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Highway 1 – Chase West to Jade Mountain

Traffic Noise Impact Assessment

PREPARED FOR:

BC Ministry of Transportation and Infrastructure

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PREPARED BY:

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per

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EXECUTIVE SUMMARY

BKL Consultants Ltd. (BKL) has been retained by BC Ministry of Transportation and Infrastructure (the Ministry) to conduct a traffic noise assessment for the proposed Highway 1 – Chase West to Jade Mountain Project (the Project). The Project involves widening the Trans-Canada Highway (Hwy 1) in and around Chase, BC, by adding extra eastbound and westbound lanes, and upgrading highway access to and from Chase.

This report outlines BKL's traffic noise assessment, which aimed to

- identify noise-sensitive land uses potentially impacted by traffic noise within the Project area;
- evaluate existing noise conditions at potentially impacted noise-sensitive receivers;
- predict the future noise environment 10 years after Project completion (2032);
- assess the noise impacts of the Project according to criteria outlined in the *Policy for Assessing and Mitigating Noise Impacts from New and Upgraded Numbered Highways* (the Policy) published by the Ministry (2016); and
- review potential noise mitigation options where warranted by the Policy.

To predict the Project-related traffic noise and assess the impacts of such noise against the Policy criteria, BKL created a 3-D noise model that considered

- the results of baseline noise measurements conducted in June 2016;
- existing and projected future traffic volumes;
- the topography and ground conditions within the Project area; and
- the location of the proposed Hwy 1 realignment.

The Policy outlines specific impact thresholds (Minor, Moderate, and Severe) to categorize potential noise impacts at residences and establishes guidelines for costs related to any potential mitigation. Alternative criteria are outlined for non-residential noise-sensitive land uses such as schools, churches, etc.

BKL identified a study area that includes 173 residences and one school (Haldane Elementary School) that could potentially be affected by noise levels that approach or exceed the Policy criteria.

According to BKL's measurements, assessment, predictions, and analysis, 91 of the 173 residences assessed would be affected by Moderate noise impacts, and zero residences would be affected by Severe noise impacts. The impacted residences include split-level and two-storey single-family dwellings and multi-family dwellings located west of Hwy 1.

Unlike homes, the Policy does not provide detailed mitigation guidance for schools and other non-residential noise-sensitive land uses. At Haldane, the predicted outdoor future noise level during the noisiest hour ($L_{eq(max\text{-}hr)}$) will be greater than 60 dBA, which warrants investigation of potential noise mitigation requirements according to the Policy. In order to investigate mitigation requirements, BKL adopted World Health Organization guidelines, which recommends an average noise level of no more than 35 dBA inside classrooms and no more than 55 dBA in outdoor play areas. BKL predicts that noise levels will meet the classroom noise limit but exceed the outdoor play areas noise limit. Hence, additional mitigation should be considered for the school.

According to predictions, the noise impacts will be due to high existing noise levels, increased traffic volumes, elevated road alignment, and reduced road alignment setbacks.

The mitigation cost allowance, as described in the Policy, for the 91 Moderately impacted dwellings is $2,275,000. The policy does not specify allowances for non-residential land uses like schools and would need to be considered on a case-by-case basis.

For eligible cases, potential noise mitigation options include noise barriers, low-noise pavement, noise control at the receiver, and noise impact avoidance. BKL modelled potential noise barrier alignments that met Project related constraints, but it was predicted to meet the mitigation objectives for only 18 out of 37 fronting moderately impacted residences described by the Policy. Furthermore, there was also only a marginal reduction in noise levels predicted at the school playgrounds.

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List of Abbreviations

Abbreviation/Acronym	Definition
ANSI	American National Standards Institute
Binnie	R.F. Binnie Associates Ltd.
BKL	BKL Consultants Ltd.
dB	decibel
dBA	A-weighted decibel
ISO	International Organization for Standardization
km	kilometre
km/h	kilometres per hour
Leq	equivalent sound level
Leq(max hr)	equivalent sound level during the loudest hour of the day
Ld	daytime (07:00 to 22:00) equivalent sound level
Ldn	day-night equivalent sound level
Ln	nighttime (22:00 to 07:00) equivalent sound level
m	metre
Ministry	British Columbia Ministry of Transportation and Infrastructure
Project	Highway 1 – Chase West to Jade Mountain

1 Introduction

BKL Consultants Ltd. (BKL) has been retained by BC Ministry of Transportation and Infrastructure (the Ministry) to provide a traffic noise impact assessment for the proposed Highway 1 – Chase West to Jade Mountain Project (the Project). The Project involves widening the Trans-Canada Highway (Hwy 1) in and around Chase, BC, by adding extra eastbound and westbound lanes, and upgrading highway access to and from Chase.

Upgrades to existing numbered highways are assessed in accordance with the *2016 Policy for Assessing and Mitigating Noise Impacts from New and Upgraded Numbered Highways* (the Policy) published by the BC Ministry of Transportation and Infrastructure (MOTI 2016).

This report documents

- existing noise exposure levels, including one short-term and two long-term measurement locations within the Project area;
- the future noise climate predicted 10 years after the completion of the Project;
- results of the impact assessment;
- potential mitigation options; and
- one proposed noise barrier alignment.

A glossary of terms is presented in Appendix A, and an introduction to sound and environmental noise assessment is presented in Appendix B.

2 Project Description

The Project scope includes the four-laning of Hwy 1 from west of Brooke Drive to the Chase Creek crossing. It also includes a new Brooke Drive interchange and safety improvements to the access to and from Coburn Street and Foothills Road. The Project is expected to be completed by 2022. An overview of the Project extents is shown in Figure 2-1.

Figure 2-1: Project Location in Chase, BC

3 Study Objectives

BKL's traffic noise study aimed to

- identify noise-sensitive land uses potentially impacted by the Project;
- evaluate existing noise conditions at potentially impacted noise-sensitive receivers;
- predict the future noise environment 10 years after Project completion;
- assess the noise impact according to the Policy; and
- identify potential noise mitigation options, where warranted by the Policy.

4 Assessment Criteria

The Policy outlines the required methodology for assessing the impact of traffic noise for the construction of new numbered highways and upgrading of existing numbered highways. The Policy also describes mitigation considerations for noise-sensitive land uses adjacent to new or upgraded numbered highways. According to the Policy, noise-sensitive land uses include residences; hospitals; educational facilities, such as schools, preschools, and commercial daycare centres; libraries; churches; museums; and passive parks and other land uses where quiet and tranquility are essential attributes.

Eligible noise-sensitive land uses must predate the highway project by receiving planning approvals prior to the first public announcement of the highway project or designation (through gazetting) of the affected lands as potential future highway rights-of-way.

4.1 Residences

For residential receivers, the Policy sets noise impact thresholds to identify areas where noise mitigation consideration is warranted. The Policy also states that "mitigation will only be carried out where total post-project noise levels are clearly dominated by highway traffic." For the purposes of the assessment, BKL has considered Hwy 1 and the associated on and off ramps within the construction limits to be highway traffic.

The Policy quantifies its thresholds with the noise metric outdoor day-night average sound Level (L_{dn}). This metric is similar to the 24-hour equivalent sound level (L_{eq24}) but it applies a 10 dBA penalty to nighttime noise to account for the public's greater sensitivity to noise between 10 pm and 7 am.

Post-Project (10 years after completion) noise predictions are compared to pre-Project levels in order to rate impacts at the noise-sensitive receivers as either No Impact, Minor, Moderate, or Severe. As a minimum, a post-Project noise level of 65 dBA or greater is a Moderate Impact and a noise level of 75 dBA or greater is a Severe Impact. Noise mitigation should be considered if the results are in the Moderate or Severe Impact zones.

According to the Policy, the main objective of noise mitigation is to reduce the total post-Project noise exposure at fronting residences by at least 5 dBA. A noise reduction of 5 dBA corresponds to approximately a 30% decrease in perceived loudness and is considered the smallest noise reduction that is clearly noticeable. Moreover, the Policy states that "the costs and benefits of mitigation measures must be weighed by [the Ministry's] Project Managers based on the particular conditions and considerations of each project."

The Policy gives benchmark mitigation cost guidelines for residential units that are directly benefiting from the noise mitigation based on the noise impact situation for that unit. The Policy states:

> *[The] benchmark mitigation cost guideline ... [is] $25,000 per directly-benefiting residential unit in Moderate noise impact situations, and $40,000 per directly-benefiting residential unit in Severe noise impact situations.*

Alternatively, noise impacts can be avoided with design decisions that do not involve actual mitigation works and "result in reduced noise exposures at adjacent sensitive land uses." Examples provided in the Policy include route selection, natural noise screening features, speed control and use of low-noise pavement.

