MARSHALL DAY Acoustics

SH16 SAFETY IMPROVEMENTS
STAGE 2: BRIGHAM CREEK ROAD TO KUMEŪ
ASSESSMENT OF ACOUSTIC EFFECTS

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Sensitivity: General

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Project: **SH16 SAFETY IMPROVEMENTS**

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1.0 INTRODUCTION

Beca has engaged Marshall Day Acoustics to provide a noise and vibration assessment of the proposed SH16 Stage 2 works. The Stage 2 works involve an upgrade of the existing State highway from Brigham Creek Road to Kumeū. This section is further split into four subsections as shown in Figure 1 below.

The report discusses noise and vibration effects from the proposed construction works, and from traffic using the road.

This report is intended to form part of an application that will be submitted to Auckland Council for their consideration under the relevant statutory process.

A glossary of terminology is attached in Appendix A.

2.0 PROJECT DESCRIPTION

Stage 2 of the SH16 works extends 4.3 km from Brigham Creek Road to Kumeū, as shown in Figure 1 below.

Figure 1: Project extent

Improvement works include the following:

- A combination of wire median barriers and wide centre lines along the length of the corridor, and construction of wire side barriers
- Providing lane widths of 3.5m, shoulder widths between 1m and 1.5m and wire median barrier centreline widths of between 1.5m and 2.5m (1.5m wide centreline and 2.5m wide median with guardrail)
- Constructing turning bays
- Accessway changes
- Construction of a roundabout at the intersection of SH16 and Coatesville-Riverhead Highway, including local connection roads and accessways

- Double lanes for both east and west bound directions from the Brigham Creek Road roundabout to the Coatesville-Riverhead Highway roundabout
- Double lanes for both directions from Coatesville-Riverhead Highway to the Taupaki Road roundabout
- Re-marking of the existing road
- Construction of a 3m wide shared path for cyclists and walkers between Kumeū and Brigham Creek
- The full extent of works, as reviewed by MDA, can be seen in drawing numbers SR1003 – 01 – CE – 1201-1213.

3.0 EXISTING ENVIRONMENT

The existing noise environment from traffic on existing roads provides a baseline for assessing noise effects. Effects can be assessed by quantifying the noise levels that people would experience due to the implementation of a project. The change in noise environment can then be interpreted in relation to subjective responses of people and possible annoyance. In addition, measured noise levels are used to verify the computer noise model.

The existing noise environment at all protected premises and facilities (PPFs) is controlled by traffic on SH16.

3.1 Surveys

Long duration noise level surveys were undertaken in June and July 2021, at two locations adjacent to the Project. Loggers were installed and measured noise levels continuously. The measured data was analysed, and 24-hour noise levels determined.

All noise level survey results are shown in Table 1.

Table 1: Noise level survey results

Location	Survey dates	dB $L_{Aeq(24h)}$
291 SH16	23 – 30 June 2021	64
315 SH1	2 – 7 July 2021	66

Diurnal variation of ambient noise levels is shown in a summary in Appendix B.

3.2 Modelling

In addition to measuring the noise levels at a number of locations along the alignment, computer noise modelling enables the prediction of existing noise levels at all PPFs within the assessment area 100 to 200 m from the edge of the carriageway for urban and rural areas respectively, in accordance with New Zealand Standard 6806:2010 *"Acoustics – Road-traffic noise- New and altered roads"* (refer Section 4.3).

3.3 Historic Buildings

The building at 238 SH16 (the former Sinton Family homestead) is close to the Project and is classed as a heritage building.

Other buildings with historic value, although not currently on the Council's heritage schedule, include:

- 191 SH16 (former Janet Sinton homestead and other buildings)
- 222A SH16 (former Alex Sinton homestead and large shed)

We have assessed these buildings accordingly, both in relation to construction vibration and traffic noise mitigation.

4.0 PERFORMANCE STANDARDS

4.1 Construction Noise

Most of the works are undertaken within the existing designations. The existing designations do not contain any conditions relating to construction noise.

Where works are undertaken outside the existing designations, the Auckland Unitary Plan (Operative in Part) (AUP) construction rules have been used as the basis of this assessment. In the absence of relevant designation conditions, we have used the AUP rules as a benchmark of assessment also for works within the existing designations.

The AUP Rule E25.6.27 provides construction noise limits. Rule E25.6.1.3 states that the noise from construction must be measured and assessed in accordance with New Zealand Standard NZS 6803: 1999 *"Acoustics - Construction Noise"*. This rule applies in all zones except the Business – City Centre Zone and the Business – Metropolitan Centre Zone.

For construction works with a duration longer than 20 weeks (such as this Project), the noise criteria when measured at 1m from an occupied building are:

Table 2: Construction noise criteria

Time of Week	Time Period (hrs)	Noise Limits	
		dB L_{Aeq}	dB L_{AFmax}
Occupied buildings containing activities sensitive to noise			
Weekdays	0630 – 0730	55	70
	0730 – 1800	70	85
	1800 – 2000	65	80
	2000 – 0630	40	70
Saturdays	0730 – 1800	70	85
	1800 – 0730	40	70
Sundays and public holidays	0730 – 1800	50	80
	1800 – 0730	40	70
Other occupied buildings			
All days	0730 – 1800	70	-
	1800 – 0730	75	-

Rule E25.6.29 relates to construction noise levels for work within the road. Rule E25.6.29 (2)(c) allows exceedance of the night-time noise criteria in Table 2 if the nature of the works and the proximity of receivers means that noise generated cannot practicably be made to comply with these limits. In that event, a Construction Noise and Vibration Management Plan (CNVMP) must be prepared (refer AUP Rule E25.6.29 (5)).

Some of the works may be undertaken at night-time. Since the night-time construction noise criterion is low at 45 dB L_{Aeq}, non-compliance would routinely occur if noisy construction works were undertaken at night-time.

4.2 Construction Vibration

4.2.1 Auckland Unitary Plan

Most of the works are undertaken within the existing designations. The existing designations do not contain any conditions relating to construction vibration. Where works are undertaken outside the existing designations, the AUP construction rules form the basis of this assessment.

In the absence of relevant designation conditions, we have used the Waka Kotahi Guide (refer Section 4.2.2) as a benchmark of assessment for all works irrespective of them being inside or outside the existing designations.

Rule E25.6.30.1 sets out construction vibration limits in two clauses. Clause (a) protects buildings from cosmetic damage due to construction vibration and specifies that construction should not exceed the limits set out in German Standard DIN 4150-3 (1999): Structural Vibration – Part 3 Effects of Vibration on Structures. These limits are shown below:

Table 3: Construction vibration limits

Type of Structure	Short-term vibration*				Long-term vibration
	PPV at the foundation at a frequency of			PPV at horizontal plane of highest floor (mm/s)	PPV at horizontal plane of highest floor (mm/s)
	1-10Hz (mm/s)	10-50Hz (mm/s)	50-100Hz (mm/s)		
Commercial / industrial	20	20 – 40	40 – 50	40	10
Residential / school	5	5 – 15	15 – 20	15	5
Historic / sensitive structure	3	3 – 8	8 – 10	8	2.5

* The Standard defines short-term as "*vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated*".

Clause (b) provides vibration amenity limits when measured within an occupied building sensitive to noise. During daytime between 0800 – 2200 hrs, the limit is 2mm/s Peak Particle Velocity (PPV). However, the rule allows for up to three days of more intensive works provided it is less than 5mm/s PPV and that prior notification is given to receivers within 50m of the works.

4.2.2 Waka Kotahi Construction Noise and Vibration Guide

In addition to the rules of the AUP, Waka Kotahi has issued its own guidelines for the assessment of construction noise and vibration. The Waka Kotahi "State Highway Construction and Maintenance Noise and Vibration Guide" (the Guide), V1.1, August 2019. In relation to noise, it references generally NZS 6803:1999 and contains some supporting information relevant for the preparation of Management plans and schedules (refer Section 5.3.4).

In relation to vibration, both the AUP and Waka Kotahi guidelines reference relevant vibration standards for construction works. These criteria are similar insofar as they address two vibration responses:

- One set has reference criteria for human amenity which act as trigger levels for consultation and communication, and
- The other set of standards are designed to avoid cosmetic building damage. This is achieved by ensuring compliance with the provisions of German Standard DIN 4150-3:1999 "Structural Vibration - Part 3: Effects of Vibration on Structures". Waka Kotahi's vibration standards also allow

for the application of the British Standard BS 5228-2:2009 "Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration" at unoccupied buildings.

We recommend the application of the Waka Kotahi vibration standards as referenced in the Guide set out in Table 4 below.

Table 4: Vibration standards at all buildings

Receiver	Location	Details	Category A	Category B
Occupied PPFs	Inside the building	Night-time 2000h-0630h	0.3 mm/s PPV	1mm/s PPV
		Daytime 0630h-2000h	1mm/s PPV	5mm/s PPV
Other occupied buildings	Inside the building	Daytime 0630h-2000h	2mm/s PPV	5mm/s PPV
All other buildings	Building foundation	Vibration – transient	5mm/s PPV	BS 5228-2 Table B.2*
		Vibration – continuous		BS 5228-2 50% of Table B.2 values*

In general terms, the Category A standards of the Waka Kotahi Guide aims to avoid annoyance of receivers. Because these criteria are conservative, there is a provision in the Guide to relax them if they cannot be practicably met, provided a vibration expert is engaged to assess and manage construction vibration to comply with the Category A standards as far as practicable. In addition, affected people should receive communication about the proposed works and anticipated effects, to avoid concern.

If Category A is not practicably achievable, the focus is then shifted to avoiding building damage rather than annoyance by applying the Category B standards. If the Category B standards are complied with, then building damage is unlikely to occur. If Category B standards are predicted to be exceeded, then monitoring of vibration levels during works and, prior to construction commencing, building condition surveys must occur to allow an assessment of and response to any effects.

The German Standard, that sets the 5mm/s Category B standard, is a conservative standard designed to avoid all (including cosmetic) damage to buildings, e.g. superficial damage like cracking in plaster. Significantly higher standards would be applied if damage to structural foundations was the only consideration.

Our assessment references both the relevant AUP rules and the Guide where appropriate.

4.3 Traffic Noise

The Project Team planners have advised that since a designation is sought, the rules from the AUP do not apply to this Project.

Our assessment is twofold:

An assessment of the effects of the Project against the existing and future existing environment in relation to the potential change in noise, and

Against the rules of the Auckland Unitary Plan Operative in Part (AUP), and the Waka Kotahi guidelines, both of which reference NZS 6806. Rule E25.6.33 of the AUP requires the following:

> *(1) All new roads and all altered roads that are within the scope of New Zealand Standard NZS 6806:2010 Acoustics – Road traffic noise – New and altered roads must comply with the requirements of New Zealand Standard NZS 6806:2010 Acoustics – Road traffic noise – New and altered roads.*

4.3.2 NZS 6806

NZS 6806 has been developed by a group of independent acoustic experts, roading industry representatives and the Ministry of Health. The Standard allows for strategic infrastructure to develop while mitigating the adverse traffic noise effects on the environment. It aims for appropriate noise levels to be achieved in relation to 'altered roads', regardless of whether those noise levels are a result of the project being undertaken. This approach is based on the consideration that the implementation of a project provides an opportunity for betterment in circumstances where noise levels are unreasonably high, which is also a requirement of Section 16 of the RMA. In this respect, the application of NZS6806 differs from the effects assessment required under the RMA (apart from Section 16) which just requires the effects from the project to be assessed.

The Standard provides separately for 'new' and 'altered' roads, with different thresholds of applicability and criteria. This Project consists of an altered road only.

Assessment Positions

The Standard identifies noise sensitive receivers called 'protected premises and facilities' (PPFs), such as, but not limited to, dwellings and educational facilities. The Standard provides criteria and processes so that these receivers are protected from road traffic noise impacts.

Commercial and business buildings uses are not PPFs as excluded from assessment as they are not considered to be noise sensitive and are often noise generators in their own right.

NZS 6806 stipulates that the assessment area is dependent on the Statistics New Zealand definition of the area, i.e. either urban or rural. This definition is not dependent on the future use of the area. In an urban area (as defined by Statistics New Zealand), all PPFs within 100 metres of the alignment shall be assessed and excludes locations outside this area. For PPFs located in a rural area, then the standard applies for all those within 200m from the alignment. According to Statistics New Zealand's boundary map[1], the Project traverses generally rural areas only, with a small section at Kumeū in the urban area.

The PPFs are grouped in assessment areas or clusters that would benefit from the same mitigation (e.g. barrier). For this Project, we have identified 18 assessment areas, ten on the eastbound side of SH16 and eight on the westbound side. Some assessment areas only contain one PPF, while others include up to 11 PPFs. The assessment areas fall into the sections (refer Figure 1) as follows.

Table 5: Assessment areas and sectors

Sector	Assessment areas
A	East 1, 2, 3 West 1, 2, 3, 4
B	East 4, 5 West 5
C	East 6 West 6
D	East 7, 8, 9, 10 West 6, 7, 8

[1] https://datafinder.stats.govt.nz/layer/105158-urban-rural-2021-generalised/

Criteria

The noise criteria of the Standard are dependent on whether the project consists of a new or altered road and are to be achieved generally at the most exposed façade of a PPF. For this Project, all PPFs have been assessed against the altered road criteria as the Project involves the upgrade of the existing SH16.

There are three criteria categories (A, B and C) which are set out in Table 6 below. These criteria are considered to provide for an acceptable level of amenity for both outdoor and indoor uses.

Table 6: NZS 6806 assessment criteria categories

Category	Altered Roads dB $L_{Aeq(24h)}$
A (primary external noise criterion)	≤ 64
B (secondary external noise criterion)	64 - 67
C (internal noise criterion)	40*

* This criterion applies only for those habitable rooms and following the implementation of the Project and all structural mitigation such as road noise barriers or specific low noise road surface.

The criteria to be achieved 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.

Traffic Noise Predictions

NZS 6806 assesses several different scenarios which are then compared. These are:

- The "existing environment" which, for altered roads, represents the current road layout and traffic volume, and for new roads the ambient noise environment as determined by survey and modelling. Both are determined based on the existing year (i.e. approximately 2021)
- A future "Do-nothing" scenario, which represents a scenario at the design year where the Project has not been implemented, however, traffic volumes and subsequent sound levels have changed – generally increased – over time
- A future "Do-minimum" scenario, which represents the circumstances at the design year where the Project has been implemented without any specific noise mitigation. This means that the selection of road surface material has not been undertaken on its sound generating characteristics, and the only barriers included are safety barriers, which are required for reasons other than noise mitigation. Note that the Do Minimum scenario is intended to assess the effect of the new/altered road. Therefore, this scenario does not include noise contributions from local roads that are outside of the Project works/designation
- Where required, mitigation options would be assessed to determine the best practicable mitigation for the circumstance

The design year is normally a year between 10 and 20 years after the opening of a project. For this Project, the design year is selected by the Project team as 2046.

Mitigation Requirements

The standard sets out mitigation requirements based on the BPO. Mitigation is split into structural (road surface, barriers, bunds etc) and building modification mitigation (improvement of building façades and ventilation, after the implementation of the structural mitigation). Any mitigation should,

as far as practicable, achieve a noticeable noise level reduction of an average of 3 decibels, or 5 decibels where individual PPFs are mitigated.

