Lions Bay Noise Mitigation Program

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Abstract

The Ministry of Transportation (MoT) of the Province of British Columbia (B.C.), Canada, noise abatement policy requires that community noise impacts of highway projects involving new or substantially upgraded highways be assessed and mitigation implemented where warranted. Increasing community demands for noise mitigation, however, may exceed policy standards and pose greater challenges for designers. This paper presents an extraordinary noise model developed to mitigate residential areas of the Village of Lions Bay on the rugged B.C. coastline along the Sea-to-Sky Highway connecting Vancouver, B.C. to Whistler, B.C., Canada home of the 2010 Winter Olympic and Paralympics Games. The CadnaA Version 3.9.15 software was used to develop a new four lane split grade alignment model incorporating two mini-interchanges. With the objective of achieving a 10 dBA noise reduction benefit, mitigation in the form of quiet pavement (OGAFC), traffic calming and 5 meter high sound walls were introduced into the model which included 115 mountain side residential receptors along a 2 km corridor at elevations of up to 35 meters above the highway. Noise reduction benefits and impacts for dwellings were further analyzed to determine contributions during specific stages of project development by creating a modular, multi-layer noise model of Lions Bay. This work was carried out under the sponsorship of BC MoT.

1   Introduction

1.1   Background

In preparation for the 2010 Winter Games to be held in the resort municipality of Whistler, British Columbia, Canada, the Sea-to-Sky Highway Improvement Project was initiated in 2005. This regional linear-development project reduces travel time along the mountainous coastline from Vancouver to Whistler while enhancing safety to and from the Olympic venues. The Lions Bay Mitigation Program evolved from a preliminary noise mitigation plan based on the BC MoT Policy [1] which led to a series of public consultations to explore effective and feasible mitigation measures that were supported by residents. This paper presents the modeling techniques used and challenges encountered in achieving the objectives of the program. In addition, the capabilities of the modeling techniques will be displayed.

1.2   Lions Bay Mitigation Program Objectives

During the detailed design phase a four-stage approach to mitigation was proposed. The primary objective of mitigation was to achieve a 5 dBA noise reduction through the use of quiet pavement and a speed reduction from 80 to 70 kmph. Subsequent stages were to achieve an additional 5 dBA noise reduction through the introduction of a split grade section, sound walls and other barrier enhancements. Priority would be given to fronting residential facades whose noise levels approached or exceeded $L_{eq}(24)$ 55 dBA in the design horizon year.

1.3   Project Description

Figure 3.3 provides a view of the new alignment (from the Vancouver end towards Whistler) which shows the final mitigated design with the split grade section in the foreground. The attributes of this alignment and the existing highway through the Lions Bay corridor are as summarized in Table 1.1.

Figure 3.3 shows that much of the intervening ground between the roadway and the residences was rocky and steep and offered little opportunity for the ground effect to occur. Aged retaining walls were commonly found at the base of the mountain slope and along the lower side of the alignment. The right-of-way (ROW) was moderately forested in most areas.

A total of 88 multi-storied residences were included in the core study along the village corridor. Of these, 55 were located at higher elevations on the mountain slope and many had elevated sundeck and patio exposures, typically 25 meters above the roadway. The remaining dwellings were located on the lower side at or below project grade. The mitigation program's objectives were to be achieved at fronting facades on both sides of the alignment.

2   Modeling Methodology

2.1   Overview

The noise environment was predicted using computer modeling techniques. A seven-part noise model was developed. This *multi-layered* approach was adopted to project residential noise levels at certain stages during the pre-project, pre-mitigation and the noise mitigation design. Noise reduction benefits and impacts would emerge as changes in residential noise levels as improvements were added. The acoustical modeling software CadnaA Version 3.9.15 was ideally suited for this purpose.

A *modular* approach was used for improved quality control and assurance. The CadnaA software provided the opportunity of maintaining classes of modeling objects in separate modules that were shared by the models and that could be updated with design changes and other project information.

