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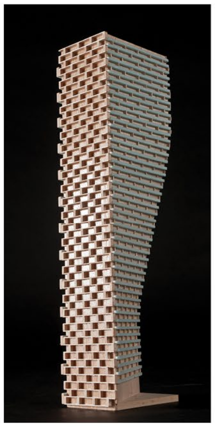
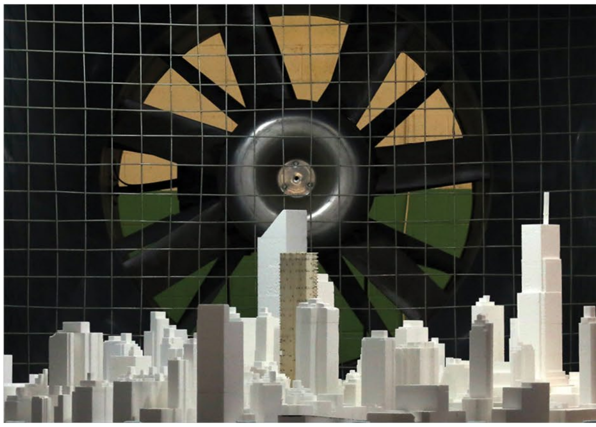
TRANSPORTATION NOISE AND VIBRATION ASSESSMENT

3725 Carp Road
Carp, Ontario

REPORT: 22-341 – Transportation Noise and Vibration





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EXECUTIVE SUMMARY

This report describes a transportation noise and vibration assessment for the proposed development located at 3725 Carp Road in Carp, Ontario. The development comprises seven buildings on an irregular parcel of land west of Carp Road. The primary sources of transportation noise include Carp Road, Donald B. Munro Drive, and the Arnprior-Nepean Railway corridor. As the site is in proximity to the Arnprior-Nepean Railway corridor, a ground vibration impact assessment from the railway on the proposed development was conducted following the procedures outlined in the Federal Transit Authorities (FTA) protocol. Figure 1 illustrates a complete site plan with the surrounding context.

The assessment is based on (i) theoretical noise prediction methods that conform to the Ministry of the Environment, Conservation and Parks (MECP), Ministry of Transportation of Ontario (MTO), and City of Ottawa requirements; (ii) noise level criteria as specified by the City of Ottawa's Environmental Noise Control Guidelines (ENCG); (iii) future vehicular traffic volumes based on the City of Ottawa's Official Plan roadway classifications; (iv) site plan drawings provided by Novatech in January 2023; and (v) ground-borne vibration criteria as specified by the Federal Transit Authority (FTA) Protocol.

The results of the current analysis indicate that noise levels will range between 37 and 67 dBA during the daytime period (07:00-23:00) and between 22 and 60 dBA during the nighttime period (23:00-07:00). The highest noise level (67 dBA) occurs at the northeast facades of Building A and Building B which are nearest and most exposed to Carp Road and the railway corridor.

Building components with a higher Sound Transmission Class (STC) rating will be required for Buildings A-C where exterior noise levels exceed 60 dBA, as outlined in Section 5.2. The results of the analysis also indicate that Buildings A-C will require central air conditioning, which will allow occupants to keep windows closed and maintain a comfortable living environment. Similarly, Building D will require forced air heating with provisions for central air conditioning as summarized in Table 5 and outlined in Figure 4. Warning Clauses will also be required to be placed on all Lease, Purchase and Sale Agreements, as summarized in Section 6.

With regard to the courtyard, noise levels are expected to be below the noise level criteria for OLAs. Therefore, no acoustic mitigation is required.

Furthermore, estimated vibration levels at the foundation nearest to the railway corridor are expected to be 0.04mm/s RMS (64 dBV), based on the FTA protocol and an offset distance of 21 m to the nearest track centerline. Details of the calculation are provided in Appendix B. Since predicted vibration levels do not exceed the criterion of 0.14 mm/s RMS at the foundation, concerns due to vibration impacts on the site are not expected. As vibration levels are acceptable, correspondingly, regenerated noise levels are also expected to be acceptable.

The stationary noise impacts of the buildings on the surroundings would be considered at a future stage once the mechanical design has progressed and equipment has been selected. Stationary noise sources associated with the development will likely include rooftop air handling units and fan coils. Should noise levels from these units exceed the criteria established in NPC-300 and ENCG, noise from these sources can be controlled to acceptable limits by judicious selection of the equipment, locating the equipment on a high roof away from nearby residential receptors, and where necessary, installing silencers or noise screens.

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1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Karson Holdings Inc. c/o Novatech to undertake a transportation noise and vibration assessment for the proposed development located at 3725 Carp Road in Carp, Ontario. This report summarizes the methodology, results, and recommendations related to the assessment of exterior and interior noise levels generated by local transportation noise and vibration sources.

Our work is based on theoretical noise calculation methods conforming to the City of Ottawa[1] noise guidelines, Ministry of the Environment, Conservation and Parks (MECP)[2] guidelines, as well as the Ministry of Transportation Ontario (MTO)[3] noise guidelines. Noise calculations were based on architectural drawings provided by Novatech in January 2023, and railway volumes based on observation of rail traffic in Carp.

2. TERMS OF REFERENCE

The focus of this transportation noise and vibration assessment is the proposed development located at 3725 Carp Road in Carp, Ontario. The proposed development comprises seven buildings labelled A through G on an irregular parcel of land west of Carp Road. The parcel of land is bounded by Carp Road to the east, Arnprior-Nepean Railway corridor to the north, and the Carp River to the west and south. Building A and B are to include 9 Lifestyle Unit Blocks / Commercial Units each, whereas the remaining blocks will consist of 12 stacked residential units each. Surrounding the buildings at grade are rows of outdoor parking spaces, a courtyard located between Building D and E, and a fire route. The site is surrounded by low-rise residential and commercial buildings to the north and east, and agricultural lands to the west and south.

The primary sources of transportation noise include Carp Road, Donald B. Munro Drive, and the Arnprior-Nepean Railway corridor. The primary source of ground-borne vibration is the Arnprior-Nepean Railway corridor. As per City of Ottawa's Official Plan, the railway corridor is situated within 75 m from the nearest

[1] City of Ottawa Environmental Noise Control Guidelines, January 2016
[2] Ontario Ministry of the Environment, Conservation and Parks – Environmental Noise Guidelines, Publication NPC-300, Queens Printer for Ontario, Toronto, 2013
[3] Environmental Guide for Noise, February 2022. Ministry of Transportation Ontario

property line. As a result, a ground vibration impact assessment from the railway system on the proposed development was conducted following the procedures outlined in the Federal Transit Authorities (FTA) protocol. Figure 1 illustrates a complete site plan with surrounding context.

Moreover, the stationary noise impacts of the buildings on the surroundings would be considered at a future stage once the mechanical design has progressed and equipment has been selected. Stationary noise sources associated with the development will likely include rooftop air handling units and fan coils. Should noise levels from these units exceed the criteria established in NPC-300 and ENCG, noise from these sources can be controlled to acceptable limits by judicious selection of the equipment, locating the equipment on a high roof away from nearby residential receptors, and where necessary, installing silencers or noise screens.

3. OBJECTIVES

The principal objectives of this study are to (i) calculate the future noise levels on the study building produced by local roadway and railway traffic, (ii) predict vibration levels on the study building produced from the railway corridor, and (iii) ensure that interior and exterior noise and vibration levels do not exceed the allowable limits specified by the City of Ottawa's Environmental Noise Control Guidelines as outlined in Section 4.2 of this report.

4. METHODOLOGY

4.1 Background

Noise can be defined as any obtrusive sound. It is created at a source, transmitted through a medium, such as air, and intercepted by a receiver. Noise may be characterized in terms of the power of the source or the sound pressure at a specific distance. While the power of a source is characteristic of that particular source, the sound pressure depends on the location of the receiver and the path that the noise takes to reach the receiver. Measurement of noise is based on the decibel unit, dBA, which is a logarithmic ratio referenced to a standard noise level (2×10^{-5} Pascals). The 'A' suffix refers to a weighting scale, which better represents how the noise is perceived by the human ear. With this scale, a doubling of power results in a 3 dBA increase in measured noise levels and is just perceptible to most people. An increase of 10 dBA is often perceived to be twice as loud.

4.2 Transportation Traffic Noise

4.2.1 Criteria for Transportation Traffic Noise

For roadway and railway traffic noise, the equivalent sound energy level, L_{eq}, provides a measure of the time-varying noise levels, which is well correlated with the annoyance of sound. It is defined as the continuous sound level, which has the same energy as a time-varying noise level over a period of time. For roadways and railways, the L_{eq} is commonly calculated on the basis of a 16-hour (L_{eq16}) daytime (07:00-23:00) / 8-hour (L_{eq8}) nighttime (23:00-07:00) split to assess its impact on residential buildings. The City of Ottawa's Environmental Noise Control Guidelines (ENCG) specifies that the recommended indoor noise limit range (that is relevant to this study) is 45 and 40 dBA for living rooms and sleeping quarters respectively, as listed in Table 1. However, to account for deficiencies in building construction and to control peak noise, these levels should be targeted toward 42, and 37 dBA.

