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SNC·LAVALIN

Hamilton Rapid Transit Preliminary Design and Feasibility Study

A-LINE

ACOUSTIC & AIR QUALITY IMPACT REVIEW

Version:2.0

METROLINX
An agency of the Government of Ontario

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Hamilton
Public Works

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DIALOG

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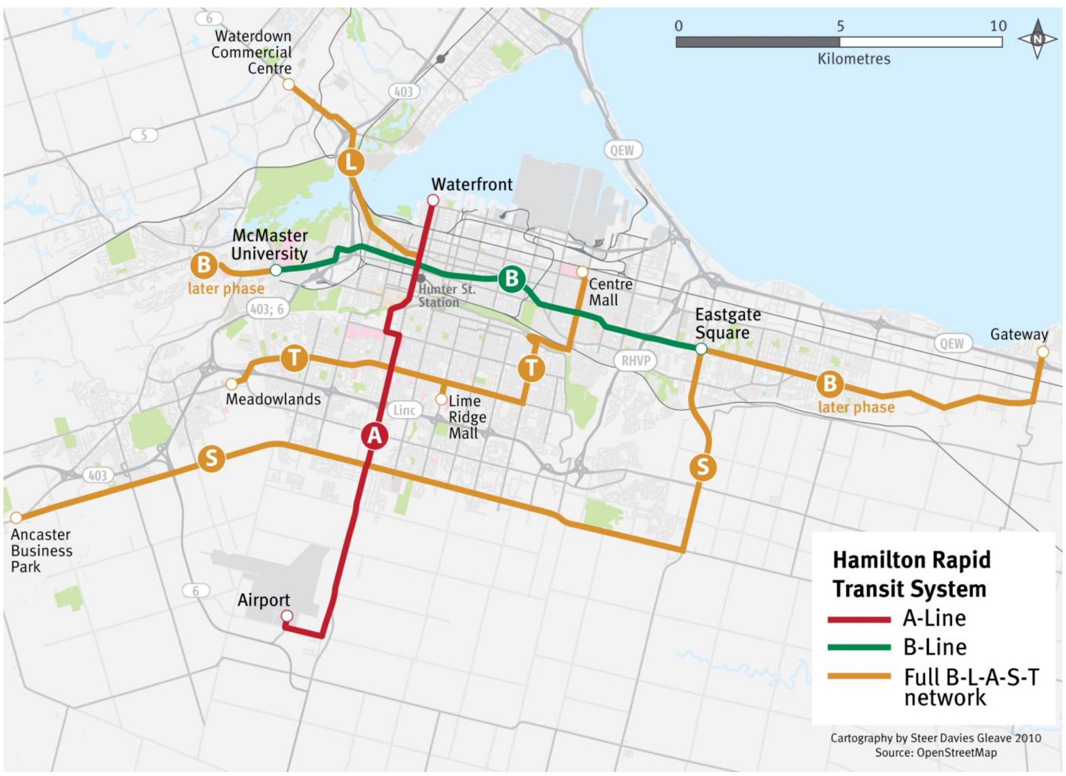
PREAMBLE

The City of Hamilton has a plan to implement a Rapid Transit network (referred to as B-L-A-S-T) which, in the long term, will encompass five corridors. The City is currently focused on Light Rail Transit (LRT) for its primary east-west corridor, along King Street and Main Street, between Eastgate Square and McMaster University (the B-Line). It is also in the process of defining a potential corridor and mode of Rapid Transit for the City's primary north-south corridor, along James Street and Upper James Street, between the Waterfront and the Hamilton International Airport (the A-Line), as shown in Figure 1.

Figure 1: General Location of the A-Line and B-Line within the B-L-A-S-T Network



This report presents a review of the Acoustic (noise and vibration) and Air Quality components conducted as part of the supplementary investigations for the Hamilton Rapid Transit Preliminary Design and Feasibility Study, as they pertain to the A-Line.

J. E. Coulter Associates Limited was retained to conduct the Acoustic review. RWDI AIR Inc. was retained to conduct the Air Quality review.

The purpose of the Acoustic and Air Quality reviews is, in part, to inform the decision-making process within the Rapid Transit Technology Opportunities study being conducted for the A-Line. The reviews have also identified sensitivities in the A-Line corridor and parameters for their respective assessments that will require additional/special attention during the Environmental Assessment of the A-Line RT project.

PRELIMINARY NOISE AND VIBRATION REVIEW
PROPOSED A-LINE TRANSIT SYSTEM
CITY OF HAMILTON

FOR

SNC-LAVALIN INC.

PREPARED BY

____
SAM N. KULENDRAN, B.A.Sc.

CHECKED BY

____
JOHN E. COULTER, B.A.Sc., P. ENG.

J. E. COULTER ASSOCIATES LIMITED
1210 SHEPPARD AVENUE EAST, SUITE 211
TORONTO, ONTARIO
M2K 1E3

FEBRUARY 27, 2012

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1.0 INTRODUCTION

J. E. Coulter Associates Limited was retained by SNC-Lavalin Inc. to conduct a preliminary noise and vibration review of the proposed City of Hamilton A-Line Rapid Transit (RT) route. The purpose of this assessment is to contrast the potential effects of either a Bus Rapid Transit (BRT) system or a Light Rail Transit (LRT) system along their respective corridors. This review precedes the Transit Project Assessment Process (or Environmental Assessment).

1.1 Project Description

The north terminus of the A-Line is at the Waterfront on the northeast corner of Guise Street East and James Street North. The south terminus of the A-Line rapid transit system is at the Hamilton International Airport. The specifics of the route are different for the BRT and LRT options but much of the two routes are identical, especially south of the Mountain.

The BRT route is as follows:

- Runs south along James Street North and James Street South until the Hunter Street GO Centre.
- At the Hunter Street GO Centre, the Southbound buses travel east through the Centre, south along John Street, and then rejoin John Street South via Charlton Avenue. The Northbound buses travel straight through on James Street South.
- Runs in a dedicated BRT right-of-way on James Mountain Road from Aberdeen Avenue to West Fifth Avenue on the Mountain.
- The route continues south on West 5th Street until Fennell Avenue West where it turns east to meet Upper James Street.
- It follows Upper James Street then continues along Homestead Drive where it turns west onto Airport Road and terminates at the Hamilton International Airport.

The LRT Route is as follows:

- Runs south along James Street North to King Street
- The A-Line then shares the B-Line tracks on King Street East, as far as Wellington Street and Victoria Avenue. The route along King Street East includes the section between Catharine Street and Walnut Street which is closed to all other road traffic, with the remainder of this section being used by local traffic only.
- The Southbound LRT route runs along Wellington Street from King Street East to the Claremont Access, while the Northbound LRT route runs along Victoria Avenue from King Street East to the Claremont Access.
- Runs along the Claremont Access to West 5th Street on the Mountain. The route continues south on West 5th Street until Fennell Avenue West where it turns east to meet Upper James Street.
- It follows Upper James Street then continues along Homestead Drive where it turns west onto Airport Road and terminates at the Hamilton International Airport.

Please see Appendix A for the preliminary LRT and BRT route plans.

1.2 Study Area

For potential noise and vibration impacts, the primary study area encompasses the sensitive receptors immediately adjacent to the proposed LRT/BRT routes, usually within 100m to either side of the proposed alignment. This area is reviewed for both potential noise and vibration impacts.

In the EA, the effects of displaced traffic along parallel routes will also need to be reviewed, though it is unlikely that such a shift in traffic will generate significant increases in noise.

2.0 PRELIMINARY NOISE AND VIBRATION REVIEW CRITERIA

The preliminary noise and vibration review criteria used to evaluate implications of the proposed LRT route are based on a set of draft protocols developed through the combined efforts of the Ministry of the Environment (MOE) and the Toronto Transit Commission (TTC). These protocols are used in the absence of any existing province-wide protocols for transit projects, specifically relating to light rail transit. The protocol that most directly relates to this project is the MOEE/TTC Draft Protocol for Noise and Vibration Assessment for the Proposed Waterfront West Light Rail Transit Line (November 11, 1993). This protocol is similar to many of the other protocols developed by the TTC and the MOE for other rapid transit projects within Ontario. The vibration limit of 0.1mm/s rms from the MOEE/TTC Draft Protocol for Noise and Vibration Assessment for the Proposed Scarborough Rapid Transit Extension is used, however, in lieu of the 0.14mm/s rms limit from the Waterfront LRT guidelines and ISO recommendations, as requested by the MOE.

The above protocols, created in the early 1990s, have several outdated references. The protocols and other guidelines that are not easily accessible are provided in Appendix B. A more current list of references is provided in Appendix C. Additional definitions are provided in Appendix D.

The noise and vibration criteria, as outlined in the above mentioned document, are summarized below. These criteria are those also used in the B-Line LRT Environmental Assessment.

2.1 Definition of Sensitive Receptors

As per the MOEE/TTC protocol, sensitive receptors are identified as those existing or municipally-approved residential developments, nursing homes, group homes, hospitals, and other such institutional land uses where people reside. Within the project area, the primary sensitive receptors are residential developments. Though there are some institutional uses located along the corridor, the primacy of residential development in those same locations implies that any evaluation at the residential receptors will be representative of other sensitive receptors. For this reason, as the residential receptors are expected to be most representative of the effects of the proposed BRT and LRT systems, the impacts at residential receptors will be used as a proxy for other sensitive receptors (land uses) in the same area. Henceforth, any references to receptors or receivers will be in regard to residential development, unless otherwise noted.

For the assessment, the protocols dictate that sound and vibration levels need to be calculated at the point of reception or point of assessment. The point of reception or point of assessment is described in the protocols as being a sensitive receptor located no less than 15m from the centreline of the nearest track. There are many points along the route where the point of assessment at a house or apartment, for example, would be closer than 15m from the nearest track centreline. As a result, the point of assessment for receptors along the corridor is taken to be the closest sensitive receptor, regardless of whether or not it is 15m or more from the nearest track centreline. The calculations are adjusted accordingly for actual setbacks.

2.2 Noise Impact Criteria

There are two primary components to the noise impact assessment criteria.

- The first and most common component in transit projects is the noise impact as a result of changes to the roadway sound levels at the receptors. Essentially, this is a comparison of sound levels with and without the project's implementation. For this analysis, sound levels without the BRT or LRT are compared to the sound levels with the BRT or LRT. The horizon year used to project the traffic volumes on the affected streets is 2021 to allow for the project and its surrounding roadways to reach a mature level of use.[1] The comparison is based on a daytime (0700-2300 hours) and nighttime (2300-0700 hours) equivalent sound level comparison, which is appropriate for non-highway projects. Where the sound levels with the project exceed the sound levels without the project by at least 5dB, noise control needs to be considered where it would be technologically, economically and administratively feasible.
- The second set of noise criteria applies to ancillary facilities and is beyond the scope of this review as discussed in Section 2.4, below.

Sound levels are calculated at the closest point of reception, which can be the closest façade or outdoor living area during the daytime and the closest façade during the nighttime. Nighttime sound levels are evaluated based on a second floor or higher (apartments) receptor.

2.3 LRT Vibration Impact Criteria

The vibration impact criteria attempt to address two potential impacts from vibration generated by the LRT.

- First, the criteria consider perceptible (ground-borne) vibration levels. This addresses vibration that can be felt by residents in a building.
- Secondly, the criteria document also mentions the sound from vibration (vibration-induced sound) but does not set a limit.

The limit for perceptible vibration levels has been set to 0.1mm/s rms (root-mean-square) velocity. If absolute vibration levels are expected to exceed this limit, mitigation methods need to be determined during the detailed design phase to meet it to the extent technologically, economically and administratively feasible.

There are no specific criteria in Ontario that set limits for the sound resulting from vibration (vibration-induced sound). The relatively lower limit of 0.1mm/s instead of 0.14mm/s (suitable for hospital vibration levels) attempts to reduce this issue. The possibility for a noise impact as a result of vibration still exists. It is dependent on the frequency spectrum of the vibration as well as the levels. Based on the United States Federal Transit Administration guidelines (2006), a guideline level of 35dBA is used in this report for residential rooms and other rooms (e.g., hospitals) where people generally sleep, for cases where the ground-borne, vibration-generated noise dominates the impression of the passby.

The vibration-induced noise criterion level of 35dBA should be taken into context along with the air-borne noise. New LRT vehicles typically exhibit maximum sound levels ranging from 78-80dBA at 7.5m while traveling at 40km/h, similar to a pair of medium-sized trucks. For rooms with exposure to the LRT and other traffic, outdoor sound levels in this range would indicate indoor sound levels of 48-50dBA, assuming a general 30dB noise reduction from closed windows. In this case, the contribution from vibration-induced noise would be negligible and often indistinguishable from the air-borne noise coming through the closed window. Thus, the criterion level for vibration induced noise is mainly applicable to those rooms with little or no window exposure to the LRT. Examples of these would be flanking

[1] 2021 is the horizon year for which traffic projections were available.

apartments/houses with little or no window exposure, inset bedrooms separated from the LRT exposure by another room, or in basement apartments with small windows.

Vibration levels are evaluated at the nearest point of a residential or sensitive-use building. The review of vibration-induced noise potential involves identifying the locations where the rail system passes close to buildings, or where there is special track work prone to creating vibration (switches). Next is the identification of the uses in the buildings and the proximity of sensitive rooms to the source of vibration. Then, the vibration levels must be estimated and, where impacts are anticipated, a level of vibration control specified.

The vibration review applies primarily to the LRT option. The BRT system, provided proper standard maintenance practices are implemented, should not generate noticeable vibration levels in most types of sensitive receptors.

2.4 Scope of Review

The preliminary noise and vibration review only assess the effects arising from the introduction of light rail vehicles (LRVs) along the LRT route and additional buses along the BRT route. The traffic volumes used in the assessment consider the reduction in traffic caused by removing lanes of traffic along the route wherever such an action is required. At this very early stage, stationary sources cannot be assessed. The vibration review is based on the B-Line Noise and Vibration Impact Assessment, dated October 4, 2011, and prepared by this office.

The subsequent Environmental Assessment will review the potential effects of stationary sources (bus terminals or transit hubs, power substations, the maintenance and storage facility) and construction.

3.0 NOISE IMPACT ASSESSMENT

3.1 Identification of Sensitive Receptors

The A-Line routes run through a variety of land uses. The most common sensitive receptors along the route are residences. There are also schools, places of worship, and medical facilities scattered throughout the corridor. Some areas with primarily commercial development at grade also incorporate second storey residential apartments. Based on a preliminary review of the corridor, several representative Points of Reception (PORs) have been identified.

Based on the LRT/BRT alignment, traffic volumes, and receptor characteristics, 13 representative Points of Reception have been identified. These receptors have been chosen because they are the most sensitive to the noise from the LRT and/or BRT routes. Generally, receptors at intersections and adjacent to high-traffic roads are less sensitive, as the existing sound levels are higher than areas with lower road traffic. Hence, the greatest impact, if any, will be in areas with lower existing (or future "no project") sound levels. The specifics of each of these receptors are summarized in Table 1, below. Each of these receptors will help provide a representative indication of the change in sound levels resulting from the introduction of the rapid transit system.

Figures 2 through 7 in Appendix A show the locations of the PORs.

Table 1: Points of Reception

POR	Type	Dominant Noise Source
1	Low rise	James Street North
2	2nd floor residential	James Street North
3	2nd floor residential	James Street North
4a	2nd floor residential	King Street East
4b	Low rise	James Street South
5a	Low rise	Claremont Access
5b	Low rise	James Mountain Road
6	Hospital (non-residential	West 5th Street
7	Low rise	Fennell Avenue West
8	Low rise	Upper James Street
9	Low rise	Upper James Street
10	Low rise	Upper James Street
11	Low rise	Airport Road

Note: Points 4a and 5a apply to LRT only and points 4b and 5b apply to BRT only.

In areas dominated by hard, reflective ground, receptors on the lower floors will generally be at least as sensitive to increases in adjacent road traffic as receptors on the upper floors. As the elevation of the receptor increases, the contribution to the overall noise from other roadways also increases. Primarily first- and second-storey levels are evaluated as an indication of the worst-case situation. For this preliminary review, it is assumed that the topography between the receptors and the noise sources is comprised of hard, reflective ground.

3.2 Light Rail Vehicles and Bus Rapid Transit

The noise impact assessment compares the sound levels along the route under two different conditions for the design year of 2021. The sound levels without the project are higher than the current sound levels due to traffic growth within the corridor. The sound levels with the project will be comprised of existing car and truck traffic and the addition of the LRT or the BRT, as well as some other non-BRT bus traffic.

Given the sound levels expected for the light rail vehicle and for buses and given the traffic volumes (with and without the project), the noise impact of the LRT and BRT routes can be determined.

Sound levels are calculated using the Ministry of the Environment's *ORNAMENT* prediction procedure. The computer program used for this analysis is the MOE's *STAMSON 5.04* computer program, which incorporates both *ORNAMENT* (road) and STEAM (rail) prediction methods. Although on rail, the LRVs are treated in the analysis as roadway sources and are evaluated based on the *ORNAMENT* procedure using a modified profile similar to but greater than medium trucks.

For this preliminary review, sound levels were not measured along the proposed route corridors. Measuring the actual sound levels for short periods should probably be conducted during the EA to ensure the validity of modelled sound levels, especially in areas where the roadway/transit route inclines sharply (i.e., in the area of the Mountain).

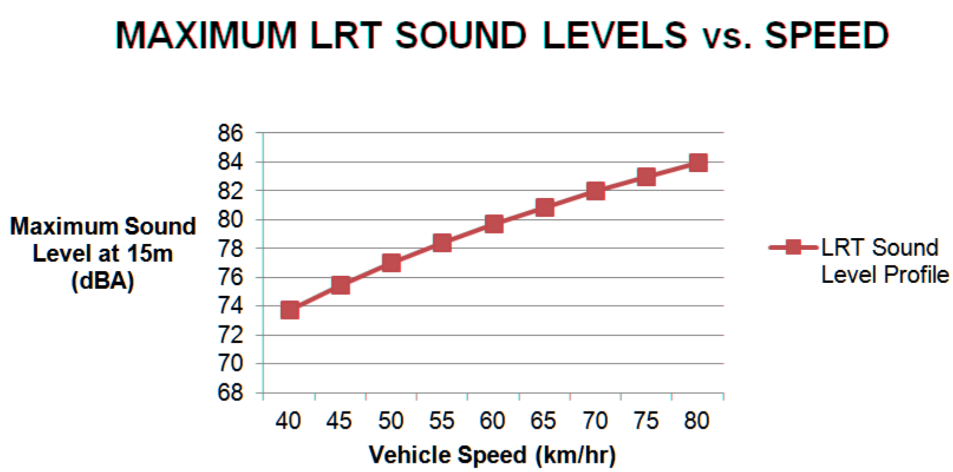
3.2.1 Light Rail Vehicle Noise Characteristics

Modern light rail vehicles come in a few different forms. They are often divided into modules, such as a passenger module or a motor module (also referred to as a passenger bogie or motor bogie). Commonly, a new LRV vehicle will have two motor bogies and maybe a passenger bogie in the middle, resulting in a vehicle length of 30-40m. These are also different from older streetcars in that they have wheel covers and are more modern in design, resulting in modestly lower sound levels. Newer, light rail wheels also have constrained damping, which, coupled with larger turning radii, greatly reduces wheel squeal noise on corners.

As the LRVs have not been selected as yet, specific noise data are unavailable. The noise impact assessments completed for some of the Toronto Transit Commission's Transit City LRT routes indicate sound levels of approximately 82dB at a distance of 7.5m for a comparable vehicle travelling at 40km/h on concrete. These are specifications only and not actual sound levels. Recently measured data from the Jerusalem LRT indicate maximum sound levels of 75dBA at 7.5m for a 35m long two-motor bogie vehicle travelling at 40km/h. For the purposes of this assessment, the focus is on the sound level of an LRV in operation. Based on the above sound level data and based on the B-Line assessment, it would be appropriate to use an approximate sound level of 74dBA maximum at 15m to represent the proposed light rail vehicles travelling at 40km/hr. Within the *ORNAMENT* procedure, the profile would follow the following equation:

$$L_{max} = 33.9\log(S) + 19.4$$

Where L_{max} is the peak sound level in decibels and S represents the speed of the vehicle in kilometres per hour. The above equation results in the following sound level vs. speed profile.



If LRT is chosen for the A-Line, manufacturer's sound level data for the B-Line's light rail vehicles should be available by the time this project reaches the Environmental Assessment stage. A more detailed noise and vibration impact assessment can then be carried out using either the above approximations or the actual sound level data.

As per standard practice, buses are classified as medium trucks and have been modelled that way in this preliminary review.

3.2.2 Traffic Volumes

Traffic volumes with and without the project have been supplied by Steer Davies Gleave (SDG) for the major sections in the corridor. These future volumes have been determined through use of the EMME model, which covers the City of Hamilton, and existing available traffic volume data. It should be noted that EMME is a regional model which has been used to predict local traffic flows in the future in the AM peak hour. These AM peak hour traffic flow predictions have then been adjusted upward to reflect the growth in flow on links for the future time required for noise assessment purposes. This approach is appropriate for the current stage of development of the A-Line. More detailed traffic modelling, however, will be required as part of the next stage of project development to arrive at flow predictions that are suitable for a detailed noise assessment for the A-Line Environmental Project Report.

Table 2 outlines the 2021 “without project” traffic volumes along the project corridor. Table 3 outlines the 2021 “with project” traffic volumes along the project corridor, assuming LRT is selected, and Table 4 outlines the 2021 “with project” traffic volumes along the project corridor, assuming BRT is selected.

Table 2: Future (2021) Without Project Traffic Volumes

POR	Main Roadway	Between Roadways	Daytime (0700-2300)				Nighttime (2300-0700)			
			Cars	Heavy Trucks	Medium Trucks and Buses	LRT	Cars	Heavy Trucks	Medium Trucks and Buses	LRT
1	James Street North	Strachan and Burlington	7,143	71	169	-	794	8	19	-
2	James Street North	Cannon and Barton	8,140	71	203	-	904	9	23	-
3	James Street North	Rebecca and King William	12,046	120	364	-	1,338	13	40	-
4a	King Street	Walnut and Ferguson[1]	0	0	0	377	0	0	0	72
4b	James Street South	Charlton and Herkimer	18,130	91	651	-	2,014	10	72	-
5a	Claremont Access	Upper James and Sherman	52,748	2,884	2,884	-	5,861	320	320	-
5b	James Mountain Road	Aberdeen and West 5th	18,069	201	687	-	2,008	22	76	-
6	West 5th Street	Brantdale and Fennell	15,831	6	493	-	1,759	1	55	-
7	Fennell Avenue West	West 5th and West 2nd	20,759	225	517	-	2,307	25	57	-
8	Upper James Street	Fennell and South Bend	28,911	1,941	2,258	-	3,212	216	251	-
9	Upper James Street	Stone Church and Rymal	14,261	402	767	-	1,585	85	45	-
10	Upper James Street	20 Rd and Dickenson	10,477	365	681	-	1,164	41	76	-
11	Airport	Airport Access and Homestead	231	0	97	-	26	0	11	-

Notes: 1. The without project traffic volumes used here are based on the fact that the A-Line is not built but that the B-Line LRT is operational.

