Section I.2:
Area B Noise and Vibration Memo

Note: This appendix refers to Area A as Segment 1 and to Area B as Segment 2, a reflection of previous project nomenclature.

Waterfront East Light Rail Transit

Environmental Project Report / TPAP

Noise and Vibration Impact Assessment - Arup

Issue | January 23, 2024

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Acronyms and glossary

dBA	A-weighted decibels
EA	Environmental Assessment
EBF Transit Class EA	East Bayfront Transit Environmental Assessment (2010)
FTA	Federal Transit Administration
L_{PASSBY}	Sound level measured for the duration of a transit car passby
$L_{eq,8h}$	The equivalent sound level measured for a duration of 8 hours
$L_{eq,16h}$	The equivalent sound level measured for a duration of 16 hours
L_{max}	The maximum sound level measured for an event
LRT	Light-rail transit
RMS	Root mean square
TPSS	Traction power substation
TTC	Toronto Transit Commission
WELRT	Waterfront East Light Rail Transit

Executive Summary

This noise and vibration impact assessment considers the predicted noise and vibration performance of the proposed LRT project in the following scenarios:

- At-grade tangent track at speeds of 60 km/h, 40 km/h and 25 km/h
- At-grade special track (crossover) at speeds of 15 km/h
- At the future Queens Quay East portal location

The performance is assessed against the TTC Design Manual noise and vibration criteria. Airborne noise levels have been predicted for the future scenario of the project using the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual for LRT noise levels and the Ontario Road Noise Analysis Method for Environment and Transportation (ORNAMENT) for vehicle traffic noise levels.. The following conclusions were made:

- The project is anticipated to achieve the proposed design goal of not surpassing the ambient L_{eq} values for residences situated at least 15 metres from the track centreline and 6 metres from the road centreline in all scenarios during daytime, as well as during nighttime for both the 25km/h and 40km/h scenarios.
- When the streetcar is traveling at 60 km/h or on special track during nighttime, it is anticipated to generate a maximum noise level of 59 dBA ($L_{eq,8h}$), which is 4 decibels higher than the design goal of ambient.
- However, the protocol limit for requiring noise mitigation is 5 dB above the maximum of ambient ($L_{eq,8h}$) or 50 dBA ($L_{eq,8h}$), whichever is greater. Considering that the predicted nighttime ambient noise level due to traffic is 55 dBA ($L_{eq,8h}$), mitigation is only required for levels above 60 dBA ($L_{eq,8h}$), hence the project is not expected to trigger the protocol.

Several noise measurements were taken of streetcar passby events on Queens Quay West to determine the passby sound level (L_{passby}). The following conclusions were made:

- Streetcar passbys measured 75 dBA L_{max}, meaning the peak sound level recorded during the passby was 75 dBA. The criterion for a single passby event is 80 dBA averaged over the duration of the passby (approximately 3-4 seconds). Hence, the streetcar passby achieves the criterion.

Groundborne vibration levels have also been predicted using guidance from the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual. The following conclusions were made:

- Based on the criterion of 0.10mm/s RMS velocity at not less than 15 metres from the centreline of the track, groundborne vibration is predicted to achieve the proposed design goal without any additional mitigation measures. The most onerous condition, 60 km/h zone, is predicted to achieve the criteria at 12 metres from the centreline of track, comfortably within the 15 metres requirement.

The predicted performance at the future portal on Queens Quay East was considered. The conclusions made are based on measurements taken at the existing portal on Queens Quay West, guidance from the FTA manual and noise and vibration, and engineering principles.

- The airborne noise levels emitted from the portal will differ from similar at-grade location in two ways – slower operating speeds and sound reverberation (multiple reflections) off the portal walls. Based on observations at the existing Queens Quay West portal, streetcars operate between 10 and 25 km/h at the portal section. At these speeds noise levels are predicted to be below the threshold for mitigation, including +3 dB to account for the effect of sound reverberation. Noise measurements taken at the existing portal confirm these predictions.
- The weight and size of transit support structures affects the vibration radiated by that structure. In general, vibration levels are lower for heavier structures, such as the concrete cut box of the portal. Speeds are also much lower in the vicinity of the portal than at sections of tangent track. For these reasons the vibration levels at the portal are predicted to be similar or lower than those predicted for at-grade locations.
- Overall, the portal section is not predicted to require noise or vibration mitigation based on the criteria set out in the TTC Design Manual.

1. Introduction

The WELRT project includes the implementation of LRT, bicycle, and pedestrian infrastructure between Union Station and Leslie Barns with connections to East Harbour and the existing Distillery Loop. The proposed corridor starts at Union Station, where the LRT alignment runs south below Bay Street using existing track and tunnel. After passing through Queens Quay Station below the intersection of Bay Street and Queens Quay West, the LRT alignment turns east and transitions to street level via the proposed east portal on Queens Quay West between Bay Street and Yonge Street. Once at grade, the LRT alignment continues east along Queens Quay East adjacent to a pedestrian promenade, an enhanced Martin Goodman Trail, and bi-directional roadway until reaching the realigned Cherry Street. The proposed corridor turns south at Cherry Street, and then east at Commissioners Street continuing until the new Villiers Loop. The proposed corridor also includes the stretch of Cherry Street between the existing Distillery Loop and Queens Quay East, where LRT infrastructure will be implemented to enable the extension of transit service from the Distillery Loop to the Villiers Loop. Later phases of the project will extend the transit infrastructure north to East Harbour and east to Leslie Barns.

Arup have been tasked with assessing the noise and vibration impact at the proposed Queens Quay East portal as well as a high-level assessment of the at-grade performance.

1.1 Project description

The project will be delivered in several phases. The first phase includes the portions of the project between Union Station and the Villiers Loop. The connections to East Harbour, Polson Loop, and Leslie Barnes will be delivered as part of future phases. The first phase of the project has been divided into three segments as shown in Exhibit 1:

• Segment 1: Bay Street from Union Station to Queens Quay West, including the east and west streetcar portals.

• Segment 2: Queens Quay West (from Bay Street to Yonge Street) and Queens Quay East (from Yonge Street to Cherry Street)

• Segment 3: Cherry Street (from Distillery Loop to Commissioners Street) and Commissioners Street (from Cherry Street to Villiers Loop).

Exhibit 1 Project study areas

1.2 Scope of this assessment

The scope of this noise and vibration impact assessment is to assess the predicted noise and vibration performance of the proposed LRT project in the following scenarios:

- At-grade tangent track at speeds of 60 km/h, 40 km/h and 25 km/h
- At-grade special track (crossover) at speeds of 15 km/h
- At the future Queens Quay East portal location

Scenarios which are not part of this scope include, but are not limited to, below grade track (primarily existing tunnel in Segment 1), wheel squeal at small radii corners, stationary sources and ancillary facilities, traction power substations (TPSS), and construction phases.