TABLE 1: INDOOR SOUND LEVEL CRITERIA [4]

Type of Space	Time Period	Road L_{eq} (dBA)	Rail L_{eq} (dBA)
General offices, reception areas, retail stores, etc.	07:00 – 23:00	50	45
Living/dining/den areas of **residences**, hospitals, schools, nursing/retirement homes, day-care centres, theatres, places of worship, libraries, individual or semi-private offices, conference rooms, etc.	07:00 – 23:00	45	40
Sleeping quarters of hotels/motels	23:00 – 07:00	45	40
Sleeping quarters of **residences**, hospitals, nursing/retirement homes, etc.	23:00 – 07:00	40	35

Predicted noise levels at the plane of window (POW) dictate the action required to achieve the recommended sound levels. An open window is considered to provide a 10 dBA reduction in noise while a standard closed window is capable of providing a minimum 20 dBA noise reduction[5]. Therefore, where noise levels exceed 55 dBA daytime and 50 dBA nighttime, the ventilation for the building should consider the need for having windows and doors closed, which triggers the need for forced air heating with

[4] Adapted from ENCG 2016 – Tables 2.2b and 2.2c
[5] Burberry, P.B. (2014). Mitchell's Environment and Services. Routledge, Page 125

provision for central air conditioning. Where noise levels exceed 65 dBA daytime and 60 dBA nighttime, air conditioning will be required and building components will require higher levels of sound attenuation[6].

Due to the characteristics of rail noise which occur over short periods (i.e. whistles, brake squealing), and a significant low frequency component produced by the movement of the locomotive along the track, road and rail traffic noise require separate analyses, particularly when assessing indoor sound levels. In order to account for the special characteristics of railway sound, the indoor sound level criteria are more stringent by 5 dB as compared to the roadway traffic criteria. This difference typically results in requirements for upgraded glazing elements to provide better noise attenuation from the building envelope. Interior noise level criteria include the influence from rail crossings and warning whistle bursts.

For designated Outdoor Living Areas (OLAs), the sound level limit is 55 dBA during the daytime period. An excess above the limit, between 55 dBA and 60 dBA, is acceptable only in cases where the required noise control measures are not feasible for technical, economic or administrative reasons. Noise levels at the OLA must not exceed 60 dBA in all cases. The development includes a courtyard to the west which has been identified as a noise-sensitive OLA and was included in the assessment.

4.2.2 Theoretical Transportation Noise Predictions

The impact of transportation noise sources on the development was determined by two computer modelling programs. To provide a general sense of noise across the site, the employed software program was Predictor-Lima which utilizes the United States Federal Highway Administration's Traffic Noise Model (TNM) to represent the roadway line sources. The TNM model has been accepted as the preferred model as per the revised guideline titled *"Environmental Guide for Noise"* prepared by the Ministry of Transportation Ontario (MTO)[7]. This computer program can represent three-dimensional surfaces and the first reflections of sound waves over a suitable spectrum for human hearing. A set of comparative calculations were performed in the current Ontario traffic noise prediction model, STAMSON, for comparisons to Predictor simulation results.

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[6] MOECP, Environmental Noise Guidelines, NPC 300 – Part C, Section 7.1.3
[7] Environmental Guide for Noise, February 2022. Ministry of Transportation Ontario

The STAMSON model is, however, older and requires each receptor to be calculated separately. STAMSON also does not accurately account for building reflections and multiple screening elements, and curved road geometry. A total of 25 receptor locations were identified around the site, as illustrated in Figure 2.

Transportation noise calculations were performed by treating each road segment as separate line sources of noise, and by using existing and proposed building locations as noise barriers. In addition to the traffic volumes summarized in Table 2, theoretical noise predictions were based on the following parameters:

- Truck traffic on all roadways was taken to comprise 5% heavy trucks and 7% medium trucks, as per ENCG requirements for noise level predictions.
- The day/night split for all sources was taken to be 92%/8%, respectively.
- The ground surface was modelled as reflective where pavement, concrete, and compact soil are present (hard ground).
- Receptor heights were taken to be 7.5 m and 1.5 m above grade, representative of the third level Plane of Window (POW), as well as at-grade Outdoor Amenity Areas (OLA), respectively.
- Topography was assumed to be a flat/gentle slope surrounding the study building.
- The terrain modelling was based on CAD mapping data prepared by the City of Ottawa.
- Massing associated with the study site and existing surrounding buildings were included as potential noise screening elements.
- Noise receptors were strategically placed at 25 locations around the study area (see Figure 2).
- Receptor distances and exposure angles, used in STAMSON calculations, are illustrated in Appendix A.
- Trains have 1 locomotive and 10 cars per train.
- Trains were modelled at a speed of 16 km/h.

4.2.1 Transportation Traffic Volumes

The ENCG dictates that noise calculations should consider future sound levels based on a roadway's and railway's classification at the mature state of development. Therefore, traffic volumes are based on the roadway classifications outlined in the City of Ottawa's Official Plan (OP) and Transportation Master Plan[8]

[8] City of Ottawa Transportation Master Plan, November 2013

which provide additional details on future roadway expansions. Average Annual Daily Traffic (AADT) volumes are then based on data in Table B1 of the ENCG for each roadway classification.

Railway volumes are based on historical observations in Carp along the Arnprior-Nepean Rail corridor. There is a single train that operates on this rail line serving the Nylene Canada Inc. manufacturing facility. It travels inbound and outbound once per week in each direction, based on observations of the facility's operations and activity on the rail line. This is in-line with historical data for the area and is not expected to deviate in the future. To design to a worst-case scenario, it is assumed that this inbound/outbound trip happens on the same day. Table 2 (below) summarizes the AADT values used for each source included in this assessment.

TABLE 2: TRANSPORTATION TRAFFIC DATA

Segment	Railway Traffic Data	Speed Limit (km/h)	Traffic Volumes
Arnprior-Nepean Rail Corridor	Railway (Service Line)	16	**2/0***
Carp Road	2-Lane Rural Arterial	50	**15,000**
Donald B. Munro Drive	2-Lane Collector	40	**8,000**

*Daytime/Nighttime volumes based on historical data for the corridor.

4.3 Indoor Noise Calculations

The difference between outdoor and indoor noise levels is the noise attenuation provided by the building envelope. According to common industry practice, complete walls and individual wall elements are rated according to the Sound Transmission Class (STC). The STC ratings of common residential walls built in conformance with the Ontario Building Code (2020) typically exceed STC 35, depending on exterior cladding, thickness and interior finish details. For example, brick veneer walls can achieve STC 50 or more. Standard commercially sided exterior metal stud walls have around STC 45. Standard good quality double-glazed non-operable windows can have STC ratings ranging from 25 to 40, depending on the window manufacturer, pane thickness and inter-pane spacing. As previously mentioned, the windows are the known weak point in a partition.

As per Section 4.2, when daytime noise levels from road sources at the plane of the window exceed 65 dBA, calculations must be performed to evaluate the sound transmission quality of the building components to ensure acceptable indoor noise levels. The calculation procedure[9] considers:

- Window type and total area as a percentage of total room floor area
- Exterior wall type and total area as a percentage of the total room floor area
- Acoustic absorption characteristics of the room
- Outdoor noise source type and approach geometry
- Indoor sound level criteria, which varies according to the intended use of a space

Based on published research[10], exterior walls possess specific sound attenuation characteristics that are used as a basis for calculating the required STC ratings of windows in the same partition. As a guideline, the anticipated STC requirements for windows have been estimated based on the overall noise reduction required for each intended use of space (STC = outdoor noise level – targeted indoor noise levels).

4.4 Ground Vibration and Ground-borne Noise

Rail systems and heavy vehicles on roadways can produce perceptible levels of ground vibrations, especially when they are in close proximity to residential neighbourhoods or vibration-sensitive buildings. Similar to sound waves in air, vibrations in solids are generated at a source, propagated through a medium, and intercepted by a receiver. In the case of ground vibrations, the medium can be uniform, or more often, a complex layering of soils and rock strata. Also, similar to sound waves in air, ground vibrations produce perceptible motions and regenerated noise known as 'ground-borne noise' when the vibrations encounter a hollow structure such as a building. Ground-borne noise and vibrations are generated when there is excitation of the ground, such as from a train or subway. Repetitive motion of the wheels on the track or rubber tires passing over an uneven surface causes vibration to propagate through the soil. When they encounter a building, vibrations pass along the structure of the building beginning at the foundation and propagating to all floors. Air inside the building excited by the vibrating walls and floors represents

[9] Building Practice Note: Controlling Sound Transmission into Buildings by J.D. Quirt, National Research Council of Canada, September 1985
[10] CMHC, Road & Rail Noise: Effects on Housing

regenerated airborne noise. Characteristics of the soil and the building are imparted to the noise, thereby creating a unique noise signature.

Human response to ground vibrations is dependent on the magnitude of the vibrations, which is measured by the root mean square (RMS) of the movement of a particle on a surface. Typical units of ground vibration measures are millimeters per second (mm/s), or inch per second (in/s). Since vibrations can vary over a wide range, it is also convenient to represent them in decibel units, or dBV. In North America, it is common practice to use the reference value of one micro-inch per second (μin/s) to represent vibration levels for this purpose. The threshold level of human perception to vibrations is about 0.10 mm/s RMS or about 72 dBV. Although somewhat variable, the threshold of annoyance for continuous vibrations is 0.5 mm/s RMS (or 85 dBV), five times higher than the perception threshold, whereas the threshold for significant structural damage is 10 mm/s RMS (or 112 dBV), at least one hundred times higher than the perception threshold level.

4.4.1 Ground Vibration Criteria

The Canadian Railway Association and Canadian Association of Municipalities have set standards for new sensitive land developments within 300 metres of a railway right-of-way, as published in their document *Guidelines for New Development in Proximity to Railway Operations*[11], which indicate that vibration conditions should not exceed 0.14 mm/s RMS averaged over a one second time-period at the first floor and above of the proposed building. As the main vibration source is due to a mainline railway which has infrequent events, the 0.14 mm/s RMS (75 dBV) vibration criteria and 40 dBA ground borne noise criteria were adopted for this study.

