NZ TRANSPORT AGENCY
WAKA KOTAHI

Roads of national significance

16 20 Western Ring Route – Waterview Connection

Assessment of Operational Noise Effects

MARSHALL DAY Acoustics

newzealand.govt.nz

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Contents

Appendices

1. Summary Statement

This report provides an assessment of operational noise effects for the Waterview Connection Project.

It contains a review of relevant operational noise criteria for traffic and non-traffic related noise sources associated with the Project, a discussion of appropriate criteria and methodologies of assessment and a detailed discussion of the determination of the "best practicable option" for traffic noise mitigation measures for each Sector of the Project.

Traffic noise has been assessed in accordance with NZS 6806:2010 "Acoustics – Road-traffic noise – New and altered roads". Preferred mitigation options have been determined by the Project team through the application of the best practicable option approach.

Mitigation measures include noise barriers and bunds, and the installation of low-noise generating road surface material, such as Open Graded Porous Asphalt and Twin Layer Open Graded Porous Asphalt.

This report identifies buildings for which the external noise criteria of NZS 6806:2010 cannot be achieved by the implementation of the preferred mitigation options. These buildings potentially require building modification mitigation and the process of implementation of such mitigation is discussed in this report.

Detailed plans show the location, height and length of the preferred mitigation options, and tables list the predicted noise levels for individual assessed dwellings for each mitigation option considered.

Non-traffic noise from ventilation and emergency systems is assessed against noise criteria that are based on the current District Plan noise limits of the underlying zoning. The criteria have been updated to be in line with the latest New Zealand acoustical Standards (NZS 6801:2008 and NZS 6802:2008). Ventilation required for the Project and its associated noise can be controlled to achieve compliance with these criteria. Emergency systems are required to operate at a more powerful level, though only intermittently. Therefore, less stringent noise criteria are proposed for operation of the emergency ventilation system.

The Project can be designed and operated to achieve compliance with relevant criteria, and the best practicable option approach to mitigation determination and design, involving the wider Project team, provides a balanced result for mitigation.

2. Introduction

The purpose of this report is to provide an assessment of the NZTA's Waterview Connection Project in relation to noise effects from traffic and other operations associated with the Project. Where this assessment identifies potential adverse operational noise effects on the environment, the report provides a scope of works to avoid, remedy or mitigate these effects. Where there is uncertainty regarding the likely effects or the significance of effects, the report recommends monitoring and, where appropriate, subsequent response.

This noise report relates closely to reports pertaining to construction noise and construction and operational vibration. It is based on information provided in the traffic report[1] for the Waterview Connection Project, specifically current and future traffic volumes on local roads and State highways, and provides input to other Project reports, such as the visual[2] and social impact[3] assessments. The results of the traffic noise assessment, specifically the management and mitigation measures, form part of the Environmental Management Plans.

[1] Technical Report No. G18 "Assessment of Transport Effects", by Beca

[2] Technical Report No. G20 "Assessment of Visual and Landscape Effects", by Stephen Brown Environments

[3] Technical Report No. G14 "Assessment of Social Effects", by Beca

3. Description of Project

3.1 Overview

In 2009 the NZTA confirmed its intention that the 'Waterview Connection Project' would be lodged with the Environmental Protection Authority as a Proposal of National Significance. The Project includes works previously investigated and developed as two separate Projects: being the SH16 Causeway Project and the SH20 Waterview Connection. The key elements of the Waterview Connection Project are:

- Completing the Western Ring Route (which extends from Manukau to Albany via Waitakere);
- Improving resilience of the SH16 causeway between the Great North Road and Rosebank Interchanges to correct historic subsidence and "future proof" it against sea level rise;
- Providing increased capacity on the SH16 corridor (between the St Lukes and Te Atatu Interchanges);
- Providing a new section of SH20 (through a combination of surface and tunnelled road) between the Great North Road and Maioro Street Interchanges; and
- Providing a cycleway throughout the surface road elements of the Waterview Connection Project corridor.

The Project generally includes the following, which will have an effect on traffic noise generation. These relate to 'sectors' identified in the Project sector diagram attached in Appendix A.

Between Te Atatu and St Lukes Interchanges the following works will be undertaken on SH16:

- Significant improvements and reconfiguration of Te Atatu Interchange to accommodate additional lanes and bus shoulder (Sector 1)
- Enlargement of the existing Whau River Bridge to accommodate additional lanes (Sector 2)
- Additional lanes between the Te Atatu and Rosebank Interchanges to provide four lanes eastbound and westbound and a bus shoulder in each direction (Sectors 3 and 4)
- Additional westbound lanes from Rosebank Road Interchange to Great North Road Interchange, to create a total of four eastbound lanes, five westbound lanes plus a dedicated bus shoulder (Sectors 3 and 4)

- In conjunction with the reclamation works across the estuary between Rosebank Peninsula and the Great North Road Interchange, the Causeway height will be increased (Sector 4) and

- Additional lanes will be provided between the Great North Road Interchange and St Lukes Interchange in the east (Sector 6)

For SH20, between Great North Road Interchange (with SH16) and Maioro Street Interchange, a new State highway alignment will be provided over a length of approximately 5 km and provision for a future capacity o three traffic lanes in each direction will be provided. The following key elements will create traffic noise effects:

- A new interchange will be built at the 'Great North Road Interchange' to provide motorway-to-motorway connections between SH16 and SH20, while maintaining the existing connections between Great North Road and SH16 at this interchange. The existing interchange will be reconfigured (Sector 5)

- The Project provides future capacity for three traffic lanes in each direction, separated by either central median barrier or separate tunnel construction. However, at opening, the Project will be constructed with two lanes in each direction, with bus shoulders where appropriate (Sectors 5 through to 9)

- The alignment between the Avondale Heights Tunnel (Sector 8) and the Maioro Street Interchange (Sector 10) is 'at-surface', along the route of the existing land set aside for rail (the Avondale Southdown Line Designation), for a length of around 900m. Richardson Road will be bridged across the State highway and north-facing ramps will be built at the Maioro Street Interchange to provide local traffic access to SH20 northbound (Sector 9) and

- An integrated road / rail corridor is proposed to retain opportunity for the existing rail designation from the Maioro Street Interchange to the southern tunnel portal in Alan Wood Reserve (Sector 9). The rail corridor will be moved eastwards to accommodate the road

3.2 Sector 1 – Te Atatu Interchange

Sector 1 includes significant improvements to the Te Atatu Interchange including the enlargement and re-configuration of off- and on-ramps to accommodate additional lanes and to provide for a bus shoulder and priority for buses and other High Occupancy Vehicles through widening of SH16 through to Henderson Creek.

The proposed works involve the realignment of the eastbound on-ramp and the westbound off-ramp, which will require the removal of several dwellings. This will result in dwellings currently shielded from traffic noise being more exposed to road-traffic noise. In addition, the new ramps will result in traffic moving closer to dwellings.

3.3 Sector 2 – Whau River

Sector 2 includes the enlargement of the existing Whau River Bridge to accommodate additional lanes. A separate dedicated cycle/pedestrian bridge is also to be constructed alongside the enlarged Whau River Bridge.

Noise from traffic on the bridge will affect dwellings in Alwyn Ave which are elevated above the road.

3.4 Sector 3 – Rosebank - Terrestrial

Sector 3 of the Project involves works on SH16 around the Rosebank Road Interchange, including additional traffic lanes and associated works to the cycleway.

In this sector, no "protected premises and facilities", such as residences or teaching facilities, exist at present, and therefore, the traffic noise assessment largely excludes this sector.

3.5 Sector 4 - Reclamation

Sector 4 involves the provision of two additional westbound lanes from the Great North Road Interchange to the Rosebank Road Interchange and one additional eastbound lane from the Rosebank Road Interchange to the Great North Road Interchange.

While the majority of the reclamation area is not in proximity to noise sensitive activities and land uses, the most eastern extent of Sector 4 is in close proximity to dwellings in the Waterview and Pt Chevalier coastal areas. The road widening results in traffic moving closer to dwellings and combined with the increase in traffic flow over time, a small increase in traffic noise is predicted.

3.6 Sector 5 – Great North Road Interchange

Sector 5 of the Project extends from the Waterview Park area, and includes the ramps and alignment associated with the motorway-to-motorway connection of SH20 to SH16 (the Great North Road Interchange), while maintaining the existing connections between Great North Road and SH16.

The SH20 alignment exits the tunnel and is largely at grade in Waterview Park before entering the elevated ramp structures above the existing SH16. Dwellings in Waterbank Crescent have line of sight to the ramps and are predicted to receive increased noise levels due to the alignment.

The proposed works will require the removal of a number of dwellings on Herdman Street, Cowley Street, and those located on Great North Road between these. As a result, the realignment causes dwellings currently shielded from traffic noise to be more exposed to road-traffic noise from Great North Road.

3.7 Sector 6 – Great North Road Interchange to St Lukes

One additional lane will be provided between the Great North Road Interchange and St Lukes Interchange (in the east).

As the road widening will result in traffic moving closer to dwellings and with an increase in traffic flow over time, a small increase in traffic noise will occur.

3.8 Sector 7 – Great North Road Underpass

From the Great North Road Interchange, the alignment will comprise two cut-cover tunnels beneath Great North Road to connect to the deep tunnel.

Although there may be a degree of screening in this case, there may be some localised increases in noise level where the tunnel portal is located.

In addition, the tunnel services building and ventilation stack will be located in this sector. Noise associated with this building and stack will be controlled to the underlying District Plan zone noise limits, as they are stationary noise sources. Generally, noise is generated by the stack outlet airflow, the associated fans and transformer. Standard noise control measures, such as attenuators, can be applied to all of these noise sources to achieve compliance with relevant noise limits (refer Sections 8.7 and 8.8).

3.9 Sector 8 – Avondale Heights Tunnel

The alignment is in two 'deep tunnels' (one in each direction) from the cut-cover tunnel beneath Great North Road through to the Alan Wood Reserve (adjacent to the Caravan Park), passing beneath Avondale Heights/ Springleigh, the North Auckland Rail Line and New North Road (Sector 8 – Avondale Heights Tunnel).

As this sector is sub-surface, road-traffic noise will not be audible above ground and no noise issues are anticipated. At the southern end of the sector, there is the potential for some road-traffic noise impacts in the vicinity of the tunnel portal, and these are considered in the assessment for Sector 9 below.

A ventilation stack will be required close to the southern tunnel portal. Noise from the stack would be assessed against the underlying District Plan zone noise rules and managed to achieve compliance, as discussed in Section 3.8 of this report.

3.10 Sector 9 – Alan Wood Reserve

The alignment between the Avondale Heights Tunnel (Sector 8) and the Maioro Street Interchange (Sector 10) is 'at-surface', along the route of the existing land set aside for rail (the Avondale Southdown Line Designation), for a length of around 900m. Richardson Road will be bridged across the State highway and north-facing ramps will be built at the Maioro Street Interchange to provide local traffic access to SH20 northbound. An integrated road / rail corridor is proposed to retain opportunity for the existing rail designation from the Maioro Street Interchange to the southern tunnel portal in Alan Wood Reserve, however, this requires relocation of the rail alignment to the north of the proposed motorway corridor.

For the length of the alignment at-surface it is anticipated that road-traffic noise impacts will occur. The cut leading into the southern tunnel portal will provide some shielding and consequent mitigation of traffic noise levels. However, the surrounding residential area at present experiences low ambient noise levels due to shielding and distance from any major noise source, including local roads. The introduction of a new road in this vicinity will cause ambient noise levels to increase.

In particular, it is anticipated that noise mitigation will be required for dwellings on Hendon Avenue, and those located (in parts) on Methuen Avenue. The proposed works will also require the removal of a number of dwellings on Hendon Avenue and Valonia Street further south due to the effects from the Project and access to the alignment.

4. Noise Performance Standards

The prediction, assessment, and control of road-traffic noise impacts for the Project can be undertaken in accordance with various methodologies, including national policy instruments, relevant New Zealand standards and legislative controls.

Potentially relevant Noise Assessment methodologies and standards include:

- New Zealand Standard NZS 6806:2010 "Acoustics – Road-traffic noise – New and altered roads" (the Standard)
- Transit (NZTA) New Zealand's "Guidelines for the Management of Road Traffic Noise – State highway Improvements" (December 1999) (the NZTA Noise Guidelines)
- NZTA Environmental Plan (June 2008)
- Resource Management Act (the RMA)

Refer to Appendix B for a definition of technical terms.

Further discussion of each of these is provided in the following sections.

4.1 New Zealand Standard NZS 6806:2010

A Standard for the assessment and control of road-traffic noise (NZS 6806:2010 "Acoustics – Road-traffic noise – New and altered roads") has recently been developed and released as a full New Zealand Standard in April 2010. It is considered appropriate that the assessment of this Project be based on the provisions of this Standard. This is the first New Zealand road-traffic noise standard and was developed by an independent multidisciplinary committee of Standards New Zealand. It is intended for all road-traffic noise assessments both from State highways, and local roads in circumstances where the traffic is within the thresholds of the Standard. The NZTA has adopted this Standard for assessment of road-traffic noise from new and altered State highways.

The Standard is an extensive and complex document; therefore, it is only practicable to present the key concepts for the purposes of this report.

The Standard retains some of the methodologies previously used in the NZTA Noise Guidelines (discussed in Section 4.2 below), such as the noise measurement index ($L_{Aeq(24h)}$) and the concept of a "design year" (the year for which the assessment is undertaken) at least ten years after opening of a Project.

4.1.1 Assessment Positions

The Standard specifies a list of types of protected premises and facilities (PPFs), which are assessed in accordance with the provisions of the Standard. In addition to premises that were protected under the NZTA Noise Guidelines (refer Section 4.2 below), such as dwellings and educational facilities, NZS 6806:2010 extends its protection to other premises such as marae, hospitals which contain in-patient facilities, motels and hotels in residential zones and playgrounds within 20 metres of educational facilities.

The assessment position for existing buildings is at the façade (i.e. an 'incident' noise level) rather than one metre in front of the façade (as was previously the case under the NZTA Noise Guidelines), thus a facade correction is no longer included.

Commercial and business uses are not considered to be PPFs and are therefore excluded from the assessment as they are not considered to be noise sensitive.

NZS 6806:2010 stipulates that, in an urban area, all protected premises and facilities within 100 metes of the alignment shall be assessed, and excludes locations outside this area. The noise assessment for the Project has generally been undertaken in accordance with this limitation, however, where appropriate in unusual circumstances, additional buildings have been included in the assessment, specifically in Sector 9. Where this has been undertaken, it is noted in this report.

4.1.2 Noise Criteria

The noise criteria of the Standard are not based on existing ambient noise levels, but distinguish between new and altered roads. There are three levels of criteria (A, B and C) as set out in the table below.

Table 4.1: Noise criteria

Category	Altered Roads	New Roads with a predicted traffic volume >75,000 AADT at the design year	New Roads with a predicted traffic volume of 2,000 to 75,000 AADT at the design year
	dB $L_{Aeq(24h)}$	dB $L_{Aeq(24h)}$	dB $L_{Aeq(24h)}$
A (primary external noise criterion)	64	64	57
B (secondary external noise criterion)	67	67	64

C (internal noise criterion)	40	40	40

For this Project, traffic volumes are predicted to be over 75,000 vehicles per day. This means that the criteria for the new road section (SH20, Sectors 7 to 10) and for the alteration of the existing road sections (SH16, Sectors 1 to 6) are the same. The "A" (or primary external) noise criterion is 64 dB $L_{Aeq(24h)}$, the "B" (or secondary external) noise criterion is 67 dB $L_{Aeq(24h)}$ and the "C" (or internal) noise criterion is 40 dB $L_{Aeq(24h)}$.

The criteria to be used depend on the application of the best practicable option (BPO) test, with the A criterion being met or bettered if this is consistent with the BPO, the B criterion being met or bettered if criterion A is not achievable with the BPO, and criterion C being achieved with the adoption of the BPO, if criterion B is not achievable with the BPO.

The Category C criterion is an internal design criterion for habitable rooms, however, while not specifically noted in NZS 6806:2010, it is assumed that the internal criterion applies to all noise sensitive rooms in protected premises and facilities, including teaching areas and in-patient care rooms where patients sleep.

