

NZTA STATE HIGHWAY NOISE BARRIER DESIGN GUIDE

Version 1.0 / August 2010



NZ TRANSPORT AGENCY
WAKA KOTAHI



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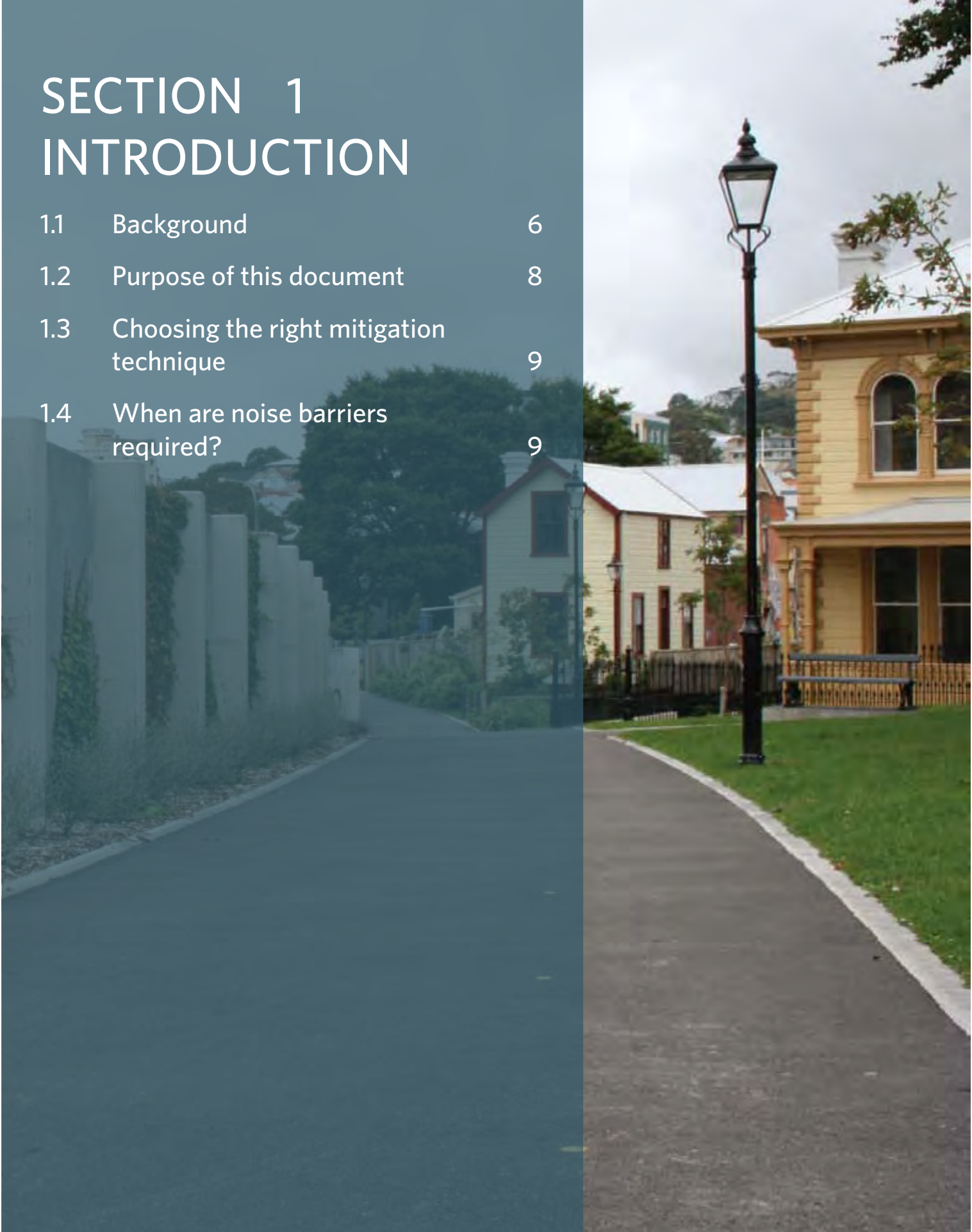
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1 INTRODUCTION

1.1 Background

The NZ Transport Agency (NZTA) aims to be a good neighbour, taking social and environmental responsibility seriously, including management of noise. This is reflected in external and internal strategy and policy documents that the NZTA is required to implement (refer Figure 1.3). These documents are consistent with the requirements of the Land Transport Management Act 2003 and Resource Management Act 1991.

The NZTA Environmental Plan¹ sets formal objectives regarding noise from the state highway network including:

- ◀ N1 Reduce exposure to high traffic noise levels from the existing state highway network.
- ◀ N2 Determine reasonable noise requirements when seeking new or altering existing designations including when designating existing local roads by using RMA procedures

Roadside noise barriers are commonly used by the NZTA to fulfil these objectives (subject to the criteria in Section 1.4). Where the criteria in Section 1.4 are not met the NZTA generally does not install noise barriers.

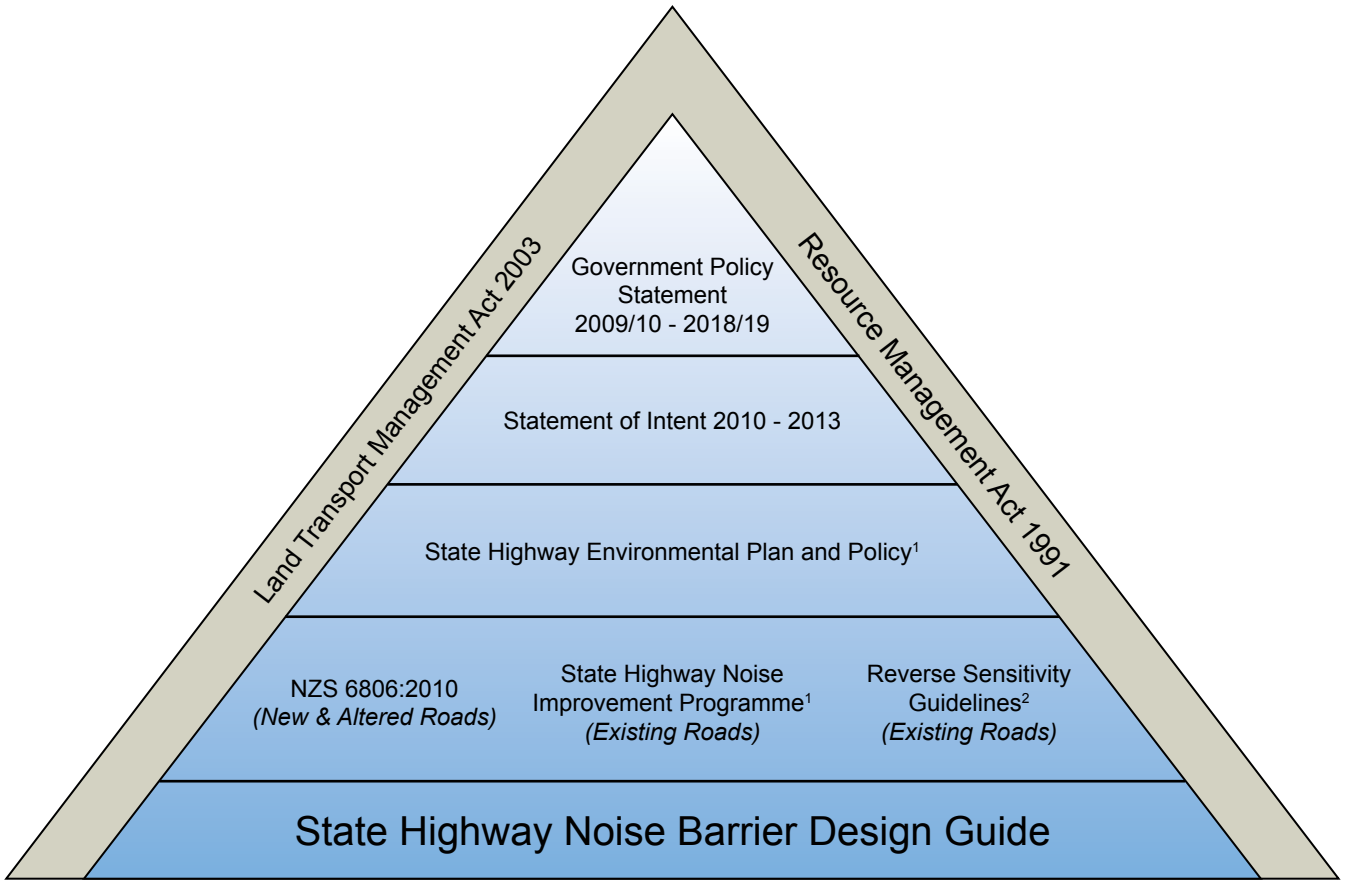
The term “noise barrier” in this guide refers to both wall type structures and berms/bunds.



Figure 1.1 Earth bund, Rolleston



Figure 1.2 Noise wall, Avalon Drive, Hamilton



¹NZTA Environmental Plan
²NZTA Planning Policy Manual

Figure 1.3 Relationship of the Noise Barrier Design Guide to key NZTA Policy and Strategy documents

INTRODUCTION

1.2 Purpose of this document

Noise barriers are probably the most widely recognised form of noise mitigation used by the NZTA. This guide has been produced to aid NZTA staff and contractors with the design, construction and maintenance of noise barriers.

Noise barriers need to be considered in the context of providing effective noise relief, while also addressing issues of appearance, urban design, site constraints, maintenance (including whole-of-life costs), safety, graffiti, cost (value-for-money) and sustainability.

In other words, the positive aspects of a new noise barrier (e.g. reduced noise levels for residents), should not bring about undue negative impacts to the road environment or the surrounding area. To this end, it is important that the increasing number of noise barriers being constructed for the NZTA should be built with a coherent, consistent approach, rather than ad hoc solutions to individual sites. This guide aims to deliver such an approach, ensuring noise barriers are designed to be fit-for-purpose as noise control structures, while at the same time minimising their impacts on the immediate surroundings and the wider environment. Territorial Authorities may also find this guide useful in regards to noise barriers for local roads. This guide does not include specifications or standards.



Figure 1.4 Noise barriers should provide effective noise relief as well as visually blending with the surrounding environment



Figure 1.5 A number of expert inputs are required to determine the most appropriate noise mitigation solution

1.3 Choosing the right mitigation technique

Due to their potential negative impacts, the installation of noise barriers should be seen as a secondary solution, after other noise mitigation options have been considered. Besides noise barriers, there are various other ways to mitigate road noise that should be considered first:

- ▮ Planning to avoid major roads near residential areas as far as practicable, and encouragement of less noise sensitive land uses near road corridors;
- ▮ Careful road design, including horizontal and vertical alignment, and where appropriate tunnelling; and
- ▮ Other noise control methods such as low noise road surfaces, design gradients and speed management.

Determining what represents the most appropriate noise mitigation solution for any given project requires a range of expert input, including advice from acoustics engineers, urban designers and cost estimators (for consideration of value-for-money).

Noise mitigation measures should be considered both individually and in combinations, as the optimum mitigation strategy may involve using a number of different measures.

1.4 When are noise barriers required?

Depending on the site specific issues, noise barriers may be required for existing, altered, and new roads. Noise barriers should only be installed where objective assessment demonstrates that they are required under the relevant noise criteria outlined in this section, and that they represent the best practicable option. For example, New Zealand Standard NZS 6806:2010² specifies that barriers should only be installed if they reduce noise levels by at least 3 dB at a cluster of houses or 5 dB at a single house. For each situation, to determine whether a noise barrier should be constructed, the following criteria need to be assessed:

INTRODUCTION

Existing roads

For state highways, Section 2.1 of the NZTA Environmental Plan details a Noise Improvement Programme. Where noise sensitive locations are exposed to state highway noise above a funding threshold of 65 dB $L_{Aeq(24h)}$, the Programme can provide funding for retro-fit noise mitigation measures. Allocation of funds under the Programme is prioritised on the basis of assessment criteria set out in the Environmental Plan.

There are restrictions on how funds from the Noise Improvement Programme can be used, including that it can only be used for:

- measures within or at the edge of the state highway corridor, and
- barriers up to a maximum height of 3 metres with landscaping where practicable.

As funds under the Noise Improvement Programme are prioritised to provide the greatest benefit, it is generally not appropriate for the NZTA to separately retro-fit noise barriers for existing roads that do not qualify for funding. For further clarification on any special cases please email environment@nzta.govt.nz.

Where new residential developments are proposed adjacent to an existing road, the developer will often need to provide mitigation measures to reduce traffic noise levels received at the new development. This issue is discussed in detail within the NZTA Reverse Sensitivity Guidelines³. For such developments any noise barriers should be constructed within the developer's land, and outside of the road corridor. The barrier would not be the responsibility of the NZTA. For the purposes of the Reverse Sensitivity Guidelines a future road that has been designated (but not yet built), and future increases in road-traffic, should both be treated as if an existing road. Refer to Section 2.12 (Examples) for illustrations of the noise exposure to houses at varying distances from roads, with and without barriers

Altered roads

Minor works, such as resurfacing and slight road widening within the existing road corridor are not classified as an altered road. In regards to noise barriers, such minor works should be treated in the same manner as existing roads (see above).

The definition of "altered road" is given in the New Zealand Standard NZS 6806:2010. A road is only considered under this category if the predicted change in noise levels exceeds certain thresholds, which will generally occur only with a significant alteration to the alignment. A web based tool to assess whether works are considered as an altered road is provided on the NZTA Transport Noise website (www.acoustics.nzta.govt.nz).

To determine whether a noise barrier is required, works that meet the threshold to be considered as an altered road should be assessed in the same way as new roads (see below), but applying the noise criteria for altered roads within NZS 6806:2010.

New roads

The criteria and assessment method used by the NZTA for noise from new and altered roads changed in 2010 to NZS 6806:2010. Under the new standard, performance targets are used, and a number of different options for noise mitigation (often including barriers) are assessed. These options are subject to an integrated design process in which the costs and benefits of noise barriers will be considered.

For a transitional period of two years, one of the options to be assessed under NZS 6806:2010 should be designed to achieve compliance with the old criteria from Transit's Noise Guidelines⁴.

When noise barriers are required to mitigate road-traffic noise, consideration should be given as to whether they could be installed at an early stage in the construction works, to provide screening of construction noise.