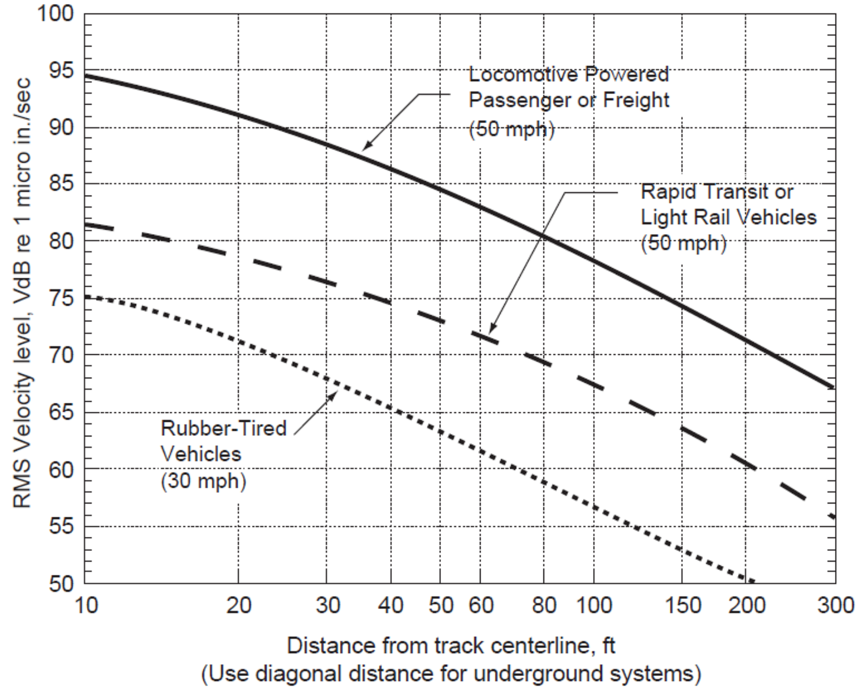
[11] Dialog and J.E. Coulter Associates Limited, prepared for The Federation of Canadian Municipalities and The Railway Association of Canada, May 2013

4.4.2 Theoretical Ground Vibration Prediction Procedure

Potential vibration impacts of the trains were predicted using the Federal Transit Authority's (FTA) *Transit Noise and Vibration Impact Assessment*[12] protocol. The FTA general vibration assessment is based on an upper bound generic set of curves that show vibration level attenuation with distance. These curves, illustrated in the figure on the following page, are based on ground vibration measurements at various transit systems throughout North America. Vibration levels at points of reception are adjusted by various factors to incorporate known characteristics of the system being analyzed, such as operating speed of vehicle, conditions of the track, construction of the track and geology, as well as the structural type of the impacted building structures. The vibration impact on the building was determined using a set of curves for Locomotive Powered Passenger or Freight Train at a speed of 50 mph. Adjustment factors were considered based on the following information:

- The maximum operating speed of the train is 16 km/h (10 mph).
- The distance between the development and the closest track is 21 m.
- The vehicles are assumed to have soft primary suspensions.
- Tracks are not welded, though in otherwise good condition.
- Soil conditions do not efficiently propagate vibrations.
- The coupling to building foundation is 3-4 Storey Masonry.

[12] C. E. Hanson; D. A. Towers; and L. D. Meister, Transit Noise and Vibration Impact Assessment, Federal Transit Administration, May 2006



FTA GENERALIZED CURVES OF VIBRATION LEVELS VERSUS DISTANCE (ADOPTED FROM FIGURE 10-1, FTA TRANSIT NOISE AND VIBRATION IMPACT ASSESSMENT)

5. RESULTS AND DISCUSSION

5.1 Transportation Noise Levels

The results of the transportation noise calculations are summarized in Table 3 below.

TABLE 3: EXTERIOR NOISE LEVELS DUE TO TRANSPORTATION SOURCES

Receptor Number	Receptor Height Above Grade/Roof (m)	Receptor Location	Roadway Noise Level (dBA)		Railway Noise Level (dBA)		Combined Noise Level (dBA)	
			Day	Night	Day	Night	Day	Night
1	7.5	POW - Building A - Southwest Facade	37	29	24	N/a*	37	29
2	7.5	POW - Building A - Southeast Facade	63	56	36	N/a*	63	56
3	7.5	POW - Building A - Northeast Facade	67	60	42	N/a*	67	60
4	7.5	POW - Building A - Northeast Facade	67	60	46	N/a*	67	60
5	7.5	POW - Building A - Northwest Facade	63	55	45	N/a*	63	55
6	7.5	POW - Building B - Southeast Facade	63	55	41	N/a*	63	55
7	7.5	POW - Building B - Northeast Facade	67	60	48	N/a*	67	60
8	7.5	POW - Building B - North Facade	65	58	52	N/a*	65	58
9	7.5	POW - Building B - North Facade	60	54	52	N/a*	61	54
10	7.5	POW - Building C - East Facade	58	51	50	N/a*	59	51
11	7.5	POW - Building C - North Facade	59	52	52	N/a*	60	52
12	7.5	POW - Building C - West Facade	47	39	49	N/a*	51	39
13	7.5	POW - Building D - East Facade	54	47	49	N/a*	55	47
14	7.5	POW - Building D - North Facade	55	48	52	N/a*	57	48
15	7.5	POW - Building D - West Facade	42	35	48	N/a*	49	35
16	7.5	POW - Building D - South Facade	42	35	32	N/a*	43	35
17	7.5	POW - Building E - North Facade	49	42	45	N/a*	50	42
18	7.5	POW - Building E - East Facade	41	34	30	N/a*	42	34

TABLE 3: EXTERIOR NOISE LEVELS DUE TO TRANSPORTATION SOURCES (CONT.)

Receptor Number	Receptor Height Above Grade/Roof (m)	Receptor Location	Roadway Noise Level (dBA)		Railway Noise Level (dBA)		Combined Noise Level (dBA)	
			Day	Night	Day	Night	Day	Night
19	7.5	POW - Building E - West Facade	42	35	40	N/a*	44	35
20	7.5	POW - Building F - North Facade	40	32	38	N/a*	42	32
21	7.5	POW - Building F - West Facade	36	29	39	N/a*	41	29
22	7.5	POW - Building F - North Facade	45	38	33	N/a*	45	38
23	7.5	POW - Building G - North Facade	52	44	37	N/a*	52	44
24	7.5	POW - Building G - East Facade	53	46	37	N/a*	53	46
25	1.5	OLA - At-Grade Courtyard	29	N/a**	40	N/a*	40	N/a**

*Noise levels during the nighttime are not considered as the train does not operate during this period.
**Noise levels during the nighttime are not considered for OLAs as per ENCG.

The results of the current analysis indicate that noise levels will range between 37 and 67 dBA during the daytime period (07:00-23:00) and between 22 and 60 dBA during the nighttime period (23:00-07:00). The highest noise level (67 dBA) occurs at the northeast facades of Building A and Building B which are nearest and most exposed to Carp Road and the railway corridor. Figures 5 and 6 illustrate daytime and nighttime noise contours throughout the site at a height of 4.5 m above grade.

Table 4 shows a results comparison between Predictor-Lima and STAMSON. Noise levels calculated in STAMSON were found to have a good correlation with Predictor-Lima and variability between the two programs was within an acceptable level of ±0-3 dBA. Sample calculations are presented in Appendix A. Upgraded building components will be required for the dwellings where noise levels exceed 60 dBA at the Plane of Window (POW), as per ENCG criteria. Building components compliant with the Ontario Building Code (OBC 2020) will be sufficient for all other dwellings.

TABLE 4: RESULTS OF STAMSON/PREDICTOR-LIMA CORRELATION

Receptor ID	Receptor Location	Receptor Height (m)	STAMSON 5.04 Noise Level (dBA)		PREDICTOR-LIMA Noise Level (dBA)	
			Day	Night	Day	Night
8	POW - Building B - North Facade	7.5	68	60	65	58
9	POW - Building B - North Facade	7.5	64	57	61	54

5.2 Noise Control Measures

The noise levels predicted due to transportation sources exceed the criteria listed in NPC-300 for building components. As discussed in Section 4.3, the anticipated STC requirements for windows have been estimated based on the overall noise reduction required for each intended use of space (STC = outdoor noise level – targeted indoor noise levels). Detailed STC calculations should be completed prior to building permit application for each unit type. The STC requirements for the windows are summarized below in Table 5 for various units within the development (see Figure 3). Where specific updated building components are not identified for these blocks, bedroom/living room/retail windows are to satisfy Ontario Building Code (OBC 2020) requirements.

TABLE 5: NOISE CONTROL REQUIREMENTS

Location	Façade	Floor Number	Min. Window STC (Bedroom/Living Room/Retail)	Exterior Wall STC*	Warning Clauses	A/C or FAH
Building A	Southeast, Northeast, Northwest	1-3	35/30/25	45	Type D	A/C
Building B	Southeast, Northeast, North	1-3	35/30/25	45	Type D	A/C
Building C	North	1-3	35/30/25	45	Type D	A/C
Building D	*N/a*	*N/a*	*N/a*	45	Type C	FAH

*Exterior walls of the first row of dwellings next to railway tracks are to be built to a minimum of brick veneer or masonry equivalent construction[13]

[13] Adapted from Paragraph 3 of Section C7.2.3 of NPC-300

A review of window supplier literature indicates that the specified STC ratings can be achieved by a variety of window systems having a combination of glass thickness and inter-pane spacing. We have not specified any particular window configurations, as there are several manufacturers and various combinations of window components that will offer the necessary sound attenuation rating. However, it is the responsibility of the manufacturer to ensure that the specified window achieves the required STC. This can only be assured by using window configurations that have been certified by laboratory testing. The requirements for STC ratings assume that the remaining components of the building are constructed and installed according to the minimum standards of the Ontario Building Code. The specified STC requirements also apply to swinging and/or sliding patio doors. All specified building components will require review by a qualified acoustical engineer for conformance to the recommendations of this report prior to the building permit application.