4.2 Non-Residential Land Uses

The Policy outlines the requirements for consideration of the following types of noise-sensitive non-residential land uses:

- hospitals;
- educational facilities;
- libraries, places of worship, and museums; and
- passive parks and other land uses where quiet and tranquility are essential attributes.

For educational land uses, the Policy criterion is based on the loudest one-hour equivalent sound level, $L_{eq(max\text{-}hr)}$, at the facade of the building. The Policy states:

> *Potential noise mitigation requirements for educational facilities will be investigated where during the noisiest hour of the school day, post-project traffic noise levels, ten years after project completion, are projected to reach Leq(max-hr) 60 dBA or more at the facility exterior facade.*

Where the $L_{eq(max\text{-}hr)}$ exceeds 60 dBA, the Policy does not provide any further guidance on determining whether mitigation is warranted for educational facilities. Therefore, BKL adopted criteria from the World Health Organization's *Guidelines for Community Noise* (WHO 1999) where it recommends an average noise level of no more than 35 dBA inside classrooms and no more than 55 dBA in outdoor play areas during school hours. However, these guidelines do not provide any cost-benefit criteria.

5 Study Area

The study area should include all noise-sensitive receivers within the Project construction limits that could potentially be affected by noise levels that approach or exceed the Policy criteria and are clearly dominated by highway traffic.

For this noise impact assessment, the study area included at least the first three rows of dwellings to the northwest of Hwy 1 and up to 200 metres from the new highway centreline between the Project's construction limits.

Within the study area, BKL identified 173 residential land uses that could potentially be affected by noise levels that approach or exceed the Policy criteria. All of the residential land uses were identified as single-family houses except for

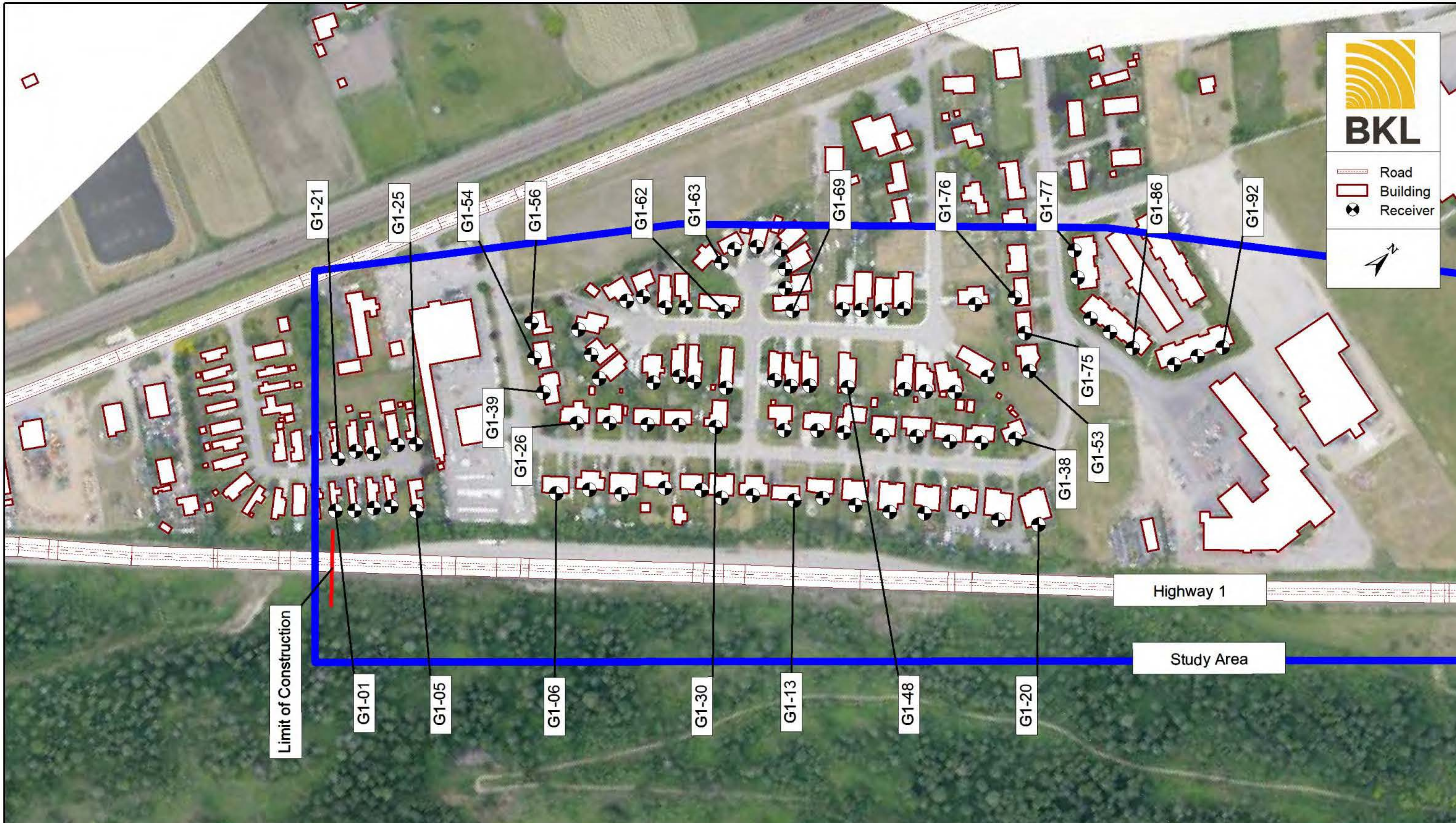
- one apartment complex on Collingwood Street, Green Briar Apartments, with an assumed eight residential units facing Hwy 1; and
- three apartment buildings on Shepherd Road within Sun Valley Estates with an assumed 32 residential units with direct exposure to Hwy 1.

Each of the potentially affected buildings is represented by a receiver in the noise model.

In addition to residential receivers, BKL included Haldane Elementary School as a noise-sensitive non-residential land use within the study area.

To simplify reporting, the receivers were assigned groups based on the geographic location. Within each group, the receivers were numbered from southwest to northeast and front row to back row. The study area and receiver groups are shown in Figure 5-1 and Figure 5-2.

Properties used for commercial or industrial purposes (including hotels/motels) are not considered to be noise-sensitive by the Policy and were therefore not included in this assessment.



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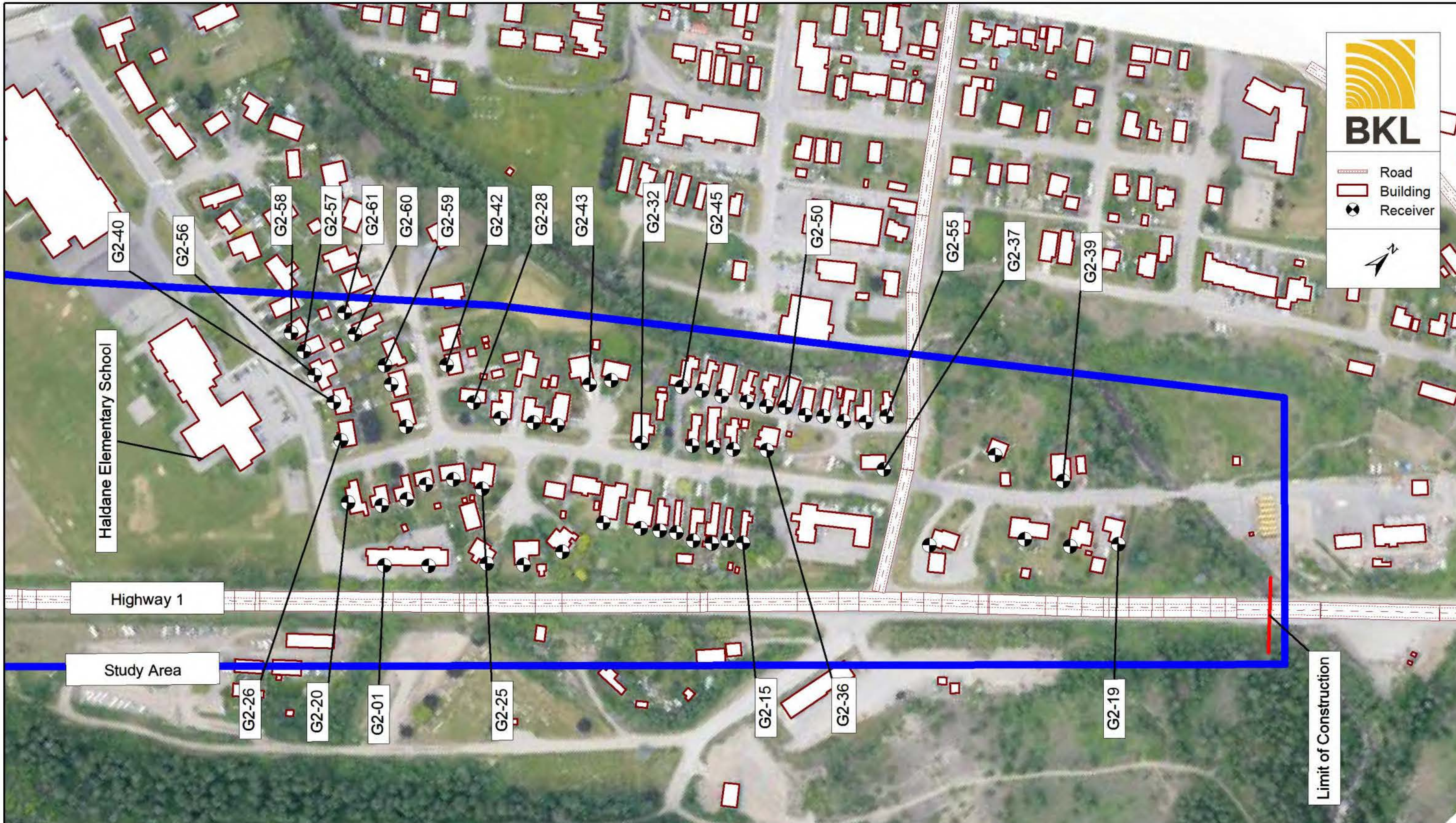
Highway 1 Chase West to Jade Mountain
Figure 5-1: Study Area - West