The 40 dB $L_{Aeq(24h)}$ criterion is required to be achieved by the adoption of the BPO, for habitable rooms which would otherwise receive internal noise levels greater than 45 dB $L_{Aeq(24h)}$, i.e. a minimum noise level reduction of five decibels is required to be achieved.

It is noted that the Standard applies to altered roads only if the implementation of a Project, when compared with the future circumstance without Project implementation, results in a noise increase of three decibels or more. This increase would need to occur independently from the noise increase due to traffic volume changes over time. The results described in Sections 7 and 8 of this report indicate that without mitigation the Project would result in a noise level change of more than three decibels for some locations.

4.1.3 Noise Assessment Scenarios

NZS 6806:2010 provides for several operational scenarios to be assessed and compared. These include:

- The existing noise environment which, for altered roads, represents the current road layout and traffic volume, and, for new roads, represents the current ambient noise level;
- A future Do-Nothing scenario, which represents a scenario at the design year where a Project has not been implemented, however, traffic volumes have changed - generally increased - over time;
- A future Do-Minimum scenario, which represents a scenario at the design year where a Project has been implemented without any specific noise mitigation. This means that the choice of road surface material is independent from its noise generating characteristics and the only barriers included are solid safety barriers, which are required for reasons other than noise mitigation;

- Several future mitigation options, which represent scenarios whereby mitigation is designed specifically to reduce noise levels in order to achieve compliance with the relevant noise criteria and fulfil the BPO test.

4.1.4 Mitigation Options

The fundamental basis of compliance with NZS 6806:2010 is the application of the BPO.

In order to ensure that the BPO is identified, NZS 6806:2010 requires that several mitigation options be developed and compared, not only in terms of noise level reductions but also in relation to other considerations such as urban design, safety, cost and others. For large Projects, such as the Waterview Connection, the Standard recommends that up to four mitigation options should be developed and a preferred option chosen.

The process of comparing mitigation options is interactive, and often additional mitigation options are developed from the collaboration of several disciplines. Therefore, the assessment result generally consists of a number of options and a preferred option developed by the entire Project team. For that reason the mitigation option chosen as the preferred option may not be the option providing the greatest noise level reduction, but an option which is considered optimal and practicable on balance, when evaluated against relevant criteria by the team.

4.1.5 Structural Noise Mitigation Requirements

One aspect of the BPO is the noise level reduction achieved by structural noise mitigation. Structural noise mitigation includes low noise road surface materials and barriers of any type, if these are chosen specifically for their noise reducing characteristics. Barriers, while often effective for noise reduction purposes, can cause adverse effects, such as shading or safety issues. While these are outside the area of expertise of the acoustic consultant, and are dealt with by other disciplines through the BPO process described in Section 4.1.4 above, structural noise mitigation measures need to be designed so that they result in worthwhile noise level reductions.

Therefore, NZS 6806:2010 includes a criterion for the effectiveness of structural mitigation measures. In urban areas, such as for the Waterview Connection Project, structural mitigation *"should only be implemented if the combination for the structural mitigation measures used would achieve ... an average reduction of at least 3 dB $L_{Aeq(24h)}$"*[4].

The circumstances of the Waterview Connection Project require the application of a common sense approach whereby assessment locations that are likely to receive noise mitigation from a barrier should be grouped in order to achieve a practicable outcome. This means that all receiver clusters should be on the same side of the road and geographically close.

[4] NZS 6806:2010:2010 Acoustics – Road-traffic noise – New and altered roads, Section 8.2.2, page 41

The reason for the minimum requirement that an average of 3 decibels mitigation should be achieved is that in an urban situation many receivers are in close proximity, and a barrier would benefit more than just one or two locations. The noise level reductions for individual assessment positions would vary, from significant for positions located immediately behind a barrier, to lesser effects for those at the ends or further removed from a barrier. (refer Section 4.7 below)

It is noted that the criteria contained in NZS 6806:2010 have been developed with the intention that they are *"reasonable criteria for the road-traffic noise from new or altered roads taking into account adverse health effects associated with noise; the effects of relative changes in noise levels on people and communities; and the potential benefits of new and altered roads to people and communities*".[5]

4.2 NZTA (Transit) Noise Guidelines

Prior to the development of NZS 6806:2010, the NZTA (formerly Transit New Zealand) had developed the 'Transit New Zealand's Guidelines for the Management of Road Traffic Noise – State highway Improvements' (NZTA Noise Guidelines), which assessed the predicted future traffic noise level for a design year 10 years from the construction of a highway with respect to the existing ambient noise levels and provided traffic noise design levels to be met for State highway Projects.

Although the NZTA Noise Guidelines did not have statutory status, they had been widely adopted up until recently as a de-facto traffic noise standard for most roading schemes.

The assessment of road traffic noise in accordance with the NZTA Noise Guidelines, while generally similar to the assessment methodology prescribed in NZS 6806:2010, differs in some fundamental aspects from the Standard. These differences include specifically:

- The criteria, which are based on ambient noise levels rather than the type of roading project
- The assessment position, which is at 1 metre from the facade rather than at the facade thus including a 2.5 decibel facade correction
- The exclusion of a "Do-Nothing" circumstance as described in Section 4.1.3 above and
- The inclusion of a maximum noise criterion (the Single Event Noise Design Criterion)

It is therefore not practicable to compare the NZTA Noise Guidelines outcomes with those determined through NZS 6806:2010.

The assessment method used by the NZTA for noise from new and altered roads has now changed from the NZTA Noise Guidelines to NZS 6806:2010. Therefore, no further reference is made to the NZTA Noise Guidelines in this assessment.

[5] NZS 6806:2010:2010 Acoustics – Road-traffic noise – New and altered roads, Section 1.1.3, page 15

4.3 NZTA Environmental Plan

The NZTA has developed an 'Environmental Plan' (Version 2, June 2008). The Environmental Plan is intended to support the NZTA's responsibilities to environmental sustainability under the Land Transport Management Act 2003 and contains sections on several issues, including noise.

The Implementation Plan for Noise within the Environmental Plan discusses a number of approaches designed to reduce noise effects on sensitive receiver positions, including land use planning opportunities, requirements of new developments adjacent to State highways to provide noise mitigation, reduction of heavy vehicle noise and a revision of the NZTA Noise Guidelines.

The Environmental Plan also states that noise assessments should be undertaken and designation conditions sought recognising reasonable noise limits for new or altered designations in areas likely to be affected by road-traffic noise. In accordance with the Environmental Plan, NZTA has contributed to and now adopted NZS 6806:2010. Therefore, this current assessment focussed on the achievement of compliance with the provisions of NZS 6806:2010 and is also consistent with the Environmental Plan.

4.4 District and Regional Plans

The Waterview Connection Project traverses the jurisdiction of three Councils, namely Auckland City, Waitakere City and the Auckland Regional Council. While the Regional and District Plans of these Councils do not contain noise rules which are relevant for a transportation Project, it is considered that non-transportation noise from the Project, specifically the ventilation stacks and associated uses, should be assessed against the underlying District Plan zone noise rules (on the basis that these Rules define an appropriate noise environment for the receiving environments). The stacks are located in the area of the Auckland City Isthmus District Plan, with the relevant rules discussed below.

4.4.1 Auckland City District Plan – Isthmus Section

Sectors 3 and 5 to 9 lie within the Auckland City Isthmus, and Sectors 7 and 8 contain non-traffic noise sources which are appropriate to be assessed against the District Plan noise rules of the underlying zone.

The Auckland City District Plan has noise rules (district-wide as well as specific to individual zoning) that are designed to control noise emissions from various activities. It is noted that these are not applicable to transportation noise.

While the transportation aspects of the Project are being assessed under the provisions of NZS 6806:2010, noise from the ventilation stacks servicing the tunnel ventilation system and associated uses, such as power generation for the ventilation system and control rooms, will be of a different character and it is not considered appropriate to assess these activities pursuant to the traffic noise criteria.

It is considered that due to the fixed nature of the stacks and the constant character of their noise, emissions from these structures should be assessed at the designation boundary, using the applicable District Plan noise limits of the underlying zoning. However, the District Plan uses outdated assessment standards. Therefore, for this assessment these criteria have been converted to reflect the requirements of the most recent standards NZS 6801:2008 and NZS 6802:2008 (refer Appendix B).

The relevant noise limits for the applicable zones are presented in Appendix C. In summary, the mechanical noise associated with the tunnel ventilation and control systems will be subject to daytime noise limits of 50 dB $L_{Aeq(15\ min)}$ and night time noise limits of 40 dB $L_{Aeq(15\ min)}$ in all zones.

These limits are considered appropriate and can be achieved with suitable design of the ventilation stacks and control buildings, such as the installation of attenuators (silencers) to the ventilation outlets, acoustic louvres to ventilation grilles on the control buildings and suitable location of transformers and barriers.

4.4.2 Waitakere District Plan

Sector 1 of the Project is located within the Waitakere City. However, no non-traffic noise sources are anticipated in this sector, and therefore, the Waitakere City District Plan noise rules have not been applied as transportation noise is assessed in accordance with NZS 6806:2010.

4.4.3 Coastal Marine Area

Sectors 2 and 4 of this Project lie within the Coastal Marine Area (CMA) in proximity to the SH16 causeway and Whau River Bridge. The sections of the motorway located in the CMA will need to be consented as reclamation.

The Auckland Regional Plan: Coastal contains noise limits activities undertaken in the coastal marine area. In summary, these rules are 55 dB L_{A10} from 7 am to 10 pm and 45 dB L_{A10} and 75 dB L_{Amax} from 10 pm to 7 am[6]. However, in Section 35.5.4 the Plan states that these noise limits shall be assessed in accordance with NZS 6802:1991 “Assessment of Environmental Sound”. This Standard excludes transportation noise from its assessment and that other standards may be more appropriate for the assessment of specific sources of transportation sound.

Therefore, for the purposes of this assessment, road-traffic noise from the Project has been treated as though it is emitted from land, whether or not some parts currently lie in the CMA, and assessment been based on NZS 6806:2010 for the entirety of the Project extent.

[6] Auckland Regional Plan: Coastal, Section 35.5.1

4.5 Resource Management Act

Under the provisions of the Resource Management Act (RMA) there is a duty to adopt the best practicable option to ensure that the noise from any development does not exceed a reasonable level. Specifically, Sections 16 and 17 reference noise effects as follows.

Section 16 states that *"every occupier of land (including any coastal marine area), and every person carrying out an activity, shall adopt the best practicable option to ensure that the emission of noise from that land or water does not exceed a reasonable level"*.

Section 17 states that *"every person has a duty to avoid, remedy, or mitigate any adverse effect on the environment arising from an activity, whether or not the activity is in accordance with a rule in a plan, a resource consent or relevant sections of the RMA"*.

4.6 Discussion and Conclusions on Noise Performance Standards

Utilisation of NZS 6806:2010 "Acoustics – Road-traffic noise – New and altered roads" to assess the Project's road-traffic noise impacts will ensure reasonable outcomes for all affected residents in the vicinity of the Project, as well as providing a suitable method of predicting the potential noise effects of the Project on future development in the vicinity. The Standard is based on the best practicable option approach, which aligns with RMA requirements. It is therefore considered that for this Project the utilisation of NZS 6806:2010 is appropriate.

5. Existing Environment

The existing noise environment of the Project area provides a base for assessing noise effects in terms of the RMA, independent from compliance with the criteria of NZS 6806:2010. Assessment is possible through an understanding of the potential change in noise level due to the implementation of the Project. For this reason, the existing noise environment in the vicinity of the Project has been investigated extensively by means of noise level surveys and computer noise modelling of the existing circumstances.

5.1 Measurement Methodology

5.1.1 Recent Surveys: 2009

During October and November 2009, Marshall Day Acoustics performed a series of measurements in the vicinity of the Waterview Connection Project area. Measurements were performed using ARL 315 Environmental Noise Data Loggers. When the loggers were set up, a ten-minute secondary sound measurement was made using a Bruel and Kjaer 2260 Investigator sound level meter. The data from the logger and the meter were compared to check that the logger was operating correctly.

An aerial view of the existing site with the noise level survey locations from 2003, 2006 and 2009 is included in Appendix D.

Care was taken to position the loggers in outdoor areas away from sound-reflecting surfaces and dwellings, thus avoiding extraneous noise sources. Surveys were undertaken in accordance with the requirements of NZS 6801 and 6802, and adverse weather conditions addressed, where appropriate, i.e. where high winds (> 5 m/s) and/or high rain fall (> 6 mm/h) were reported for the closest available NIWA weather station, the noise levels for corresponding 15-minute periods were removed from the analysis. While not all data is included in this report due to size and practicability, background information can be provided if required.

Noise levels required adjustment for adverse weather conditions for 20 October 2009 between 1 pm and 5 pm and 23 October 2009 between 10 am and 3 pm. Due to the extended period that was required to be removed, these days were removed from the overall assessment. However they are shown in the summary figures in Appendix D.

The loggers continuously measured $L_{Aeq(15\,min)}$ sound levels every 15 minutes over the monitoring duration. These levels were converted into $L_{Aeq(24h)}$ values, which are relevant to NZS 6806:2010 (refer Section 4.1 above).

All noise levels were for a free-field circumstance, i.e. no adjustment was made to allow for facade correction. Therefore, levels are directly comparable with the NZS 6806:2010 noise criteria.

5.1.2 Previous Surveys: 2003 and 2006

In 2003, MDA was involved in route evaluation for the Project and carried out a study of the noise effects of various possible options for the Western Ring Route. Later, in October 2005, MDA was engaged to carry out a detailed study of the noise effects of the Western Ring Route, and further noise level surveys were undertaken in 2006.

For the current Project in 2010 it is considered that the 2003 and 2006 surveys remain largely valid, and the noise levels determined at those times have been used, in conjunction with the current survey results, to verify the computer noise model. In this regard it is noted that traffic noise generation is relatively insensitive to small changes in traffic flow, and noise levels have changed only slightly from 2003 to 2010. (refer Table 6-3 below)

Nine sites, four of these with ARL 315 continuous data logging equipment, were surveyed between January and May 2003. The additional five measurements were carried out with a Bruel and Kjaer 2260 Investigator sound level meter and consist of short duration verification measurements.

Two sites were measured during the 2006 survey, giving a total of 11 sites from past measurements (refer Appendix D for Site Map).

All surveys were undertaken in free-field circumstances, and no facade adjustment was required. However, it is noted that for surveys undertaken in 2003 and 2006, weather conditions were not addressed to the same extent as for the 2009 surveys. During the previous long duration noise level measurements, weather conditions were observed informally and considered suitable for environmental surveys, and no further adjustment was undertaken.

5.1.3 Survey results

Measured noise levels ($L_{Aeq(24h)}$) are shown in Table 5-1 below. Detailed summaries of the 12 long-duration measurements can be found in Appendix D including graphical summaries displaying diurnal noise variation. A plan is also contained in Appendix D showing the survey positions for 2003, 2006 and 2009.

Table 5.1: Long-Duration Noise Level Survey Results

No	Measurement Position	Close to or inside Project Sector	Survey Year	Measurement Results (Free-field)
				dB $L_{Aeq(24h)}$
1	1553 Great North Rd	8	2003	71
2	25 Hendon Ave	8/9	2003	49
3	14 Phyllis St	8	2003	46
4	53 Powell St	8	2003	50
5	36 Cradock St	8	2006	47
6	5 Valonia St	9	2006	53
7	17 Milich Terrace	1	2009	67
8	20 Titoki Street	1	2009	68
9	77 Herdman Rd	4/5	2009	65
10	204 Methuen Rd	9	2009	47
11	1102g Great North Rd	6	2009	71
12	21 Alwyn Ave	1	2009	50

Results from the long duration logger surveys in the area were utilised to obtain diurnal variations of hourly average noise levels including a statistical deviation, to a base of 24-hour average noise levels.

Short duration surveys were used to derive average daily noise levels for the locations which were then compared with the resultant graph and a daily average noise level derived. Measured and derived noise levels for the short duration noise surveys are shown in Table 5-2 below.