Results of the calculations also indicate that Buildings A-C will require air conditioning (or a similar mechanical system), which will allow occupants to keep windows closed and maintain a comfortable living environment. Building D will require forced air heating with provisions for air conditioning which will allow occupants to keep windows closed and maintain a comfortable living environment. In addition to ventilation requirements, Warning Clauses will also be required to be placed on all Lease, Purchase and Sale Agreements, as summarized in Section 6. However, it is expected that all buildings will include air conditioning systems for occupant comfort purposes.

With regard to the courtyard, noise levels are expected to be below the noise level criteria for OLAs. Therefore, no acoustic mitigation is required.

5.3 Ground Vibrations and Ground-Borne Noise Levels

Estimated vibration levels at the foundation nearest to the railway corridor are expected to be 0.04mm/s RMS (64 dBV), based on the FTA protocol and an offset distance of 21 m to the nearest track centerline. Details of the calculation are provided in Appendix B. Since predicted vibration levels do not exceed the criterion of 0.14 mm/s RMS at the foundation, concerns due to vibration impacts on the site are not expected. As vibration levels are acceptable, correspondingly, regenerated noise levels are also expected to be acceptable.

6. CONCLUSIONS AND RECOMMENDATIONS

The results of the current analysis indicate that noise levels will range between 37 and 67 dBA during the daytime period (07:00-23:00) and between 22 and 60 dBA during the nighttime period (23:00-07:00). The highest noise level (67 dBA) occurs at the northeast facades of Building A and Building B which are nearest and most exposed to Carp Road and the railway corridor. Figures 5 and 6 illustrate daytime and nighttime noise contours throughout the site at a height of 7.5 m above grade.

Building components with a higher Sound Transmission Class (STC) rating will be required for Buildings A-C where exterior noise levels exceed 60 dBA, as outlined in Section 5.2. The results of the analysis also indicate that Buildings A-C will require central air conditioning, which will allow occupants to keep windows closed and maintain a comfortable living environment. Warning Clauses will also be required to be placed on all Lease, Purchase and Sale Agreements, as summarized below:

Type D

> *"This dwelling unit has been supplied with a central air conditioning system which will allow windows and exterior doors to remain closed, thereby ensuring that the indoor sound levels are within the sound level limits of the Municipality and the Ministry of the Environment, Conservation and Parks."*

Similarly, Building D will require forced air heating with provisions for central air conditioning as summarized in Table 5 and outlined in Figure 4. Warning Clauses will also be required to be placed on all Lease, Purchase and Sale Agreements, as summarized below:

Type C

> *"This dwelling unit has been designed with the provision for adding central air conditioning at the occupant's discretion. Installation of central air conditioning by the occupant in low and medium density developments will allow windows and exterior doors to remain closed, thereby ensuring that the indoor sound levels are within the sound level limits of the Municipality and the Ministry of the Environment, Conservation and Parks."*

With regard to the courtyard, noise levels are expected to be below the noise level criteria for OLAs. Therefore, no acoustic mitigation is required.

Furthermore, estimated vibration levels at the foundation nearest to the railway corridor are expected to be 0.04mm/s RMS (64 dBV), based on the FTA protocol and an offset distance of 21 m to the nearest track centerline. Details of the calculation are provided in Appendix B. Since predicted vibration levels do not exceed the criterion of 0.14 mm/s RMS at the foundation, concerns due to vibration impacts on the site are not expected. As vibration levels are acceptable, correspondingly, regenerated noise levels are also expected to be acceptable.

The stationary noise impacts of the buildings on the surroundings would be considered at a future stage once the mechanical design has progressed and equipment has been selected. Stationary noise sources associated with the development will likely include rooftop air handling units and fan coils. Should noise levels from these units exceed the criteria established in NPC-300 and ENCG, noise from these sources can be controlled to acceptable limits by judicious selection of the equipment, locating the equipment on a high roof away from nearby residential receptors, and where necessary, installing silencers or noise screens.

This concludes our transportation noise and vibration assessment and report. If you have any questions or wish to discuss our findings, please advise us. In the interim, we thank you for the opportunity to be of service.

Sincerely,

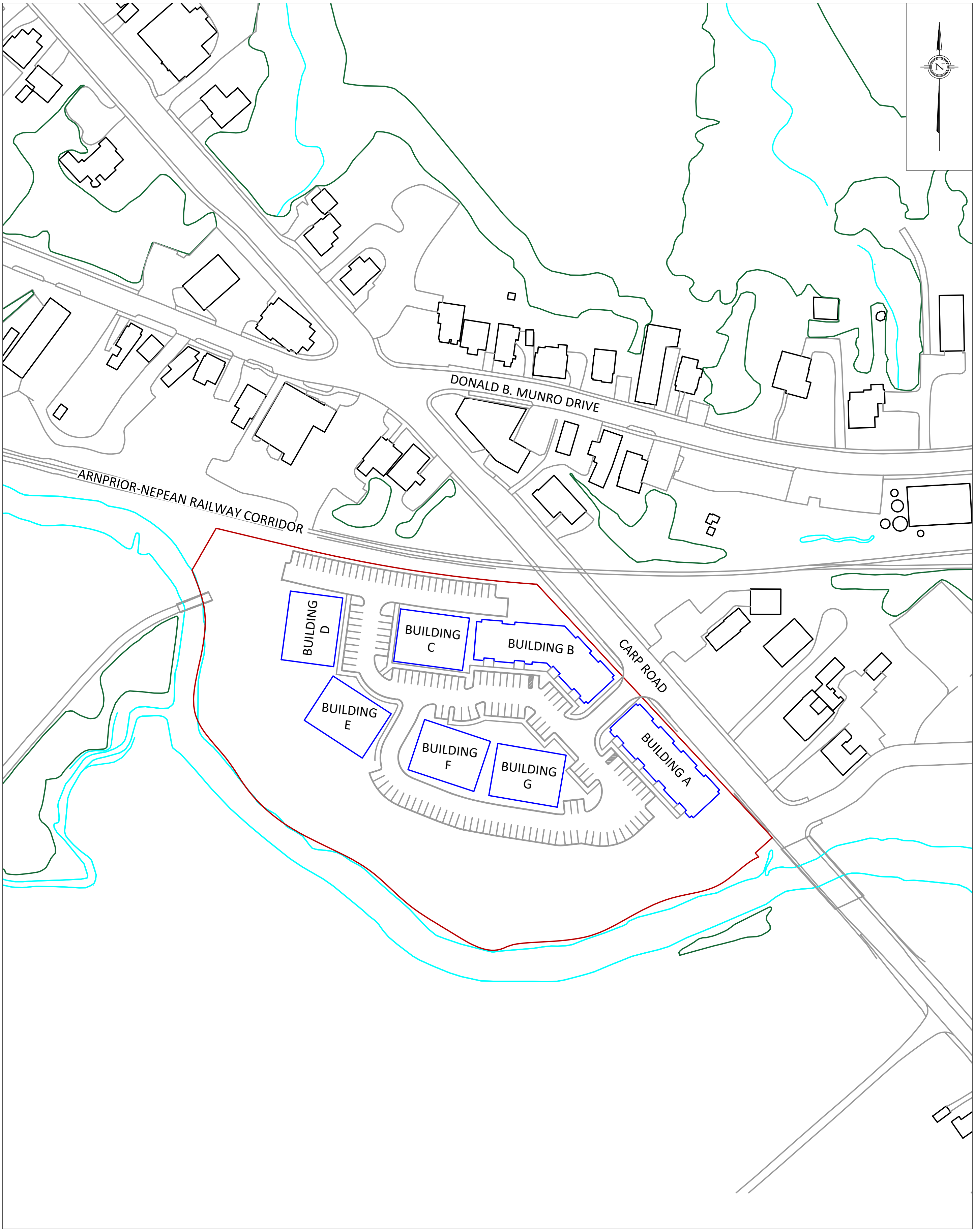
Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
J. R. FOSTER
100155655
March 20, 2023
PROVINCE OF ONTARIO

Giuseppe Garro, MASc.
Environmental Scientist

Joshua Foster, P.Eng.
Lead Engineer

Gradient Wind File #22-341



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PROJECT: 3725 CARP ROAD, CARP TRANSPORTATION TRAFFIC NOISE ASSESSMENT		DESCRIPTION: FIGURE 1: SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:2000 (APPROX.)	DRAWING NO.: GW22-341-1	
DATE: FEBRUARY 17, 2023	DRAWN BY: G.G.	