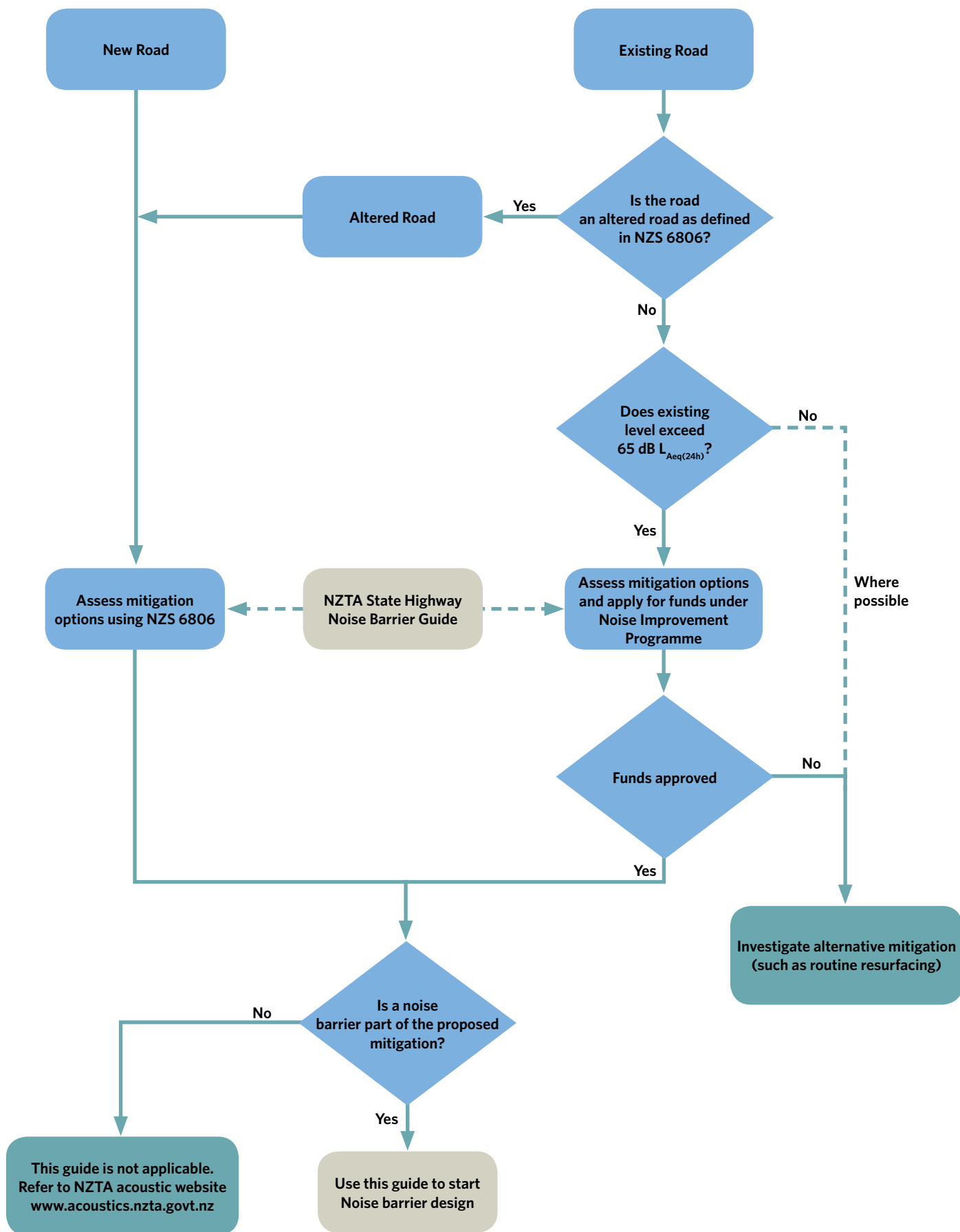


Figure 1.6 Criteria for determining if noise barriers are required



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2 ACOUSTICS DESIGN

The information contained within this section is generally based upon the NSW Roads and Transport Authority (RTA) - "Noise wall design guideline"⁵, and has been produced with their permission.

The purpose of this section is to outline the basic acoustics principles associated with noise barrier design.

2.1 Overview

Sound sources cause changes in air pressure which are detected by our ears. These changes can also be measured by a sound level meter. The pressure changes are expressed in decibels, which is written as "dB". As this is a logarithmic scale familiar mathematical rules for addition do not apply e.g. 55 dB + 55 dB = 58 dB. An increase of 3 dB is a doubling of sound energy. However, a 3 dB increase is only just perceptible to the human ear. As a rule-of-thumb a 10 dB increase corresponds approximately to a doubling of perceived loudness e.g. 60 dB sounds twice as loud as 50 dB.

Sound can occur across a whole range of frequencies from low frequency rumbles to high frequency chirps. Measured sound levels include all frequencies, but as our hearing is less sensitive to lower frequencies, the measured levels are adjusted to correspond to human hearing. This adjustment is called "A weighting" and is identified by the letter A, e.g. 60 dB L_{Aeq(24h)}.

The difference between the terms sound and noise is subjective, but generally speaking noise is defined as unwanted sound. In this guide the terms "road-traffic noise" and "noise barrier" are used.

It is useful to consider sound propagation as a series of rays emanating from the source of the sound (although in fact sound travels in waves). Thus the sound can reach a listener either directly (in a straight line) or indirectly by reflection or diffraction, which can cause sound to "bend" around a corner. When a noise barrier is present,

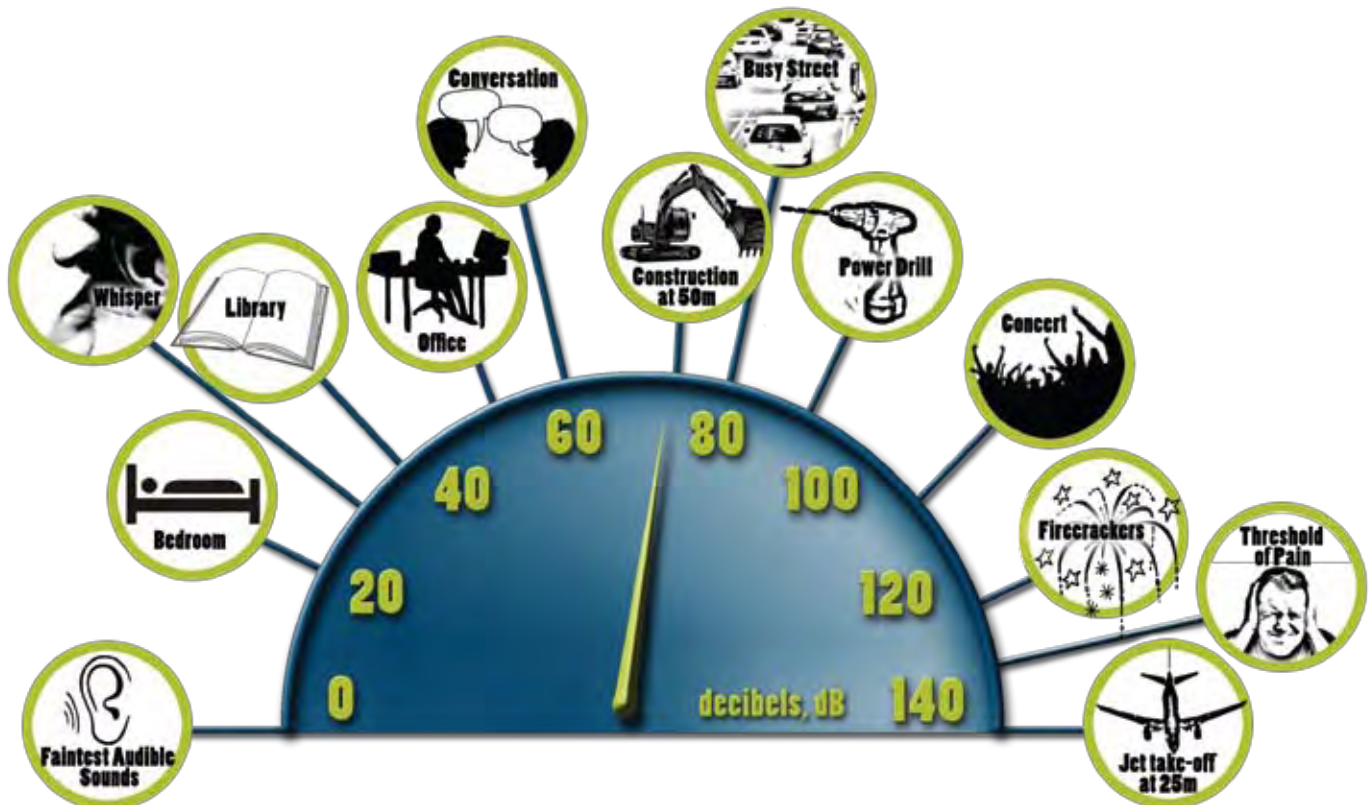


Figure 2.1 Typical noise levels

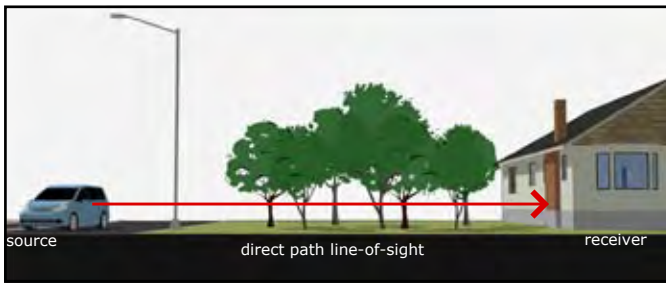


Figure 2.2 Level ground with no noise barrier

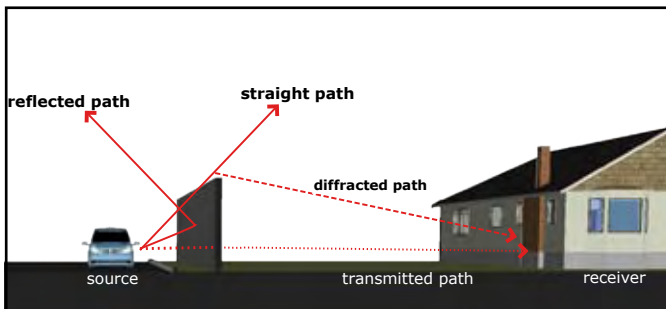


Figure 2.3 Level ground with noise barrier

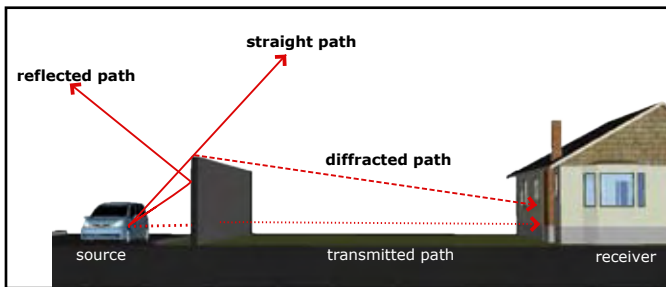


Figure 2.4 Noise barrier located close to source of sound

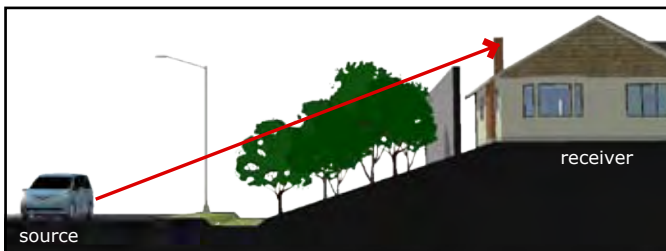


Figure 2.5 Noise barrier located at top of cutting

sound can be partly absorbed by the material of the barrier, and some sound can be transmitted through the barrier.

The straight sound path is usually the most significant and by introducing a barrier between the source and the receiver, the amount of sound reaching the receiver can be significantly reduced (Figure 2.2 and 2.3).

2.2 Location

The first issue to consider is the optimum location for noise barriers. In principle a noise barrier is most effective located as close to the road as possible (Figure 2.4). However, for a road located in a cutting it is better to place the barrier at the top of the cutting, where it will have a greater effect (Figure 2.5). These principles may need some compromise where there are physical constraints, clearance requirements on a route for oversized loads, or overarching aesthetic/urban design objectives to consider.

For an individual house a barrier could also be effective if located close to that receiver. However, the NZTA should generally only install barriers within the road corridor, and a barrier close to one receiver is not likely to be as effective for other receivers further from the road.

ACOUSTICS DESIGN

2.3 Height

The height of a noise barrier is also a key parameter. Generally the higher the barrier, the greater the level of noise reduction. As a general rule, a noise barrier should at least be high enough to block the line-of-sight from a house to the engines of vehicles on a road. This line should be assessed from a point 1.5 metres above the floor of an adjacent house to the furthest point 1 metre above the road surface (Figure 2.6). When a noise barrier just breaks the line-of-sight between the noise source and the receiver there is approximately 5 dB attenuation of noise. The theoretical limit for noise barrier attenuation is about 20 dB in the shadow zone, however in practice a realistic limit is about 15 dB⁶.

The noise reduction required from a noise barrier, and therefore the barrier height, is dependent upon the noise criteria at the receivers behind the barrier. This criteria may need to include a "safety margin" to account for uncertainty in the acoustics assessment, but that margin should not exceed 2 dB as otherwise the barrier may become unnecessarily high (NZS 6806 specifies that

modelling software should have an accuracy of ± 2 dB).

For multiple-lane roads, the noise from the furthest traffic lanes will not be reduced by a noise barrier as much as noise from the nearest lanes because of the different path angles (Figure 2.7), unless the road is on a bridge or embankment above houses. A substantial (often impractical) increase in the barrier height may be required to significantly reduce noise from the furthest traffic lane. One possible solution is to locate a second noise barrier in the median strip, but this has visual implications that must be considered (Figure 2.8).

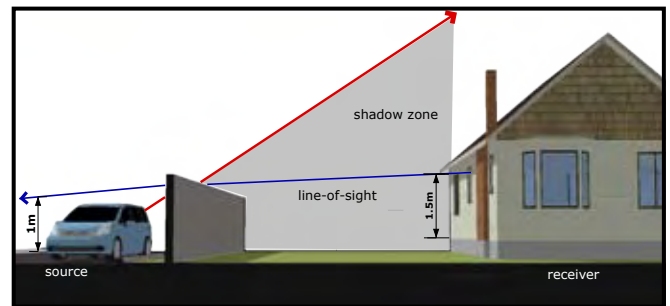


Figure 2.6 Line-of-sight and the noise barrier shadow zone

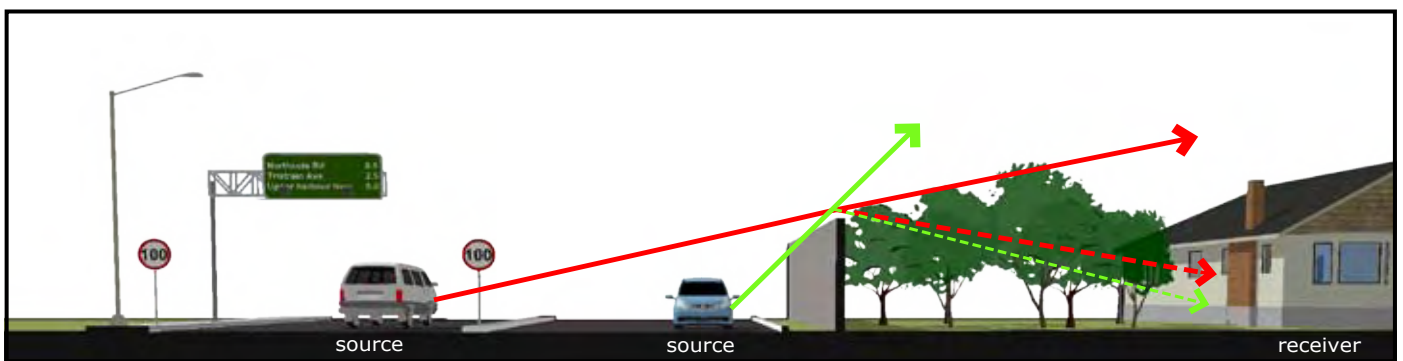


Figure 2.7 Noise from furthest traffic lanes will not be reduced as much

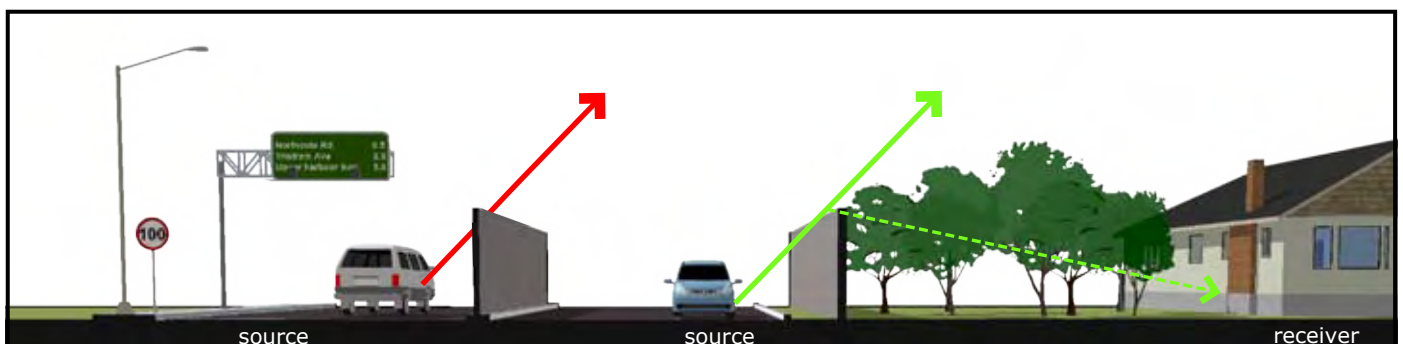


Figure 2.8 Noise barrier located in median

Where noise barriers are located on both sides of a road (or both sides of a lane with a noise barrier in the median strip), an absorptive barrier construction may be required to reduce the impact of reflected noise (refer also Section 2.4 - Reflections).