Table 5.2: Short duration verification surveys (10 to 15 minutes)

No	Measurement Position	Survey Year	Measurement Results (Free-field)	Average Noise Levels (Derived)	Project Sector close to or inside
			dB $L_{Aeq(10-15\ min)}$	dB $L_{Aeq(24h)}$	
13	Bollard Ave/New North Rd	2003	54	53	8
14	Phyllis St Reserve	2003	48	47	8
15	Dorje Chang (Powell St)	2003	49	47	8
16	Valonia St Reserve	2003	46	45	9
17	Waterview Park	2003	57	59	5

5.2 Summary of Existing Noise Environments

Ambient noise measurements demonstrated a range of noise levels from 46 dB to 71 dB $L_{Aeq(24h)}$ demonstrating the varying effect of relative proximity to busy roads.

The following sections summarise the existing noise environments present for each sector of the Project.

5.2.1 Sector 1 – Te Atatu Interchange

Noise levels in Sector 1 are relatively high, and determined by proximity to SH16, which is the dominant noise source. Measurements at residences on Milich Terrace, Titoki Street, and Alwyn Ave showed $L_{Aeq(24h)}$ levels of 67 dB, 68 dB, and 50 dB respectively. Although this sector contains much unoccupied open space, there are also a significant number of residences in close proximity to SH16.

5.2.2 Sector 2 – Whau River

Sector 2 encompasses only the SH16 road bridge over the Whau River and the surrounding water. SH16 is the only significant source of noise in this sector and the noise level at any position is strongly dependant on proximity to SH16.

Although there are no affected receivers within this sector, SH16 traffic on the bridge contributes to noise levels at some properties in Alwyn Ave in Sector 1.

5.2.3 Sector 3 – Rosebank – Terrestrial

Traffic on SH16, Rosebank and Patiki Roads is the main noise source in Sector 3, where the only affected receivers are light-industrial businesses, which are not considered noise sensitive and are not classified as protected premises and facilities by NZS 6806:2010.

5.2.4 Sector 4 – Reclamation

Sector 4 contains no noise sources except for SH16, and no affected receivers except for the residences on Herdman Street which are 100 to 150 metres from SH16 across a tidal stream. Noise levels at 77 Herdman Street have been measured as 66 dB $L_{Aeq(24h)}$.

5.2.5 Sector 5 – Great North Road Interchange

Sector 5 encompasses the interchange between Great North Road and SH16 – two significant arterial roads. Noise levels in this area are consequently high. There are many affected residences to the north and the south-west of the interchange, and the UNITEC tertiary education facility to the south-east. Noise levels at 77 Herdman Street have been measured as 66 dB $L_{Aeq(24h)}$.

5.2.6 Sector 6 – Great North Road Interchange to St Lukes

SH16 is the dominant noise source in Sector 5, and runs closely parallel to Great North Road. Noise levels in this sector are high, and a number of residences are very close to the motorway, 13 metres or less. A long duration measurement at 1102G Great North Road resulted in the highest measured existing noise level for the Project, of 75 dB $L_{Aeq(24h)}$.

5.2.7 Sector 7 – Great North Road Underpass

Noise levels in Sector 7 are dominated by traffic on Great North Road. This section of road is lined with residences to the west, and the UNITEC campus to the east.

5.2.8 Sector 8 – Avondale Heights Tunnel

Noise levels in Sector 8 are governed by proximity to Great North Road, Blockhouse Bay Road, and New North Road. Measured noise levels ranged from 71 dB $L_{Aeq(24h)}$ at 1553 Great North Road to 46 dB $L_{Aeq(24h)}$ in Phyllis St Reserve. A large part of this sector is remote from any of these major roads, and measured noise levels are indicative of a quiet urban area.

5.2.9 Sector 9 – Alan Wood Reserve

Much of Sector 9 is unoccupied open space containing no major roads. Richardson Road is the only major traffic noise source in this sector, and noise levels were measured between 48 and 49 dB $L_{Aeq(24h)}$, in Hendon and Methuen Avenues.

6. Assessment Methodology

6.1 Existing Noise Environment

Traffic noise has been assessed in accordance with the New Zealand Standard NZS 6806:2010. The assessment method differs from that contained within the NZTA Noise Guidelines, insofar as existing ambient noise levels do not form the basis for the noise level criteria. Nevertheless it is important to gain an understanding of the existing noise environment thus enabling an accurate assessment of noise effects due to changes to noise levels as a result of the Project in accordance with the RMA (refer Sections 4.7 and 5).

Existing ambient noise level information was obtained by a combination of measurement (refer Section 5) and prediction (refer Section 6.4) and was subsequently used in the effects assessment for all identified receiver positions. Surveys of the existing noise environment were carried out in potentially affected areas in the vicinity of noise sensitive activities between January and May 2003, in April 2006, and again in 2009. These measurements were used to validate the computer noise model utilised for predicting existing and future traffic noise levels.

Ambient noise measurements showed a range of noise levels from 46 dB to 71 dB $L_{Aeq(24h)}$ (refer Section 5.1.3) demonstrating the varying effect of relative proximity to busy roads, with noise levels at the lower end representing positions located away from the existing roading network and at the higher end representing positions close to existing major roads and motorways (such as SH16 and Great North Road).

6.2 Highway Parameters

The traffic noise prediction method most commonly used in New Zealand is the UK Department of Transportation, Welsh Office "Calculation of Road Traffic Noise", adjusted for New Zealand conditions, specifically the road surfaces, in accordance with LTNZ Report No. 326.

This calculation methodology takes into consideration multiple factors which affect the road noise level. These include, amongst others, the traffic volume, vehicle speed, road gradient, angle of view, percentage of heavy vehicles and road surface material.

6.2.1 Design Year

2026 has been selected as the design year for this Project and aligns with the traffic modelling of the Project. The anticipated opening year for the road is 2016. NZS 6806:2010 requires the assessment of traffic noise at least 10 years after the opening of a new or altered road making the 2026 design year appropriate.

6.2.2 Traffic Volume

The volume of traffic flowing on a highway is one of the key factors in determining the level of traffic noise generated. Traffic flows generally increase with time.

In this circumstance, the operation of the new highway would also result in decreased traffic flows for a number of local roads, including Carrington Road and Sandringham Road. This will provide a beneficial reduction in noise level for some residences adjacent to local roads which are some distance from the proposed new highway, e.g. for Sandringham Road, traffic volumes are predicted to reduce by 50% which equates to approximately a three decibel noise level reduction. (refer Section 6.5 below)

Traffic flow figures modelled for the years 2006 and 2026 were provided by Beca and were used to predict traffic noise level generation. Traffic flow volumes in 2010 would be similar to those of 2006 with changes causing less than one decibel change in noise level.

It is noted that current ambient noise level predictions are based on traffic on the local roading network and the existing State highways. The traffic flow data for these roads was compiled using traffic flow information from Beca (refer Transport Assessment, Document Reference No. 20.1.11-R-C-904) and the Auckland City Council website (2006 and 2009). The Beca traffic model formed the basis of assessment for the noise assessment.

Noise level predictions for the Design Year 2026 were based on traffic flow figures for the proposed highway and its associated ramps, excluding local roads, in accordance with the requirements of NZS 6806:2010.

6.2.3 Road Surface Material

The selection of road surface for new or altered roading infrastructure can have a significant effect on traffic noise generation as road/tyre interaction is the controlling source of traffic noise at highway speeds (40 km/h and above). This has been shown in numerous studies and is described in detail by Prof. Ulf Sandberg in the Tyre/Road Noise Reference Book[7]. The following table is an excerpt from that book, describing the cross-over speed at which the road/tyre interaction becomes the controlling noise source over engine noise.

[7] Ulf Sandberg, Jerzy A. Ejsmont: Tyre/Road Noise Reference Book, Informex 2002, ISBN 91-631-2610-9

Table 6.1: Road/Tyre Noise

"Table 5.1 Crossover speeds for various cases, i.e. the speed above which tyre/road noise is more important than power unit noise.		
Vehicle type	Cruising	Accelerating
Cars made 1985-95	30-35 km/h	45-50 km/h
Cars made 1996-	15-25 km/h	30-45 km/h
Heavies made 1985-95	40-50 km/h	50-55 km/h
Heavies made 1996-	30-35 km/h	45-50 km/h"

Appendix C of NZS 6806:2010 contains extensive discussion of the application of low noise road surfaces. It confirms that "open graded porous asphalt" (OGPA), a porous and smooth layered asphalt surface, can reduce noise levels by around six decibels when compared with "chip seal", the noisiest surface. This is a noticeable difference. However, in order for this reduction in noise level to be achieved and maintained, OGPA must be laid to a sufficient depth, properly drained and regularly cleaned.

The selection of road paving has a effect on traffic noise generation as road tyre interaction is the major source of traffic noise at highway speeds. It is understood that, for non-acoustic reasons, the entire alignment of the Project's new and altered highways, where these are above ground, will have an asphalt surface such as OGPA or stone mastic asphalt. Additional noise mitigation can be obtained from using surfaces comprising twin layer open graded porous asphalt (twin layer OGPA), and this assessment determines where such surfaces are required to comply with NZS 6806:2010.

Achieving compliance with the noise criteria for road sections within the tunnel is not dependent on the selection of road surface material. However, in-tunnel noise levels should be sufficiently controlled to allow the operation of audible warning devices. These warning devices require a signal (alarm) to noise (traffic noise) ratio of at least 10 decibels, i.e. the warning device should be at least 10 decibels louder than the traffic noise level. In addition, driver experience in the tunnel could be enhanced by reducing reverberant noise levels in the tunnel. In order to manage in-tunnel noise levels, a low noise road surface material such as asphalt may be utilised.

6.2.4 Safety Barriers

For safety requirements, any new bridges within the highway alignment, including the ramps of the new Waterview Interchange, will include solid concrete edge barriers of either 820 mm or 1100 mm in height on both sides and in the median where relevant. These barriers have been considered in this assessment where they provide acoustically effective shielding to sensitive receiver locations.

In addition to the solid road edge safety barriers, which also fulfil the role of noise mitigation, specifically designed noise barriers are required for several sectors of the Project. These are discussed in Section 6.3 below.

6.3 Traffic Noise Mitigation Measures

There are three general methods for the control of the generation and propagation of traffic noise in the circumstances under consideration. These are:

- selection of an appropriate road surface (refer Section 6.2.3 above)
- construction of traffic noise barriers and
- upgrade of building envelopes to provide mitigation of internal noise levels, including improvements to wall and ceiling insulation, upgrade of external windows and doors and installation of ventilation.

6.3.1 Road Surface

The choice of low-noise generating road surface material for this Project has already been discussed in Section 6.2.3 above.

While Open Graded Porous Asphalt (OGPA) is the most common low-noise road surface used on the Auckland motorway network, other options have also been considered, including the utilisation of twin layer OGPA, which has been shown to reduce noise levels by another two decibels compared to OGPA. Where appropriate, twin layer OGPA has been considered as a mitigation measure for this Project.

For some areas where increased shear resistance for the pavement is required, e.g. for areas where vehicles brake, accelerate or turn, more substantial structural road surface material is required. In these instances, Stone Mastic Asphalt (SMA) or similar may be utilised. This material, while also smooth and therefore generating less noise than chip seal, is non-porous. Therefore, noise levels are slightly higher than those for OGPA.

6.3.2 Traffic Noise Barriers

Traffic noise barriers can take a variety of forms such as:

- Earth bunds (if space is available)
- Solid barrier walls: Concrete; fibre cement; bio barriers (planted walls)
- Transparent barriers: Acrylic; polycarbonate; glass

- Tunnels: Below ground; above ground (full enclosure); trenches/cuts: fully open or partially covered (i.e. trench tunnel combination)

As discussed previously, NZS 6806:2010 requires that several mitigation options be developed (refer Section 4.1.2). This process involves input from all design disciplines, including urban design. Therefore, the final form of the preferred barriers has been derived through an iterative process with relevant members of the Project team. The process used for this Project to determine the BPO is described in Section 8 below.

6.3.3 Building Envelope Improvements

The NZTA will use noise mitigation within the road corridor if possible. As discussed above, such mitigation will normally comprise low-noise road surfaces and/or barriers. However, dwellings and other protected buildings, where the relevant external noise criteria cannot be achieved with mitigation in the road corridor, will require further attention in order to ensure that the relevant internal noise criterion in NZS 6806:2010 of 40 dB $L_{Aeq(24h)}$ can be complied with. The Category C criterion is triggered if the noise level without mitigation inside habitable rooms is 45 dB $L_{Aeq(24h)}$ or more, i.e. at least a five decibel noise level reduction is required to be achieved.

The improvements required would vary from building to building. While some buildings in high noise areas have already been designed to achieve suitable internal noise environments, with the choice of heavy building materials, improved glazing and insulation, and well fitting doors and windows, other building structures may not provide sufficient attenuation.

Therefore, a case-by-case assessment is required for those buildings identified to fall within Category C.

The assessment and implementation of building modification mitigation would require several steps to be undertaken in order to allow for a practicable and suitable result to be achieved. These would involve:

1. Identification of buildings which would fall within Category C, e.g. which are predicted to receive external noise levels above 67 dB $L_{Aeq(24h)}$ following the implementation of the preferred mitigation option(s). This would be facilitated through computer noise modelling and calculation once the preferred mitigation option(s) are finalised through detailed design.

2. Notifying the owner of a property identified in Step 1 above and requesting to visit the property and enter the building in order to undertake a noise level survey determining the building envelope noise reduction performance. At this stage, information about the building envelope can be gathered, including joinery and glazing, wall and ceiling construction, insulation or the lack thereof etc.

3. Following the site visit and noise survey, determination of whether the building meets the requirements of NZS 6806:2010, i.e. if the internal noise level in habitable rooms, following the implementation of the preferred mitigation option, would be 45 dB $L_{Aeq(24h)}$ or higher, and if practicably, an internal noise level in habitable rooms of 40 dB $L_{Aeq(24h)}$ can be achieved with the use of building modification mitigation. Several building modification mitigation options may be developed,

e.g. a combination of glazing and ventilation or insulation and ventilation or different types of glazing and joinery.

4. The building modification mitigation options would then be provided to the building owner, and discussions held between the NZTA and the building owner to determine a satisfactory outcome and reach agreement as to the choice of mitigation option.

5. Finally, the NZTA would ensure that the agreed building modification mitigation option would be implemented at an agreed time. This may be prior to, during or following construction of the Project, in discussion with the building owner. From an acoustic view, it would be preferable to provide building modification mitigation as early as practicable during construction in order to obtain the greatest noise mitigation benefit possible during noisy construction activities.

Often, improvements to glazing and joinery may be sufficient to achieve the required internal noise levels, or simply provision of mechanical ventilation so windows can remain closed.

Any insulation or other building envelope improvements have to be implemented concurrently with the achievement of the requirements of Clause G4 of the New Zealand Building Code, which governs the ventilation requirements for buildings. Therefore, in many instances an alternative mechanical ventilation system would be required in order to ensure sufficient ventilation is provided while maintaining suitable internal noise levels commensurate with the NZS 6806:2010 Category C requirements.

6.3.4 Maintenance of Mitigation Measures

The acoustic performance of noise mitigation measures, i.e. the effectiveness and amount of noise level reduction, needs to be maintained over time. NZS 6806:2010 states that “structural mitigation measures should be designed in such a way that they retain the same noise-reduction properties up to the design year”.[8]

This means that the barriers porposed for the Project should not develop gaps or other openings, and porous road surface materials should be maintained to retain their porosity, in order to achieve the same noise reducing qualities as following initial installation, for the ten year design period, i.e. the year 2026 for the Project.

In relation to barriers, this means that any damage, vandalism, or material failure resulting in openings in the barrier or between the barrier and the ground, will need to be repaired or remedied.

Road surface materials would require maintenance in the event of cracks or settlement resulting in uneven surfaces, which would result in increased noise level generation. Porous road surfaces, including OGPA and Twin layer OGPA, rely to some extent on their porosity to absorb sound. Therefore, porosity needs to be retained at a high level in order to achieve the noise reduction performance assumed in the noise level predictions (refer Section 6.4 below). Porosity of road surfaces can be retained for extended duration through high pressure water cleaning and regular resurfacing, should the material deteriorate excessively.

[8] NZS 6806:2010:2010 Acoustics – Road-traffic noise – New and altered roads, Section 8.2.5, page 42

Maintenance of structural mitigation measures to the performance standards of NZS 6806:2010 should be undertaken for the Project in order to achieve the noise level reductions on which the noise level predictions are based.