Date: February 2020



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Highway 1 Chase West to Jade Mountain
Figure 5-2: Study Area - East

Date: February 2020

6 Existing Noise Conditions

BKL conducted 24-to-48-hour baseline noise monitoring to measure the existing noise exposure at two locations within the study area in June 2016; these results are summarized in Table 6-1, and are not expected to have changed in the past three years. The details of the baseline measurements are presented in BKL's report titled *Highway 1 Four Laning: Hoffman's Bluff to Jade Mountain Baseline Noise Monitoring* (Baseline Report) dated July 11, 2016. The dominant noise source throughout both measurement locations was road traffic from Hwy 1. Railway noise from the tracks north of Hwy 1 did not contribute to the overall baseline noise levels measured.

Table 6-1: Summary of Baseline Monitoring Results at Residences

Location	Address	Baseline Noise Level, L_{dn} (dBA)
1	221 Brooke Drive, Chase	61
2	911 Paquette Road, Chase	68

Short-term measurements were also taken inside the two classrooms at Haldane Elementary School with the most direct exposure to Hwy 1 traffic. The indoor noise level during the loudest hour ($L_{eq\ max\text{-}hr}$) was then calculated using the short-term and long-term measurement results. The calculated $L_{eq\ max\text{-}hr}$ were 31 and 33 dBA inside the two classrooms.

7 Noise Prediction Methodology

7.1 Model Calibration

The future noise levels (10 years after expected Project completion, 2032) were calculated using the noise model and traffic inputs described in Appendix C. The noise model was calibrated using the baseline monitoring results described in Section 6. The most significant noise source in the model is road traffic from Hwy 1.

BKL modelled and calibrated the traffic noise to provide an accurate correlation between the measurements and the noise model. This involved adding barriers to represent parked trucks at the pull-out and rest area near Baseline Location 1.

The average difference between the modelled and measured results at the two measurement points was 0.1 dBA, and all modelled results were within 1.4 dBA of the measurement values.

7.2 Receivers

For dwellings, calculations were performed using point receivers at the mid-point of the upper floors, i.e., the floors with the highest noise exposures. The majority of residences within the study area are split-level houses; therefore, first floor receivers were assumed to be at a height of 2.5 metres above the ground. Some residences, particularly those near Baseline Location 1, are two-storey houses where the first floor is generally at grade. For these two-storey residences, the second-floor receivers were assumed to be at a height of 4.3 metres above the ground.

For the school, calculations were performed using point receivers at a height of 1.5 metres in the outdoor play areas.

The local geometries of buildings and terrain were modified as required (such as the inclusion of garages) to match the site conditions observed during the baseline measurements. Figure 7-1 shows an example 3-D view of the noise model.

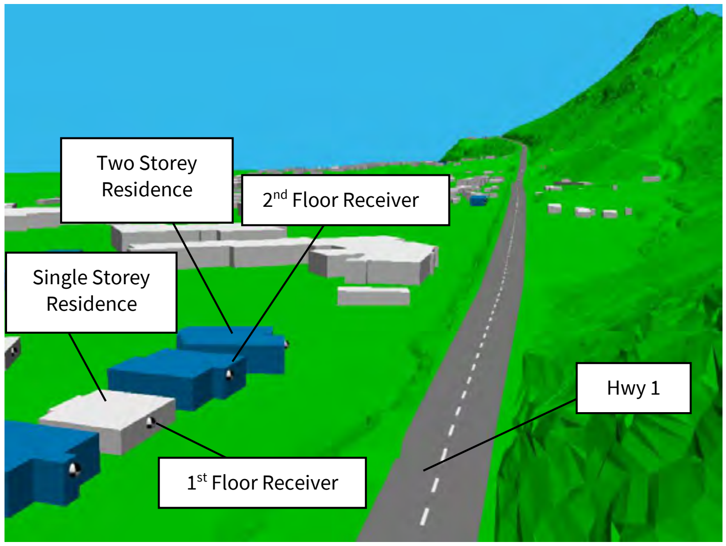


Figure 7-1: Example 3-D View of Road Noise Source, and Receivers on Elevated Terrain

8 Noise Prediction Results and Impact Assessment

8.1 Residential Land Uses

The future noise levels (10 years after expected Project completion, 2032) were calculated using the noise model and traffic inputs described in Appendix C. The modelled baseline (2016) and post-Project (2032) noise levels at each receiver are summarized in Appendix D. The Policy rates each impact by assessing the change between pre-Project and post-Project noise levels. The following figures provide a graphical representation of the impacts for each receiver based on the Policy assessment methodology. Figure 8-1 plots the model results and shows a comparison of pre- and post-Project noise levels. Figure 8-2 presents the predicted increase in noise levels. Figure 8-3 and Figure 8-4 show the receivers that are predicted to be affected by Moderate Impacts.

The predicted change in total noise ranges from -6 dBA to +4 dBA, and on average is an increase of 1 dBA.

The Policy assigns a Moderate Impact if the future noise environment is predicted to be L_{dn} 65 dBA or greater, regardless of any increase. The assessment indicates that a total of 91 out of 173 residences assessed for the Project would be affected by Moderate Impacts. No receivers would be affected by Severe Impacts.

8.2 Non-Residential Land Uses

The predicted existing exterior noise level at the nearest facade of Haldane Elementary School is $L_{eq\ max\text{-}hr}$ 64 dBA, with an estimated increase of 0.5 dBA after project completion. The predicted facade noise level at the loudest hour exceeds the Policy criteria of 60 dBA, and therefore potential noise mitigation requirements should be investigated.

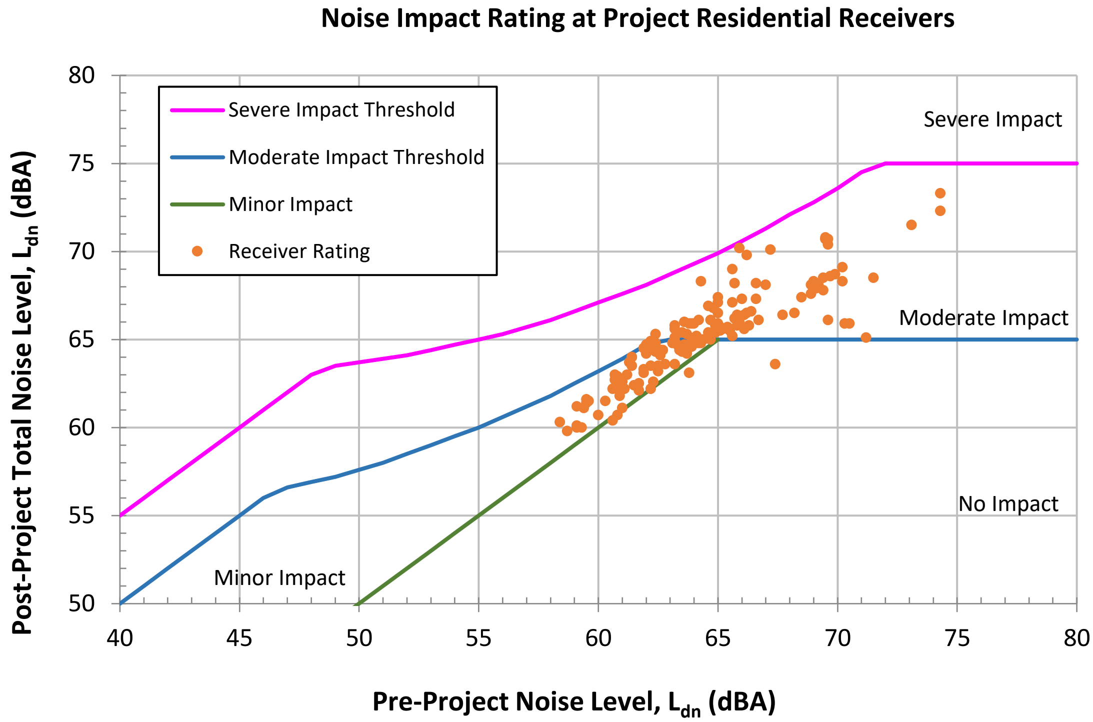


Figure 8-1: Comparison of Pre-and Post-Project Noise Levels and Noise Impact Rating