Noise barriers do not necessarily have to be of constant height. The height should initially be determined on the basis of the noise criteria at each house. This may result in increased noise barrier height in the vicinity of isolated houses and reduced height or no barrier in between. However the changes in vertical or horizontal alignment of a noise barrier need to be carefully managed to ensure the structure isn't visually jarring (refer Section 3.4 - Urban Design).

2.4 Reflections

Reflected sound rays are an important consideration when designing noise barriers (Figure 2.9). Multiple reflections between parallel noise barriers, or between barriers and high sided vehicles, can reduce the benefit of a barrier.

For parallel barriers, ensure that the distance

between the two barriers is at least ten times their average height. Recent studies suggest less than a 10:1 width-to-height ratio will result in a degradation of the effectiveness of the noise barrier e.g. 3 dB or greater increase in noise levels⁷⁻⁸.

It is possible to reduce the acoustic reflectivity of a noise barrier by using an absorptive material (e.g. mineral wool or fibre glass) with an appropriate facing. Alternative absorptive materials include "hard" surfaces that are porous or have resonant cavities. For all new state highway noise barriers, multiple reflections should be assessed and absorptive barriers specified where appropriate. Alternatively the vertical angle of a noise barrier can be used to avoid multiple reflections and to reflect noise away from the receiver (Figure 2.10). A rule-of-thumb is that sloping a noise barrier outwards by as little as 7° reduces the impacts of reflections⁹ (refer also Section 3.4 - Urban Design). Another approach could be to maintain a vertical barrier but use a relief pattern with angled component geometry to achieve an upwardly dispersed reflection.

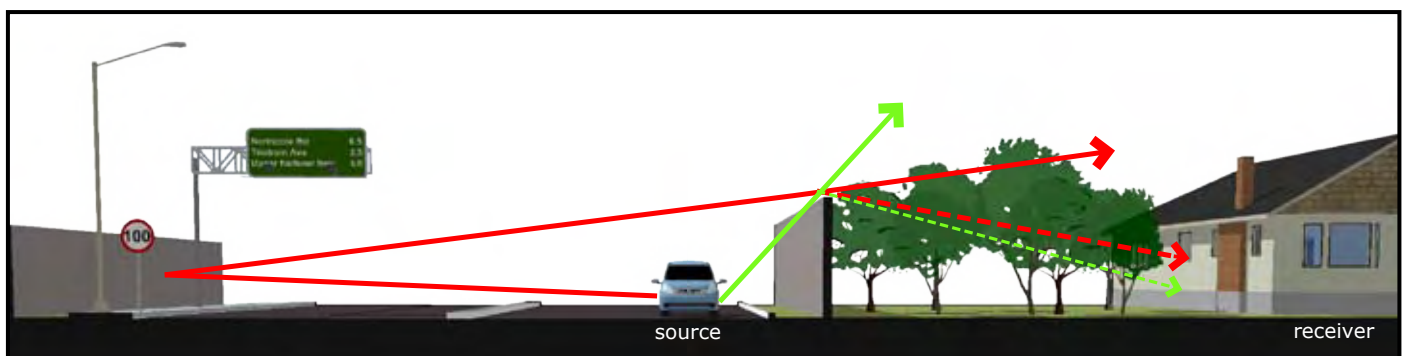


Figure 2.9 Reflected sound rays can become an issue with parallel noise barriers located close together

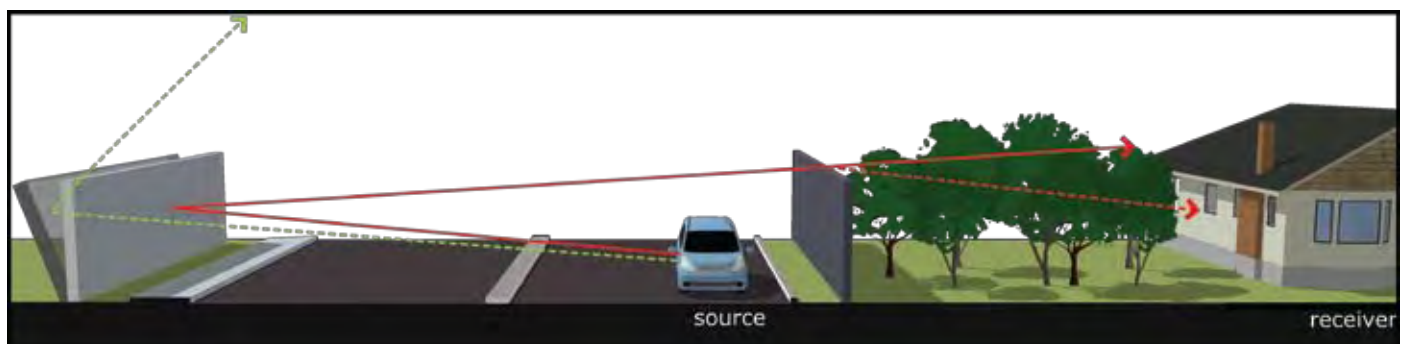


Figure 2.10 Tilted noise barriers can direct noise away from the receiver

ACOUSTICS DESIGN

2.5 Top shape

Modifying the shape of the top edge of a noise barrier can increase the performance of the barrier without increasing the height and associated visual impacts. Shapes include T-tops, Y-tops, pear-shaped tops, cantilevered walls and others. Given the same total height of wall, these can improve barrier attenuation by 1 to 10 dB¹⁰. Figure 2.11 shows some different barrier tops. Use of these top shapes is not established in New Zealand and it is likely to be an expensive solution at the current time.

For further information on improving the acoustic performance of noise barriers see Kotzen and English (2009), pages 51-58¹¹.

2.6 Bunds

Where space is available, bunds (which are a form of noise barrier) can be a more attractive solution, either on their own or with a low wall type barrier on top of the bund. This is generally only an option in suburban or rural projects where wide corridor widths are possible. Bunds have been successfully integrated into the SH18 Hobsonville motoway extension (2007) in Auckland. A combination of 3 metre high marine plywood walls and planted earth bunds were designed as a noise mitigation solution that would complement the surrounding semi-rural landscape (Figure 2.12).

For acoustical design the top of the bund should be treated as a wall of the same height. However, if a bund has a wide top then greater barrier attenuation is achieved. To model this effect in the acoustical design, the effective height of the bund should be assumed to be higher than the actual physical height (Figure 2.13).

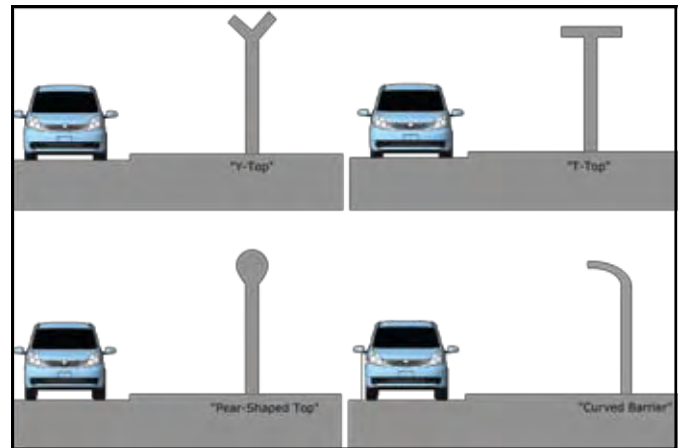


Figure 2.11 Different top shapes



Figure 2.12 SH18 in Auckland Hobsonville has a combination of earth bunds and noise walls to provide an effective noise mitigation solution

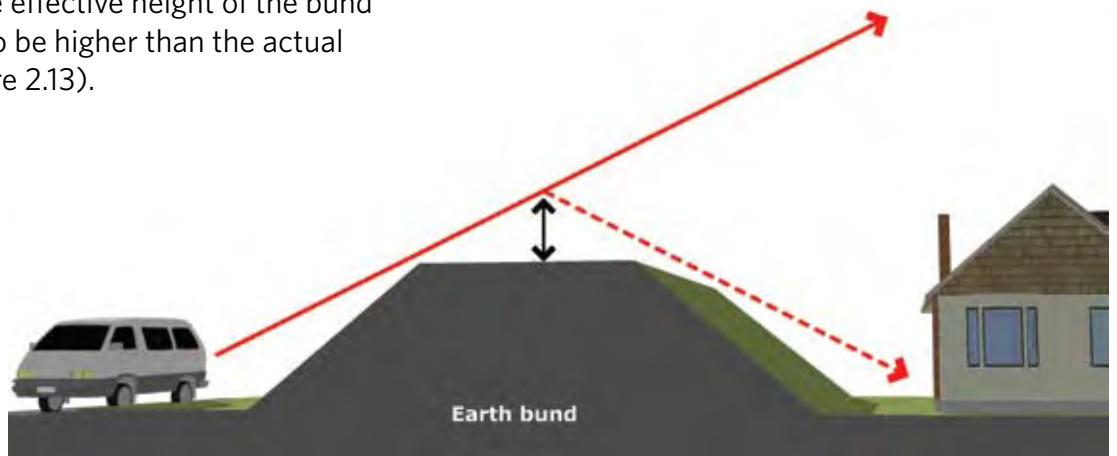


Figure 2.13 Effective height of an earth bund

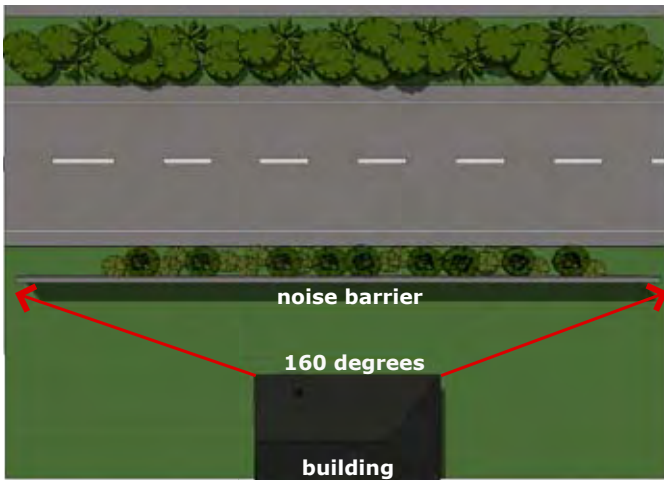


Figure 2.14 Noise barrier length

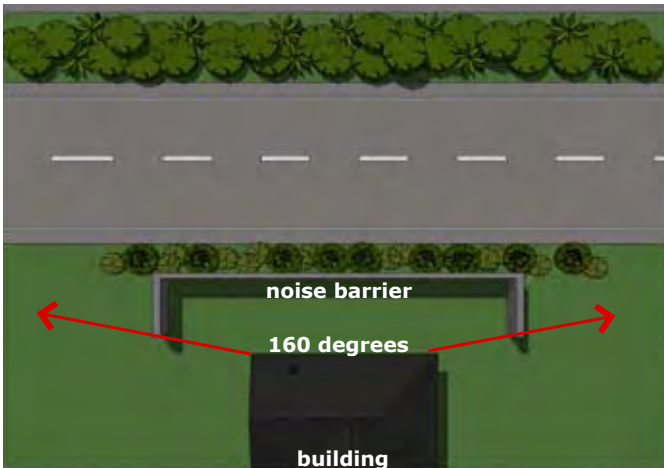


Figure 2.15 Noise barrier with return

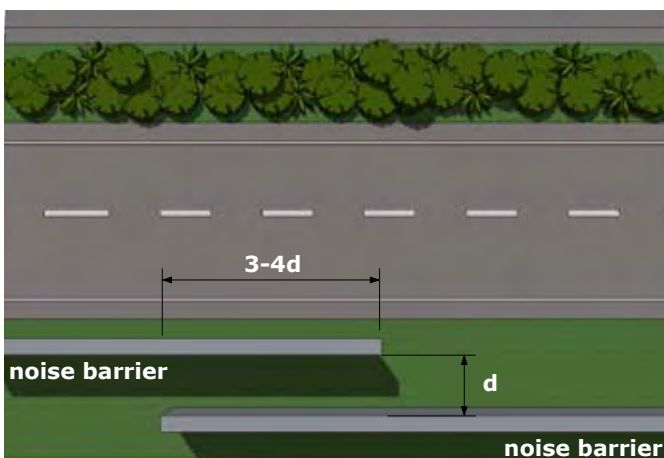


Figure 2.16 Relationship between openings in noise barriers

2.7 Length

Diffraction of sound occurs not only at the top edge of a barrier but also around the ends. As such, the length of a noise barrier is important. However it should be noted that sound diffracted around the ends of a barrier will usually be less significant than sound diffracted over the top, as the transmission path around the ends travels close to the ground and will be subject to ground absorption effects¹².

A rule-of-thumb to determine the required length of a noise barrier is that it must cover a horizontal angle of 160 degrees viewed from the receiver (Figure 2.14). This assumes a level site. If necessary due to site constraints, the length of a barrier can be reduced by returning the ends of the structure (Figure 2.15). However, this option is not always appropriate where the returned ends would be outside the road corridor and NZTA land.

The required lengths for noise barriers cannot be achieved where there are gaps for driveways. In some instances solid gates across the driveways can maintain the barrier performance. However, if there are numerous driveways then a noise barrier will generally not be an appropriate mitigation solution.

2.8 Continuity

In order to be effective, noise barriers must be continuous over the required length, with no vertical or horizontal gaps. In practice this is not always possible. For example it is often necessary to break barriers to allow access for pedestrians/cyclists, emergency vehicles, or for inspection and maintenance (refer to Section 4.4 - Access). Overlapping walls can be used to resolve this issue. They can also be used in the visual design where changes in vertical or horizontal alignment are required or where there are changes in materials. The overlap should be at least three to four times the opening width (Figure 2.16).

ACOUSTICS DESIGN

2.9 Materials

When a low to moderate performance is required from a noise barrier i.e. less than 10 dB reduction, the material from which the barrier is to be constructed is not critical from an acoustics perspective (although other considerations such as environmental, maintenance and aesthetics remain important). For noise reduction greater than 10 dB, or where the barrier height is over 2 metres, from an acoustics perspective, material selection becomes more important.