6.4 Modelling Process

Computer modelling of noise generated by road-traffic is a vital tool in the prediction of traffic noise impact on areas in the vicinity of major roads and for the determination of mitigation measures. Modelling enables a comprehensive and overall picture of future noise impacts to be produced. For this Project 'SoundPLAN' software has been utilised which is an internationally recognised computer noise modelling programme.

In summary, SoundPLAN uses a digital topographical terrain map of the area as its base. Each noise source (motorway lane) is located in the map and the software then calculates traffic noise generation for multiple directions, allowing for terrain, topography, shielding, and meteorological conditions. The SoundPLAN model uses the calculation algorithms of the "Calculation of Road Traffic Noise" methodology referred to in Section 6.2 above. The adjustments for New Zealand conditions, specifically road surface types, are included in the model by including correction factors in the input of the traffic characteristics, thus allowing the resulting output to be utilised without further adjustment.

The noise levels predicted by the model, for the existing road and traffic flow situation, were checked against the measured levels in order to verify the accuracy of the model. A comparison of the measured and predicted levels shows that for the majority of positions there is good agreement between measured and predicted levels, with generally a less than two decibels difference. This accuracy fulfils the requirements of NZS 6806:2010 which states in Section 5.3.4.2 *"The difference between measured and predicted levels should not exceed ± 2 dB."*

The table below shows the comparison of measured and predicted noise levels for the Project area.

Table 6.2: Computer Noise Model Validation – Measured and Predicted Noise Levels

No	Position	Measured Noise Level	Predicted Noise Level	Difference
		dB $L_{Aeq\ (24h)}$	dB $L_{Aeq\ (24h)}$	decibel
Long duration noise level surveys				
1	1553 Great North Rd	71	70	-1
2	25 Hendon Ave	49	50	+1
3	14 Phyllis St	46	48	+2
4	53 Powell St	50	48	-2
5	36 Cradock St	47	47	0
6	5 Valonia St	53	55	+2
7	17 Milich Terrace	67	67	0
8	20 Titoki Street	68	70	+2
9	77 Herdman St	65	63	-2
10	204 Methuen Rd	47	46	-1
11	1102g Great North Road	71	69	-2
12	21 Alwyn Ave	50	52	+2
Short Duration Noise Level Surveys				
13	Bollard Ave/New North Rd	53	53	0
14	Phyllis St Reserve	47	49	+2
15	Dorje Chang (Powell St)	47	47	0
16	Valonia St Reserve	45	46	+1
17	Waterview Reserve	59	60	+1

The computer model produces plans showing noise level contours and also calculates the noise levels at selected point receiver positions for increased accuracy.

6.4.1 Individual Receiver Noise Levels

Noise levels received at individual dwellings and other noise sensitive positions, for the base situation in 2011 and for the design year 2026, are contained in the tables in Appendix F(i) to F(iv). The locations of these dwellings are shown on the plans in Appendix F(i) to F(iv).

These levels have been calculated for all floor levels of each dwelling within 100 metres of the Project as required by NZS 6806:2010. In most circumstances, the highest floor is the most affected floor which controls the mitigation measures to be implemented. However, it is noted that other floors at lower levels would generally benefit to a greater extent from the proposed mitigation measures and therefore, receive lower noise levels. The design of appropriate noise mitigation measures has been based on the compliance with the relevant criteria being complied with at all affected floors.

Individual receiver noise levels have been shown as a graphic representation by colouring the buildings with the colour scale showing NZS 6806:2010 Category A buildings in green, Category B buildings in yellow and Category C buildings in red. Those buildings shown in grey on the figures are outside the assessment area of 100 metre from the road alignment or are not PPFs (e.g. garages, sheds, business premises etc).

6.4.2 Noise Contour Plans

Noise contour plans for the entire Project area are included in Appendix G. These plans show indicative free-field noise bands at 5 decibel intervals.

6.5 Subjective Perception of Noise Changes

Noise is measured on a logarithmic scale and the subjective impression of changes in noise can generally be correlated with the numerical change in noise level. While every individual reacts differently to noise level changes, research has shown a general correlation between noise level changes and subjective responses. The table below shows indicative values to aid comprehension of the noise level assessment contained in this report.

It is noted that each column, i.e. increase in traffic volume and change in distance, are independent from one another. The noise level change described is based on either one of these factors. In the event of both changes occurring, e.g. doubling of traffic and halving of distance, the noise level increase would be 6 decibels rather than 3 decibels.

Table 6.3: Noise level change compared with subjective perception, traffic volume change and distance to road

Noise Level Increase	General Subjective Perception	Traffic Volume Increase (example to a base of 20,000 vehicles per day)	Change in Distance to Road (Example to a base of 100 metres)	Impact / RMA Adverse Effect
1 – 2 decibels	Insignificant change	Less than double (33,000 vpd)	More than half (60 m)	Negligible/Less than minor
3 – 4 decibels	Perceptible change	Approximately double (40,000 vpd)	Approximately half (50 m)	Slight/Minor
5 – 8 decibels	Appreciable change	Approximately 6 times increase (112,000 vpd)	Approximately one fifth (20 m)	Moderate
9 – 11 decibels	Doubling of loudness	Approximately 10 times increase (200,000 vpd)	One tenth (10 m)	Significant/ Substantial
> 12 decibels	More than doubling of loudness	More than 10 times increase (> 300,000 vpd)	Less than one tenth (< 6 m)	Severe

The perception of these noise level changes generally applies to immediate changes in noise level, similar to those areas where SH20 is a new road, e.g. Sector 9. For gradual changes over time, such as for Sectors 1 to 7 where the current noise environment is controlled by the existing SH16, the subjectively perceived effects of the changes might be generally less noticeable.

7. Noise Level Assessment: Existing and Future Do-Nothing Scenarios

Noise level assessments in accordance with NZS 6806:2010 include several scenarios, including existing and future Do-Nothing circumstances. These are further explained in Section 4.1.2 above. This section of the report addresses the existing and Do-Nothing scenarios only.

7.1 Existing Noise Environment

The existing noise environment is a factor used to assess the potential noise effects from any Project. The computer noise model for the existing noise environment for the Project includes all local roads and State highways in the assessment area and beyond. For this Project, local roads as far as 2 km from the alignment were included in the model.

As previously discussed in Section 6.4, noise level survey results were used to verify the computer model. Following the verification of the model, noise levels were predicted for all assessment positions within 100 metres of the alignment for each floor level of interest. Resulting noise levels are shown in the tables and figures in Appendix F(i) to F(iv).

For those sections of the road which consist of a "new road" as defined in accordance with NZS 6806:2010, there is no Do-Nothing scenario, and the existing noise environment is used for comparative assessments, in accordance with the requirements of NZS 6806:2010. This specifically relates to Sector 9 of the Project.

7.2 Do-Nothing Scenario

The Do-Nothing scenario is required to be established for those sections of the Project that consist of an "altered road" as defined in accordance with NZS 6806:2010, specifically Sectors 1 to 6, and includes assessment positions in Sector 7.

The Do-Nothing scenario consists of the existing State highway, which is identified as the road to be altered ("altered road") with the existing layout and the traffic flow volume for the design year. In accordance with the Standard, local roads were excluded from the assessment of the Do-Nothing scenario.

The reason for excluding local roads from any assessment scenario but the "existing scenario" is that the assessment is for the noise effects from the State highway only. Local roads, industry or other noise sources, while contributing to the ambient (existing) noise level, are not the subject of this assessment, and the NZTA has no control over those noise sources and would not apply mitigation to them.

NZS 6806:2010 contains noise level criteria which are independent from the ambient noise level, and are based on the type of project to be assessed (i.e. altered or new road). Therefore, the 'existing' and 'Do-Nothing' scenarios are used for an assessment of effects in relation to the RMA only and not to determine compliance with the traffic noise criteria.

Noise levels have been predicted for all identified assessment positions. Generally, the Do-Nothing noise levels are in the order of one to two decibels higher than those of the existing noise environment described in Section 7.1 above. This is due to the projected increase in traffic volume on the State highway network.

Noise levels predicted for the Do-Nothing Scenario are shown in the tables and figures in Appendix F(i) to F(iii).

For "new" roads as defined in NZS 6806:2010, no Do-Nothing Scenario is provided. While for existing (altered) roads the ambient noise level is generally controlled by the (altered) road which is to be assessed, in the circumstance of a new road the controlling source of ambient noise is non-specific, including all noise sources near and far (refer Appendix B for an explanation of technical terms). It is not practical to predict future ambient noise levels from non-specific noise sources as these predictions could not be verified by noise level surveys as is the case for existing ambient noise levels.

Therefore, for "new" roads, the assessment of noise effects in accordance with the RMA is based on existing ambient noise levels in the assessment area.

8. Operational Noise Effects Assessment

The implementation of the Project will result in varying effects throughout the Project area. Each sector will have individual effects and issues to be managed which are set out in the sections below.

For each sector that contains an "altered road" in accordance with NZS 6806:2010, the Do-Minimum scenario has been assessed. The Do-Minimum scenario (refer Section 4.1.3) is compared with the Do-Nothing scenario, in order to ascertain if the road is an "altered road". For this Project, the noise level change due to the Project implementation is considerable in some areas, with changes ranging in the most affected instances from 13 to 21 decibels. The Do-Minimum scenario is also utilised for the Benefit Cost Ratio (BCR) for which examples are contained in Appendix D of NZS 6806:2010. As cost is one of the factors taken into consideration for the determination of the BPO, the Do-Minimum scenario serves an important purpose in the assessment of noise mitigation options.

NZS 6806:2010 requires that several mitigation options be considered in order to ensure that the BPO approach is effective. Therefore, each sector assessment set out below contains a summary of all mitigation options considered and a detailed description of the preferred mitigation option.

The determination of the BPO has been undertaken by means of workshops. Prior to workshops, noise mitigation options were circulated to the Project team, and an assessment matrix for each assessment area was filled in by relevant team members. Discussion during the workshop served to refine the pre-circulated mitigation options. For this Project, the planner, having received input from all team members, was responsible for determining which option constituted the BPO. The BPO option was then re-modelled in the computer noise model for the final calculation of noise levels.

The matrices containing the information used to identify the preferred mitigation options are attached in Appendix F(i) to F(iv).

Mitigation measures for each sector have been developed based on the receiving environment, i.e. those assessment positions that would benefit from a specific mitigation measure or barrier. Therefore, each relevant sector contains several mitigation options for each receiving environment.

For example, Sector 6 between the Waterview Interchange and St Lukes Interchange has two distinct receiving environments, one north of SH16 and one south. Mitigation has been designed individually for either side, and a preferred option for the north and south chosen. Once this choice has been made, the preferred barriers for the entire Sector 6, including the northern and southern barriers, have been entered into the computer noise model to constitute "the preferred mitigation option" for Sector 6.

8.1 Sector 1 – Te Atatu Interchange

The widening and realignment of SH16 and the Te Atatu Interchange ramps constitute an "altered road" in accordance with NZS 6806:2010. State highway 16 is an existing road which is proposed to be altered. In addition, the Do-Minimum scenario, when compared with the Do-Nothing scenario (refer Section 4.1.3) is predicted to result in a noise level change of at least 3 decibels at one or more assessment positions.

Sector 1 contains three receiving environments; north of SH16 on the Te Atatu Peninsula side, south of SH16 and east of Te Atatu Road following Alwyn Ave, and south of SH16 and west of Te Atatu Road towards Henderson Creek. Mitigation options for each of these environments were developed individually and are discussed below.

A workshop matrix, containing input from all relevant Project disciplines, to the mitigation options for this Sector is contained in Appendix F(i). Figures showing the barrier heights and extents, and predicted noise levels for buildings assessed for all mitigation options are also shown in Appendix F(i). For detailed noise level predictions, the spreadsheet in Appendix F(i) shows all mitigation options for this and other receiving environments in Sector 1.

8.1.1 North of SH16 – Te Atatu Peninsula

(Images taken from Google Earth Pro, licensed to Marshall Day Acoustics Ltd)

Dwellings in Titoki, Toru and Karamu Streets have been assessed, being inside the 100 metre assessment distance. Three mitigation options were developed.

8.1.1.1 Do-Minimum Scenario

The Do-Minimum scenario shows that the proposed widening of SH16 would have a moderate effect on the surrounding dwellings, with noise level increases up to 5 decibels. Of the assessed positions, 13 would exceed the Category A criterion and another two the Category B criterion without the implementation of noise mitigation measures. This information formed the basis of the mitigation option designs.

8.1.1.2 Mitigation Option 1

Mitigation Option 1 consists of barriers up to 2.5 metres high along the road and designation boundary. Of the 51 assessment positions, 42 are within Category A, i.e. having an external noise level of 64 dB $L_{Aeq(24h)}$ or less. Nine positions are within Category B, i.e. receiving an external noise level above 64 dB and up to 67 dB $L_{Aeq(24h)}$. Mitigation Option 1 was designed to represent a boundary fence arrangement which may integrate with the residential character of the receiving environment.

The noise barriers are predicted to result in an average mitigation of only 1 decibel, well short of the required 3 decibels reduction (refer Section 4.1.5 above).

8.1.1.3 Mitigation Option 2

Mitigation Option 2 provides for barriers up to 3 metes high. This option achieves compliance with Category A for 47 assessment positions and Category B for the remaining four positions.

This option achieves the highest noise level reduction (an average of 3 decibels) and the highest percentage of receivers in Category A. The barriers would constitute boundary fences for the affected dwellings. However, the urban design team considers a 3 metre high barrier would be overpowering. Therefore, in the Project team's overall assessment of the BPO for this area, the wider Project team discounted this option, most significantly for visual and urban design considerations.

8.1.1.4 Mitigation Option 3

Mitigation Option 3 has been developed as a combination of Options 1 and 2, with a barrier extended further towards the west similar to Mitigation Option 1, and the retention of a constant height of 2.5 metres in order to reduce visual effects on neighbouring properties. Forty six assessment positions of the 51 positions assessed are predicted to be within Category A, and the remaining five positions in Category B. On average, the noise level reduction achieved by the barriers is 2 decibels, with several positions achieving a 3 decibel reduction.

8.1.1.5 Preferred Mitigation Option

The Project team's preferred mitigation option for the receiving environment north of SH16 in Sector 1 is Option 3. While Option 2 has a larger number of assessment positions predicted to be within Category A, urban design and visual issues resulted in Option 3 being preferred by the team. The predicted difference in mitigation in relation to Option 2 is insignificant in comparison to Option 3, with noise levels for some dwellings being 1 decibel higher. This is an insignificant difference. (refer Section 6.5) Noise level predictions and figures showing barrier lengths and heights of the preferred barrier option are included in Appendix F(i).

8.1.2 South East of SH16 and Te Atatu Road

A total of 36 positions have been assessed for this receiving environment, including positions in Alwyn and Bridge Avenues. Three mitigation options have been developed.

8.1.2.1 Do-Minimum Scenario

The Do-Minimum scenario shows that noise levels would increase by up to eight decibels for some assessment positions, with 11 positions being predicted to receive noise levels above the Category A criterion and another three positions above the Category B criterion. Without mitigation, noise levels are predicted to increase for almost all receivers with the implementation of the Project.

8.1.2.2 Mitigation Option 1

Mitigation Option 1 was developed extensively during 2009 while this section of the Project was assessed as a separate project. A mitigation design was developed, which consisted of a 3 metre high bund connected to a 2 to 2.5 metre high barrier on either end. While four dwellings (facing south east towards the Rosebank Peninsula) and one further dwelling in Alwyn Ave are predicted to be in Category C thus potentially requiring building improvements, 28 dwellings are predicted to be within Category A and five in Category B. Noise level reduction up to four decibels are predicted.

While Mitigation Option 1 is considered to be the preferred option, further assessments have been undertaken to gain an understanding whether it would be feasible to avoid the potential for any dwellings falling into Category C therefore potentially requiring building modification.

8.1.2.3 Mitigation Option 2

Mitigation Option 2 has been developed by placing a barrier up to 4 metres high on the cycle bridge over the Whau River in addition to the barrier along Alwyn Avenue. The Project team found this option to be inconsistent with urban design and visual aspirations for the Project. However, with this option only two dwellings would remain in Category C.