The term "barrier" is used as a combined term to mean any acoustically effective boundary fence, earth bund or wall, indicating that the form of the barrier (when within certain parameters regarding weight and lack of gaps) is open to be determined by the urban design team.

Application and Limitations of the Standard

There are two steps that must be followed to determine whether an assessment is required to be carried out in accordance with the road noise standard.

The first step in this process is to determine if the proposal includes roads defined in the Standard as a 'new road' or as an 'altered road'. For this Project, Stage 2 is considered an "altered road".

The second step is then to determine whether the standard would further apply to the Project with respect to clause 1.5.2 for altered roads. In summary, the standard applies only when the do-minimum noise environment is compared to the do–nothing noise environment, and certain criteria are met. These are:

- the do-minimum noise environment is greater than or equal to 64 dB $L_{Aeq(24h)}$ and noise levels are predicted to increase by 3 dB, or;
- the do minimum noise environment is greater than or equal to 68 dB $L_{Aeq(24h)}$ and noise levels are predicted to increase by 1 dB

For the requirements of Clause 1.5.2 to be considered, the do-nothing and do-minimum noise levels must be predicted for representative PPFs within the assessment area. Our predictions indicate that the Project qualifies as an altered road.

4.4 Waka Kotahi Traffic Noise Assessment Guide

In addition, Waka Kotahi has released its *"Guide to assessing road-traffic noise using NZS 6806 for state highway asset improvement projects (Version 1.1, August 2016)"* (Waka Kotahi Guide). The Waka Kotahi Guide describes how NZS 6806 should be implemented. In addition, some Waka Kotahi specific processes are described, such as the use of a Waka Kotahi internal matrix of project discipline feedback when determining the BPO for noise mitigation. Overall, the Waka Kotahi Guide provides background on how to implement NZS 6806 and is therefore a useful complimentary document to the Standard itself and has been applied to this Project for the assessment of the BPO.

4.5 Subjective perception of noise level changes

In addition to the application of NZS 6806, we have assessed the potential effects on people guided by the predicted change in noise level.

The subjective impression that people have of road noise are related to a number of aspects, e.g. the changes in noise level, people's feeling about a road or projects, the character of noise and if it remains unchanged etc.

For this Project, the character of noise will not change, i.e. the upgrade of the existing road will not result in a change in the controlling noise source (traffic).

When looking at the change in noise level, while every person reacts differently to noise level changes, research shows a general correlation between noise level changes and subjective responses.[2] Table 7 shows indicative subjective responses to explain the noise level changes discussed in this report.

[2] For instance, LTNZ Research Report No. 292: Road traffic noise: determining the influence of New Zealand Road surfaces on noise levels and community annoyance, Table 18.

The perception of these noise level changes generally applies to immediate changes in noise level, unlike for this Project where an existing road is modified in a minor way. In addition, people may subjectively have an annoyance reaction to a greater or lesser degree, depending on their perception of the Project or their personal sensitivity.

Table 7: Noise level change compared with general subjective perception

Noise level change	General subjective perception[3]
1–2 decibels	Insignificant/imperceptible change
3–4 decibels	Just perceptible change
5–8 decibels	Appreciable to clearly noticeable change
9–11 decibels	Halving/doubling of loudness

Noise is measured on a logarithmic scale, meaning that a doubling in traffic volume (e.g. from 10,000 vehicles per day (vpd) to 20,000 vpd) results in a noise level increase of 3 decibels, a just-perceptible change. A tenfold increase in traffic volume (e.g. from 10,000 to 100,000 vpd) would result in a noise level increase of 10 decibels, which would sound twice as loud.

5.0 ASSESSMENT OF CONSTRUCTION NOISE AND VIBRATION

5.1 Noise

Indicative sound power levels for equipment likely to be used in the construction phase are listed in Table 8. The table also shows predicted noise levels at distance, and the compliance setback distance at which the daytime noise limit would be complied with (without mitigation/shielding). We note that the terrain throughout the Project extent is slightly undulating so there would be little shielding provided by the local terrain. The predicted levels below assume uninterrupted line-of-sight and are therefore a worst-case level.

Table 8: Indicative construction noise levels without mitigation or shielding (unless noted)

Equipment	Equipment Sound Power Level (dB L_{Aeq})	Noise Level at 1m from the facade (dB L_{Aeq})			Compliance Setback (m)
		20 m	50 m	100 m	70 dB L_{Aeq}
Dozer	109	78	69	61	44
Truck (driving)*	108	72	63	55	25
Bored or screw piling (small)	103	72	63	55	25
Concrete truck and pump (Discharging)	103	72	63	55	25
Excavator (20T)	103	72	63	55	25
Paving Machine	103	72	63	55	25
Vibratory roller	103	72	63	55	25
Concrete drill**	108	67	58	50	14
Bitumen emulsion	94	63	54	46	9
Generator (150kVA)	93	62	53	45	8

[3] Based on research by Zwicker & Scharf (1965); and Stevens (1957, 1972).

Equipment	Equipment Sound Power Level (dB L_{Aeq})	Noise Level at 1m from the facade (dB L_{Aeq})			Compliance Setback (m)
		20 m	50 m	100 m	70 dB L_{Aeq}
Truck (idling)	91	60	51	43	6

* Takes account of time component of passing noise source.
** 10 dB shielding allowed for

Based on the above, for most daytime works, noise levels would comply at most locations. For dwellings located closer than 25m from works, management and mitigation would need to be implemented.

Notwithstanding this, the construction noise standard requires in all cases that the best practicable option is implemented irrespective of whether compliance is achieved, based on the high relative noise levels generated from on-site construction activity.

We understand that limited night-time works may be required where daytime works would cause traffic disruption (e.g. where SH16 would need to be closed for the works). In order to achieve compliance with the night-time noise limit, a large setback distance would be required if line-of-sight is maintained.

For many of the dwellings this means that construction noise levels would exceed the night-time noise limit (even with mitigation) by a considerable margin, and management and mitigation would need to be implemented, including potentially offers of temporary relocation if noise or vibration effects from the works cannot be managed otherwise. It is noted that construction will travel along the alignment progressively, thus each dwelling will only be affected for a limited time when works are in the vicinity. This may extend from two nights to potentially up to 10 nights, depending on the works required and the line-of-sight from the receiving dwelling to the works.

5.2 Vibration

Construction vibration levels would generally be low for all works, with the exceptions of the retaining wall installation and the use of earthmoving equipment and vibratory rollers for road widening.

Where these activities occur, they are generally not close to dwellings (i.e. more than 30 metres away). In any event, the retaining walls would not require vibratory or impact piling, but rather be constructed as drilled piles, thus reducing construction vibration levels further.

Use of vibratory rollers is the main source of vibration. The safe setback distance, where outside of which, it is predicted that there is no exceedance of the vibration limit, is given below in Table 9. These values are based on a large number of measurements of vibratory rollers, conducted by Marshall Day Acoustics across Auckland and New Zealand. We have used values that are at the higher end of the range to be conservative. In addition, these setback distances include a 100% safety margin to account for different ground types and equipment variation. They are conservative and based on all vibration surveys undertaken by Marshall Day Acoustics, vibration levels will generally be lower at the setback distances given in the table below.

Table 9: Vibratory roller safe setback distance (with 100% safety margin)

Equipment	Vibration Amenity (2mm/s)	Cosmetic Building Damage		
		Heritage (2.5mm/s)	Residential (5mm/s)	Commercial (10 mm/s)
Vibratory Roller	38	30	14	6

Several dwellings are within 14m of a potential vibratory rolled area. These receivers are 175, 218, 291, 340, 407A and 507 SH16. Two commercial buildings appear within 6m of the alignment edge, The Grind Café at 1 Kennedys Road and The Kumeu Produce Market at 407A SH16.

The Sinton buildings at 191, 222A and 238 SH16 are all between 25 and 30 metres from the proposed works.

Therefore, in order to manage vibration effects, alternative ways of compaction may need to be used. We recommend that, if practicable, a static roller is used instead. If this is impracticable, we recommend that a pre-construction building condition survey is carried out. This will enable determination of liability due to damage that may be caused due to and during the vibratory rolling. It is also important that communication with affected parties is carried out. This is discussed further in Section 5.3.1 below.

With respect to amenity, there will be a number of affected parties. We recommend that all receivers within 40m of the alignment are notified prior to any vibration works occurring so that vibration effects are minimised.

5.3 Mitigation and Management

Night-time works may be required. This would mean that compliance with the relevant criteria is not practicable, even with mitigation in place. Therefore, the activities would need to be managed through a CNVMP, as per AUP Rule E25.6.29 (5).

Mitigation measures, which will be outlined in the CNVMP are discussed below. The CNVMP will contain information regarding noise performance standards, predicted levels, affected receivers, on-site management, mitigation options, communication procedures, and complaints procedures.

The CNVMP should be implemented on site for the duration of the construction works. It is considered a living document and should be kept up to date regarding actual timing/equipment use and methodologies, should these change throughout the construction process.

5.3.1 Engagement

The most important management tool for construction noise and vibration is consultation and communication.

Any persons affected by noise levels higher than the construction noise and vibration limits would need to be informed of the proposed works, including timing. Notice should be provided to those households prior to works being carried out, by means of letter drops or similar. In addition, a contact phone number should be available to residents should they have concerns about the works or require further information.

It is understood that a communication plan has already been developed for this Project. This Plan should reflect the communication requirements for noise issues contained in the CNVMP.

5.3.2 Barriers

Placing temporary noise barriers, such as sheets of plywood or construction noise curtains, between dwellings and the construction activities can reduce noise levels by up to 10 decibels. While some works can benefit from localised screening (e.g. using a concrete drill or saw for the installation of the wire barriers), other activities are linear and cannot be practicably mitigated by barriers.

5.3.3 Avoidance of Unnecessary Noise and Vibration

At many construction sites, some practices unnecessarily increase noise or vibration levels. Examples include the sounding of horns when a truck is fully laden, the utilisation of tonal reversing alarms or the forced cleaning of excavator buckets by thumping them on the ground.

In addition, noisiest works such as concrete drilling or cutting should be scheduled for early in the night (before midnight) to manage effects.

Noise and vibration levels can be reduced by means of site management and protocols, fitting of mufflers to trucks, the replacement of tonal reversing alarms with broadband reversing alarms and considerate use of machinery.

5.3.4 Site Specific Construction Noise and Vibration Management Schedule

At present, only potential effects have been assessed, based on potential worst-case scenarios. However, when a contractor has been appointed and equipment, timing and staging is better understood, these facts will be included in the CNVMP. To determine the most appropriate and best practicable option for mitigation and management for each dwelling, we recommend that a Schedule be prepared prior to works in the vicinity. This plan will be based on actual predicted noise levels for the dwelling in question, including any terrain shielding present, and take account of the actual duration of the works to be undertaken.

Consultation with the affected residents will then enable an appropriate response, ranging from management such as timing of works, through mitigation in the form of temporary barriers or choice of equipment, to the offer of temporary relocation in extreme cases where ongoing night-time works near dwellings are required.

Therefore, we recommend that both an overarching CNVMP and additional Schedules be produced to ensure the more appropriate implementation of noise management and mitigation

6.0 ASSESSMENT OF TRAFFIC NOISE

6.1 Assessment of traffic noise effects

We have assessed the traffic noise effects on people twofold:

- In relation to compliance with NZS 6806 following the BPO process for noise mitigation and focussing on achieving the most stringent noise criteria category practicable, and
- In relation to noise level changes and associated noise effects (both beneficial and adverse)

The reason for the two-pronged approach is that in some circumstances, compliance with the Standard does not necessarily mean that the effects of a project will be minor, and vice versa.

Potentially, the effects can be positive under NZS 6806 despite high resultant noise levels, e.g. where the Project results in a noise level reduction below existing noise levels.

Overall, we note that any traffic noise effects due to change in noise level (positive or negative) are generally somewhat temporary. People typically become habituated to their environment, including noise levels, particularly where the character of the sound does not change (i.e. if existing traffic noise increases). Nevertheless, high noise levels can result in adverse health effects, and mitigation is required to avoid such levels as far as practicable, irrespective of the change in noise level.

6.2 Methodology

6.2.1 Computer noise modelling

The propagation of road traffic noise is affected by multiple factors, amongst them:

- Terrain elevations, including shielding from intervening terrain and exposure due to elevation
- Ground condition, including absorptive ground such as meadows
- Atmospheric conditions, including wind or temperature inversions and
- Road parameters, including road surface, traffic speed, vehicle types and gradient

Because of the multiple factors and their interaction, computer noise modelling is a vital tool in predicting traffic noise impacts in the vicinity of major roads and for the determination of mitigation

measures. Modelling enables a comprehensive and overall picture of noise impacts to be produced, taking into consideration all the factors potentially affecting noise propagation.

We used the software 'SoundPLAN', which is an internationally recognised computer noise modelling programme. In summary, SoundPLAN uses a three-dimensional digital topographical terrain map of the area as its base. In addition, we entered data into the model for existing buildings and structures (including auxiliary buildings and existing Transport Agency noise barriers) within the assessment area. We digitised road traffic noise sources, with road lanes located on the terrain file.

The SoundPLAN model uses the calculation algorithms of the "Calculation of Road Traffic Noise" methodology which is referenced in NZS 6806 in Section 5.3.2. The calculation algorithms take account of all the factors set out above, including relevant atmospheric and ground conditions within appropriate parameters.

The adjustments for New Zealand road conditions, specifically road surface types, are also included in the model. Therefore, modelling results can be compared with the relevant criteria without further adjustment.

6.2.2 Model input

The road parameters used in the model are set out in Table 10. The speed for all roads and scenarios is 80 km/h.

Table 10: Road parameters

	Existing 2021				Do-Nothing 2046				Do-Minimum 2046			
Road	**AADT[1]**	**%HCV[2]**	**Surface**	**Corr.[3]**	**AADT**	**% HCV**	**Surface**	**Corr.**	**AADT**	**% HCV**	**Surface**	**Corr.**
SH16 nth of CRH[4]	37045	5.8	SMA11	-4.2	28500	5.8	SMA11	-4.2	28500	5.8	SMA11	-4.2
SH16 sth of CRH	29200	6.8	PA10/ HSPA10	-5.6	20900	6.8	PA10/ HSPA10	-5.6	20900	6.8	PA10/ HSPA10	-5.6
CRH	7300	9	AC	-5	12775	9	AC	-5	12775	9	AC	-5

[1] Annual average daily traffic

[2] Percentage heavy commercial vehicles

[3] Road surface correction in accordance with page 36 of the NZTA Guide, adjusted by -3dB to account for the conversion of $L_{A10(18h)}$ to $L_{Aeq(24h)}$

[4] Coatesville-Riverhead Highway

6.2.3 Model verification

The computer model needs to be verified. We have predicted noise levels in the existing situation model at the survey positions.

Table 11: Computer noise model verification

Location	**Measured noise level**	**Predicted noise level**	**Difference**
	dB $L_{Aeq(24h)}$	**dB $L_{Aeq(24h)}$**	**dB**
291 SH16	66	66	0
315 SH16	64	64	0

A comparison of the measured and predicted levels shows that there is excellent agreement between measured and predicted levels. This accuracy fulfils the requirements of NZS 6806 which states in Section 5.3.4.2: *"The difference between measured and predicted levels should not exceed ± 2 dB."*

6.2.4 Individual receiver noise levels

We have assessed noise effects at all PPFs. We have included predicted noise levels for all PPFs, for all scenarios, in Appendix D. The locations of these dwellings are shown in the drawings in Appendix E.