The reduction in noise transmitted through a barrier is measured as the “airborne sound insulation”. The barrier material should be selected to reduce transmitted noise through the barrier by at least 10 dB more than the overall desired barrier noise reduction e.g. if the barrier is to provide an overall reduction of 20 dB, the barrier material must reduce transmission through the barrier by at least 30 dB. This ensures that the main noise path to be considered in the acoustical design is the diffracted noise path (over the top). To achieve this, barriers should generally be constructed of materials that have a surface mass of at least 10 kg/m² and are built with no gaps. Suitable materials can include concrete, fibre cement board, steel and timber.

Any openings in a noise barrier either through material issues such as timber warping (Figure 2.17) or design/construction faults (Figure 2.18), can decrease the airborne sound insulation values and can seriously compromise the overall performance of a noise barrier. For a further discussion on testing for the sound insulation properties of noise barrier materials, refer to Section 5.5 (Sound insulation) of this guide.

Refer to Section 4.5 (Material selection) for a discussion on the overall advantages and disadvantages of different types of materials that can be used in noise barriers.



Figure 2.17 Timber planks are prone to warping, Auckland



Figure 2.18 Gaps can compromise the overall performance of a noise barrier, Auckland



Figure 2.19 Vegetation can provide a perception of noise reduction greater than the objective barrier performance, Newton onramp, SH16, Auckland

2.10 Vegetation

There is a commonly held belief that vegetation can be employed as a noise barrier. Typically vegetation is not an effective noise barrier and a 30 metre wide strip of suitably dense trees may only reduce noise by up to 5 dB where it obstructs the line-of-sight between the source and receiver. The role of planting in reducing noise is mostly psychological (if you can't see the traffic it reduces the perception of noise), although this can be a powerful mitigation tool in itself. Often the removal of vegetation between houses and the road can trigger noise complaints, with residents experiencing a perceived increase in noise, rather than any actual increase. This should be an important consideration when undertaking any roadside vegetation removal on NZTA land.

2.11 Wind

When conducting an assessment in accordance with NZS 6806, road-traffic noise level predictions are made for an average noise level over a year, not taking account of short-term meteorological variations. However, certain downwind conditions can reduce the effectiveness of a noise barrier, as sound is "bent" over the top of the barrier by the wind (Figure 2.20)¹³. Recent evidence has found that the presence of a row of trees behind a noise barrier can improve the downwind performance of a barrier. The effects of wind may need to be considered in the acoustics analysis of noise barriers at sites where high winds often occur and houses are further from the barrier.

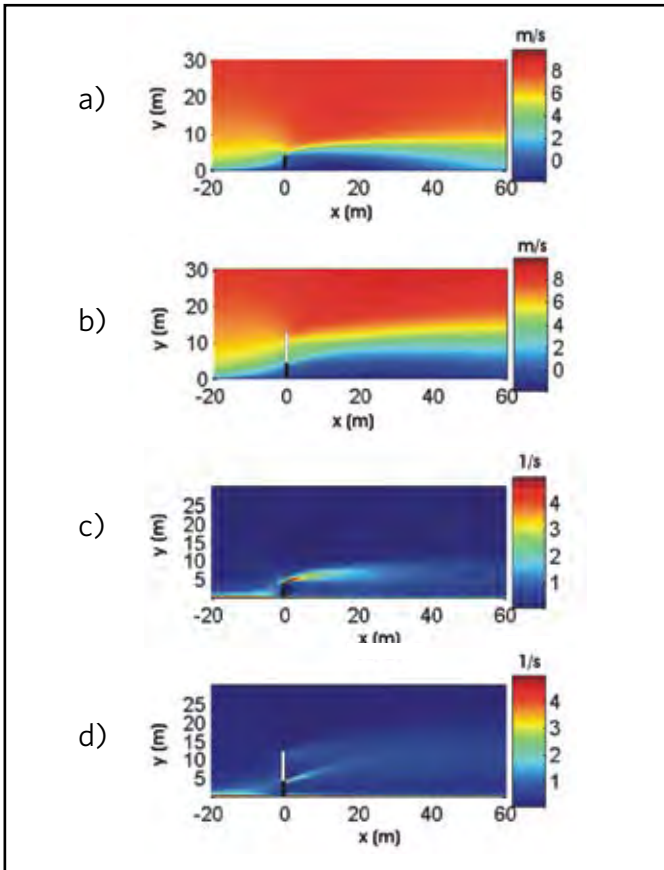


Figure 2.20 a) and c) depict wind speeds near a 4 metre high noise barrier (horizontal and vertical gradient respectively); b) and d) show reduced wind speeds with a row of trees directly behind the noise barrier

ACOUSTICS DESIGN

2.12 Examples

Figures 2.21 and 2.22 illustrate the reduction in noise levels that may be achieved by roadside noise barriers, at different distances from a road and with varying traffic flows. These examples have been calculated using the road noise calculator on the NZTA Transport Noise website (www.acoustics.nzta.govt.nz).

The traffic volumes and distances in these examples correspond with categories used in the NZTA Reverse Sensitivity Guidelines³.

Assumptions in Figures 2.21 and 2.22 are:

- Heavy vehicles = 10%
- Vehicle speed = 100 km/h
- Gradient = 0%
- Road surface = Grade 2 Chipseal
- Receiver height = 1.5 m
- Ground absorption = 0.6 to 0.8
- Angle of view of road segment = 160°
- Noise levels = free field

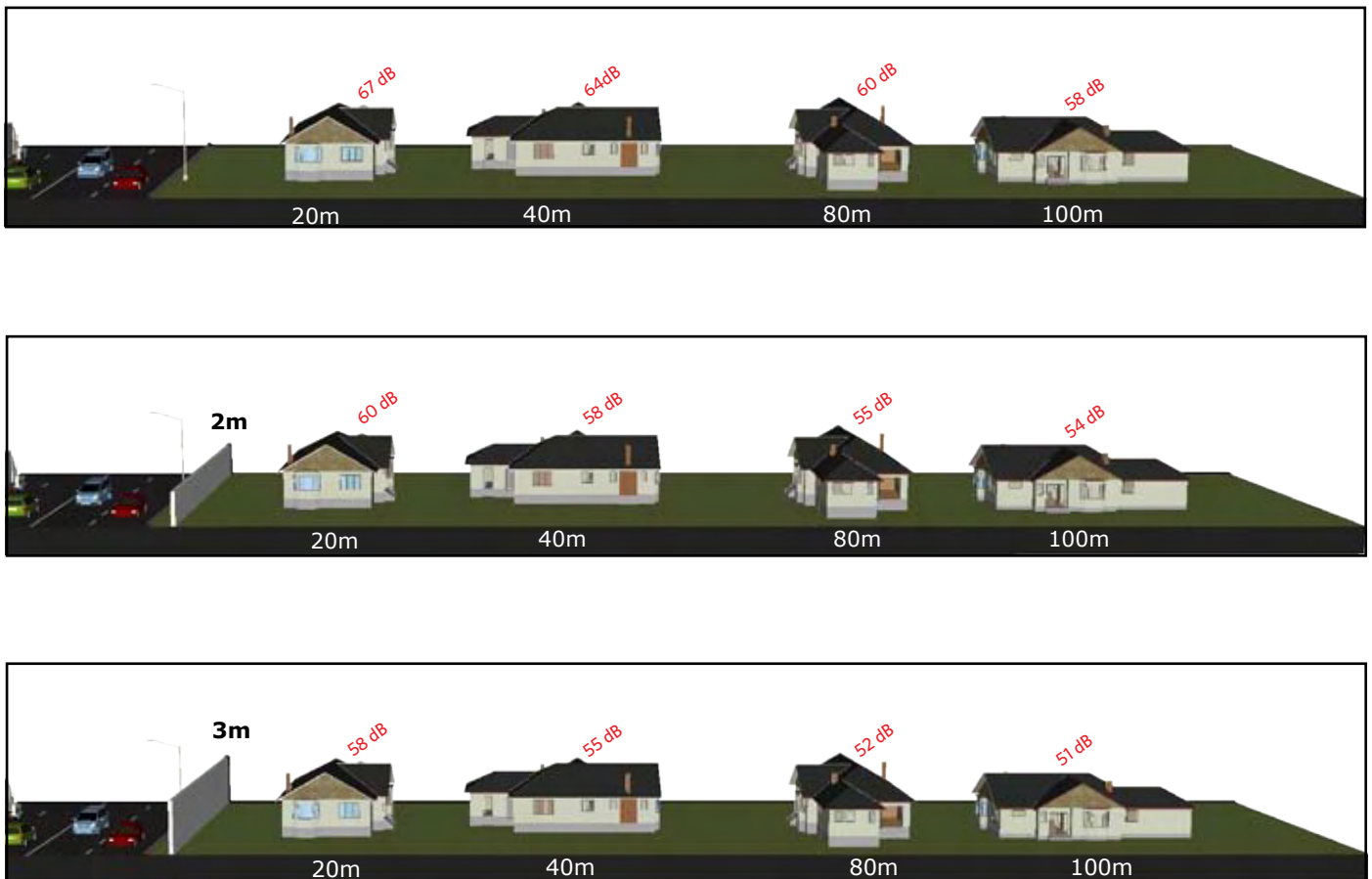


Figure 2.21 Noise levels at varying distances from a road with 10,000 vehicles per day (AADT)

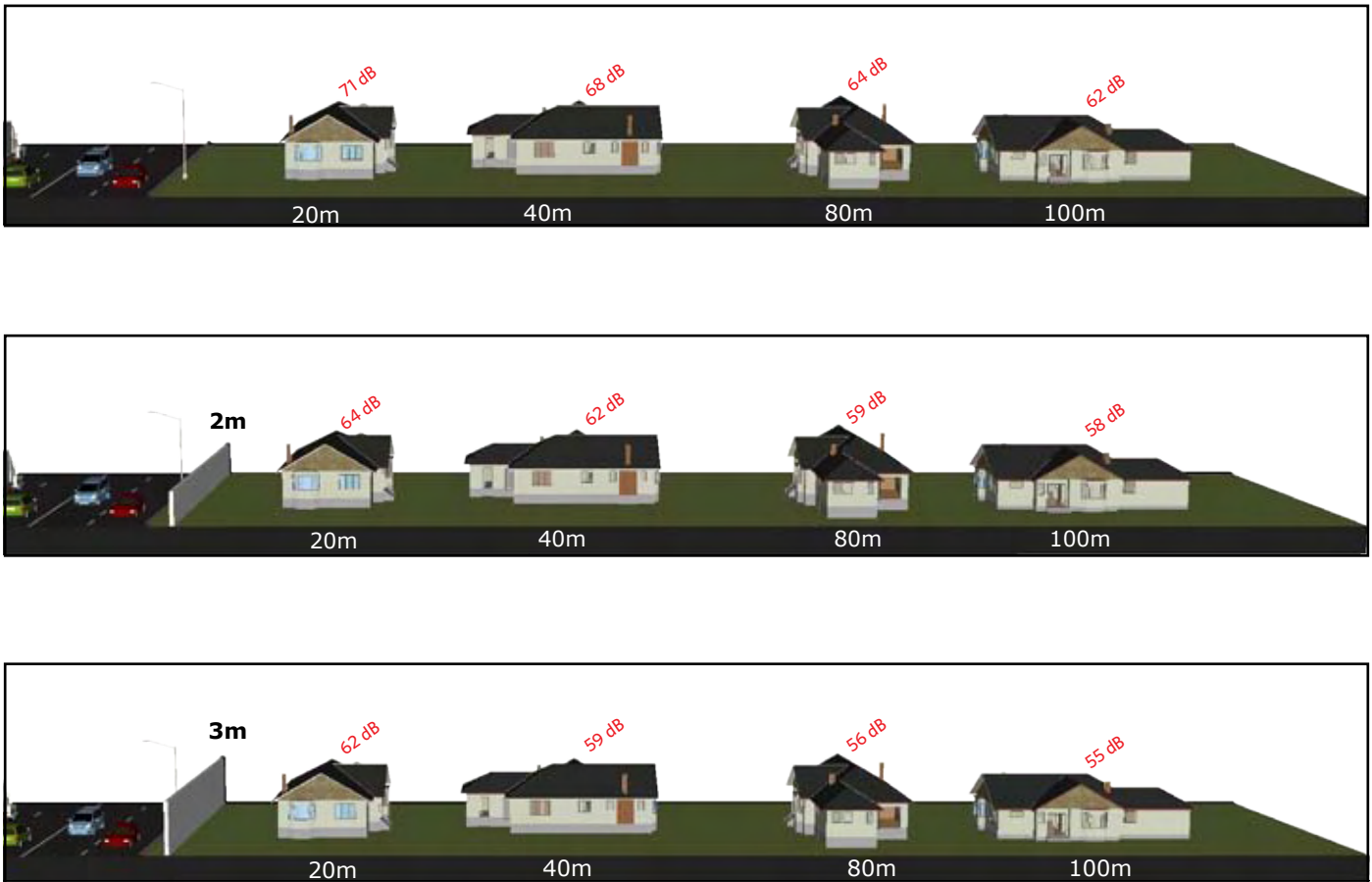


Figure 2.22 Noise levels at varying distances from a road with 25,000 vehicles per day (AADT)



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3 URBAN DESIGN

Although the acoustics function is the primary reason for building a noise barrier, this should not be done in isolation or to the detriment of the surrounding landscape and its visual context.

Noise barriers should be regarded as three dimensional objects with good noise barrier design considering form (the vertical and horizontal alignment), as well as texture (the materials, design and quality finish).

The following urban design principles should guide the location and design of noise barriers for the NZTA.

3.1 Site integration

Noise barriers should integrate with the design of the overall road corridor and complement the road structures, landscape, roadscape and any public art elements of the project. A long-term strategy for design of the entire corridor should be formulated early on, especially if it is known that noise barriers might be retrofitted later.

Certain elements of aesthetic design should be evaluated and considered separately in the design process dependant on whether the noise barrier surface is seen from the road or the adjacent land. Noise barriers should reflect local land use and integrate with the overall landscape character.



Figure 3.1 Integrated noise barriers with adjacent open space, Sydney



Figure 3.2 The scale of noise barriers can dominate open space in urban environments, and therefore barriers need careful planning and detailing to integrate with their surroundings, Melbourne



Figure 3.3 The location of noise barriers in relation to public space, shared paths and edge planting can help retain the character of an area, Wellington



Figure 3.4 The design of the Craigieburn bypass noise barrier blurs the boundaries between function, sculptural features and a pedestrian bridge, creating a unified roadway experience, Melbourne

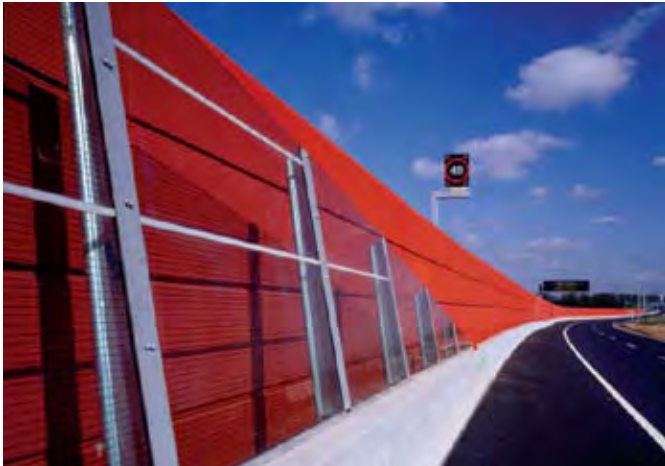


Figure 3.5 Noise barriers overlapping to accommodate for change in materials, Sydney



Figure 3.6 Undesirable long shadows can be cast by noise barriers, Maioro Street, Auckland

3.2 Height

The higher the noise barrier the greater the noise attenuation, but this is not always the best outcome for affected residents. Consider limiting the height of the noise barrier to balance noise and visual impacts. Separate overlapping walls can be used to accommodate any necessary changes in height, horizontal alignment, form and material.