2.2   Noise Model

The attributes of the noise model are listed in Table 2.1. From the first row of the table, the Baseline-Model represents pre-project conditions of the existing facility in 2004 featuring two lanes of conventional pavement with a posted speed of 80 kmph. In the second row, the Base-Model projects the existing facility to the design horizon year 2018 (10 years after project completion as per BC MoT noise policy). The Base-Model establishes *pre-project* noise levels with *2018* traffic. In the third row, the Basic Design-Model departs from the existing facility with

the proposed new four lane design incorporating improved roadside and median safety barriers. In the fourth row, First Stage Mitigation introduces quiet pavement in the form of Open Graded Asphalt Friction Coarse (OGAFC) and a speed reduction from 80 to 70 kmph to reduce source emissions. Also, at this stage, the replacement of a weathered wooden roadside barrier with a new concrete barrier was required. During Second Stage Mitigation a 750 m long split grade section was proposed at the Vancouver end of the village corridor, to provide additional screening for adjacent residences on both sides of the highway (see Figure 3.3). The split grade face developed a maximum height difference of 2 m at its mid-section. During Third Stage Mitigation standard concrete sound walls with heights ranging from 2.3 to 5 m above local ground level were proposed and optimized for location, height and length using CadnaA. All potential wall locations from the roadside to the ROW were explored. Fourth Stage Mitigation included further enhancements to the sound walls. Enhancements included, for example 2.3 m high roadside barriers on span at the two creek crossings in central Lions Bay.

All models computed first order reflections. The last three models were also run in absorptive mode to assess the advantage of lining vertical screening surfaces with absorptive materials. Such surfaces were numerous and included – existing retaining walls at the base of the mountain slope and along the sides of the creek beds, the split grade face, the mini-change abutments, the sound walls and the barrier enhancements.

3 Summary of Modeling Results and Interpretation

The results from the seven-part noise model are summarized in Figures 3.1 and 3.2 with 2018 Base-Model noise levels in dBA inscribed next to the receptor site numbers. Each series depicted shows the fluctuations in noise benefits and impacts along the corridor during a particular stage of pre-project, pre-mitigation or noise mitigation design. The first of the series, labelled Growth, reflects a conservatively stated 1.6 dBA increase in noise levels at all locations that will accompany traffic growth over the 14 years, 2004 to 2018. The second of the series, labelled Basic Design, indicates the noise benefits/impacts that the pre-mitigation design would bring. In this regard, (see Figure 3.1) 45 of 55 receptors on the mountain slope side would receive either benefits or impacts of less than 1 dBA, eight would receive benefits in the range 1 to 3 dBA and two would receive impacts in the range 1 to 1.6 dBA.

The origins of these effects are revealed in the accompanying 3D visualizations taken from the perspective of the receptor sites. For example the 1.1 dBA benefit at Site 41 is attributed to a decrease in this receptor's exposure resulting from the displacement of the near lane to a location under the top-of-cut that provides increased screening (see Figures 3.4a and b). By contrast, the impact at Site 14 of 1.6 dBA is attributed to increased exposure from the widening of the highway, as clearly evident when Figures 3.5a and b are compared. This effect is also seen at Site 26 to a lesser degree.

Figure 3.2 shows that for the majority of receptors on the lower side, the basic design would provide noise reduction benefits - a trend that is primarily due to design features including decreases in exposure resulting from the widening/realignment and increased screening from improved roadside barriers mounted on lower side retaining walls.

The Quiet Pavement/Speed Reduction series of Figures 3.1 and 3.2 exhibit the relatively consistent effect that the first stage of mitigation would provide; that is noise reduction benefits in the range of 4 to 5 dBA at fronting residential facades on both sides. Fluctuations are believed to be due to the interactions involving the altered source spectra of tires on OGAFC at reduced speed and screening along the noise propagation path.