Table 3: Future (2021) With Project (LRT) Traffic Volumes

POR	Main Roadway	Between Roadways	Daytime (0700-2300 Hours)				Nighttime (2300-0700 Hours)			
			Cars	Heavy Trucks	Medium Trucks and Buses	LRT	Cars	Heavy Trucks	Medium Trucks and Buses	LRT
1	James Street North	Strachan and Burlington	6,656	67	164	332	740	7	18	72
2	James Street North	Cannon and Barton	6,441	64	186	332	716	7	21	72
3	James Street North	Rebecca and King William	11,353	114	357	332	1,261	13	40	72
4a	King Street	Walnut and Ferguson	0	0	0	709	0	0	0	144
5a	Claremont Access	Upper James and Sherman	41,298	1,028	1,028	332	4,589	114	114	72
6	West 5th Street	Brantdale and Fennell	9,369	49	243	332	1,041	5	27	72
7	Fennell Avenue West	West 5th and West 2nd	12,823	152	347	332	1,536	17	39	72
8	Upper James Street	Fennell and South Bend	18,094	1,813	1,910	332	2,010	201	212	72
9	Upper James Street	Stone Church and Rymal	8,493	335	481	332	944	37	53	72
10	Upper James Street	20 Rd and Dickenson	16,755	468	566	332	1,862	52	63	72
11	Airport	Airport Access and Homestead	231	0	0	128	26	0	0	36

Table 4: Future (2021) With Project (BRT) Traffic Volumes

POR	Main Roadway	Between Roadways	Daytime (0700-2300)				Nighttime (2300-0700)			
			Cars	Heavy Trucks	Medium Trucks and Buses	BRT	Cars	Heavy Trucks	Medium Trucks and Buses	BRT
1	James Street North	Strachan and Burlington	4,890	49	146	453	543	5	16	108
2	James Street North	Cannon and Barton	5,228	52	174	453	581	6	19	108
3	James Street North	Rebecca and King William	11,167	112	355	453	1,241	12	39	108
4b	James Street South	Charlton and Herkimer	11,158	61	487	453	1,240	7	54	108
5b	James Mountain Road	Aberdeen and West 5th	0	0	0	453	0	0	0	108
6	West 5th Street	Brantdale and Fennell	2,300	6	6	453	256	1	1	108
7	Fennell Avenue West	West 5th and West 2nd	15,344	134	377	453	1,705	15	42	108
8	Upper James Street	Fennell and South Bend	17,279	633	730	453	1,920	70	81	108
9	Upper James Street	Stone Church and Rymal	8,140	140	286	453	904	16	32	108
10	Upper James Street	20 Rd and Dickenson	16,707	359	456	453	1,856	40	51	108
11	Airport	Airport Access and Homestead	231	0	0	151	26	0	0	36

The following assumptions were used in modelling the traffic data:

- With the exception of the LRT/BRT volumes, daily traffic has been divided into daytime and nighttime volumes, using a typical 90% daytime/10% nighttime split.
- A conversion factor of 13.52 has been used to convert non-LRT/BRT AM Peak Hour volumes into Average Annual Daily Traffic volumes.
- Nighttime LRT operations are expected to stop between 0130 and 0500 hours for maintenance.
- LRT/BRT volumes south of the Mountain Transit Centre are substantially lower.
- The speed limit for regular traffic is assumed to be 60km/h on Upper James Street and the Claremont Access and 50km/h everywhere else.
- The operating speed of the LRT/BRT will be the same as regular traffic.
- Due to the nature of sound, changes in traffic volumes of +25%/-20% would change the overall sound levels by 1dB only.

3.2.3 Assessment Analysis and Results

Table 5 summarizes the “Without Project” and “With Project” sound levels, as well as the expected daytime and nighttime impacts for the LRT option. Table 6 summarizes the “Without Project” and “With Project” sound levels, as well as the expected daytime and nighttime impacts for the BRT option.

Table 5: Expected LRT Sound Levels and Expected Impacts

POR	Without Project Sound Levels (dB)		With Project Sound Levels (dB)						Impact (dB)	
	Daytime (16hr L_{eq})	Nightime (8hr L_{eq})	Daytime (16hr Leq)			Nighttime (8hr Leq)			Daytime	Nighttime
			Traffic	LRT	TOTAL[1]	Traffic	LRT	TOTAL[1]		
1	63	56	62	61	65	56	57	60	2	4
2	64	58	64	62	66	58	58	61	2	3
3	66	59	66	62	67	60	58	62	1	3
4a	63	59	0	66	66	0	62	62	3	3
5a	70	64	67	56	67	60	53	61	-3	-3
6	60	53	58	59	62	51	55	56	2	3
7	68	61	66	62	67	60	58	62	-1	1
8	73	67	73	61	73	67	57	67	0	0
9	65	59	64	58	65	57	55	59	0	0
10	64	58	65	61	66	59	57	61	2	3
11	52	46	44	56	56	38	53	53	1	3

Notes: 1. The “With Project Sound Levels” have been divided into Traffic Only and LRT Only sound levels to show the relative significance of each. They are then added together to obtain the TOTAL sound level, which is used to determine the potential impact.

2. Estimated setbacks have been used in the above assessment. The actual distance between the centreline of the LRT route and the PORs will affect the noise impacts summarized above.

Table 6: Expected BRT Sound Levels and Expected Impacts

POR	No Project Sound Levels (dB)		With Project Sound Levels (dB)						Impact (dB)	
	Daytime (16hr L_{eq})	Nightime (8hr L_{eq})	Daytime (16hr Leq)			Nighttime (8hr Leq)			Daytime	Nighttime
			Traffic Only	BRT Only	TOTAL[1]	Traffic Only	BRT Only	TOTAL[1]		
1	63	56	61	59	63	55	56	59	0	3
2	64	58	63	60	65	57	57	60	1	2
3	66	59	66	60	67	59	57	61	1	2
4b	65	59	64	58	65	57	55	58	0	0
5b	69	62	0	61	61	0	58	58	-8	-4
6	60	53	50	57	58	44	54	55	-2	1
7	68	61	66	60	67	60	57	62	-1	1
8	73	67	70	59	70	63	56	64	-3	-3
9	65	59	62	57	63	55	53	57	-2	-2
10	64	58	65	59	66	58	56	60	2	2
11	52	46	44	54	54	38	50	50	-1	0

Notes: 1. The “With Project Sound Levels” have been divided into Traffic Only and BRT Only sound levels to show the relative significance of each. They are then added together to obtain the TOTAL sound level, which is used to determine the potential impact.

2. Estimated setbacks have been used in the above assessment. The actual distance between the centreline of the BRT route and the PORs will affect the noise impacts summarized above.

The impacts of the LRT and BRT routes are summarized in Table 7, below.

Table 7: Summary of LRT and BRT Noise Impacts

POR	LRT Impact (dB)		BRT Impact (dB)	
	Daytime	Nighttime	Daytime	Nighttime
1	2	4	0	3
2	2	3	1	2
3	1	3	1	2
4a	-3	0	N/A	N/A
4b	N/A	N/A	0	0
5a	-3	-3	N/A	N/A
5b	N/A	N/A	-8	-4
6	2	3	-2	1
7	-1	1	-1	1
8	0	0	-3	-3
9	0	0	-2	-2
10	2	3	2	2
11	1	3	-1	0

In no case does the introduction of the project (either LRT or BRT) generate a noise impact in excess of 5dB along either of the primary routes. There are, however, areas where the increase in sound level will be noticeable, especially during the nighttime periods. For example, POR1 experiences a 2dB and 4dB increase in daytime and nighttime sound levels, respectively, under the LRT option whereas it experiences a 0dB and 3dB increase in daytime and nighttime sound levels, respectively, under the BRT option. A 3dB or greater change in sound levels would be noticeable to residents living along the corridor.

Careful attention should be paid to the final alignment of the LRT through some of the quieter areas, like POR1 and POR11. An offset of the noisier vehicular traffic could result in a 5dB impact.

Comparing the 2 options, the BRT clearly generates lower noise impacts. This is mostly explained by the fact that a light rail vehicle is slightly noisier than a typical bus. A single LRV, as modeled, generates about 3dB more noise than a single bus. The daytime volumes of BRT vs. LRT are 453 vs. 332, which represent a 1.3dB difference. Thus, the LRT-only sound levels are 2dB greater than the BRT-only sound levels during the daytime, as is demonstrated in Tables 5 and 6, above. There also seems to be a greater traffic re-assignment for the BRT option. That is, there is a larger reduction in the amount of vehicular traffic on the respective routes when comparing the 2021 BRT option to the 2021 LRT option traffic volumes. This is to be expected as the BRT option closes James Mountain Road to other vehicles whereas the LRT option removes 2-lanes from the Claremont Access.

There are light rail vehicles in the market that produce sound levels lower than the hypothetical LRV used in this noise assessment. A quieter LRV would then “blur” the small sound level differences between the LRT option and BRT option.

Sample calculations are provided in Appendix E.

3.2.4 Wheel Squeal Issues

If the LRT option is selected, careful attention will need to be paid to the possibility of wheel squeal. There are a number of relatively small radius turns proposed along the route. The larger the turning radius, the lower the likelihood and the maximum sound level of wheel squeal. The B-Line LRT did not have such 90 degree turns and hence wheel squeal was not found to be a concern along that route. Particular attention should be paid to the turning radii at the relatively quiet north and south terminus areas of the LRT route.

3.3 Noise Impact on Future Development

The Urban Hamilton Official Plan and Transit Oriented Design Guidelines, approved by Council, define the major transit routes (including the A-Line) as intensification areas. As such, the areas along this corridor are intended to include an intensification of residential (sensitive receptor) uses at grade and above commercial ground floor uses. Both of the aforementioned Council approved documents require pedestrian friendly developments where buildings are located as close as possible to the street.

The specifics of such future development are currently unknown. The feasibility of dealing with the noise of the LRT or BRT can be determined based on the predicted future sound levels. In most cases, the introduction of LRT or BRT along the corridor will cause a net reduction in sound levels. Because of this reduction, developments located along the corridor should not require anything more substantial (in terms of noise control) than similar developments already located along the corridor. In the event of development extremely close to the traffic noise sources (for example 1.5m away from the edge of the roadway), noise mitigation measures such as upgraded windows and air-conditioning are readily available to new development. The need for these measures is little affected by whether or not there is an LRT or BRT along the corridor. It is unlikely that typical residential development will require upgraded glazing unless the development features very large window areas and is located very close to the roadway. The conclusion is that future development close to the transit corridor will not be encumbered by the LRT or BRT. The development may require upgraded noise control measures such as acoustic barriers, air-conditioning, and enhanced glazing (windows) which are all standard for new development along arterial roads due to road traffic noise.

It is the responsibility of the proponent of the future development to provide the necessary noise control measures to satisfy both MOE and City of Hamilton noise guidelines. In addition, it is up to the proponent of the development to design according to the intended use of the facility, which may be more sensitive than the typical residential development.

4.0 VIBRATION IMPACT ASSESSMENT

The vibration impact assessment is based on a prediction of future vibration levels due to the project in the corridor. The closest sensitive receptors to the corridor are considered, but vibration impacts will be negligible beyond 50m. As outlined in the criteria section, the upper limit for vibration levels is 0.10mm/s rms, based on the MOEE/TTC Draft Protocol for the Scarborough Rapid Transit Extension. A limit of 35dBA in quiet sleeping quarters has been suggested for vibration-induced noise, as per the FTA guidelines.

The effects of the light rail vehicles on the vibration and sound levels within adjacent structures have been considered between the two ends of the LRT route wherever there are sensitive receptors located adjacent to the tracks.

This analysis evaluates primarily the effects from tangent track and follows the procedures and assumptions used in the B-Line vibration impact assessment. The Environmental Assessment of the A-Line will likely be based on preliminary data and this review has been based on less refined inputs. The following review, however, may be useful in selecting and detailing a proposed route that, while still effective from a transit service perspective, limits the amount of upgraded vibration isolation that may be required.

Please note that only the LRT is assessed for potential vibration impacts. The BRT system, provided standard road maintenance practices are implemented, is unlikely to produce noticeable vibration levels or vibration-induced noise at the sensitive human hearing frequencies.

4.1 Critical Factors and Assumptions

The unsprung mass per axle, the soil conditions, the distance from the track to the receiver, and the speed of the vehicle will all affect the vibration levels at the receiver. Although the technology is different, the basic factors controlling the vibration from the LRV will be comparable to those of the streetcars currently in use in the City of Toronto. It is assumed that, where the LRT is running along roadways, the track will be embedded in concrete.

The total weight of a 30-40m long light rail vehicle will be in the range of 40,000kg. The new vehicles' unsprung mass per axle, along with the stiffness of the suspension that dictates the nature of the vibration levels, will not be markedly different than that for the typical Canadian Light Rail Vehicles (CLRVs) currently in use in Toronto.

A general review of the soils in the City of Hamilton does not indicate the persistence of finely-compacted sandy soils. As a result, vibration propagation along the route is expected to be similar to that in Toronto. More detailed geotechnical data will need to be obtained for the detailed design, as well as verification of the vibration propagation characteristics of the soils in critical areas.

In contrast to current CLRVs, the proposed light rail vehicles could include an additional two axles. This can be expected to increase the peak vibration levels by 50%.

Vibration levels typically increase linearly with speed. For sections on most roadway rights-of-way, the LRT system can be expected to operate at the same posted speed limit as the adjacent traffic:

- 60km/h on the Claremont Access and Upper James Street
- 50km/h everywhere else.

In the following sections, a decibel scale has been used to depict a change from one level of vibration to another. For example, a 10dB reduction means that the vibration levels are 1/3 of their otherwise expected levels. A 10dB reduction when the initial vibration levels are 1.0mm/s would result in a reduced vibration level of 0.33mm/s.

4.2 Measurement of Existing Streetcar Vibration Levels

Vibration levels of existing streetcar lines have been measured by J. E. Coulter Associates Limited over the past several years at various locations in the Toronto area that are similar to areas along the proposed B-Line LRT route, which are also similar to the proposed A-Line LRT route. The streetcar lines measured in the past typically operate at speeds in the range of 25-30km/h, so the measured vibration levels will have to be increased accordingly to suit the assumed A-Line LRT option.

The measured peak vibration levels have been adjusted to reflect the presence of an additional two axles and the various speeds throughout the corridor.

4.3 Light Rail Vibration Isolation Systems

There are several forms of vibration isolation that can be used for light rail systems running on track embedded in concrete.

For rail embedded in concrete, the typical vibration isolation systems are:

- Rubber-embedded or encapsulated track (also referred to colloquially as the rubber boot). The rubber material reduces the vibration transmission into the concrete and subsequently into the adjacent structures. There are various embedded rail systems with differing properties.

- Another isolation method for rail in concrete is a floating slab system. This system floats on a concrete rail bed mounted on rubber isolators, reducing the transmission of vibration from the concrete into the soil and adjacent structures.

For the purposes of the vibration impact assessment, it is assumed that there will be at least a simple rubber embedded rail system that achieves a 5dB reduction in vibration levels.

4.4 Prediction of Vibration Levels

Both the ground-borne vibration (perceptible vibration) and the vibration-induced noise resulting from the proposed LRT system have been estimated. The perceptible vibration levels are evaluated based on the MOEE/TTC Protocol's guideline limit of 0.10mm/s RMS. The vibration-induced noise from the LRT is evaluated at residences based on the FTA guideline level of 35dBA, wherever the air-borne noise would not dominate the vibration-induced sound.

The predicted vibration levels are based on the posted speed limit assumptions of the LRT along the various sections.

4.4.1 Perceptible Vibration Levels on Concrete Track

On concrete-embedded track, the CLRVs were measured at various distances. Table 8, below, summarizes the measured vibration levels.

Table 8: Measured Vibration Levels on Concrete Track Bed

Distance from Track Centreline (m)	Vibration Levels (mm/s rms)
3	0.19
7	0.13
12	0.11

As discussed earlier, all new light rail systems include at least a basic (Level 1) version of the embedded rail. Considering the 5dB reduction (44% reduction) from this system, the increase in speed to 40km/h, and the addition of an extra axle, the vibration levels from the LRT in place can be estimated. Again, it is assumed that clayey soils persist throughout the areas with concrete-embedded track.

Table 9, below, summarizes the estimated vibration levels that would be present at various setbacks from the centreline of the nearest track.

Table 9: Expected LRT Vibration Levels on Concrete Track Bed

Distance from Track Centreline (m)	Vibration Levels at Various Speeds	
	50km/h	60km/h
6	0.17	0.21
10	0.11	0.14
15	0.10	0.12
20	0.08	0.10

As can be seen from Table 9, any residential receptors located 20m or more from the centreline of the nearest track will meet the guideline limit of 0.10mm/s without any additional vibration control measures when the LRT is operating at a speed of 60km/h. Any residential receptors located 15m or more from the centreline of the nearest track will meet the guideline limit of 0.10mm/s when the LRT is operating at a speed of 50km/h. Otherwise, residential receptors located closer than the setbacks listed above may require additional vibration isolation to reduce the vibration levels to 0.10mm/s rms. For concrete embedded track, however, vibration control to limit vibration-induced noise is more critical and will supersede the requirements for perceptible vibration mitigation (refer to Section 4.4.2).

4.4.2 Vibration-Induced Sound

For light rail on a concrete track bed, vibration-induced sound (the rumble) tends to be more of an issue than perceptible vibration, especially at close setbacks. At greater setbacks, vibration-induced sound becomes less critical as the damping characteristics of clayey soils reduce the vibration levels in the octave bands that human hearing is sensitive to. At setbacks of 20m or more from the nearest track, perceptible (ground-borne vibration) is more critical than vibration-induced noise. The following analysis for vibration-induced noise is based on setbacks of 20m or less, which occurs primarily wherever the LRT is operating at 50km/h.

Wherever the centreline of the LRT is within 30m of a sensitive residential receptor, upgraded vibration isolation may be required if the operating speed of the LRVs is 60km/h or greater. With a speed limit of 50km/h and a setback of 20m or less from the LRT centreline, upgraded isolation may also be required.

4.5 Vibration-sensitive Land Uses and Equipment

Specific aspects of institutional uses (e.g., hospitals) and commercial uses are not well addressed by the MOEE/TTC protocol. As prepared for the B-Line, the City should compile a list of sensitive uses such as lecture halls, theatres, hospitals, scientific research facilities, recording studios, etc. that may be affected by the vibration from the LRT.

St. Joseph's Healthcare Hamilton, located on the northwest corner of West 5th Street and Fennell Avenue, is known to have plans for vibration-sensitive equipment (an MRI). This equipment has already been designed so that building vibrations (e.g., those resulting from footfalls or from mechanical equipment) do not affect the equipment's operations. The proposed LRT route runs closer to the hospital than the street. Although the vibration levels are unlikely to be perceptible by the occupants of the hospital, the effect on the hospital's special equipment would likely need to be looked at during the EA and detailed design phases. Upgraded vibration isolation for the tracks may be sufficient, given that some of the equipment already incorporates forms of vibration control.

4.6 Vibration Impact on Future Development

As discussed in Section 3.3, the future A-Line corridor is slated for intensification. The possibility that such development may be affected by the vibration from the future A-Line LRT has been considered. If BRT is adopted for the A-Line, vibration will not be an issue.

The primary assumption of the vibration impact assessment is that the LRT system will incorporate at least a basic level of vibration isolation (a simple rubber embedded rail providing approximately 5dB insertion loss). In the event that future development is located very close to the LRT tracks, the developer will need to consider the potential effects of vibration. In the event that the basic vibration isolation is insufficient, the developer can readily implement receptor based vibration control measures. The most common and most practical method to control vibration from surface transit systems is foundation lining.

It is the responsibility of the proponent of the future development to provide the necessary vibration control measures to satisfy both MOE and City of Hamilton vibration guidelines. In addition, it is up to the proponent of the development to design according to the intended use of the facility, in the case that it is more sensitive than the typical residential development.

5.0 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

The noise output of the LRT option is slightly higher than the BRT option, even after accounting for a higher volume of transit vehicles under the BRT scenario. There are some areas, such as on James Street North, where the introduction of the LRT will generate an approximately 3dB impact. The BRT, in most cases, is about 1dB to 3dB quieter than the LRT option and so does not approach a 5dB impact as often as the LRT option does. It should be noted that the actual vehicle selected may be quieter than that modeled in either this assessment or the assessment of the B-Line LRT. A quieter vehicle would then "blur" the differences in noise effects between the LRT and BRT options. In any case, the difference is small.

In terms of vibration, the BRT option would generate negligible vibration levels at the typical setbacks throughout the corridor provided that standard road maintenance practices are implemented. The LRT option, however, would likely need some upgraded vibration isolation, especially when it travels through the downtown core of Hamilton. During the planning stages of the LRT option, attention to setback from sensitive receptors and careful consideration of maximum speeds could limit and even eliminate the need for upgraded vibration isolation.

This noise and vibration review was completed using preliminary data and the data contained within the B-Line noise and vibration report. A more detailed study of the preferred option would need to be completed for the Transit Project Assessment Process. This study would also look at the other effects of the proposed option, such as ancillary facilities (hubs, stations, terminals, power substations, etc.) and special conditions (e.g., bus loops for BRT or special trackwork for LRT).