The performance in the above scenarios will be assessed against the TTC Design Manual noise and vibration criteria.

2. Noise and Vibration Criteria

The noise and vibration criteria for this project are set out in TTC Design Manual DM-0106-00. The criteria related to the scope of this assessment are reproduced below in Exhibit 2.

Exhibit 2 Summary of noise and vibration criteria

Source	Receiver	Descriptor	Protocol Limit Requiring Mitigation[1]	Proposed Design Goal
Vehicle/train anywhere on line	Residence not less than 15 metres from nearest track centreline	Daytime $L_{eq,16h}$ (7:00-23:00)	for transit vehicles: 5 dB above maximum of ambient $L_{eq,16h}$ or 55 dBA whichever is greater	for transit vehicles: maximum of ambient $L_{eq,16h}$ or 55 dBA whichever is greater
		Nighttime $L_{eq,8h}$ (23:00-7:00)	for transit vehicles: 5 dB above maximum of ambient $L_{eq,8h}$ or 50 dBA whichever is greater	for transit vehicles: maximum ambient $L_{eq,8h}$ or 50 dBA whichever is greater
Vehicle/train on tangent track not less than 100 metres from special trackwork and excluding wheel squeal	Residence not less than 15 metres from nearest track centreline	Passby sound level L_{PASSBY}	5 dB above 80 dBA	80 dBA
Vehicle/train anywhere on line	Ground outside residence not less than 15 metres from nearest track centreline	Vertical vibration velocity	0.1 mm/s RMS	0.1 mm/s RMS

[1] Ambient is the sound existing at the point of reception in the absence of all noise from the transit system. 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

No specific criteria are provided for ground borne noise resulting from vibration. The relatively low limit of 0.10mm/s RMS is possibly intended to limit the risk of noise impact due to ground vibration. Assessing the predicted ground borne noise levels within residential or sensitive-use buildings is beyond the scope of this study but may be considered appropriate during the detailed design stage when greater level of information is known.

3. Noise Impact Assessment

Airborne noise levels have been predicted using the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual for the future scenario of with project (LRT and vehicle traffic). These values have then been compared with the noise criteria in Exhibit 2.

3.1 Traffic and LRT volumes

The Arup Transport Planning team have provided anticipated traffic volumes for the future reference year, 2041. These values are intended as an approximation of the future traffic volumes. Deviation from these numbers due to factors such as seasonal variation are not anticipated to change the outcome of this assessment. LRT passby frequencies are equivalent to an average headway of 4 minutes during daytime hours and 8 minutes during nighttime hours, with 30 hourly passbys in daytime and 15 hourly passbys in nighttime hours.

Exhibit 3 Total future traffic volumes for day and night periods

	Cars	Heavy Duty Vehicle	LRT Passbys
Daytime (7:00 – 23:00)	7256	382	480
Nighttime (23:00 – 7:00)	679	36	120

3.2 Noise predictions

Airborne noise levels have been predicted for several operating scenarios. Ambient road traffic noise has been predicted with the Ontario Road Noise Analysis Method for Environment and Transportation (ORNAMENT) using the STAMSON computerized ORNAMENT algorithm. LRT noise has been predicted using the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual Calculations (FTA manual). The following assumptions have been made in the assessment:

- All vehicle traffic is assumed to travel at 40 km/h and at a distance of 6 metres from the centreline of the roadway to receiver locations. STAMSON results at 15 metres have been adjusted to 6 metres (correction of 4 dB or 10LOG(15/6)).
- Vehicle traffic volumes are the combined volumes for east-bound and west-bound directions of travel.
- Heavy duty vehicle volume is assumed to be 5% of the total vehicle volume, with 50% of this volume modelled as medium trucks and 50% modelled as heavy trucks.
- Daytime vehicle traffic volumes include the hours of 07:00 (inclusive) through 23:00 (exclusive).

- Nighttime vehicle traffic volumes include the hours of 23:00 (inclusive) through 07:00 (exclusive).
- The future LTR streetcars are assumed to be 30.2 metres long and produce an average maximum sound level of 75 dBA *max* at 15 metres on an embedded concrete track at 40 km/h. These values are in line with survey measurements taken of the streetcar on Queens Quay West in May 2021.
- LTR streetcar sound levels are calculated at a distance of 15 metres.
- All computed sound levels are rounded to the nearest whole decibel.

The results of the noise level assessment are presented in Exhibit 4.

Exhibit 4 Predicted airborne noise levels

LRT Speed Scenario	Daytime ($L_{eq,16h}$ dBA)			Nighttime ($L_{eq,8h}$ dBA)		
	Traffic (40 km/hr)	LRT	Combined	Traffic (40 km/hr)	LRT	Combined
At grade 60km/h	66	62	67	55	59	60
At grade 40km/h	66	58	66	55	55	58
At grade 25km/h	66	58	66	55	55	58
At grade Special track 15km/h	66	62	67	55	59	61

The noise criteria set out in the TTC Design Manual are based on comparing the proposed LRT against the ambient (i.e., road traffic only) scenario. The project is anticipated to achieve the proposed design goal of not surpassing the ambient L_{eq} values for residences situated at least 15 metres from the track centreline in all scenarios during daytime, as well as during nighttime for both the 25km/h and 40km/h scenarios.

When the streetcar is traveling at 60 km/h or on special track during nighttime, it is anticipated to generate a maximum noise level of 59 dBA ($L_{eq,8h}$), which is 4 decibels higher than the design goal of ambient.

However, the protocol limit for requiring noise mitigation during nighttime hours is 5 dB above the maximum of ambient ($L_{eq,8h}$) or 50 dBA ($L_{eq,8h}$), whichever is greater. Considering that the predicted ambient noise level due to traffic is 55 dBA ($L_{eq,8h}$), the streetcar is not expected to trigger the protocol.

3.3 Special considerations

3.3.1 Portal

The airborne noise levels emitted from the portal will differ from similar at-grade location in two ways – slower operating speeds and sound reverberation (multiple reflections) off the portal walls. Based on observations at the existing Queens Quay West portal, streetcars operate between 10 and 25 km/h in the portal section.

Measured sound levels taken near the portal at Queens Quay West between York Street and Bay Street measured between 64 dBA L_{max} and 75 dBA L_{max}. Please note that these noise levels include vehicle noise on Queens Quay West. In addition to the measured noise levels Arup computed sound levels using the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual for 10 km/h and 25 km/h then added +3 dB to the result to account for reflections from the vertical wall of the portal opening. The results of the calculation do not exceed ambient levels by more than 5 decibels. At this stage mitigation for airborne noise is not considered necessary to achieve the noise criteria.