During the public consultation process feedback from residents in the end sections of Alwyn Ave indicated that a key reason for their choice of property was the outlook over the estuary. The preference of these residents is to retain the views, even if this requires building modification to their dwellings. The BPO assessment includes reference to community opinions, and in this circumstance, the community view of potentially affected residents appeared to be against the placement of any barrier that may interfere with the water views.

8.1.2.4 Mitigation Option 3

Mitigation Option 3 has been assessed in an attempt to reduce the number of dwellings in Category B and C when compared with Mitigation Option 1. While this could be achieved, the 5 metre barrier along the northern boundary at Alwyn Ave would have adverse visual effects, making this option overall undesirable.

8.1.2.5 Preferred Mitigation Option

Mitigation Option 1 is the Project team's preferred option for the receiving environment south east of SH16 in Sector 1. This means that building modification mitigation may be required for up to three dwellings (Nos. 38, 40A and 42 Alwyn Ave) in order to achieve a suitable internal noise level. These are the dwellings that currently have extensive views over the estuary, which residents indicated they would like retained. The Project is likely to result in moderate noise level increases for these dwellings of between 1 and 4 decibels.

In order to determine the specific building modifications required for the Alwyn Ave dwellings, further assessment of the building envelope performance and existing internal noise level will be required. From an external inspection, it is anticipated that the requirements may include upgraded glazing and the installation of alternative ventilation for habitable rooms facing SH16 and the estuary.

8.1.3 South West of SH16 and Te Atatu Road

The assessment area south west of SH16 extends from Te Atatu Road to Henderson Creek. A large number of positions (99 assessment locations) are within 100 metres of the road.

Existing noise levels in this area vary from 56 dB $L_{Aeq(24h)}$ for dwellings in the second row, at some distance and shielded from SH16, to 75 dB $L_{Aeq(24h)}$ for dwellings facing SH16. Dwellings in Milich Terrace and Paton Ave are particularly affected by high noise levels, up to 11 decibels above the preferred Category A criterion of 64 dB.

8.1.3.1 Do-Minimum Scenario

The Do-Minimum Scenario shows that noise levels will remain virtually unchanged with the implementation of the Project. However, as noted previously, existing noise levels are very high and NZS 6806:2010 provides for a reduction in noise levels beyond those presently existing if this is feasible with the adoption of the BPO.

8.1.3.2 Mitigation Option 1

Mitigation Option 1 provides mitigation in the form of 2.5 to 3 metres high barriers which would be installed along SH16. The barriers would provide an average of 2 decibels mitigation, just short of the 3 decibels required. However, seven dwellings are predicted to be within Category C, which means that some form of building improvements may be required to achieve the internal noise criterion of 40 dB $L_{Aeq(24h)}$. All remaining dwellings are within Category A (76 of the total of 99) and Category B (16 of 99).

This option was considered unsuitable for noise mitigation reasons because of the high number of dwellings receiving noise levels in excess of 67 dB $L_{Aeq(24h)}$, accordingly other mitigation options were developed to reduce the number of dwellings in Category C.

8.1.3.3 Mitigation Option 2

Mitigation Option 2 involves ensuring that no dwellings fall into Category C. This can only be achieved by means of high barriers (up to 5 metres) in close proximity to the dwellings. The existing topography is such that the installation of road side barriers is not considered the BPO for some locations as the dwellings are located above the State highway. In these circumstances, barriers would be placed more effectively along the common designation and property boundary.

Structural mitigation measures for this option are predicted to achieve an average noise level reduction of 5 decibels, a noticeable reduction.

This mitigation option, while favourable from an acoustics point of view, was seen as disadvantageous by the Project's urban design team. High barriers (up to 5 metres) would have to be installed along the northern boundary of residential properties, resulting in issues of shading and potentially resulting in overpowering visual impacts on the sites. Therefore, this mitigation option was not pursued further.

8.1.3.4 Mitigation Option 3

Mitigation Option 3 is a combination of Options 1 and 2, whereby the barrier height has been reduced to a maximum of 3.5 metres. It was concluded in the options evaluation that in terms of visual effects and urban design response this height can be adequately addressed in the vicinity of these residential sites. While this lower barrier results in a number of dwellings moving into Category B (10 of 99), and two dwellings being in Category C, thus potentially requiring building improvements, the majority of dwellings (87 of 99, or 88%) are in Category A.

An average noise level reduction of 4 decibels can be achieved by the structural mitigation measures determined for Option 3, which satisfies the provisions of the Standard, with individual dwellings receiving up to 8 decibels noise level reduction.

8.1.3.5 Preferred Mitigation Option

Mitigation Option 3 is the Project team's preferred option for the receiving environment south west of SH16 in Sector 1 as it provides a practicable compromise between the desired outcome for noise mitigation and the potential urban design and visual effects.

8.1.4 Preferred Mitigation Options – Sector 1

Through the BPO process, the mitigation options preferred by the Project team for Sector 1 are:

- North of SH16 – Mitigation Option 3

- South east of SH16 and Te Atatu Road – Mitigation Option 1
- South west of SH16 and Te Atatu Road – Mitigation Option 3.

Noise level predictions for Sector 1, including the preferred mitigation options, and a figure showing the barrier lengths and heights are shown in Appendix E(i).

8.2 Sector 2 – Whau River

Sector 2 does not contain any protected premises and facilities as defined in NZS 6806:2010. However, noise emanating from Sector 2 has been included in the assessment of noise effects on dwellings in Sector 1.

For Mitigation Option 2 of the south eastern receiving environment (refer Section 8.1.2 above) a barrier up to 4 metres high was assessed for the proposed cycle bridge over the Whau River. However, as discussed previously, this option was not developed further due to urban design and residents' considerations which preferred the views over the estuary.

Feedback from residents during the consultation process included comments about noise from vehicles passing over the Whau bridge expansion joints. This noise source, while part of the overall noise environment and therefore captured by the traffic noise descriptor $L_{Aeq(24h)}$, can cause annoyance due to its character being intermittent and impulsive.

In order to avoid the noise source, the road surface shall be laid and maintained so that there is no noticeable height difference between the road surface and the expansion joint. This will reduce the noise from tyres impacting on an edge.

No further traffic noise assessment of Sector 2 has been undertaken.

8.3 Sector 3 – Rosebank Terrestrial

The land use on the Rosebank Peninsula is generally of business and industrial nature. These uses are not protected under NZS 6806:2010 as they are considered noise insensitive.

Traffic noise from this sector would have no appreciable effect on sensitive receiving environments in other sectors, however, SH16 traversing Sector 3 has been included in all computer noise modelling for other sectors.

No further traffic noise assessment of Sector 3 has been undertaken.

8.4 Sector 4 – Reclamation

Traffic noise from Sector 4 is predicted to affect noise sensitive locations in Waterview and Point Chevalier. While some of the assessment positions would strictly be located in Sector 4, for ease of assessment these have been included in the Sector 5 assessment (refer Section 8.5 below).

No further traffic noise assessment of Sector 4 has been undertaken.

8.5 Sector 5 – Great North Road Interchange

The widening and realignment of the Great North Road Interchange constitute "altered roads" as defined in NZS 6806:2010, while the construction of the new ramps connecting SH20 to SH16 would constitute "new roads". As the noise performance criteria for both are the same (refer Section 4.1.2), Sector 5 was assessed as an "altered road" as set out in NZS 6806:2010.

Sector 5 contains three receiving environments; south of SH16 including receivers in the suburb of Waterview, north of SH16 on the Pt Chevalier side, and south east of SH20 being limited to the UNITEC campus. It is noted that the receivers assessed south of SH16 in Waterview include a number of assessment positions which would strictly be located in Sectors 4 and 7, however, the main contributing noise source at these receivers is contained in Sector 5, and for practicality reasons all noise sensitive locations in Waterview were assessed through Sector 5. Nevertheless, traffic noise from all sectors has been included in the assessment of all locations.

Mitigation options for each of the three environments described above have been developed individually and are discussed below.

A workshop matrix, containing input from all relevant Project disciplines, for the mitigation options for Sector 5 is contained in Appendix F(ii). Figures showing the barrier heights and extents, and predicted noise levels for buildings assessed for all mitigation options are also shown in Appendix F(ii). For detailed noise level predictions, the spreadsheet in the same appendix shows all mitigation options for this and other receiving environments in Sector 5.

8.5.1 South of SH16 – Waterview

The receiving environment south of SH16 and west of SH20/Great North Road takes in a part of Wateview. Small sections of this environment are located in Sector 4 (specifically some dwellings in Hemington, Herdman and Daventry Streets) and Sector 7 (including Waterview Primary School and Kindergarten). These positions cannot be separated from the remaining assessment positions in Sector 5 as they are affected by the same noise sources and are interrelated.

8.5.1.1 Do-Minimum Scenario

The comparison of the Do-Minimum scenario with the Do-Nothing scenario shows that the proposed additional ramps and widening of the existing SH16 will have a noticeable effect on some dwellings where noise levels are predicted to increase by up to 5 decibels, while remaining dwellings will receive insignificant noise level increases of around one to two decibels. Of the 78 positions assessed, 46 would exceed the Category A criterion and 15 the Category B criterion without the implementation of noise mitigation measures. Exceedances of both Category A and B are up to 5 decibels. A noise level reduction of this magnitude is generally achievable for barriers in most circumstances.

It is noted that a number of dwellings in this Sector are duplexes. Therefore, while only one dwelling is shown on the figures, all individual residential units are shown in the spreadsheet. Therefore, the number of

assessment positions in each individual Category A, B and C is larger than can be seen on the figures in Appendices E and F(ii).

8.5.1.2 Mitigation Options 1 to 4

Initially, four mitigation options were developed, for which barriers have been placed on the SH20 to SH16 westbound ramp. This is the closest carriageway to Waterview, and barriers provide additional shielding from carriageways further north.

Barriers assessed range in height from 2 metres to 5 metres. Generally, the Project's urban design team has been in favour of lower barriers, preferably 2 metres in height or less, in order to avoid unnecessary shading and visual impact from the combination of a high structure (the ramp) with a high barrier. Therefore, Mitigation Options 2 and 3 have been preferred over Option 1.

However, as noted previously, the utilisation of road noise barriers is considered not to constitute the BPO if other mitigation measures could be utilised. Therefore, further investigations have been undertaken, including the use of alternative noise mitigation measures such as road surface materials that provide even lower noise levels than OGPA. One possible material is a twin layer OGPA, which in tests has been shown to provide an additional two decibels noise reduction when compared with commonly used OGPA.

8.5.1.3 Mitigation Option 5 to 7

Mitigation Options 5, 6 and 7 involve the use of twin layer OGPA instead of commonly used single layer OGPA, for the entire Great North Road Interchange, including SH16 east and west bound, and SH20 to SH16 ramps in all directions.

Mitigation Option 5 assesses a combination of twin layer OGPA road surface material and barriers up to 2 metres along the SH20 to SH16 westbound ramp. This option achieves good compliance with the intention of NZS 6806:2010, with 74 % of receivers being within Category A, and the remaining 26 % in Category B, and results in an average noise mitigation of 3 decibels, as required by NZS 6806:2010.

Following extensive discussions with the Project team, two further mitigation options have been developed (Mitigation Options 6 and 7), utilising twin layer OGPA road surface material.

These are based on Option 5 and include 1.1 metre high concrete edge safety barriers (TL5) for all ramps within the Great North Road Interchange.

In addition, the shortest possible length of additional 2 metre barrier has been designed to achieve compliance with Category A for the largest number of assessment positions. The resulting barrier arrangement is shown in Mitigation Option 6. Of the positions assessed, three quarters are predicted to be within Category A, with the remaining positions in Category B.

Following further feedback from the urban design and construction team, for Mitigation Option 7 a barrier arrangement has been tested whereby only 1.1m high edge safety barriers would be installed along the SH20 to SH16 westbound ramp. The barrier would extend beyond the bridge part of the ramp towards the west as shown on the figure in Appendix E(ii).

The noise level predictions show that the results are very similar to those of Mitigation Option 6, without the need to install specifically designed noise barriers and therefore avoid visual issues relating to a bridge structure with high barriers. Mitigation Option 7 is predicted to achieve noise levels within the Category A range for 58 of the 78 receiver locations (equivalent to 74 %) and noise levels in the Category B range for the remaining 20 positions.

8.5.1.4 Preferred Mitigation Option

Following assessment by the design team, Mitigation Option 7 has been chosen as the preferred mitigation option for the Waterview side of Sector 5.

The combination of a well performing low noise road surface such as twin layer OGPA and 1.1 metre high safety edge barriers on the SH20 to SH16 westbound ramp for an extended section is predicted to achieve average structural mitigation of 3 decibels. This would result in the majority of assessment positions receiving noise levels within Category A, and the remaining positions levels within Category B. No building improvements would be required to any dwelling.

8.5.2 North of SH16 – Pt Chevalier

The suburb of Pt Chevalier is located north of SH16 in Sector 5. Due to existing topography in this area, dwellings are generally situated above SH16 with sites sloping towards the State highway. The established suburban setting results in a large number (150) of protected premises and facilities having been assessed. It

is noted that for some sites, there are several floor levels of interest as set out in the Standard, and therefore each floor has been assessed separately. This is shown in the table in Appendix F(ii).

8.5.2.1 Do-Minimum Scenario

The existing noise environment in this assessment area is elevated due to the close proximity to SH16, with more than one third of positions currently receiving noise levels in excess of the Category A criterion. The Project is predicted to result in a further average increase in noise level of 2 decibels, increasing the number of positions receiving noise levels above Category A to 95 of 150, of which 19 positions would receive noise levels in excess of Category B criteria.

While the Category B criterion of 67 dB $L_{Aeq(24h)}$ is predicted to be exceeded by up to 2 decibels only, options for mitigation measures which would effectively mitigate noise levels are limited by the existing topography and location of the dwellings. Nevertheless, the noise level reductions required to fall within Category A or B are considered achievable.

8.5.2.2 Mitigation Options 1 and 2

Visual inspection of the site and utilisation of the computer noise model resulted in two mitigation options being developed which consisted of barriers along the northern side of the SH16 to SH20 southbound ramp. This ramp passes at high elevation above the entire Great North Road Interchange and is not shielded from the dwellings. In addition, barriers have been designed for the SH16 to Great North Road off ramp and the SH20 to SH16 city bound ramp. These ramps are the closest to the Pt Chevalier dwellings and have some effect on the noise environment in the area.

Barriers up to 2.5 metres high (Mitigation Option 1) have been designed in order to achieve compliance with the criteria of Category A in the first instance, and Category B for those dwellings which could not be well shielded. An average of 4 decibels mitigation would be achieved with this option, and 96% of all assessment positions would be within Category A. While this option results in good noise level mitigation for the Pt Chevalier area, a considerable length of 2.5 metre barrier would be required.

Mitigation Option 2 is a variation of the Option 1 barrier arrangement whereby barriers up to 3 metres in height would be positioned only along the SH16 to Great North Road off ramp and a small section along the SH20 to SH16 city bound ramp. Barriers nearest to the Pt Chevalier point overlooking the water have been found to be less effective with insignificant noise level reductions for the dwellings in Hawea Road and Maryland Steet and have been excluded from the design of Mitigation Option 2.

Although an average noise mitigation of 3 decibels can be achieved by this mitigation option, one dwelling is predicted to be within Category C, thus potentially requiring building improvements in order to achieve compliance with the internal noise criterion of 40 dB $L_{Aeq(24h)}$. The remaining positions are predicted to be in Categories A or B.

8.5.2.3 Mitigation Option 3

Placement of barriers is an important consideration for the effectiveness of all noise mitigation designs, but particularly for areas where the dwellings are located in positions elevated above the State highway as is the case in Pt Chevalier. A different approach has been taken in Mitigation Option 3 where barriers have been designed for location on the property boundaries of the most affected dwellings, where this has been considered suitable when taking into consideration access to the property and dwelling height.

As the urban design team had already indicated that barriers in excess of 2 metres would be unsuitable for this environment, barrier heights have been restricted to 2 metres. Barriers have been designed to be located along the south facing property boundaries at Alberta and Montrose Streets.