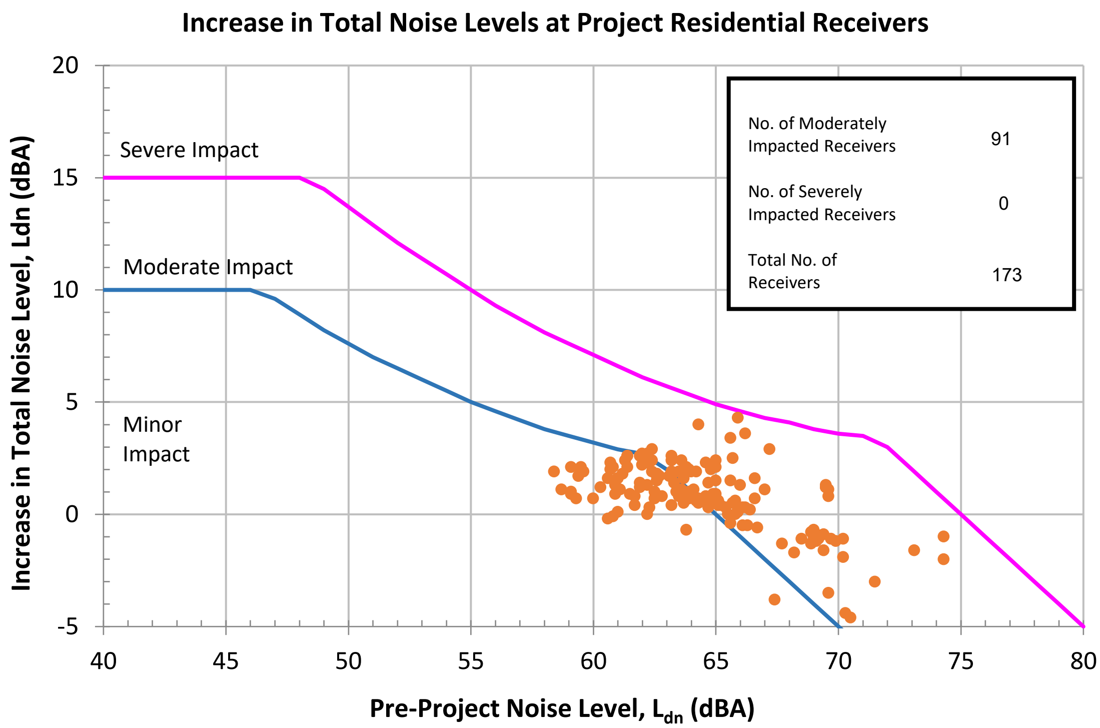
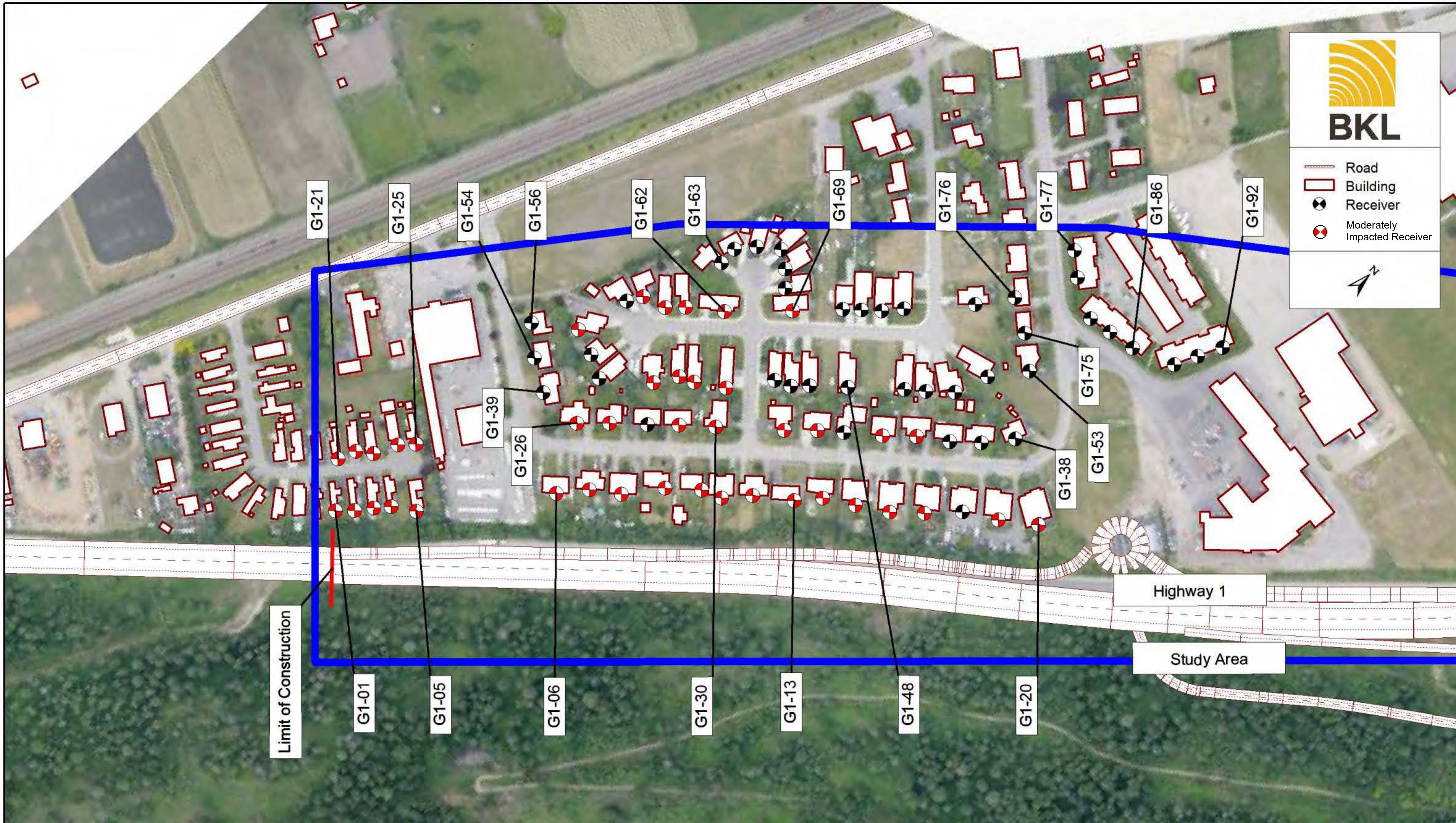