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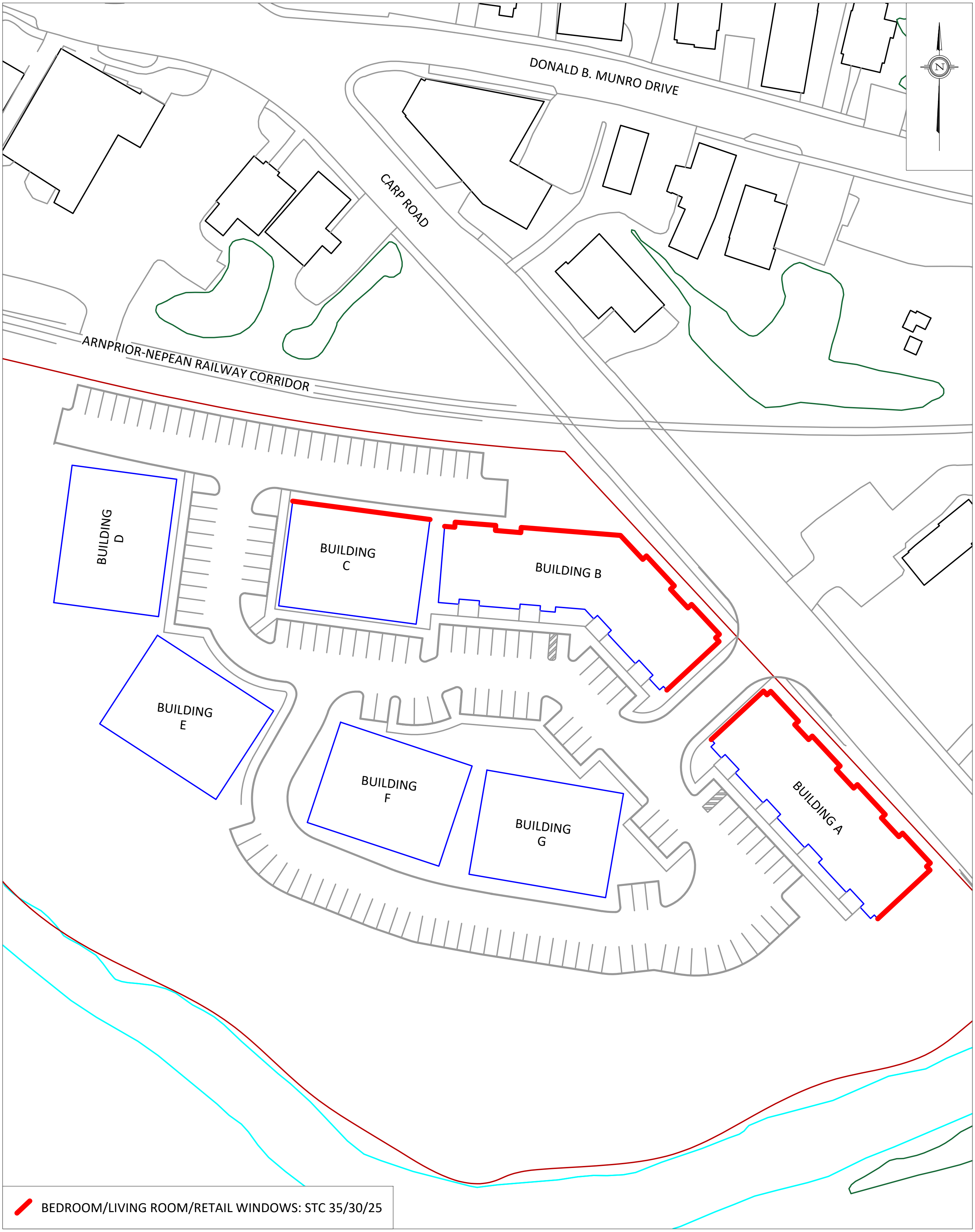
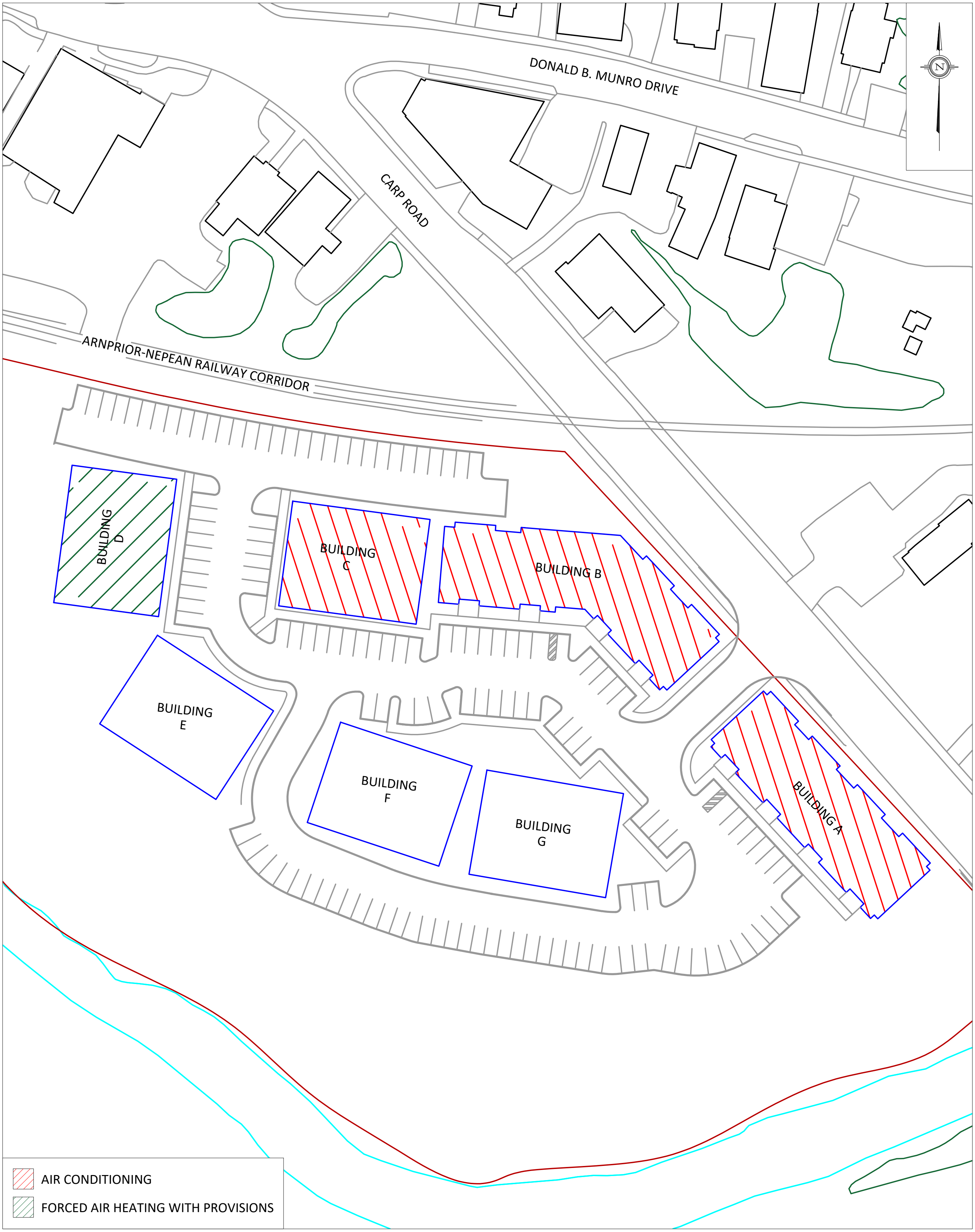
PROJECT	3725 CARP ROAD, CARP TRANSPORTATION TRAFFIC NOISE ASSESSMENT		
SCALE	1:1000 (APPROX.)	DRAWING NO.	GW22-341-2
DATE	FEBRUARY 17, 2023	DRAWN BY	G.G.

DESCRIPTION

FIGURE 2:
RECEPTOR LOCATIONS



GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD , OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT	3725 CARP ROAD, CARP TRANSPORTATION TRAFFIC NOISE ASSESSMENT		DESCRIPTION FIGURE 3: WINDOW STC REQUIREMENTS
	SCALE 1:1000 (APPROX.)		DRAWING NO. GW22-341-3	
	DATE FEBRUARY 17, 2023		DRAWN BY G.G.	



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PROJECT	3725 CARP ROAD, CARP TRANSPORTATION TRAFFIC NOISE ASSESSMENT		
SCALE	1:1000 (APPROX.)	DRAWING NO.	GW22-341-4
DATE	FEBRUARY 17, 2023	DRAWN BY	G.G.

DESCRIPTION

FIGURE 4:
VENTILATION REQUIREMENTS

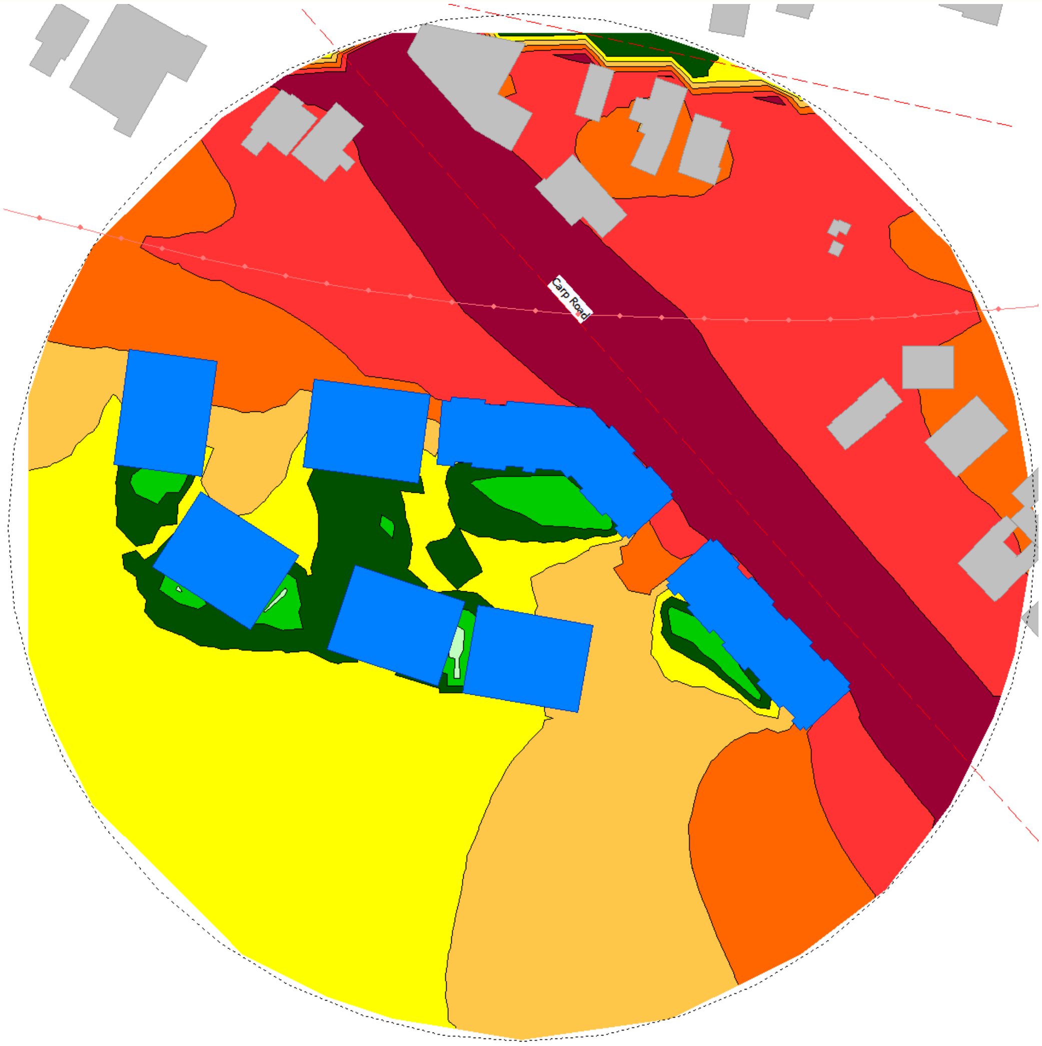
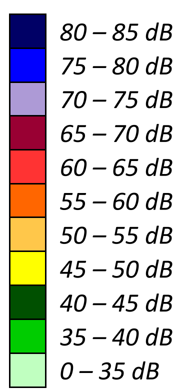