3.3 Proximity

Noise barriers over-shadowing properties should be avoided; this can create a microclimate that reduces light and ventilation. Noise barriers should also be designed to maintain sight-lines for surveillance within the community for security purposes. A balance needs to be struck between reducing traffic noise from the road and potential impacts on personal security. Refer to Section 4.2 (Safety) of this guide for a more detailed discussion on the personal and road safety implications of installing noise barriers, including Crime Prevention through Environmental Design (CPTED) principles.

URBAN DESIGN

3.4 Alignment

A slight lean outwards can bring a considerable improvement in the visual impact of the noise barrier on road users, reducing the “tunnel” effect (this also serves an acoustics purpose by avoiding multiple reflections). However care needs to be taken to avoid reducing the effective height of the barrier. Consideration should also be given to spatial relationships from outside a noise barrier with a slight lean outwards.

Generally a noise barrier should follow the geometry of the road surface allowing room for clearzones (refer Section 4.2 - Safety) and street furniture e.g. signs and gantrys (refer Section 4.1 - Engineering). The strongest visual element of a noise barrier is the top edge because it is usually the most visible and is contrasted against the surrounding background. In general, the edge should be simple and smooth with consistent moderated stepping. Where noise barriers have a significant change in height, consideration should be given to separating the walls with an overlap.

Horizontal alignment with the carriageway is also important. Horizontally curved barriers can help to create a sense of place, and manage changes in alignment. Horizontal angles and sharp changes in direction should generally be avoided.



Figure 3.7 Angled noise barrier, Melbourne

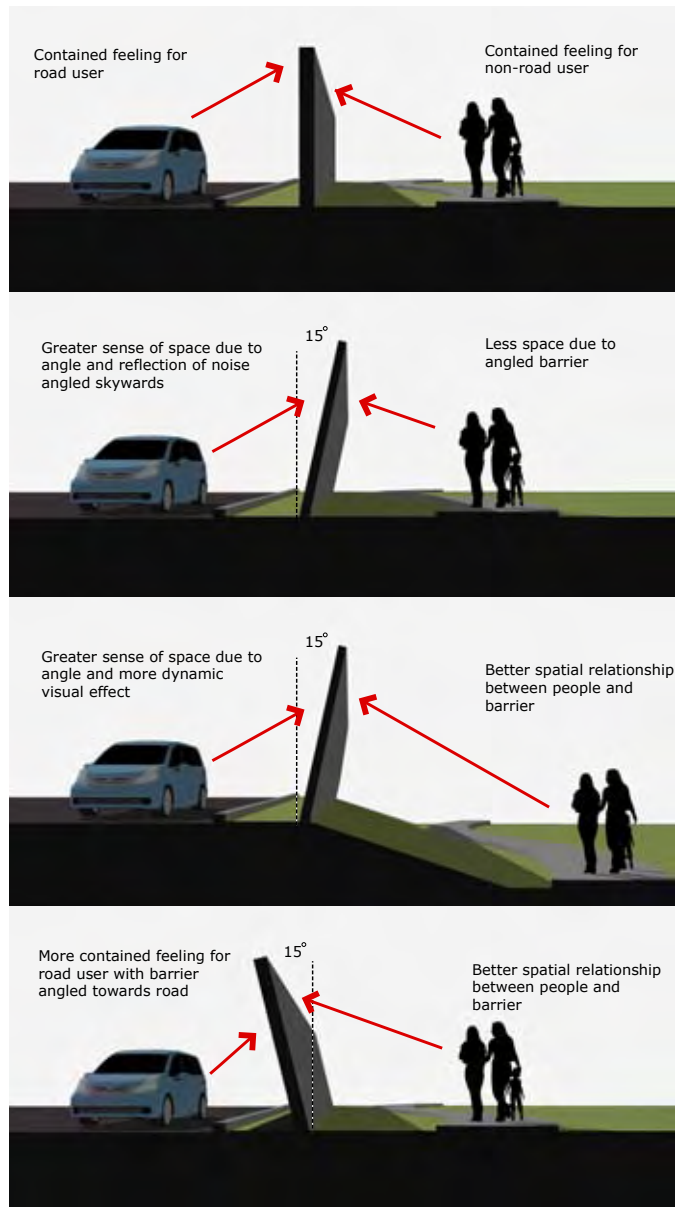


Figure 3.8 Angled noise barriers and spatial effects

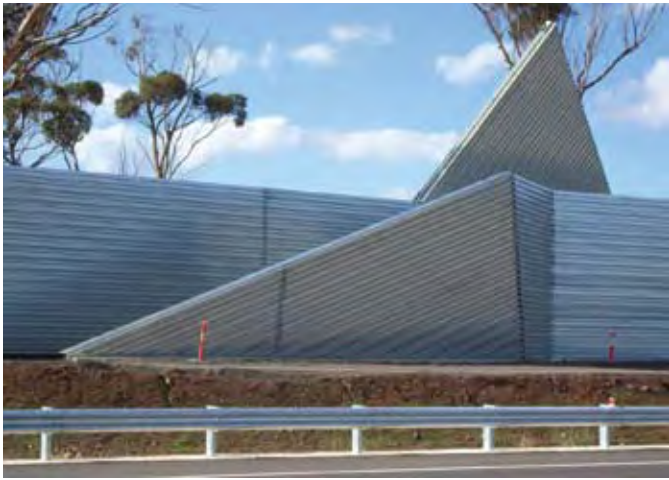


Figure 3.9 Distinct height changes and overlap, Melbourne



Figure 3.10 Architectural noise barrier emphasises change in height and overlap, Melbourne



Figure 3.11 Angled transparent noise barrier, Melbourne



Figure 3.12 Curved noise barrier showing overlaps to delineate change in height and length, Melbourne



Figures 3.13 and 3.14 Change in height and material effectively implemented by the use of overlaps, Melbourne



URBAN DESIGN

3.5 Length

In most cases noise barriers should maintain a parallel relationship with the road. However excessively long sections of noise barrier on both sides of the road should be avoided. Overlaps, curves, differing materials and heights are all ways of dealing with excessive length.

3.6 Consistency

Noise barriers should be consistent in materials, form, colour and detailing along the length of a road corridor. Avoid frequent changes in design or excessive stepping of the top of the wall as these may be distracting for road users and visually have a jarring effect. If steps are required, ensure they are small and regular.

3.7 Safety

The detail on the road face of a noise barrier should be uncomplicated, that is not overly distracting to a driver. However, over-simplification and monotony should also be avoided. A system of simple, abstract, formulated pattern can be effective. Arrangements of planting, maintenance provisions, lighting, drainage facilities and safety barriers need to be considered, as this contributes to the overall visual impression.

Refer to Section 4.2 (Safety) of this guide for a more detailed discussion on the personal and road safety implications of installing noise barriers.

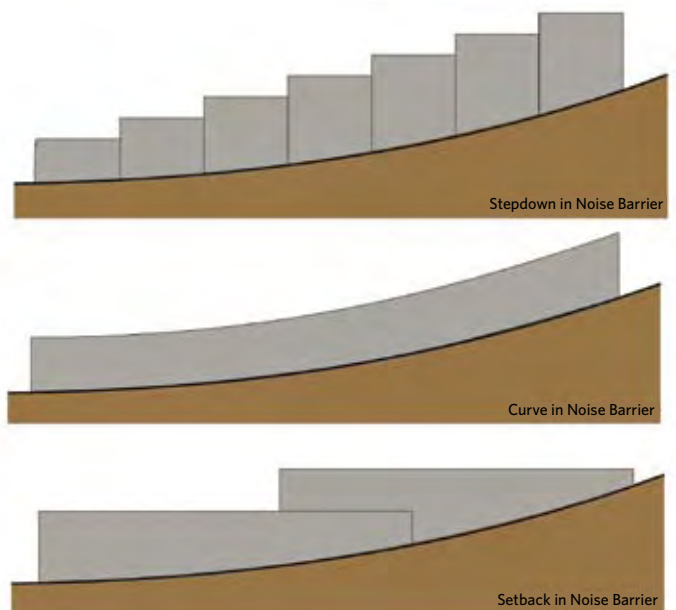


Figure 3.15 Noise barrier change in length



Figure 3.16 Poorly considered stepping is unattractive, Maoro Street, Auckland



Figure 3.17 An integrated concrete safety and noise barrier, with simple, uncomplicated pattern so as not to distract drivers, SH20, Auckland



Figure 3.18 The outer face of a noise barrier can be disguised through planting, SH18, Auckland



Figure 3.19 Poor detailing of retaining wall, fence and noise wall at Maoro Street, Auckland



Figure 3.20 I-section posts can be emphasised attractively with colour where panels overlap, SH16 concept, Auckland

3.8 Detailing

If a noise barrier face is viewed from an adjacent residence or pedestrian route it should have a two sided face, or incorporate screen planting to reduce the exposed outer “hard featured” face. Harsh abrupt edges to noise barriers should be avoided. Consider tapering noise barrier ends into the landform, and having a return or a planting scheme that can complement the edge.

Overlapping individual panels and recessed support posts can bring visual benefits to road users. Posts can be hidden from view and the panels can be angled so they follow the grade of the road or topography. The visual effect of these details for residents needs to be considered.

URBAN DESIGN

3.9 Surfaces

Surface finishes are important for amenity and maintenance reasons. Surfaces can include a combination of colours, textures and patterns. If artworks are to be included these should be integral to the design of the noise barrier and not be regarded as an applied finish to a wall designed purely on engineering grounds. For example stencil designs applied to the road side surface of the SH18 Hobsonville noise barriers (2007), are visually appealing as well as a cost effective graffiti prevention measure. Artwork can be highly subjective, which is a reason why it should be well-founded as part of the architecture of the noise barrier. Walls, road and bridges can be considered as a piece of artwork or sculpture in their own right. For example the Craigieburn bypass noise barrier in Australia (refer Figure 3.4).

3.10 Form

Noise barriers should be considered with two faces performing different functions. The inner-face is viewed at speed by road users. Their perception is fleeting and only bold designs, geometric patterns and the overall shape of the wall will be viewed. The outer face is viewed from the landscape or surrounding urban area. The noise barriers will form a static, permanent feature in the environment and depending on the proximity of viewers, construction and design details may be visible.



Figure 3.21 Timber barriers should have a paint finish even where graffiti is not a serious risk; leaving some panels unpainted has resulted in a patchwork on this example in Auckland



Figure 3.22 Visually appealing stencil designs on noise barriers can also act as an effective graffiti prevention measure, SH18, Hobsonville

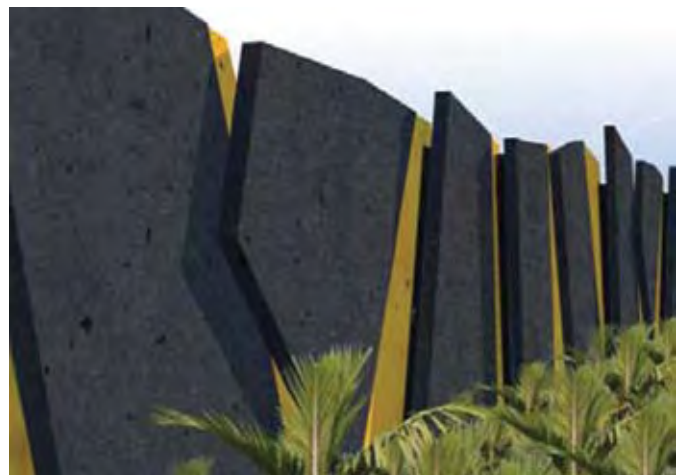


Figure 3.23 A dynamic pattern and bold noise wall concept design, SH20, Auckland



Figure 3.24 The tunnelling effect is created when parallel noise barriers create a feeling of confinement for the road user. This concept is illustrated by the similar effect of these roadside tree shelter belts on SH33, Te Puke



Figure 3.25 Transparent panels can give visual relief for pedestrians, Brisbane



Figure 3.26 Transparent panels with patterns and lighting can be very effective, Melbourne

3.11 Views

The “tunneling effect” is where noise barriers run parallel to each other on either side of the carriageway. This vertical and horizontal symmetry can create confined views for the road user, and can produce a homogenous section that cuts off the road user from the local environment.

Where there is public access to a noise barrier, light and a feeling of openness needs to be considered in design, especially where there is little natural light available.

Noise barriers should be designed to avoid blocking significant views both towards and from the road. In special circumstances transparent noise barrier material can be used to open up views to landmarks and special vistas. However, vandalism is an important issue to consider when using transparent materials as glass is easily broken and acrylic is more readily scratched. The visual character of the noise barrier supports should be carefully considered when using transparent panels, as they will become particularly noticeable. Overall, the use of transparent materials usually comes with high capital and maintenance costs.

Competing demands to maintain views, achieve value-for-money, avoid opportunities for vandalism and provide appropriate noise mitigation all need to be balanced when considering the use of transparent materials.

URBAN DESIGN

3.12 Materials

The use of materials must be considered on a site specific basis. The type of material used for a noise barrier should fit within the parameters of soil type, aesthetics, finished detail, existing and/or new vistas, noise attenuation, context, alignment, landscaping, maintenance and weathering.

Refer to Section 4.5 (Material selection) of this guide for a discussion on the overall advantages and disadvantages of different types of materials that can be used in noise barriers.



Figure 3.27 Transparent panels can be built taller and closer to buildings as they are less visually intrusive, Melbourne

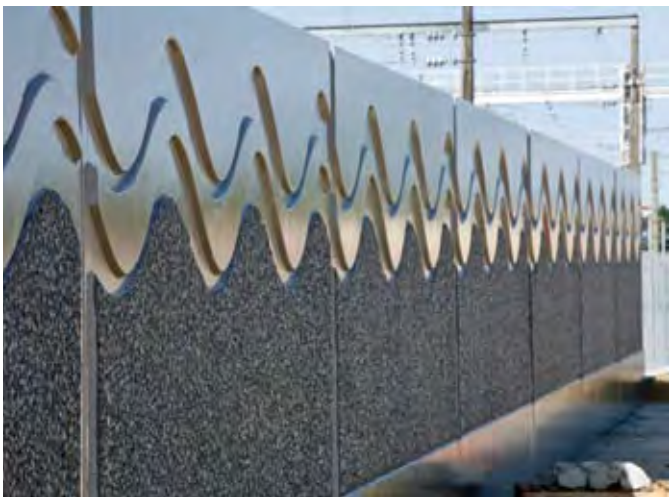


Figure 3.28 The aesthetics of concrete noise barriers can be improved by adding carefully selected texturing and patterns onto the wall face, Hamilton



Figure 3.29 Timber noise barrier showing added design detail, Melbourne



Figure 3.30 Corrugated iron panels attached to safety barrier with simple horizontal colours, Pakenham Bypass, Adelaide



Figure 3.31 Gabions walls can be a visually effective noise barrier



Figure 3.32 An earth bund planted with native plant species can be a good noise mitigation solution, SH1, Rolleston



Figure 3.33 Noise walls can be located at the top of an earth bund, Melbourne

3.13 Earth bunds

In rural or semi-rural environments, landscaped earth bunds may offer a more attractive solution than noise walls and can, once fully established, become unrecognisable as noise barriers. Earth bunds can be used on their own or with a noise wall on top. They also provide an opportunity to utilise excess fill from a project.