Noise criteria categories for the PPFs are shown as a graphic representation by colouring the buildings with a colour scale, showing NZS 6806 Category A buildings in green, Category B buildings in orange and Category C buildings in red. Any buildings not shown in these three colours on the figures are outside the assessment area of 200m from the road alignment, or are not PPFs, e.g. garages, sheds, or business premises.

6.2.5 Noise contour plans

Noise contour plans are a useful tool to obtain a graphical overview of a project area including currently vacant land that may be developed in the future. The contours are calculated by the computer programme by interpolating many individual points. Therefore, noise contour maps should not be used to "read" noise levels for specific locations. For such individual levels, the receiver noise levels in the tables should be used (refer Appendix D).

Noise contour plans are contained in drawings in Appendix E. These plans show interpolated noise level bands at 5 decibel intervals from 55 dB to 70 dB $L_{Aeq(24h)}$.

6.3 Determination of preferred mitigation option under NZS 6806

In accordance with NZS 6806, we have developed several mitigation options. The process involves the following steps:

1. The acoustic consultant develops mitigation options for individual assessment areas as appropriate.
2. These mitigation options are provided to, and reviewed by, relevant persons in the Project team (e.g. representatives for the urban design team, planning, construction etc) for comment and feedback.
3. Feedback on the options is provided in a round table discussion, enabling fine tuning of the initial mitigation options. Often, at that time, the team develops further mitigation options that will need to be tested by the acoustic consultant. A workshop with the project team was held on 25 November 2021. (A couple of further PPFs identified subsequently were assessed via email.)
4. The preferred mitigation representing the BPO is chosen by the team to be put forward to community consultation and any consenting authority.
5. Following consenting, during the detailed design and prior to construction, the detailed and final mitigation will be tested by the acoustic consultant to test if it represents the BPO at that time to ensure that the outcome is at least equivalent to that put forward with the preferred mitigation option.

6.4 Predictions and Assessment

This section of the report describes the assessment of traffic noise effects from the Project on PPFs within 100 to 200m of the alignment against the altered road criteria of NZS 6806 and in relation to the noise level change that would be caused by the Project.

All PPFs have been combined in assessment areas (refer Section 0). The locations of the assessment areas, named East 1 to East 10, and West 1 to West 8 (denominating the side of the road they are on) are shown in the figures in Appendix C.

Not all assessment areas will require mitigation. For assessment areas East 2, 5 and 10, and West 8 all PPFs are predicted to receive noise levels in Category A, and no mitigation is therefore required.

For the other assessment areas, mitigation has been assessed (refer Section 6.4.4).

6.4.1 Changes as a result of the Project

The Do-nothing scenario (where the Project is not built, but traffic changes over time) showed that noise levels would decrease by approximately one decibel along SH16 until the design year, due to the predicted decrease in traffic volume based on the assumption that projects[4] in the vicinity have been implemented. If other projects in the area are not implemented prior to 2046 (the design year), the reduction in traffic volume would not occur. In that event, the Do-nothing noise levels would remain similar to (or slightly above) the existing noise levels. This would mean that a larger number of PPFs would receive noise levels in Categories B and C.

The Do-minimum scenario (where the Project is built with no noise mitigation) showed that noise levels would remain within one to two decibels (ranging from -1 to +2 decibels) compared with the Do-nothing scenario. This would be an unnoticeable and therefore negligible difference (refer Section 4.4). Though, at high noise levels, even a small increase in noise level may have adverse effects on people's health. Should projects in the vicinity not be implemented, then the change in noise levels as described above would remain similar, i.e. -1 to +2 decibels). This would result in a small number of PPFs that receive noise levels within Categories B and C.

6.4.2 Assessment in accordance with NZS 6806

Irrespective of the surrounding projects being implemented, existing and future noise levels are high at some PPFs which makes some sites not well suited for residential uses. Therefore, mitigation is recommended to be investigated by NZS 6806, which also fulfils the requirements of Section 16 of the RMA. Mitigation should reduce traffic noise to a more reasonable level from existing levels and will result in positive effect a result of the Project.

We understand that alternative road surface is not a suitable option for this road for various reasons; mostly because the curves and inclines require structural surfacing, and several surface changes over shorter distances are not appropriate. However, for completeness we have included low noise road surface for all assessment areas.

Besides road surface, the only other mitigation options involve barriers of varying heights along the alignment. We have limited the barrier heights to 2 to 2.5m to be in keeping with the rural residential character of the receiving environment. In addition, the number of PPFs receiving noise levels within Category C (i.e. > 67 dB $L_{Aeq(24h)}$) is noted as these PPFs would need to be assessed for building modification mitigation.

All predicted noise levels are shown in Appendix D, including the noise criteria category by colour (Category A = green, Category B = Orange and Category C = Red). The noise level contours over the wider area, and the PPFs in their respective category colour, are show in Appendix E.

Should projects in the vicinity not be implemented, then a small number of additional PPFs would receive noise levels within Categories B and C due to slightly higher noise levels. However, it is unlikely that the recommended BPO mitigation option would change as road surfacing is limited due to gradient and curve alignment, and barriers are only of limited efficiency for some PPFs.

6.4.3 Change in noise level

Traffic flows are predicted to be the same for the Do-nothing and Do-minimum scenarios, resulting in no change in noise level. Even if surrounding projects are not implemented, the traffic volumes would

[4] Projects in the area include those administered by Te Tupu Ngātahi Supporting Growth Alliance, on behalf of Auckland Transport and Waka Kotahi. Some of these projects are not currently consented or funded, but are expected to be implemented by 2048.

remain in the same relationship to each other, which means that the noise level changes would be the same.

The road widening of the Do-minimum scenario would result in no significant change in noise levels with changes ranging from -3 to +2 dB.

With the proposed mitigation option in place, the noise level change compared with the Do-nothing scenario will be a slight to noticeable noise level reduction for those PPFs where barriers are proposed.

This means that high noise levels are not further increased, and an overall slight reduction is achieved.

Table 12: Number of PPFs with associated noise level changes (compared with Do-nothing)

Noise level change	Do-minimum	Preferred Mitigation Option
Significant reduction (-6 to -7 dB)	-	2
Noticeable reduction (-4 to -5 dB)	-	1
Slight reduction (-2 to -3 dB)	5	11
No change (-1 to +1 dB)	45	38
Slight increase (+2 to +3 dB)	2	-

Overall, all PPFs within Category B and C will receive noise levels that are similar to, or lower than, those that would be experienced without the project.

6.4.4 Assessment areas for which mitigation was investigated

The following sections give an overview of the assessment areas where PPFs were predicted to receive noise levels above Category A, and where therefore mitigation was investigated. The location of the assessment areas is shown in the figure in Appendix C, the assessment results in accordance with the Waka Kotahi framework are shown in Appendix F, and relevant matrices of the BPO determination are included in Appendix G.

Assessment area East 1

Figure 2: Assessment area East 1 – Aerial photo

This area contains a group of dwellings including on Brigham Creek Road, Kennedys Road and SH16. All dwellings have driveway access to their respective roads, which will need to be retained.

Several PPFs currently receive noise levels in Category C (>67 dB $L_{Aeq(24h)}$) and would remain so without and with the project if no mitigation is implemented.

Mitigation options investigated included lower noise road surface (which is not feasible because of safety and maintenance reasons), boundary fencing allowing for driveway access, and a slip road allowing for continuous fencing (which would require additional land take).

In accordance with the requirements of NZS6806, the Project team considers that the BPO mitigation would be the use of 2m high boundary fencing. This will achieve a noise level reduction of 2-3 dB at the most affected houses, reducing their noise level generally to be within Category A or B. Only one PPF (173 SH16), which is a double storey dwelling, would receive noise levels just within Category C at the upper floor as boundary fences cannot practicably high enough to break line-of-sight from the upper floor to the road.

Assessment area East 3

Figure 3: Assessment area East 3 – Aerial photo

The two PPFs (291 and 299 SH16) in this assessment area are close to the existing road and receive very high noise levels within Category C. This will remain largely unchanged with the proposed changes. Both dwellings are double storey and therefore difficult to shield with barriers.

In accordance with the requirements of NZS6806, as improved road surface is not a viable option in this location, the Project team recommended that 2m boundary fence be installed to reduce the noise levels slightly at the upper floor, but noticeably at the ground floor.

Assessment area East 4

Figure 4: Assessment area East 4 – Aerial photo

Four of the five PPFs in this assessment area front Coatesville-Riverhead Highway, with only one PPF close to SH16. Due to the greater distance to SH16, these PPFs receive lower noise levels. Coatesville-Riverhead Highway carries less traffic than SH16 and is therefore a secondary noise source.

For the one PPF fronting SH16 (315 SH16), the predicted noise levels are within Category C.

In accordance with NZS 6806, a 2m high boundary fence has been recommended as BPO by the Project team. This will reduce the noise level to within Category B. Alternative road surface is not feasible due to the intersection requiring high shear and skid resistance.

Assessment area East 6

Figure 5: Assessment area East 6 – Aerial photo

There are four PPFs in this assessment area. One (429 SH16) is close to the road and predicted to currently, and in the future, receive noise levels within Category B.

In the future, with the reduction in traffic volume, traffic noise is predicted to reduce at this dwelling, but remain within Category B.

We investigated two mitigation options: the use of low noise road surface (PA10) and the installation of a 2m barrier. We understand that the use of PA10 is not appropriate in this location due to the curve in the road. The installation of a 2m boundary fence would need to occur both north and south of the driveway to provide sufficient shielding. This makes entering the road relatively unsafe due to reduced sight lines, and a larger gap would need to be kept, which would make the barrier inefficient.

Therefore, the Project team considers that the Do-minimum scenario is the most appropriate option to implement for this PPF.

Assessment area East 7

Figure 6: Assessment area East 7 – Aerial photo

This assessment area consists of three PPFs, 451, 465 and 475 SH16. Only 451 SH16 is predicted to receive noise levels within Category B for all scenarios, existing and future.

With the installation of a 2m high boundary fence just within the designation boundary, the noise level at 451 SH16 can be reduced by 2 dB, into Category A. The Project team considers this to be the BPO.

Assessment area East 8

Figure 7: Assessment area East 8 – Aerial photo

This assessment area consists of two PPFs, 491 SH16 and 489 SH16 (which is an Early Childhood Education Centre (ECEC)). Only the ECEC is close to SH16 and predicted to receive noise levels within Category C and in the future within Category B.

With the installation of a 2m high boundary fence, the noise levels can be reduced by nearly 6 dB, into Category A. The Project team considers this to be the BPO.

Assessment area East 9

Figure 8: Assessment area East 9 – Aerial photo

This assessment area consists of two PPFs, one dwelling (at 505 SH16) and one large retirement village building (at 507 SH16). The Kumeū Retirement Village is relatively new (constructed after 2012) and very close to the road edge. It is unclear, if the façade construction of the village includes sound insulation considerations, and if the rooms can be adequately ventilated without opening of windows. Therefore, we have assessed this building as if mitigation will be required.

Two mitigation options were assessed, a 2m and a 2.5m high boundary fence. With the 2.5m barrier, the retirement building would receive noise levels within Category B (otherwise, with the 2m barrier, within Category C).

Consultation with the Kumeū Retirement Village was undertaken by the Project team. The retirement village does not want a noise wall, irrespective of the noise levels received on site. We therefore do not recommend any additional mitigation.

Assessment area West 1

Figure 9: Assessment area West 1 – Aerial photo

Only one PPF is part of this assessment area (218 SH16, the small dwelling on the north-eastern corner of the site). The dwelling is strongly affected by traffic noise from SH16, with noise levels consistently within Category C. Since an alternative road surface is not a feasible option, we have tested a 2m boundary fence. This would achieve a small noise level reduction of slightly more than 3 dB, which would reduce noise levels to within Category B.

The Project team considers the fence to be the BPO.

Assessment area West 2

Figure 10: Assessment area West 2 – Aerial photo

This assessment area also only consists of one PPF (222A SH16). We understand that this dwelling has historic significance (though not currently on the Council's heritage schedule).

The dwelling receives noise levels within Category B at presents, and this will remain unchanged with the implementation of the project. In terms of improving the existing situation under NZS 6806, with a 2m boundary fence, the noise levels could be reduced slightly to be within Category A, however, the reduction would be minimal (less than 1 dB) compared with a circumstance where the project is not implemented, and less than 2 dB compared with no mitigation. This would not represent the BPO.

Therefore, no mitigation is proposed under NZS 6806 for this assessment area.

Assessment area West 3

Figure 11: Assessment area West 3 – Aerial photo

Two PPFs are in this assessment area. 256 SH16 is at some distance from SH16 and receives noise levels within Category A across the scenarios. 238 SH16 is a listed historic building. It currently receives noise levels within Category C. With surrounding projects implemented, and with the Project in place, the overall noise level is predicted to slightly decrease to be within Category B.

The location of this dwelling, slightly elevated above SH16 and in a curve thus having extended line of sight to the road, means that any barrier would need to be significantly long (more than 140m) and high (more than 2.5m). This would reduce the historic value by blocking views to the building, and only achieve limited noise levels reductions of less than 2 dB.

An alternative road surface is not a feasible option for safety reasons, due to the corner and road gradient.

The Project team considers that no mitigation would represent BPO, and therefore, Do-minimum scenario has been put forward as selected option.

Assessment area West 4

Figure 12: Assessment area West 4 – Aerial photo

There are three PPFs in this area; 300 and 264 SH16 are main dwellings, while 264A SH16 is a minor dwelling close to SH16.

Both 264 and 300 SH16 are well set back from the road and received some shielding from the embankment rising up from SH16, with noise levels in Category A for all assessed scenarios.

264A SH16 is a minor dwelling with line-of-sight to the road. The proposed improvements to SH16 will bring the road somewhat closer. The line of trees along the current boundary will be removed for the construction works. This PPF would receive noise levels in Category B in the Do-minimum scenario.

With a 2m high boundary fence along the top of the newly formed and regraded embankment, the noise level reduction at 264A SH16 is predicted to be 6 dB, a noticeable improvement which would reduce noise levels to be within Category A.

This 2m barrier is considered to be the BPO by the Project team.

Assessment area West 5

Figure 13: Assessment area West 5 – Aerial photo

Only one PPF is in this assessment area (340 SH16). It receives noise levels within Category B which will largely remain unchanged irrespective of the project implementation.

With a 2m high boundary fence, the noise levels could be reduced to be within Category A, which was considered by the Project team to represent BPO.

Assessment area West 6

Figure 14: Assessment area West 6 – Aerial photo

This assessment area consists of eight PPFs, four fronting Taupaki Road and four fronting SH16. All PPFs except one (436 SH16) are predicted to receive noise levels within Category A.

436 SH16 is predicted to receive a noise level of 65 dB L_{Aeq} that would be marginally within Category B.

This assessment area is at an intersection of SH16 with Taupaki Road, which means that alternative road surface material is not a feasible option because of safety reasons.

With the Project implemented, the noise level is predicted to reduce at 436 SH16 (though still within Category B), and no further mitigation is recommended by the Project team.

Assessment area West 7

Figure 15: Assessment area West 7 – Aerial photo

Only one PPF is in this assessment area (550 SH16). The current and future noise levels at this PPF are within Category B, with only minimal changes.