3.4 On-site noise measurements

On May 27, 2021 Arup personnel measured sound levels in the vicinity of the proposed WELRT project. Sound levels measured include both vehicle noise and LRT noise. Exhibit 5 shows the measurement locations and measured sound levels, as follows:

- Location A on Queens Quay West measuring existing at grade light rail passbys and vehicle noise. LRT streetcar passbys measured 75 $dBA_{,max}$, meaning the maximum sound level recorded was 75 dBA. The criterion for a single passby event is 80 dBA averaged over the duration of the passby (approximately 3-4 seconds). Hence, the LRT streetcar passby is clearly under the criterion.
- Location B on Queens Quay West measuring existing light rail passbys and vehicle noise as the light rail enters and exits the existing portal. Combined passbys measured between 64 and 75 $dBA_{,max}$.
- Location C at the corner of Queens Quay West and Yonge Street measuring ambient noise levels in the absence of nearby light rail activities. Measured sound levels were between 68 and 69 dBA $L_{eq,(15\text{-}min)}$.

Exhibit 5 Arup site survey measurement locations

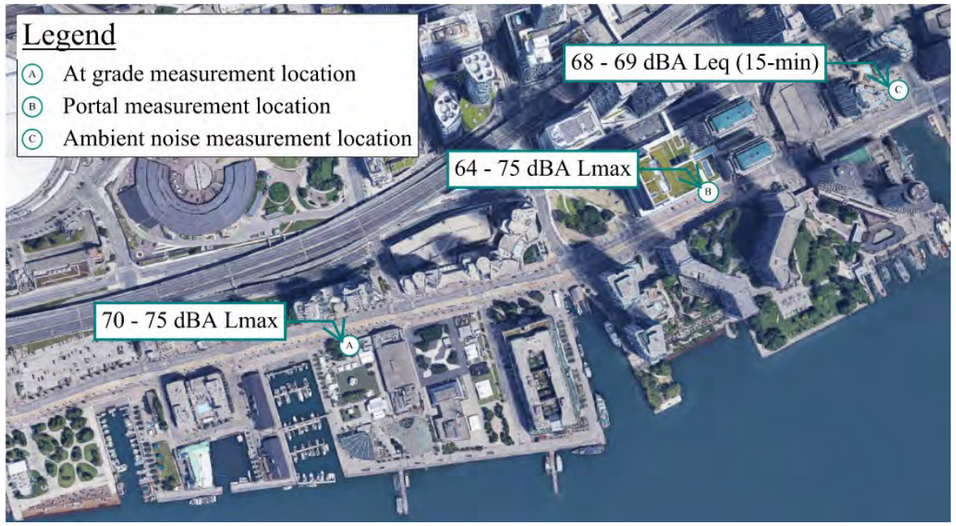
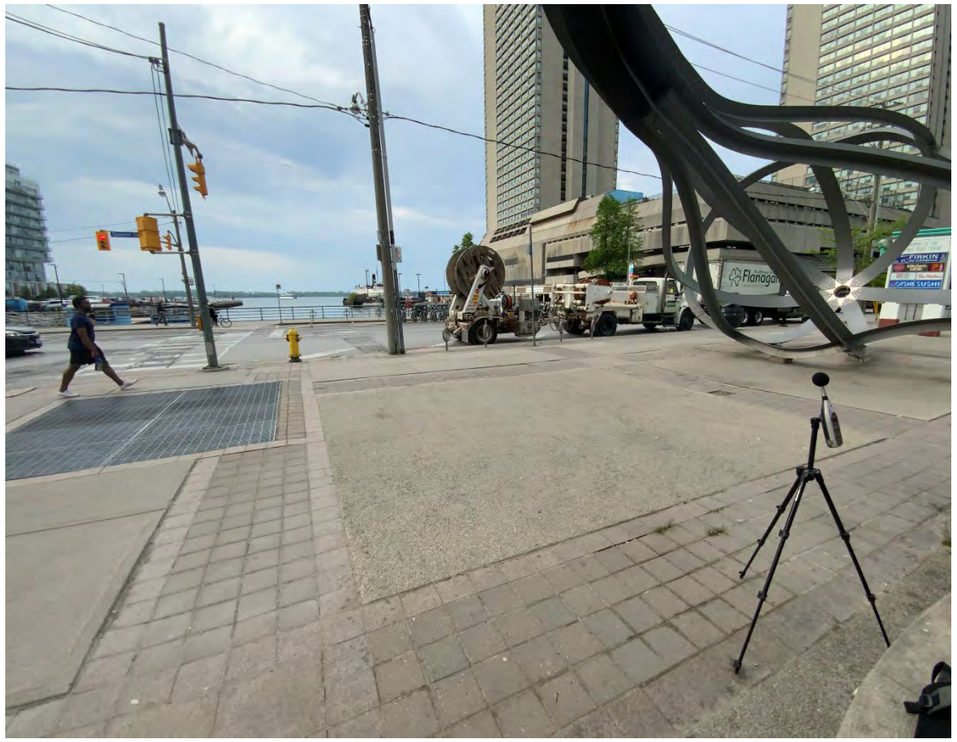


Exhibit 6 Picture taken at measurement location A.

Exhibit 7 Picture taken at measurement location B.

Exhibit 8 Picture taken at measurement location C.



4. Vibration Impact Assessment

Groundborne vibration levels have been predicted using the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual. These values have then been compared with the vibration criteria in Exhibit 2.

4.1 Vibration predictions

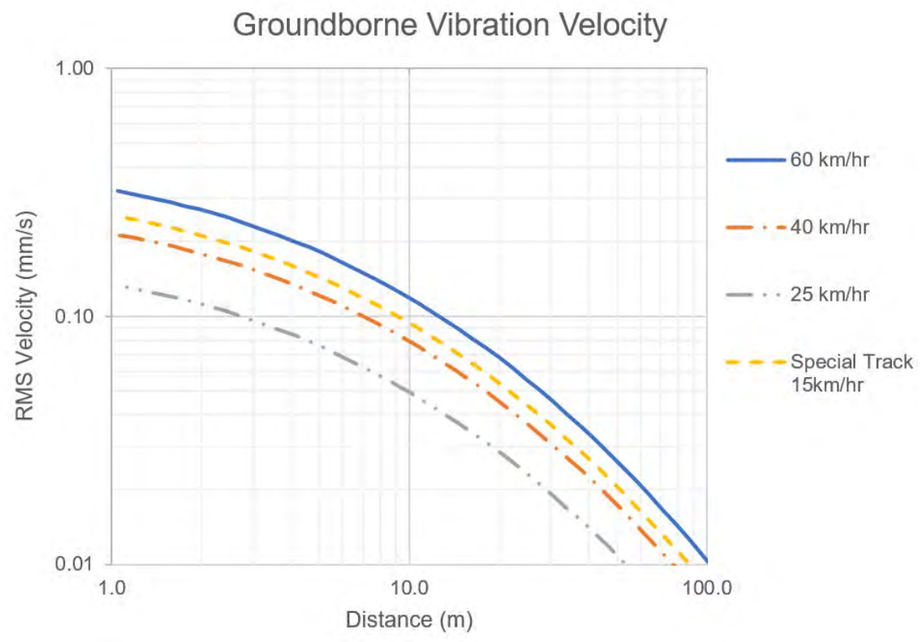
Groundborne vibration levels have been predicted using guidance from the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual.