URBAN DESIGN

3.14 Landscaping

Planting can be used to complement or screen a noise barrier and can help integrate the barrier with the wider landscape. Planting can also provide an attractive interface with nearby properties, public spaces, footpaths and cycleways and can also be used to promote biodiversity and discourage graffiti.

Any landscape design surrounding a noise barrier should ensure there is enough light and space for plant growth, nutrition and water retention in the soil. It is also important that the noise barrier and landscape design allows access for routine maintenance.

The following criteria should be considered when selecting species to plant adjacent to a noise barrier:

- ▶ Hardiness – ability to withstand frosts and potential shading;
- ▶ Life span - a minimum 20 years should be targeted;
- ▶ Fast growing – screening and graffiti mitigation can be achieved faster;
- ▶ Low maintenance - species that do not require watering and are natural weed suppressants;
- ▶ Meet the NZTA safety policies – for example meets clear zone requirements; and
- ▶ Ability to self seed – reducing need for cyclic planting.

For more information refer to the NZTA Guidelines for Highway Landscaping¹⁴ for planting types.



Figure 3.34 Visually effective low level planting against metal noise barrier, Melbourne

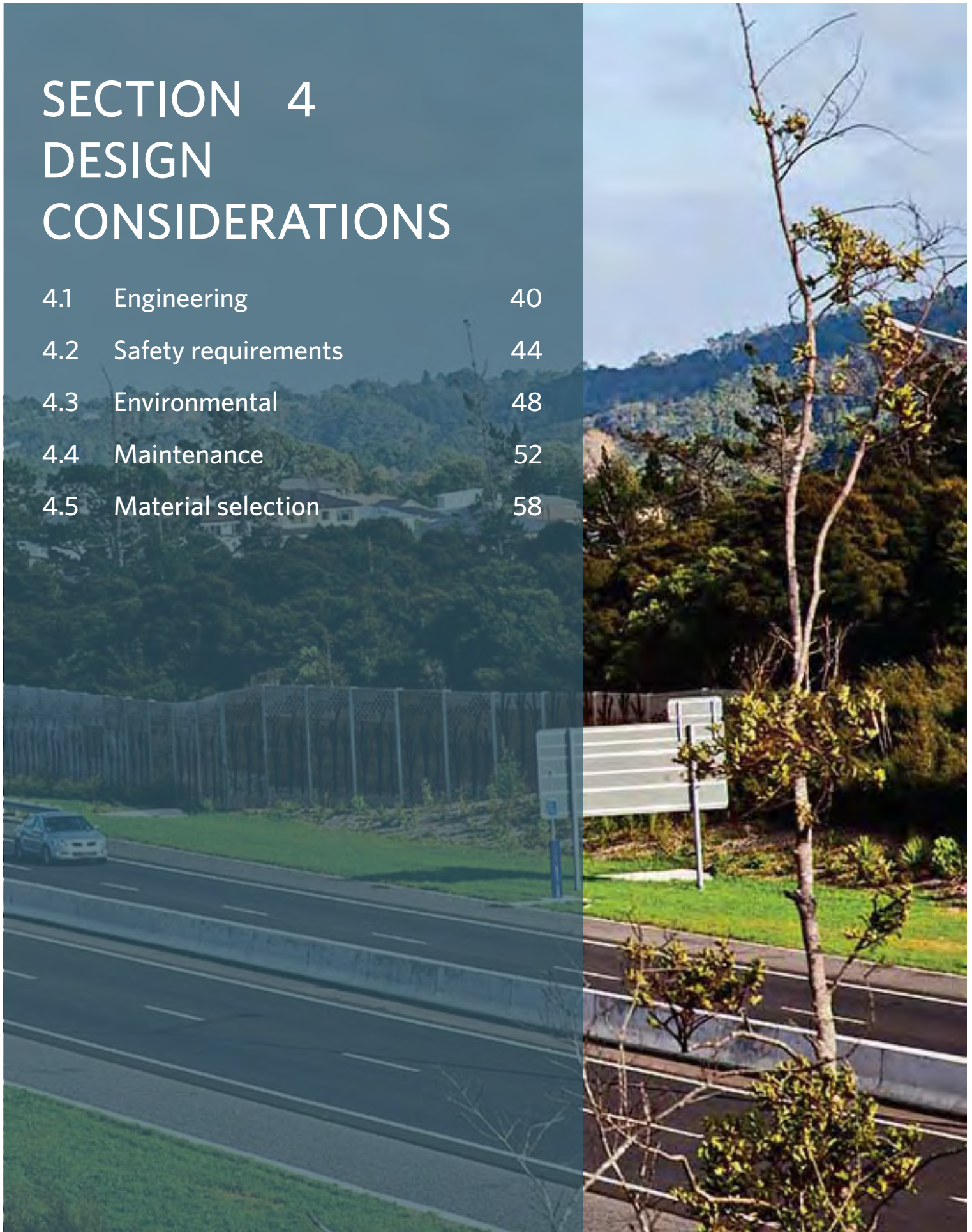


Figure 3.35 Noise barriers can play a large role in the overall landscaping of surrounding environments, SH18, Auckland



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4 DESIGN CONSIDERATIONS

To be successful the design of a noise barrier should be led by the noise control objective, and be visually acceptable. However, noise barriers must also comply with engineering, safety, maintenance and environmental requirements. These requirements are discussed in this section.

4.1 ENGINEERING

Engineering requirements that should be considered when designing noise barriers include:

- ▶ Design Life;
- ▶ Wind loading including the effects of dynamic loading due to passing vehicles;
- ▶ Seismic loading;
- ▶ Snow loading (if any) on the barriers;
- ▶ Self weight - the dry weight to allow an estimate of sound insulation to be made and, where appropriate, the wet weight;
- ▶ Constructability - the ability to build the structure when considering all of the site constraints;
- ▶ Impact loading, including impact of vehicles and impact of stones and other debris during normal road use; and
- ▶ Clearzone distances (refer Section 4.2 - Safety), as well as allowances for street furniture e.g. signs and gantrys.

The expected design life of a noise barrier is currently determined by the NZTA on a project-by-project basis, and should be included within the specifications for the barriers. As a general guide, noise barriers should have a design life of at least 50 years (dependent upon maintenance). For example the Hobsonville SH18 extension project (2007) has specified a minimum design life of 50 years for the proposed plywood noise barriers, and suppliers have been required to verify that this criterion can be met.

Where it is likely that future road widening/ extensions may occur, noise barriers can be designed to accommodate such changes. For example, the use of post and panel noise barrier



Figure 4.1 Plywood noise barriers on the Hobsonville SH18 extension project have a specified minimum design life of 50 years

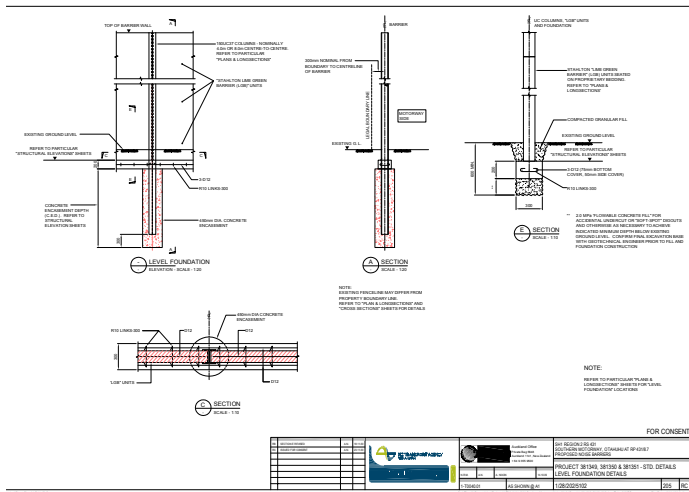


Figure 4.2 Noise wall design plan, SH1, Otahuhu

systems mean higher posts can be constructed, allowing extra panels to be inserted if required. Foundations should also be made stronger to accommodate any potential height increase.

Noise barriers often take the form of panels spanning between supports, which resist horizontal overturning forces. In the majority of cases, the critical force to be resisted by an exposed surface is that caused by the action of wind. When a noise barrier is relatively close to the road other forces may need to be considered, such as aerodynamic forces and vibration effects caused by passing vehicles, as well as the possibility of impact by out-of-control vehicles. The forces are to be considered as acting independently and in combination. The loads and their combinations should be considered in accordance with the relevant loading standards such as AS/NZS 1170¹⁵ and the NZTA Bridge Manual¹⁶.

The action of wind on a noise barrier depends on its exposure relative to the surrounding topography. Large scale features such as hills accelerate wind speeds; smaller scale features such as housing causes surface roughness which reduces wind speeds in the boundary layer within about 20 metres of the ground. Wind loads on noise barriers increase rapidly with height and simple cantilever posts may become unreasonably heavy. As such, it may be desirable to use space frames or buttresses to restrain high barriers against wind. Refer also to Section 2.11 (Wind) for a discussion on the acoustic implications of wind on the effectiveness of a noise barrier.

The European Committee for Standardisation¹⁷ has prepared a standard covering the non-acoustic aspects of noise barrier design, and should be referenced for further detail.

Please refer to the NZTA Transport Noise website (www.acoustics.nzta.govt.nz) for a range of example noise barrier/bund designs.

4.1 ENGINEERING

Bunds

If material is being reused from a site for an earth bund, geotechnical investigations should be undertaken to ascertain the quality of material to be used for the bund. The lower the grade of material e.g. highly organic soils, the gentler the side slopes need to be due to stability issues. Wider strips of land are needed to create higher bunds. For example, a 3 metre high earth mound with 1:3 slopes and a 1 metre wide crest would require a minimum land width of 19 metres. Steeper slopes (and subsequently a smaller bund footprint) can be obtained through the use of a retaining wall or structural supports such as gabions or a crib wall. Vegetation can also be planted to provide additional support to a less stable/steeper slope. Additionally, underlying ground conditions such as peat or non-engineered fill, can put limitations on the potential height of a bund due to settlement and/or ground instability.



Figure 4.3 Retaining walls can be used to stabilise steeper slopes, SH1, Auckland

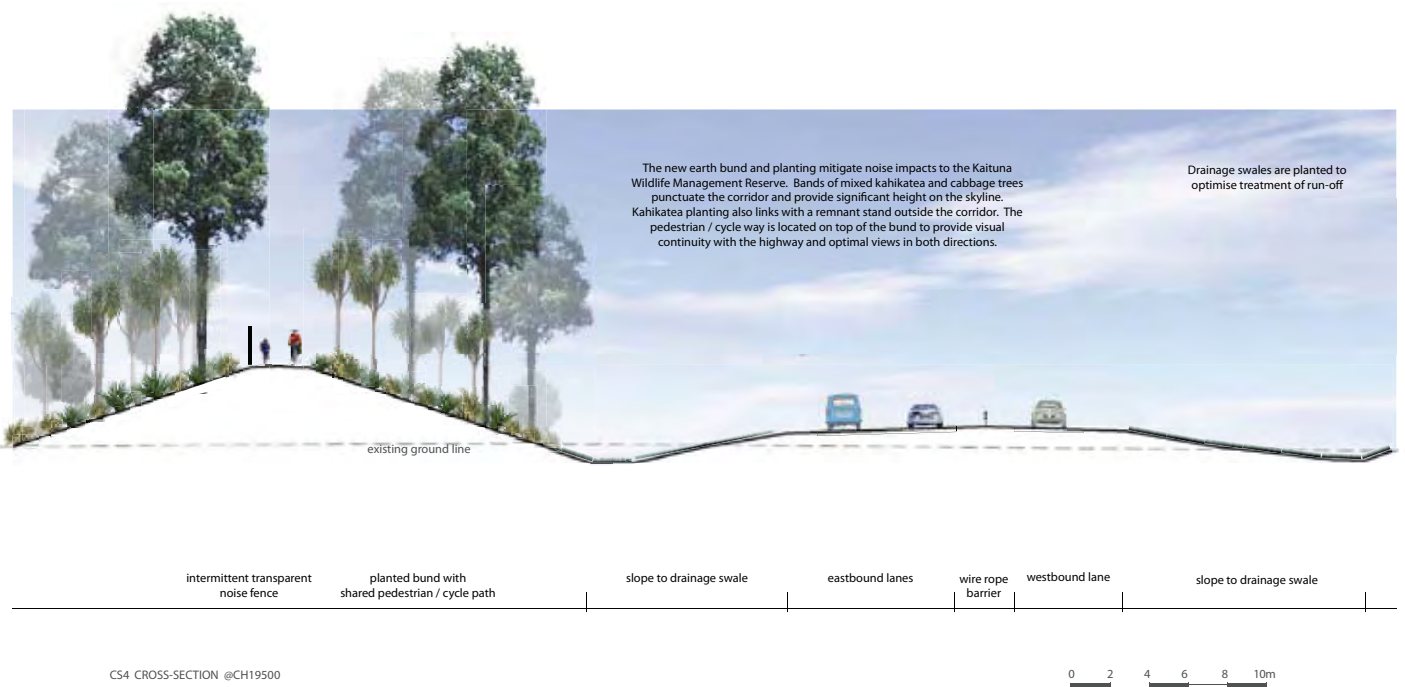


Figure 4.4 Earth bund design concept, Tauranga Eastern Link



Figure 4.5 Swales can provide a stormwater solution next to a noise barrier

Flooding and stormwater

Noise barriers are designed to be solid and non-permeable in order to maximise sound attenuation. As a result noise barriers have the potential to interrupt overland water flow paths, causing flooding to roads or adjacent properties during storm events. It is therefore important to check during the design of a project council flood maps, catchment management plans and NZTA road drainage plans. In the event that overland flow paths are affected, appropriate engineering solutions should be developed that do not compromise the acoustic integrity of the noise barrier, and the level of risk should be identified (benefits of noise mitigation weighed against flood risks).

A solution the Auckland Motorway Alliance is considering on a noise barrier alongside SH1, Auckland (2010) is the creation of a wide slot below the noise wall to allow overland flow to pass beneath it under minimal hydraulic head. A second noise wall is to be constructed in front of the slot to maintain acoustics integrity. Alternatively, depending on the specific site, overlapping barriers could be used (refer Section 2.8 - Continuity).

Noise barriers installed close to the roadside should be integrated with new or existing stormwater systems without compromising acoustics integrity. Swales may provide a good solution in such instances, or where space is available, stormwater systems should be installed between the roadside and the noise barrier. Consideration can also be given to the provision of access through noise barriers for the maintenance of stormwater and roadside drains (refer Section 4.4 - Maintenance).

4.2 SAFETY REQUIREMENTS

Road safety

Road user safety is of primary importance to the NZTA, and is a key consideration in the design of any roadside structure such as a noise barrier.

To avoid vehicle collisions, noise barriers (walls and bunds) should be located beyond clearzones (as defined by the Austroads Guide to Road Design Part 6¹⁸) or protected by road safety barriers that comply with NZTA standards. Protection can be in the form of rigid (e.g. concrete), semi-rigid (e.g. guard rail) or flexible (e.g. wire rope) barriers. Deflection distances of different safety barriers should be taken into account when placing or combining noise barriers with safety barriers i.e. rigid barriers have no deflection, compared with flexible barriers which can move up to 1 metre upon impact.

Noise barriers may need to be angled outwards vertically at onramps/offramps and bridges to avoid being scraped by passing trucks. Noise barriers should be located clear of all visibility lines for traffic, cycles, and pedestrians and should be placed clear of all over-dimension traffic routes i.e. used by oversized vehicles/trucks. They should also be located and constructed with the required electrical clearances for aerial power lines.