Figure 8-2: Predicted Increase in Noise Levels and Noise Impact Rating



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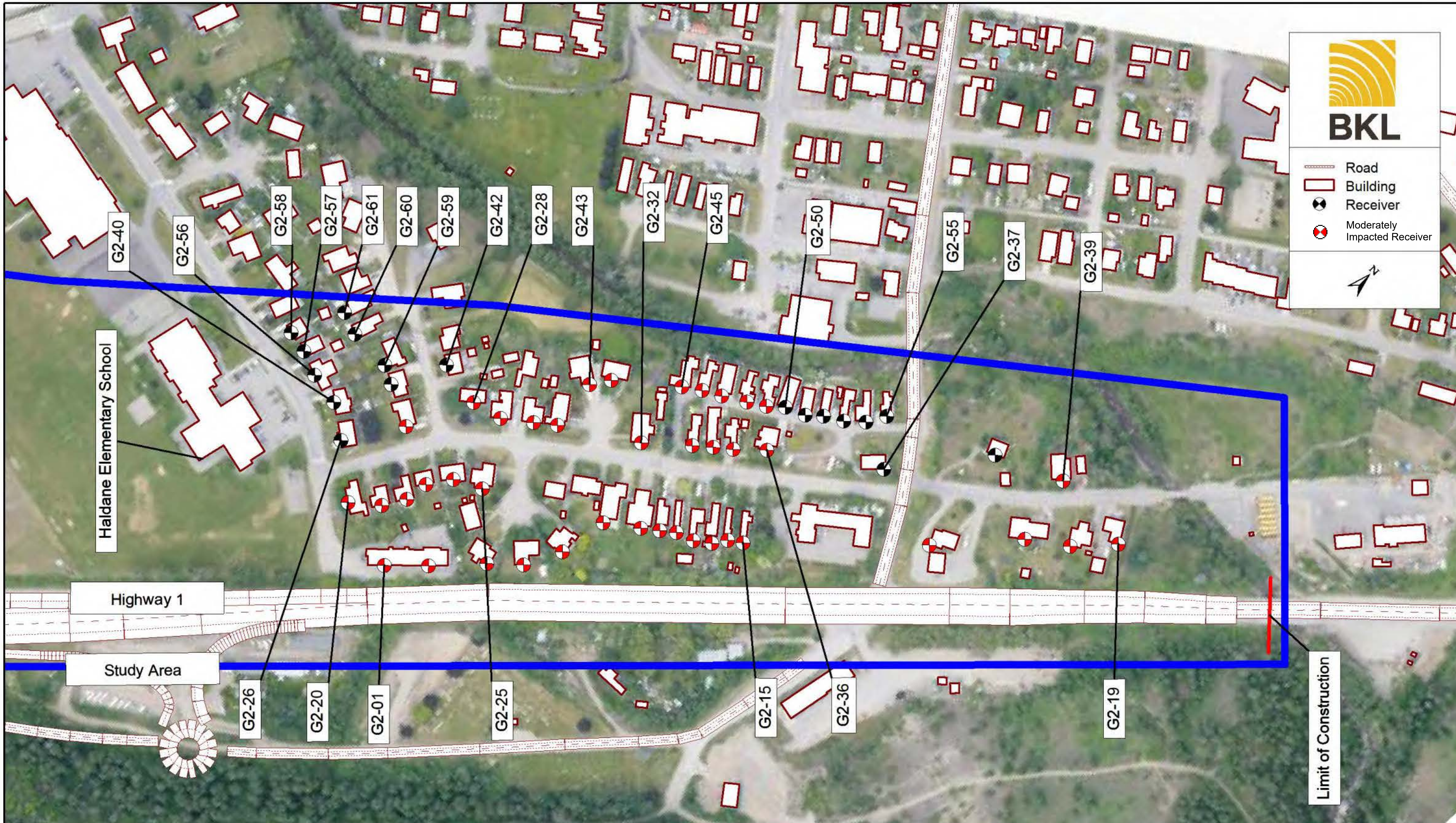
Highway 1 Chase West to Jade Mountain
Figure 8-3: Residences with a Moderate Noise Impact Rating - West

Date: February 2020



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Highway 1 Chase West to Jade Mountain
Figure 8-4: Residences with a Moderate Noise Impact Rating - East

Date: February 2020

9 Potential Mitigation

9.1 Noise Policy Mitigation Allowance for Residences

The total number of residential dwellings was estimated based on a review of the residential properties within the study area. Based on the analysis in Section 8, the Policy mitigation allowance is $2,275,000, as summarized in Table 9-1.

Table 9-1: Summary of Noise Policy Mitigation Allowance for Residences

Noise Impact	Number of Residences	Mitigation Allowance per Residence	Total Mitigation Allowance
Minor/No Impact	82	$0	$0
Moderate Impact	91	$25,000	$2,275,000
Severe Impact	0	$40,000	$0
Total	173	-	$2,275,000

9.2 Noise Mitigation for Non-Residential Land Uses

In the absence of further noise mitigation guidance from the Policy, BKL adopted criteria from the World Health Organization's *Guidelines for Community Noise* (WHO 1999) where it recommends an average noise level of no more than 35 dBA inside classrooms and no more than 55 dBA in outdoor play areas during school hours. BKL approximated the average noise level during school hours with the daytime noise level, L_d. As summarized in Table 9-2, predicted classroom noise levels do not exceed the relevant criterion while predicted noise levels in the playgrounds exceed the relevant criterion. Therefore, noise mitigation options should be investigated for the outdoor playgrounds, but there is no clear methodology to determine whether or not noise mitigation would be cost-effective.

Table 9-2: Summary of Predicted Noise Levels at Haldane Elementary School

Location	Predicted Noise Level (dBA)	WHO Criterion (dBA)	Exceeds WHO Criterion?
Classroom	34	35	No
Outdoor Playgrounds	58-64	55	Yes

9.3 Noise Mitigation Options

The Policy lists four general mitigation options: noise barriers (sound walls and earth berms), low-noise pavements, noise control at the receiver, and noise impact avoidance.

Vegetation buffer strips are often brought up as noise barrier alternatives or improvements but a single row of trees or hedges placed between the noise source and receiver would not provide any acoustical benefit. However, studies have found that trees or hedging that obstructs the view of noise sources can provide a psychological benefit, since people tend to perceive sounds as being quieter when the noise source cannot be seen. Hence, a row of trees would provide a positive psychological effect. Other studies have found that trees that are placed near sound walls can reduce the acoustical benefit of the noise barrier because sound is scattered and redirected downwards as it passes through tree foliage above noise barriers. These factors should be considered when assessing noise mitigation options.

9.3.1 Noise Barriers

The Policy limits the height of vertical noise barriers to 5 metres. Earth berms could be considered for the site but it is understood that there is no right-of-way available to construct a useful berm.

This assessment considered the acoustical benefit of sound walls while incorporating the following constraints set out by the Ministry for the Project:

- the noise barrier cannot be located on top of any retaining walls;
- the noise barrier cannot be located on the edge of pavement;
- the noise barrier should be aligned to the edge of Ministry right-of-way; and
- the noise barrier needs to provide emergency vehicle access to Hwy 1 on Coburn Street.

Given these constraints, BKL modelled three barrier segments each at a height of five metres along the northern edge of the right-of-way:

- from the western construction limit of the Project to Brooke Drive;
- from Haldene Elementary School to Coburn Street; and
- from Coburn Street to the eastern construction limit of the Project.

The mitigation objectives as described by the Policy indicate that mitigation measures should reduce total noise exposures at fronting residences by at least 5 dBA; however, the resulting reduction in noise levels met the 5 dBA criteria for 18 out of 37 fronting moderately impacted dwellings. There was also only a marginal reduction in noise levels predicted at the school playgrounds. Therefore, these barriers will not be effective for a majority of land uses according to the Policy's mitigation objectives.

9.3.2 Low-Noise Pavement

The Policy deems low-noise pavement to be effective only when an average benefit of at least 3 dBA is demonstrated. This benefit can be achieved only with high vehicle speeds and low truck percentages. Based on the high percentage of trucks on this section of Hwy 1, low-noise pavement may not be an effective mitigation option for the Project.

9.3.3 Noise Control at the Receiver

Performing adequate noise control at the receiver is usually very detailed and site specific. The scope of this review did not include analysis of receiver noise control requirements for each affected residence. Suitable options and costs vary significantly depending on the type and size of building and would need to be determined on a case-by-case basis. In general, road traffic noise in buildings can be improved by

- providing double-glazed windows for homes with existing single-glazed windows facing the Project;

- ensuring adequate ventilation and thermal comfort (especially in summer) such that exterior windows/doors facing the highway can remain closed and any fresh air vents facing the highway can be avoided/eliminated;
- ensuring adequate seals exist around exterior windows/doors;
- increasing the window glazing thickness and/or airspace (such as adding a storm window) if it can be shown to be the primary source of noise ingress; and
- adding an extra layer of exterior sheathing or wallboard if all other measures have been deemed ineffective by an acoustical engineer.

Typically, a site visit to each residence would be required to determine the performance of existing noise insulation features and to determine the improvements that would be required. This could be investigated for the Project because in most cases the Moderate Impacts are predicted at only the second floor of the impacted dwellings.

9.3.4 Noise Impact Avoidance

According to the Policy, noise impact avoidance measures can include

- route selection;
- speed control; and
- use of low-noise pavement.

This study assumes that there are no practical noise impact avoidance options.

10 Conclusions

BKL Consultants Ltd. was retained by the BC Ministry of Transportation and Infrastructure to conduct a noise impact assessment for the Highway 1 – Chase West to Jade Mountain Project. The noise impact assessment was completed by

- performing a baseline noise survey;
- modelling baseline and future noise levels;
- rating the impacts of future noise levels using the Policy criteria;
- reviewing potential noise mitigation options; and
- providing one noise barrier alignment option.