Appendix A

Figures

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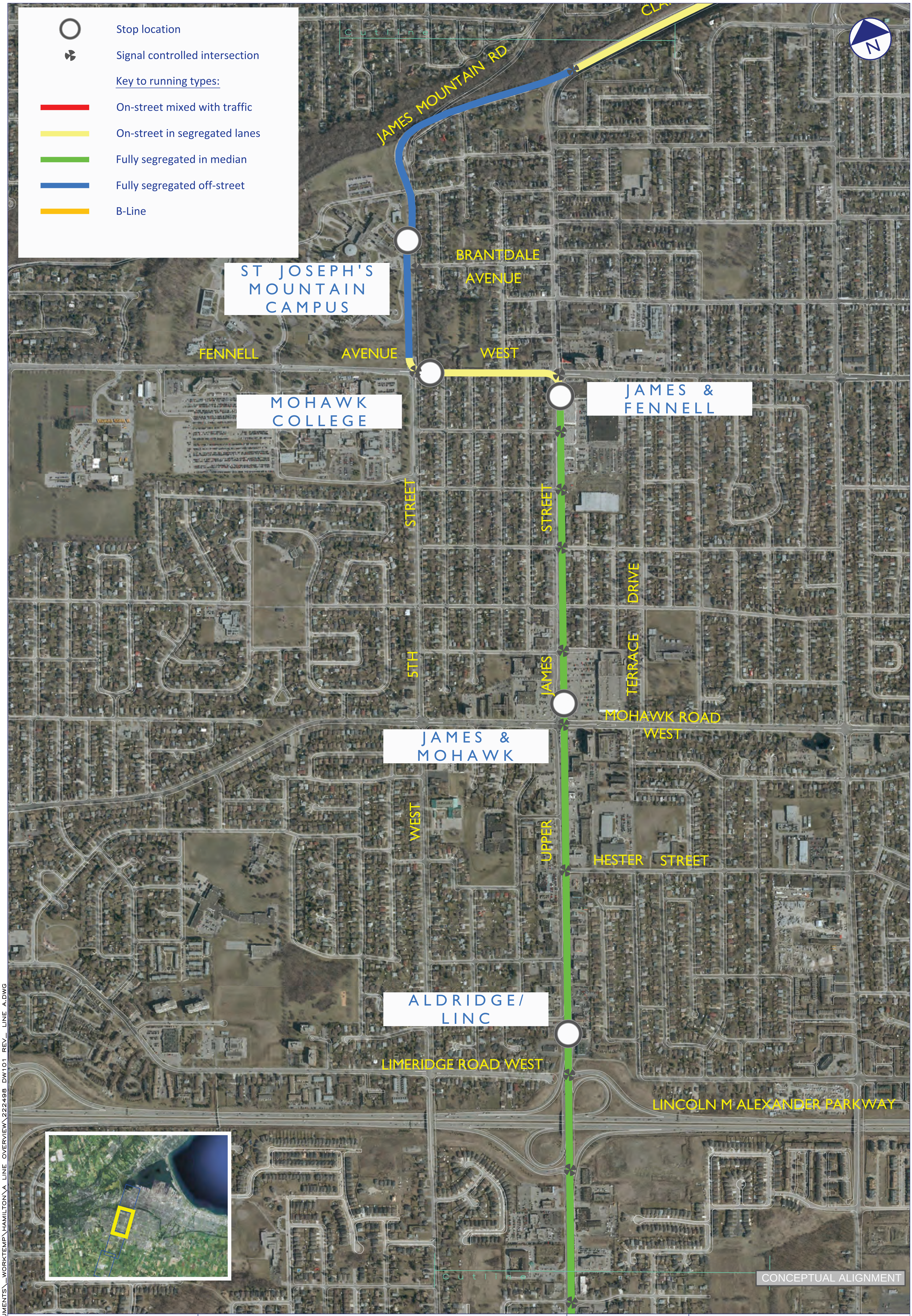

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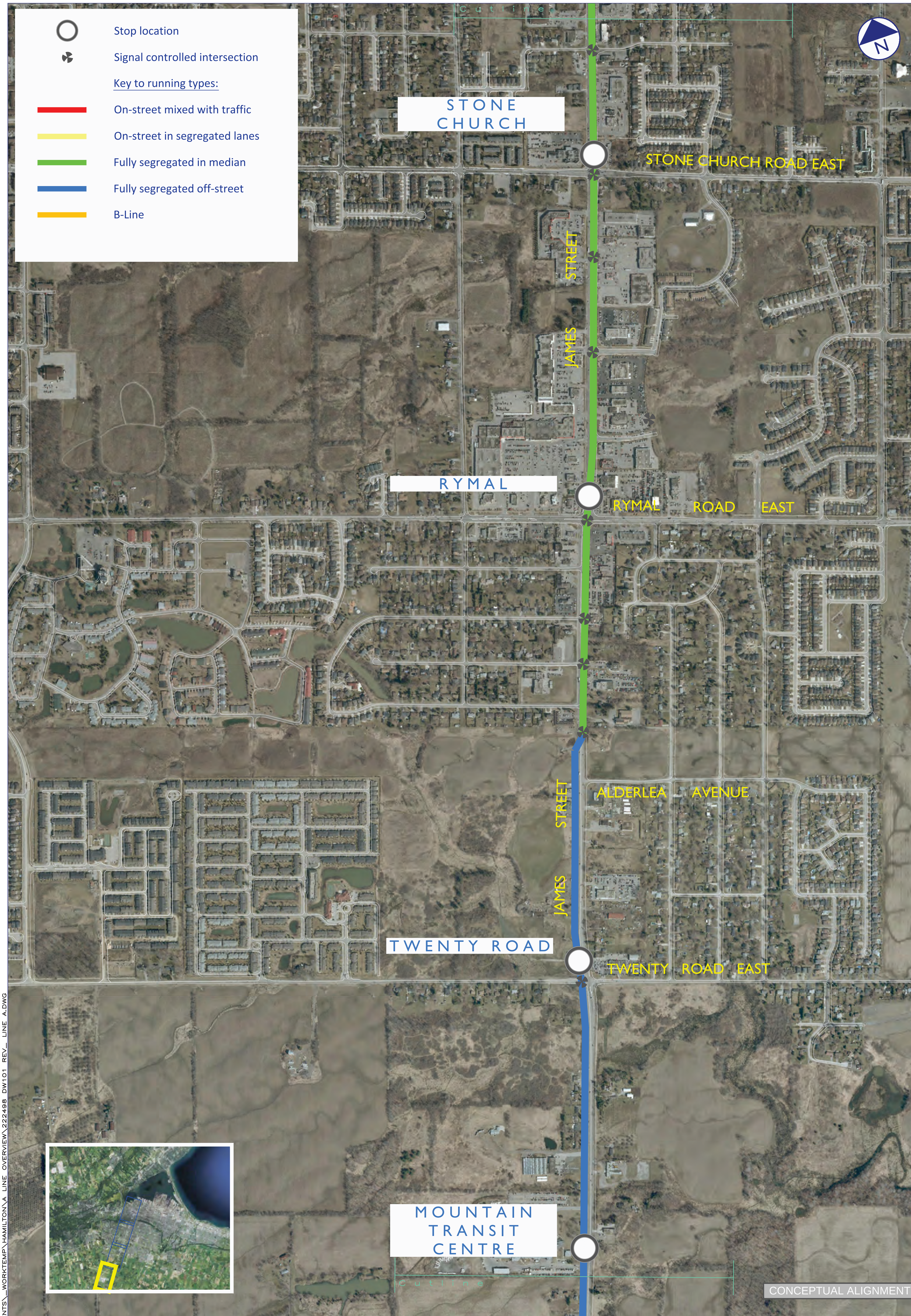

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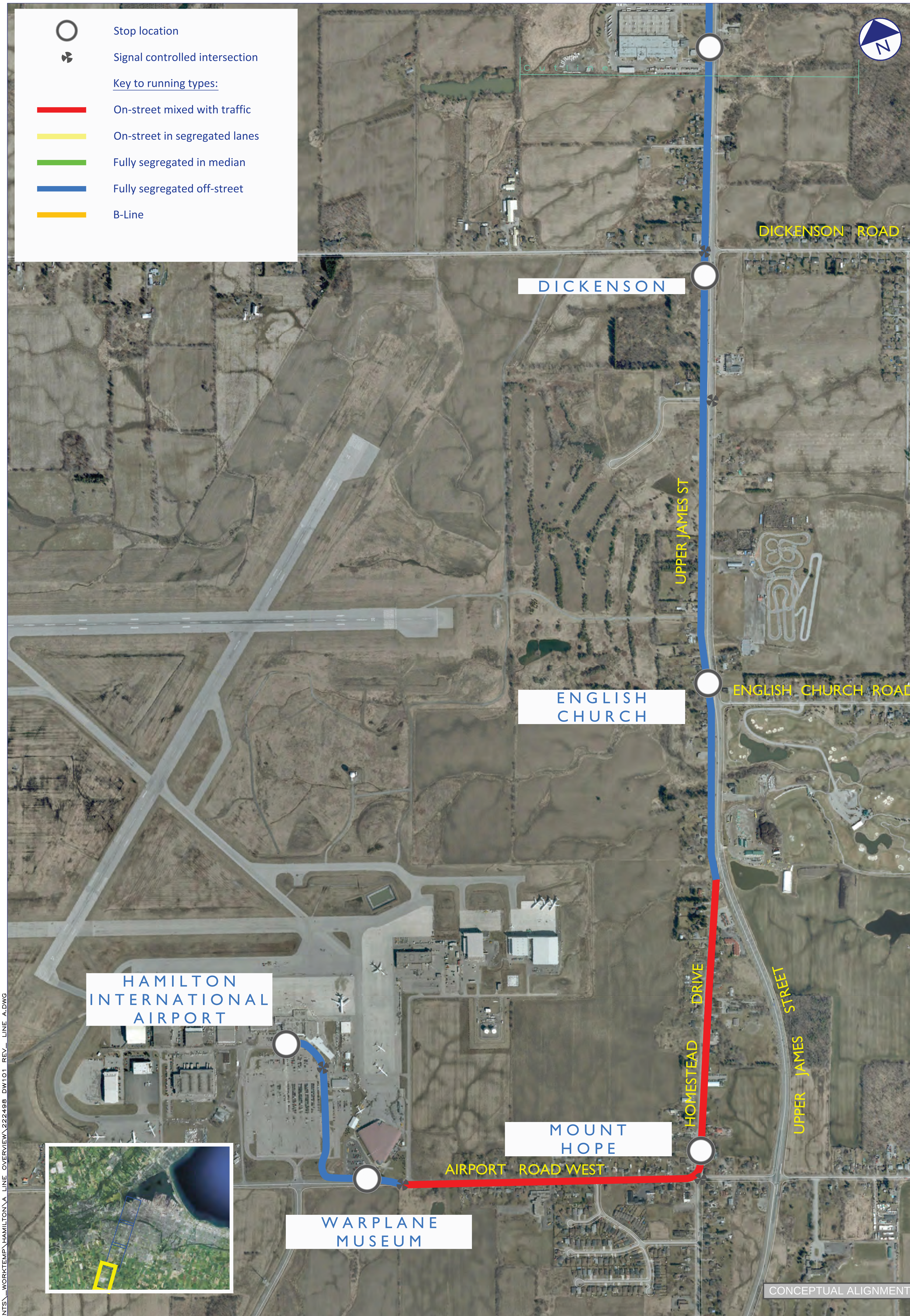

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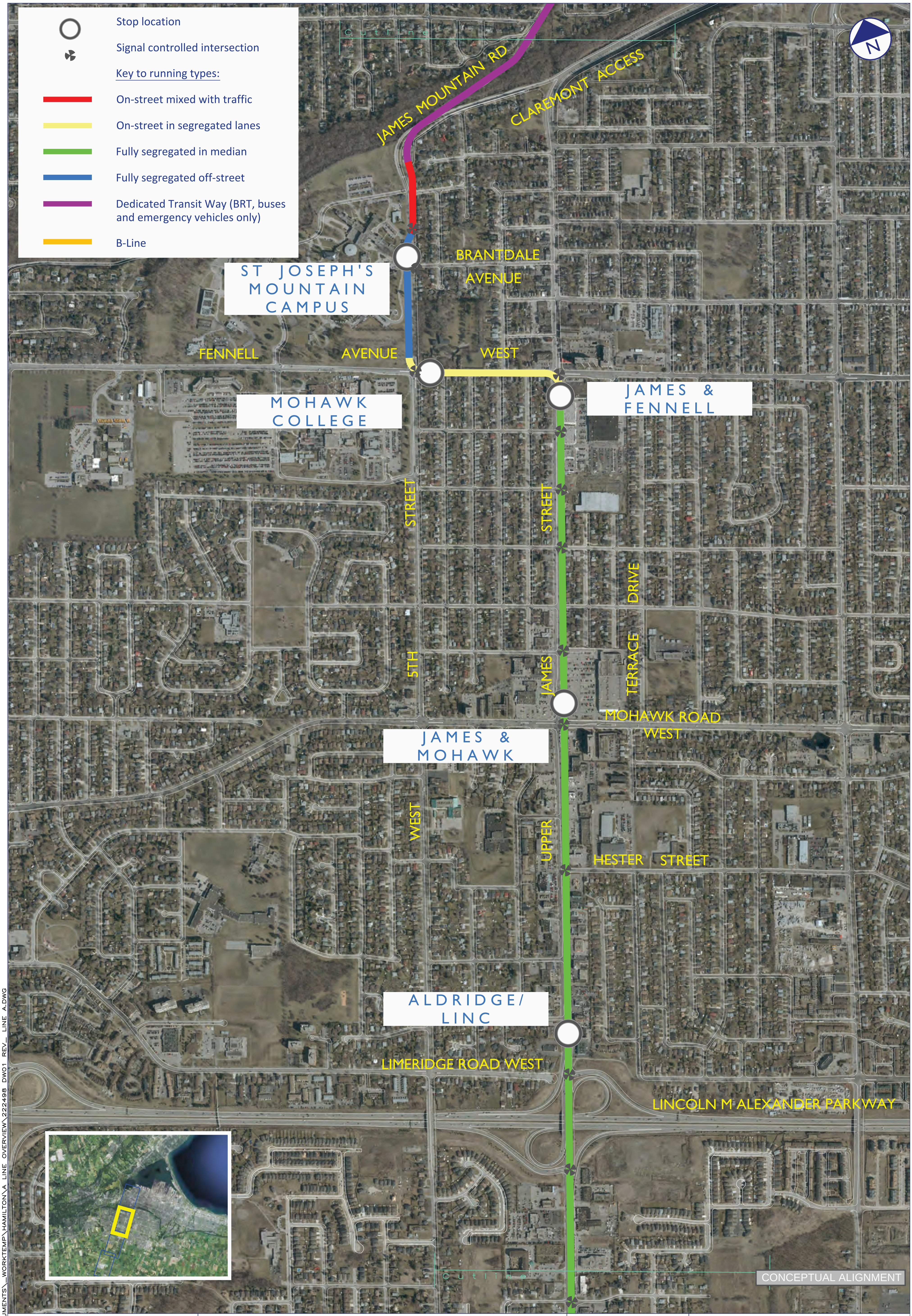

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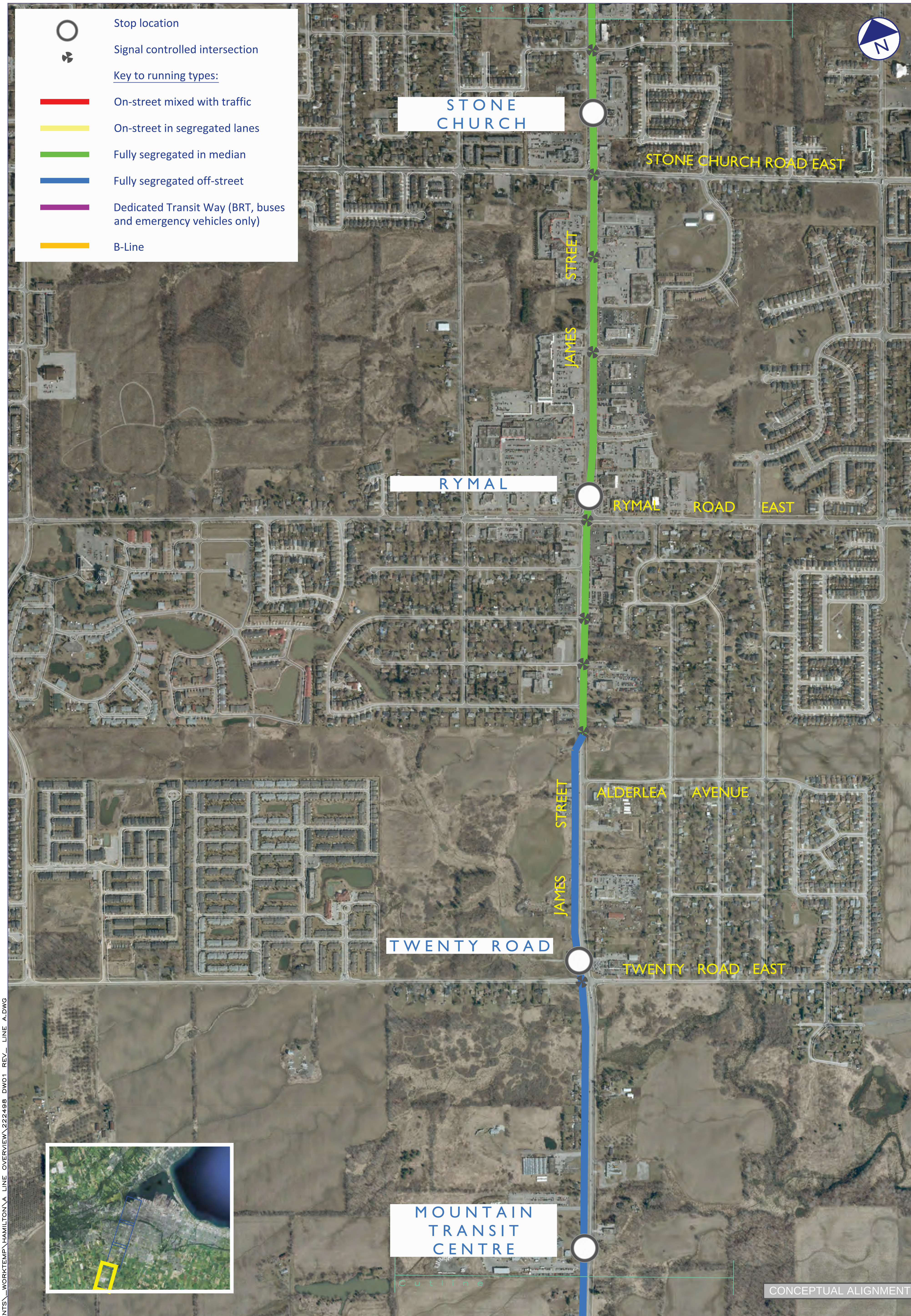

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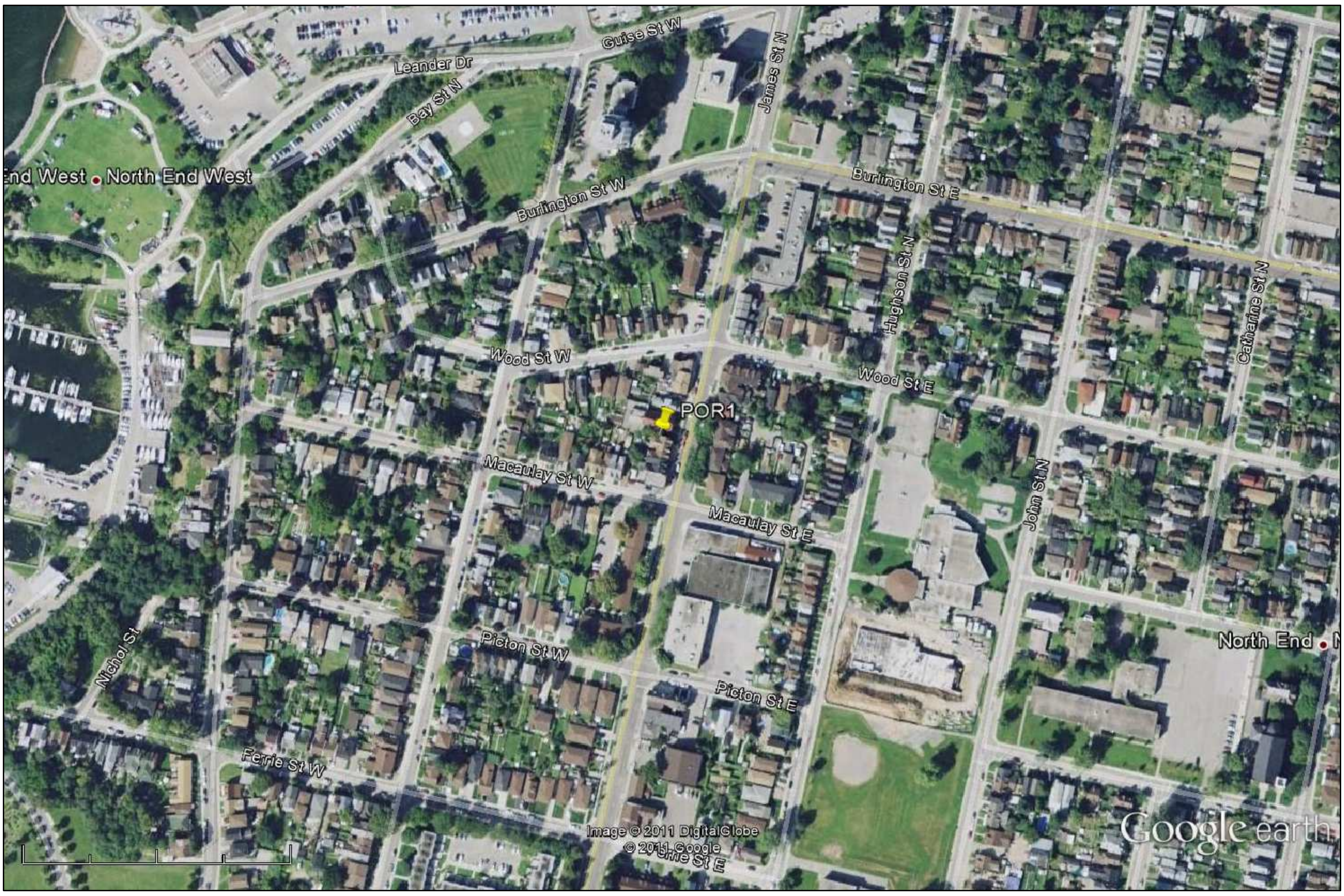