With the installation of a 2m high boundary fence, the noise level at the dwelling can be noticeably reduced (by nearly 7 dB) and brought into Category A.

The Project team considers a fence the BPO for this assessment area.

6.5 Preferred mitigation option

In summary, the following mitigation options have been assessed by the project team as preferred:

Table 13: Summary of preferred mitigation options for each relevant assessment area

Assessment area	Mitigation option	Mitigation	Preferred
East 1	1	2m barrier	MO1
	2	PA10	
	3	PA10 and 2m barrier	
	4	Slip lane and 2m barrier	
East 2	n/a	n/a, all PPFs in Category A	Do-minimum
East 3	1	2m barrier	MO1
	2	2.5m barrier	
	3	PA10 and 2/2.5m barrier	
East 4	1	2m barrier	MO1
	2	PA10	
	3	PA10 and 2m barrier	
East 5	n/a	n/a, all PPFs in Category A	Do-minimum

Assessment area	Mitigation option	Mitigation	Preferred
East 6	1	PA10	Do-minimum
	2	2.5m barrier	
East 7	1	2m barrier	MO1
East 8	1	2m barrier	MO1
	2	PA10	
	3	PA10 and 2m barrier	
East 9	1	2m barrier	Do-minimum (due to feedback from village)
	2	2.5m barrier	
East 10	n/a	n/a, all PPFs in Category A	Do-minimum
West 1	1	2m barrier	MO 1
	2	PA10	
	3	PA10 and 2m barrier	
West 2	1	2m barrier	Do-minimum
West 3	1	2m barrier	Do-minimum
	2	PA10	
	3	PA10 and 2m barrier	
	4	3m barrier longer – check matrix	
West 4	1	2m barrier	MO1
West 5	1	2m barrier	MO1
West 6	1	PA10	Do-minimum
West 7	1	2m barrier	MO1
West 8	n/a	n/a, all PPFs in Category A	Do-minimum

Table 14 below summarises the number of PPFs in each NZS 6806 noise category for the entire Project. The relevant Waka Kotahi assessment basis for each assessment area is included in Appendix F and the assessment matrices compiled during the BPO workshop in Appendix G.

The resultant noise levels (refer Appendix D) are generally lower than would be the case without the project, and lower than exiting noise levels.

Table 14: Number of PPFs in each NZS 6806 noise criteria category

Situation	Category A	Category B	Category C
Existing (2021)	32	11	9
Do-nothing (2046)	33	14	5
Do-minimum (2046)	33	11	8
Preferred Mitigation Option (2046)	38	11	3

6.6 Other traffic noise generation

Traffic noise is not only generated by traffic movements on the road (controlled by the road-tyre-interaction for speeds above 40 – 50 km/h). Other aspects can also have an impact on road traffic noise but are not covered by NZS 6806 or the Calculation of Road Traffic Noise (refer Section 6.2.1).

These include:

- roundabouts that cause traffic to slow down and speed up, resulting in a change in engine noise characteristics when decelerating and accelerating
- raised safety platforms that also cause traffic to slow down on approach and speed up after, in addition to the possibility of tires impacting on the raised surface causing additional noise and/or vibration
- bridge joints where traffic needs to pass over a metal piece or vertical discontinuities which may cause a bump/impact of the tire
- audible tactile profiles (ATP) which, if installed close to dwellings and close to the live traffic lane, can cause additional noise if traffic routinely passes over them
- trucks using engine brakes as they approach a roundabout, raised platform or corner

Each of these causes may influence traffic noise generation. Generally, the character of the traffic noise changes to include a tonal (e.g. ATP, engine braking) or impact (e.g. bridge joints, raised safety platforms) component, or noise level or character changes (e.g. traffic accelerating from roundabouts or raised platforms, engine braking).

Good design can reduce the change in noise level or character. For instance, ATP should not be installed within 100m of dwellings, and potential adverse noise effects should be evaluated prior to installation.[5]

Similarly, engine braking by trucks can be reduced if road design clearly indicates a drop in speed environment, enabling truck drivers to pre-empt the speed reduction. Further information is provided on the Waka Kotahi website.[6]

Each of the above aspects must be taken into consideration during the detailed design of the Project to ensure that unnecessary and unreasonable noise generation is avoided. Waka Kotahi has a comprehensive set of design criteria dealing with each of the above issues, which will ensure that the BPO mitigation and management is included at the design stage.

7.0 CONCLUSION

We have assessed construction noise and vibration and traffic noise for the road improvement project along SH16 between Brigham Creek Road to Kumeū.

Construction noise and vibration criteria are predicted to be exceeded at limited times for some receivers within a closer setback distance from the alignment. To minimise effects, mitigation measures have been recommended to be implemented. The works should be managed through a Construction Noise and Vibration Management Plan and associated Schedules.

While the Project is predicted to generally result in reduced traffic noise levels, current levels are already above desirable levels. Therefore, mitigation options have been assessed in accordance with

[5] https://www.nzta.govt.nz/assets/resources/audio-tactile-profiled-roadmarkings-guidelines/docs/atp-guidelines.pdf

[6] https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/noise-and-vibration/frequently-asked-questions/engine-braking-faqs/

NZS 6806. Traffic noise mitigation is recommended in the form of barriers for individual PPFs where required, retaining access from SH16.

The noise effects from the Project, based on the change in noise level, are negligible to marginally positive with overall noise level decreases of 1 to 2 decibels, and for some PPFs currently receiving noise levels at the higher end reductions up to 6 decibels with the use of barriers. With barrier mitigation in place, the number of PPFs predicted to receive undesirably high noise levels would be reduced (and be generally restricted to double storey PPFs where barriers are ineffective for the upper floor).

Overall, we consider that the project can be constructed and operated within reasonable levels provided mitigation and management as recommended is implemented.

APPENDIX A GLOSSARY OF TERMINOLOGY

Noise	A subjective term used to describe sound that is unwanted by, or distracting to, the receiver.
A-weighting	A set of frequency-dependent sound level adjustments that are used to better represent how humans hear sounds. Humans are less sensitive to low and very high frequency sounds. Sound levels using an "A" frequency weighting are expressed as dB L_A. Alternative ways of expressing A-weighted decibels are dBA or dB(A).
dB	Decibel. The unit of sound level.
L_{A90}	The A-weighted sound level exceeded for 90 % of the measurement period, measured in dB. Commonly referred to as the background noise level.
L_{Aeq}	The equivalent continuous A-weighted sound level. Commonly referred to as the average sound level and is measured in dB.
$L_{Aeq,24h}$	The L_{Aeq} sound level averaged over a 24-hour period from midnight to midnight.
L_{Amax}	The A-weighted maximum sound level. The highest sound level which occurs during the measurement period. Usually measured with a fast time–weighting i.e. L_{AFmax}
NZS6801	New Zealand Standard NZS 6801:2008 *Acoustics – Measurement of environmental sound*
NZS6802	New Zealand Standard NZS 6802:2008 *Acoustics - Environmental Noise*
NZS6803	New Zealand Standard NZS 6803: 1999 *Acoustics - Construction Noise*
NZS 6806	New Zealand Standard NZS 6806:2010 *Acoustics - Road-traffic noise - New and altered roads*
Vibration	When an object vibrates, it moves rapidly up and down or from side to side. The magnitude of the sensation when feeling a vibrating object is related to the vibration velocity. Vibration can occur in any direction. When vibration velocities are described, it can be either the total vibration velocity, which includes all directions, or it can be separated into the vertical direction (up and down vibration), the horizontal transverse direction (side to side) and the horizontal longitudinal direction (front to back).
PPV	Peak Particle Velocity. The measure of the vibration aptitude, zero to maximum. Used for building structural damage assessment.

APPENDIX B NOISE LEVEL SURVEY RESULTS

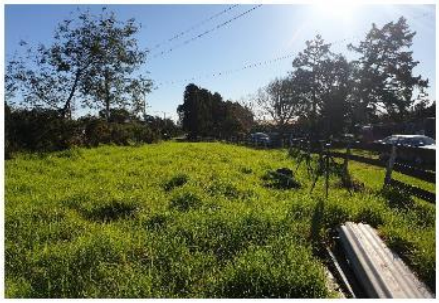
Logger Measurements

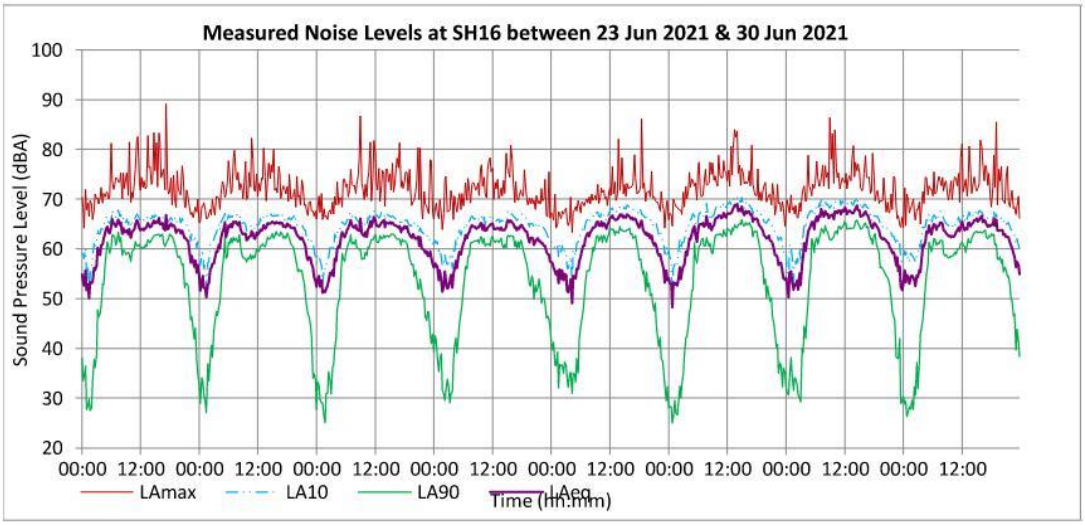
Date:	Wednesday, 6 October 2021
File name:	I:\JOBS\2021\20210877\03 Survey Data & Measurements\20180167 mm 210622 - 210701 (291 SH16)\[291 SH16 15min ARL Summary.xlsx]Logger_Summary
Job number:	20210877
Job name:	SH16 Stage 2 Safety Improvements
Initials:	SRK
Measurement Dates:	Wednesday, 23 June 2021 to Wednesday, 30 June 2021
Weather during Measurement:	No adjustments have been made
Notes:	SH16 main oise source

OVERVIEW SUMMARY SHEET

Noise Level, dB		L_{Aeq}	L_{A10}	L_{A95}	
Day (0700-1800)	Lowest	62	64	53	69
	Average	65	67	62	74
	Highest	69	71	66	89
Evening (1800-2200)	Lowest	59	63	42	66
	Average	63	65	56	72
	Highest	66	68	64	86
Night (2200-0700)	Lowest	48	49	25	63
	Average	60	62	42	69
	Highest	67	69	63	79

$L_{Aeq\ 24\text{-}hr}$ 64 dB





MARSHALL DAY Acoustics

Logger Measurements

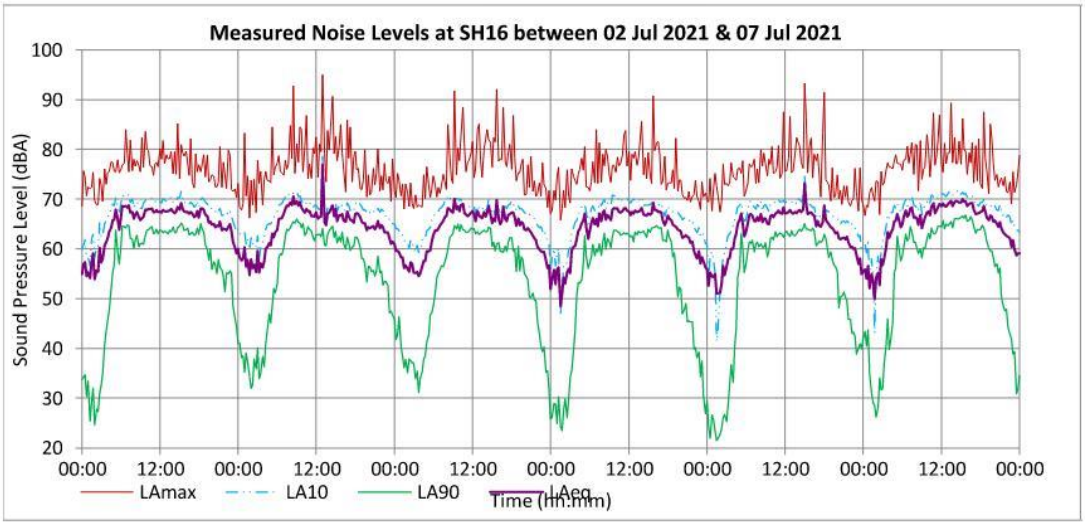
MARSHALL DAY Acoustics

Date:	Wednesday, 6 October 2021
File name:	I:\JOBS\2021\20210877\03 Survey Data & Measurements\20180167 mm 210701 - 210708 (315 SH16)\[315 SH16 15min ARL Summary.xlsx]Logger_Summary
Job number:	20210877
Job name:	SH16 Stage 2 Safety Requirements
Initials:	SRK
Measurement Dates:	Friday, 02 July 2021 to Wednesday, 07 July 2021
Weather during Measurement:	No adjustments have been made
Notes:	SH16 main noise source