According to BKL's assessment, predictions, and analysis, 91 of the 173 residences assessed would be affected by Moderate noise impacts, and zero residences would be affected by Severe noise impacts. Noise levels at Haldane Elementary School also exceed the Policy threshold for investigating mitigation requirements. The impacted residences are primarily split-level and two-storey single-family dwellings near the highway corridor with one low-rise multi-family apartment building. According to predictions, the noise impacts will be due to high existing noise levels, increased traffic volumes, elevated road alignment, and reduced road alignment setbacks.

The Policy does not provide any specific mitigation guidance for schools. Therefore, BKL adopted World Health Organization recommendations for indoor classroom and outdoor playground noise levels. The predicted classroom noise levels are not a concern, but additional mitigation would be needed to achieve outdoor playground noise levels meeting World Health Organization recommendations.

Potential noise mitigation options include noise barriers, low-noise pavement, noise control at the receiver, and noise impact avoidance. Given particular constraints provided by the Ministry, BKL modelled a 5 metre noise barrier along the edge of Hwy 1 right-of-way, but the predicted noise reduction did not achieve at least 5 dBA for a majority of the nearest fronting residences. For Haldane Elementary School, there was also only a marginal reduction in noise levels predicted at the school playgrounds.

NOTICE

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This document contains the expression of the professional opinion of BKL, at the time of its preparation, as to the matters set out herein, using its professional judgment and reasonable care. The information provided in this report was compiled from existing documents and data provided by the Client, site noise measurements and by applying currently accepted industry practice and modelling methods. Unless expressly stated otherwise, assumptions, data and information supplied by or gathered from other sources (including the Client, other consultants, testing laboratories and equipment suppliers, etc.) upon which BKL's opinion as set out herein is based has not been verified by BKL; BKL makes no representation as to its accuracy and disclaims all liability with respect thereto.

This document is meant to be read as a whole, and sections or parts thereof should thus not be read or relied upon out of context. BKL reserves the right to modify the contents of this report, in whole or in part, to reflect any new information that becomes available. If any conditions become apparent that differ significantly from the understanding of conditions as presented in this report, BKL should be notified immediately to reassess the conclusions provided herein.

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Appendix A Glossary

A-weighting – A standardized filter used to alter the sensitivity of a sound level meter with respect to frequency so that the instrument is less sensitive at low and high frequencies where the human ear is less sensitive. Also written as dBA.

ambient/existing level – The pre-project noise or vibration levels.

daytime equivalent sound level (L_d) - The equivalent sound level over daytime hours (7 am to 10 pm).

day-night equivalent sound level (L_{dn}) – The sound exposure level for a 24-hour day calculated by logarithmically adding the sound exposure level obtained during the daytime (L_d) (7 am to 10 pm) and to 10 times the sound exposure level obtained during the nighttime (L_n) (10 pm to 7 am) to account for greater human sensitivity to evening and nighttime noise.

decibel – The standard unit of measurement for sound pressure and sound power levels. It is the unit of level that denotes the ratio between two quantities that are proportional to pressure or power. The decibel is 10 times the logarithm of this ratio. The reference pressure used for airborne sound is 20 µPa, while the typical reference pressure used for underwater sound is 1 µPa. Also written as dB.

equivalent sound level - The steady level that would contain the same amount of energy as the actual time-varying level. Although it is, in a sense, an "average," it is strongly influenced by the loudest events because they contain the majority of the energy.

frequency – With reference to noise and vibration signals, the number of cycles per second. Hertz (Hz) is the unit of frequency measurement.

frequency spectrum – Distribution of frequency components of a noise or vibration signal.

L_n – Percentile noise level, where n can be any number from 1 to 99. The reported L_n is the noise level exceeded for n% of the measurement time.

metric – Measurement parameter or descriptor.

nighttime equivalent sound level (L_n) – The equivalent sound level over the nighttime hours (10 pm to 7 am).

noise-sensitive land use – Land where the intended use may be adversely affected by noise.

octave bands – A standardized set of bands making up a frequency spectrum. The centre frequency of each octave band is twice that of the lower band frequency.

receiver – A noise-sensitive stationary position at which noise levels are received.

sound – The fluctuating motion of air or other elastic medium which can produce the sensation of sound when incident upon the ear.

sound power – The total sound energy radiated by a source per unit time.

Appendix B Introduction to Sound and Environmental Noise Assessment

B.1 General Noise Theory

The two principal components used to characterize sound are loudness (magnitude) and pitch (frequency). The basic unit for measuring magnitude is the decibel (dB), which represents a logarithmic ratio of the pressure fluctuations in air relative to a reference pressure. The basic unit for measuring pitch is the number of cycles per second, or hertz (Hz). Bass tones are low frequency and treble tones are high frequency. Audible sound occurs over a wide frequency range, from approximately 20 Hz to 20,000 Hz, but the human ear is less sensitive to low- and very high–frequency sounds than to sounds in the mid-frequency range (500 to 4,000 Hz). “A-weighting” networks are commonly employed in sound level meters to simulate the frequency response of human hearing, and A-weighted sound levels are often designated “dBA” rather than “dB”.

If a continuous sound has an abrupt change in level of 3 dB it will generally be noticed, while the same change in level over an extended period of time will probably go unnoticed. A change of 6 dB is clearly noticeable subjectively and an increase of 10 dB is generally perceived as being twice as loud.

B.2 Basic Sound Metrics

While the decibel, or A-weighted decibel, is the basic unit used for noise measurement, other indices are also used to describe environmental noise. The equivalent sound level, abbreviated L_{eq}, is commonly used to indicate the average sound level over a period of time. The L_{eq} represents the steady level of sound which would contain the same amount of sound energy as the actual time-varying sound level. Although the L_{eq} is an average, it is strongly influenced by the loudest events occurring during the time period because these events contain most of the sound energy. Another common metric used is the L_{90}, which represents the sound level exceeded for 90 per cent of a time interval and is typically referred to as the background noise level.

The L_{eq} can be measured over any period of time using an integrating sound level meter. Some common time periods used are 24 hours, noted as the L_{eq24}, daytime hours (7 am to 10 pm), noted as the L_d, and nighttime hours (10 pm to 7 am), noted as the L_n. As the impact of noise on people is judged differently during the day and during the night, 24-hour noise metrics have been developed that reflect this.

The day-night equivalent sound level (L_{dn}) is one metric commonly used to represent community noise levels. It is derived from the L_d and the L_n with a 10 dB penalty applied to the L_n to account for increased human sensitivity to nighttime noise.

Appendix C Noise Prediction Methodology

C.1 Acoustical Model

BKL predicted transportation noise levels using the French standard for road traffic noise prediction, NMPB-Routes-1996 (NMPB 1997), the international standard ISO 9613-2 (1996), and the Dutch standard SRM II (VROM 1996), implemented in the outdoor sound propagation software Cadna/A, version 2019. *The Good Practice Guide for Noise Mapping* points out that these standards are recommended by the European Commission as current best practice to obtain accurate prediction results (WG-AEN 2007).

NMPB-Routes-96 specifies octave band sound power levels for roadways, dependant on traffic volumes, average travel speed, percentage of heavy vehicles (i.e., trucks, buses), road gradient and flow conditions (continuous, accelerating, decelerating vehicles). BKL has found that this standard provides a high level of agreement with traffic noise measurements conducted in BC.

Second order reflections were considered in the acoustic model. Model calculations were performed in octave bands, considering ground cover, topography and shielding objects (see following sections).

C.2 Ground Absorption

The acoustic properties of the ground surface can have a considerable effect on the propagation of noise. Flat, non-porous surfaces such as concrete, asphalt, buildings, calm water, etc., are highly reflective to noise, and, in the model, have a ground constant of G=0. Soft, porous surfaces such as foliage, loam, soft grass, fresh snow, etc., are highly absorptive to noise and have a ground constant of G=1.

In order to approximate the ground effect on sound propagation, the ground surface has been modelled as absorptive (G=1) throughout except for roads and buildings, which were modelled as reflective (G=0).

C.3 Meteorological Conditions

A temperature of 10°C and relative humidity of 80% were used in the model settings to best represent average weather conditions based on the selection available in Cadna/A. Favourable sound propagation was assumed to occur for 50% of the time during the day and 100% of the time during the night.

Variations in temperature and humidity generally have little effect on the overall noise propagation.

C.4 Topography and Obstacles

The intervening terrain and building outlines have been modelled by directly importing ground contours of the area provided by Binnie. Concrete roadside barriers (CRBs) were modelled as reflective sound barriers with a height of 0.5 metres as per Binnie's design drawings.