In order to achieve some mitigation for dwellings on Pt Chevalier point, a 3.5 metre barrier has been designed to be located along the SH16 to Great North Road off ramp.

Noise level predictions show that 14 positions would receive noise levels above 67 dB and, therefore, potentially require building improvements. Half of all assessed positions would be within the Category B criterion but the average structural mitigation was minimal with only 1 decibel.

This mitigation option has not been addressed further as the results are not considered to reflect the BPO for this receiving environment.

8.5.2.4 Mitigation Option 4

Following examination of the Great North Road Interchange as a whole, it became evident that it would be advantageous and satisfy the BPO requirement, for all carriageways to be surfaced with low-noise road surface material such as twin layer OGPA.

Therefore, Mitigation Option 4 has been developed to determine if further noise barriers would be required in addition to the installation of 1.1 metres safety edge barriers on the ramps and bridges and the utilisation of twin layer OGPA seal for all carriageways within the Great North Road Interchange. It is noted that the Do-Minimum scenario involves 0.8 metre high edge safety barriers, rather than the 1.1 metre high barriers included in Mitigation Option 4.

The Project's urban design and construction teams prefer limiting any additional barriers on the ramps and bridges of the Interchange for visual, safety and construction reasons.

The resulting noise levels for this mitigation option show that approximately three quarters of all assessment positions (114 of 150) would receive noise levels compliant with the Category A criterion, and the remaining quarter (35 of 150) with the Category B criterion. Only one dwelling is predicted to receive a noise level above 67 dB (49 Montrose St). This dwelling may require building improvements to the habitable rooms facing SH16. The dwelling is positioned such that any structural mitigation is difficult to apply, and high barriers would be needed to provide the required 1 decibel noise level reduction.

8.5.2.5 Preferred Mitigation Option

Mitigation Option 4 is considered by the Project team to be the preferred noise mitigation option for the Pt Chevalier receiving environment. It provides a satisfactory balance between highest noise level reductions and visual impacts.

8.5.3 South East of SH16 – UNITEC

UNITEC campus occupies the south eastern corner of Sector 5, being bordered by SH16 to the north and Great North Road and the new SH20 ramps to the west.

UNITEC buildings are generally multi-storey and of substantial construction (brick and tile). The main complex consists of one large building with several wings (refer Building (1) on the figure above). Other buildings on the site are single or double storey only and of less solid construction (light weight walls and steel roofing).

NZS 6806:2010 defines teaching facilities as protected premises and facilities. Each facade facing SH16 or Great North Road/SH20 has been identified as a separate assessment point. For each facade, noise levels for all floor levels of interest (i.e. all floors) have been predicted to provide a comprehensive assessment.

No inspection of the UNITEC buildings has been undertaken, and therefore it has not been established that all assessed positions are used for teaching areas. However, this assessment constitutes a conservative approach as it is based on the assumption that rooms facing the Project are being utilised for teaching purposes.

8.5.3.1 Do-Minimum Scenario

The UNITEC buildings are located in a high noise environment, affected by traffic noise from SH16, Great North Road and Carrington Road. The implementation of the Waterview Connection Project is predicted to increase noise levels further, particularly for those buildings facing the new SH20 ramps connecting with SH16.

Of the 26 positions assessed, six are predicted to receive noise levels in excess of 64 dB $L_{Aeq(24h)}$ (Category A), and an additional five have noise levels above 67 dB $L_{Aeq(24h)}$ (Category B).

Exceedance of the Category B criterion of 67 dB by up to four decibels has been predicted. Therefore, a noticeable reduction in noise level would be required in order to achieve compliance with Category A or B criteria. As noted previously, the main building is relatively high, and upper floors are more affected by high noise levels due to less shielding from terrain and other existing buildings and structures.

8.5.3.2 Mitigation Options 1 to 3

The most affected UNITEC building is the main complex (Building (1) marked on the figures in Section 8.5.3 above) on the corner of Carrington Road and SH16. This building is predicted to receive noise levels up to 71 dB $L_{Aeq(24h)}$ at the upper floors. Therefore, barriers were considered along the proposed southbound ramp from SH16 to SH20 which represents the carriageway closest to the UNITEC site.

Due to the height of the building, barriers would need to be of considerable height. Three mitigation options were designed with barriers of varying height and length. Barrier heights of four, five and six metres were developed for Mitigation Options 1, 2 and 3 respectively. The longest barrier was proposed for Mitigation Option 2, and the shortest barrier for Mitigation Option 1.

Mitigation achieved by the three options is very similar. Approximately 17 positions of the 26 assessed were predicted to fall within Category A for Mitigation Options 1, 2 and 3. Similar numbers could also be achieved for Category B, with eight positions predicted to be within Category B. For Mitigation Option 3 with barriers up to 5 metres in height, only one position remains in Category C with a predicted noise level of 69 dB $L_{Aeq(24h)}$, which is the same as the current predicted noise level at this position.

Of these options, none has been identified as a preferred option due to issues such as excessive barrier height and minimal noise reductions achieved.

8.5.3.3 Mitigation Option 4

Mitigation Option 4 has been developed following the decision to pursue a high performance low-noise road surface such as a twin layer OGPA as a viable mitigation method.

In addition to utilisation of twin layer OGPA on all carriageways of the Great North Road Interchange, 1.1 metre high safety edge barriers have been assumed for all ramps and bridges that are part of the Interchange (but excluding those on local roads such as Carrington Road bridge).

An average structural mitigation of 2 decibels could be achieved by this mitigation option. While three positions are still predicted to be above the Category B criterion, all remaining positions would receive noise levels compliant with Category A and B criteria.

Potentially, the most affected facades may require upgrades in order to achieve the internal noise criterion of 40 dB $L_{Aeq(24h)}$, however, as noted previously the building is a substantial structure which is likely to achieve a good degree of noise reduction presently. This will need to be assessed in more detail prior to construction of the Project.

It is understood that the UNITEC building in question has heritage status, and that therefore approval from the Historic Places Trust would be required for any building mitigation modification to be undertaken.

8.5.3.4 Preferred Mitigation Option

The Project team decided that the preferred option for the receiving environment south east of SH16 in Sector 5 is Mitigation Option 4, involving the use of high performance low-noise road surface material.

For this option, no additional noise barriers would be required, which is advantageous given the considerable barrier height required to achieve any useful noise reduction benefit. Since a high performance low-noise road surface material would benefit all receiving environments in Sector 5, its additional cost is considered to be potentially outweighed by the other related BPO considerations, such as urban design and visual impact.

8.5.4 Preferred Mitigation Options – Sector 5

Through the BPO process, the mitigation options preferred by the Project team for Sector 5 are:

- South of SH16 (Waterview) – Mitigation Option 7
- North of SH16 (Pt Chevalier) – Mitigation Option 4
- South East of SH16 (UNITEC) – Mitigation Option 4.

Figures showing the noise level predictions for Sector 5, including the preferred mitigation options, including showing the barrier lengths and heights are shown in Appendix E(ii).

8.6 Sector 6 – Great North Road Interchange to St Lukes

As part of the Project the existing SH16 will be widened to accommodate one additional lane in each direction from the Great North Road Interchange to St Lukes Road to provide for additional traffic volume with the connection of SH20. The Project in this area constitutes an "altered road" as defined by NZS 6806:2010, and has been assessed accordingly.

Sector 6 contains two distinct receiving environments; one north of SH16 including parts of Pt Chevalier, and one south of SH16, including parts of northern Mt Albert. Mitigation Options for these environments have been developed and are discussed below.

The Project team provided input into the noise mitigation design. A matrix containing feedback from all relevant disciplines is contained in Appendix F(iii). Figures showing mitigation designs and detailed predicted noise levels for all mitigation options are also shown in Appendix F(iii).

Relevant information on the preferred mitigation options is contained in Appendix E(iii).

8.6.1 North of SH16

A number of dwellings are located between Great North Road and SH16. The terrain slopes towards the State highway resulting in dwellings not being shielded from traffic noise. In response to the topography, some dwellings were constructed on high basements. This increases the angle of view from the dwellings to SH16 as less shielding is provided by other structures.

Three dwellings in Parr Road North form a separate cluster as they are surrounded by business sites. Other dwellings are located on Great North Road, with some subdivisions abutting SH16 thus reducing the separation distance from noise source to receiver.

For a Project to be defined as an "altered road", the Do-Minimum noise level must increase by at least 3 decibels when compared with the Do-Nothing scenario. However, for existing high noise environments where the existing noise level is 68 dB $L_{Aeq(24h)}$ or higher, one decibel increase in noise level is sufficient to trigger a noise assessment in accordance with NZS 6806:2010.

For Sector 6 North, the noise level increase due to the implementation of the Project is predicted to be at most 2 decibels, however, many of the assessment positions receive noise levels in excess of 68 dB, and therefore, an assessment of noise effects is required.

8.6.1.1 Do-Minimum Scenario

Dwellings north of SH16 in Sector 6 are located in a high noise area, with ambient noise levels in excess of 70 dB $L_{Aeq(24h)}$. The implementation of the Project is predicted to result in a further noise level increase of up to 3 decibels. Of the 56 assessment locations, 28 are predicted to receive noise levels above the Category B criterion of 67 dB $L_{Aeq(24h}$. Only fourteen positions are predicted to be within Category A with received noise levels below 64 dB.

Noise levels would be up to 9 decibels above 67 dB, a considerable exceedance, which is difficult to mitigate, particularly given the elevation of the dwellings above SH16.

8.6.1.2 Mitigation Options 1 and 2

Initial development of mitigation options focussed on the intention to avoid any dwellings receiving noise levels above the Category B criterion of 67 dB $L_{Aeq(24h)}$.

Mitigation Option 1 consists of a barrier up to 6 metres in height located along SH16, which would put all dwellings to below the Category B criterion and results in a significant average noise level reduction of 7 decibels. This is a considerable betterment over existing noise levels.

However, the Project team considers that the installation of such a barrier would create more adverse effects, in terms of visual and social issues, than are solved by greatly reducing noise levels. Therefore, though preferred in terms of noise level reduction, the Project team eliminated this mitigation option as it did not fulfil the requirements of the BPO.

Mitigation Option 2 provides an alternative to Option 1, with similar barrier placement, but with barrier heights being restricted to 4 metres. While satisfactory noise level reductions with an average of 6 decibels would be achieved, a number of dwellings, particularly in Parr Road North and those dwellings in Great North Road closest to SH16, would receive noise levels above Category B. Up to six assessment positions have been identified that would potentially require building modifications to achieve compliance with the internal noise criterion. In the circumstance of multi-storey dwellings or duplex dwellings with more than one individual residential unit, an assessment position is assigned to each floor and each unit. Therefore, while the

spreadsheet in Appendix F(iii) shows all assessed positions, the figures in the same appendix only show one level per dwelling.

8.6.1.3 Mitigation Option 3

A mitigation option has been developed intent on reducing the visual impact of mitigation measures, involving barriers of up to 3 metres.

The predicted noise levels for this mitigation option, when compared with the requirements of NZS 6806:2010, show that 21 positions (38% of all positions assessed) would fall within Category C and potentially require building improvements. Only 34% of positions are predicted to receive noise levels within the Category A range.

While this option was favoured by the urban design team due to its relatively minor impact on the visual amenity of the dwellings assessed, it is not considered BPO in terms of noise level reduction and has not been developed further.

8.6.1.4 Mitigation Option 4

Median barriers with increased heights have been used in other Projects to achieve noise level reductions while avoiding high barriers adjacent to residential properties. This method has also been tested for Sector 6.

Mitigation Option 4, which is similar to Mitigation Option 2, but includes a 2 metre high median barrier, does not result in sufficient improvement to be pursued further. Results are similar to those of Option 2.

8.6.1.5 Mitigation Option 5

None of the previous mitigation options is considered to be the BPO for the receiving environment north of SH16, and a further option has been developed with input from the Project's urban design team, involving the placement of a bund, up to 6 metres high, between the clusters of dwellings closest to SH16, with barriers extending further along the southern property boundaries.

Mitigation Option 5 would potentially require building improvements for six buildings. However, more than two thirds of assessment positions would be within Category A resulting in a considerable betterment over existing noise levels. The average structural mitigation is predicted to be 4 decibels, which is adequate in relation to the requirements of NZS 6806:2010.

The dwellings in Parr Road North (8, 10 and 12 Parr Road North) have been assessed separately, and it was considered that these dwelling should be treated by providing building envelope improvements if required. It

is not practicable to install effective noise barriers for these dwellings as they are located above the motorways and orientated perpendicular to the carriageway, and therefore, alternative mitigation should be considered.

8.6.1.6 Mitigation Option 6

Following examination of the use of low-noise road surface such as twin layer OGPA for utilisation in Sector 5, it was considered that its use could prove similarly beneficial for Sector 6 as for Sector 5 of the Project (Great North Road Interchange). As shown, the topography provides challenges in placing barriers in effective locations, and treatment of the road surface may provide some noise level reduction thus enabling the design of lower noise barriers. Therefore, Mitigation Option 6 has been developed to determine if noise barrier heights could be reduced and compliance with Category A and B criteria achieved.

The assessment of this mitigation option shows that barriers similar to Mitigation Option 5 would be required, however, the overall height requirement reduced from 6 metres to 5 metres.

The resulting noise levels for this mitigation option show that approximately half of all assessment positions (29 of 56) would receive noise levels compliant with the Category A criterion, and of the remaining positions, half each receive noise levels within the Category B (14 of 56) and Category C (13 of 56) range.

The average mitigation is predicted to be 3 decibels, which is adequate in relation to the requirements of NZS 6806:2010.

Similarly to Mitigation Option 5, the dwellings in Parr Road North may require building modification to achieve compliance with the Category C noise criterion of 40 dB $L_{Aeq(24h)}$. Building modification is likely to involve the improvement or replacement of joinery, potential ceiling insulation and the provision of alternative ventilation for habitable rooms facing SH16.

8.6.1.7 Preferred Mitigation Option

Overall, the Project team determined that Mitigation Option 5 is the preferred option for dwellings north of SH16 in Sector 6.

The majority of positions assessed (64%) are predicted to receive noise levels of 64 dB $L_{Aeq(24h)}$ or less, and 11% are predicted to receive noise levels of between 64 and 67 dB. This is a considerable betterment over existing noise levels without the Project, with mitigation for individual dwellings up to 11 decibels.

Six buildings have been identified that potentially require building envelope improvements to achieve compliance with the internal noise criterion of 40 dB $L_{Aeq(24h)}$.

8.6.2 South of SH16

South of SH16 and east of Carrington Road, dwellings are in close proximity to the State highway. In the vicinity of Carrington Road, dwellings are elevated above SH16, however, towards the east, the terrain flattens and dwellings are level with the carriageways. A small bank slightly below the properties runs along the edge of SH16.

8.6.2.1 Do-Minimum Scenario

As for dwellings north of SH16, the existing noise environment south of SH16 is elevated, generally between 65 and 70 dB $L_{Aeq(24h)}$. The Project is predicted to increase noise levels in this area further, up to 77 dB for individual dwellings. These noise levels are not considered suitable for residential use.

Forty positions have been assessed in this area, half of which would receive noise levels above 67 dB, i.e. may require building envelope improvements. Exceedance of the Category B criterion is predicted to be up to ten decibels, which is a considerable exceedance.

8.6.2.2 Mitigation Option 1

Placement of the barriers is critical for topography such as that south of SH16 in Sector 6, whereby dwellings are elevated above SH16 and terrain slopes down towards the State highway. Therefore, a barrier has been tested for a location along the highest point between road and properties, in an attempt to obtain the most effective shielding.

Barrier heights have been determined which would allow the greatest noise level reduction for assessment positions, which resulted in barrier heights up to 8 metres. As these barriers would be placed along the

northern property boundary, barriers of such height would have detrimental effects on the properties due to shading and similar issues.

Input from the Project team citing fatal flaws, including considerable shading for properties and the number of properties predicted to require building modification in addition to the substantial barrier, resulted in this option not being pursued further.

8.6.2.3 Mitigation Option 2

A further mitigation option involves barriers being trialled along the edge of SH16. Barriers up to 5 metres in height have been designed. However, this placement of barriers has been determined not to be the most suitable location, particularly in the vicinity of Carrington Road where SH16 is well below the dwellings. Locating a barrier along the State highway edge below the dwellings resulted in reduced effectiveness of the barrier.