The two Split Grade series of Figure 3.1 indicate that with either reflective or absorptive screening, the 750 m long split grade section incorporating a 2 m high face and 1.5 m high median barrier provided benefits up to 2.4 dBA for receptors located on elevated sundecks on the mountain slope. The split grade design also provided benefits up to 1.2 dBA (see Figure 3.2) for receptors located on the lower side if the median barrier, split grade face and mini-change abutment were reflective and 2.2 dBA if these vertical surfaces were absorptive.

The two Sound Wall series in Figure 3.1 show the effectiveness of third stage mitigation. Due to cost, sound walls were only proposed for mountain slope residences with greater exposures. However, due to the substantial receptor heights involved in some residential areas, 5 m high sound walls were found to be ineffective (see Figure 3.6). In other areas CadnaA predicted that reflective sound walls would provide benefits starting at 1 dBA up to 6.4 dBA with absorptive sound walls providing up to 6.6 dBA.

The two Enhancement series exhibit the effectiveness of the fourth and final stage of mitigation. The enhancements included lower profile barriers proposed in strategic locations on either side of the alignment. For example a reduced 2.3 m high barrier-on-span was proposed to screen emissions from creek bridge decks that were known to limit the effectiveness of the higher sound walls. A 2.3 m high barrier was also proposed at a key location along the propagation path between the split grade face/mini-change abutment to exposed receptors at grade on the lower side. The purpose of this barrier enhancement was to screen reflections from these vertical surfaces and was therefore not relevant in the absorptive case.

The two bolded series in Figures 3.1 and 3.2 obtained by adding the benefits/impacts on a site-by-site basis indicated the cumulative effects of the pre-project, pre-mitigation and four stage mitigation design. It may be seen from the Figure 3.1 series that the mitigation program's primary objective of achieving an initial 5 dBA noise reduction was met or exceeded at numerous receptor locations on the mountain slope except where there were substantial impacts from the widening and realignment. The Figure 3.2 series shows that receptors on the lower side that did not receive a 5 dBA noise reduction had base (2018) noise levels that were substantially below $L_{eq}(24)$ 55 dBA.

4   Conclusions

The Lions Bay Mitigation Program was shown to reduce 2018 traffic noise levels by at least 4.5 dBA for 41 of the mountain slope residences and by at least 6 dBA for the majority of residences on the lower side with base (2018) levels approaching or exceeding $L_{eq}(24)$ 55 dBA.

While the primary objective of achieving an initial 5 dBA noise reduction was substantially attained, the overall objective of a 10 dBA noise reduction could not be met consistently along the project corridor although it was approached at 9 locations on the mountain slope where noise levels were reduced by 8 dBA or more.