OVERVIEW SUMMARY SHEET

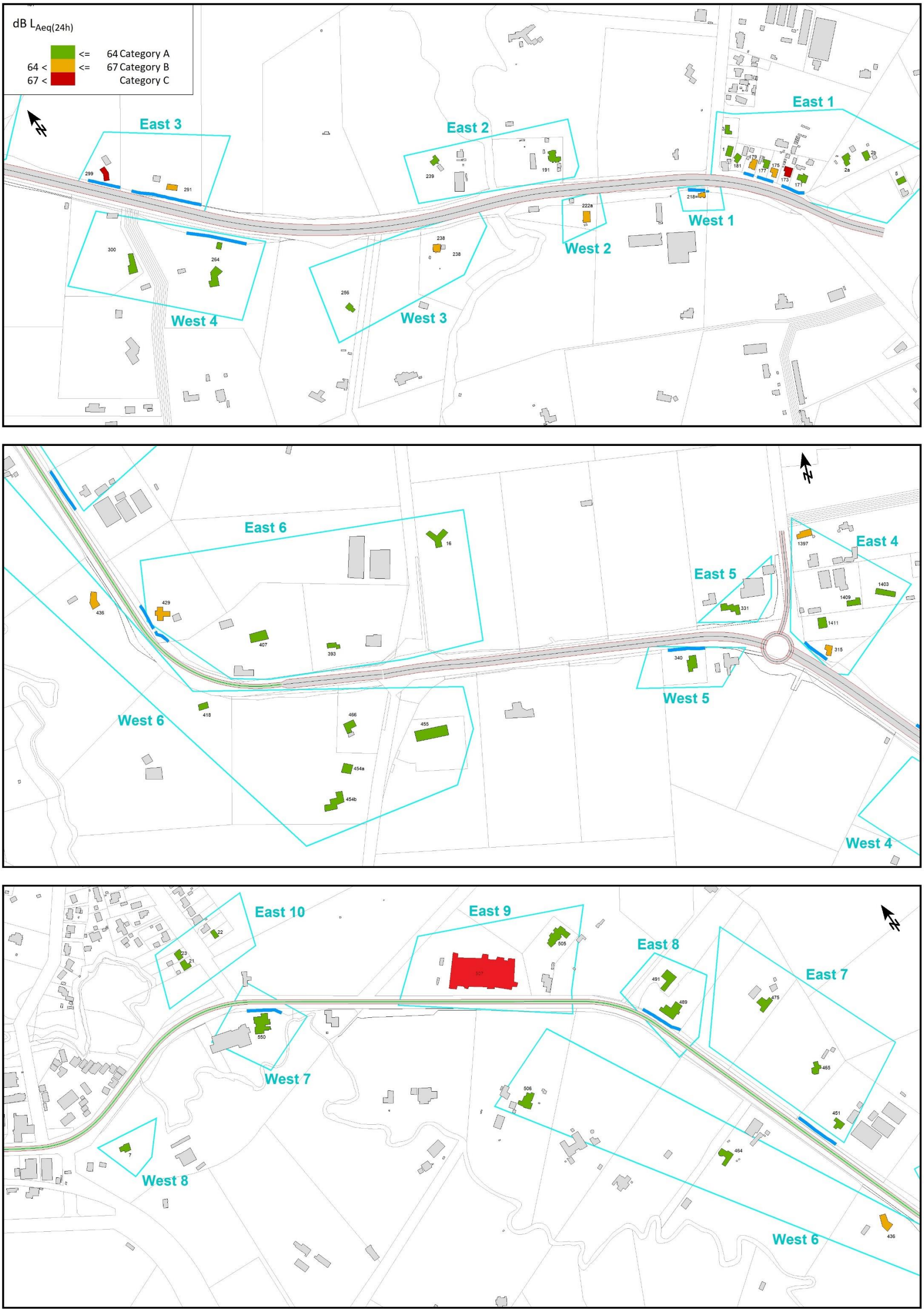
Noise Level, dB		L_{Aeq}	L_{A10}	L_{A95}	
Day	Lowest	64	66	56	70
(0700-1800)	Average	68	69	63	79
	Highest	77	79	67	95
Evening	Lowest	61	65	45	69
(1800-2200)	Average	65	68	56	75
	Highest	69	70	65	92
Night	Lowest	49	41	22	66
(2200-0700)	Average	62	63	42	73
	Highest	71	72	66	91

$L_{Aeq\ 24\text{-}hr}$ 66 dB



MARSHALL DAY Acoustics

APPENDIX C ASSESSMENT AREAS



MARSHALL DAY Acoustics

APPENDIX D PREDICTED TRAFFIC NOISE LEVELS

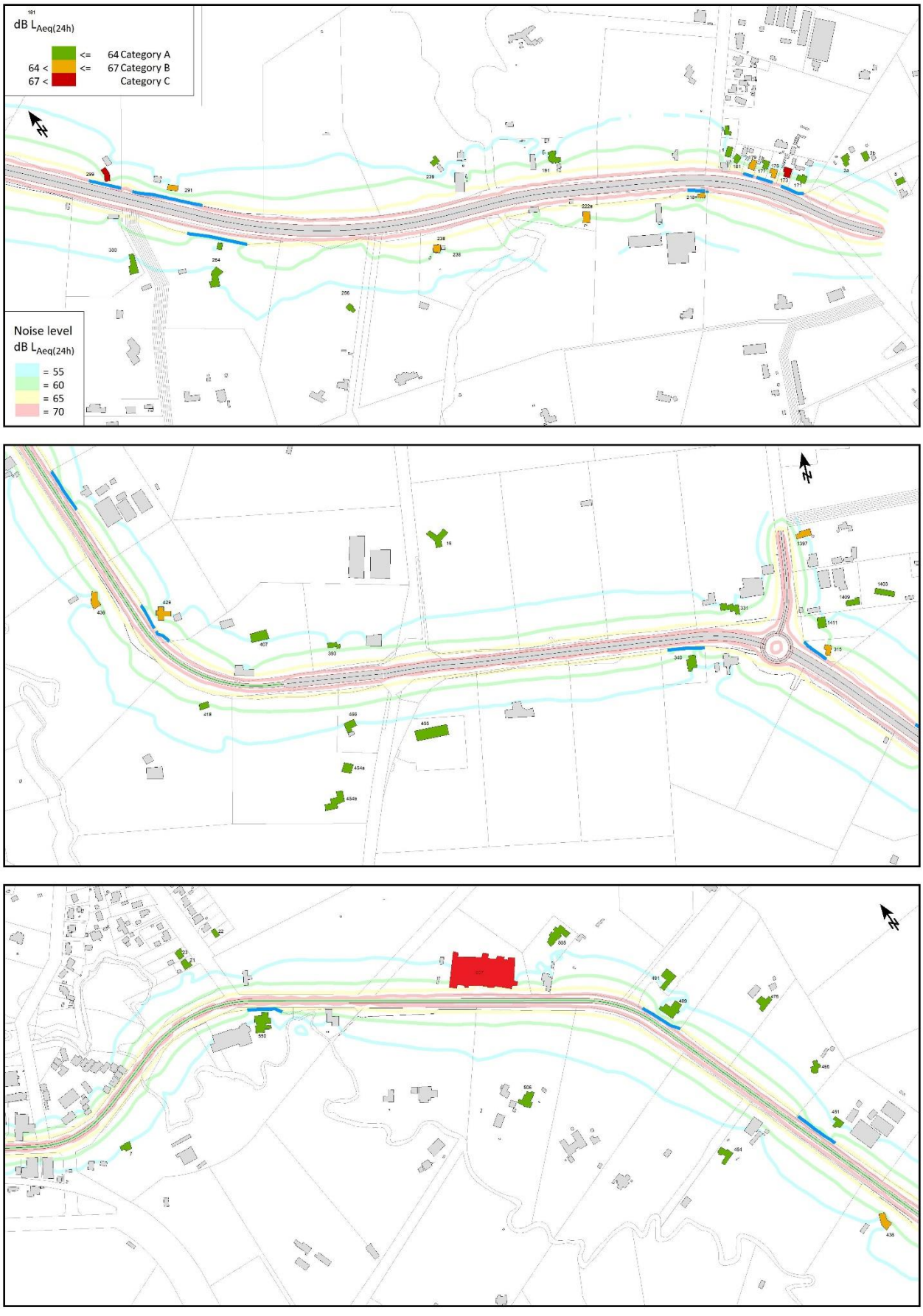
(Note: Green noise levels are within Category A, Yellow noise levels are within Category B, and Red noise levels are within Category C)

House ID	Floor Level	Existing	Do-nothing	Do-minimum	Change	Preferred Mitigation	Change
		dB $L_{Aeq(24h)}$	dB $L_{Aeq(24h)}$	dB $L_{Aeq(24h)}$	dB	dB $L_{Aeq(24h)}$	dB
Brigham Creek Road 002a	G	57.0	55.9	56.0	0	55.7	0
Brigham Creek Road 002b	G	55.1	54.0	53.9	0	53.9	0
Brigham Creek Road 005	G	56.0	54.9	54.8	0	54.6	0
Coatesville-Riverhead Hwy 1397	F2	62.6	64.7	64.6	0	64.6	0
Coatesville-Riverhead Hwy 1403	G	52.9	52.0	52.3	0	52.2	0
Coatesville-Riverhead Hwy 1409	G	55.5	54.6	54.8	0	54.7	0
Coatesville-Riverhead Hwy 1411	G	61.8	61.5	62.4	1	62.3	1
Kennedys Road 001	F2	63.3	62.1	62.7	1	62.6	1
Kennedys Road 003	G	58.0	56.9	57.4	1	57.4	1
Old North Road 016	F2	54.8	54.7	53.4	-2	53.4	-1
Riverhead Road 021	G	58.4	58.4	56.9	-2	57.0	-1
Riverhead Road 022	F2	57.6	57.6	56.1	-2	56.2	-1
Riverhead Road 023	G	53.3	53.3	51.8	-2	51.8	-2
SH16 007	F2	61.6	61.6	60.3	-1	60.3	-1
SH16 171	G	67.2	66.0	67.0	1	64.5	-2
SH16 173	F2	69.2	68.1	68.6	1	67.6	-1
SH16 175	G	69.7	68.6	69.4	1	66.6	-2
SH16 177	G	66.1	65.0	65.1	0	62.0	-3
SH16 179	G	68.5	67.3	67.6	0	64.8	-3
SH16 181	G	64.8	63.7	63.9	0	63.2	-1
SH16 191	G	64.7	63.5	63.4	0	63.4	0
SH16 218	G	70.1	68.9	70.1	1	65.6	-3
SH16 222a	G	65.6	64.5	65.6	1	65.6	1
SH16 238	G	67.6	66.4	66.9	1	66.9	1
SH16 239	G	55.7	54.6	54.8	0	54.7	0
SH16 256	G	56.5	55.4	56.0	1	56.0	1
SH16 264	G	60.9	59.8	60.2	0	59.2	0
SH16 264A	G	61.5	66.1	66.4	0	60.6	-6
SH16 291	F2	68.5	67.3	68.7	1	66.0	-1

House ID	Floor Level	Existing	Do-nothing	Do-minimum	Change	Preferred Mitigation	Change
		dB $L_{Aeq(24h)}$	dB $L_{Aeq(24h)}$	dB $L_{Aeq(24h)}$	dB	dB $L_{Aeq(24h)}$	dB
SH16 299	F2	70.2	69.1	71.3	2	70.4	1
SH16 300	F2	61.3	60.2	60.5	0	60.5	0
SH16 315	G	67.7	66.5	68.5	2	67.3	1
SH16 331	G	63.4	63.1	63.0	-1	63.1	0
SH16 340	G	66.1	66.1	65.6	-1	63.9	-2
SH16 393	G	62.2	62.2	62.0	-1	62.0	0
SH16 407	G	57.6	57.6	56.8	-2	56.8	-1
SH16 418	G	62.9	62.9	62.3	-1	62.3	-1
SH16 429	G	65.7	65.7	65.5	-1	65.5	0
SH16 436	F2	66.1	66.1	64.8	-2	64.8	-1
SH16 451	G	66.5	65.0	65.2	0	63.3	-2
SH16 464	F2	58.1	58.1	56.8	-2	56.9	-1
SH16 465	F2	59.4	59.4	58.1	-2	57.9	-2
SH16 475	G	56.1	56.1	54.8	-1	54.6	-2
SH16 489 (ECEC)	G	67.4	67.4	67.0	-1	61.4	-6
SH16 491	F2	62.0	62.0	61.7	-1	60.7	-1
SH16 505	F2	59.1	59.1	58.4	-1	58.2	-1
SH16 506	G	54.6	54.6	53.7	-1	54.1	-1
SH16 507 (Rest home)	G	70.9	70.9	69.1	-2	69.1	-4
SH16 550	G	65.8	65.8	64.8	-1	59.2	-7
Taupaki Rd 455 (ECEC)	G	58.0	58.0	55.3	-2	55.3	-3
Taupaki Road 454A	G	53.8	53.8	53.2	-2	53.2	-1
Taupaki Road 454B	G	53.1	53.1	52.4	-2	52.4	-1
Taupaki Road 466	G	58.7	58.7	59.0	-1	59.0	0

MARSHALL DAY Acoustics

APPENDIX E PREDICTED TRAFFIC NOISE LEVEL CONTOURS



APPENDIX F WAKA KOTAHI ASSESSMENT

F1 East 1

Project
SH16 Stage 2
East 1

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	5	6	6	7	7	9	10	0	0
Category B	3	3	2	3	3	2	1	0	0
Category C	3	2	3	1	1	0	0	0	0
Total			11	11	11	11	11	0	0

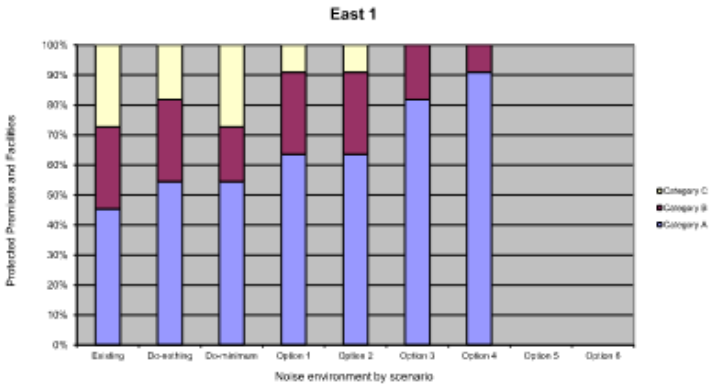
Benefit-Cost Ratio

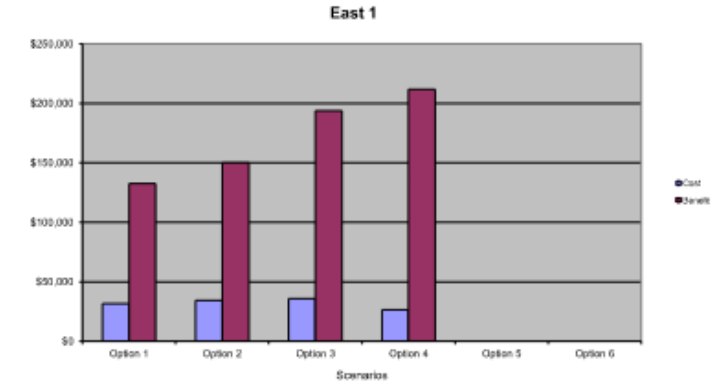
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$31,560	$34,383	$35,943	$26,400	$0	$0
Benefit	$132,480	$150,120	$193,680	$211,680	$0	$0
BCR	4.20	4.37	5.39	8.02	–	–
Structural	1.9 dB	1.3 dB	2.2 dB	4.0 dB		

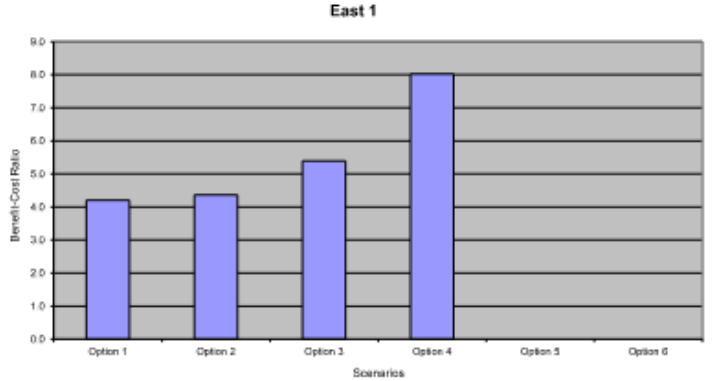
Assessment matrix

	Option 1	Option 2	Option 3	Option 4
NZS 6806 compliance	--	--	+	+
Structural mitigation	-	- -	-	+
BCR	+ + +	+ + +	+ + +	+ + +

Graphs







F2 East 3

Project
SH16 Stage 2
East 3

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	0	0	0	0	0	1	0	0	0
Category B	0	1	0	1	1	1	0	0	0
Category C	2	1	2	1	1	0	0	0	0
Total			2	2	2	2	0	0	0