Where circumstances permit, modified concrete safety barriers can address both road safety and noise issues as a single cost-effective solution. Due to space constraints on the SH20 Mount Roskill Extension (2009) in Auckland, concrete safety barriers have been modified and increased in height to provide an effective noise barrier. On the Christchurch Southern Motorway duplication (2010) the motorway is elevated above the surrounding residents. As such the concrete safety barriers will also act as noise barriers without any modification required.

Light reflection/glare to motorists can be a potential safety concern arising from noise barriers constructed from certain light reflective materials e.g. metals, glass, acrylic, polycarbonate. On the Victoria Park Tunnel project (2010) in Auckland concerns had been raised over the potential solar reflections from the transparent noise barriers on the St Marys



Figure 4.6 Noise barriers can be integrated with safety barriers, SH20 Mt Roskill Extension, Auckland

Bay section of SH1. An assessment of the specific geometry was undertaken to determine if light reflection would be a concern for on-coming motorists' line-of-sight at certain high risk times of the day (after sunrise/before sunset). Recommendations included changing the orientation of each 2.5 metre section of panel by five degrees clockwise. The use of smaller panels can also assist in breaking up any reflection image into a series of smaller images. Alternatively, the transparency of the barrier can be sacrificed for a matt surface finish.

Additional safety considerations for noise barriers may also include:

- ◀ impact of stones during normal road use;
- ◀ secondary safety associated with risk of falling debris after impact (this is particularly important when barriers are installed on bridges or between carriageways);
- ◀ for long stretches of noise barriers, provision of access and egress for people and vehicles in an emergency and for maintenance (the

acoustic performance of the barrier should not be compromised by the presence of escape or access routes);

- ◀ where there is a risk of vehicle impact, transparent panels should be made shatterproof by using laminated glass or embedding fiberglass within acrylic sheets;
- ◀ avoiding permanent shadow zones which encourage ice formation on the road;
- ◀ wind gusts generated by noise barriers may travel across nearby traffic lanes and upset the stability of vehicles and surprise drivers. High sided vehicles and motor cyclists are especially at risk; and
- ◀ flammability and fire risk. It may be advisable to avoid the use of flammable materials such as creosote treated timber and acrylics, in areas where arson is a risk. Lightning and fires in dry undergrowth may also need to be considered as a potential risk elsewhere, and it may be appropriate to install fire breaks to limit the spread of fire in a flammable type of noise barrier.

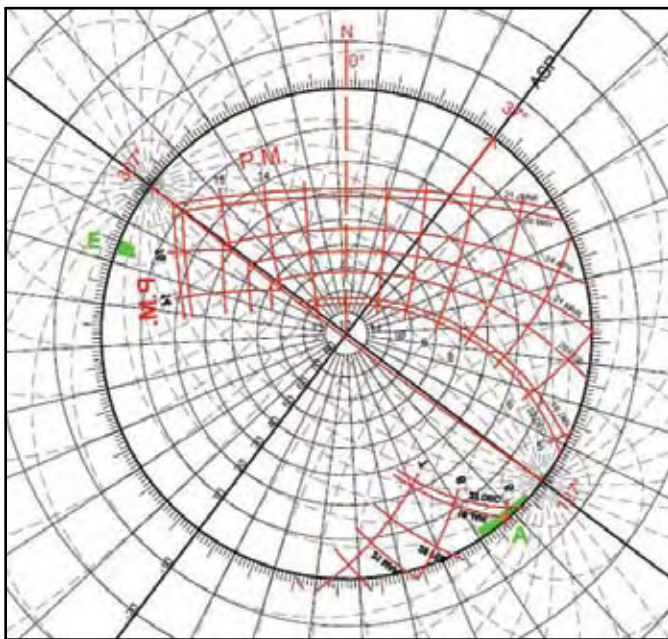


Figure 4.7 Solar glare assessment - Motorist at position "A" will experience solar reflection but motorist position "E" will not.

The European Committee for Standardisation has prepared a standard¹⁹ covering the safety aspects of barrier design, which should be referenced for further detail.

The design of noise barriers should also consider construction and maintenance safety issues with regards to working and accessing barriers adjacent to live traffic. With increasing noise barrier height, the use of modular barrier systems that can be installed by crane may be advantageous. Additionally, construction times can be reduced through careful selection of materials and noise barrier designs.

4.2 SAFETY REQUIREMENTS

Crime Prevention through Environmental Design

Crime Prevention through Environmental Design (CPTED) provides a framework for incorporating crime prevention through quality urban design. Applying CPTED principles such as passive surveillance or creating a sense of community ownership can reduce the motivation to offend. In regards to noise barriers, the risk of crime can relate directly to the noise barriers such as providing access to structures for graffiti, or indirectly, by creating an unsafe environment for the public.

The Ministry of Justice has a National Guideline for CPTED²⁰ with seven principles to characterise well designed, safer places:

Access: Safe movement and connections

Places with well-defined routes, spaces and entrances that provide for convenient and safe movement without compromising security.

Surveillance and sightlines: See and be seen

Places where all publicly accessible spaces are overlooked, and clear sightlines and good lighting provide maximum visibility.

Layout: Clear and logical orientation

Places laid out to discourage crime, enhance perception of safety and help orientation and way-finding.

Activity mix: Eyes on the street

Places where the level of human activity is appropriate to the location and creates a reduced risk of crime and a sense of safety at all times by promoting a compatible mix of uses and increased use of public spaces.

Sense of ownership: Showing a space is cared for

Places that promote a sense of ownership, respect, territorial responsibility and community.



Figure 4.8 Noise barriers can create unsafe environments for the public where there are no clear sightlines, Tullamarine, Australia



Figure 4.9 CPTED principles have been applied on the Kingsland cycleway, SH1, Auckland

◀ **Quality environments: Well designed, managed and maintained environments**

Places that provide a quality environment and are designed with management and maintenance in mind to discourage crime and promote community safety in the present and the future.

◀ **Physical protection: Using active security measures**

Places that include necessary, well designed security features and elements.

CPTED emphasises the employment of natural strategies where possible, so that crime prevention is integrated into design. More formal and expensive mechanical strategies (e.g. lighting, security cameras) should be considered as a last resort.

The application of the above principles to noise barrier design may include the use of physical protection, such as vegetation screening to prevent graffiti, or provision of gated access to only allow for maintenance operators. Where possible noise barriers should be located against boundaries to prevent the creation of a “no mans land” (refer Section 4.4 – Boundaries). Additionally, where public access is provided alongside noise barriers, the design should allow for clear sight-lines of the public, avoiding designs that create recessed areas and hiding places.

4.3 ENVIRONMENTAL

The construction of a noise barrier may influence a range of environmental issues besides just noise. These are discussed below.

Sustainability

Sustainability in regards to transport typically considers the appropriate transport solutions at an early stage in the planning of any new project. This guide assumes that these considerations have been taken into account for new roading projects, and as such is focussed on opportunities specific to noise barriers.

Sustainability can be defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs²¹. This can relate to social/cultural, environmental and financial considerations, and is becoming increasingly relevant in the design of all modern structures, including noise barriers. During the planning and specification process of designing noise barriers, this could mean consideration of a range of factors, such as:

- locally sourced materials and products;
- timber sourced from certified sustainable forests;
- locally sourced native plants for use on earth bunds or alongside noise barriers;
- incorporation of material that is reused or recycled, such as recycled plastic, glass or concrete aggregate;
- consideration of embodied carbon in the selected materials or solution, i.e. the carbon required (or sequestered) to produce the product used to provide mitigation;
- the full life cycle of the materials or solution selected, including the source of the materials, end-of-life opportunities for reuse or recycling and the longevity of the product or solution;
- environmentally accredited paint and finishing products, such as those bearing an environmental choice label or equivalent;
- minimising maintenance requirements and whole-of-life costs;
- economic considerations i.e. capital outlay and return; and

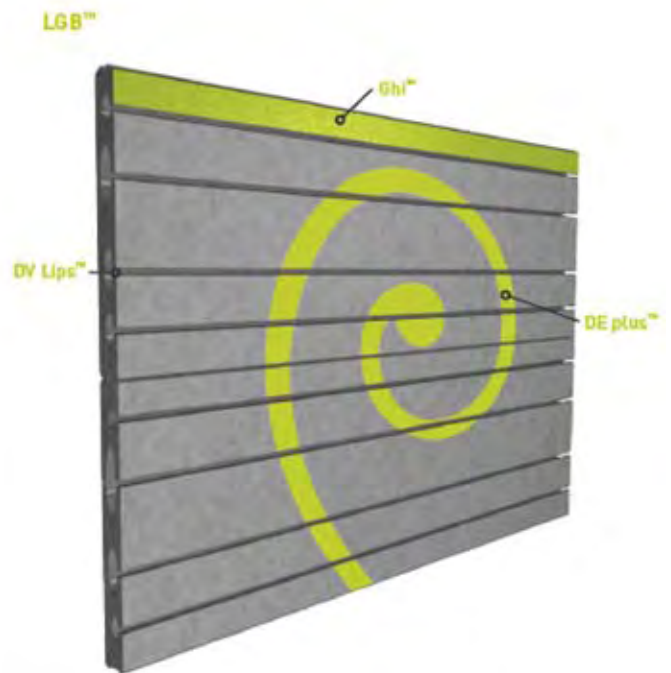


Figure 4.10 A proprietary barrier system incorporating 25% recycled concrete



Figure 4.11 Noise barriers can be planted with native NZ species to enhance biodiversity, SH18, Auckland



Figure 4.12 Noise barriers can provide dual environmental benefit such as the production of solar power, Tullamarine, Australia



Figure 4.13 Roadsides are attractive to some New Zealand bird species like the Pukeko

- opportunities for social/cultural benefits such as improved amenity, improved visual context and the incorporation of culturally relevant art works or materials.

Noise barriers can be designed for multiple environmental benefits, bringing about further positive environmental gain beyond just noise reduction. Due to the abundance of available surface area noise barriers can be well suited for the production of “clean” solar energy. Photovoltaic modules which capture the sun’s energy to produce solar power have been incorporated into noise barriers on the M2 motorway in Tullamarine Australia, and also the A92 Autobahn at Freising, Germany where the worlds largest photovoltaic noise barrier (6000 m²) is located. Although the upfront costs of installing such technology may be high, the long-term use and pay-back should be calculated when considering such a design.

Wildlife

Studies have shown that noise can affect the physical condition and behaviour of animals, in particular birds (for further reading see Kotzen and English (2009) pages 234-236²²). With regards to some species of birds, road noise can result in louder singing in heavy traffic areas, although any resulting physical and behavioural consequences are not well understood. A number of European studies have also found that the number of breeding birds/nests of some species reduce in proportion to the density of traffic on the road²³. Other animal species that can be affected by road noise include bats, whales, honeybees and earthworms²³. In extreme examples, there may be a case for considering the provision of noise barriers to screen unique wildlife sites. It should be noted however that there are some birds that flourish near roadside verges, due to an abundance of suitable food and an apparent tolerance to noise. For example in some roadside areas in New Zealand Pukeko population numbers can increase to pest proportions²⁴.

4.3 ENVIRONMENTAL

A further consideration for bird populations is the use of transparent panels and the possibility of birds flying into noise barriers (“bird strikes”). Birds use a range of urban environments such as city parks, streetscape vegetation, waterfront business districts, and other green areas. Bird strike can occur as birds attempt to access potential perches, water and food sources, nesting areas and other lures beyond a noise barrier. This issue is especially important in areas where barriers may be erected within bird flight paths and along migration routes. Options for minimising bird strikes include visual markers on barrier panels e.g. hawk decal or thin stripes, bird strike resistant UV glass or selective plant screening.

The movements of wildlife should also be considered in the design of noise barriers. Where necessary, suitable crossing points should be provided for animals in conjunction with road crossings, and may include culverts, special tunnels and wildlife bridges (eco-viaducts). There is also the potential to add bird nesting boxes to the rear faces of barriers, where it is generally quieter and more secluded.

The concept of using noise barriers to actually enhance biodiversity exists. Landscape planting around noise barriers with native New Zealand species can help to promote native birds, animals and invertebrates to the area, and also excludes non-native vegetative pest species. For full details of appropriate species, reference should be made to the NZTA Guidelines for Highway Landscaping¹⁴. Plants can also be fully integrated within noise barrier design to imitate habitats and encourage biodiversity or specific forms of wildlife. Bio noise barriers consist of an inner core containing planting mixture, which is then contained by a geotextile and then typically supported by a reinforcing meshing. A “living wall” can also be created where plants are attached to an existing noise barrier usually with metal supports. These types of barriers can require continued maintenance though, with most examples occurring in Europe. For further reading see Kotzen and English (2009), Pages 178-186, 209-219²⁵.



Figure 4.14 Some manufacturers are now producing barriers with bird deterrent markings in the form of thin black stripes. It is purported that these stripes are visible obstacles for birds while providing maximum transparency of the panel. (Source: Evonik Industries)



Figure 4.15 Bird decals can be applied to transparent panels to discourage bird strike

Air pollution

The impacts of air pollution in regard to noise barriers is an emerging yet potentially significant consideration when it comes to assessing how noise barriers may affect human health. Noise barriers located beside roads have the potential to affect pollutant concentrations around the structure by blocking initial dispersion, and increasing turbulence and initial mixing close to vehicles on the road. This can inhibit lateral air movements off the road, leading to elevated on-road and near-road pollutant concentrations. This has the potential to cause pollution “hot-spots” (such as at congested junctions or in street canyons where dispersion is limited). In the absence of careful planning and design this may also increase the exposure of commuters (such as pedestrians and cyclists) or sensitive members of the public (such as the young, sick and elderly) to road-traffic pollutants.

In addition, barriers are likely to affect pollutant dispersion, leading to increased vertical mixing due to the upward deflection of airflow caused by the structure. International studies suggest that this upward deflection of air may create a flow recirculation region extending from 3 to 40 times the wall height downwind of the barrier²⁶⁻²⁷. This region may result in relatively lower and then



Figure 4.16 Air quality roadside monitoring can highlight pollution hotspots, Wairau Road, Auckland

higher pollution concentrations as the plume moves downwind²⁶⁻²⁹.

Several recent designs of noise barriers claim to be able to reduce concentrations of road-traffic pollutants, such as the Stahlton “Lime Green Barrier”. This concrete barrier has a narrow band of coating along its top edge, which contains a catalyst (such as titanium dioxide) to accelerate the breakdown of nitrogen dioxide through a photocatalytic reaction using sunlight as energy. European designs include the “clean screen barrier” by van Redubel (which uses a permeable, gabion-like structure filled with titanium dioxide impregnated lava stones), the “Una” barrier by TNO (which incorporates filters and elliptical wings to capture pollutants) and the “AeroStick-T” by the Dura Vermeer Groep NV, which uses an air-filtering system at the top of the barrier³⁰. Reference should be made to Kotzen and English (2009) for graphic illustrations of these barriers and other types of barriers not included here.

The research into the effectiveness and performance of filters, catalysts (such as titanium dioxide) and absorptive materials positioned on noise barriers in reducing roadside concentrations of nitrogen dioxide and particulate is still very much in its early stages. Their use also raises some concern in terms of the potential servicing and maintenance costs that may be involved, particularly as the effectiveness of reducing roadside pollutant concentrations is still unknown. Therefore, at this stage, such devices are generally not recommended for use by the NZTA.

Where noise barriers are proposed, each design should consider the potential of the barrier to cause the displacement of road-traffic pollutants to hot-spots and/or the potential to cause an increase in exposure to commuters, pedestrians or residents. This may require undertaking an assessment of the potential air quality effects using quantitative assessment techniques, such as dispersion modelling and/or ambient air quality monitoring. Refer to the NZTA Air Quality website (www.air.nzta.govt.nz) for further details of such techniques.

