenic greenhouse gas emissions – over 170 Mt in 2011 and growing by about 1.2% per annum[1]. Approximately three-quarters of this amount is attributable to road transportation. The principal transportation related GHG is carbon dioxide (CO_2). Other important GHGs include methane (CH_4) and nitrous oxide (N_2O). The relative impacts of various GHGs are often expressed in terms of their global warming potential (GWP) relative to CO_2. GWP represents a basis for combining the emissions of individual greenhouse gases by normalizing individual mass emission rates, based on the ability of each greenhouse gas to trap heat in the atmosphere relative to CO_2 over a specified time horizon.

GHG emissions were developed for changing levels of vehicle traffic associated with each of the alternatives, in accordance with the Guide. Based on the Guide, the following steps were taken to determine GHG emission levels:

1) Calculate the CO_2e emission factors (expressed as grams per vehicle miles travelled) for different type of vehicles for each alternative (i.e., boulevard, hybrid) using the MOBILE6.2C model.
2) Quantify the hourly GHG emissions within the regional study area (Dundas St, to Lake Ontario and from Spadina Ave to Woodbine Ave) by multiplying the emission factors by the vehicle miles travelled (VMT) for each alternative.
3) Compare the total hourly GHG emissions among the two scenarios and benchmark them against the total Ontario GHG emissions in 2011 (calculated from the annual GHG emissions value). The results are expressed as the GHG emissions change.

The GHG assessment allows for a comparison of GHG emissions associated with traffic volumes for each of the alternatives. From a broader perspective, there may be GHG benefits (reductions) accrued from instances where transportation system modelling has assumed that vehicles on the road will be replaced with users opting for public transit (modal shift). Such changes will enhance the apparent GHG reduction of alternatives that reduce traffic volumes. Therefore, the analysis presented would be considered conservative.

7.1 Phase 1 Assessment

Table 12 lists the total GHG emissions and changes with respect to the total hourly Ontario emissions in 2011. It should be noted that the estimated hourly GHG emissions, as shown in Table 12, are very conservative due to the conservative assumptions made in this evaluation. However, the conservative assumptions made here should not skew the evaluation as they have been applied equally to all four alternatives.

Based on the emissions presented in Table 12, the Remove alternative is the most preferred alternative and Maintain is the least preferred alternative.

[1] Ministry of Transportation, 2012, Environmental Guide for Assessing and Mitigating the Air Quality Impacts and Greenhouse Gas Emissions of Provincial Transportation Projects.

Table 13: Estimated Total GHG Emissions for Phase 1 Alternatives

Scenario	Estimated Hourly CO_2e Emissions (t/yr.)	Notes
Maintain	57	AM Peak expressed as emissions for peak hour
Improve	55	
Replace	55	
Remove	47	
2011 Ontario	19475	
Scenario	Ranking	Notes
Maintain	1	Lower emission has higher ranking; higher number is better (preferred)
Improve	2	
Replace	3	
Remove	4	
Scenario	Burden	Notes
Maintain	0.29%	Lower number is better (preferred)
Improve	0.28%	
Replace	0.28%	
Remove	0.24%	

Table 14: Evaluation Matrix Based on GHG Emissions for Phase 1 Assessment

Scenario	Evaluation Matrix for GHG Emissions
Maintain	Least Preferred
Improve	Moderately Preferred
Replace	Moderately Preferred
Remove	Most Preferred

7.2 Phase 2 Assessment

Table 14 lists the total GHG emissions and changes with respect to the total hourly Ontario emissions in 2011. It should be noted that the estimated hourly GHG emissions, as shown in Table 14, are very conservative due to the conservative assumptions made in this evaluation. However, the conservative assumptions made here should not skew the evaluation as they have been applied equally to both alternatives.

Based on the emissions presented in Table 14, the Boulevard alternative is preferred.

Table 15: Estimated Total GHG Emissions for Two Subsequent Alternatives

Scenario	Estimated Hourly CO_2e Emissions (t/hr)	Notes
Hybrid	61	AM Peak expressed as emissions for peak hour
Boulevard	54	
2011 Ontario	19475	
Scenario	Ranking	Notes
Hybrid	1	Lower emission has higher ranking; higher number is better (preferred)
Boulevard	2	
Scenario	Burden	Notes
Hybrid	0.31%	Lower number is better (preferred)
Boulevard	0.28%	

Table 16: Evaluation Matrix Based on GHG Emissions for Phase 2 Assessment

Scenario	Evaluation Matrix for GHG Emissions
Hybrid	Less Preferred
Boulevard	More Preferred

8.0 CONCLUSIONS

The alternative solutions evaluation has been performed using a regional air quality burden analysis, a local air quality assessment and GHG emissions according to the Guide. The MOBILE6.2C model was used to determine site-specific mobile vehicle emission factors. Re-entrained particulate emissions were quantified according to US EPA AP-42, Section 13.2.1, 2011. The US EPA's CAL3QHCR model was used to predict the maximum concentrations of NOx, PM2.5 and VOCs (as a surrogate for air toxics) at all receptors.

For the Phase 1 assessment, based on the regional air quality burden analysis, local air quality impact assessment and GHG emissions evaluation matrix, the results consistently indicate that the Remove alternative is the most preferred. Depending on the evaluation approach used, the other three alternatives have different ranks. However, it is reasonable to conclude that Maintain is the least preferred, Improve and Replace are moderately preferred, as summarized below:

Study Lens/ Criteria Group	Criteria	Measures	MAINTAIN	IMPROVE	REPLACE	REMOVE
Social, Health, Recreation and Businesses	Health (Air Quality)& Climate Change	· Extent of change in regional air quality	Least Preferred	Moderately Preferred	Moderately Preferred	Most Preferred
		· Extent of change in local air quality	Least Preferred	Moderately Preferred	Moderately Preferred	Most Preferred
		· Level of GHG Emissions	Least Preferred	Moderately Preferred	Moderately Preferred	Most Preferred

This primarily reflects the Remove alternative's reduction in vehicle miles travelled in comparison to the Maintain alternative.

For the Phase 2 Assessment, based on the regional air quality burden analysis, local air quality impact assessment and GHG emissions evaluation matrix, the results indicate that the Boulevard alternative is preferred.

Study Lens/ Criteria Group	Criteria	Measures	BOULEVARD	HYBRID
Social, Health, Recreation and Businesses	Health (Air Quality) & Climate Change	· Extent of change in regional air quality	Moderately Preferred	Moderately Preferred
		· Extent of change in local air quality	More Preferred	Less Preferred
		· Level of GHG Emissions	More Preferred	Less Preferred

Limitations within this evaluation process that should be noted include:

- All links have been treated as free flow links with average traveling speeds. No queue links and signalization have been considered due to the complexity of such modelling and the timeline available to conduct the assessment.
- MOBILE6.2C produces fleet averaged emission rates typically in grams per vehicle-mile even though the vehicles travelling on the roadways are at different average speeds, e.g., predicts almost constant emission factors for both $PM_{2.5}$ and CO_2e. The model does not have the capability to produce emission factors varying by vehicular modal activities such as acceleration, deceleration, idle and cruise, at higher temporal resolution, particularly under congested conditions.
- CAL3QHCR only allows the release height to be 10 m or less while the Replace alternative would elevate the Gardiner by another 5 m which could not be accounted for.
- All the emissions quantified and maximum concentrations predicted are very conservative.

Respectfully Submitted

DILLON CONSULTING LIMITED