Groundborne vibration levels are dependant on several factors related to the locomotive, track, and speed. The following assumptions have been made for this assessment:

- Locomotive – the unsprung mass per axel, chassis and suspension characteristics, and wheel condition all dictate the vibration magnitude and frequency profile. It has been assumed that the performance and maintenance of the proposed future streetcars will be equal to that of the streetcars currently operating on the Queens Quay West line (Bombardier Flexity Outlook).
- Track – it is assumed that the track condition and construction (concrete embedded with 115RE modified rail boot) will be similar to the existing condition at the Queens Quay West portal. Wheel flats and corrugated track should be maintained regularly.
- Speed – it is assumed that streetcar will operate at 60 km/h at exclusive track zones, 40 km/h at semi-exclusive track zones, 25 km/h at intersections and 15 km/h at special track locations (e.g., crossover).

Exhibit 9 presents the predicted decay curve of groundborne vibration at grade for a rapid transit or light rail vehicle travelling at the anticipated speeds. An increase of +10 dB (factor of 3) has been adopted for special trackwork.

Exhibit 9 Groundborne vibration levels with distance



Based on the criteria set out in the TTC Design Manual of 0.10mm/s RMS velocity at not less than 15 metres from the centreline of the track, groundborne vibration is predicted to achieve the proposed design goal without any additional mitigation measures. The most onerous condition, 60 km/h zone, is predicted to achieve the criteria at 12 metres from the centreline of track.

4.2 Special considerations

4.2.1 Portals

The weight and size of transit support structures affects the vibration radiated by that structure. In general, vibration levels are lower for heavier structures, such as the concrete cut box of the portal. Speeds are also likely to be low in the vicinity of the portal, as observed at the at the existing Queens Quay West portal. For these reasons the vibration levels at the portal are predicted to be similar or lower than those predicted for at-grade locations.

4.2.2 Damage to fragile structures

The magnitude of vibration required to cause damage to a structure are orders of magnitude higher than the criteria considered for human perception. For example, BS 5228-2 Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration provides limits for cosmetic damage of structures subjected to transient groundborne vibration. The most onerous limit is a peak

particle velocity of 15mm/s at 4 Hz, which is 100 times greater than the 0.10mm/s RMS limit considered for human perception (assuming a crest factor of 1.5).

5. Construction Phase Impacts

Construction phase impacts have not been considered explicitly in this assessment, however the following statements are reflective of the noise and vibration impacts of LRT infrastructure construction in an urban environment.

Construction of at-grade LRT infrastructure primarily consists of demolition of existing infrastructure, shallow excavation for utility diversion and foundations, preparation and casting of the reinforced concrete track bed, installation of the steel rails and installation of the overhead catenary system. Other sources of noise and vibration emissions include diesel powered generators, construction vehicles, and delivery or haul trucks. All of these activities have potential to produce noise emissions in excess of construction noise criteria if not adequately controlled. Demolition and excavation activities, as well as the movement of construction vehicles, pose the greatest risk of onerous vibration levels.

Several built heritage resources are present within the Segment 2 study area. Heritage buildings may be more sensitive to vibration impacts, either due to increased vulnerability or lower tolerance to damage. Recommendations for a baseline vibration assessment have been made in the cultural heritage report.

It is recommended that a noise and vibration control plan be developed prior to commencement of construction. The plan should adopt appropriate performance requirements, identify sources of noise and vibration, identify possible sensitive receivers, and provide a mitigation strategy for compliance. The performance requirements would be expected to include City of Toronto construction vibration limits (City of Toronto Municipal Code Chapter 363, Article 5, Construction Vibrations) and may include guidance from the FTA manual, U.S. Federal Highway Administration (FHWA) Construction Noise Handbook.

6. Conclusions and Recommendations

Airborne noise levels have been predicted for the future scenario of the project using the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual for LRT noise levels and the Ontario Road Noise Analysis Method for Environment and Transportation (ORNAMENT) for vehicle traffic noise levels. The following conclusions were made:

- The project is anticipated to achieve the proposed design goal of not surpassing the ambient L_{eq} values for residences situated at least 15 metres from the track centreline and 6 metres from the road centreline in all scenarios during daytime, as well as during nighttime for both the 25km/h and 40km/h scenarios.
- When the streetcar is traveling at 60 km/h or on special track during nighttime, it is anticipated to generate a maximum noise level of 59 dBA ($L_{eq,8h}$), which is 4 decibels higher than the design goal of ambient.
- However, the protocol limit for requiring noise mitigation is 5 dB above the maximum of ambient ($L_{eq,8h}$) or 50 dBA ($L_{eq,8h}$), whichever is greater. Considering that the predicted nighttime ambient noise level due to traffic is 55 dBA ($L_{eq,8h}$), mitigation is only required for levels above 60 dBA ($L_{eq,8h}$), hence the project is not expected to trigger the protocol.

Several noise measurements were taken of streetcar passby events on Queens Quay West to determine the passby sound level (L_{passby}). The following conclusions were made:

- Streetcar passbys measured 75 $dBA_{,max}$, meaning the maximum sound level recorded during the passby was 75 dBA. The criterion for a single passby event is 80 dBA averaged over the duration of the passby (approximately 3-4 seconds). Hence, the streetcar passby is clearly under the criterion.

Groundborne vibration levels have also been predicted using guidance from the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual. The following conclusions were made:

- Based on the criterion of 0.10mm/s rms velocity at not less than 15 metres from the centreline of the track, groundborne vibration is predicted to achieve the proposed design goal without any additional mitigation measures. The most onerous condition, 60 km/h zone, is predicted to achieve the criteria at 12 metres from the centreline of track, comfortably within the 15m requirement.