Benefit-Cost Ratio

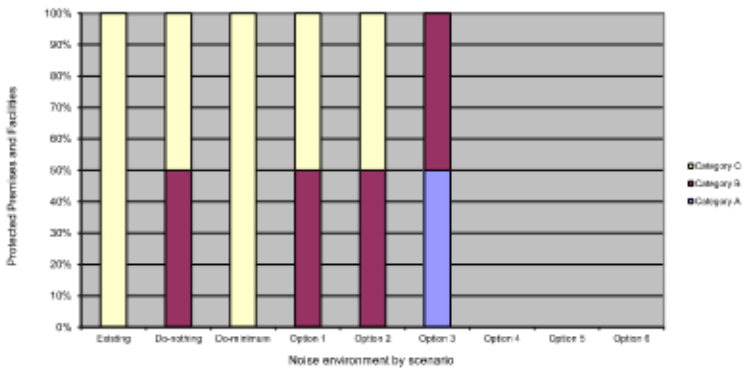
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$55,080	$81,800	$74,404	$0	$0	$0
Benefit	$79,920	$73,440	$99,360	$0	$0	$0
BCR	1.45	0.90	1.34	-	-	-
Structural	1.8 dB	1.3 dB	5.1 dB			

Assessment matrix

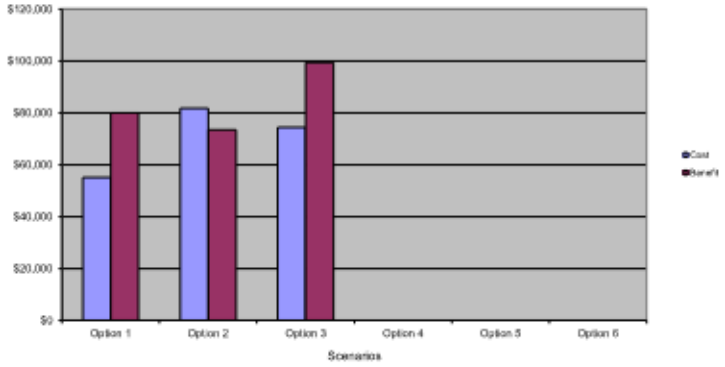
	Option 1	Option 2	Option 3
NZS 6806 compliance	---	---	+
Structural mitigation	-	- -	+ + +
BCR	+ +	o	+ +

Graphs

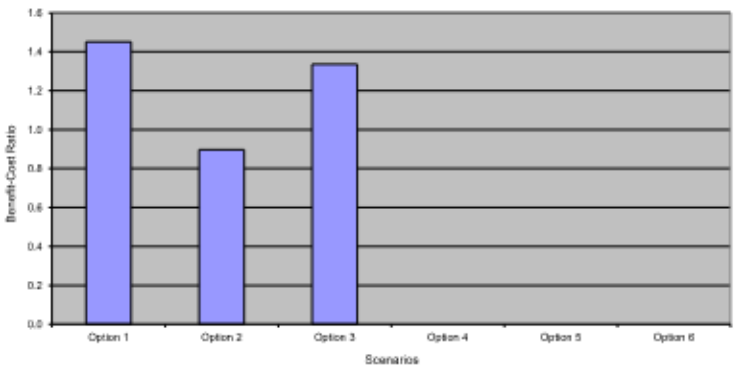
East 3



East 3



East 3



F3 East 4

Project
SH16 Stage 2
East 4

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	4	3	3	3	3	3	0	0	0
Category B	0	2	1	2	2	2	0	0	0
Category C	1	0	1	0	0	0	0	0	0
Total			5	5	5	5	0	0	0

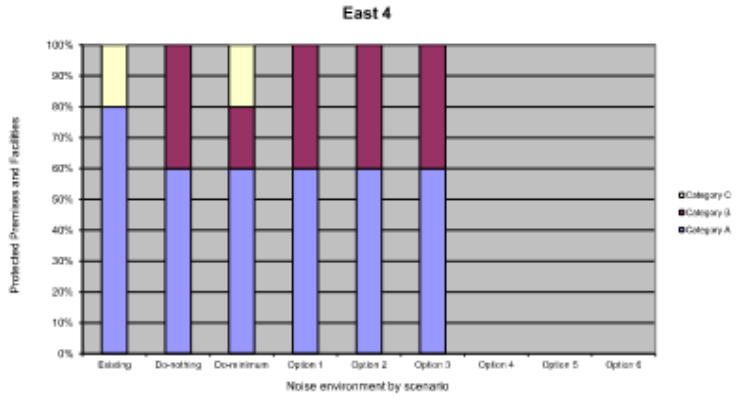
Benefit-Cost Ratio

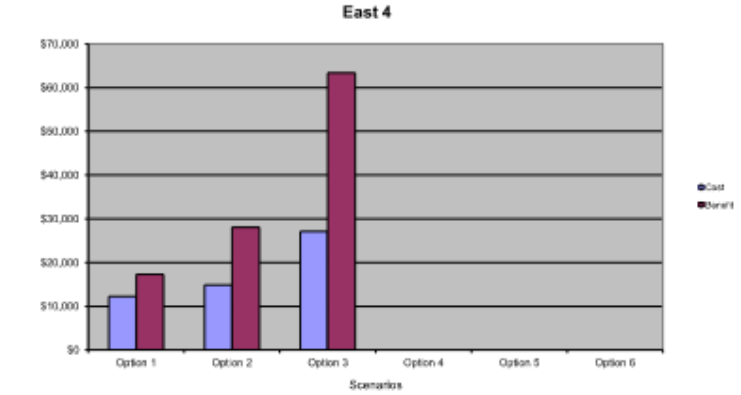
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$12,240	$14,860	$27,100	$0	$0	$0
Benefit	$17,280	$28,080	$63,360	$0	$0	$0
BCR	1.41	1.89	2.34	-	-	-
Structural	1.5 dB	0.9 dB	1.7 dB			

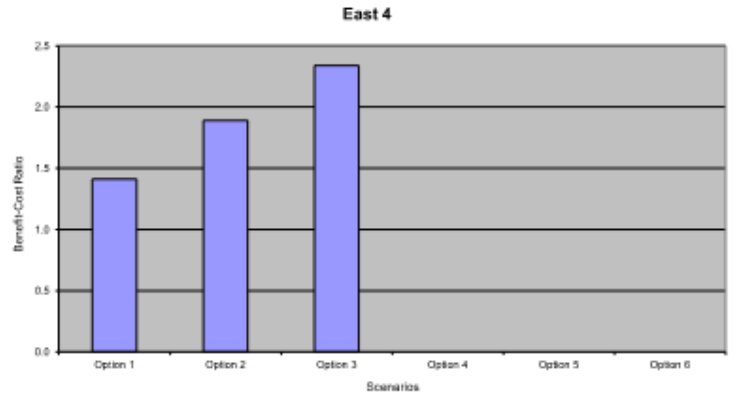
Assessment matrix

	Option 1	Option 2	Option 3
NZS 6806 compliance	+	+	+
Structural mitigation	- -	- -	-
BCR	+ +	+ + +	+ + +

Graphs







F4 East 6

Project
SH16 Stage 2
East 6

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	3	3	3	4	4	0	0	0	0
Category B	1	1	1	0	0	0	0	0	0
Category C	0	0	0	0	0	0	0	0	0
Total			4	4	4	0	0	0	0

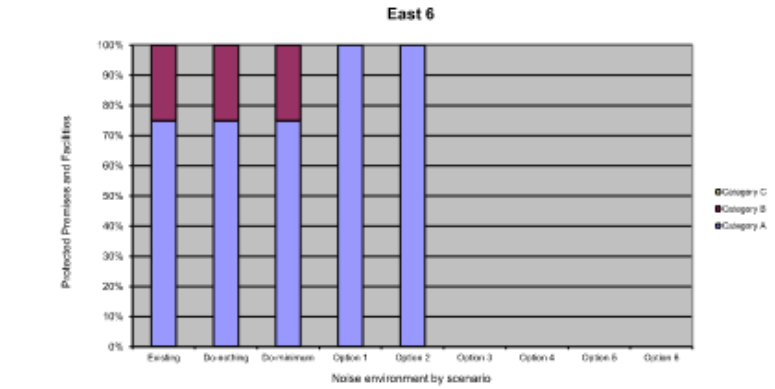
Benefit-Cost Ratio

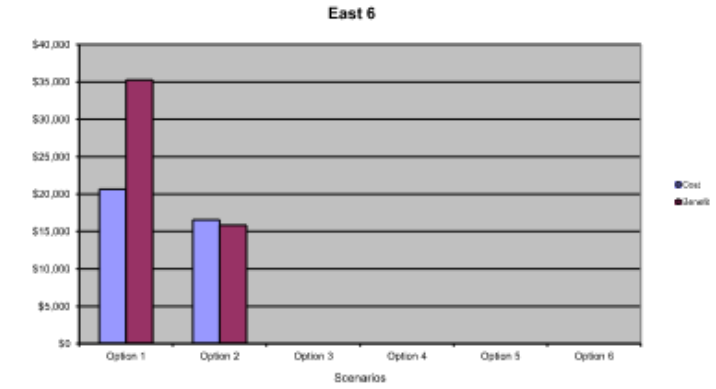
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$20,675	$16,560	$0	$0	$0	$0
Benefit	$35,280	$15,840	$0	$0	$0	$0
BCR	1.71	0.96	-	-	-	-
Structural	1.1 dB	1.7 dB				

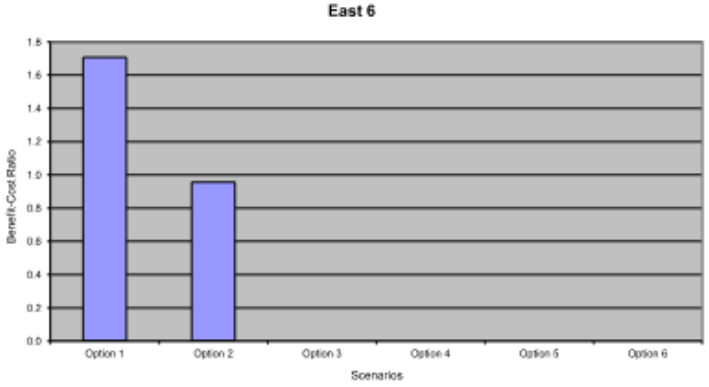
Assessment matrix

	Option 1	Option 2
NZS 6806 compliance	+ + +	+ + +
Structural mitigation	- -	-
BCR	+ + +	o

Graphs







F5 East 7

East 7

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution			○	◉	○	○	○	○	○
Category A	2	2	2	3	0	0	0	0	0
Category B	1	1	1	0	0	0	0	0	0
Category C	0	0	0	0	0	0	0	0	0
Total			3	3	0	0	0	0	0

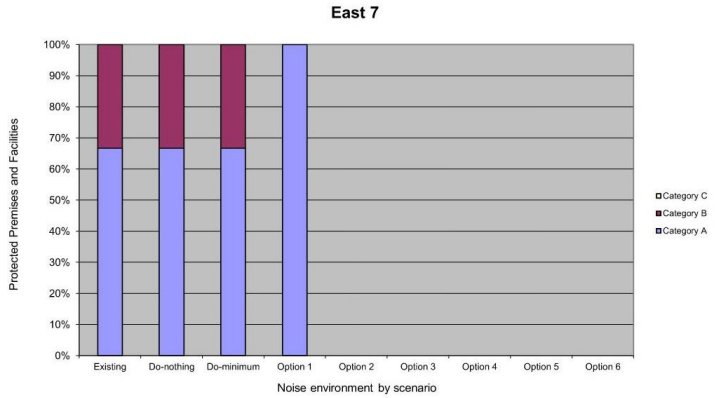
Benefit-Cost Ratio

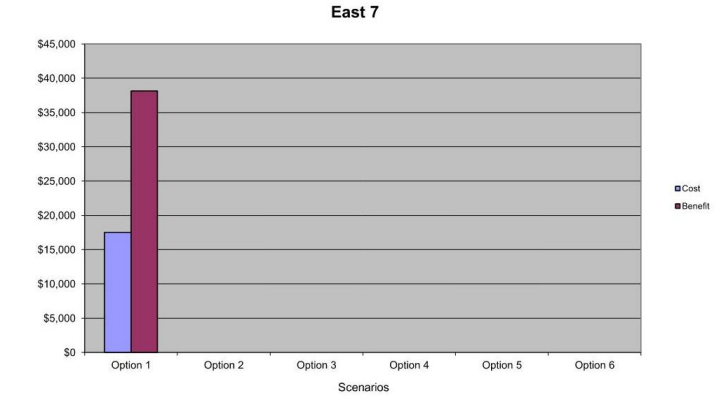
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$17,520	$0	$0	$0	$0	$0
Benefit	$38,160	$0	$0	$0	$0	$0
BCR	2.18	-	-	-	-	-
Structural	1.0 dB					

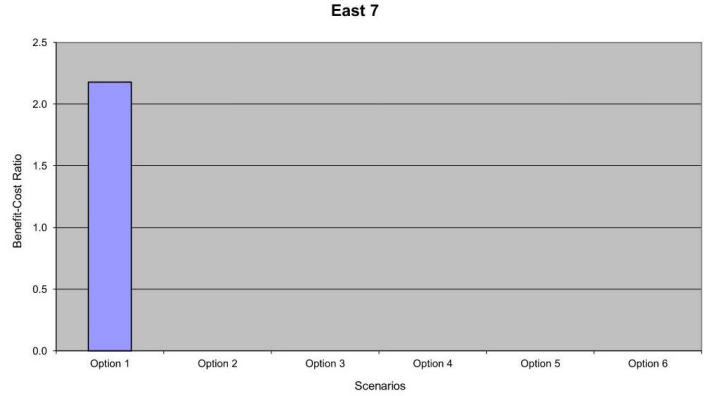
Assessment matrix

NZS 6806 compliance	+++
Structural mitigation	- -
BCR	+ + +

Graphs







F6 East 8

Project
SH16 Stage 2
East 8

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	1	1	1	2	1	2	0	0	0
Category B	0	1	1	0	1	0	0	0	0
Category C	1	0	0	0	0	0	0	0	0
Total			2	2	2	2	0	0	0

Benefit-Cost Ratio

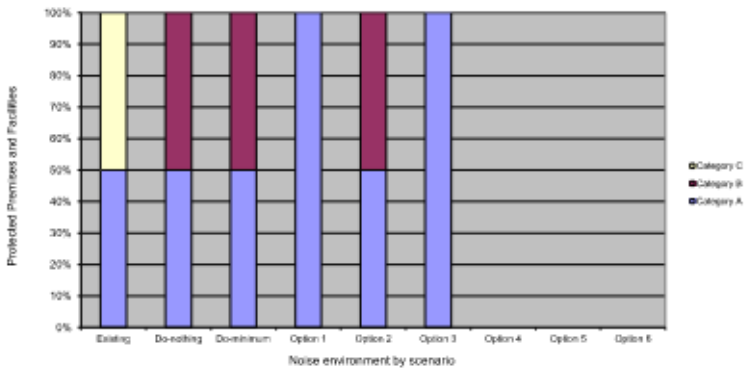
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$16,080	$10,984	$27,064	$0	$0	$0
Benefit	$48,240	$15,840	$56,160	$0	$0	$0
BCR	3.00	1.44	2.08	-	-	-
Structural	3.3 dB	1.1 dB	3.9 dB			