FIGURE 5: DAYTIME TRAFFIC NOISE CONTOURS (7.5 M ABOVE GRADE)



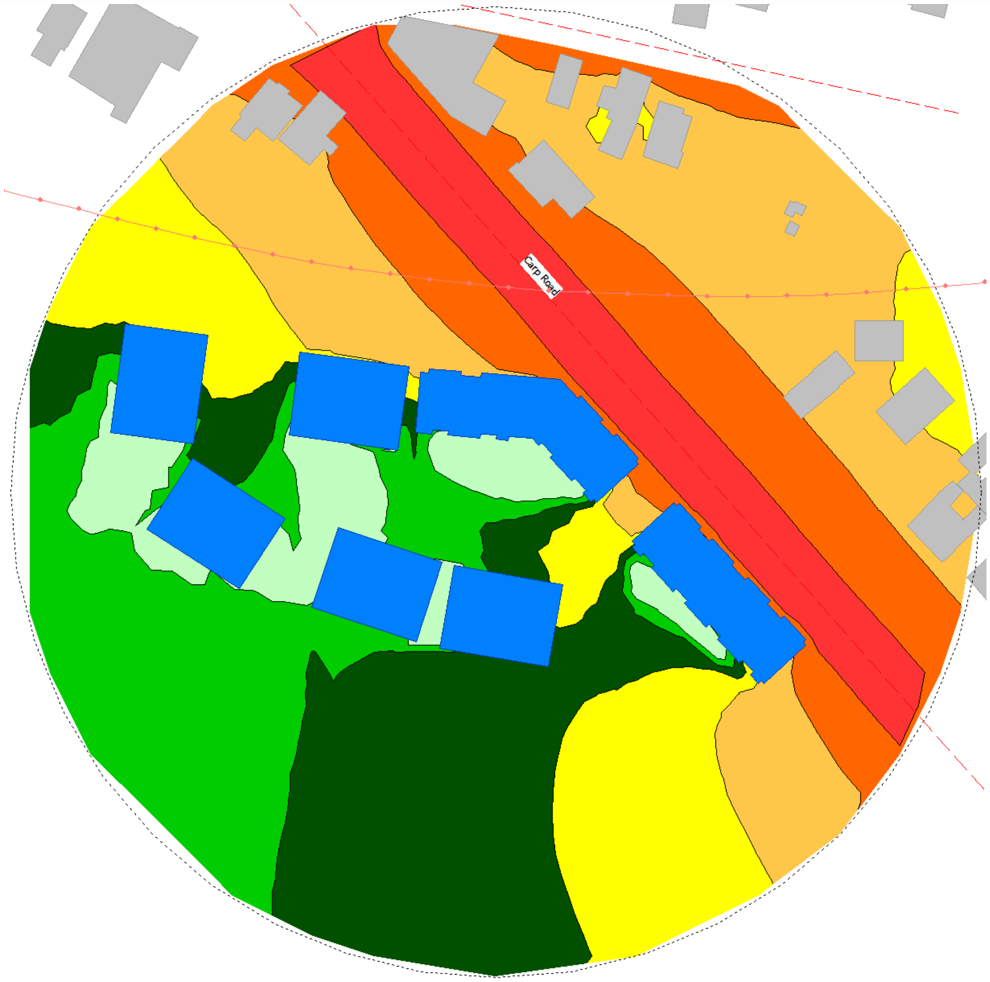
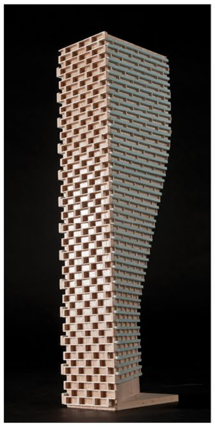
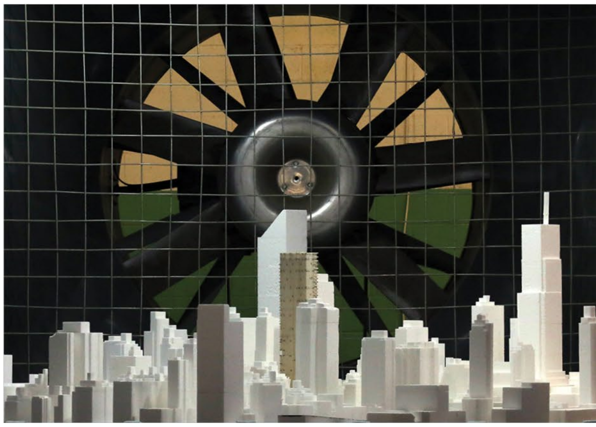


FIGURE 6: NIGHTTIME TRAFFIC NOISE CONTOURS
(7.5 M ABOVE GRADE)

80 – 85 dB
75 – 80 dB
70 – 75 dB
65 – 70 dB
60 – 65 dB
55 – 60 dB
50 – 55 dB
45 – 50 dB
40 – 45 dB
35 – 40 dB
0 – 35 dB





APPENDIX A

STAMSON 5.04 – INPUT AND OUTPUT DATA

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

```
STAMSON 5.0        NORMAL REPORT        Date: 17-02-2023 14:46:09
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: r8.te                 Time Period: Day/Night 16/8 hours
Description:


Rail data, segment # 1: ANRC (day/night)
----------------------------------------
Train            ! Trains       ! Speed !# loc !# Cars! Eng  !Cont
Type             !              !(km/h) !/Train!/Train! type !weld
-----------------+--------------+-------+------+------+------+----
  1. NYLENE      !   2.0/0.0    !  16.0 !  1.0 ! 10.0 !Diesel!  No

Data for Segment # 1: ANRC (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  :  22.00 / 22.00  m
Receiver height           :   7.50 / 7.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
No Whistle
Reference angle           :   0.00

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

LOCOMOTIVE (0.00 + 51.47 + 0.00) = 51.47 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90     90   0.00  53.13  -1.66   0.00   0.00   0.00   0.00  51.47
----------------------------------------------------------------------

WHEEL (0.00 + 38.53 + 0.00) = 38.53 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90     90   0.00  40.19  -1.66   0.00   0.00   0.00   0.00  38.53
----------------------------------------------------------------------

Segment Leq : 51.69 dBA

Total Leq All Segments: 51.69 dBA
```

```
Results segment # 1: ANRC (night)
---------------------------------

LOCOMOTIVE (0.00 + -1.66 + 0.00) = 0.00 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90     90   0.00   0.00  -1.66   0.00   0.00   0.00   0.00  -1.66
----------------------------------------------------------------------

WHEEL (0.00 + -1.66 + 0.00) = 0.00 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90     90   0.00   0.00  -1.66   0.00   0.00   0.00   0.00  -1.66
----------------------------------------------------------------------

Segment Leq : 0.00 dBA

Total Leq All Segments: 0.00 dBA

Road data, segment # 1: DBMD (day/night)
----------------------------------------
Car traffic volume  :  6477/563   veh/TimePeriod  *
Medium truck volume :   515/45    veh/TimePeriod  *
Heavy truck volume  :   368/32    veh/TimePeriod  *
Posted speed limit  :    40 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

* Refers to calculated road volumes based on the following input:

    24 hr Traffic Volume (AADT or SADT):   8000
    Percentage of Annual Growth        :   0.00
    Number of Years of Growth          :   0.00
    Medium Truck % of Total Volume     :   7.00
    Heavy Truck  % of Total Volume     :   5.00
    Day (16 hrs) % of Total Volume     :  92.00

Data for Segment # 1: DBMD (day/night)
--------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      1       (Absorptive ground surface)
Receiver source distance  :  85.00 / 85.00  m
Receiver height           :   7.50 / 7.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00
```

```
Road data, segment # 2: CR (day/night)
--------------------------------------
Car traffic volume  : 12144/1056  veh/TimePeriod  *
Medium truck volume :   966/84    veh/TimePeriod  *
Heavy truck volume  :   690/60    veh/TimePeriod  *
Posted speed limit  :    50 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

* Refers to calculated road volumes based on the following input:

    24 hr Traffic Volume (AADT or SADT):  15000
    Percentage of Annual Growth        :   0.00
    Number of Years of Growth          :   0.00
    Medium Truck % of Total Volume     :   7.00
    Heavy Truck  % of Total Volume     :   5.00
    Day (16 hrs) % of Total Volume     :  92.00

Data for Segment # 2: CR (day/night)
------------------------------------
Angle1   Angle2            : -90.00 deg   55.00 deg
Wood depth                 :      0       (No woods.)
No of house rows           :      0 / 0
Surface                    :      2       (Reflective ground surface)
Receiver source distance   :  15.00 / 15.00  m
Receiver height            :   7.50 / 7.50   m
Topography                 :      1       (Flat/gentle slope; no barrier)
Reference angle            :   0.00


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

Source height = 1.50 m

ROAD (0.00 + 51.67 + 0.00) = 51.67 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj
SubLeq
--------------------------------------------------------------------------
--
   -90     90   0.48  63.96   0.00 -11.15  -1.14   0.00   0.00   0.00
51.67
--------------------------------------------------------------------------
--

Segment Leq : 51.67 dBA
```

```
Results segment # 2: CR (day)
-----------------------------

Source height = 1.50 m

ROAD (0.00 + 67.54 + 0.00) = 67.54 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj
SubLeq
--------------------------------------------------------------------------
--
   -90     55   0.00  68.48   0.00   0.00  -0.94   0.00   0.00   0.00
67.54
--------------------------------------------------------------------------
--

Segment Leq : 67.54 dBA

Total Leq All Segments: 67.65 dBA


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

Source height = 1.50 m

ROAD (0.00 + 44.07 + 0.00) = 44.07 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj
SubLeq
--------------------------------------------------------------------------
--
   -90     90   0.48  56.36   0.00 -11.15  -1.14   0.00   0.00   0.00
44.07
--------------------------------------------------------------------------
--

Segment Leq : 44.07 dBA


Results segment # 2: CR (night)
-------------------------------

Source height = 1.50 m

ROAD (0.00 + 59.94 + 0.00) = 59.94 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj
SubLeq
--------------------------------------------------------------------------
--
   -90     55   0.00  60.88   0.00   0.00  -0.94   0.00   0.00   0.00
59.94
```

```
--------------------------------------------------------------------------
--

Segment Leq : 59.94 dBA

Total Leq All Segments: 60.05 dBA


TOTAL Leq FROM ALL SOURCES (DAY): 67.76
                         (NIGHT): 60.05
```