The predicted performance at the future portal on Queens Quay East was considered. The conclusions made are based on measurements taken at the existing portal on Queens Quay West, guidance from the FTA manual and noise and vibration, and engineering principles.

- The airborne noise levels emitted from the portal will differ from similar at-grade location in two ways – slower operating speeds and sound reverberation (multiple reflections) off the portal walls. Based on observations at the existing Queens Quay West portal, streetcars operate between 10 and 25 km/h at the portal section. At these speeds noise levels are predicted to be below the threshold for mitigation, including +3 dB to account for the effect of sound reverberation. Noise measurements taken at the existing portal confirm these predictions.
- The weight and size of transit support structures affects the vibration radiated by that structure. In general, vibration levels are lower for heavier structures, such as the concrete cut box of the portal. Speeds are also much lower in the vicinity of the portal than at sections of tangent track. For these reasons the vibration levels at the portal are predicted to be similar or lower than those predicted for at-grade locations.
- Overall, the portal section is not predicted to require noise or vibration mitigation based on the criteria set out in the TTC Design Manual.

The conclusions of this assessment are aligned to those of the prior East Bayfront Transit Environmental Assessment conducted in 2010 by RWDI AIR Inc. This assessment report is included for information in Appendix 1-2.

This assessment has not taken into consideration any noise barriers or hard/soft landscaping. Whilst the assessment methodology does not consider hard or soft landscaping, it is recognised that these features often have a positive benefit on people's perception of noise in an urban environment, either thought noise attenuation, reflection or obscuring the view of the noise source from the receiver.

This assessment has not explicitly considered construction phase impacts. It is recommended that a noise and vibration control plan be developed prior to commencement of construction.

Appendix 1-1

Noise Calculations and Input Data

Exhibit 10 Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual Calculations – LRT at 60 km/h at grade

Noise Source Parameters		Source 2
	Source Type:	Fixed Guideway
	Specific Source:	Rail Transit Vehicle/Streetcar > 25 mph
Daytime hrs	Avg. Number of Transit Vehicles/train	1
	Speed (mph)	38
	Avg. Number of Events/hr	30
Nighttime hrs	Avg. Number of Transit Vehicles/train	1
	Speed (mph)	38
	Avg. Number of Events/hr	SS
Distance	Distance from Source to Receiver (ft)	49
	Number of Intervening Rows of Buildings	0
Adjustments	Noise Barrier?	No
	Joint Track/Crossover?	No
	Embedded Track?	Yes
	Aerial Structure?	No

Source 2 Results

Leq(day):	61.9 dBA
Leq(night):	58.9 dBA
Ldn:	65.9 dBA
Incremental Ldn (Src 1-2):	67.8 dBA

Exhibit 11 Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual Calculations – LRT at 40 km/h at grade

Noise Source Parameters		Source 1
	Source Type:	Fixed Guideway
	Specific Source:	Rail Transit Vehicle/Streetcar <= 25 mph
Daytime hrs	Avg. Number of Transit Vehicles/train	1
	Speed (mph)	25
	Avg. Number of Events/hr	30
Nighttime hrs	Avg. Number of Transit Vehicles/train	1
	Speed (mph)	25
	Avg. Number of Events/hr	15
Distance	Distance from Source to Receiver (ft)	49
	Number of Intervening Rows of Buildings	0
Adjustments	Noise Barrier?	No
	Joint Track/Crossover?	No
	Embedded Track?	Yes
	Aerial Structure?	No

Source 1 Results

Leq(day):	58.3 dBA
Leq(night):	55.3 dBA
Ldn:	62.3 dBA

Exhibit 12 Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual Calculations – LRT at 25 km/h at grade

Noise Source Parameters		Source 1
	Source Type:	Fixed Guideway
	Specific Source:	Rail Transit Vehicle/Streetcar <= 25 mph
Daytime hrs	Avg. Number of Transit Vehicles/train	1
	Speed (mph)	15.5
	Avg. Number of Events/hr	30
Nighttime hrs	Avg. Number of Transit Vehicles/train	1
	Speed (mph)	15.5
	Avg. Number of Events/hr	15
Distance	Distance from Source to Receiver (ft)	49
	Number of Intervening Rows of Buildings	0
Adjustments	Noise Barrier?	No
	Joint Track/Crossover?	No
	Embedded Track?	Yes
	Aerial Structure?	No

Source 1 Results

Leq(day): 57.9 dBA
Leq(night): 54.9 dBA
Ldn: 61.9 dBA

Exhibit 13 Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual Calculations – LRT at 15 km/h at grade special track

Noise Source Parameters		Source 1
	Source Type:	Fixed Guideway
	Specific Source:	Rail Transit Vehicle/Streetcar <= 25 mph
Daytime hrs	Avg. Number of Transit Vehicles/train	1
	Speed (mph)	9.3
	Avg. Number of Events/hr	30
Nighttime hrs	Avg. Number of Transit Vehicles/train	1
	Speed (mph)	9.3
	Avg. Number of Events/hr	15
Distance	Distance from Source to Receiver (ft)	50
	Number of Intervening Rows of Buildings	0
Adjustments	Noise Barrier?	No
	Joint Track/Crossover?	Yes
	Embedded Track?	Yes
	Aerial Structure?	No

Source 1 Results

Leq(day): 62.3 dBA
Leq(night): 59.3 dBA
Ldn: 66.3 dBA

Exhibit 14 Traffic Volumes Used for Vehicle Noise Calculations

Traffic volumes with proposed LRT Projects		
Time	EB	WB
0:00	59	62
1:00	39	41
2:00	27	23
3:00	19	14
4:00	11	12
5:00	21	21
6:00	67	48
7:00	175	121
8:00	316	236
9:00	288	250
10:00	237	208
11:00	218	205
12:00	246	218
13:00	234	211
14:00	236	215
15:00	235	257
16:00	260	289
17:00	383	342
18:00	329	344
19:00	284	263
20:00	203	185
21:00	177	158
22:00	151	164
23:00	118	133

Exhibit 15 STAMSON Daytime 16hr Leq with Vehicle Noise at 40 km/h

```
STAMSON 5.0        NORMAL REPORT        Date: 22-01-2024 14:25:03
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: 40km16hr.te          Time Period: 16 hours
Description: Daytime 16hr Leq at 15m for projected traffic


Road data, segment # 1: QueensQuay
----------------------------------
Car traffic volume  :  7256 veh/TimePeriod
Medium truck volume :   191 veh/TimePeriod
Heavy truck volume  :   191 veh/TimePeriod
Posted speed limit  :    40 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: QueensQuay
--------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  15.00 m
Receiver height           :   4.50 m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00

↑
Results segment # 1: QueensQuay
-------------------------------

Source height = 1.26 m

ROAD (0.00 + 61.57 + 0.00) = 61.57 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
-------------------------------------------------------------------------------
   -90     90   0.00  61.57   0.00   0.00   0.00   0.00   0.00   0.00  61.57
-------------------------------------------------------------------------------

Segment Leq : 61.57 dBA

Total Leq All Segments: 61.57 dBA

↑


TOTAL Leq FROM ALL SOURCES:       61.57
↑
↑
```