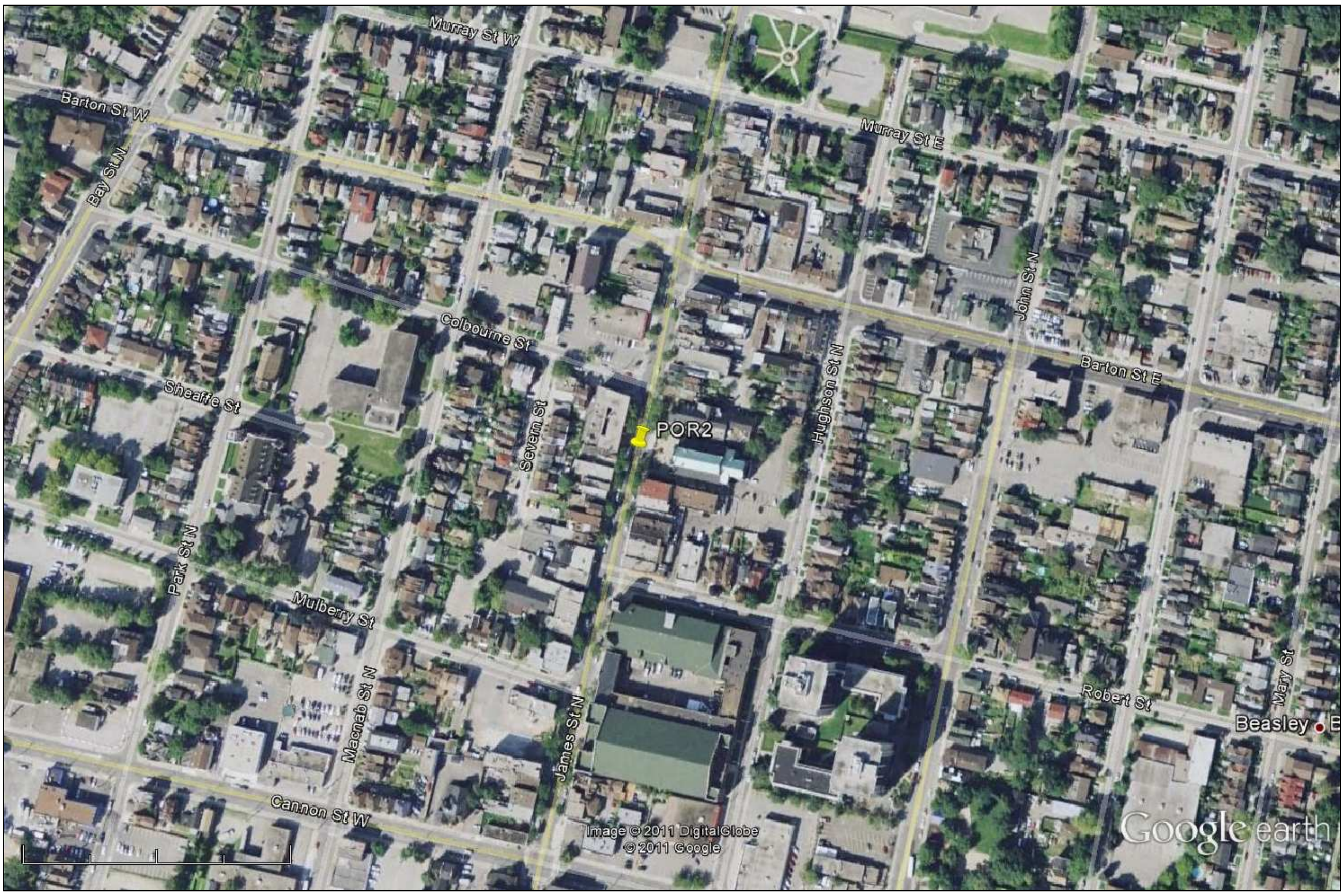


FIGURE 2
SENSITIVE RECEPTORS
POR1 AND POR2

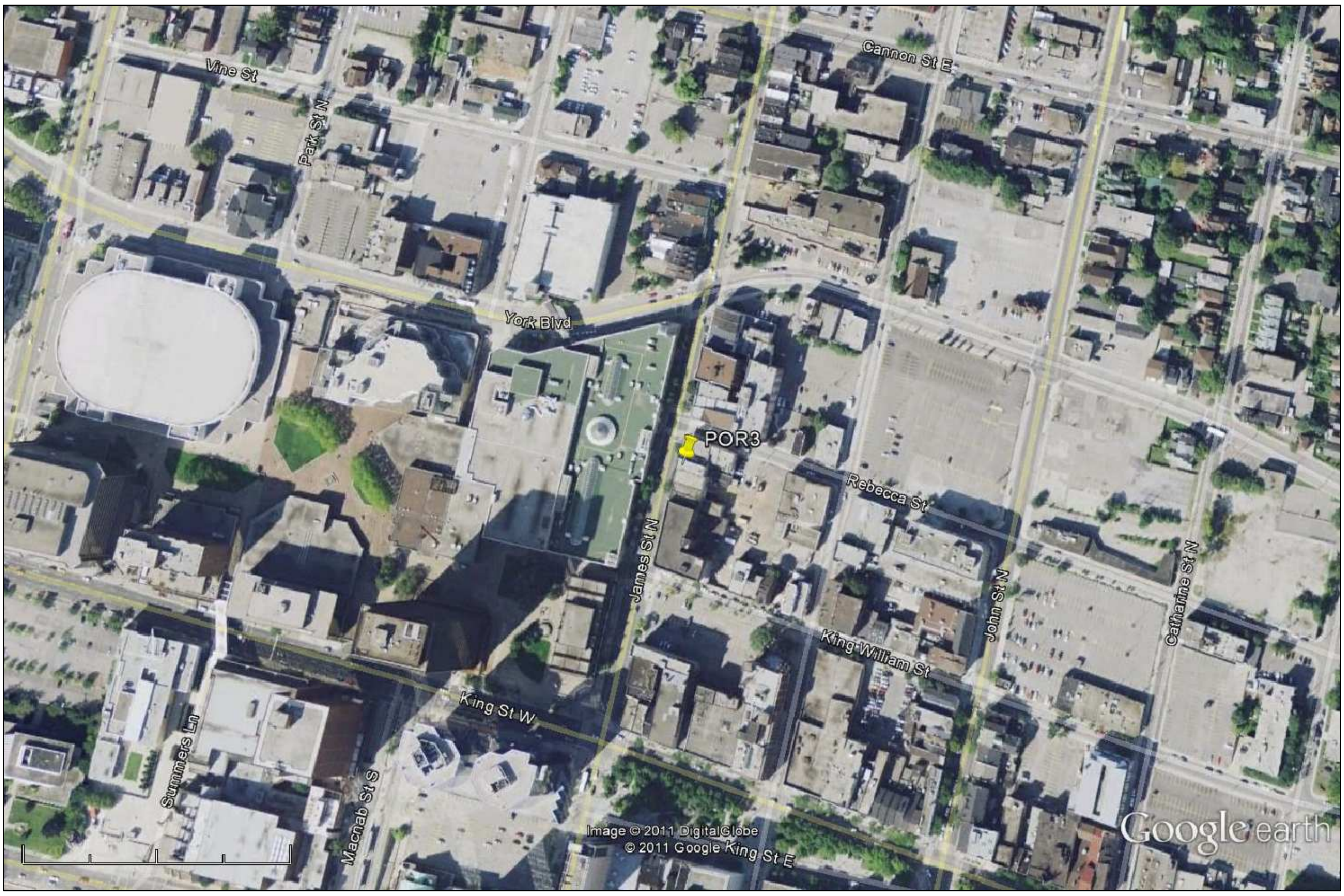


FIGURE 3
SENSITIVE RECEPTORS
POR3 AND POR4a

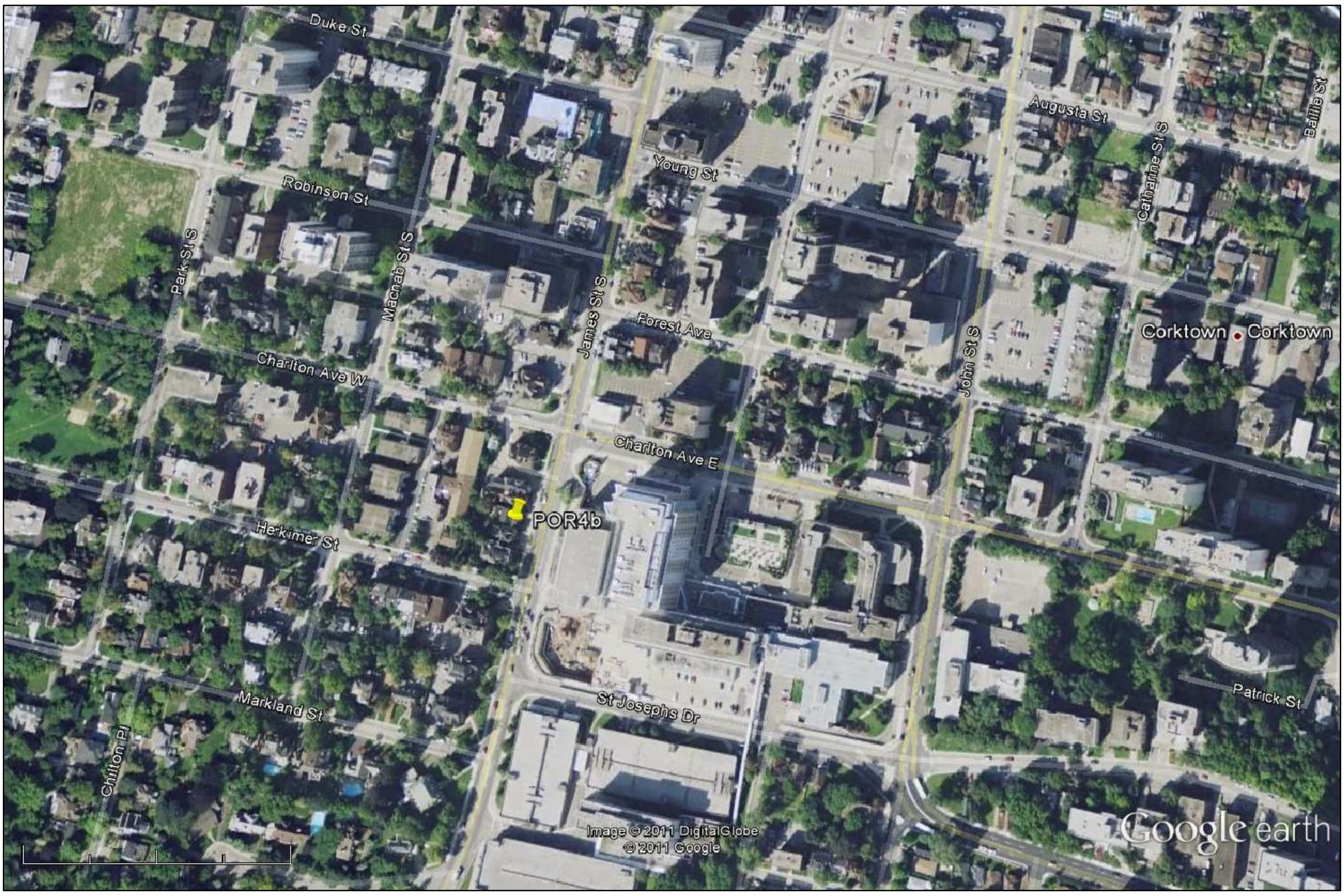


FIGURE 4
SENSITIVE RECEPTORS
POR4b AND POR5a

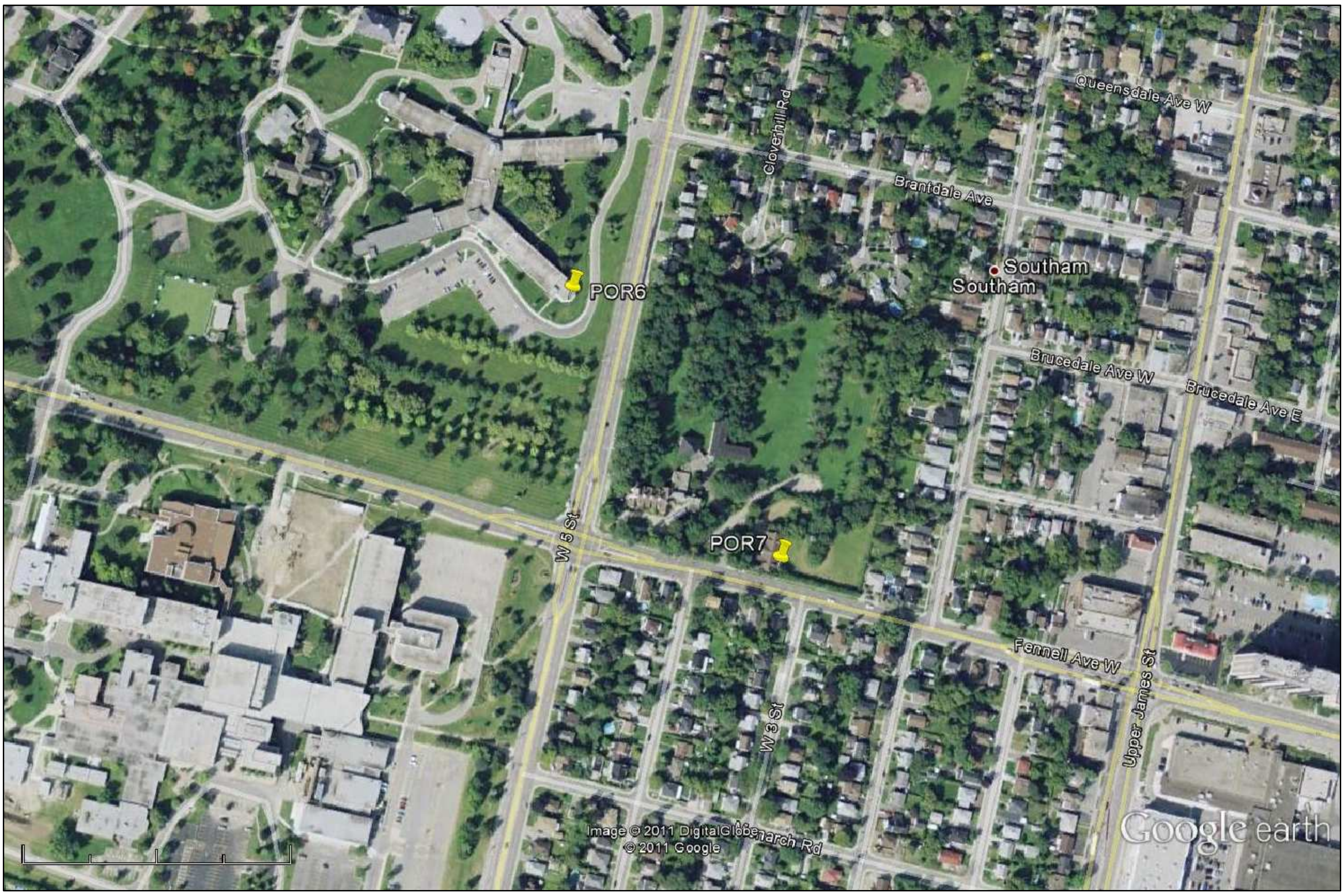
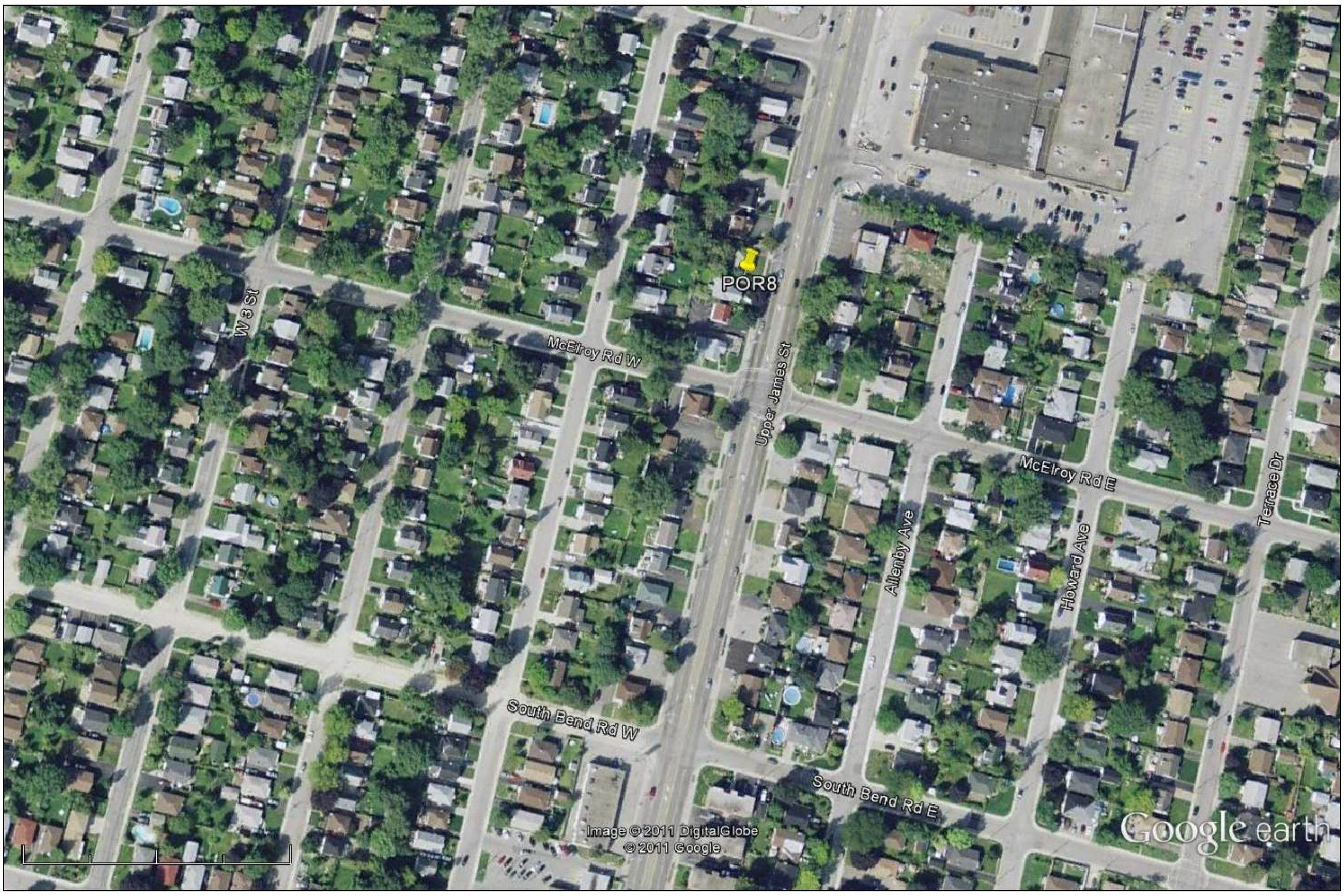


FIGURE 5
SENSITIVE RECEPTORS
POR5b, POR6 AND POR7



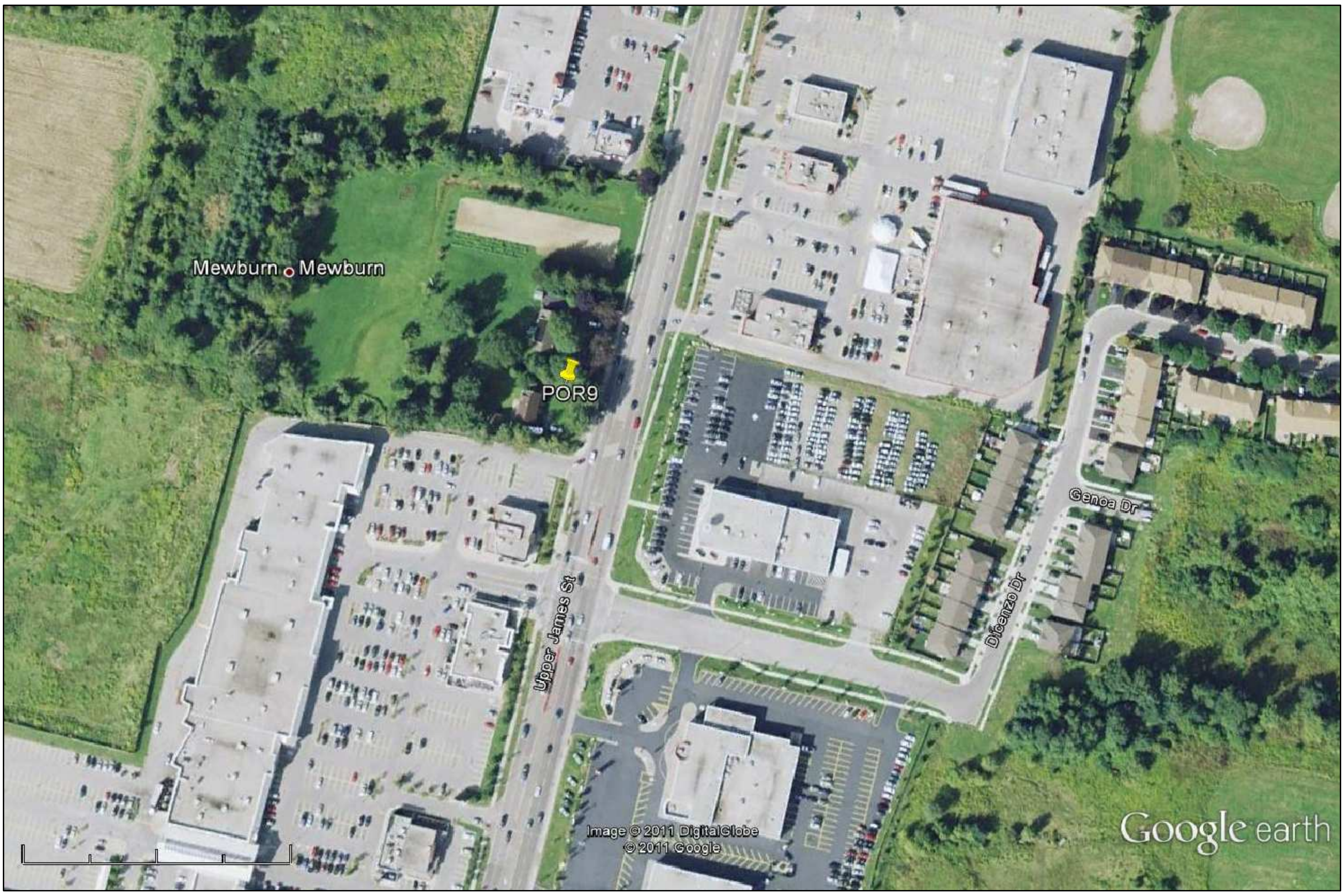


FIGURE 6
SENSITIVE RECEPTORS
POR8 AND POR9

FIGURE 7
SENSITIVE RECEPTORS
POR10 AND POR11

Appendix B

Guidelines

MOEE/TTC
DRAFT

PROTOCOL FOR NOISE AND VIBRATION ASSESSMENT FOR THE PROPOSED SCARBOROUGH RAPID TRANSIT EXTENSION

May 11, 1993

DRAFT

TABLE OF CONTENTS

PROTOCOL FOR NOISE AND VIBRATION ASSESSMENT

PART A. PURPOSE

The Toronto Transit Commission (TTC) and the Ministry of the Environment and Energy (MOEE) recognize that transit facilities produce noise and vibration which may affect neighbouring properties within urbanized areas. This document identifies the framework within which criteria will be applied for limiting wayside air-borne noise and ground-borne noise and vibration from the TTC's proposed Scarborough Rapid Transit Line Extension (the "Line"). This proposed extension is to run from McCowan station to Markham Road and Sheppard Avenue East. The framework presented in this document is to be applied for planning purposes in order to address the requirements of the Environmental Assessment Act and is to be utilized during implementation of the Line.

The passby sound levels and vibration velocities in this protocol have been developed specifically for the Line and this protocol is not to be applied retroactively to existing TTC transit Lines, routes or facilities, including the existing SRT line, nor to transit authorities other than TTC. Further, the criteria specified for this project are not precedent setting for future projects.

Prediction and measurement methods are being developed by the TTC. This will be done in consultation with MOEE and the Ministry of Transportation (MTO). Studies pertaining to noise and vibration levels are also being conducted by TTC. Upon completion of these studies, the TTC may revisit the assessment criteria and methods in this protocol to modify them as required in consultation with MOEE and the Ministry of Transportation (MTO).

PART B. GENERAL

During design of the Line, predicted wayside sound levels and vibration velocities are to be compared to criteria given in this protocol. This will permit an impact assessment and help determine the type or extent of mitigation measures to reduce that impact. Sound levels and vibration velocities will be predicted from sound levels and velocities of TTC's existing rail technologies.

The criteria presented in this document are based on good operating conditions and the impact assessment assumes this condition. Good operating conditions exist when well maintained vehicles operate on well maintained continuous welded rail without significant rail corrugation. It is recognised that wheel flats or rail corrugations will inevitably occur and will temporarily increase sound and vibration levels until they are corrected. Levels in this protocol do not reflect these occasional events, nor do they apply to maintenance activities on the Line. TTC recognizes that wheel rail squeal is a potential source of noise which may pose a concern to the community. TTC is investigating and will continue to investigate measures to mitigate wheel rail squeal and will endeavour to mitigate this noise source. TTC endeavours to minimize the noise and vibration impacts associated with its transit operations and is committed to providing good operating conditions to the extent technologically, economically and administratively feasible.

It is recognised that levels of sound and vibration at special trackwork, such as at crossovers and turnouts, are inevitably higher than along tangent track. Also, there is a limit to the degree of mitigation that is feasible at special trackwork areas. This is to be taken into account in predicting sound and vibration levels near these features and in applying the levels in this protocol. Special trackwork, such as at crossovers and turnouts, is encompassed within the framework of this document.

This protocol applies to existing and proposed residential development having municipal approval on the date of this protocol. The protocol also applies to existing and municipally approved proposed nursing homes, group homes, hospitals and other such institutional land uses where people reside. This protocol does not apply to commercial and industrial land uses.

This protocol does not apply closer than 15 m to the centreLine of the nearest track. Any such cases shall be assessed on a case by case basis.

Part D of this document deals with airborne noise from the Line and its construction. Part E deals with groundborne noise and vibration from the Line.