The multi-layered modeling technique together with the visualization features of CadnaA made it possible to diagnose the origins of noise benefits/impacts from pre-project to the pre-mitigation design and through four stages of mitigation along a corridor with complex source/receiver geometry. With the visualization features of CadnaA it was possible to confirm that it would not be possible to achieve noise reductions over 5 dBA at many mountain slope locations without considering sound wall heights in excess of 5 m.
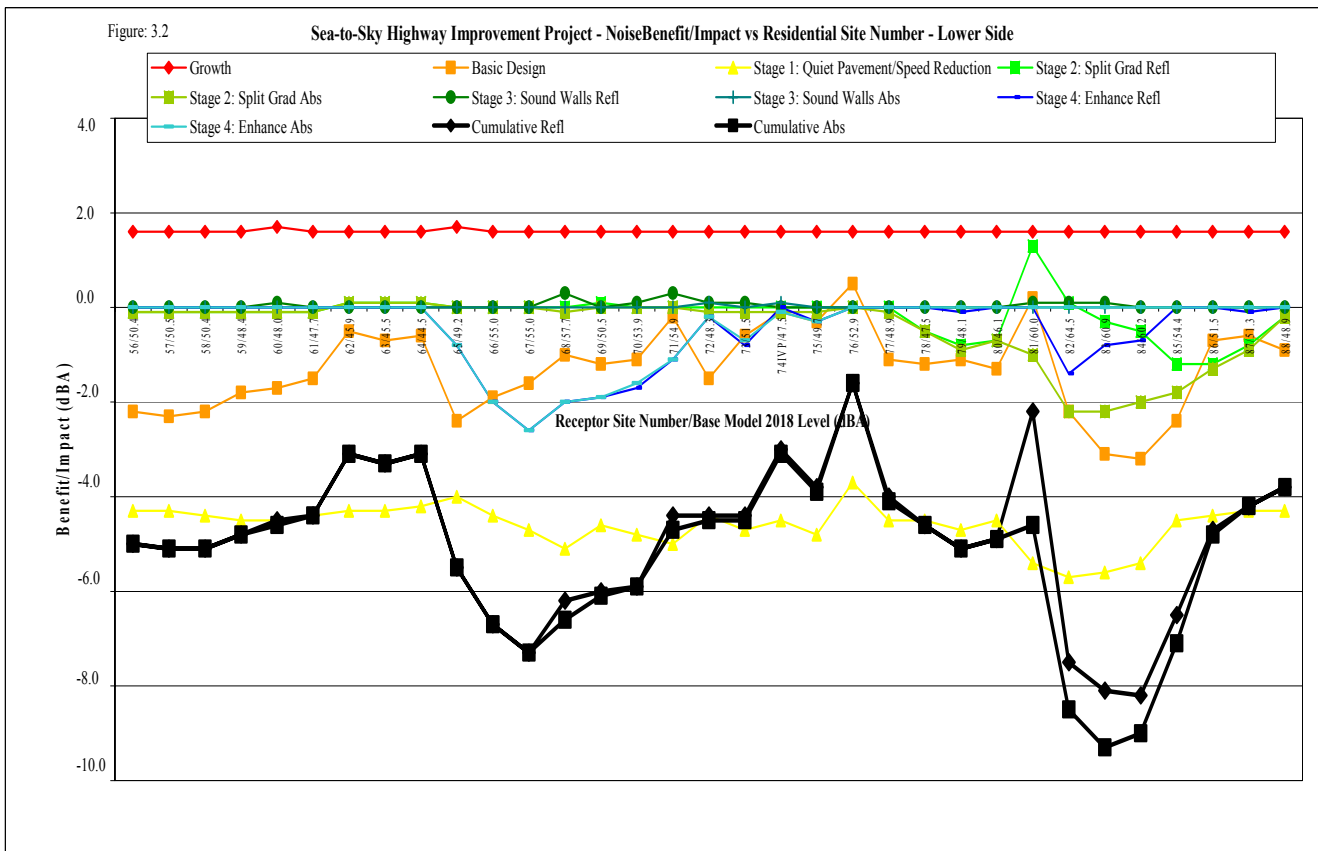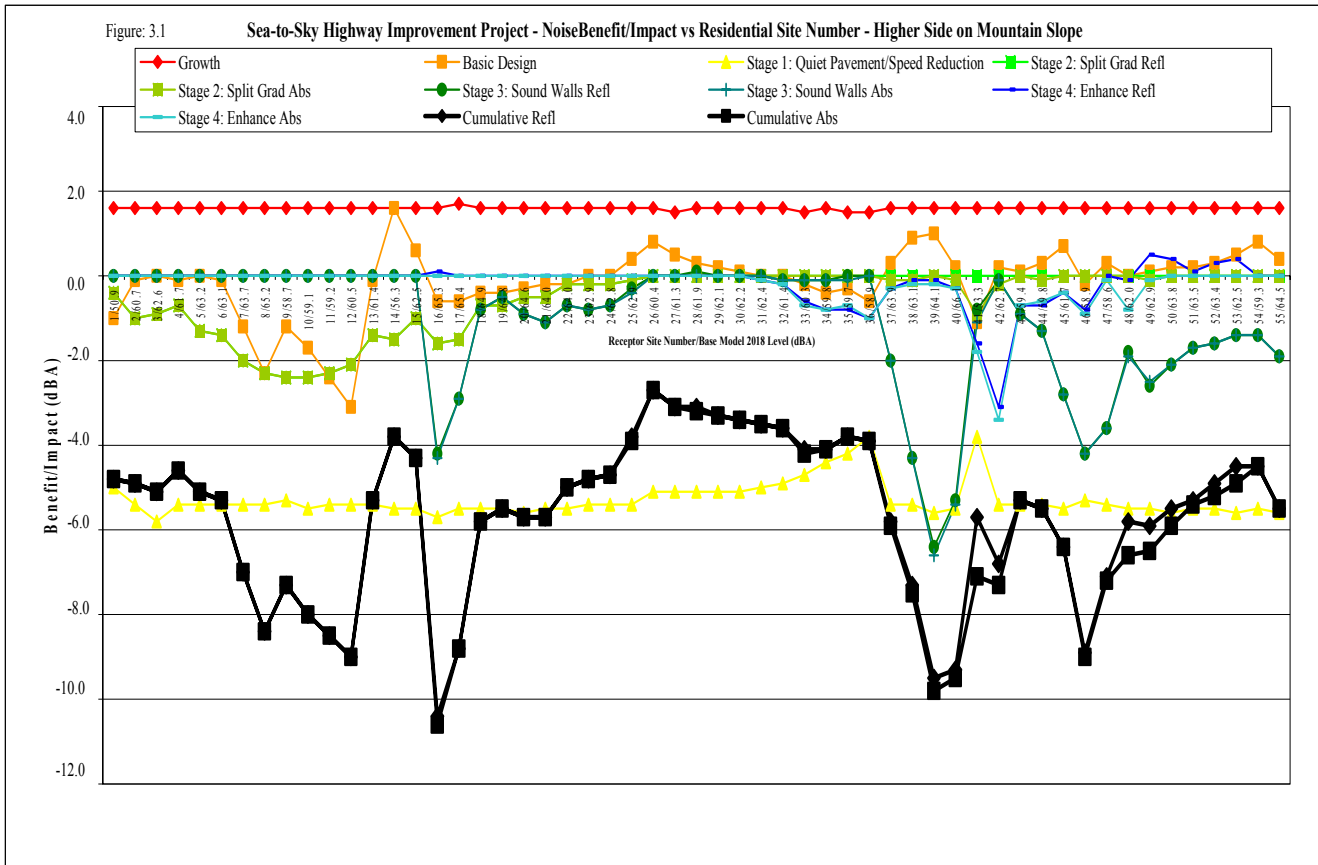
Acknowledgments