Exhibit 16 STAMSON Nighttime 8hr Leq with Vehicle Noise at 40 km/h

```
STAMSON 5.0        COMPREHENSIVE REPORT        Date: 22-01-2024 14:29:27
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: 40km8hr.te           Time Period: 16 hours
Description: Nighttime 8hr Leq at 15m for projected traffic


Road data, segment # 1: QueensQuay
----------------------------------
Car traffic volume  :   679 veh/TimePeriod
Medium truck volume :    18 veh/TimePeriod
Heavy truck volume  :    18 veh/TimePeriod
Posted speed limit  :    40 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

Data for Segment # 1: QueensQuay
--------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  15.00 m
Receiver height           :   4.50 m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00

Segment # 1: QueensQuay
-----------------------

Source height = 1.26 m

ROAD (0.00 + 51.30 + 0.00) = 51.30 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
-------------------------------------------------------------------------------
   -90     90   0.00  51.30   0.00   0.00   0.00   0.00   0.00   0.00  51.30
-------------------------------------------------------------------------------

Segment Leq : 51.30 dBA

Total Leq All Segments: 51.30 dBA


TOTAL Leq FROM ALL SOURCES:       51.30
```

Exhibit 17 Combined road and LRT predicted noise levels

Job No.	Job Title			
272263-33.0	WELRT TPAP EPR			
Date Created	By	Date Revised	Rev	Sheet
23 Jan 2024	CH	23 Jan 2024	2	45314
Date Reviewed	By	Review Type	Review Status	
15 Feb 2024	GM			

Waterfront East LRT TPAP, Road and Rail Predicted Noise Levels

Item / Description	Predicted Noise Level: STAMSON Adjustment	Predicted Noise Level: Leq, dB(A)
Distance Adjustment from 15m to 6m	3.98	
Road Noise, Daytime Leq,16hr, STAMSON at 15m		61.57
Road Noise, Daytime Leq,16hr, STAMSON result with distance correction		**65.55**
Road Noise, Nighttime Leq,8hr, STAMSON at 15m		51.30
Road Noise, Nighttime Leq,8hr, STAMSON result with distance correction		**55.28**
LRT, 60 km/hr, Leq (FTA calculation) - Daytime		61.90
Combined Road and LRT - Daytime		**67.11**
LRT, 60 km/hr, Leq (FTA calculation) - Nighttime		58.90
Combined Road and LRT - Nighttime		**60.47**
LRT, 40 km/hr, Leq (FTA calculation) - Daytime		58.30
Combined Road and LRT - Daytime		**66.30**
LRT, 40 km/hr, Leq (FTA calculation) - Nighttime		55.30
Combined Road and LRT - Nighttime		**58.30**
LRT, 25 km/hr, Leq (FTA calculation) - Daytime		57.90
Combined Road and LRT - Daytime		**66.24**
LRT, 25 km/hr, Leq (FTA calculation) - Nighttime		54.90
Combined Road and LRT - Nighttime		**58.10**
LRT, 15 km/hr with special track, Leq (FTA calculation) - Daytime		62.30
Combined Road and LRT - Daytime		**67.23**
LRT, 15 km/hr with special track, Leq (FTA calculation) - Nighttime		59.30
Combined Road and LRT - Nighttime		**60.75**

Appendix 1-2

Prior Noise & Vibration Assessment

CONSULTING ENGINEERS
& SCIENTISTS

March 17, 2010

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

A member of the RWDI Group of Companies

Mr. Hank Wang
McCormick Rankin Corporation
2655 North Sheridan Way, Suite 300
Mississauga, Ontario,
L5K 2P8

Re: Noise & Vibration Assessment, East Bayfront - Queens Quay East
RWDI Project W07-5120B **Email:** Hwang@mrc.ca

Dear Hank,

RWDI AIR Inc. (RWDI) was retained by McCormick Rankin Corporation (MRC) to conduct an environmental noise and vibration study for the Toronto Transit Commission (TTC) Eastern Waterfront Project located in Toronto, Ontario. This study was limited to the proposed street car rails to be located on Queens Quay East between Yonge Street and the end loop just east of Parliament Street. This report presents the results of our studies.

METHODOLOGY

This study was based on the Transit Noise and Vibration Impact Assessment algorithms published by the U.S. Department of Transportation Federal Transit Administration (FTA). The FTA model was previously validated for modeling of TTC street car installations by comparison against noise and vibration measurements of existing tracks conducted by RWDI (RWDI W07-5120C). Inputs to this assessment were from drawings of the proposed road and rail layouts (Drawing 6377-Q-2 received April 21, 2009) along Queens Quay East.

The predicted noise levels were assessed against the MOE / TTC Transit Expansion Protocols. These guidelines state that the 16 hour equivalent sound level (L_{eq}(16h)) for daytime operation must not exceed the higher of 55 dBA or the existing background ambient sound level, and that the 8 hour equivalent sound level (L_{eq}(8h)) must not exceed the higher of 50 dBA or the existing background ambient sound level. The location for assessment of daytime noise levels is at the Outdoor Living Area (OLA) of each receptor, and the assessment of night-time noise levels is at the plane of the receptor's windows. Maximum rail pass-by noise levels (L_{max}) are limited to 77 dBA to 80 dBA at any time of the night or day as assessed at the plane of the receptor's windows.

The predicted vibration levels were assessed against the CN Rail vibration level guidelines. These guidelines state that the vibration levels from a single pass-by should not exceed 0.144 mm/s RMS. The guidelines are applicable to the floor of a dwelling unit, but since calculation of building-borne vibration is beyond the scope of this study, assessment is made at the foundation of the receptors. The predicted vibration levels are also shown against the ISO 2631-2 guideline limits for whole body vibration in buildings.