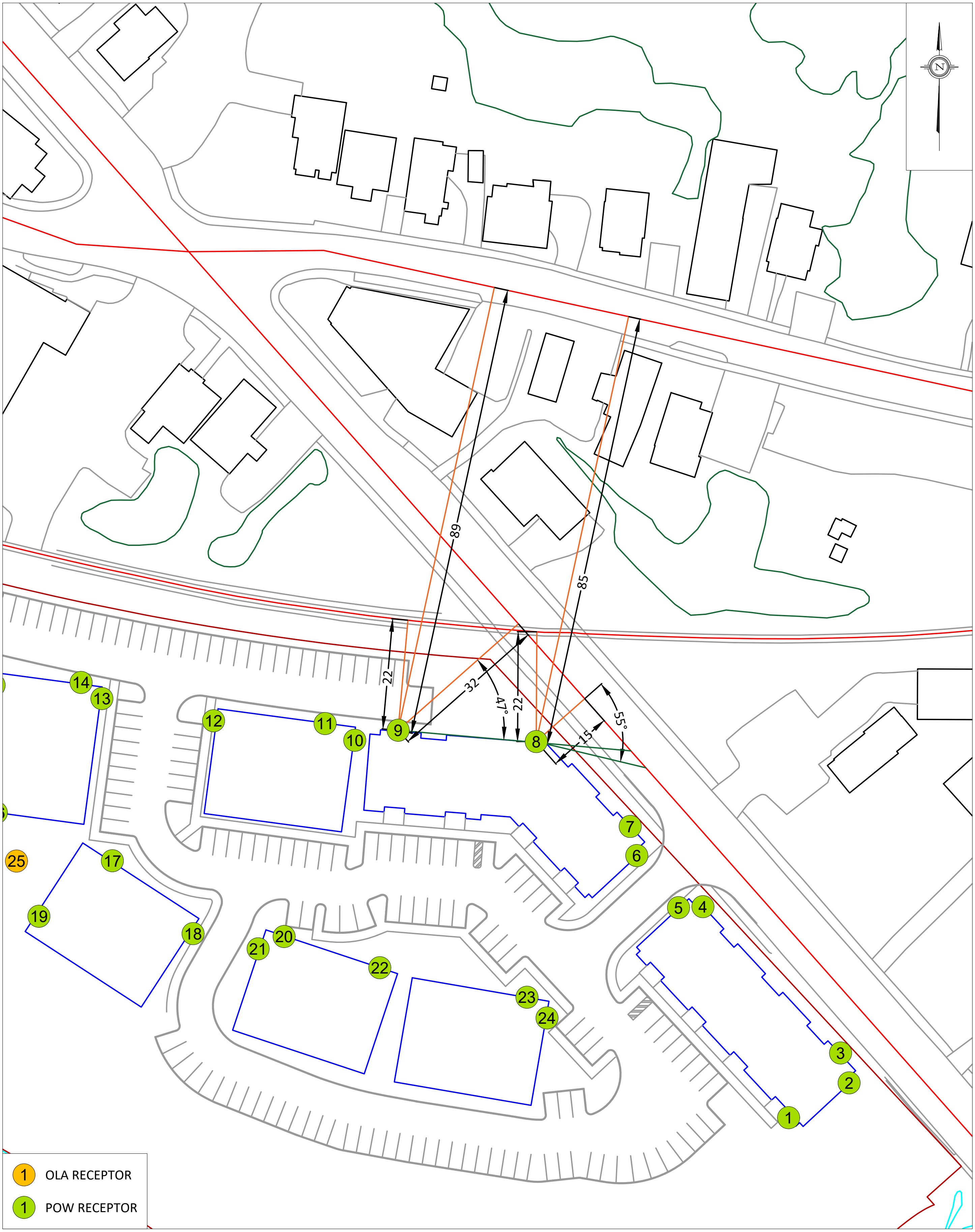
```
STAMSON 5.0          NORMAL REPORT          Date: 17-02-2023 14:46:17
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: r9.te                   Time Period: Day/Night 16/8 hours
Description:


Rail data, segment # 1: ANRC (day/night)
----------------------------------------
Train            ! Trains       ! Speed !# loc !# Cars! Eng  !Cont
Type             !              !(km/h) !/Train!/Train! type !weld
-----------------+--------------+-------+------+------+------+----
  1. NYLENE      !   2.0/0.0    !  16.0 !  1.0 ! 10.0 !Diesel!  No

Data for Segment # 1: ANRC (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  :  22.00 / 22.00  m
Receiver height           :   7.50 / 7.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
No Whistle
Reference angle           :   0.00


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

LOCOMOTIVE (0.00 + 51.47 + 0.00) = 51.47 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90     90   0.00  53.13  -1.66   0.00   0.00   0.00   0.00  51.47
----------------------------------------------------------------------

WHEEL (0.00 + 38.53 + 0.00) = 38.53 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90     90   0.00  40.19  -1.66   0.00   0.00   0.00   0.00  38.53
----------------------------------------------------------------------

Segment Leq : 51.69 dBA

Total Leq All Segments: 51.69 dBA
```

```
Results segment # 1: ANRC (night)
---------------------------------

LOCOMOTIVE (0.00 + -1.66 + 0.00) = 0.00 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90     90   0.00   0.00  -1.66   0.00   0.00   0.00   0.00  -1.66
----------------------------------------------------------------------

WHEEL (0.00 + -1.66 + 0.00) = 0.00 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90     90   0.00   0.00  -1.66   0.00   0.00   0.00   0.00  -1.66
----------------------------------------------------------------------

Segment Leq : 0.00 dBA

Total Leq All Segments: 0.00 dBA


Road data, segment # 1: DBMD (day/night)
----------------------------------------
Car traffic volume  :  6477/563   veh/TimePeriod  *
Medium truck volume :   515/45    veh/TimePeriod  *
Heavy truck volume  :   368/32    veh/TimePeriod  *
Posted speed limit  :    40 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

* Refers to calculated road volumes based on the following input:

    24 hr Traffic Volume (AADT or SADT):   8000
    Percentage of Annual Growth        :   0.00
    Number of Years of Growth          :   0.00
    Medium Truck % of Total Volume     :   7.00
    Heavy Truck  % of Total Volume     :   5.00
    Day (16 hrs) % of Total Volume     :  92.00

Data for Segment # 1: DBMD (day/night)
--------------------------------------
Angle1   Angle2           : -90.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      1       (Absorptive ground surface)
Receiver source distance  :  89.00 / 89.00  m
Receiver height           :   7.50 / 7.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00
```

```
Road data, segment # 2: CR (day/night)
--------------------------------------
Car traffic volume  : 12144/1056  veh/TimePeriod  *
Medium truck volume :   966/84    veh/TimePeriod  *
Heavy truck volume  :   690/60    veh/TimePeriod  *
Posted speed limit  :    50 km/h
Road gradient       :     0 %
Road pavement       :     1 (Typical asphalt or concrete)

* Refers to calculated road volumes based on the following input:

    24 hr Traffic Volume (AADT or SADT):  15000
    Percentage of Annual Growth        :   0.00
    Number of Years of Growth          :   0.00
    Medium Truck % of Total Volume     :   7.00
    Heavy Truck  % of Total Volume     :   5.00
    Day (16 hrs) % of Total Volume     :  92.00

Data for Segment # 2: CR (day/night)
------------------------------------
Angle1   Angle2           : -90.00 deg   47.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  32.00 / 32.00  m
Receiver height           :   7.50 / 7.50   m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


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

Source height = 1.50 m

ROAD (0.00 + 51.37 + 0.00) = 51.37 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj
SubLeq
--------------------------------------------------------------------------
--
   -90     90   0.48  63.96   0.00 -11.45  -1.14   0.00   0.00   0.00
51.37
--------------------------------------------------------------------------
--

Segment Leq : 51.37 dBA
```

```
Results segment # 2: CR (day)
-----------------------------

Source height = 1.50 m

ROAD (0.00 + 64.00 + 0.00) = 64.00 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj
SubLeq
--------------------------------------------------------------------------
--
   -90     47   0.00  68.48   0.00  -3.29  -1.19   0.00   0.00   0.00
64.00
--------------------------------------------------------------------------
--

Segment Leq : 64.00 dBA

Total Leq All Segments: 64.23 dBA


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

Source height = 1.50 m

ROAD (0.00 + 43.78 + 0.00) = 43.78 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj
SubLeq
--------------------------------------------------------------------------
--
   -90     90   0.48  56.36   0.00 -11.45  -1.14   0.00   0.00   0.00
43.78
--------------------------------------------------------------------------
--

Segment Leq : 43.78 dBA

Results segment # 2: CR (night)
-------------------------------

Source height = 1.50 m

ROAD (0.00 + 56.41 + 0.00) = 56.41 dBA
Angle1 Angle2  Alpha RefLeq  P.Adj  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj
SubLeq
--------------------------------------------------------------------------
--
   -90     47   0.00  60.88   0.00  -3.29  -1.19   0.00   0.00   0.00
56.41
--------------------------------------------------------------------------
--
```

```
Segment Leq : 56.41 dBA

Total Leq All Segments: 56.64 dBA


TOTAL Leq FROM ALL SOURCES (DAY): 64.47
                         (NIGHT): 56.64
```