References

[1] "Revised Policy For Mitigating the Effects of Traffic Noise from Freeways and Expressways", *Province of British Columbia Ministry of Transportation and Highways – Highway Environment Branch*, (1993).

Attribute	Existing Alignment	Proposed Alignment
Lane Configuration	2 lane standard	4 lane standard/split grade
Pavement Type	Aged Conventional HMA	New OGAFC
Average Daily Traffic (vpd)/Year	14,363/2004	19,680/2018
Average Hourly Traffic (vph)/Year	598/2004	820/2018
Day/Night Traffic Split	~10:1	~10:1
Percent Heavy Vehicles/Year	2%/2004	3%/2018
Posted Speed (kmph)	80	70
Highway Grade	<2%	<2%
Elevation (m above Sea Level)	60-79	60-79
Length (km)	2	2
Sections on Span	3	3

Table 1.1: Existing and Proposed Alignment through Lions Bay

Model Name	Alignment	Traffic	Barriers	Pavement/ Speed	Cross Section	Sound Walls	Barrier Enhancements
Baseline	Existing 2 lane	2004	Existing CRB/CMB	Conventional/ 80 kmph	On grade	-	-
Base	Existing 2 lane	2018	Existing CRB/CMB	Conventional/ 80 kmph	On grade	-	-
Basic Design	New 4 lane	2018	New CRB/CMB	Conventional/ 80 kmph	On grade	-	-
First Stage Mitigation	New 4 lane	2018	New CRB/CMB	**OGAFC/ 70 kmph**	On grade	-	-
Second Stage Mitigation	New 4 lane	2018	New CRB/CMB	OGAFC/ 70 kmph	**Split grade**	-	-
Third Stage Mitigation	New 4 lane	2018	New CRB/CMB	OGAFC/ 70 kmph	Split grade	**2.3 - 5 m**	-
Fourth Stage Mitigation	New 4 lane	2018	New CRB/CMB	OGAFC/ 70 kmph	Split grade	2.3 - 5 m	**1.5-2.5 m**

Table 2.1: Noise Model – Introduction of Mitigation Initiatives Bolded

Figure: 3.1 **Sea-to-Sky Highway Improvement Project - NoiseBenefit/Impact vs Residential Site Number - Higher Side on Mountain Slope**

Figure: 3.2 **Sea-to-Sky Highway Improvement Project - NoiseBenefit/Impact vs Residential Site Number - Lower Side**
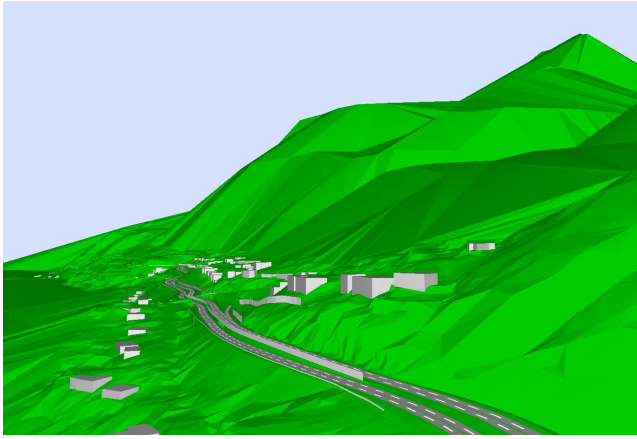
Figure 3.3: View of Sea-to-Sky Highway through Lions Bay from Vancouver End towards Whistler (Proposed Four Lane Configuration) - Showing 750 m Long Split Grade Section with 1.5 m High Median Barrier.
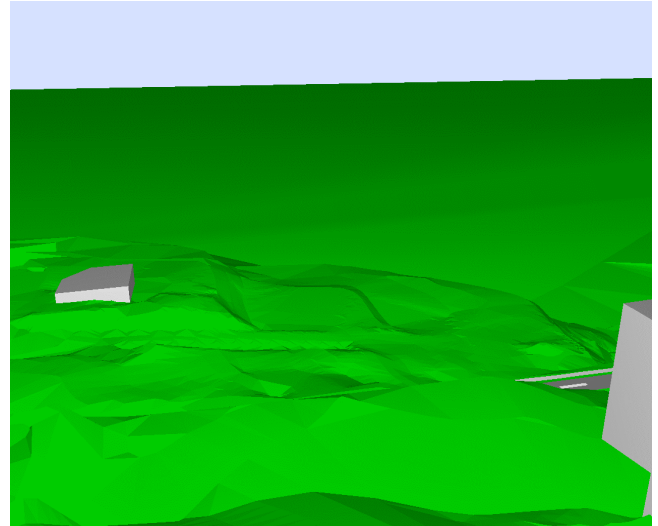

Figure 3.4a: View Looking Over Site 41 in Base Model (Existing Two Lane Configuration) - Showing Screening of Near Lane by Top-of-Cut and the Details of a Weathered Wooden Fence to be Replaced under Stage 1 Mitigation.