Assessment matrix

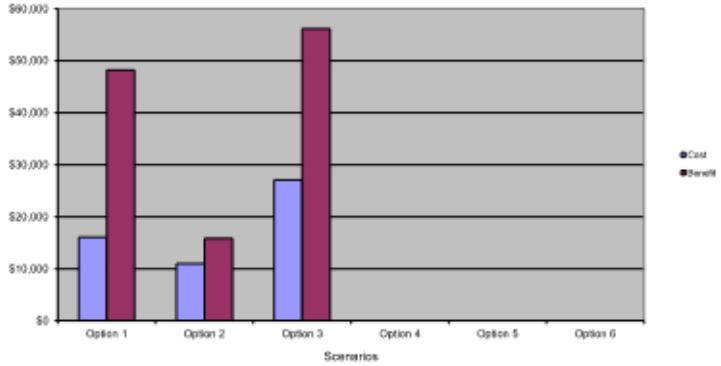
	Option 1	Option 2	Option 3
NZS 6806 compliance	+++	+	+++
Structural mitigation	o	- -	+
BCR	+ + +	+ +	+ + +

Graphs

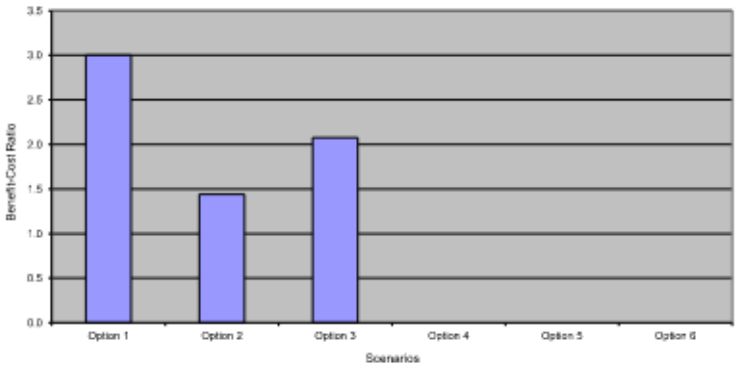
East 8



East 8



East 8



F7 East 9

Project
SH16 Stage 2
East 9

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	1	1	1	1	1	0	0	0	0
Category B	0	0	0	0	1	0	0	0	0
Category C	1	1	1	1	0	0	0	0	0
Total			2	2	2	0	0	0	0

Benefit-Cost Ratio

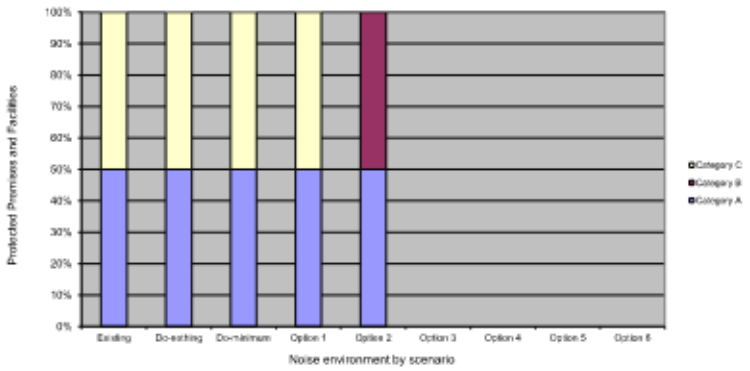
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$57,960	$71,600	$0	$0	$0	$0
Benefit	$37,800	$17,280	$0	$0	$0	$0
BCR	0.65	0.24	-	-	-	-
Structural	1.2 dB	2.4 dB				

Assessment matrix

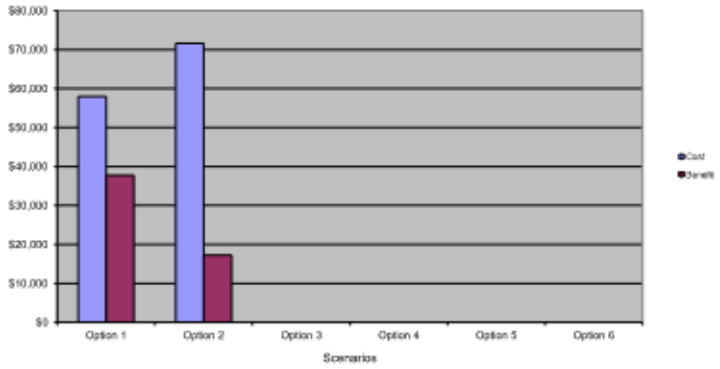
	Option 1	Option 2
NZS 6806 compliance	---	+
Structural mitigation	- -	-
BCR	-	- - -

Graphs

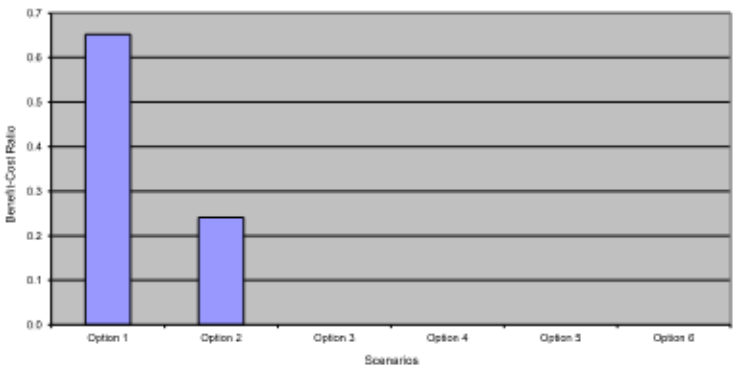
East 9



East 9



East 9



F8 West 1

Project
SH16 Stage 2
West 1

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	0	0	0	0	0	1	0	0	0
Category B	0	0	0	1	0	0	0	0	0
Category C	1	1	1	0	1	0	0	0	0
Total			1	1	1	1	0	0	0

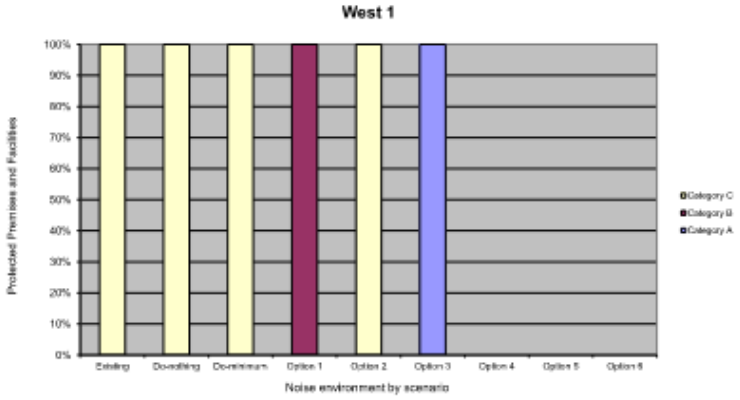
Benefit-Cost Ratio

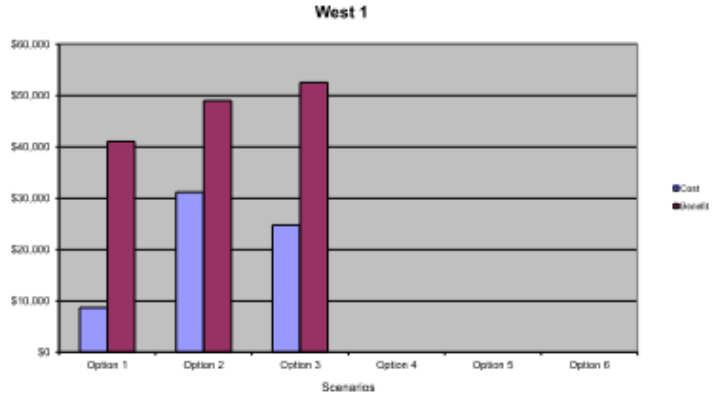
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$8,640	$31,153	$24,793	$0	$0	$0
Benefit	$41,040	$48,960	$52,560	$0	$0	$0
BCR	**4.75**	**1.57**	**2.12**	-	-	-
Structural	4.5 dB	1.3 dB	6.1 dB			

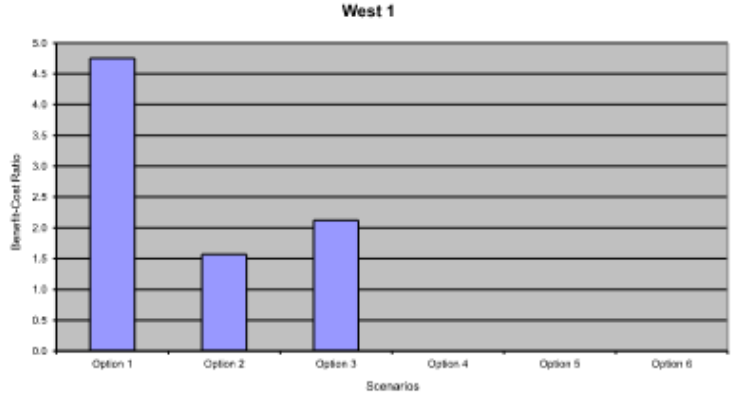
Assessment matrix

	Option 1	Option 2	Option 3
NZS 6806 compliance	+	---	+++
Structural mitigation	+ +	- -	+ + +
BCR	+ + +	+ + +	+ + +

Graphs







F9 West 2

Project
SH16 Stage 2
West 2

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution			●	○	○	○	○	○	○
Category A	0	0	0	1	0	0	0	0	0
Category B	1	1	1	0	0	0	0	0	0
Category C	0	0	0	0	0	0	0	0	0
Total			1	1	0	0	0	0	0

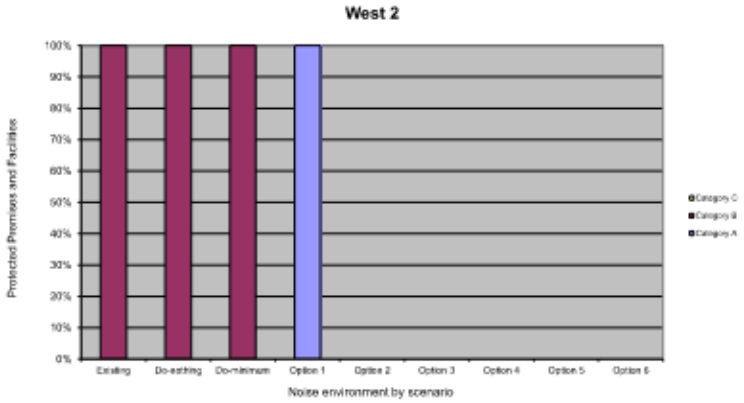
Benefit-Cost Ratio

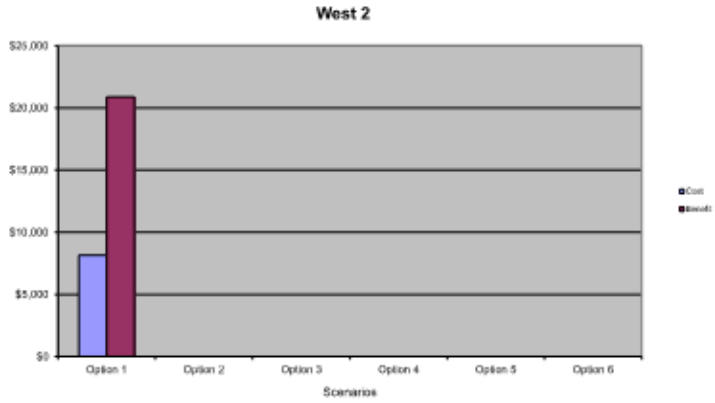
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$8,160	$0	$0	$0	$0	$0
Benefit	$20,880	$0	$0	$0	$0	$0
BCR	2.56	-	-	-	-	-
Structural	1.8 dB					

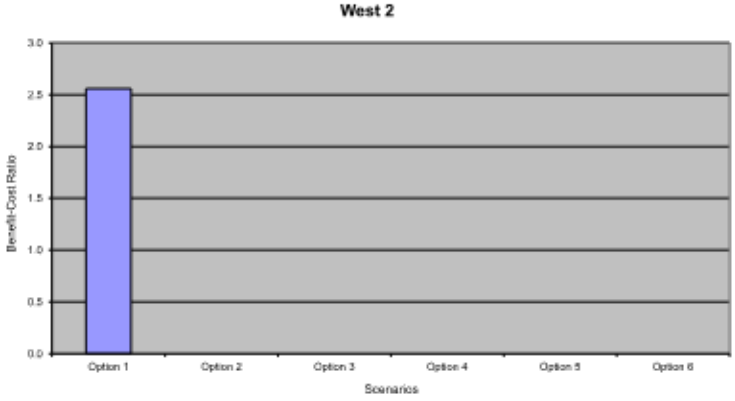
Assessment matrix

NZS 6806 compliance	+++
Structural mitigation	-
BCR	+++

Graphs







F10 West 3

Project
SH16 Stage 2
West 3

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution			●	○	○	○	○	○	○
Category A	1	1	1	1	1	2	1	0	0
Category B	0	1	1	1	1	0	1	0	0
Category C	1	0	0	0	0	0	0	0	0
Total			2	2	2	2	2	0	0

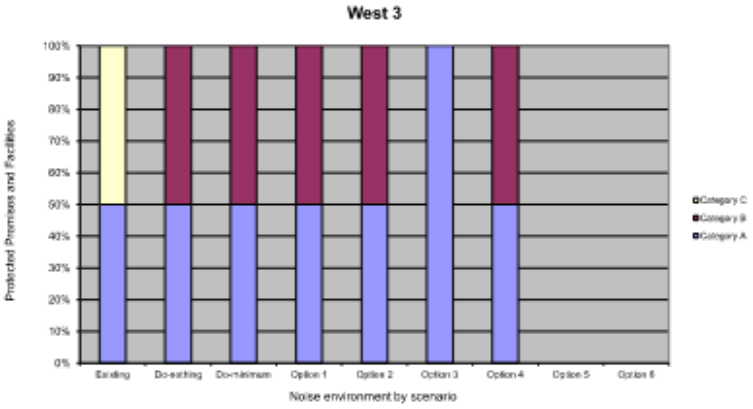
Benefit-Cost Ratio

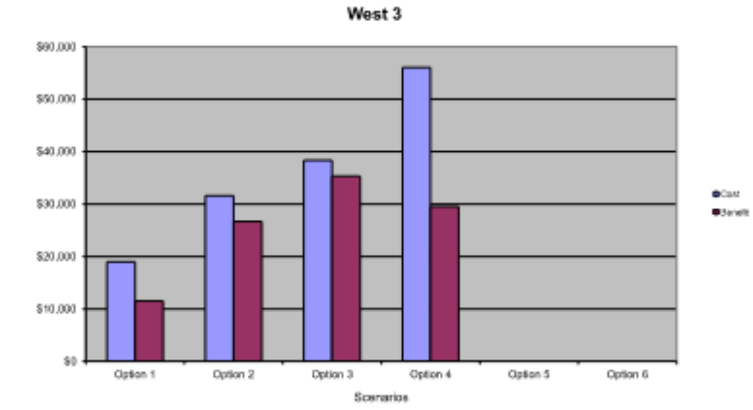
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$18,960	$31,600	$38,343	$56,000	$0	$0
Benefit	$11,520	$26,640	$35,280	$29,520	$0	$0
BCR	0.61	0.84	0.92	0.53	–	–
Structural	1.1 dB	1.3 dB	1.9 dB	1.5 dB		