C.5 Roadway Geometry

The existing highway alignment was modelled using aerial photographs and existing highway and road alignments provided by Binnie. Future highway alignments and associated road alignments were modelled based on design drawings provided by Binnie.

C.6 Traffic Inputs

Pre-Project highway traffic volumes and inputs for 2016 and future highway volume predictions for 2032 were provided by Binnie in the *Highway 1 Shuswap Chase Creek Road to jade Mountain 100% Functional*

Design Traffic Memorandum Rev. 0 issued on May 7, 2019. Existing and future modelled vehicle speeds and truck percentages were 100 km/h and 24%, respectively.

Table C-1 lists the Summer Average Daily Traffic (SADT) used for the model.

Table C-1: Annual Average Daily Traffic

Road Segment	2016 SADT	2032 SADT
Hwy Mainline	12659	16064
New Brooke Drive off-ramp from WB Hwy 1	-	1305
New Brooke Drive on-Ramp to WB Hwy 1	-	456
New Foothills Road off-ramp from EB Hwy 1	-	1284
New Foothills Road on-ramp to EB Hwy 1	-	2398

Roadways were modelled with standard asphaltic pavement.

Appendix D Noise Modelling Results

Table D-1: Noise Impact at Assessed Receivers according to the Policy

Receiver	Receiver Height	L_{dn} (dBA)			Noise Impact Threshold L_{dn} (dBA)		Noise Impact Rating
		Pre-Project	Post-Project	Predicted Change	Moderate Impact	Severe Impact	
G1-01	1st Floor	69.6	70.4	0.8	65.0	73.3	Moderate
G1-02	1st Floor	69.5	70.8	1.3	65.0	73.2	Moderate
G1-03	1st Floor	69.6	70.7	1.1	65.0	73.3	Moderate
G1-04	1st Floor	69.5	70.7	1.2	65.0	73.2	Moderate
G1-05	1st Floor	69.5	70.7	1.2	65.0	73.2	Moderate
G1-06	2nd Floor	67.2	70.1	2.9	65.0	71.5	Moderate
G1-07	2nd Floor	66.2	69.8	3.6	65.0	70.8	Moderate
G1-08	1st Floor	65.9	70.2	4.3	65.0	70.6	Moderate
G1-09	1st Floor	64.3	68.3	4.0	65.0	69.5	Moderate
G1-10	1st Floor	65.0	67.4	2.4	65.0	69.9	Moderate
G1-11	2nd Floor	65.6	69.0	3.4	65.0	70.3	Moderate
G1-12	2nd Floor	65.7	68.2	2.5	65.0	70.4	Moderate
G1-13	1st Floor	64.9	65.8	0.9	65.0	69.9	Moderate
G1-14	1st Floor	64.7	65.0	0.3	65.0	69.7	Moderate
G1-15	2nd Floor	67.7	66.4	-1.3	65.0	71.9	Moderate
G1-16	2nd Floor	69.6	66.1	-3.5	65.0	73.3	Moderate
G1-17	2nd Floor	70.3	65.9	-4.4	65.0	73.9	Moderate
G1-18	1st Floor	67.4	63.6	-3.8	65.0	71.6	Minor/No Impact
G1-19	2nd Floor	70.5	65.9	-4.6	65.0	74.1	Moderate
G1-20	2nd Floor	71.2	65.1	-6.1	65.0	74.6	Moderate
G1-21	1st Floor	65.6	67.1	1.5	65.0	70.3	Moderate
G1-22	1st Floor	66.0	67.3	1.3	65.0	70.6	Moderate
G1-23	1st Floor	66.6	67.3	0.7	65.0	71.0	Moderate
G1-24	1st Floor	67.0	68.1	1.1	65.0	71.3	Moderate
G1-25	1st Floor	66.6	68.2	1.6	65.0	71.0	Moderate
G1-26	1st Floor	63.8	65.9	2.1	65.0	69.2	Moderate
G1-27	1st Floor	63.2	65.8	2.6	65.0	68.8	Moderate
G1-28	1st Floor	61.4	64.0	2.6	64.2	67.8	Minor/No Impact
G1-29	1st Floor	62.4	65.3	2.9	65.0	68.3	Moderate
G1-30	1st Floor	63.2	65.6	2.4	65.0	68.8	Moderate
G1-31	2nd Floor	64.7	66.1	1.4	65.0	69.7	Moderate
G1-32	2nd Floor	65.0	66.5	1.5	65.0	69.9	Moderate
G1-33	1st Floor	63.1	64.8	1.7	65.0	68.7	Minor/No Impact
G1-34	2nd Floor	64.0	65.9	1.9	65.0	69.3	Moderate

Receiver	Receiver Height	L_{dn} (dBA)			Noise Impact Threshold L_{dn} (dBA)		Noise Impact Rating
		Pre-Project	Post-Project	Predicted Change	Moderate Impact	Severe Impact	
G1-35	2nd Floor	64.2	66.1	1.9	65.0	69.4	Moderate
G1-36	1st Floor	61.3	63.7	2.4	64.1	67.7	Minor/No Impact
G1-37	1st Floor	62.6	64.1	1.5	65.0	68.4	Minor/No Impact
G1-38	1st Floor	63.8	63.1	-0.7	65.0	69.2	Minor/No Impact
G1-39	1st Floor	60.7	63.0	2.3	63.7	67.4	Minor/No Impact
G1-40	1st Floor	60.6	62.2	1.6	63.6	67.4	Minor/No Impact
G1-41	1st Floor	64.6	66.9	2.3	65.0	69.7	Moderate
G1-42	1st Floor	65.0	67.1	2.1	65.0	69.9	Moderate
G1-43	1st Floor	64.8	66.8	2.0	65.0	69.8	Moderate
G1-44	1st Floor	63.5	65.4	1.9	65.0	69.0	Moderate
G1-45	1st Floor	62.7	64.4	1.7	65.0	68.5	Minor/No Impact
G1-46	1st Floor	62.5	63.5	1.0	65.0	68.4	Minor/No Impact
G1-47	1st Floor	61.4	63.5	2.1	64.2	67.8	Minor/No Impact
G1-48	1st Floor	59.5	61.6	2.1	62.8	66.8	Minor/No Impact
G1-49	1st Floor	61.7	62.1	0.4	64.4	67.9	Minor/No Impact
G1-50	1st Floor	63.3	64.7	1.4	65.0	68.9	Minor/No Impact
G1-51	1st Floor	62.0	64.2	2.2	64.7	68.1	Minor/No Impact
G1-52	1st Floor	61.4	64.0	2.6	64.2	67.8	Minor/No Impact
G1-53	1st Floor	63.6	64.7	1.1	65.0	69.0	Minor/No Impact
G1-54	1st Floor	59.1	61.2	2.1	62.6	66.6	Minor/No Impact
G1-55	1st Floor	61.9	63.3	1.4	64.6	68.0	Minor/No Impact
G1-56	1st Floor	58.4	60.3	1.9	62.1	66.3	Minor/No Impact
G1-57	1st Floor	64.1	65.2	1.1	65.0	69.4	Moderate
G1-58	1st Floor	63.2	64.9	1.7	65.0	68.8	Minor/No Impact
G1-59	1st Floor	63.2	65.1	1.9	65.0	68.8	Moderate
G1-60	1st Floor	63.7	65.3	1.6	65.0	69.1	Moderate
G1-61	1st Floor	63.9	65.9	2.0	65.0	69.2	Moderate
G1-62	1st Floor	63.6	66.0	2.4	65.0	69.0	Moderate
G1-63	1st Floor	62.2	64.5	2.3	64.8	68.2	Minor/No Impact
G1-64	1st Floor	62.4	64.3	1.9	65.0	68.3	Minor/No Impact
G1-65	1st Floor	62.4	64.8	2.4	65.0	68.3	Minor/No Impact
G1-66	1st Floor	60.8	62.9	2.1	63.8	67.5	Minor/No Impact
G1-67	1st Floor	60.7	62.7	2.0	63.7	67.4	Minor/No Impact
G1-68	1st Floor	59.5	61.4	1.9	62.8	66.8	Minor/No Impact
G1-69	1st Floor	62.2	64.9	2.7	64.8	68.2	Moderate
G1-70	2nd Floor	62.6	64.4	1.8	65.0	68.4	Minor/No Impact
G1-71	1st Floor	62.0	64.7	2.7	64.7	68.1	Moderate
G1-72	1st Floor	61.9	64.5	2.6	64.6	68.0	Minor/No Impact