Therefore, notwithstanding the considerable heights of these barriers, some dwellings are predicted to remain in Category C, and one quarter of dwellings are predicted to receive noise levels between 64 and 67 dB $L_{Aeq(24h)}$ thus likely to require improving of the buildings.

8.6.2.4 Mitigation Option 3

Mitigation option 3 provides for reduced visual impact of structural mitigation in the form of a 3 metre high barrier, however, the average mitigation would be 2 decibels only, which is less than the requirements of NZS 6806:2010. In addition, 15 of the 40 positions assessed would remain in Category C and would therefore potentially require building improvements.

This option is not considered to constitute the BPO in accordance with NZS 6806:2010 as it does not take account of the degraded existing noise environment and resulting adverse effects for residents in the vicinity. It is therefore not discussed further and has been included for completeness only.

8.6.2.5 Mitigation Options 4 and 5

Both of these options involve locating an uninterrupted barrier along the northern property boundary of residential sites south of SH16. Barrier heights up to 4.5 metres are required, and the utilisation of an additional 2 metre high median barrier has been examined.

While the noise level reduction is significant with an average noise level reduction of 5 and 6 decibels for Mitigation Options 4 and 5 respectively, the feedback from the urban design team has been that barriers of such height along the northern boundary of a residential property would have a detrimental effect. It has also

been noted that the installation of such a high barrier would introduce a different (visual rather than noise related) adverse effect to these properties, which could not be sufficiently mitigated.

Therefore, options 4 and 5 are not considered to fulfil the requirements of the BPO.

8.6.2.6 Mitigation Option 6

Further input from members of the Project team has provided the basis for the development of Mitigation Option 6. While a barrier height of 4 metres has been retained, the barrier has been placed in the bank below the property boundaries thus offsetting the adverse effects to some degree.

The noise level predictions show that with such barrier placement only one property would remain in Category C (26A Carrington Road), and that the exceedance would be small, only 2 decibels. It is also noted that 26A Carrington Road currently receives noise levels of up to 74 dB $L_{Aeq(24h)}$, therefore, the implementation of the mitigation would provide a significant betterment for this dwelling.

Nevertheless, the potential for building improvements in addition to the barrier would require assessment at a later stage in order to achieve compliance with the internal noise criterion of 40 dB $L_{Aeq(24h)}$.

8.6.2.7 Mitigation Option 7

The receiver positions assessed south of SH16 in Sector 6 will be affected by the same extent of carriageway as those assessed on the northern side. Therefore, it is considered that mitigation measures which would benefit all positions assessed in Sector 6 should be tested. This refers specifically to the utilisation of twin layer OGPA surface on SH16 through Sector 6, as discussed in Section 8.6.1.6 above.

Mitigation in the form of barriers for the receivers south of SH16 is considered to be problematic due to visual and shading effects noted by the urban design team, and any reduction of barrier height is considered a positive outcome.

Twin layer OGPA surface was trialled in Mitigation Option 7, and results show that barrier heights can be reduced from 4 metres to 2.5 metres along the northern property boundaries, a considerable improvement in terms of the urban design requirements. Of the positions assessed, 90 percent would receive noise levels compliant with the Category A criterion. Only one dwelling (26A Carrington Road) is predicted to receive noise levels in excess of the 67 dB criterion, however, the exceedance is predicted to be 1 decibel only, an unnoticeable difference (refer Section 4.7).

Mitigation Option 7 for the area south of SH16 is associated with Mitigation Option 6 for the area north of SH16 (refer Section 8.6.1.6 above) due to the proposed Twin layer OGPA surface being required for both east and westbound lanes of SH16. Therefore, it is not possible to select one without the other.

While Mitigation Option 7 provides for the best outcome in terms of noise level reduction, the cost implication (refer BCR determination in the Matrix in Appendix F(iii)) does not support this option as BPO.

8.6.2.8 Preferred Mitigation Option

Of the seven mitigation options developed, Mitigation Option 6 is considered to be the preferred option by the design team. It achieves an acceptable overall noise level reduction (of 6 decibels) with the least number of positions being in Category C.

8.6.3 Preferred Mitigation Options – Sector 6

Through the BPO process, the mitigation options preferred by the Project team for Sector 6 are:

- North of SH16 – Mitigation Option 5
- South of SH16 – Mitigation Option 6

Noise level predictions for Sector 6, including the preferred mitigation options, and figures showing the barrier lengths and heights are shown in Appendix E(iii).

8.7 Sector 7 – Great North Road Underpass

State Highway 20 and its associated ramps will be located in a tunnel in Sector 7. Therefore, noise will be effectively mitigated, and no traffic noise effects have been assessed. However, the tunnel services building, transformers and ventilation shaft will be located in this sector, and have been assessed as noise sources associated with the operation of SH20.

8.7.1 Noise Sources

As discussed in Section 4.4 above, the mechanical noise associated with the tunnel services building and ventilation shaft are of a different character to traffic noise. These noise sources are stationary and can be controlled to an appropriate level.

The tunnel services building and associated activities include:

- Substation
- Control and switch room
- Ventilation fan connected to ventilation stack.

It is considered that noise associated with the tunnel services building, transformer and ventilation systems should generally comply with the noise rules of the underlying zoning of the relevant District Plan, in this instance the Auckland City District Plan – Isthmus Section. It is anticipated that the tunnel services building and ventilation stack will be located on sites zoned Residential.

8.7.2 Noise Criteria

The relevant noise limits for the residential zone are set out in Appendix C, and are, in summary, 50 dB L_{A10} daytime and 40 dB L_{A10} night time.

As proposed in Section 4.4.1 of this report, it is proposed that the noise descriptors of these limits be updated to current standards (NZS 6801:2008 and NZS 6802:2008) to 50 dB $L_{Aeq(15\ min)}$ and 40 dB $L_{Aeq(15\ min)}$ respectively.

Since the noise generation from the services building and ventilation shafts is likely to be relatively constant throughout any 24 hour period, the design limit will be the more stringent limit of 40 dB $L_{Aeq(15\ min)}$.

8.7.3 Tunnel Services Building

The tunnel services building would be underground to some extent. This, and the use of heavy construction materials, such as concrete, for the external walls, would act as effective mitigation measures for noise generated inside the building.

The final design of the tunnel services building has not been completed yet, however, preliminary designs show that facades facing residential sites in the vicinity are of solid construction without openings.

Should any ventilation openings be required facing dwellings, treatment by means of acoustic louvres can be undertaken as necessary to achieve compliance with the relevant noise limits. A wide range of mitigation options is available for the treatment of ventilation openings, and compliance with the most stringent night time noise criterion at the closest residential boundary can be achieved by conventional noise control engineering measures, such as acoustic louvres and the choice of ventilation equipment. The current design shows that sufficient space has been allowed for mitigation measures.

The final design of the mechanical services will be undertaken during the detailed design stage, and relevant noise control measures will be included at that time.

8.7.4 Transformers

The locations of the required transformers have not yet been determined, however, it is anticipated that one transformer is located at either end of the tunnel in the tunnel services building underground, with an additional four transformers throughout the tunnel (also underground). Ventilation of the transformers will occur to the surface, however, noise levels from such ventilation will be mitigated by means of acoustic louvres if required.

Sound power levels of transformers vary; for transformers similar to those potentially used for this Project the noise levels are likely to be 80 to 85 dB. Based on a representative transformer located in the tunnel services building underground, noise levels at the closest receiver position is predicted to be inaudible and therefore, readily compliant with the most stringent recommended noise limit of 40 dB $L_{Aeq(15min)}$, including adjustment for special audible characteristics as noted above.

8.7.5 Ventilation Systems

The mechanical services systems are still at a very early stage of design. Considering this, detailed predictions of noise levels and specification of noise control equipment is not possible. However an initial review of the ventilation systems has been undertaken to identify any area of concern and to highlight key acoustical issues.

There are three primary noise generating components associated with the proposed ventilation system: the vehicle exhaust fans, the in-tunnel jet fans and the (emergency) smoke exhaust fans (located in Sector 8 and discussed in detail in Section 8.8 below).

A summary of the issues associated with the vehicle exhaust fans and in-tunnel jet fans is provided below:

8.7.5.1 Vehicle Exhaust Fans

There are two vehicle exhaust stations, one at either end of the tunnel. Air is extracted from the tunnel and exhausted through a large ventilation stack (approx 25 m high). The current design includes four very large axial fans with a total maximum flow of approximately 550 m^3/s.

The exhaust system would operate continuously, however variable speed drives (VSD) are proposed for each of the fans and the exhaust system will run at reduced flow during off-peak times. This is advantageous acoustically with lower noise levels during the night-time period.

The current design allows for approximately 4 m long attenuators either side of the fans to control noise emissions into the ventilation stack and into the tunnel. The available plenum area after the attenuator would provide sufficient area for acoustic treatment in the form of acoustically absorptive wall lining. High velocities are required in the ventilation stack to ensure good air dispersion. Considering this, additional attenuation inside the stack itself would not be practicable.

Initial calculations based on theoretical calculations of fan sound power levels and preliminary attenuator performance estimates indicate that the noise from the extract fans could be designed to achieve compliance with the recommended 40 dB $L_{Aeq(15\,min)}$ noise limit.

8.7.5.2 In-tunnel Jet Fans

Banks of in-tunnel jet fans are proposed at approximately 120 m intervals along the tunnel (55 fans in total) with the nearest fans at least 120 m from the tunnel openings. The first 50 metres of the tunnel at each end are proposed to be treated with acoustic absorption.

The propagation of ventilation noise within the tunnel is relatively complex and will require further review once the layout of fans in the tunnel has been finalised.

The jet fans are to incorporate attenuators to reduce noise emissions into and from the tunnel. The extent of the attenuation required will depend on the acoustic environment within the tunnel and the fan selection. At this stage it is anticipated that at least 2D long attenuators will be required on the intake and discharge of each of the fans. This means that the attenuator length has to be at least twice the fan diameter.

With appropriate attenuation of the fans and acoustic treatment within the tunnel itself it is predicted that the relevant noise limit of 40 dB $L_{Aeq(15\ min)}$ can be achieved.

8.8 Sector 8 – Avondale Heights Tunnel

8.8.1 Traffic Noise

In Sector 8, SH20 is located in a full tunnel. Traffic noise will be mitigated effectively by enclosing the State highway in a tunnel, and therefore no adverse noise effects are anticipated.

No further traffic noise assessment has been undertaken for this sector.

8.8.2 Smoke Extract

A separate smoke extract system for emergency situations is proposed for the tunnel in addition to the main vehicle emissions exhaust. A plant room is proposed at ground level in Sector 8, at 36 Cradock Street, approximately above the halfway point of the tunnel. The plant room is to house large centrifugal fans which will draw the smoke exhaust from the tunnel via a 50 m high vertical shaft. An exhaust stack of approximately 10 metres in height will be required beside the plant room for discharge.

This system is not part of the general ventilation system and will only operate during emergencies and during maintenance tests. However attenuation will be required to both the intake and discharge sides of the fan.

Attenuation is required to the discharge side of the fan to prevent exceedance of boundary noise conditions during testing periods. Attenuation will be required to the intake side if the fan to reduce noise levels inside the tunnel sufficiently to enable voice alarms to be intelligible.

The plant room should be constructed from heavy materials, such as block work, to minimise noise breakout from the building itself.

It is understood that the smoke extract fans require monthly tests in order to ensure they work effectively. The testing will be undertaken during daytime only, and will require full speed operation of the fans.

In the event of an emergency, the fans would be operating at any time of the day or night. The required rate of smoke extraction limits the mitigation that can be applied to the fans, and it is considered impracticable to achieve the recommended noise limits (refer Section 4.4.1) for emergency operations and the short duration testing during daytime.

Therefore, a higher noise criterion of 65 dB $L_{Aeq(15\ min)}$ is proposed for the operation and testing of the emergency smoke extract system, subject to a restriction on the hours of testing.

8.9 Sector 9 – Alan Wood Reserve

Sector 9 provides for a new road at surface level to link the existing SH20 Mt Roskill to the Waterview Connection and SH16. In this sector, no road currently exists, and therefore, the proposed SH20 constitutes a "new road" as defined by NZS 6806:2010. This means that there is no Do-Nothing scenario to be assessed, and the existing ambient noise levels are utilised as the comparison level.

Sector 9 contains three distinct receiving environments that have been addressed separately; residential areas north of the alignment between New North Road and Richardson Road, generally following Hendon Ave; residential areas south of the alignment between Bollard Ave and Richardson Road, generally following Methuen Ave and Valonia Street; and the site of Christ the King school south of the alignment which incorporates a small number of residential sites. For each of these environments, several mitigation options have been developed and discussed, and a preferred mitigation option chosen based on the BPO criteria.

Alan Wood Reserve is at present in a quiet urban area, which is generally unaffected by significant noise sources such as major transportation routes or businesses. The southern termination where the Waterview Connection would join the Mt Roskill section of SH20, currently receives moderate noise levels from the existing SH20 and major local roads such as Richardson Road.

A current rail designation (presently not given effect to) extends along the Hendon Ave side of the open space, following, and overlapping, the proposed road alignment. Therefore, a realignment of the rail designation is required to accommodate the road alignment. It is noted that it is currently unknown if and when a rail track would be constructed in this area. Therefore, the rail noise would be assessed if and when rail is being designed and constructed and mitigation provided at that stage.

The topography of Sector 9 is generally flat, with the terrain to the south of the proposed route being slightly elevated. This results in dwellings overlooking the alignment. However, those dwellings that are elevated are generally at greater separation distances from the road.

The proposed road alignment will exit the tunnel at approximately the level of 79 Hendon Ave, where the carriageway will be some 15 metres below the current ground level. In the vicinity of 115 Hendon Ave, the carriageway will be approximately level with the surrounding terrain and continue at grade until its connection with the Mt Roskill section of SH20.

While the road is in a deep cut approaching the tunnel portal, traffic noise will be well shielded from surrounding sites. The less depressed the roadway, the less shielding will be provided by the cutting, and other structural noise mitigation measures may be required in order to achieve compliance with the relevant noise criteria.

8.9.1 South of SH20

South of the proposed alignment, 69 assessment positions have been identified. These are residential sites in Methuen Road, Valonia Street and Richardson Road which are within 100 metres of the road alignment. Predicted existing noise levels range from 45 to 64 dBA $L_{Aeq(24h)}$, depending on the proximity of these positions to major transportation routes such as Richardson Road. Noise levels at the lower end of the range are generally experienced by those dwellings facing Alan Wood Reserve and Hendon Park.

Dwellings in Methuen Road are generally slightly elevated above the open space with uninterrupted views over the proposed alignment. Seven mitigation options have been developed for this receiving environment.

8.9.1.1 Do-Minimum Scenario

As noted above, Sector 9 involves a new road being introduced to a currently relatively quiet area. The Do-Minimum scenario, when compared with the existing noise environment, shows noise level increases of up to 21 decibels, with an average noise level increase of 11 decibels. This is a significant change in noise level, and would be very noticeable to residents in the area.

Traffic noise from the new road is predicted to generate noise levels which, without mitigation, would exceed the Category A criterion by up to 8 decibels, and the Category B criterion by up to 5 decibels. These levels are high, and their reduction to acceptable levels would require the implementation of extensive mitigation measures.

It is noted that even with the implementation of mitigation measures, resultant traffic noise levels will be higher than are currently being experienced by residents in the area. Due to the considerable increase in noise level which will occur with the Project, mitigation design has been undertaken with the view of reducing noise levels to the greatest extent practicable, to below the Category A criterion, if this can be demonstrated to be reasonable and feasible.

8.9.1.2 Mitigation Options 1 and 2

Mitigation Option 1 provides for a barrier that would achieve compliance with the Category A criterion of 64 dB $L_{Aeq(24h)}$ at all positions assessed. The resultant 5 metre high barrier would have to be located along the top of the cutting approaching the tunnel, and extend, at varying heights, for a total of 360 metres. The average structural mitigation achieved by this barrier is predicted to be 4 decibels, which is adequate to satisfy the requirements of NZS 6806:2010.