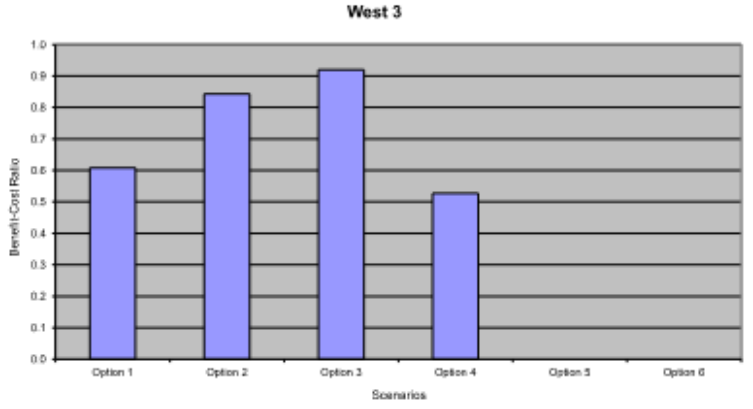
Assessment matrix

	Option 1	Option 2	Option 3	Option 4
NZS 6806 compliance	+	+	+++	+
Structural mitigation	– –	– –	–	–
BCR	–	o	o	–

Graphs







F11 West 4

Project
SH16 Stage 2
West 4

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution				◉					
Category A	3	2	2	3	0	0	0	0	0
Category B	0	1	1	0	0	0	0	0	0
Category C	0	0	0	0	0	0	0	0	0
Total			3	3	0	0	0	0	0

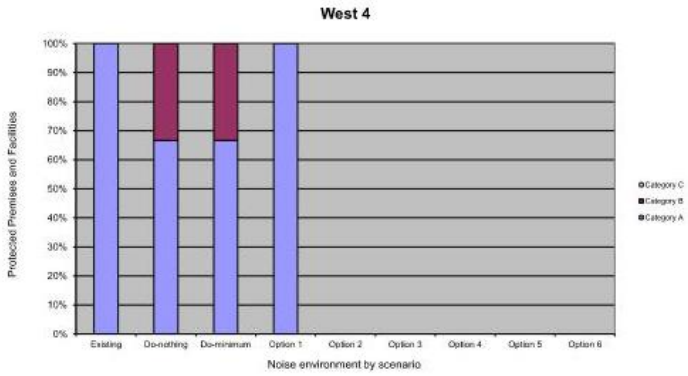
Benefit-Cost Ratio

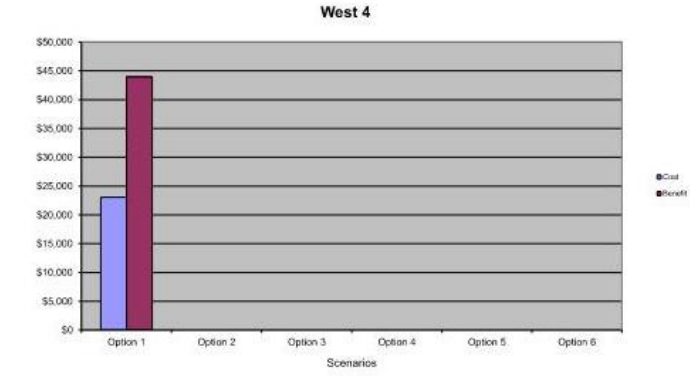
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$23,040	$0	$0	$0	$0	$0
Benefit	$43,920	$0	$0	$0	$0	$0
BCR	1.91	-	-	-	-	-
Structural	3.4 dB					

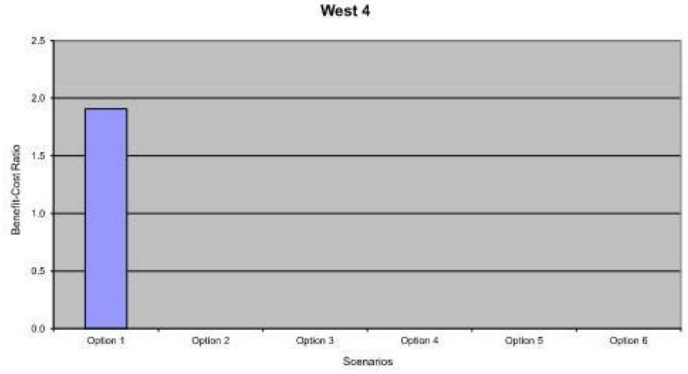
Assessment matrix

NZS 6806 compliance	+ + +
Structural mitigation	o
BCR	+ + +

Graphs







F12 West 5

Project
SH16 Stage 2
West 5

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	0	0	0	1	0	0	0	0	0
Category B	1	1	1	0	0	0	0	0	0
Category C	0	0	0	0	0	0	0	0	0
Total			1	1	0	0	0	0	0

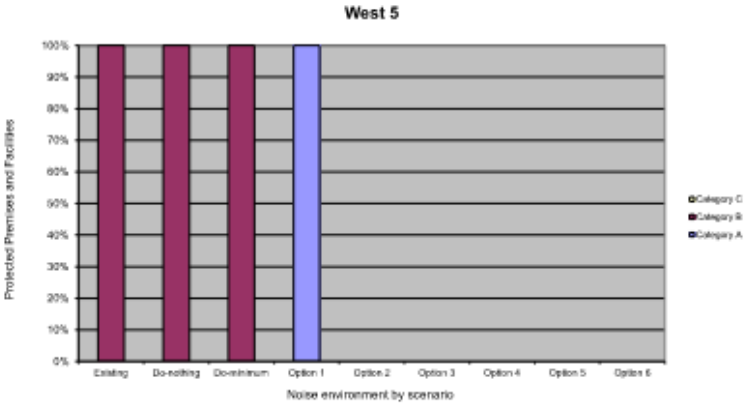
Benefit-Cost Ratio

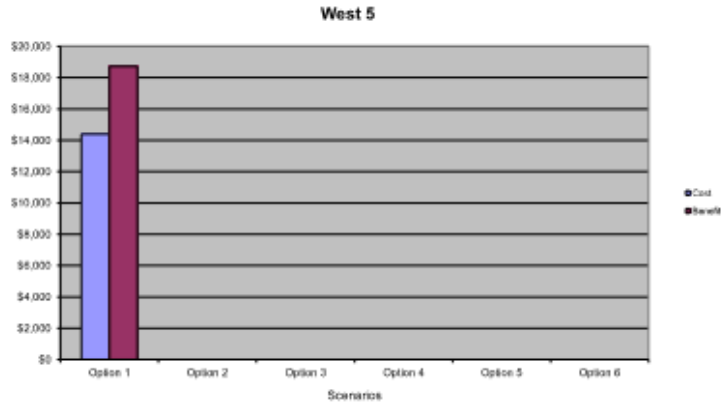
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$14,400	$0	$0	$0	$0	$0
Benefit	$18,720	$0	$0	$0	$0	$0
BCR	1.30	-	-	-	-	-
Structural	1.7 dB					

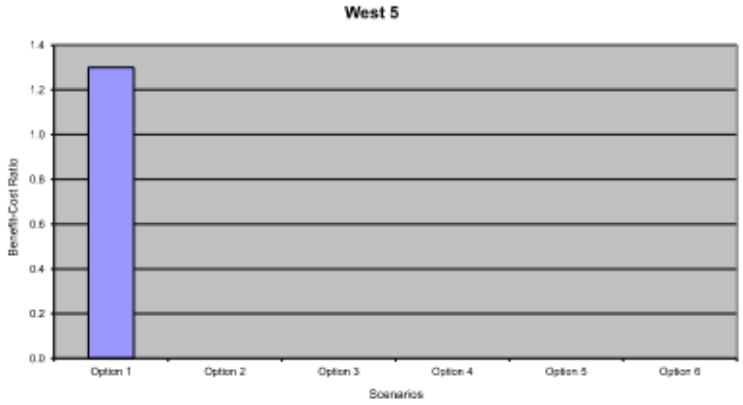
Assessment matrix

NZS 6806 compliance	+++
Structural mitigation	-
BCR	++

Graphs







F13 West 6

Project
SH16 Stage 2
West 6

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution			◉	○	○	○	○	○	○
Category A	7	7	7	8	0	0	0	0	0
Category B	1	1	1	0	0	0	0	0	0
Category C	0	0	0	0	0	0	0	0	0
Total			8	8	0	0	0	0	0

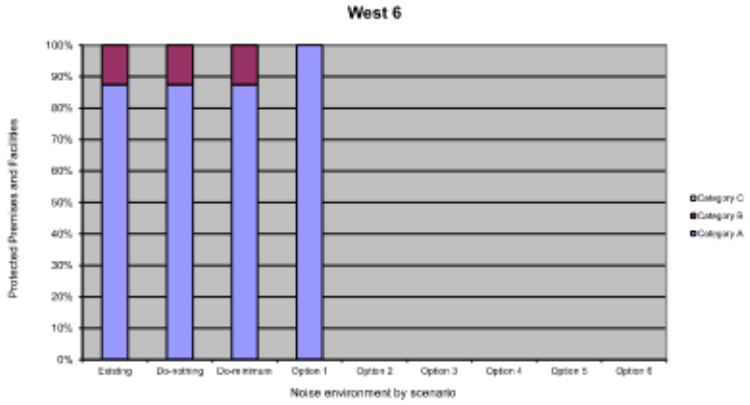
Benefit-Cost Ratio

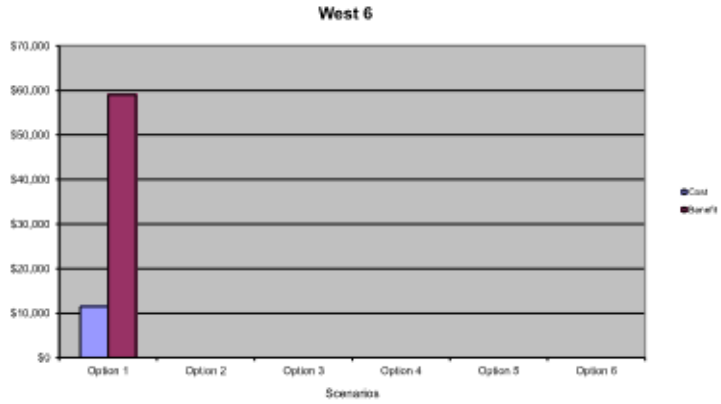
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$11,501	$0	$0	$0	$0	$0
Benefit	$59,040	$0	$0	$0	$0	$0
BCR	5.13	-	-	-	-	-
Structural	0.9 dB					

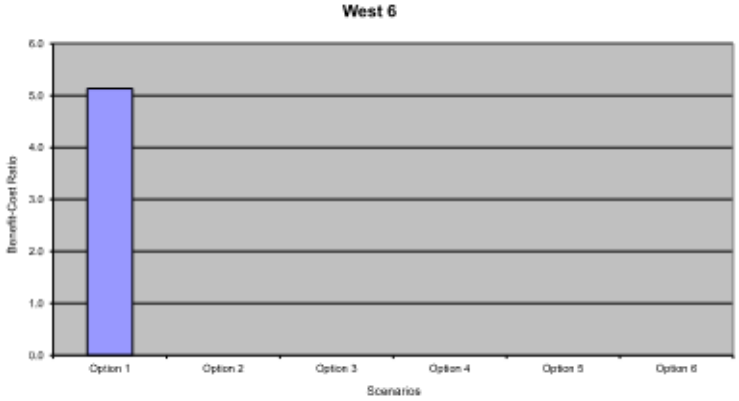
Assessment matrix

NZS 6806 compliance	+++
Structural mitigation	- -
BCR	+ + +

Graphs







F14 West 7

Project
SH16 Stage 2
West 7

Protected Premises and Facilities

	Existing	Do-nothing	Do-minimum	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Selected solution									
Category A	0	0	0	1	0	0	0	0	0
Category B	1	1	1	0	0	0	0	0	0
Category C	0	0	0	0	0	0	0	0	0
Total			1	1	0	0	0	0	0

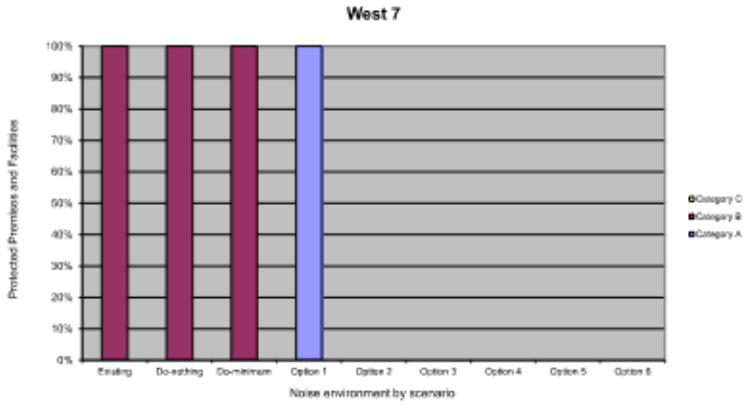
Benefit-Cost Ratio

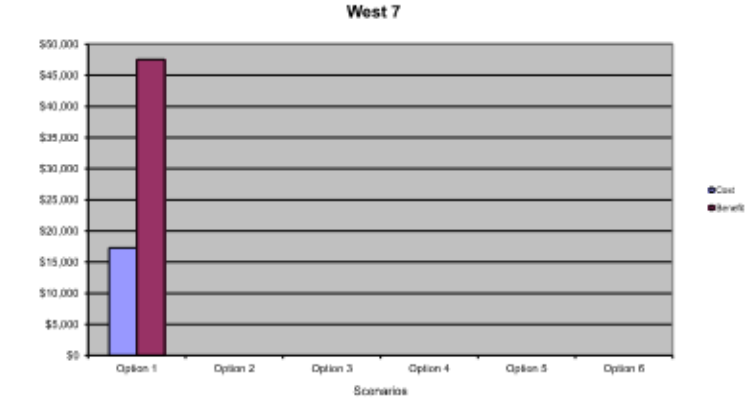
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Cost	$17,280	$0	$0	$0	$0	$0
Benefit	$47,520	$0	$0	$0	$0	$0
BCR	2.75	-	-	-	-	-
Structural	5.6 dB					

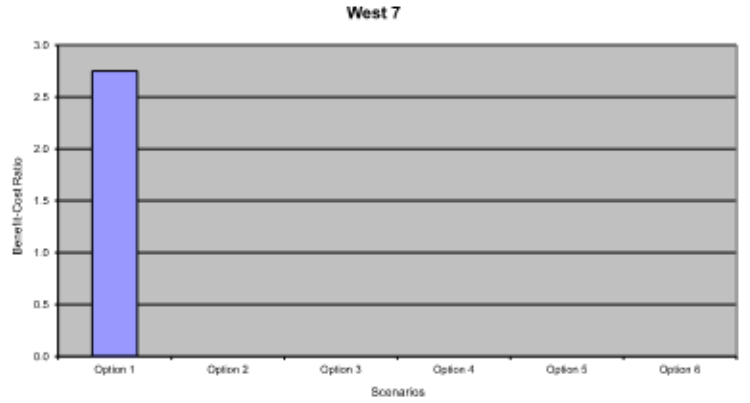
Assessment matrix

NZS 6806 compliance	+++
Structural mitigation	+ + +
BCR	+ + +

Graphs







APPENDIX G BPO MATRICES