The noise levels were assessed for eight representative receptors in the expansion area. The receptors are referred to as NR1 through NR8. The receptors are spread across the entire project study area and are shown in the future build case after the area undergoes change. There are certain sections of the new zoning bylaw that is currently under appeal to the Ontario Municipal Board (OMB) to be rezoned as potentially residential to the north of Queens Quay between Jarvis Street and Bonnycastle Street. For this analysis, it is assumed that this area will be resolved and zoned residential. The zoning of the lands within the study boundaries is shown in Figure 1. A copy of the amendment to the zoning by-law for the area can be found in Appendix A. The representative receptors are shown in Figure 2. These receptors represent the worst case impacts expected from the rail expansion. Currently noise and potentially vibration sensitive lands are found between the Yonge Street Slip and the Redpath Sugar lands. Noise and potentially vibration sensitive lands are also found between the Lower Jarvis Slip and the Sherbourne Park South Lands. These areas are not expected to be impacted by noise or vibration due to the elevated levels created by local vehicle traffic.

The vibration study was based on rail speeds of 50 km/h, on the track nearest each receptor. The study did not take into account any special track work since it is anticipated to be located only in the underground section of the rail line. Since the CN Rail vibration guidelines are based on a worst-case pass-by, there is no consideration given to differences in levels of service during the daytime, evening, and night-time.

The noise study was also based on rail speeds of 50 km/h, at a distance equal to that from between the two tracks to the property of the future receptor as the exact set back distances are not presently known. The study took into account “wheel squeal” produced by railcars rounding the end loop at the east side of Parliament Street, and the TTC’s expected operating times during the daytime, evening, and night-time. Background levels for the noise study were determined through road noise modeling using the Ontario Road Noise Method for Environment and Transportation (ORNAMENT) algorithm. Inputs to the ORNAMENT algorithm were based on traffic predictions for the project area. The greater of the background sound levels or defaults (55 dBA for daytime and 50 dBA for night-time) are used as the guideline sound level limits. All receptors have been calculated to have elevated background sound levels above the defaults. The resulting Guideline Sound Level Limits can be found in Table 1 in the Noise Assessment Results section of this report.

NOISE ASSESSMENT RESULTS

The predicted noise levels at each receptor are below the applicable guideline limits at each of the eight receptors. Predicted levels are compared with guideline limits in Tables 1 and 2.

Table 1: Noise Assessment Results, L_{eq} Assessment

Receptor ID	Time Period	Predicted Sound Level (dBA) [1]	Guideline Sound Level Limit (dBA) [1]	Meets Criteria?
NR1	Day	57	64	Yes
	Night	50	57	Yes
NR2	Day	56	67	Yes
	Night	50	60	Yes
NR3	Day	56	67	Yes
	Night	50	60	Yes
NR4	Day	56	67	Yes
	Night	50	60	Yes
NR5	Day	57	64	Yes
	Night	51	58	Yes
NR6	Day	56	67	Yes
	Night	50	61	Yes
NR7	Day	57	65	Yes
	Night	51	58	Yes
NR8	Day	58	67	Yes
	Night	51	60	Yes

Notes: 1. Sound levels are presented as $L_{eq}(16)$ for daytime periods and $L_{eq}(8h)$ for night-time periods

Table 2: Noise Assessment Results, L_{max} Assessment

Receptor ID	Predicted Maximum Sound Level (dBA)	Guideline Sound Level Limit (dBA)	Meets Criteria?
NR1	75	77	Yes
NR2	74	77	Yes
NR3	73	77	Yes
NR4	73	77	Yes
NR5	75	77	Yes
NR6	73	77	Yes
NR7	75	77	Yes
NR8	72	77	Yes

VIBRATION ASSESSMENT RESULTS

The predicted vibration levels (track above grade) are shown graphically as the distance between the nearest track and receptor varies, in Figure 3. The most important criterion of the five is the CN guideline. The other four are shown for reference purposes. The MOE / TTC Transit Expansion Protocols specify that "any point on the outdoor premises of a person not closer than 15 m from the track centerline where sound originating from transit operations is received." The predicted vibration levels are below all of the applicable receptors at a distance greater than 15 m.

The predicted vibration levels (below grade) are compared with the CN guideline limits in Figure 3. The difference between the two results is the distance between the nearest track and the underlying bedrock. Since the distance between the track and the bedrock is unknown, both situations are shown below. The calculation was completed assuming a minimum separation distance of 15 m between the track and the receptor.

CONCLUSIONS

The predicted noise levels are below the guideline limits at each of the eight receptors. The predicted vibration levels are below the guideline limits at all receptors, if the minimum separation distance of 15 m is maintained between the centre line of the tracks and the façade of the sensitive receptor. All future developments within the study area of this project should require a noise and vibration study to ensure they comply with the applicable noise and vibration criteria.

Yours very truly,

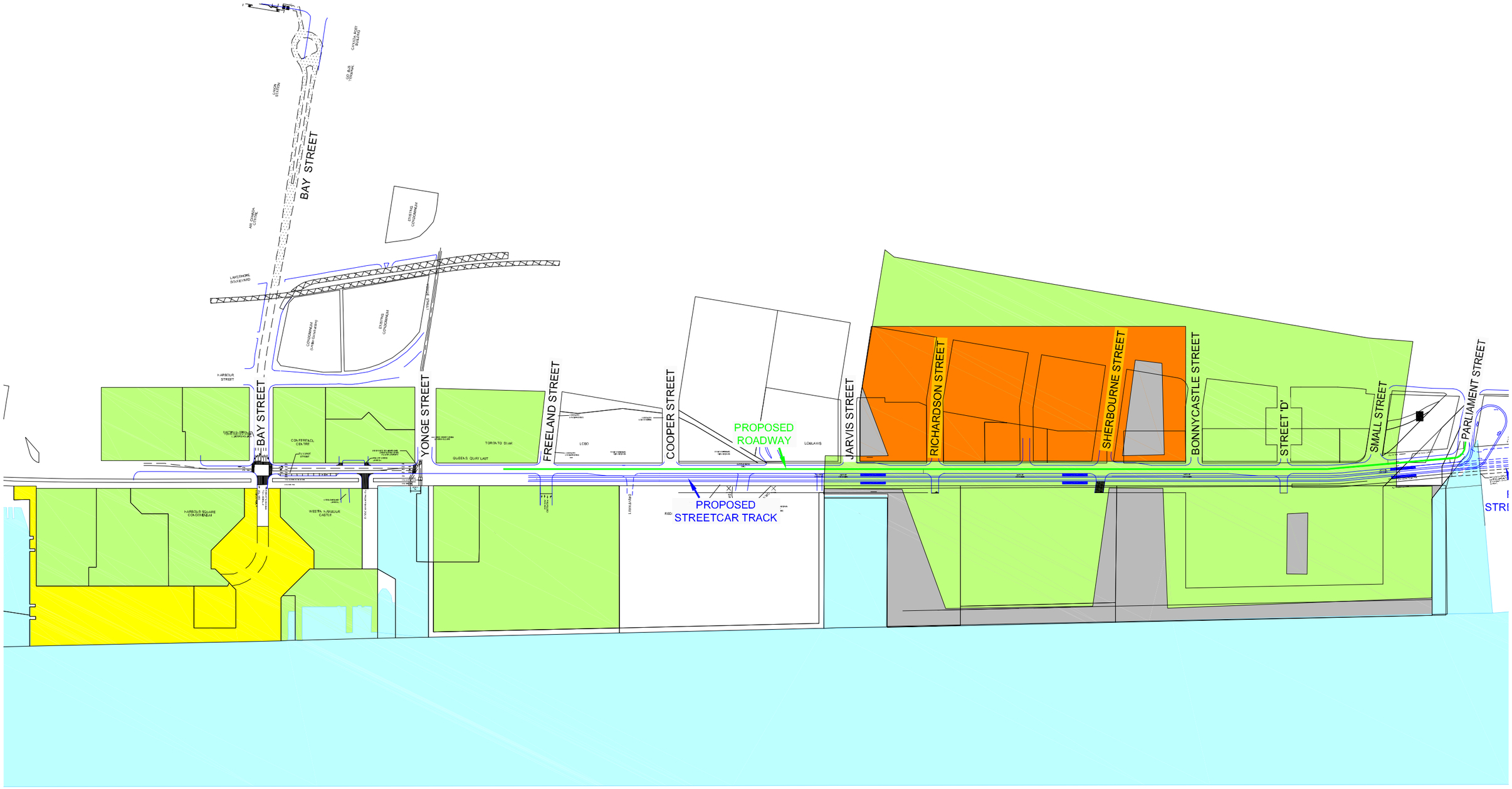
RWDI AIR Inc.