PART C. DEFINITIONS

The following definitions apply to both parts D and E of this document:

Ancillary Facilities:

Subsidiary locations associated with either the housing of personnel or equipment engaged in TTC activities or associated with mainLine revenue operations. Examples of ancillary facilities include, but are not limited to, subway stations, bus terminals, emergency services buildings, fans, fan and vent shafts, substations, mechanical equipment plants, maintenance and storage facilities, and vehicle storage and maintenance facilities.

Passby Time Interval:

The passby time interval of a vehicle or train is given by its total length and its speed. The start of the pass-by is defined as that point in time when the leading wheels pass a reference point. The end of the pass-by is defined as that point in time when the last wheels of the vehicle or train pass the same reference point. The reference point is to be chosen to give the highest level at the point of reception or point of assessment, i.e. usually at the point of closest approach. From a signal processing perspective, the passby time interval will be defined in the prediction and measurement methods being developed.

PART D. AIR BORNE NOISE

1.0 DEFINITIONS

The following definitions are to be used only within the context of Part D of this document.

Ambient:

The ambient is the sound existing at the point of reception in the absence of all noise from the Line. In this protocol the ambient is taken to be the noise from road traffic and existing industry. The ambient specifically excludes transient noise from aircraft and railways, except for pre-existing TTC rail operations.

Daytime Equivalent Sound Level:

$L_{eq,16h}$ is the daytime equivalent sound level. The definition of equivalent sound level is provided in Reference 2. The applicable time period is from 07:00 to 23:00 hours.

Nighttime Equivalent Sound Level:

$L_{eq,8h}$ is the nighttime equivalent sound level. The applicable time period is from 23:00 to 07:00 hours.

Point of Reception:

Daytime: 07:00 - 23:00 hours

Any outdoor point on residential property, 15 m or more from the nearest track's centreLine, where sound originating from the Line is received.

Nighttime: 23:00 - 07:00 hours

The plane of any bedroom window, 15 m or more from the nearest track's centreLine, where sound originating from the Line is received. At the planning stage, this is usually assessed at the nearest facade of the premises.

Passby Sound Level, L_{passby} :

Within the context of this document, the passby sound level is defined as the A-weighted equivalent sound level, L_{eq} [Reference 2] over the passby time interval.

2.0 RAIL TRANSIT

In the assessment of noise impact, rail transit is considered to include the movement of trains between stations, the movement and idling of trains inside stations as well as the movement of trains between the mainline and ancillary facilities. Ancillary facilities are not considered part of the rail transit and are assessed as stationary sources. Trains idling in maintenance yards and storage facilitities are part of the stationary source.

The assessment of noise impact resulting from Line is to be performed in terms of the following sound level descriptors:

1) Daytime equivalent sound level, $L_{eq,16h}$,
2) Nighttime equivalent sound level, $L_{eq,8h}$,
3) Passby Sound Level, L_{passby}.

The predicted daytime and nighttime equivalent sound levels include the effects of both passby sound level and frequency of operation and are used to assess the noise impact of the Line. The Passby Sound Level criterion is used to assess the sound levels received during a single train passby. The criteria and methods to be used are discussed in Sections 2.1 and 2.2.

2.1 Criteria

Noise impact shall be predicted and assessed during design of the Line using the following sound level criteria:

DAYTIME EQUIVALENT SOUND LEVEL:

The limit at a point of reception for the predicted daytime equivalent sound levels for rail transit operating alone (excluding contributions from the ambient) is 55 dBA or the ambient $L_{eq,16h}$, whichever is higher.

NIGHTTIME EQUIVALENT SOUND LEVEL:

The limit at a point of reception for the predicted nighttime equivalent sound levels for rail transit operating alone (excluding contributions from the ambient) is 50 dBA or the ambient $L_{eq,8h}$, whichever is higher.

PASSBY SOUND LEVEL:

The limit at a point of reception for predicted L_{passby} for a single train operating alone and excluding contributions from other sources is 80 dBA. This limit is based on vehicles operating on tangent track. It does not apply within 100m of special trackwork and excludes wheel rail squeal.

Mitigating measures will be incorporated in the design of the Line when predictions show that any of the above limits are exceeded by more than 5 dB. All mitigating measures shall ensure that the predicted sound levels are as close to, or lower than, the respective limits as is technologically, economically, and administratively feasible.

2.2 Prediction

In most cases, a reasonable estimate of the ambient sound level can be made using a road traffic noise prediction method such as that described in Reference 9, and the minimum sound levels in Table 106-2 of Reference 6. Prediction of road traffic L_{eq} is preferred to individual measurements in establishing the ambient. Prediction techniques for the L_{eq} from road traffic and the L_{eq} or L_{passby} from transit shall be compatible with one another. Any impact assessment following this protocol shall include a description of the prediction method and the assumptions and sound level data inherent in it. Prediction and measurement methods compatible with MOEE guidelines and procedures are being developed by the TTC at the date of this protocol in consultation with MTO and MOEE.

3.0 ANCILLARY FACILITIES

Predicted noise impacts from ancillary facilities shall be assessed during the design of the Line in accordance with the stationary source guideLines detailed in Reference 5. The predictions used shall be compatible with and at least as accurate as CSA Standard Z107.55.

4.0 BUSES IN MIXED TRAFFIC

Where buses are part of the road traffic there are no additional criteria requirements beyond those presented in the Ministry of Transportation of Ontario Protocol for dealing with noise concerns during the preparation, review and evaluation of Provincial Highways Environmental Assessments [Reference 1]. Buses should be considered as medium trucks in the traffic noise prediction models.

5.0 CONSTRUCTION

Noise impacts from the construction of the Line are to be examined. For the purposes of impact assessment and identifying the need for mitigation, the Ministry of the Environment and Energy guideLines for construction presented in Reference 7 are to be referred to.

PART E. GROUND-BORNE VIBRATION

The assessment of ground-borne vibration impact is confined to the vibration that is produced by the operation of the Line and excludes vibration due to maintenance activities.

In recognition of the fact that the actual vibration response of a building is affected by its own structural characteristics, this document deals with the assessment of ground borne vibration only on the outside premises. Structural characteristics of buildings are beyond the scope of this protocol and beyond the control of the TTC.

1.0 DEFINITIONS

The following definitions are to be used only within the context of Part E of this document.

Point of Assessment:

A point of assessment is any outdoor point on residential property, 15 m or more from the nearest track's centreLine, where vibration originating from the Line is received.

Vibration Velocity:

Vibration Velocity is the root-mean-square (rms) vibration velocity assessed during a train pass-by. The unit of measure is metres per second (m/s) or millimetres per second (mm/s). For the purposes of this protocol only vertical vibration is assessed. The vertical component of transit vibration is usually higher than the horizontal. Human sensitivity to horizontal vibration at the frequencies of interest is significantly less than the sensitivity to vertical vibration.

2.0 VIBRATION ASSESSMENT

Vibration velocities at points of assessment shall be predicted during design of the Line. If the predicted rms vertical vibration velocity from the Line exceeds 0.1 mm/sec, mitigation methods shall be applied during the detailed design to meet this criterion to the extent technologically, economically, and administratively feasible.

Any impact assessment following this protocol shall include a description of the prediction method and the assumptions and data inherent in it. Prediction and measurement methods are being developed by the TTC at the date of this protocol in cooperation with MTO and MOEE.

References

1)**A Protocol for Dealing With Noise Concerns During the Preparation, Review and Evaluation of Provincial Highways Environmental Assessments**, Ministry of Transportation, February 1986.

2)**Model Municipal Noise Control By-Law, Final Report, Publication NPC-101 Technical Definitions**, Ministry of the Environment, August 1978.

3)**Model Municipal Noise Control By-Law, Final Report, Publication NPC-103 Procedures**, Ministry of the Environment, August 1978.

4)**Model Municipal Noise Control By-Law, Final Report, Publication NPC-104 Sound Level Adjustments**, Ministry of the Environment, August 1978.

5)**Model Municipal Noise Control By-Law, Final Report, Publication NPC-105 Stationary Sources**, Ministry of the Environment, August 1978.

6)**Model Municipal Noise Control By-Law, Final Report, Publication NPC-106 Sound Levels of Road Traffic**, Ministry of the Environment, August 1978.

7)**Noise Control GuideLine For Class Environmental Assessment of Undertakings**, February 1980, Ministry of the Environment.

8)**Toronto Subway System Track Vibration Isolation System (Double Tie) - Technical Report**, TTC Engineering Department, June 1982.

9)**STAMSON 4.1**, Ontario Ministry of the Environment Road and Rail Noise Prediction Software

MOEE/TTC

DRAFT

PROTOCOL FOR NOISE AND VIBRATION ASSESSMENT FOR THE PROPOSED WATERFRONT WEST LIGHT RAIL TRANSIT LINE

November 11, 1993

TABLE OF CONTENTS

PROTOCOL FOR NOISE AND VIBRATION ASSESSMENT

PART A. PURPOSE

The Toronto Transit Commission (TTC) and the Ministry of the Environment and Energy (MOEE) recognise that transit facilities produce noise and vibration which may affect neighbouring properties within urbanised areas. This document identifies the framework within which criteria will be applied for limiting wayside air-borne noise, ground-borne noise and vibration from the TTC's proposed Waterfront West Light Rail Transit Line (the "Line"). The proposed line is to run from Spadina and Queen's Quay West to the CNE Dufferin Street Gate and from the Humber Loop to Legion Road. The framework presented in this document is to be applied for planning purposes in order to address the requirements of the Environmental Assessment Act and is to be utilized during implementation of the Line.

The passby sound levels and vibration velocities in this protocol have been developed specifically for the Line and this protocol is not to be applied retroactively to existing TTC transit lines, routes or facilities, including the existing lines with which this line will intersect, nor to transit authorities other than TTC. Further, the criteria specified for this project are not precedent setting for future projects.

Prediction and measurement methods are being developed by the TTC. This will be done in consultation with MOEE and the Ministry of Transportation (MTO). Studies pertaining to noise and vibration levels are also being conducted by TTC. Upon completion of these studies, the TTC may revisit the assessment criteria and methods in this protocol to modify them as required in consultation with MOEE and the Ministry of Transportation (MTO).

PART B. GENERAL

During design of the Line, predicted wayside sound levels and vibration velocities are to be compared to criteria given in this protocol. This will permit an impact assessment and help determine the type or extent of mitigation measures to reduce that impact. Sound levels and vibration velocities will be predicted from sound levels and velocities of TTC's existing rail technologies.

The criteria presented in this document are based on good operating conditions and the impact assessment assumes this condition. Good operating conditions exist when well maintained vehicles operate on well maintained continuous welded rail without significant rail corrugation. It is recognised that wheel flats or rail corrugations will inevitably occur and will temporarily increase sound and vibration levels until they are corrected. Levels in this protocol do not reflect these occasional events, nor do they apply to maintenance activities on the Line. TTC recognizes that wheel rail squeal is a potential source of noise which may pose a concern to the community. TTC is investigating and will continue to investigate measures to mitigate wheel rail squeal and will endeavour to mitigate this noise source. TTC endeavours to minimize the noise and vibration impacts associated with its transit operations and is committed to providing good operating conditions to the extent technologically, economically and administratively feasible.

It is recognised that levels of sound and vibration at special trackwork, such as at crossovers and turnouts, are inevitably higher than along tangent track. Also, there is a limit to the degree of mitigation that is feasible at special trackwork areas. This is to be taken into account in predicting sound and vibration levels near these features and in applying the levels in this protocol. Special trackwork, such as at crossovers and turnouts, is encompassed within the framework of this document.

This protocol applies to existing and proposed residential development having municipal approval on the date of this protocol. The protocol also applies to existing and municipally approved proposed nursing homes, group homes, hospitals and other such institutional land uses where people reside. This protocol does not apply to commercial and industrial land uses.

This protocol does not apply closer than 15 m to the centreline of the nearest track. Any such cases shall be assessed on a case by case basis.

Part D of this document deals with air-borne noise from the Line and its construction. Part E deals with ground-borne noise and vibration from the Line.

PART C. DEFINITIONS

The following definitions apply to both parts D and E of this document.

Ancillary Facilities:

Subsidiary locations associated with either the housing of personnel or equipment engaged in TTC activities or associated with mainline revenue operations. Examples of ancillary facilities include, but are not limited to, subway stations, bus terminals, emergency services buildings, fans, fan and vent shafts, substations, mechanical equipment plants, maintenance and storage facilities, and vehicle storage and maintenance facilities.

Passby Time Interval:

The passby time interval of a vehicle is given by its total length and its speed. The start of the pass-by is defined as that point in time when the leading wheels pass a reference point. The end of the pass-by is defined as that point in time when the last wheels of the vehicle pass the same reference point. The reference point is to be chosen to give the highest level at the point of reception or point of assessment, i.e. usually at the point of closest approach. From a signal processing perspective, the passby time interval will be defined in the prediction and measurement methods being developed.

PART D. AIR-BORNE NOISE

1.0 DEFINITIONS

The following definitions are to be used only within the context of Part D of this document.

Ambient:

The ambient is the sound existing at the point of reception in the absence of all noise from the Line. In this protocol the ambient is taken to be the noise from road traffic and existing industry. The ambient specifically excludes transient noise from aircraft and railways, except for pre-existing TTC rail operations.

Daytime Equivalent Sound Level:

$L_{eq,16h}$, is the daytime equivalent sound level. The definition of equivalent sound level is provided in Reference 2. The applicable time period is from 07:00 to 23:00 hours.

Nighttime Equivalent Sound Level:

$L_{eq,8h}$ is the nighttime equivalent sound level. The applicable time period is from 23:00 to 07:00 hours.

Point of Reception:

Daytime: 07:00 - 23:00 hours

Any outdoor point on residential property, 15 m or more from the nearest track's centreline, where sound originating from the Line is received.

Nighttime: 23:00 - 07:00 hours

The plane of any bedroom window, 15 m or more from the nearest track's centreline, where sound originating from the Line is received. At the planning stage, this is usually assessed at the nearest facade of the premises.

Passby Sound Level, L_{passby} :

Within the context of this document, the passby sound level is defined as the A-weighted equivalent sound level, L_{eq} [Reference 2] over the passby time interval.

2.0 RAIL TRANSIT

In the assessment of noise impact, rail transit is considered to include the movement of vehicles between stations, the movement and idling of vehicles inside stations as well as the movement of vehicles between the mainline and ancillary facilities. Ancillary facilities are not considered part of the rail transit and are assessed as stationary sources. Vehicles idling in maintenance yards and storage facilities are part of the stationary source.

The assessment of noise impact resulting from the Line is to be performed in terms of the following sound level descriptors:

1) Daytime equivalent sound level, $L_{eq,16h}$,
2) Nighttime equivalent sound level, $L_{eq,8h}$,
3) Passby Sound Level, L_{passby}.

The predicted daytime and nighttime equivalent sound levels include the effects of both passby sound level and frequency of operation and are used to assess the noise impact of the Line. The Passby Sound Level criterion is used to assess the sound levels received during a single vehicle passby. The criteria and methods to be used are discussed in Sections 2.1 and 2.2.

2.1 Criteria

Noise impact shall be predicted and assessed during design of the Line using the following sound level criteria:

DAYTIME EQUIVALENT SOUND LEVEL:

The limit at a point of reception for the predicted daytime equivalent sound levels for rail transit operating alone (excluding contributions from the ambient) is 55 dBA or the ambient $L_{eq,16h}$, whichever is higher.

NIGHTTIME EQUIVALENT SOUND LEVEL:

The limit at a point of reception for the predicted nighttime equivalent sound levels for rail transit operating alone (excluding contributions from the ambient) is 50 dBA or the ambient $L_{eq,8h}$, whichever is higher.

PASSBY SOUND LEVEL:

The limit at a point of reception for predicted L_{passby} for a single vehicle operating alone and excluding contributions from other sources is 80 dBA. This limit is based on vehicles operating on tangent track. It does not apply within 100m of special trackwork and excludes wheel rail squeal.

Mitigating measures will be incorporated in the design of the Line when predictions show that any of the above limits are exceeded by more than 5 dB. All mitigating measures shall ensure that the predicted sound levels are as close to, or lower than, the respective limits as is technologically, economically, and administratively feasible.

2.2 Prediction

In most cases, a reasonable estimate of the ambient sound level can be made using a road traffic noise prediction method such as that described in Reference 8, and the minimum sound levels in Table 106-2 of Reference 6. Prediction of road traffic L_{eq} is preferred to individual measurements in establishing the ambient. Prediction techniques for the L_{eq} from road traffic and the L_{eq} or L_{passby} from transit shall be compatible with one another. Any impact assessment following this protocol shall include a description of the prediction method and the assumptions and sound level data inherent in it. Prediction and measurement methods compatible with MOEE guidelines and procedures are being developed by the TTC at the date of this protocol in consultation with MTO and MOEE.

3.0 ANCILLARY FACILITIES

Predicted noise impacts from ancillary facilities shall be assessed during the design of the Line in accordance with the stationary source guidelines detailed in Reference 5. The predictions used shall be compatible with and at least as accurate as CSA Standard Z107.55.

4.0 BUSES IN MIXED TRAFFIC

Where buses are part of the road traffic there are no additional criteria requirements beyond those presented in the Ministry of Transportation of Ontario Protocol for dealing with noise concerns during the preparation, review and evaluation of Provincial Highways Environmental Assessments [Reference 1]. Buses should be considered as medium trucks in the traffic noise prediction models.

5.0 CONSTRUCTION

Noise impacts from the construction of the Line are to be examined. For the purposes of impact assessment and identifying the need for mitigation, the Ministry of the Environment and Energy guidelines for construction presented in Reference 7 are to be referred to.

PART E. GROUND-BORNE VIBRATION

The assessment of ground-borne vibration impact is confined to the vibration that is produced by the operation of the Line and excludes vibration due to maintenance activities.

In recognition of the fact that the actual vibration response of a building is affected by its own structural characteristics, this document deals with the assessment of ground-borne vibration only on the outside premises. Structural characteristics of buildings are beyond the scope of this protocol and beyond the control of the TTC.

It is recognised that ground-borne vibration can produce air-borne noise inside a structure and there is a direct correlation between the two. The TTC can only control ground-borne noise by controlling ground-borne vibration. Accordingly, ground-borne noise will be predicted and assessed in terms of vibration measured at a point of assessment using the limit in Section 2.0, Vibration Assessment.

1.0 DEFINITIONS

The following definitions are to be used only within the context of Part E of this document.

Point of Assessment:

A point of assessment is any outdoor point on residential property, 15 m or more from the nearest track's centreline, where vibration originating from the Line is received.

Vibration Velocity:

Vibration Velocity is the root-mean-square (rms) vibration velocity assessed during a vehicle pass-by. The unit of measure is metres per second (m/s) or millimetres per second (mm/s). For the purposes of this protocol only vertical vibration is assessed. The vertical component of transit vibration is usually higher than the horizontal. Human sensitivity to horizontal vibration at the frequencies of interest is significantly less than the sensitivity to vertical vibration.

2.0 VIBRATION ASSESSMENT

Vibration velocities at points of assessment shall be predicted during design of the Line. If the predicted rms vertical vibration velocity from the Line exceeds 0.14 mm/sec, mitigation methods shall be applied during the detailed design to meet this criterion to the extent technologically, economically and administratively feasible.

Any impact assessment following this protocol shall include a description of the prediction method and the assumptions and data inherent in it. Prediction and measurement methods are being developed by the TTC at the date of this protocol in cooperation with MTO and MOEE.

Appendix C

References

APPENDIX C: REFERENCES

1. Ministry of the Environment, "Model Municipal Noise Control By-Law, Final Report", August, 1978.

2. Ministry of the Environment, Noise Assessment Criteria in Land Use Planning, Publication *LU-131*, October 1997 and its Annex, October 1997.

3. Ministry of the Environment's *STAMSON* Computer Programme (Version 5.03).

4. Ministry of Transportation of Ontario, Provincial and Environmental Planning Office "Environmental Guide for Noise", October 2006.

5. Model Municipal Noise Control By-Law, Final Report, Publication *NPC-101* Technical Definitions, Ministry of the Environment, August 1978

6. Model Municipal Noise Control By-Law, Final Report, Publication *NPC-102* Instrumentation, Ministry of the Environment, August 1978

7. Model Municipal Noise Control By-Law, Final Report, Publication *NPC-103* Procedures, Ministry of the Environment, August 1978

8. Model Municipal Noise Control By-Law, Final Report, Publication *NPC-104* Sound Level Adjustments, August 1978

9. Ministry of the Environment, Sound Level Limits for Stationary Sources in Class 1 and 2 Areas (Urban), Publication NPC-205, October 1995

10. Ministry of the Environment, Sound Levels Due to Road Traffic, Publication *NPC-206*, October 1995

11. City of Toronto Municipal Code, Chapter 591, Noise, Amended December 2007

12. City of Toronto Municipal Code, Chapter 363, Building Construction and Demolition, December 2008

13. Model Municipal Noise Control By-Law, Final Report, Publication *NPC-115*, Construction Equipment, August 1978

Appendix D

Definitions

APPENDIX D: DEFINITIONS

1 dB CHANGE (Noise)

For sounds experienced by a listener, one immediately following the other, a 1 dB change is the smallest increment which can be reliably detected by most people. If the time delay between experiencing the sounds is more than a few seconds, the change is not reliably detected (i.e., the listener is not sensitive to a 1 dB change occurring over 1 year's time). In environmental noise, a 1 dB change occurs with an increase in traffic of 25%.

3 dB CHANGE (Noise)

An increase in the L_{eq} of 3 dB is reliably detected by most listeners, and is the smallest change considered significant by most planning authorities. It is the smallest change in the overall L_{eq} (all sounds combined) which can be reliably detected by standard noise monitoring techniques. A doubling of traffic in a community will cause a 3 dB change, if traffic is the only major noise source.

5 dB CHANGE (Noise)

An increase in the overall L_{eq} of 5 dB represents a relatively significant impact in terms of overall Leq, particularly if an area is already at or above daytime L_{eq} of 55.

10 dB CHANGE (Noise)

A 10 dB increase in overall L_{eq} represents a doubling in the loudness of the sound, and represents a major impact on an urban community, especially if the levels are already above 50 L_{eq}.

Leq

L_{eq} is the sound pressure level averaged over the measurement period. It can be considered as the continuous steady sound pressure level that would have the same total acoustic energy as the real fluctuating noise over the same time period. This index is the most representative measure of community response to sound levels.

Ground-borne Vibration

Ground-borne vibration is vibration transmitted through the soil that is felt, rather than heard. Typically, vibration levels are most felt at frequencies below 50Hz.

Vibration-induced Noise

Vibration-induced noise is a result of ground-borne vibration being transmitted into the structure of a building and radiating as a “rumbly” sound that is more audible than “feelable” to the touch. Generally, vibration-induced noise is a concern at frequencies greater than 50Hz.

Vibration Velocity

Vibration velocity is the speed at which the building or ground moves up and down or sideways as it oscillates. It is does not relate to how fast the vibration wave is moving along in the soil.

Double Crossover

A type of special trackwork structure that allows a rail vehicle to switch directions, without the need for a loop.

Double-ended Pocket Track

A type of special trackwork structure that allows a vehicle to be stored in between two tracks in case of emergencies/vehicle breakdown.