Receiver	Receiver Height	L_{dn} (dBA)			Noise Impact Threshold L_{dn} (dBA)		Noise Impact Rating
		Pre-Project	Post-Project	Predicted Change	Moderate Impact	Severe Impact	
G1-73	1st Floor	62.6	64.3	1.7	65.0	68.4	Minor/No Impact
G1-74	1st Floor	62.6	64.4	1.8	65.0	68.4	Minor/No Impact
G1-75	1st Floor	61.2	63.0	1.8	64.1	67.7	Minor/No Impact
G1-76	1st Floor	60.3	61.5	1.2	63.4	67.2	Minor/No Impact
G1-77 (Multi-Family)	1st Floor	59.4	61.1	1.7	62.8	66.8	Minor/No Impact
G1-78 (Multi-Family)	2nd Floor	58.7	59.8	1.1	62.3	66.4	Minor/No Impact
G1-79 (Multi-Family)	1st Floor	59.6	61.5	1.9	62.9	66.9	Minor/No Impact
G1-80 (Multi-Family)	2nd Floor	59.1	60.1	1.0	62.6	66.6	Minor/No Impact
G1-81 (Multi-Family)	1st Floor	61.0	62.6	1.6	63.9	67.6	Minor/No Impact
G1-82 (Multi-Family)	2nd Floor	61.7	62.5	0.8	64.4	67.9	Minor/No Impact
G1-83 (Multi-Family)	1st Floor	61.0	62.6	1.6	63.9	67.6	Minor/No Impact
G1-84 (Multi-Family)	2nd Floor	61.9	63.1	1.2	64.6	68.0	Minor/No Impact
G1-85 (Multi-Family)	1st Floor	60.9	61.8	0.9	63.8	67.5	Minor/No Impact
G1-86 (Multi-Family)	2nd Floor	62.2	63.5	1.3	64.8	68.2	Minor/No Impact
G1-87 (Multi-Family)	1st Floor	60.8	60.7	-0.1	63.8	67.5	Minor/No Impact
G1-88 (Multi-Family)	2nd Floor	62.5	63.2	0.7	65.0	68.4	Minor/No Impact
G1-89 (Multi-Family)	1st Floor	60.6	60.4	-0.2	63.6	67.4	Minor/No Impact
G1-90 (Multi-Family)	2nd Floor	62.3	62.6	0.3	64.9	68.3	Minor/No Impact
G1-91 (Multi-Family)	1st Floor	61.0	61.1	0.1	63.9	67.6	Minor/No Impact
G1-92 (Multi-Family)	2nd Floor	62.2	62.2	0.0	64.8	68.2	Minor/No Impact
G2-01 (Multi-Family)	1st Floor	70.2	69.1	-1.1	65.0	73.8	Moderate
G2-02 (Multi-Family)	2nd Floor	74.3	73.3	-1.0	65.0	75.0	Moderate
G2-03 (Multi-Family)	1st Floor	70.2	68.3	-1.9	65.0	73.8	Moderate
G2-04 (Multi-Family)	2nd Floor	74.3	72.3	-2.0	65.0	75.0	Moderate
G2-05	1st Floor	71.5	68.5	-3.0	65.0	74.9	Moderate
G2-06	1st Floor	73.1	71.5	-1.6	65.0	75.0	Moderate
G2-07	1st Floor	69.4	67.8	-1.6	65.0	73.2	Moderate
G2-08	1st Floor	68.9	67.6	-1.3	65.0	72.8	Moderate
G2-09	1st Floor	69.4	68.5	-0.9	65.0	73.2	Moderate
G2-10	1st Floor	69.2	68.1	-1.1	65.0	73.0	Moderate
G2-11	1st Floor	68.9	68.1	-0.8	65.0	72.8	Moderate
G2-12	1st Floor	68.5	67.4	-1.1	65.0	72.5	Moderate
G2-13	1st Floor	69.1	67.9	-1.2	65.0	72.9	Moderate
G2-14	1st Floor	69.0	67.9	-1.1	65.0	72.8	Moderate
G2-15	1st Floor	69.7	68.6	-1.1	65.0	73.4	Moderate
G2-16	1st Floor	68.2	66.5	-1.7	65.0	72.2	Moderate
G2-17	1st Floor	69.0	68.3	-0.7	65.0	72.8	Moderate
G2-18	1st Floor	69.9	68.7	-1.2	65.0	73.6	Moderate

Receiver	Receiver Height	L_{dn} (dBA)			Noise Impact Threshold L_{dn} (dBA)		Noise Impact Rating
		Pre-Project	Post-Project	Predicted Change	Moderate Impact	Severe Impact	
G2-19	1st Floor	69.1	68.2	-0.9	65.0	72.9	Moderate
G2-20	1st Floor	66.7	66.1	-0.6	65.0	71.1	Moderate
G2-21	1st Floor	66.3	65.8	-0.5	65.0	70.8	Moderate
G2-22	1st Floor	65.9	66.0	0.1	65.0	70.6	Moderate
G2-23	1st Floor	65.8	65.8	0.0	65.0	70.5	Moderate
G2-24	1st Floor	65.6	65.2	-0.4	65.0	70.3	Moderate
G2-25	1st Floor	66.1	65.6	-0.5	65.0	70.7	Moderate
G2-26	1st Floor	64.2	64.8	0.6	65.0	69.4	Minor/No Impact
G2-27	1st Floor	65.5	65.5	0.0	65.0	70.3	Moderate
G2-28	1st Floor	65.4	65.7	0.3	65.0	70.2	Moderate
G2-29	1st Floor	65.9	66.2	0.3	65.0	70.6	Moderate
G2-30	1st Floor	66.4	66.6	0.2	65.0	70.9	Moderate
G2-31	1st Floor	66.2	66.5	0.3	65.0	70.8	Moderate
G2-32	1st Floor	65.8	66.4	0.6	65.0	70.5	Moderate
G2-33	1st Floor	65.0	65.9	0.9	65.0	69.9	Moderate
G2-34	1st Floor	64.9	65.5	0.6	65.0	69.9	Moderate
G2-35	1st Floor	65.2	65.6	0.4	65.0	70.1	Moderate
G2-36	1st Floor	65.1	65.5	0.4	65.0	70.0	Moderate
G2-37	1st Floor	64.4	65.0	0.6	65.0	69.6	Moderate
G2-38	1st Floor	63.7	64.3	0.6	65.0	69.1	Minor/No Impact
G2-39	1st Floor	64.6	65.2	0.6	65.0	69.7	Moderate
G2-40	1st Floor	61.5	62.4	0.9	64.3	67.8	Minor/No Impact
G2-41	1st Floor	63.7	64.2	0.5	65.0	69.1	Minor/No Impact
G2-42	1st Floor	63.2	63.6	0.4	65.0	68.8	Minor/No Impact
G2-43	1st Floor	66.1	66.4	0.3	65.0	70.7	Moderate
G2-44	1st Floor	65.7	66.2	0.5	65.0	70.4	Moderate
G2-45	1st Floor	64.6	65.4	0.8	65.0	69.7	Moderate
G2-46	1st Floor	65.0	65.5	0.5	65.0	69.9	Moderate
G2-47	1st Floor	64.3	65.0	0.7	65.0	69.5	Moderate
G2-48	1st Floor	65.1	65.7	0.6	65.0	70.0	Moderate
G2-49	1st Floor	64.9	65.4	0.5	65.0	69.9	Moderate
G2-50	1st Floor	63.9	64.6	0.7	65.0	69.2	Minor/No Impact
G2-51	1st Floor	63.9	64.6	0.7	65.0	69.2	Minor/No Impact
G2-52	1st Floor	64.3	64.8	0.5	65.0	69.5	Minor/No Impact
G2-53	1st Floor	63.5	64.3	0.8	65.0	69.0	Minor/No Impact
G2-54	1st Floor	63.4	64.4	1.0	65.0	68.9	Minor/No Impact
G2-55	1st Floor	63.9	64.9	1.0	65.0	69.2	Minor/No Impact
G2-56	1st Floor	60.0	60.7	0.7	63.2	67.1	Minor/No Impact

Receiver	Receiver Height	L_{dn} (dBA)			Noise Impact Threshold L_{dn} (dBA)		Noise Impact Rating
		Pre-Project	Post-Project	Predicted Change	Moderate Impact	Severe Impact	
G2-57	1st Floor	59.1	60.0	0.9	62.6	66.6	Minor/No Impact
G2-58	1st Floor	59.3	60.0	0.7	62.7	66.7	Minor/No Impact
G2-59	1st Floor	62.8	63.6	0.8	65.0	68.6	Minor/No Impact
G2-60	1st Floor	61.1	62.2	1.1	64.0	67.6	Minor/No Impact
G2-61	1st Floor	60.9	62.2	1.3	63.8	67.5	Minor/No Impact