Scott Penton, P.Eng.
Project Director / Associate

SLP/anc

Attach.

FIGURES



LEGEND:

- OMB Hearing for Re-zoning of Land Use
- Commercial Residential
- Park Space
- Open Space

0 90 180m

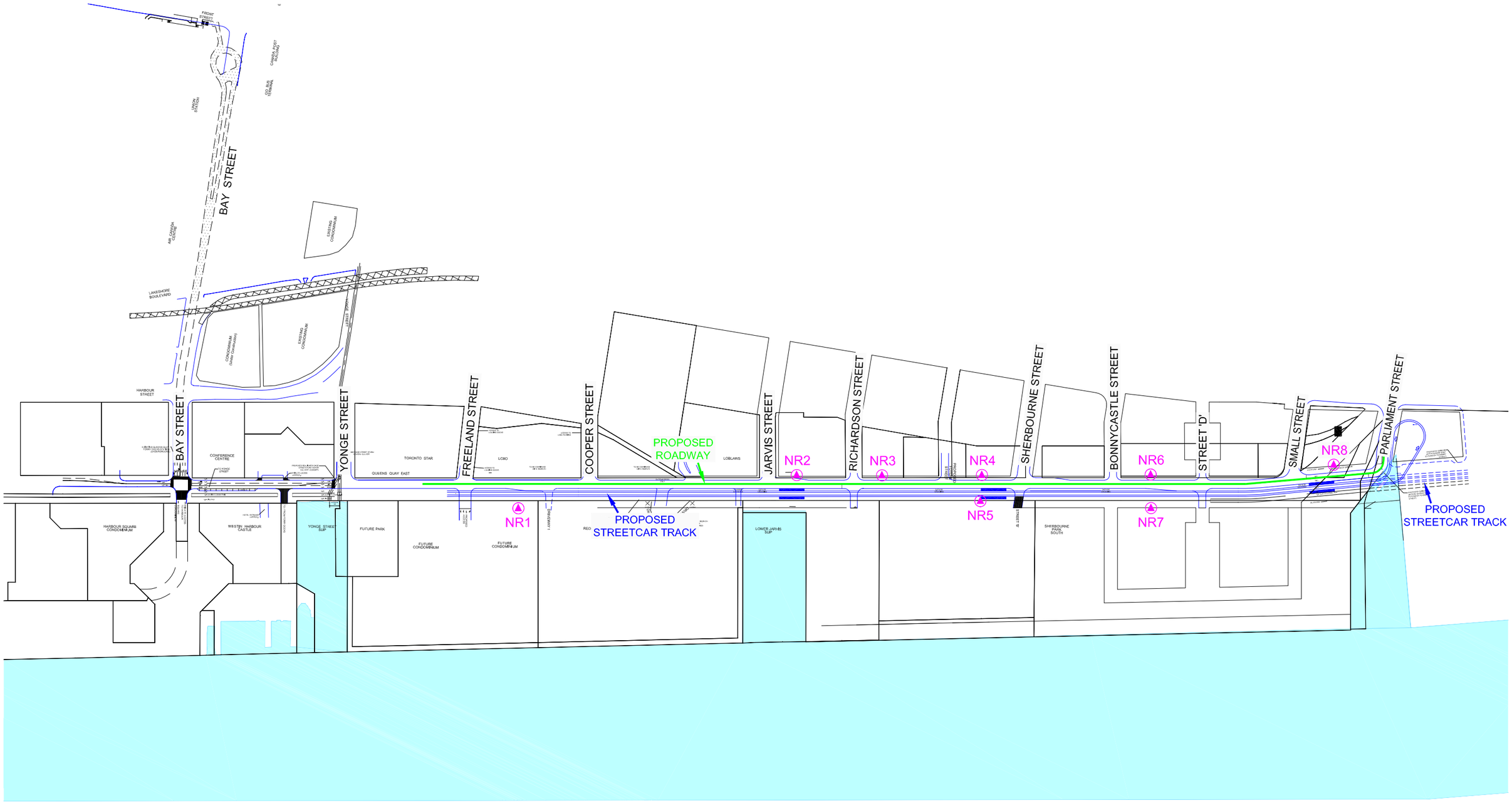
Zoning of Land Uses

True North

TTC Eastern Waterfront - Easy Bayfront - Queens Quay East - Toronto, Ontario

Project #W07-5120B

Drawn by: NTN	Figure: 1	RWDI
Approx. Scale:	1:4500	
Date Revised: Dec. 10, 2009		



0 90 180m

LEGEND:

Noise Sensitive Receptor

Representative Noise Sensitive Receptors

True North

TTC Eastern Waterfront - Easy Bayfront - Queens Quay East - Toronto, Ontario

Project #W07-5120B

Drawn by: NTN	Figure:	2	RWDI
Approx. Scale:	1:4500		
Date Revised:	Nov 30, 2009		

Figure 3 - Ground-Borne Vibration versus Distance