Figure 3.4b: View Looking Over Site 41 in Basic Design Model (Proposed Four Lane Configuration) - Showing Pre-mitigation Benefit of 1.1 dBA due to a Further Displacement of the Near Lane under the Top-of-Cut.

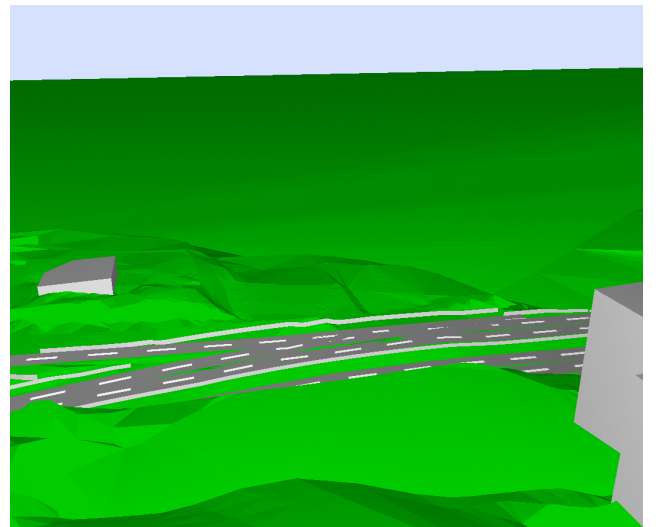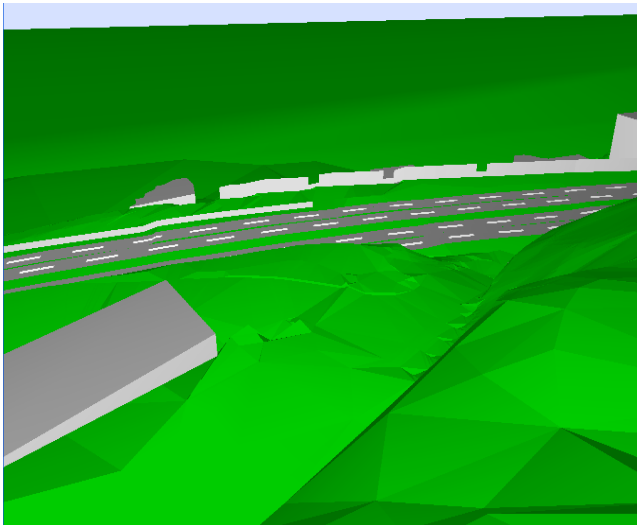Figure 3.5a: View from Sundeck of Site 14 in Base Model (Existing Two Lane Configuration).

Figure 3.5b: View from Site 14 from Basic Design Model (Proposed Four Lane Configuration) - Showing Project Impact of 1.6 dBA due to Widening/Realignment.
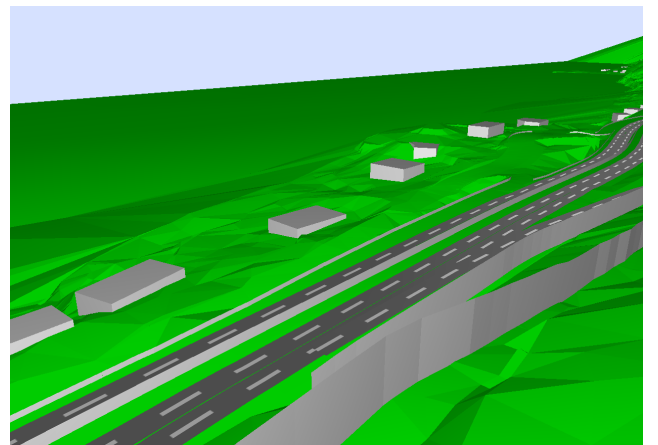

Figure 3.6: View from Sundeck of Site 5 in the Stage 3 Mitigation Model (Proposed Four Lane Configuration) - Depicting an Effective Split Grade Section with 1.5 m High Median Barrier and Two Ineffective Sound Wall Options.