Mitigation Option 2 provides for a slightly lower barrier than Option 4 (up to 4 metres), which has a length of 430 metres. While the average structural mitigation for this option is also 4 decibels, four positions assessed would receive noise levels above the Category A criterion. These positions are generally the upper floors of dwellings where the level would be up to 66 dB $L_{Aeq(24h)}$. The lower floors are predicted to receive noise levels at or below 64 dB $L_{Aeq(24h)}$ thus achieving compliance with the Category A criterion.

Feedback from the Project team, specifically from the visual amenity and urban design team, favoured Mitigation Option 2 over Option 1 due to the reduced barrier height.

8.9.1.3 Mitigation Option 3

Mitigation Option 3 has been developed to assess the benefit of providing a higher barrier which may reduce noise levels further beyond the Category A criterion of 64 dB $L_{Aeq(24h)}$. The Standard requires the implementation of the BPO which includes noise mitigation providing additional benefits to receivers should this be practicable. Mitigation Option 3 consists of barriers up to 6 metres in height, for a total extent of approximately 550 metres.

Barriers of such magnitude are considered not to constitute the BPO in terms of visual effects and landscape design, and are understood to potentially involve safety issues for cyclists using the cycleway, due to not being visible from the State highway. However, in terms of noise reduction effects, the barriers designed for Mitigation Option 6 would perform to a high standard with an average structural mitigation of 6 decibels.

However, with input from all relevant disciplines considered, the following further option has been developed which is considered to represent a more robust outcome.

8.9.1.4 Mitigation Option 4

Mitigation Option 4 is based on Option 2 discussed above. While limiting the overall height of the barrier to 5 metres for visual reasons, the increased barrier length results in further shielding for the dwellings in Valonia Street, and therefore, a slightly better percentage of compliance with the Category A criterion (96% versus 93%).

Input from the Project team (visual and urban design) means that the barrier heights are more regular in height, thus providing for an improved visual outcome. The average structural mitigation for this option is predicted to be 4 decibels, which satisfies the requirements of NZS 6806:2010.

8.9.1.5 Preferred Mitigation Option

The Project team considers Mitigation Option 4 to be the preferred option. It achieves the requirements of NZS 6806:2010 in terms of noise level reductions, and is considered practicable in terms of height and constructability.

The Project team (particularly urban and visual design members) had a strong influence on the development of mitigation measures for this sector of the Project due to the sensitivity of the receiving environment. This influence related not only to noise impacts, but also to the adverse impact that a large structure, such as a noise barrier, would have on what is currently an open space

8.9.2 North of SH20

Part of Hendon Park and Alan Wood Reserve are currently designated for rail purposes. The proposed road alignment requires a realignment of the rail corridor towards the north, closer towards Hendon Ave. This provides for two potential locations for noise barriers, either along the road boundary or along the property/designation boundary.

The topography in this area is level, which would result in the road being in a deep cut at locations close to dwellings, before rising up to grade east of Hendon Ave.

8.9.2.1 Mitigation Option 1 to 3

Three mitigation options have been developed for barriers immediately beside the road boundary, which provide noise level reductions so that all assessment positions would fall within Category A. Generally, noise mitigation should be implemented either close to the noise source or close to the noise receiver, to achieve the most effective noise level reduction. Positioning noise mitigation close to the noise source protects the largest areas possible from noise effects, while positioning mitigation close to the receiver protects a smaller, more focussed area. Therefore, locating noise mitigation closest to the source is generally preferred.

Barrier heights for Mitigation Options 1 to 3 vary from 2 to 4 metres, with Mitigation Option 2 providing the lowest barrier of between 2 and 2.5 in height.

Feedback from the Project team indicated that the positioning of barriers along the edge of the roading corridor may have adverse visual effects on residential sites in Hendon Ave, particularly high barriers in excess of 2.5 metres. Therefore, a further mitigation option was developed limiting the barrier height to 2.5 metres and reducing the length overall while still achieving Category A criteria at all positions.

8.9.2.2 Mitigation Option 4

Mitigation Option 4 provides for a shorter barrier with an overall length of approximately 260 metres and heights of 2 to 2.5 metres.

The average mitigation of this barrier is 3 decibels, which is adequate in accordance with NZS 6806:2010, with individual positions receiving noise levels reductions of 4 decibels. All assessment positions are predicted to fall within Category A, with noise levels below 64 dB.

8.9.2.3 Mitigation Option 5

Mitigation Option 5 has a barrier located along the property boundaries. In order to provide integration with the residential style location of the barrier, the height has been restricted to 2 metres, which is similar in height to a boundary fence.

This barrier is predicted to provide an average mitigation of 3 decibels (sufficient in accordance with NZS 6806:2010). However, one property would receive a noise level marginally above the Category A criterion.

8.9.2.4 Preferred Mitigation Option

Mitigation Option 4 is the Project team's preferred option. It fulfils the BPO requirements of noise level reduction, achieving the Category A criterion and the visual, planning and urban design requirements by being of a residential scale.

8.9.3 South East of SH20 – Christ the King School

At the southern termination of the Project, where the Waterview Connection will connect with the Mt Roskill section of SH20, the predominant land use is business/ industry. On the southern side, Christ the King School is bounded by SH20 to the north east, Richardson Road to the west and Maioro Street to the south. During the designation process for the Mt Roskill section of SH20, a property agreement (the agreement) was reached with the school, which specified the external and internal noise criteria to be achieved on the school site and in the new school buildings, and detailing some of the mitigation measures required to be implemented.

The construction of the new school buildings has been completed, and some of the specified structural mitigation measures have already been implemented. Further barriers will be required to be constructed once the Project is implemented in the vicinity of the school.

In addition to the school site, a small number of residential properties are located in a small area of residentially zoned land accessed from Richardson Road which Projects into the school property towards the

proposed alignment of SH20. These dwellings had not been included in the previous assessment (2006) for the Mt Roskill section of SH20. The traffic noise effects on these dwellings are therefore addressed in this report.

8.9.3.1 Noise Level Criteria – Christ the King

A private property agreement (dated 9 February 2007) was reached between NZTA (former Transit New Zealand) and Christ the King School during the designation process for the Mt Roskill part of SH20. This agreement contains noise performance standards and mitigation requirements for the school site and new school buildings, to be undertaken by NZTA.

The requirements relating to noise are:

(a) noise screening along the western (Richardson Road), south-eastern (Mt Roskill Extension link road) and north-eastern (future Avondale Motorway extension) boundaries of the Remainder Parish Site when construction commences;

(b) noise monitoring, and if necessary measures to the ground of the Existing Parish Site (other than the buildings comprising the Parish Facilities), to ensure that noise levels comply with the levels specified in the attached report from Hegley Acoustic Consultants dated 15 June 2005 and 28 February 2006.

The noise performance standards agreed with the School are:

- 35 dB $L_{Aeq(24h)}$ within the new classroom block
- Mid fifties (55 dB $L_{Aeq(24h)}$) in the courtyards of each classroom block
- Mid to high fifties ($L_{Aeq(24h)}$) in the playing fields.

Barriers agreed to be installed include a 3 metre high barrier along Maioro Street and a 4 metre high barrier along the Waterview Connection.

At present, the new school building has been completed, and the noise barrier along Maioro Street has been installed. The barrier required along the Waterview Connection would be constructed in conjunction with this Project.

As a result of the agreement with the NZTA the new Christ the King school buildings were designed such that an internal noise criterion of 35 dB L_{Aeq} would not be exceeded as a result of the operation of the completed SH20. The design of the building facades was based on predicted external noise levels, which are contained in the agreement.

As construction of the school buildings has been completed based on calculated external noise levels generated by traffic on SH20, these levels are considered to be "de facto" criteria for noise incident on the facades of the school buildings, to ensure compliance with the internal noise criteria.

It is noted that the dwellings located in the middle of the school grounds are assessed against the relevant criteria of NZS 6806:2010 as they are independent of the school.

8.9.3.2 Do-Minimum Scenario

The agreement with the school sets out noise mitigation measures which must be implemented in the construction of the school. These also include external 'structural' mitigation measures such as a 3 metre high barrier along Maioro Street and a 3 to 4 metre high barrier along the proposed Waterview Connection alignment.

These barriers are assumed to constitute the "Do-Minimum scenario" in accordance with NZS 6806:2010 as they are required, by the agreement with the school, to be included in the design of the Waterview Connection.

Do-Minimum noise levels are predicted to increase above existing noise levels by up to 15 decibels, particularly for those assessment positions that are currently unaffected by noise from the recently completed Mt Roskill section of SH20. Do-Minimum external noise levels range from 51 dB $L_{Aeq(24h)}$ for the school courtyard, to 68 dB $L_{Aeq(24h)}$ for the upper floor of one of the Richardson Road dwellings.

While noise levels at the school site are generally compliant with the criteria of Category A and B, the property agreement with the school provides target noise levels that were used as the basis of building envelope design. Therefore, these noise levels constitute 'de facto' criteria for this assessment.

With the implementation of the Project, the Do-Minimum scenario results in compliance with the agreement at all new school buildings.

The dwellings in Richardson Road are assessed against the relevant criteria of NZS 6806:2010, independently from the requirements for the school. One of these positions is predicted to receive noise levels in excess of 67 dB, and mitigation would be required.

8.9.3.3 Mitigation Option 1

Mitigation Option 1 is based on the requirements of the property agreement (as for the Do-Minimum scenario) with a 3 metre high barrier along Maioro Street and 3.6 metre high barrier along the edge of SH20, but then extending past the Richardson Road dwellings.

Predictions show that noise levels would comply with the agreement, and achieve compliance with Category A and B criteria at the Richardson Road dwellings.

8.9.3.4 Mitigation Option 2

Mitigation Option 2 was developed in order to achieve compliance with the Category A criterion at all dwellings in Richardson Road. Longer and higher barriers would be required along the boundaries with Maioro Street and SH20 respectively. Therefore, the barrier abutting Maioro Street has been extended towards Richardson Road, and the barrier along SH20 increased in height from 3.6 metres to 4.5 metres.

The resulting noise levels show that this change in barrier arrangement is unlikely to provide significant improvements. Therefore, Option 2 is considered not to constitute the BPO.

8.9.3.5 Mitigation Option 3

Information from the Mt Roskill Project team relating to the most up to date barrier heights and locations for the school has resulted in the computer noise model being adjusted slightly. The refined barrier location will provide more effective mitigation. With the aim of reducing the noise level predicted to be received at the Richardson Road dwellings (68 dB $L_{Aeq(24h)}$), the 4 metre barrier has been extended towards the north, past the Richardson Road residential sites. This is in addition to the barriers that are 3 metres high along Maioro Street, and 4 metres high along SH20.

This mitigation option is predicted to result in all dwellings complying with the Category B criterion. Noise levels at the school buildings are shown to be compliant with those noise levels set out in the agreement.

8.9.3.6 Preferred Mitigation Option

Mitigation Option 3 is the Project team's preferred option. It fulfils the BPO requirements of noise level reduction, achieving the Category A and B criteria at the Richardson Road dwellings and fulfils the requirements of the Property agreement with Christ the King School.

8.9.4 Preferred Mitigation Options – Sector 9

Through the BPO process, the mitigation options preferred by the Project team for Sector 9 are:

- South of SH20 – Mitigation Option 4
- North of SH20 – Mitigation Option 4
- South west of SH20 (Christ the King School) – Mitigation Option 3

Noise level contours for Sector 9, including the preferred mitigation options and figures showing the barrier lengths and heights are shown in Appendices G and E respectively.

8.9.5 Tunnel Ventilation

Sector 9 includes the southern tunnel portal and ventilation shaft. As discussed in Section 8.7 above, noise from non-traffic sources, such as the ventilation shaft, have been assessed against the District Plan noise rules of the underlying zone. In this instance, the ventilation shaft is proposed to be located between the carriageways in the vicinity of the tunnel portal, and therefore, in the Special Purposes Activity zone.

Relevant noise limits for this zone are shown in Appendix C and are the same as for Residential zones, i.e. 50 dB L_{Aeq} daytime and 40 dB L_{Aeq} night time.

The closest noise sensitive positions would be more than 60 metres from the ventilation shaft. With suitable placement of the stack, and mitigation similar to that discussed in Section 8.7 above, it is predicted that compliance with the relevant District Plan noise limits can be achieved.

9. Summary and Conclusions

An extensive and detailed assessment of operational noise effects for the proposed Waterview Connection Project has been undertaken. Each Project sector has been assessed separately, and mitigation designed for relevant sectors (1, 5, 6 and 9).

The assessment of traffic noise effects is based on New Zealand Standard NZS 6806:2010 Acoustics – Road-traffic noise - New and Altered Roads.

The assessment is based on a combination of measurement and predictions undertaken by computer noise modelling. Noise level surveys were conducted in 2003, 2006 and 2009 and have been used to verify the computer model. Traffic volumes for the years 2010 and 2026 (the design year) have been utilised to predict existing and future noise levels, with and without the Project in place.

Detailed assessments of effects and development of numerous mitigation options has been undertaken specifically for Sectors 1, 5, 6 and 9 as these contain a considerable number of protected premises and facilities such as dwellings and teaching facilities. This process is in accordance with the requirements of NZS 6806:2010 and is based on the best practicable option (BPO) approach of the Resource Management Act.

The mitigation options have been presented to, and assessed with, the full Project team. The resultant extensive feedback and input provided has resulted in mitigation options being developed and refined. For all sectors, preferred mitigation options have been selected and presented in this report, together with a description of the processes by which decisions were made.

Noise mitigation proposed for this Project include various types of measures such as low-noise road surface material, road side barriers, higher edge safety barriers, bunds and building improvements, where necessary and appropriate. The most effective placement of barriers has been determined for each sector in order to fulfil the requirements of NZS 6806:2010 that structural noise mitigation achieves a minimum noise reduction performance to be considered practicable.

It is considered that the principle of the best practicable option has been applied consistently throughout this assessment, and resulting mitigation options are practicable and achieve appropriate noise level reductions.

Preferred mitigation Options for each of the relevant sectors are:

- Sector 1
    - North of SH16 (Te Atatu Peninsula) – Mitigation Option 3
    - South east of SH16 and Te Atatu Road – Mitigation Option 1
    - South west of SH16 and Te Atatu Road – Mitigation Option 3

- Sector 5
    - South of SH16 (Waterview) - Mitigation Option 10
    - North of SH16 (Pt Chevalier) - Mitigation Option 5
    - South east of SH16 and SH20 (UNITEC) - Mitigation Option 4
- Sector 6
    - North of SH16 - Mitigation Option 5
    - South of SH16 - Mitigation Option 6
- Sector 9
    - South of SH20 - Mitigation Option 4
    - North of SH20 - Mitigation Option 4
    - South east of SH20 (Christ the King School) - Mitigation Option 3.

As this assessment is based on a detailed process to determine the BPO, it is not possible to then apply a retrospective performance specification (i.e. a numerical limit) to define that outcome. Any designation conditions should instead require the actual physical mitigation measures determined by this assessment to be implemented.

In most sectors there are a number of buildings that have been identified where building modification may be required. The process for the individual assessment of these dwellings is discussed in Section 6.3.3 of this report.

The buildings with the potential to require building modification are shown in Table 9.1 below.

Table 9.1: Dwellings predicted to be in Category C (> 67 dB $L_{Aeq(24\ h)}$)

Address	Predicted Noise Level dB $L_{Aeq(24\ h)}$
Sector 1	
14 Milich Terrace	69
38 Alwyn Avenue	73
40A Alwyn Avenue	72
42 Alwyn Avenue	68
Sectors 4, 5 and 7	
49 Montrose Road	68
UNITEC (approx. 3 façades)	70
Sector 6	
1102 C, D, E, F, G, H Great North Road	69 - 77
10 Parr Rd Nth	68
12 Parr Rd Nth	74
26A Carrington Rd	69

Noise sources other than traffic, specifically the tunnel services building and associated activities, and the ventilation stacks, are assessed against the District Plan noise limits of the underlying zone. Based on the proposed placement of these activities, the relevant noise limits can be complied with at all relevant receiver locations, with the utilisation of standard and readily available engineering solutions.

Overall, it is considered that the Waterview Connection Project can be operated such that significant noise effects can generally be avoided, remedied or mitigated by utilising the best practicable option approach and the achievement of compliance with the relevant criteria of NZS 6806:2010.