Appendix E

Sample Calculations

```
STAMSON 5.0        NORMAL REPORT        Date: 04-01-2012 15:58:28
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: nppor1.te            Time Period: Day/Night 16/8 hours
Description: POR 1 - No Project  DISTANCES DOUBLED

Road data, segment # 1: James (day/night)
-----------------------------------------
Car traffic volume  :  7143/794   veh/TimePeriod
Medium truck volume :   169/19    veh/TimePeriod
Heavy truck volume  :    71/8     veh/TimePeriod
Posted speed limit  :    50 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: James (day/night)
---------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  24.00 / 24.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


Results segment # 1: James (day)
--------------------------------

Source height = 0.99 m

ROAD (0.00 + 59.50 + 0.00) = 59.50 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  61.54   0.00  -2.04   0.00   0.00   0.00   0.00  59.50
----------------------------------------------------------------------------

Segment Leq : 59.50 dBA

Total Leq All Segments: 59.50 dBA


Results segment # 1: James (night)
----------------------------------

Source height = 0.99 m

ROAD (0.00 + 53.00 + 0.00) = 53.00 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  55.04   0.00  -2.04   0.00   0.00   0.00   0.00  53.00
----------------------------------------------------------------------------

Segment Leq : 53.00 dBA

Total Leq All Segments: 53.00 dBA


TOTAL Leq FROM ALL SOURCES (DAY): 59.50
                         (NIGHT): 53.00
```

STAMSON 5.0 NORMAL REPORT Date: 04-01-2012 15:58:50
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: wplrt.te Time Period: Day/Night 16/8 hours
Description: POR 1 - With LRT Project **DISTANCES DOUBLED**

Road data, segment # 1: James (day/night)

```
Car traffic volume  :  6656/740   veh/TimePeriod
Medium truck volume :   164/18    veh/TimePeriod
Heavy truck volume  :    67/7     veh/TimePeriod
Posted speed limit  :    50 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)
```

Data for Segment # 1: James (day/night)

```
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  23.00 / 23.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00
```

Results segment # 1: James (day)

Source height = 0.99 m

ROAD (0.00 + 59.43 + 0.00) = 59.43 dBA

Angle1	Angle2	Alpha	RefLeq	P.Adj	D.Adj	F.Adj	W.Adj	H.Adj	B.Adj	SubLeq
-90	90	0.00	61.28	0.00	-1.86	0.00	0.00	0.00	0.00	59.43

Segment Leq : 59.43 dBA

Total Leq All Segments: 59.43 dBA

Results segment # 1: James (night)

Source height = 0.98 m

ROAD (0.00 + 52.80 + 0.00) = 52.80 dBA

Angle1	Angle2	Alpha	RefLeq	P.Adj	D.Adj	F.Adj	W.Adj	H.Adj	B.Adj	SubLeq
-90	90	0.00	54.66	0.00	-1.86	0.00	0.00	0.00	0.00	52.80

Segment Leq : 52.80 dBA

Total Leq All Segments: 52.80 dBA

TOTAL Leq FROM ALL SOURCES (DAY): 59.43
(NIGHT): 52.80

STAMSON 5.0   NORMAL REPORT   Date: 04-01-2012 15:59:30
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: lrtpor1.te   Time Period: Day/Night 16/8 hours
Description: POR 1 - LRT Only **DISTANCES DOUBLED, LRT Volumes Increased x10**

Road data, segment # 1: LRT (day/night)

```
Car traffic volume  :     0/0     veh/TimePeriod
Medium truck volume :  6640/1440  veh/TimePeriod
Heavy truck volume  :     0/0     veh/TimePeriod
Posted speed limit  :    50 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)
```

Data for Segment # 1: LRT (day/night)

```
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  24.00 / 24.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00
```

Results segment # 1: LRT (day)

Source height = 0.50 m

ROAD (0.00 + 67.91 + 0.00) = 67.91 dBA

Angle1	Angle2	Alpha	RefLeq	P.Adj	D.Adj	F.Adj	W.Adj	H.Adj	B.Adj	SubLeq
-90	90	0.00	69.95	0.00	-2.04	0.00	0.00	0.00	0.00	67.91

Segment Leq : 67.91 dBA

Total Leq All Segments: 67.91 dBA

Results segment # 1: LRT (night)

Source height = 0.50 m

ROAD (0.00 + 64.28 + 0.00) = 64.28 dBA

Angle1	Angle2	Alpha	RefLeq	P.Adj	D.Adj	F.Adj	W.Adj	H.Adj	B.Adj	SubLeq
-90	90	0.00	66.32	0.00	-2.04	0.00	0.00	0.00	0.00	64.28

Segment Leq : 64.28 dBA

Total Leq All Segments: 64.28 dBA

TOTAL Leq FROM ALL SOURCES (DAY): 67.91
(NIGHT): 64.28

```
STAMSON 5.0        NORMAL REPORT        Date: 04-01-2012 15:59:11
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: wpbrt.te             Time Period: Day/Night 16/8 hours
```
Description: POR 1 - With BRT Project **DISTANCES DOUBLED**

```
Road data, segment # 1: James (day/night)
-----------------------------------------
Car traffic volume  :  4890/543   veh/TimePeriod
Medium truck volume :   146/16    veh/TimePeriod
Heavy truck volume  :    49/5     veh/TimePeriod
Posted speed limit  :    50 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: James (day/night)
---------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  23.00 / 23.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


Results segment # 1: James (day)
--------------------------------

Source height = 0.99 m

ROAD (0.00 + 58.25 + 0.00) = 58.25 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  60.10   0.00  -1.86   0.00   0.00   0.00   0.00  58.25
----------------------------------------------------------------------------

Segment Leq : 58.25 dBA

Total Leq All Segments: 58.25 dBA


Results segment # 1: James (night)
----------------------------------

Source height = 0.97 m

ROAD (0.00 + 51.59 + 0.00) = 51.59 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  53.45   0.00  -1.86   0.00   0.00   0.00   0.00  51.59
----------------------------------------------------------------------------

Segment Leq : 51.59 dBA

Total Leq All Segments: 51.59 dBA


TOTAL Leq FROM ALL SOURCES (DAY): 58.25
                         (NIGHT): 51.59
```

```
STAMSON 5.0        NORMAL REPORT        Date: 04-01-2012 15:59:42
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: brtpor1.te            Time Period: Day/Night 16/8 hours
Description: POR 1 - BRT Only DISTANCES DOUBLED, BRT Volumes Increased x10


Road data, segment # 1: BRT (day/night)
---------------------------------------
Car traffic volume  :     0/0     veh/TimePeriod
Medium truck volume :  4530/1080  veh/TimePeriod
Heavy truck volume  :     0/0     veh/TimePeriod
Posted speed limit  :    50 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: BRT (day/night)
-------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  24.00 / 24.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


Results segment # 1: BRT (day)
------------------------------

Source height = 0.50 m

ROAD (0.00 + 66.24 + 0.00) = 66.24 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  68.29   0.00  -2.04   0.00   0.00   0.00   0.00  66.24
----------------------------------------------------------------------------

Segment Leq : 66.24 dBA

Total Leq All Segments: 66.24 dBA


Results segment # 1: BRT (night)
--------------------------------

Source height = 0.50 m

ROAD (0.00 + 63.03 + 0.00) = 63.03 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  65.07   0.00  -2.04   0.00   0.00   0.00   0.00  63.03
----------------------------------------------------------------------------

Segment Leq : 63.03 dBA

Total Leq All Segments: 63.03 dBA


TOTAL Leq FROM ALL SOURCES (DAY): 66.24
                         (NIGHT): 63.03
```

```
STAMSON 5.0        NORMAL REPORT        Date: 04-01-2012 16:11:43
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: mp.te                Time Period: Day/Night 16/8 hours
Description: POR 8 - No Project


Road data, segment # 1: James (day/night)
-----------------------------------------
Car traffic volume  : 28911/3212  veh/TimePeriod
Medium truck volume :  2257/251   veh/TimePeriod
Heavy truck volume  :  1941/216   veh/TimePeriod
Posted speed limit  :    60 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: James (day/night)
---------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  18.00 / 18.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


Results segment # 1: James (day)
--------------------------------

Source height = 1.56 m

ROAD (0.00 + 73.38 + 0.00) = 73.38 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
---------------------------------------------------------------------------
   -90     90   0.00  74.18   0.00  -0.79   0.00   0.00   0.00   0.00  73.38
---------------------------------------------------------------------------

Segment Leq : 73.38 dBA

Total Leq All Segments: 73.38 dBA


Results segment # 1: James (night)
----------------------------------

Source height = 1.56 m

ROAD (0.00 + 66.86 + 0.00) = 66.86 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
---------------------------------------------------------------------------
   -90     90   0.00  67.65   0.00  -0.79   0.00   0.00   0.00   0.00  66.86
---------------------------------------------------------------------------

Segment Leq : 66.86 dBA

Total Leq All Segments: 66.86 dBA


TOTAL Leq FROM ALL SOURCES (DAY): 73.38
                         (NIGHT): 66.86
```

```
STAMSON 5.0        NORMAL REPORT        Date: 04-01-2012 16:11:57
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: wplrt.te             Time Period: Day/Night 16/8 hours
Description: POR 8 - With LRT Project


Road data, segment # 1: James (day/night)
-----------------------------------------
Car traffic volume  : 18094/2010  veh/TimePeriod
Medium truck volume :  1910/212   veh/TimePeriod
Heavy truck volume  :  1813/201   veh/TimePeriod
Posted speed limit  :    60 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: James (day/night)
---------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  16.00 / 16.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


Results segment # 1: James (day)
--------------------------------

Source height = 1.70 m

ROAD (0.00 + 73.24 + 0.00) = 73.24 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  73.52   0.00  -0.28   0.00   0.00   0.00   0.00  73.24
----------------------------------------------------------------------------

Segment Leq : 73.24 dBA

Total Leq All Segments: 73.24 dBA


Results segment # 1: James (night)
----------------------------------

Source height = 1.70 m

ROAD (0.00 + 66.70 + 0.00) = 66.70 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  66.98   0.00  -0.28   0.00   0.00   0.00   0.00  66.70
----------------------------------------------------------------------------

Segment Leq : 66.70 dBA

Total Leq All Segments: 66.70 dBA



TOTAL Leq FROM ALL SOURCES (DAY): 73.24
                         (NIGHT): 66.70
```

```
STAMSON 5.0        NORMAL REPORT        Date: 04-01-2012 16:13:21
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: lrt.te               Time Period: Day/Night 16/8 hours
Description: POR 8 - LRT Only VOLUMES INCREASED x10
```

```
Road data, segment # 1: LRT (day/night)
---------------------------------------
Car traffic volume  :     0/0     veh/TimePeriod
Medium truck volume :  6640/1440  veh/TimePeriod
Heavy truck volume  :     0/0     veh/TimePeriod
Posted speed limit  :    60 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: LRT (day/night)
-------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  18.00 / 18.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


Results segment # 1: LRT (day)
------------------------------

Source height = 0.50 m

ROAD (0.00 + 71.05 + 0.00) = 71.05 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  71.84   0.00  -0.79   0.00   0.00   0.00   0.00  71.05
----------------------------------------------------------------------------

Segment Leq : 71.05 dBA

Total Leq All Segments: 71.05 dBA


Results segment # 1: LRT (night)
--------------------------------

Source height = 0.50 m

ROAD (0.00 + 67.42 + 0.00) = 67.42 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  68.21   0.00  -0.79   0.00   0.00   0.00   0.00  67.42
----------------------------------------------------------------------------

Segment Leq : 67.42 dBA

Total Leq All Segments: 67.42 dBA



TOTAL Leq FROM ALL SOURCES (DAY): 71.05
                         (NIGHT): 67.42
```

```
STAMSON 5.0        NORMAL REPORT        Date: 04-01-2012 16:12:53
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: wpbrt.te             Time Period: Day/Night 16/8 hours
Description: POR 8 - With BRT Project


Road data, segment # 1: James (day/night)
-----------------------------------------
Car traffic volume  : 17279/1920  veh/TimePeriod
Medium truck volume :   730/81    veh/TimePeriod
Heavy truck volume  :   633/70    veh/TimePeriod
Posted speed limit  :    60 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: James (day/night)
---------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  16.00 / 16.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


Results segment # 1: James (day)
--------------------------------

Source height = 1.36 m

ROAD (0.00 + 69.65 + 0.00) = 69.65 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  69.93   0.00  -0.28   0.00   0.00   0.00   0.00  69.65
----------------------------------------------------------------------------

Segment Leq : 69.65 dBA

Total Leq All Segments: 69.65 dBA


Results segment # 1: James (night)
----------------------------------

Source height = 1.36 m

ROAD (0.00 + 63.11 + 0.00) = 63.11 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------------
   -90     90   0.00  63.39   0.00  -0.28   0.00   0.00   0.00   0.00  63.11
----------------------------------------------------------------------------

Segment Leq : 63.11 dBA

Total Leq All Segments: 63.11 dBA



TOTAL Leq FROM ALL SOURCES (DAY): 69.65
                         (NIGHT): 63.11
```

STAMSON 5.0   NORMAL REPORT   Date: 04-01-2012 16:13:30
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: brt.te   Time Period: Day/Night 16/8 hours
Description: POR 8 - BRT Only **VOLUMES INCREASED x10**

```
Road data, segment # 1: BRT (day/night)
---------------------------------------
Car traffic volume  :     0/0     veh/TimePeriod
Medium truck volume :  4530/1080  veh/TimePeriod
Heavy truck volume  :     0/0     veh/TimePeriod
Posted speed limit  :    60 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: BRT (day/night)
-------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  18.00 / 18.00  m
Receiver height           :   1.50 / 4.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00
```

Results segment # 1: BRT (day)

Source height = 0.50 m

ROAD (0.00 + 69.39 + 0.00) = 69.39 dBA

Angle1	Angle2	Alpha	RefLeq	P.Adj	D.Adj	F.Adj	W.Adj	H.Adj	B.Adj	SubLeq
-90	90	0.00	70.18	0.00	-0.79	0.00	0.00	0.00	0.00	69.39

Segment Leq : 69.39 dBA

Total Leq All Segments: 69.39 dBA

Results segment # 1: BRT (night)

Source height = 0.50 m

ROAD (0.00 + 66.17 + 0.00) = 66.17 dBA

Angle1	Angle2	Alpha	RefLeq	P.Adj	D.Adj	F.Adj	W.Adj	H.Adj	B.Adj	SubLeq
-90	90	0.00	66.96	0.00	-0.79	0.00	0.00	0.00	0.00	66.17

Segment Leq : 66.17 dBA

Total Leq All Segments: 66.17 dBA

TOTAL Leq FROM ALL SOURCES (DAY): 69.39
                         (NIGHT): 66.17

Appendix F

Traffic Data

2021 BRT Option Final Output Table

			AM Peak Hour			Daily					
						Daytime			Nighttime		
Street	From	To	Cars	Buses	Trucks	Cars	Medium Tru	Heavy Truck	Cars	Medium Tru	Heavy Trucks
Charlton Ave	Charlton Ave East	Charlton Ave West	847	0	39	10306	237	237	1145	26	26
John Street	Young St	Charlton Ave East	1287	35	13	15660	505	79	1740	56	9
John Street	Augusta St	Young St	1287	35	13	15660	505	79	1740	56	9
John Street	John St	Augusta St	1168	38	10	14212	523	61	1579	58	7
Hunter St	Hughson St South	John St	1015	7	100	12351	694	608	1372	77	68
Hunter St	Hunter St	Hughson St South	1015	7	315	12351	2002	1916	1372	222	213
James Street	Strachan St	Burlington St West	402	8	8	4890	146	49	543	16	5
James Street	Murray St	Strachan St	402	8	8	4890	146	49	543	16	5
James Street	Barton St	Murray St	342	4	7	4167	90	42	463	10	5
James Street	Cannon St	Barton St	430	10	9	5228	174	52	581	19	6
James Street	York Blvd	Cannon St	532	10	11	6476	186	65	720	21	7
James Street	Rebecca St	York Blvd	905	17	18	11008	317	110	1223	35	12
James Street	King William St	Rebecca St	918	20	18	11167	355	112	1241	39	12
James Street	King St West	King William St	868	20	17	10561	349	106	1173	39	12
James Street	King St East	King St West	613	52	1	7459	639	6	829	71	1
James Street	Main Street	King St East	613	52	1	7459	639	6	829	71	1
James Street	Jackson St East	Main Street	468	53	0	5695	645	0	633	72	0
James Street	Hunter St	Jackson St East	917	53	14	11158	730	85	1240	81	9
James Street	Bold St	Hunter St	1000	38	290	12168	2227	1764	1352	247	196
James Street	Augusta St	Bold St	1358	41	189	16524	1649	1150	1836	183	128
James Street	Duke St	Augusta St	1239	38	189	15076	1612	1150	1675	179	128
James Street	Charlton Ave West	Duke St	829	35	190	10087	1582	1156	1121	176	128
James Street	St. Joseph's Drive	Charlton Ave West	872	35	176	10610	1497	1071	1179	166	119
James Street	Markland St	St. Joseph's Drive	367	4	5	4466	79	30	496	9	3
James Street	Aberdeen Ave	Markland St	367	0	16	4466	97	97	496	11	11
James Mtn Rd	Claremont Drive	Aberdeen Ave				0	0	0	0	0	0
West 5th Ave	Brantdale Ave	Claremont Drive	1045	0	31	12716	189	189	1413	21	21
West 5th Ave	West 5th St.	Brantdale Ave	189	0	5	2300	30	30	256	3	3
Fennell Ave W	West 2nd St.	West 5th St.	1261	20	22	15344	377	134	1705	42	15
Fennell Ave W	Fennell Ave	West 2nd St.	1279	20	22	15563	377	134	1729	42	15
Upper James St.	South Bend Rd	Fennell Ave	1420	8	104	17279	730	633	1920	81	70
Upper James St.	Mohawk Rd	South Bend Rd	1484	8	107	18057	748	651	2006	83	72
Upper James St.	Aldridge St.	Mohawk Rd	1173	8	77	14273	566	468	1586	63	52
Upper James St.	LA Pkwy WB Offramp	Aldridge St.	1874	8	103	22803	724	627	2534	80	70
Upper James St.	LA Pkwy WB Onramp for James NB traffic	LA Pkwy WB Offramp	1531	8	85	18629	614	517	2070	68	57
Upper James St.	LA Pkwy EB Onramp for James SB traffic	LA Pkwy WB Onramp for James NB traffic	1807	8	99	21988	700	602	2443	78	67
Upper James St.	LA Pkwy WB Offramp	LA Pkwy EB Onramp for James SB traffic	1406	8	79	17108	578	481	1901	64	53
Upper James St.	LA Pkwy EB Onramp for James NB traffic	LA Pkwy WB Offramp	1326	8	58	16135	450	353	1793	50	39
Upper James St.	Chipman Ave	LA Pkwy EB Onramp for James NB traffic	1598	8	71	19444	529	432	2160	59	48
Upper James St.	Stone Church Rd	Chipman Ave	854	8	34	10391	304	207	1155	34	23
Upper James St.	Rymal Road	Stone Church Rd	669	12	23	8140	286	140	904	32	16
Upper James St.	Alderlea Ave	Rymal Road	1457	8	81	17729	590	493	1970	66	55
Upper James St.	Twenty Rd	Alderlea Ave	1457	8	81	17729	590	493	1970	66	55
Upper James St.	Mountain Transit Centre	Twenty Rd	1373	8	59	16707	456	359	1856	51	40
Upper James St.	Dickenson Rd	Mountain Transit Centre	1342	0	66	16329	402	402	1814	45	45
Upper James St.	English Church Rd	Dickenson Rd	1798	0	89	21878	541	541	2431	60	60
Upper James St.	Homestead Drive	English Church Rd	1473	0	73	17923	444	444	1991	49	49
Homestead Drive	Airport Road	Upper James St.	209	0	4	2543	24	24	283	3	3
Airport Rd	Airport Access Road	Homestead Drive	19	0	0	231	0	0	26	0	TRUE

2021 BAU for BRT Links Final Output Table

			AM PEAK HOUR			DAILY VOLUMES					
						Daytime			Nighttime		
Street	From	To	Cars	Buses	Trucks	Cars	Medium Trucks and Bu	Heavy Trucks	Cars	Medium Tru	Heavy Trucks
Charlton Ave	Charlton Ave East	Charlton Ave West	827	0	24	10063	146	146	1118	16	16
John Street	Young St	Charlton Ave East	1343	46	18	16342	669	110	1816	74	12
John Street	Augusta St	Young St	1343	46	18	16342	669	110	1816	74	12
John Street	John St	Augusta St	1184	49	13	14407	675	79	1601	75	9
Hunter St	Hughson St South	John St	1100	7	346	13385	2190	2105	1487	243	234
Hunter St	Hunter St	Hughson St South	1100	7	74	13385	535	450	1487	59	50
James Street	Strachan St	Burlington St West	587	8	12	7143	169	71	794	19	8
James Street	Murray St	Strachan St	587	8	12	7143	169	71	794	19	8
James Street	Barton St	Murray St	587	4	12	7143	120	71	794	13	8
James Street	Cannon St	Barton St	669	10	13	8140	203	81	904	23	9
James Street	York Blvd	Cannon St	741	10	15	9016	212	90	1002	24	10
James Street	Rebecca St	York Blvd	944	17	19	11487	322	115	1276	36	13
James Street	King William St	Rebecca St	990	20	20	12046	364	120	1338	40	13
James Street	King St West	King William St	1026	20	21	12484	368	125	1387	41	14
James Street	King St East	King St West	751	63	5	9138	797	30	1015	89	3
James Street	Main Street	King St East	751	63	5	9138	797	30	1015	89	3
James Street	Jackson St East	Main Street	1101	64	9	13397	834	55	1489	93	6
James Street	Hunter St	Jackson St East	1576	64	24	19177	925	146	2131	103	16
James Street	Bold St	Hunter St	1929	49	73	23472	1040	444	2608	116	49
James Street	Augusta St	Bold St	1985	52	25	24153	785	152	2684	87	17
James Street	Duke St	Augusta St	1826	49	25	22219	748	152	2469	83	17
James Street	Charlton Ave West	Duke St	1530	46	27	18617	724	164	2069	80	18
James Street	St. Joseph's Drive	Charlton Ave West	1490	46	25	18130	712	152	2014	79	17
James Street	Markland St	St. Joseph's Drive	1375	40	7	16731	529	43	1859	59	5
James Street	Aberdeen Ave	Markland St	1375	40	28	16731	657	170	1859	73	19
James Mtn Rd	Claremont Drive	Aberdeen Ave	1485	40	33	18069	687	201	2008	76	22
West 5th Ave	Brantdale Ave	Claremont Drive	2372	40	31	28862	675	189	3207	75	21
West 5th Ave	West 5th St.	Brantdale Ave	1301	40	1	15831	493	6	1759	55	1
Fennell Ave W	West 2nd St.	West 5th St.	1706	24	37	20759	517	225	2307	57	25
Fennell Ave W	Fennell Ave	West 2nd St.	1721	24	38	20941	523	231	2327	58	26
Upper James St.	South Bend Rd	Fennell Ave	2376	26	319	28911	2257	1941	3212	251	216
Upper James St.	Mohawk Rd	South Bend Rd	2463	26	325	29970	2294	1977	3330	255	220
Upper James St.	Aldridge St.	Mohawk Rd	2331	26	308	28364	2190	1874	3152	243	208
Upper James St.	LA Pkwy WB Offramp	Aldridge St.	3005	26	260	36565	1898	1582	4063	211	176
Upper James St.	LA Pkwy WB Onramp for James NB traffic	LA Pkwy WB Offramp	2767	26	248	33669	1825	1509	3741	203	168
Upper James St.	LA Pkwy EB Onramp for James SB traffic	LA Pkwy WB Onramp for James NB traffic	3089	26	264	37587	1923	1606	4176	214	178
Upper James St.	LA Pkwy WB Offramp	LA Pkwy EB Onramp for James SB traffic	2661	26	242	32379	1789	1472	3598	199	164
Upper James St.	LA Pkwy EB Onramp for James NB traffic	LA Pkwy WB Offramp	2397	26	211	29167	1600	1284	3241	178	143
Upper James St.	Chipman Ave	LA Pkwy EB Onramp for James NB traffic	2678	26	225	32586	1685	1369	3621	187	152
Upper James St.	Stone Church Rd	Chipman Ave	1768	26	180	21513	1411	1095	2390	157	122
Upper James St.	Rymal Road	Stone Church Rd	1172	30	66	14261	767	402	1585	85	45
Upper James St.	Alderlea Ave	Rymal Road	1841	26	83	22401	821	505	2489	91	56
Upper James St.	Twenty Rd	Alderlea Ave	1841	26	83	22401	821	505	2489	91	56
Upper James St.	Mountain Transit Centre	Twenty Rd	861	26	15	10477	408	91	1164	45	10
Upper James St.	Dickenson Rd	Mountain Transit Centre	1465	8	65	17826	493	395	1981	55	44
Upper James St.	English Church Rd	Dickenson Rd	1861	8	85	22645	614	517	2516	68	57
Upper James St.	Homestead Drive	English Church Rd	1537	8	68	18702	511	414	2078	57	46
Homestead Drive	Airport Road	Upper James St.	221	8	0	2689	97	0	299	11	0
Airport Rd	Airport Access Road	Homestead Drive	19	8	0	231	97	0	26	11	0