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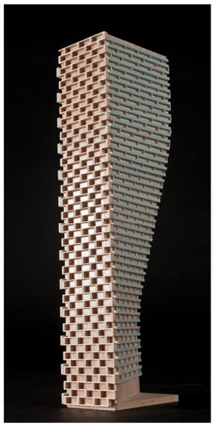
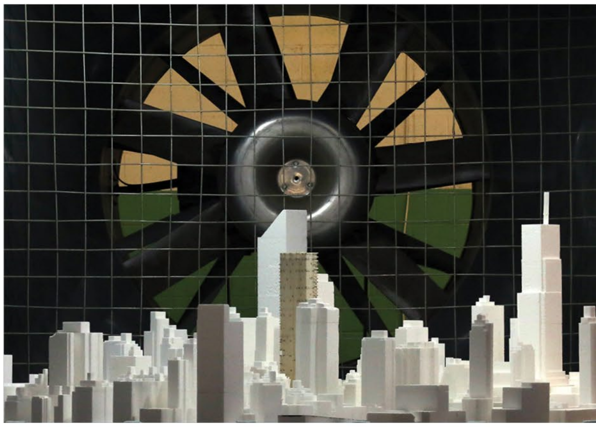
PROJECT	3725 CARP ROAD, CARP TRANSPORTATION TRAFFIC NOISE ASSESSMENT	
SCALE 1:1000 (APPROX.)	DRAWING NO. GW22-341-A1	
DATE FEBRUARY 17, 2023	DRAWN BY G.G.	

DESCRIPTION

FIGURE A1:
STAMSON INPUT PARAMETERS





APPENDIX B

FTA VIBRATION CALCULATIONS

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

GW22-341 17-Feb-23

Possible Vibration Impacts
Predicted using FTA General Assesment

Train Speed 16 km/h 10 mph

	Distance from C/L of track to Edge of Fdn	
	(m)	(ft)
ANRC	21.0	68.9

	Vibration	
From FTA Manual Fig 10-1		
Vibration Levels at distance from track	82	dBV re 1 micro in/sec
Adjustment Factors FTA Table 10-1		
Speed reference 50 mph	-14.00	Speed Limit of 16 km/h (10 mph)
Vehicle Parameters	0	Assume Soft primary suspension, Wheels run true
Track Condition	0	None
Track Treatments	0	None
Type of Transit Structure	0	None
Efficient vibration Propagation	0	None
Vibration Levels at Fdn	68	
Coupling to Building Foundation	-10	3-4 Storey Masonry
Floor to Floor Attenuation	0.0	Ground Floor Occupied
Amplification of Floor and Walls	6	
Total Vibration Level	64	dBV or 0.040 mm/s
Noise Level in dBA	29	dBA

Table 10-1. Adjustment Factors for Generalized Predictions of Ground-Borne Vibration and Noise

Factors Affecting Vibration Source				
Source Factor	**Adjustment to Propagation Curve**			**Comment**
		Reference Speed		
Speed	Vehicle Speed	50 mph	30 mph	Vibration level is approximately proportional to 20*log(speed/speed$_{ref}$). Sometimes the variation with speed has been observed to be as low as 10 to 15 log(speed/speed$_{ref}$).
	60 mph	+1.6 dB	+6.0 dB	
	50 mph	0.0 dB	+4.4 dB	
	40 mph	-1.9 dB	+2.5 dB	
	30 mph	-4.4 dB	0.0 dB	
	20 mph	-8.0 dB	-3.5 dB	
Vehicle Parameters (not additive, apply greatest value only)				
Vehicle with stiff primary suspension	+8 dB			Transit vehicles with stiff primary suspensions have been shown to create high vibration levels. Include this adjustment when the primary suspension has a vertical resonance frequency greater than 15 Hz.
Resilient Wheels	0 dB			Resilient wheels do not generally affect ground-borne vibration except at frequencies greater than about 80 Hz.
Worn Wheels or Wheels with Flats	+10 dB			Wheel flats or wheels that are unevenly worn can cause high vibration levels. This can be prevented with wheel truing and slip-slide detectors to prevent the wheels from sliding on the track.
Track Conditions (not additive, apply greatest value only)				
Worn or Corrugated Track	+10 dB			If both the wheels and the track are worn, only one adjustment should be used. Corrugated track is a common problem. Mill scale on new rail can cause higher vibration levels until the rail has been in use for some time.
Special Trackwork	+10 dB			Wheel impacts at special trackwork will significantly increase vibration levels. The increase will be less at greater distances from the track.
Jointed Track or Uneven Road Surfaces	+5 dB			Jointed track can cause higher vibration levels than welded track. Rough roads or expansion joints are sources of increased vibration for rubber-tire transit.
Track Treatments (not additive, apply greatest value only)				
Floating Slab Trackbed	-15 dB			The reduction achieved with a floating slab trackbed is strongly dependent on the frequency characteristics of the vibration.
Ballast Mats	-10 dB			Actual reduction is strongly dependent on frequency of vibration.
High-Resilience Fasteners	-5 dB			Slab track with track fasteners that are very compliant in the vertical direction can reduce vibration at frequencies greater than 40 Hz.

Table 10-1. Adjustment Factors for Generalized Predictions of Ground-Borne Vibration and Noise (Continued)

Factors Affecting Vibration Path		
Path Factor	**Adjustment to Propagation Curve**	**Comment**
Resiliently Supported Ties	-10 dB	Resiliently supported tie systems have been found to provide very effective control of low-frequency vibration.
Track Configuration (not additive, apply greatest value only)		
Type of Transit Structure	Relative to at-grade tie & ballast: Elevated structure -10 dB Open cut 0 dB	The general rule is the heavier the structure, the lower the vibration levels. Putting the track in cut may reduce the vibration levels slightly. Rock-based subways generate higher-frequency vibration.
	Relative to bored subway tunnel in soil: Station -5 dB Cut and cover -3 dB Rock-based - 15 dB	
Ground-borne Propagation Effects		
Geologic conditions that promote efficient vibration propagation	Efficient propagation in soil +10 dB	Refer to the text for guidance on identifying areas where efficient propagation is possible.
	Propagation in rock layer — **Dist.** / **Adjust.**: 50 ft +2 dB 100 ft +4 dB 150 ft +6 dB 200 ft +9 dB	The positive adjustment accounts for the lower attenuation of vibration in rock compared to soil. It is generally more difficult to excite vibrations in rock than in soil at the source.
Coupling to building foundation	Wood Frame Houses -5 dB 1-2 Story Masonry -7 dB 3-4 Story Masonry -10 dB Large Masonry on Piles -10 dB Large Masonry on Spread Footings -13 dB Foundation in Rock 0 dB	The general rule is the heavier the building construction, the greater the coupling loss.
Factors Affecting Vibration Receiver		
Receiver Factor	**Adjustment to Propagation Curve**	**Comment**
Floor-to-floor attenuation	1 to 5 floors above grade: -2 dB/floor 5 to 10 floors above grade: -1 dB/floor	This factor accounts for dispersion and attenuation of the vibration energy as it propagates through a building.
Amplification due to resonances of floors, walls, and ceilings	+6 dB	The actual amplification will vary greatly depending on the type of construction. The amplification is lower near the wall/floor and wall/ceiling intersections.
Conversion to Ground-borne Noise		
Noise Level in dBA	Peak frequency of ground vibration: Low frequency (<30 Hz): -50 dB Typical (peak 30 to 60 Hz): -35 dB High frequency (>60 Hz): -20 dB	Use these adjustments to estimate the A-weighted sound level given the average vibration velocity level of the room surfaces. See text for guidelines for selecting low, typical or high frequency characteristics. Use the high-frequency adjustment for subway tunnels in rock or if the dominant frequencies of the vibration spectrum are known to be 60 Hz or greater.