2021 LRT Final Output Table

			AM PEAK HOUR			DAILY VOLUMES					
						Daytime			Nighttime		
Street	**From**	**To**	**Cars**	**Buses**	**Trucks**	**Cars**	**Medium Tru**	**Heavy Truck**	**Cars**	**Medium Tru**	**Heavy Trucks**
Wellington St	Main St	Jackson St E	1686	6	75	20515	529	456	2279	59	51
Wellington St	King St	Main St	1452	0	73	17668	444	444	1963	49	49
James Street	Strachan St	Burlington St West	547	8	11	6656	164	67	740	18	7
James Street	Murray St	Strachan St	547	8	11	6656	164	67	740	18	7
James Street	Barton St	Murray St	487	4	10	5928	108	59	659	12	7
James Street	Cannon St	Barton St	529	10	11	6441	186	64	716	21	7
James Street	York St	Cannon St	663	10	13	8069	202	81	897	22	9
James Street	Rebecca St	York St	882	17	18	10732	314	107	1192	35	12
James Street	King William St	Rebecca St	933	20	19	11353	357	114	1261	40	13
James Street	King St	King William St	922	20	18	11225	356	112	1247	40	12
King Street	Hughson St N	James St	333	51	0	4052	621	0	450	69	0
King Street	John St	Hughson St N	366	47	0	4453	572	0	495	64	0
King Street	Walnut	John St	0	9	0	0	110	0	0	12	0
King Street	Ferguson Ave S	Walnut	0	9	0	0	110	0	0	12	0
King Street	Ferguson Ave N	Ferguson Ave S	0	9	0	0	110	0	0	12	0
King Street	Wellington St	Ferguson Ave N	0	9	0	0	110	0	0	12	0
King Street	West Ave N	Wellington St	833	6	49	10136	371	298	1126	41	33
King Street	Victoria Ave	West Ave N	833	6	49	10136	371	298	1126	41	33
Victoria Ave	Main St	King St	1748	2	50	21270	329	304	2363	37	34
Victoria Ave	Stinson St	Main St	1798	2	52	21878	341	316	2431	38	35
Claremont Access	Young St	Stinson St	3242	0	162	39449	986	986	4383	110	110
Claremont Access	Charlton Ave East	Young St	3242	0	162	39449	986	986	4383	110	110
Claremont Access	Offramp to Sherman Access	Charlton Ave East	3242	0	162	39449	986	986	4383	110	110
Claremont Access	Upper James St	Offramp to Sherman Access	3394	0	169	41298	1028	1028	4589	114	114
Claremont Drive	West 5th Ave	Upper James St	456	0	299	5549	1819	1819	617	202	202
West 5th St	Brantdale Ave	Claremont Drive	1696	16	35	20637	408	213	2293	45	24
West 5th St	Fennell Ave W	Brantdale Ave	770	16	8	9369	243	49	1041	27	5
Fennell Ave W	West 2nd St	West 5th St	1136	16	25	13823	347	152	1536	39	17
Fennell Ave W	Upper James St	West 2nd St	1152	16	24	14018	341	146	1558	38	16
Upper James St.	South Bend Rd	Fennell Ave W	1487	8	298	18094	1910	1813	2010	212	201
Upper James St.	Mohawk Rd	South Bend Rd	1551	8	300	18873	1923	1825	2097	214	203
Upper James St.	Aldridge St.	Mohawk Rd	1212	8	270	14748	1740	1643	1639	193	183
Upper James St.	LA Pkwy WB Offramp	Aldridge St.	1911	8	294	23253	1886	1789	2584	210	199
Upper James St.	LA Pkwy WB Onramp for James NB traffic	LA Pkwy WB Offramp	1560	8	277	18982	1783	1685	2109	198	187
Upper James St.	LA Pkwy EB Onramp for James SB traffic	LA Pkwy WB Onramp for James NB traffic	1827	8	290	22231	1862	1764	2470	207	196
Upper James St.	LA Pkwy WB Offramp	LA Pkwy EB Onramp for James SB traffic	1457	8	272	17729	1752	1655	1970	195	184
Upper James St.	LA Pkwy EB Onramp for James NB traffic	LA Pkwy WB Offramp	1383	8	178	16828	1180	1083	1870	131	120
Upper James St.	Chipman Ave	LA Pkwy EB Onramp for James NB traffic	1647	8	191	20041	1259	1162	2227	140	129
Upper James St.	Stone Church Rd	Chipman Ave	901	8	154	10963	1034	937	1218	115	104
Upper James St.	Rymal Rd	Stone Church Rd	698	12	55	8493	481	335	944	53	37
Upper James St.	Alderlea Ave	Rymal Rd	1454	8	81	17692	590	493	1966	66	55
Upper James St.	Twenty Rd	Alderlea Ave	1454	8	81	17692	590	493	1966	66	55
Upper James St.	Mountain Transit Centre	Twenty Rd	1377	8	77	16755	566	468	1862	63	52
Upper James St.	Dickenson Rd	Mountain Transit Centre	1344	0	65	16354	395	395	1817	44	44
Upper James St.	English Church Rd	Dickenson Rd	1817	0	90	22109	548	548	2457	61	61
Upper James St.	Homestead Drive	English Church Rd	1493	0	73	18167	444	444	2019	49	49
Homestead Drive	Airport Rd	Upper James St	210	0	5	2555	30	30	284	3	3
Airport Rd	Airport Access Rd	Homestead Drive	19	0	0	231	0	0	26	0	0
Claremont Access	Jackson St E	Stinson St	1442	0	43	17546	262	262	1950	29	29
James Mtn Rd	Claremont Drive	Aberdeen Ave	1240	16	321	15088	2148	1953	1676	239	217

2021 BAU for LRT Links Final Output Table

Street	From	To	AM PEAK HOUR			DAILY VOLUMES					
						Daytime			Nighttime		
Street	From	To	Cars	Buses	Trucks	Cars	Medium Tru	Heavy Truck	Cars	Medium Tru	Heavy Trucks
Wellington St	Main St	Jackson St E	2222	6	90	27037	621	548	3004	69	61
Wellington St	King St	Main St	1831	0	85	22280	517	517	2476	57	57
James Street	Strachan St	Burlington St West	587	8	12	7143	169	71	794	19	8
James Street	Murray St	Strachan St	587	8	12	7143	169	71	794	19	8
James Street	Barton St	Murray St	587	4	12	7143	120	71	794	13	8
James Street	Cannon St	Barton St	669	10	13	8140	203	81	904	23	9
James Street	York St	Cannon St	741	10	15	9016	212	90	1002	24	10
James Street	Rebecca St	York St	944	17	19	11487	322	115	1276	36	13
James Street	King William St	Rebecca St	990	20	20	12046	364	120	1338	40	13
James Street	King St	King William St	1026	20	21	12484	368	125	1387	41	14
King Street	Hughson St N	James St	420	60	0	5111	730	0	568	81	0
King Street	John St	Hughson St N	566	56	0	6887	681	0	765	76	0
King Street	Walnut	John St	0	9	0	0	110	0	0	12	0
King Street	Ferguson Ave S	Walnut	0	9	0	0	110	0	0	12	0
King Street	Ferguson Ave N	Ferguson Ave S	0	9	0	0	110	0	0	12	0
King Street	Wellington St	Ferguson Ave N	0	9	0	0	110	0	0	12	0
King Street	West Ave N	Wellington St	1107	6	57	13470	420	347	1497	47	39
King Street	Victoria Ave	West Ave N	1107	6	57	13470	420	347	1497	47	39
Victoria Ave	Main St	King St	1917	2	55	23326	359	335	2592	40	37
Victoria Ave	Stinson St	Main St	2036	2	59	24774	383	359	2753	43	40
Claremont Access	Young St	Stinson St	4192	0	467	51008	2841	2841	5668	316	316
Claremont Access	Charlton Ave East	Young St	4192	0	467	51008	2841	2841	5668	316	316
Claremont Access	Offramp to Sherman Access	Charlton Ave East	4192	0	467	51008	2841	2841	5668	316	316
Claremont Access	Upper James St	Offramp to Sherman Access	4335	0	474	52748	2884	2884	5861	320	320
Claremont Drive	West 5th Ave	Upper James St	888	0	44	10805	268	268	1201	30	30
West 5th St	Brantdale Ave	Claremont Drive	2372	40	31	28862	675	189	3207	75	21
West 5th St	Fennell Ave W	Brantdale Ave	1301	40	1	15831	493	6	1759	55	1
Fennell Ave W	West 2nd St	West 5th St	1706	24	37	20759	517	225	2307	57	25
Fennell Ave W	Upper James St	West 2nd St	1721	24	38	20941	523	231	2327	58	26
Upper James St.	South Bend Rd	Fennell Ave W	2376	26	319	28911	2257	1941	3212	251	216
Upper James St.	Mohawk Rd	South Bend Rd	2463	26	325	29970	2294	1977	3330	255	220
Upper James St.	Aldridge St.	Mohawk Rd	2331	26	308	28364	2190	1874	3152	243	208
Upper James St.	LA Pkwy WB Offramp	Aldridge St.	3005	26	260	36565	1898	1582	4063	211	176
Upper James St.	LA Pkwy WB Onramp for James NB traffic	LA Pkwy WB Offramp	2767	26	248	33669	1825	1509	3741	203	168
Upper James St.	LA Pkwy EB Onramp for James SB traffic	LA Pkwy WB Onramp for James NB traffic	3089	26	264	37587	1923	1606	4176	214	178
Upper James St.	LA Pkwy WB Offramp	LA Pkwy EB Onramp for James SB traffic	2661	26	242	32379	1789	1472	3598	199	164
Upper James St.	LA Pkwy EB Onramp for James NB traffic	LA Pkwy WB Offramp	2397	26	211	29167	1600	1284	3241	178	143
Upper James St.	Chipman Ave	LA Pkwy EB Onramp for James NB traffic	2678	26	225	32586	1685	1369	3621	187	152
Upper James St.	Stone Church Rd	Chipman Ave	1768	26	180	21513	1411	1095	2390	157	122
Upper James St.	Rymal Rd	Stone Church Rd	1172	30	66	14261	767	402	1585	85	45
Upper James St.	Alderlea Ave	Rymal Rd	1841	26	83	22401	821	505	2489	91	56
Upper James St.	Twenty Rd	Alderlea Ave	1841	26	83	22401	821	505	2489	91	56
Upper James St.	Mountain Transit Centre	Twenty Rd	861	26	60	10477	681	365	1164	76	41
Upper James St.	Dickenson Rd	Mountain Transit Centre	1465	8	65	17826	493	395	1981	55	44
Upper James St.	English Church Rd	Dickenson Rd	1861	8	85	22645	614	517	2516	68	57
Upper James St.	Homestead Drive	English Church Rd	1537	8	68	18702	511	414	2078	57	46
Homestead Drive	Airport Rd	Upper James St	221	8	0	2689	97	0	299	11	0
Airport Rd	Airport Access Rd	Homestead Drive	19	8	0	231	97	0	26	11	0
Claremont Access	Jackson St E	Stinson St	1936	0	58	23557	353	353	2617	39	39
James Mtn Road	Claremont Drive	Aberdeen Ave	1485	40	33	18069	687	201	2008	76	22

Tel: 519.823.1311
Fax: 519.823.1316

RWDI AIR Inc.
650 Woodlawn Road West
Guelph, Ontario, Canada
N1K 1B8

CONSULTING ENGINEERS & SCIENTISTS

CANADA'S 50 BEST MANAGED COMPANIES

Hamilton Rapid Transit A-Line

Hamilton, Ontario

Final Report

Climate and Air Quality Review

RWDI # 1011063
February 2012

SUBMITTED TO
Ian Upjohn, MCIP, RPP
Principal Planner
Environment Division
SNC Lavalin Inc.
Toronto, Ontario
Ian.Upjohn@snclavalin.com

SUBMITTED BY
Mike Lepage
Principal
mike.lepage@rwdi.com

Alain Carrière
Senior Project Manager
alain.carriere@rwdi.com

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1. INTRODUCTION

Pre-Feasibility work on the A-Line Rapid Transit has included looking at potential routes and mode, land use challenges and opportunities and public consultation. Supplementary activities associated with the current work include establishing an inventory of the atmospheric environment, including climate and air quality, and an air quality impact review, based on the mode of choice and the future air quality due to traffic congestion and displacement within the corridor. These supplementary activities are documented in this report.

2. INVENTORY OF CLIMATE AND EXISTING AIR QUALITY

2.1 Information Sources

RWDI documented available information on existing climate and air quality, both in the Downtown and in the area of Hamilton that is above the Escarpment, in a report entitled "Hamilton LRT Environmental Assessment, Air Quality Existing Conditions," dated November 23, 2010. Detailed information on the data sources can be found in that report. Climate information came from Environment Canada's Canadian Climate Normals, 1971-2000, and is based on weather data collected at Hamilton Airport, Hamilton Municipal Laboratory, Hamilton Psychiatric Hospital and the Royal Botanical Gardens (RBG). Information on air quality consisted of measurement data from a number of monitoring stations in Hamilton, operated by the Ontario Ministry of the Environment, the National Air Pollution Surveillance Network (NAPS) and the Hamilton Air Monitoring Network (HAMN).

2.2 Climate Data

A summary of Hamilton climate data and historical air quality monitoring data are provided in Table 2.1. The Hamilton region generally has warm, humid summers and cold winters. Due to the moderating effect of the Great Lakes, the climate is relatively temperate, compared to mid-continental locations that are away from the lakes. During the summer months, the daytime temperatures are usually below 30 ºC and the nighttime temperatures are typically around 17 ºC, based on the Hamilton Municipal Lab and RBG stations, which are located near the waterfront. Temperatures from the Airport Station, located at a higher elevation, are typically 1-2 ºC lower than temperatures from the other stations. Daytime humidity during the summer is moderate, usually averaging between 50 and 60% at the Airport Station, which is the only station in the area that records this statistic. Winter weather conditions are also moderate, with high temperatures usually above -10 ºC, and low temperatures seldom below -20 ºC.

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Table 2.1: Hamilton Climate Normals

Parameter	Hamilton Royal Botanical Gardens	Hamilton Psychiatric Hospital	Hamilton Airport	Hamilton Municipal Lab
General Location	Near Waterfront	Mid-town Hamilton	On top of Mountain	Near Waterfront
Station Elevation	102 m	198 m	238 m	76 m
Most frequent wind direction	SW	n/a	SW	n/a
Mean wind speed - January	13.8 km/hr	n/a	21.2 km/hr	n/a
Mean wind speed - July	9.6 km/hr	n/a	13.1 km/hr	n/a
Extreme gust speed	n/a	n/a	133 km/hr	n/a
Daily max/min temperature – January	-1.1 / -8.8 ºC	-1.7 / -8.9 ºC	-2.2 / -9.7 ºC	-0.4 / -6.8 ºC
Daily max/min temperature - July	27.3 / 16.6 ºC	26.8 / 16.5 ºC	26.3 / 15.1 ºC	27 / 17.9 ºC
Extreme minimum temperature	-28.3 ºC	-27 ºC	-28 ºC	-25 ºC
Extreme maximum temperature	38.8 ºC	38 ºC	37.4 ºC	38.5 ºC
Average afternoon relative humidity	n/a	n/a	65.2%	n/a
Annual snowfall	126.1 cm	119 cm	161.8 cm	113.2 cm
Annual rainfall	768.5 mm	821.7 mm	764.8 mm	750.8 mm
Average snow depth - February	8 cm	n/a	9 cm	n/a
Rainfall greater than 0.2mm	117.7 days/year	113.4 days/year	117.7 days/year	120.3 days/year
Snowfall greater than 0.2 cm	38.1 days/year	27.1 days/year	55.7 days/year	28.8 days/year

The area receives between 113 and 162 cm of snowfall in an average winter, with the depth of snow on the ground averaging less than 10 cm. Snowfall occurs often through the winter, with appreciable amounts (greater than 0.2 cm) occurring an average of 27 to 56 days/year, depending on location.

Annual rainfall varies from 751 to 822 mm. Like snowfall, rain also occurs fairly often during the warmer months, with appreciable rainfall (greater than 0.2 mm) occurring on 113 to 120 days/year, on average. The driest month of the year is February, with an average precipitation of 55 to 59 mm; the wettest month tends to be September, with an average of 82 to 92 mm of rainfall. The months with the fewest number of days of precipitation are June through August, which average approximately 10 to 11 days precipitation above 0.2 mm.

2.3 Air Quality Data for Downtown Hamilton

Table 2.2 provides a summary of the air quality conditions in the Downtown area. Most of the relevant air contaminants occur at levels that are within their provincial Ambient Air Quality Criteria (AAQC). The exceptions are inhalable and respirable particulate matter (PM_{10} and $PM_{2.5}$), as well as certain exhaust hydrocarbons (benzene and benzo(a)pyrene or BaP). These contaminants are found to exceed their criteria at many locations throughout Southern Ontario.

Table 2.2: Ambient Monitoring Data for Stations in Hamilton Downtown and Industrial Basin (2003-2009)

Pollutant	Statistic	Result (Over all Years and Stations)		AAQC or CWS
		Maximum	Average	(µg/m³)
NO_2 (µg/m³)	1-hr Maximum	101	85	400
	24-hr Maximum	76	55	200
	Annual Mean	26	20	- -
	1hr-90th Percentile	45	40	- -
	Times > 1-hr AAQC (400)	0	0	- -
	Times > 24-hr AAQC (200)	0	0	- -
CO (µg/m³)	1-hr Maximum	7,195	4,375	36,200
	8-hr Maximum	2,109	1,782	15,700
	Annual Mean	530	354	- -
	1hr-90th Percentile	1,302	747	- -
	Times > 1-hr AAQC (36,200)	0	0	- -
	Times > 24-hr AAQC (15,700)	0	0	- -
$PM_{2.5}$ (µg/m³)	1-hr Maximum	108	80	- -
	24-hr Maximum	46	41	30
	Annual Mean	11	8.9	- -
	1hr-90th Percentile	24	20.4	- -
	24hr-90th Percentile	21	18.1	- -
	Times > CWS (30)	15	7.8	- -
PM_{10} (µg/m³)	1-hr Maximum	1,000	558	- -
	24-hr Maximum	338	141	50
	Annual Mean	41	31	- -
	1hr-90th Percentile	n/a	n/a	- -
	24hr-90th Percentile	n/a	n/a	- -
	Times > 24-hr AAQC (50)	83	45	- -

Pollutant	Statistic	Result (Over all Years and Stations)		AAQC or CWS (µg/m³)
		Maximum	Average	
SO_2 (µg/m³)	1-hr Maximum	221	150	690
	24-hr Maximum	60	46	275
	Annual Mean	11	7	55
	1hr-90th Percentile	16	14	- -
	Times > 1-hr AAQC (690)	0	0	- -
	Times > 24-hr AAQC (275)	0	0	- -
Formaldehyde* (µg/m³)	24-hr Maximum	11.1	7.1	65
	Annual Mean	2.8	2.7	- -
	1hr-90th Percentile	5.8	4.6	- -
Acetaldehyde* (µg/m³)	24-hr Maximum	5.1	4.4	500
	Annual Mean	1.8	1.7	- -
	1hr-90th Percentile	3.2	2.7	- -
Benzene (µg/m³)	24-hr Maximum	193	19	2.3
	Annual Mean	2.4	1.4	0.45
	24hr-90th Percentile	3.8	3.6	- -
1,3-Butadiene (µg/m³)	24-hr Maximum	0.72	0.54	10
	Annual Mean	0.15	0.13	2
	1hr-90th Percentile	0.43	0.29	- -
Acrolein* (µg/m³)	24-hr Maximum	0.90	0.44	4.5
	Annual Mean	0.10	0.10	0.4
	1hr-90th Percentile	0.30	0.22	- -
Benzo(a)Pyrene (ng/m³)	24-hr Maximum	8.0	4.4	0.05
	Annual Mean	1.6	0.9	0.01
	Times > 24-hr value of 1.1 ng/m^3 (former AAQC)	13	7	- -

* Data for aldehydes were not available for Hamilton. Data from West Toronto (Ruskin & Perth) are provided to give an indication of what can be expected.

2.4 Air Quality Data for Upper Hamilton

The available data for the area above the Niagara Escarpment, which are limited to a smaller number of pollutants, are summarized in Table 2.3. These data indicate that the relevant air contaminants occur at levels that are comparable to, but somewhat lower than those in the Downtown area. As in the Downtown area, $PM_{2.5}$ exceeds its criterion for 24-hour concentration about 8 days per year, on average.

Table 2.3: Ambient Monitoring Data for Hamilton Mountain Station (2003-2008)

Pollutant	Statistic	Result (Over all Years)		AAQC or CWS (µg/m³)
		Maximum	Average	
NO_2 (µg/m³)	1-hr Maximum	87	79	400
	24-hr Maximum	61	50	200
	Annual Mean	17	15	- -
	1hr-90th Percentile	36	30	- -
	Times > 1-hr AAQC (400)	0	0	- -
	Times > 24-hr AAQC (200)	0	0	- -
$PM_{2.5}$ (µg/m³)	1-hr Maximum	74	70	- -
	24-hr Maximum	49	44	30
	Annual Mean	10	8.7	- -
	1hr-90th Percentile	23	19.8	- -
	24hr-90th Percentile	22	18.4	- -
	Times > CWS (30)	15	7.7	- -
SO_2 (µg/m³)	1-hr Maximum	131	94	690
	24-hr Maximum	47	31	275
	Annual Mean	6	5	55
	1hr-90th Percentile	16	11	- -
	Times > 1-hr AAQC (690)	0	0	- -
	Times > 24-hr AAQC (275)	0	0	- -

3. AIR QUALITY IMPACT REVIEW

3.1 Data Sources and Approach

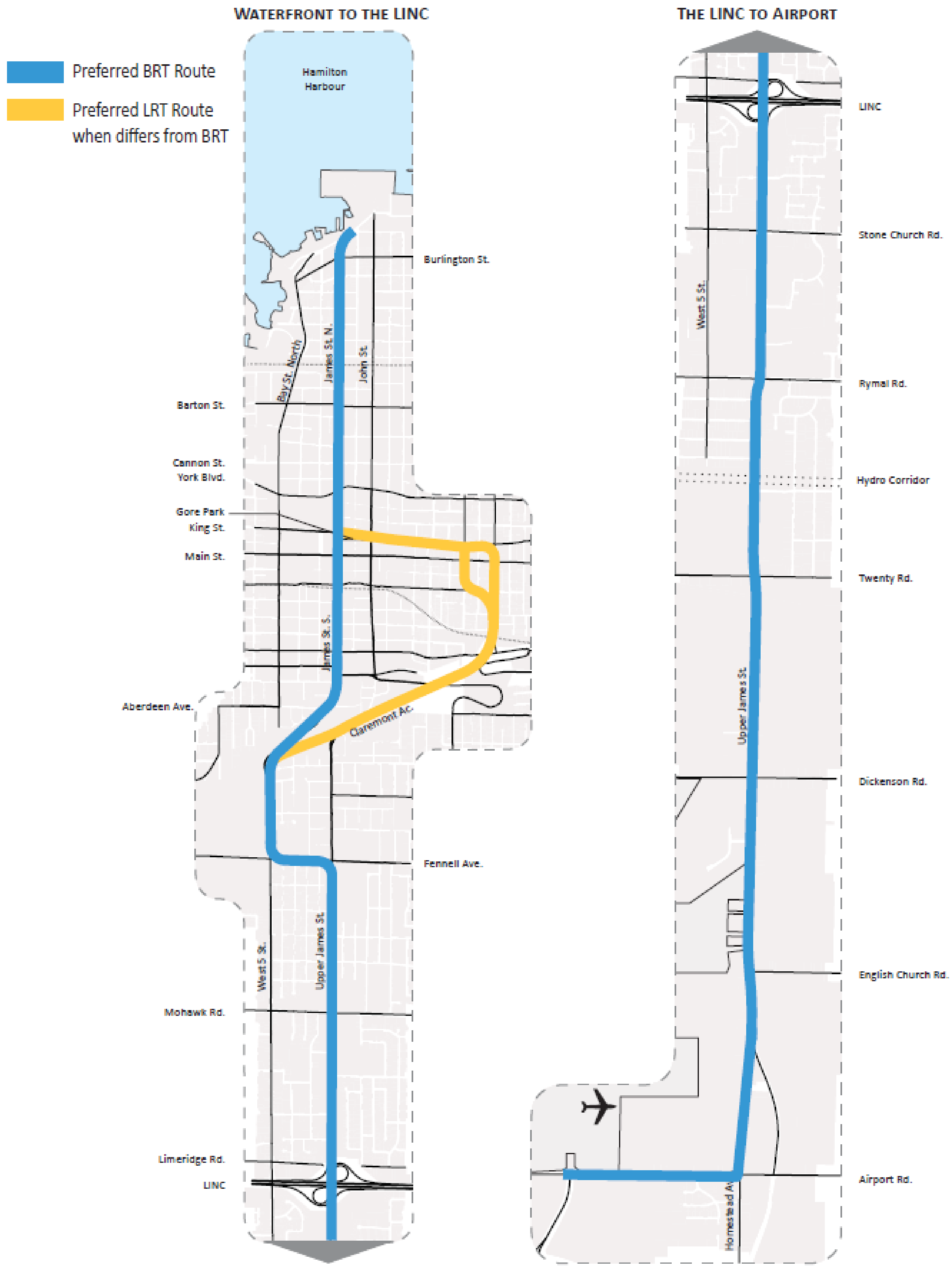
The air contaminants in the study area arise from various sources, including vehicle traffic, industrial emissions and long-range transport of pollutants (especially fine particulate matter and ground-level ozone) from upwind sources, such as the Central U.S. The selection of the mode of transport for the A-Line, using either a BRT or LRT system, will have an effect on one of these sources (i.e., vehicle traffic).

Steer Davies Gleave (SDG) provided information on predicted traffic in the corridor for a Business As Usual (BAU) scenario, a Light Rapid Transit scenario (LRT) and a Bus Rapid Transit scenario (BRT). The air quality implications of the traffic changes were interpreted using results from a more detailed analysis that RWDI previously undertook for the B-Line ("Hamilton LRT B-Line, Final Report, Air Quality Assessment", Oct. 3, 2011). Detailed modeling of air quality impacts of the A-Line was not performed as part of this review. It is expected that such modeling will be completed later, as part of the Environmental Assessment and Preliminary Design phase work.

3.2 General Discussion

Figure 3.1 shows the preferred alignments of the BRT and LRT options for the A-Line. The preferred route for the A-Line (Figure 3.1) is essentially the same for both the LRT and BRT option, except in the vicinity of Hamilton Mountain, where the LRT option requires a shallower slope for ascent and descent of the Escarpment. In the section extending from the waterfront to the top of Hamilton Mountain, the proposed route will mainly be on-street, in segregated lanes. Atop the mountain, it will mainly be segregated and located in the median, until south of Rymal Road. From there, it will be located off-street until it reaches Homestead Drive, at which point it mixes with the street traffic until it reaches the Airport.

Figure 3.1: Proposed A-Line Corridor – Preferred Routes



In at least some of these areas, the route will displace traffic lanes that are currently available for general traffic and will affect vehicular traffic patterns along the corridor.

The proposed A-Line will affect only a modest portion of the overall vehicle travel within the City of Hamilton. Since it has only a modest effect on only one of the various emission sources that contribute air contaminants, its effect on local air quality, whether positive or negative, will not be large in magnitude for any pollutant. The largest effects will occur locally in areas where sensitive receptors are adjacent to a busy roadway and the project leads to a significant increase or decrease in traffic on that roadway.

In the detailed air quality assessment for the B-Line ("Hamilton LRT B-Line, Final Report, Air Quality Assessment", Oct. 3, 2011), RWDI predicted that local roadways contributed no more than about one third of the overall concentrations of PM and benzene occurring at residences located adjacent to those roadways. Thus, in a case where the B-Line was expected to alter the traffic on a roadway by 50%, the predicted effect on air quality levels at adjacent residences was less than 20%. The same is expected to be true for the A-Line.

3.3 Effects of A-Line on Emissions from Buses

Table 3.1 shows the anticipated service frequency for the proposed A-Line, for either mode of operation (LRT or BRT), and Table 3.2 shows the effect of the A-Line on other bus transit routes in the corridor. In these tables, MTC means Mountain Transit Centre, located on Upper James Street, south of Twenty Road.

With an LRT system, the service would be provided by electric trains, with no local air pollutant emissions along the corridor. As shown in Table 3.2, the A-Line would displace some existing bus traffic. Along Upper James Street, the bus traffic would be reduced by 30 to 40%. South of Main Street in the Downtown area, it would be reduced on the order of 10%, and north of Main Street, there would be no change in bus traffic. Overall, the net effect of the LRT option is to reduce corridor emissions associated with bus transit, compared to the Business As Usual scenario (BAU).

Table 3.1: Proposed A-Line Frequencies

Day	Period	Times	Service Frequency (Vehicles per Hour)			
			LRT		BRT	
			Waterfront to MTC	MTC to Airport	Waterfront to MTC	MTC to Airport
Weekday	Early	05:00-07:00	8	4	12	4
	AM peak	07:00-10:00	15	5	24	8
	Interpeak	10:00-14:00	10	4	15	5
	PM Peak	14:00-18:30	15	5	24	8
	Evening	18:30-01:30	8	4	12	4
Saturday	Early	05:00-09:00	6	2	9	3
	Daytime	09:00-18:00	10	4	15	5
	Evening	18:00-01:30	8	4	12	4
Sunday	Early	05:00-11:00	6	2	9	3
	Daytime	11:00-18:00	8	4	12	4
	Evening	18:00-00:30	6	2	9	3

Table 3.2: Anticipated Bus Volumes (Daily Trips During the Weekday Peak Period)

Road	Section	Bus Volume (Total Both Directions) BAU	With A-Line Network Changes	Difference
James Nth	Waterfront to Burlington	0	0	+0
	Burlington to Barton	54	54	+0
	Barton to Cannon	83	83	+0
	Cannon to Wilson	109	109	+0
	Wilson to King	169	169	+0
	King to Main	197	197	+0
	Main to Hunter	473	439	-34
	Hunter to St Joseph's Drive	276	242	-34
James Mtn	St Joseph's Drive to Fennell	158	80	-78
Fennell	W 5th to Upper James	94	104	+10
Upper James	Fennell to Stone Church	110	68	-42
	Stone Church to Rymal	137	95	-42
	Rymal to MTC	110	68	-42
	MTC to Airport	42	0	-42

With the BRT option instead of LRT, the service would be provided by diesel buses, with emissions contributed by those vehicles. Table 3.1 shows that the BRT service would consist of up 24 buses per hour during peak periods (07:00 to 10:00 and 14:00 to 18:30). This would amount to 180 bus trips over the entire peak period, which more than offsets the anticipated reductions in other bus volumes shown in Table 3.2. Unlike the LRT option, therefore, the expected overall effect of the BRT option is to increase bus emissions compared to BAU.

Bus traffic represents a small part of the overall vehicle traffic. So, it is also necessary to consider how the proposed A-Line will affect other vehicle traffic besides buses.

3.4 Effects of A-Line on Emissions from Other Vehicles

Tables 3.3a and b summarize predicted peak hour traffic volumes (total of northbound and southbound) in the corridor for the BAU, LRT and BRT scenarios. Percent change relative to the BAU case is also shown. In areas where the proposed A-Line consists of dedicated traffic lanes or segregated lanes in the median, it may displace one or more existing traffic lanes and thereby reduce vehicle traffic and emissions in the corridor. The most significant changes in traffic occur along Upper James Street, between Rymal Road and Fennell Avenue, where both the BRT and LRT options are expected to reduce peak hour traffic by about 400 to over 1,000 vehicles. For the BRT option, these reductions in overall traffic are considerably more substantial than the anticipated increase in bus traffic and will easily offset the added bus emissions.

In the Downtown area, the net effect on traffic is generally smaller. On James Street, south of York Boulevard, for example, the projected net reduction in traffic is under 50 vehicles in the peak hour. For the BRT option, these reductions may not fully offset increased bus emissions in this area.

The section of Upper James Street, between the Mountain Transit Centre and Twenty Road, is expected to experience an increase in traffic with the project in place, on the order of 500 vehicles in the peak hour, and, therefore, will experience an increase in emissions.

Table 3.3a: AM Peak-Hour Street Traffic Volume in the Corridor (2021) for Business As Usual (BAU) and with the A-Line in Place (LRT option)

STREET	FROM	TO	BAU	LRT	% CHANGE
Airport Rd	Airport Access Rd	Homestead Drive	27	19	-30%
Homestead Drive	Airport Rd	Upper James St	229	215	-6%
Upper James St.	Homestead Drive	English Church Rd	1613	1566	-3%
Upper James St.	English Church Rd	Dickenson Rd	1954	1907	-2%
Upper James St.	Dickenson Rd	Mountain Transit Centre	1538	1409	-8%
Upper James St.	Mountain Transit Centre	Twenty Rd	947	1462	54%
Upper James St.	Twenty Rd	Alderlea Ave	1950	1543	-21%
Upper James St.	Alderlea Ave	Rymal Rd	1950	1543	-21%
Upper James St.	Rymal Rd	Stone Church Rd	1268	765	-40%
Upper James St.	Stone Church Rd	Chipman Ave	1974	1063	-46%
Upper James St.	Chipman Ave	LA Pkwy EB Onramp for James NB traffic	2929	1846	-37%
Upper James St.	LA Pkwy EB Onramp for James NB traffic	LA Pkwy WB Offramp	2634	1569	-40%
Upper James St.	LA Pkwy WB Offramp	LA Pkwy EB Onramp for James SB traffic	2929	1737	-41%
Upper James St.	LA Pkwy EB Onramp for James SB traffic	LA Pkwy WB Onramp for James NB traffic	3379	2125	-37%
Upper James St.	LA Pkwy WB Onramp for James NB traffic	LA Pkwy WB Offramp	3041	1845	-39%
Upper James St.	LA Pkwy WB Offramp	Aldridge St.	3291	2213	-33%
Upper James St.	Aldridge St.	Mohawk Rd	2665	1490	-44%
Upper James St.	Mohawk Rd	South Bend Rd	2814	1859	-34%
Upper James St.	South Bend Rd	Fennell Ave W	2721	1793	-34%
Fennell Ave W	Upper James St	West 2nd St	1783	1192	-33%
Fennell Ave W	West 2nd St	West 5th St	1767	1177	-33%
West 5th St	Fennell Ave W	Brantdale Ave	1342	794	-41%
West 5th St	Brantdale Ave	Claremont Drive	2443	1747	-28%
Claremont Drive	West 5th Ave	Upper James St	932	755	-19%
Claremont Access	Upper James St	Offramp to Sherman Access	4809	3563	-26%
Claremont Access	Offramp to Sherman Access	Charlton Ave East	4659	3404	-27%
Claremont Access	Charlton Ave East	Young St	4659	3404	-27%
Claremont Access	Young St	Stinson St	4659	3404	-27%
Victoria Ave	Stinson St	Main St	2097	1852	-12%
Victoria Ave	Main St	King St	1974	1800	-9%
King Street	Victoria Ave	West Ave N	1170	888	-24%

STREET	FROM	TO	BAU	LRT	% CHANGE
King Street	West Ave N	Wellington St	1170	888	-24%
King Street	Wellington St	Ferguson Ave N	9	9	0%
King Street	Ferguson Ave N	Ferguson Ave S	9	9	0%
King Street	Ferguson Ave S	Walnut	9	9	0%
King Street	Walnut	John St	9	9	0%
King Street	John St	Hughson St N	622	413	-34%
King Street	Hughson St N	James St	480	384	-20%
James Street	King St	King William St	1067	973	-9%
James Street	King William St	Rebecca St	1030	984	-4%
James Street	Rebecca St	York St	980	929	-5%
James Street	York St	Cannon St	766	698	-9%
James Street	Cannon St	Barton St	692	562	-19%
James Street	Barton St	Murray St	603	513	-15%
James Street	Murray St	Strachan St	607	578	-5%
James Street	Strachan St	Burlington St West	607	578	-5%
Wellington St	King St	Main St	1916	1525	-20%
Wellington St	Main St	Jackson St E	2318	1767	-24%
Claremont Access	Jackson St E	Stinson St	1994	1485	-26%

Table 3.3b: AM Peak-Hour Street Traffic Volume in the Corridor (2021) for Business As Usual (BAU) and with the A-Line in Place (BRT option)

STREET	FROM	TO	BAU	BRT	% CHANGE
Airport Rd	Airport Access Road	Homestead Drive	27	29	7%
Homestead Drive	Airport Road	Upper James St.	229	223	-3%
Upper James St.	Homestead Drive	English Church Rd	1613	1556	-4%
Upper James St.	English Church Rd	Dickenson Rd	1954	1897	-3%
Upper James St.	Dickenson Rd	Mountain Transit Centre	1538	1418	-8%
Upper James St.	Mountain Transit Centre	Twenty Rd	902	1470	63%
Upper James St.	Twenty Rd	Alderlea Ave	1950	1576	-19%
Upper James St.	Alderlea Ave	Rymal Road	1950	1576	-19%
Upper James St.	Rymal Road	Stone Church Rd	1268	734	-42%
Upper James St.	Stone Church Rd	Chipman Ave	1974	926	-53%
Upper James St.	Chipman Ave	LA Pkwy EB Onramp for James NB traffic	2929	1707	-42%
Upper James St.	LA Pkwy EB Onramp for James NB traffic	LA Pkwy WB Offramp	2634	1422	-46%
Upper James St.	LA Pkwy WB Offramp	LA Pkwy EB Onramp for James SB traffic	2929	1523	-48%

Upper James St.	LA Pkwy EB Onramp for James SB traffic	LA Pkwy WB Onramp for James NB traffic	3379	1944	-42%
Upper James St.	LA Pkwy WB Onramp for James NB traffic	LA Pkwy WB Offramp	3041	1654	-46%
Upper James St.	LA Pkwy WB Offramp	Aldridge St.	3291	2015	-39%
Upper James St.	Aldridge St.	Mohawk Rd	2665	1288	-52%
Upper James St.	Mohawk Rd	South Bend Rd	2814	1629	-42%
Upper James St.	South Bend Rd	Fennell Ave	2721	1562	-43%
Fennell Ave W	Fennell Ave	West 2nd St.	1783	1351	-24%
Fennell Ave W	West 2nd St.	West 5th St.	1767	1333	-25%
West 5th Ave	West 5th St.	Brantdale Ave	1342	220	-84%
West 5th Ave	Brantdale Ave	Claremont Drive	2443	1106	-55%
James Mtn Rd	Claremont Drive	Aberdeen Ave	1558	30	-98%
James Street	Aberdeen Ave	Markland St	1443	413	-71%
James Street	Markland St	St. Joseph's Drive	1422	406	-71%
James Street	St. Joseph's Drive	Charlton Ave West	1551	947	-39%
James Street	Charlton Ave West	Duke St	1584	885	-44%
James Street	Duke St	Augusta St	1882	1298	-31%
James Street	Augusta St	Bold St	2044	1420	-31%
James Street	Bold St	Hunter St	1987	1060	-47%
James Street	Hunter St	Jackson St East	1656	1009	-39%
James Street	Jackson St East	Main Street	1177	556	-53%
James Street	Main Street	King St East	819	696	-15%
James Street	King St East	King St West	819	696	-15%
James Street	King St West	King William St	1067	935	-12%
James Street	King William St	Rebecca St	1030	986	-4%
James Street	Rebecca St	York Blvd	980	970	-1%
James Street	York Blvd	Cannon St	766	583	-24%
James Street	Cannon St	Barton St	692	478	-31%
James Street	Barton St	Murray St	603	383	-36%
James Street	Murray St	Strachan St	607	448	-26%
James Street	Strachan St	Burlington St West	607	448	-26%
Hunter St	Hunter St	Hughson St South	461	373	-19%
Hunter St	Hughson St South	John St	460	369	-20%
John Street	John St	Augusta St	1246	1231	-1%
John Street	Augusta St	Young St	1407	1350	-4%
John Street	Young St	Charlton Ave East	1407	1350	-4%
Charlton Ave	Charlton Ave East	Charlton Ave West	839	876	4%

3.5 Effects on Nearby Sensitive Receptors

The effect of the project on local air quality also depends on the proximity of sensitive receptors. In keeping with Ontario Ministry of the Environment guidelines, sensitive receptors are defined here as buildings or outdoor amenity areas associated with residences (including senior citizens homes), schools and daycares, hospitals, churches and other similar institutions. There are many sections of the corridor where these types of uses are separated from the roadway by intervening areas of commercial uses, which reduces the air quality impact of the local roadway at the sensitive receptors. This is the case, for example, on Upper James Street between Rymal Road and Mohawk Road.

The following are areas where significant numbers of sensitive uses are adjacent to the roadway:

- Parts of Upper James Street between Airport Road and the Mountain Transit Centre;
- Upper James Street between the Mountain Transit Centre and Twenty Road;
- Parts of Upper James Street between Mohawk Road and the Claremont Access;
- James Upper Mountain Road and James Street south of Charlton Avenue;
- James Street, north of Barton Street (particularly north of Strachan Street).

<u>Upper James from Airport Road to Mountain Transit Centre</u>

A net increase in bus traffic may occur in this area with the BRT option, but the effect on overall traffic is small. Therefore, the A-Line should have relatively little impact (positive or negative) on local air quality at sensitive receptors in this area. The LRT option would be slightly better than the BRT option.

<u>Mountain Transit Centre to Twenty Road</u>

The project is expected to increase traffic in this area by on the order of 500 vehicles in the peak hour. A number of residences front Upper James Street in this area, but the majority of these residences are located on the west side of the road, placing them upwind for the prevailing winds. Peak pollutant levels may be somewhat higher than for the BAU case, but average levels should experience minimal change compared to the BAU. The LRT option would be slightly better than the BRT option.

<u>Upper James from Mohawk Road to the Claremont Access</u>

Increases in bus traffic in this area are expected to be offset by significant reductions in overall traffic. Both the BRT and LRT options represent an improvement in local air quality for sensitive receptors along Upper James Street in this area compared to the BAU. As discussed in Section 3.2, the expected improvement in levels of key pollutants is modest (less than20%).

<u>James Mountain Road</u>

Significant reductions in traffic on the Claremont Access are expected with the LRT option, which would provide a small improvement in local air quality. With the BRT option, bus traffic would be introduced in this area, providing a small negative effect on the local air quality compared to the BAU.

James Street, North of Barton Street

With the LRT option, modest expected reductions in street traffic with the A-Line in place will slightly improve local air quality. With the BRT option, such improvements will be offset by an increase in bus traffic, and the resulting effect on local air quality may be neutral or even slightly negative compare to the BAU.

3.6 Secondary Air Quality Effects

As mentioned in Section 3.4, a significant reduction in traffic is expected on Upper James Street, between Rymal Road and Fennell Avenue, once the A-Line is in place. A portion of this reduction is due to a reduced number of general purpose lanes on Upper James Street, and consists of traffic that is still on the road network, but has been diverted to other roads, such as West Fifth Street and Upper Wellington Street. These roads, therefore, may experience a modest increase in traffic. Both West Fifth and Upper Wellington Street are fronted by extensive amounts of residential use. Both the LRT and BRT options may produce a small increase in key air pollutants at these receptors relative to the BAU case.

4. CONCLUSIONS

The following is a summary of the findings from the air quality assessment.

- The existing air quality in the study area is currently good for most pollutants, but key exceptions are inhalable and respirable particulate matter (PM_{10} and $PM_{2.5}$), and certain hydrocarbons (benzene and benzo(a)pyrene). These pollutants exceed their applicable criteria in many parts of Southern Ontario.
- Along certain sections of the proposed A-Line corridor, the project will significantly reduce traffic and provide a modest improvement in the key pollutants compared to the Business As Usual alternative (especially on Upper James Street, between Rymal Road and the Claremont Access, and also to some extent on James Street, north of Barton Street).
- On Upper James Street, between Twenty Road and the Mountain Transit Centre, the project will increase road traffic, resulting in a small negative effect on the key pollutants compared to Business As Usual.
- Along other sections of the corridor, the project is expected to have little or no effect on the local traffic (e.g., on Upper James Street south of Dickenson Road). In these areas, the LRT option will have essentially a neutral effect on air quality, and the BRT option will contribute added bus emissions, potentially causing a small negative effect on air quality.
- The BRT option would bring new bus traffic in proximity to residences near James Mountain Road, resulting a small negative effect on air quality in that area.
- The project may also divert some traffic away from Upper James Street to other arterial roads, such as West Fifth Street and Upper Wellington Street, and potentially cause a small negative effect on air quality in those areas (either the BRT or the LRT option).