4.4 MAINTENANCE

In line with the requirements of the Interim State Highway Asset Management Plan³¹, keeping whole-of-life maintenance costs low should be a key consideration when selecting noise barrier form, shape, location and landscaping. This section provides guidance on designing noise barriers to reduce such costs, as well as discussing other noise barrier maintenance issues relevant to the NZTA.

Materials

Material selection for noise barriers has important implications in reducing the need for ongoing maintenance. Concrete requires little or no maintenance during its potential life span of up to 100 years³², compared with timber barriers which may need replacement after as little as 2 years depending on design and quality of material. Section 5.5 (Durability) of this guide gives a standardised procedure that assesses the durability of a noise barrier over a 20 year period.

The selection of suitable materials also involves consideration of what is appropriate to the surrounding landscape of an area, as well as the preferences of residents (refer Section 5.2 - Stakeholder engagement). For example in some more rural areas noise bunds or timber walls may be more suitable than concrete panels, even though concrete panels have a longer life span.

The quality and type of materials used for a noise barrier should be appropriate to the location. Noise barriers built in relatively inaccessible locations or in areas likely to be subject to extreme weather conditions will need more durable components than those which can be more easily maintained or are in relatively sheltered positions. Additionally, the use of transparent panels might not be appropriate in areas that are easily reached by the public and are prone to graffiti. Although glass possesses excellent light transmittal properties, it is prone to breaking/shattering through vandalism. Acrylic is more durable with better light transmittal than polycarbonate, but it is easily scratched. Polycarbonate is the most durable transparent material available, and may be more suitable for graffiti prone areas, however it loses transparency

much faster than glass or acrylic. Many manufacturers will offer warranties for acrylic (up to 30 years) and polycarbonate (up to 15 years) for physical properties such as light transmittal and breakage. Refer to Table 4.1 for a comparison of the advantages/disadvantages of transparent noise barrier materials. The Tauranga Harbour Link project (2009) included the installation of glass noise barriers (which were toughened and laminated), on a causeway bridge which had pedestrian access. Glass panels were smashed by a passer-by only 3 days after the bridge opened, and the noise barrier was removed to be replaced by a more suitable design solution. This example highlights the importance of site specific issues when designing noise barriers.

Refer to Section 4.5 (Material selection) for a discussion on the overall advantages and disadvantages of different types of materials that can be used in noise barriers.



Figure 4.17 Damaged glass noise barrier on Tauranga Harbour Link



Figure 4.18 Replaceable concrete panels with steel posts have been used on SH1, Market Road, Auckland (pre-landscaping)



Figure 4.19 Modular marine plywood panels and steel post system have been used on the SH18 Hobsonville motorway extension (non-motorway side view)

Construction

The use of smaller sections of replaceable panels within a noise barrier can provide a faster and more cost effective maintenance solution when barrier sections require replacement or repair. A steel post and marine plywood system has been successfully used on the SH18 Hobsonville motorway extension (2007), and likewise for noise barriers consisting of steel posts with concrete panels on SH1 Market Road, Auckland (2009).

Care should be taken over design details to eliminate possible moisture traps which would encourage rot or chemical attack. Timber treated to an appropriate hazard class (e.g. H5) can be used to prevent deterioration between steel and timber, or concrete and timber. Alloy and metal fittings should be carefully selected to avoid differences in electrochemical potential which would accelerate corrosion. It is preferable that timber does not come into contact with soil irrespective of the timber species or any special treatment as this can cause wood to rot.

All new noise barrier structures should be added into RAMM (the NZTA asset management database) as a minor structure, and therefore treated like all other assets on the state highway network.

Access

Doors (or gaps between overlapping barriers) should be provided at reasonable intervals (every 200 metres is the UK policy³³) to give access to either side of the barrier and the road for maintenance or emergency. Maintenance access should be designed to reach existing services, stormwater systems and for undertaking infrastructure repairs. Access may also be required for pedestrians, cyclists and residents. The acoustic integrity of the noise barrier should always be assessed where access is provided (refer to Section 2.8 - Continuity). Pedestrian access close to a barrier may render it vulnerable to vandalism, and the choice of form and materials, as well as design, should take this factor into account.

4.4 MAINTENANCE

Boundaries

In terms of ease of maintenance, in urban areas noise barriers should generally be placed on, or just inside e.g. 300 mm, the boundary between the state highway reserve and adjoining properties unless there is an acoustic requirement for them to be closer to the carriageway. Ideally the barriers should either replace or butt up against existing boundary fences. This allows easy access for repair and maintenance of the barrier and vegetation from within the NZTA land. Additionally, placing noise barriers at the state highway reserve boundary may allow for future road widening without having to relocate noise barriers.

Placing a noise barrier at the state highway reserve boundary prevents the creation of a “no mans land” behind the barrier that cannot be accessed, and may become overgrown, used as a dump and potentially infested by vermin. This is a common scenario on many of Auckland’s motorways where noise barriers have been placed in the middle of the state highway reserve. For example, before works began on the Kingsland Cycleway project adjacent to SH16, 30 tonnes of dumped rubbish and overgrown vegetation had to be removed from behind the noise barriers located in the middle of the state highway reserve.

In circumstances where noise barriers are placed on the NZTA boundary (preferably in place of the boundary fence), noise barrier maintenance and repair may remain the responsibility of the NZTA for both sides of the barrier i.e. including the face on the neighbours’ side. In these cases, it is advantageous to design noise barriers to ensure little or no maintenance is required for the neighbours’ side, to avoid access issues. Alternatively, an easement through neighbouring land for access to undertake maintenance could be agreed.

The overall responsibility for the maintenance of a particular noise barrier will depend upon the specific circumstances of each case. It is recommended that legal advice is sought if in any doubt about the NZTA’s responsibilities in regards to boundary maintenance issues.

When installing new barriers it should not be assumed that any existing fence is located on the legal boundary between the state highway reserve and an adjoining property. Encroachment onto road reserve is a common occurrence on many parts of the road network, and can be a time consuming and sensitive issue to resolve. Encroachment of around 70% of properties into road reserve at the proposed site of noise barriers beside SH1 at Otahuhu (2010) has caused considerable delay to the project, as the boundary fence alignment was not checked in the initial property survey.



Figure 4.20 No mans land can be created when noise barriers are not placed on the boundary, Auckland



Figure 4.21 Placement of noise barriers back from property boundaries can lead to encroachment into road reserve, Auckland



Figure 4.22 Planting grass on bunds requires regular mowing and therefore increased maintenance costs, SH18, Auckland

Cleaning

Cleaning requirements from contaminants such as water splash and airborne grime should be considered in the design of noise barrier surfaces. Concrete may not need cleaning when washed by rain water and any textured finishing may also control staining. Flat surfaces could require more regular cleaning as contamination is more apparent and may detract from the appearance of the barrier.

Frequent access will be needed to clean both sides of a transparent barrier, and on bridges and viaducts this might necessitate the use of specialised equipment.

Painting and treating of metal or timber surfaces can be reduced by using anodised aluminium, galvanised or weathering steel, or by pressure treating timber. Where colours are used, they may need to be refreshed periodically if they are an important element in the design. Accordingly, the use of colour on noise barrier surface design should be carefully considered.

Vegetation

From a maintenance perspective, plants selected for use in conjunction with a noise barrier should be a fast growing, self seeding, hardy species of at least a 20 year life span, which require a low level of maintenance i.e. watering, thinning refer to Section 3.14 (Landscaping) for a further discussion on appropriate planting plans for noise barriers.

Where noise bunds have been installed the planting of grass is discouraged, as this requires regular mowing, increasing maintenance costs. Instead, plants with low maintenance requirements should be used.

4.4 MAINTENANCE

Graffiti

As discussed in Section 4.2 (Safety), Crime Prevention through Environmental Design (CPTED) is based on the idea that the surrounding environment can influence people's behaviour. CPTED promotes design principles to minimise the potential for criminal behaviour to occur, such as graffiti or tagging. This section discusses graffiti mitigation measures that are based upon the CPTED principles of: surveillance (e.g. lighting where appropriate), access management (e.g. restricting access through physical barriers), territorial reinforcement (e.g. community art), and quality environments (e.g. easy graffiti removal).

Graffiti or "tagging" is one of the biggest problems the NZTA faces in maintaining noise barriers. One of the most effective way of deterring graffiti is through the use of planting. Climbing plants supported on wires e.g. *Tigamanthus*, or those which fix themselves to noise barriers can screen the wall surface and provide an organic and difficult façade on which to apply paint. Planting shrubs or hedges in front of walls can be used to screen the blank wall from view, and also make access for tagging difficult. Vandals are less likely to tag a surface where there is no public exposure of the tag. Ideally vegetation should be planted at the start of a construction project so that a suitable height has been achieved by the time noise barriers come to be installed.

The design of the barrier surface can also be used as a graffiti deterrent. Examples include the use of Punga logs attached onto overlapping timber noise barriers along the Tauranga Harbour Link carriageway (2009). Another method is to apply pre-designed graffiti or urban art to the walls as part of the design. This could even be designed by local "urban artists", and is more likely to gain the respect of the local community and help prevent tagging. Such an idea has been used for noise barriers constructed at the Highbrook Interchange in Auckland. Even the use of more visually striking designs may deter graffiti, as the visual impact of tagging or graffiti becomes limited. However this method is not ideal in every location, with bold designs not always fitting into the local context of certain areas.



Figure 4.23 Climbing plants supported on wires can screen the wall surfaces and provide an organic and difficult face to graffiti, Hill Road, SH1, Auckland



Figure 4.24 The design of the noise barrier surface can be an effective graffiti deterrent, such as the use of Punga logs on these timber noise barriers on the Tauranga Harbour Link



Figure 4.25 Graffiti or tagging is one of the biggest noise barrier maintenance issues facing the NZTA, Newton onramp, SH16, Auckland



Figure 4.26 A paint repelling coating on the surface prevents paint from adhering properly (Source: SEI Chemicals)

The use of any noise barrier surface design should be carefully considered in the light of potential graffiti removal. Designs can be difficult and costly to replace if tagged over, and if used, options should be available to easily replicate designs, or easily replace affected sections.

The last resort with graffiti is to retrospectively remove and paint over graffiti. Although this can be a costly and frustrating exercise, it is necessary in order to deter further graffiti. The faster graffiti is removed, the less likely the area is to be tagged in the future.

The use of anti-graffiti coatings and films are most commonly used to protect material surfaces from permanent damage. Spray coatings can be classified as permanent or sacrificial. Permanent coatings are transparent 'paint repelling' chemical covers that make it difficult for paint or markers to adhere to the treated surface, thus making graffiti easy to wash off either with water jets or by other mechanical methods. The coating remains on the surface after the graffiti removal process has been completed and will continue to protect the surface. Sacrificial coatings are removed along with the graffiti, often with the assistance of a mild chemical and low pressure water blasting. Surfaces will need re-coating after the removal procedure is complete.

Transparent films can be applied to transparent noise barriers e.g. glass, to help protect the surface from deliberate and accidental damage such as chemical etching, scratching and paint. Films will require replacement over time once they become unsightly and unserviceable.

4.5 MATERIAL SELECTION

Material selection has already been raised in this design guide in relation to acoustics (Section 2.9), urban design (Section 3.12), sustainability (Section 4.3) and maintenance (Section 4.4). Further guidance is also given in relation to material cost (Section 5.4).

The intention of this section is to provide a summary of general design advantages and disadvantages for common materials that may be used in New Zealand noise barriers, specifically barrier panels/surfaces (but not support structures). It is intended as general guide to ensure relevant issues are considered when choosing materials. The NZTA Transport Noise website (www.acoustics.nzta.govt.nz) will be updated with a more detailed description of material types, including potential suppliers.

Concrete

Advantages

- Can allow flexibility in design e.g. concrete noise barriers can be amalgamated with safety barriers (refer Figure 4.6);
- Impervious and therefore acoustically effective;
- Durable and weathers well;
- Long design life (up to 100 years depending on quality and design);
- Impervious surface allows for easier cleaning/ graffiti removal than timber for example (especially with the use of anti-graffiti coatings on concrete);
- Opportunity to use recycled materials as aggregate alternatives e.g. recycled crushed concrete or glass;
- Lightweight precast concrete panels can be used which allow quick and easy construction and then easy replacement of individual panels if damaged e.g. if hit by a vehicle; and
- Modular systems with concrete panels in steel columns can be compatible with barrier designs incorporating horizontal or vertical angles, as well as architectural features.

Disadvantages

- Concrete is heavy, making it more difficult to fix, particularly in retrofit situations and on existing structures;
- Typically more embodied carbon than timber on a per weight basis³⁴;
- From an urban design perspective care should be taken as concrete is often used without appropriate design, which can result in flat areas of dull concrete. Aesthetics of walls can be improved by planting, texturing and/or painting patterns on wall faces, but should be undertaken with careful consideration and in consultation with the NZTA Environment and Urban Design Team (Email: environment@nzta.govt.nz); and
- There can be difficulty ensuring quality control with concrete cast in-situ.



Figure 4.27 Lightweight modular precast concrete panels can be used in noise barrier design, Market Road, Auckland (pre-landscaping)

Timber

Advantages

- ◀ Use of treated timber (e.g. H5) can lengthen design life of timber up to 50 years;
- ◀ Aesthetically is often preferred by residents who are impacted by the presence of noise barriers;
- ◀ Typically less embodied carbon than concrete on a per weight basis; usually positive due to forest sequestration³⁴;
- ◀ Simple and often easily available designs; and
- ◀ Relatively fast construction times.



Figure 4.28 Simple timber noise barriers are commonly installed alongside New Zealand roads, Maoro Street, Auckland

Disadvantages

- ◀ Often installed as a simple boundary style fence with insufficient consideration of acoustics requirements;
- ◀ Acoustic integrity and shortened design life is a problem due to the prevalent use of inappropriate timber and poor design and construction. Planks are prone to developing openings or gaps due to shrinkage, warping, splitting, weathering, or bad construction.
Suggestions to overcome these issues include:
 - Tongue and groove or overlapping of timber;
 - Where higher barriers (i.e. over 2 metres) are required then a harder material than pine may be more appropriate e.g. Macrocarpa, or plywood. The type selected should also take into account its durability and the need for any treatment or coating;
 - The use of wider planks can provide additional strength to prevent warping; and
 - Plywood panels are generally more durable than timber planks, and can be used in a modular system in a similar manner to lightweight concrete panels. Metal strapping can be used to prevent the warping effects of plywood.
- ◀ Certain species of timber are unsustainable and their use should be avoided. Only timbers from certified sustainable forests should be used;
- ◀ Timber is not easily cleaned and graffiti more difficult to remove, requiring painting over every time it occurs; and
- ◀ Soil can rot timber and it is preferable that timber does not come into contact with soil, irrespective of the species or treatments (sacrificial boards may be used to close the gap at the bottom of a timber fence).

4.5 MATERIAL SELECTION

Transparent panels

Advantages

- ▮ Allows for maintenance of views, which might be important either from the road to particular landmarks or vistas, or where there are views across the road from adjacent buildings;
- ▮ Transparent panels can be used where a reduction in visual bulk is required, such as on a bridge or wall; and
- ▮ Improved public safety in areas where surveillance and sightlines may be compromised.

Disadvantages

- ▮ Often expensive compared with more conventional alternatives (refer Table 5.2);
- ▮ Prone to vandalism - glass easily broken, acrylic easily scratched;
- ▮ Glare from reflections of the sun or headlights is a potential problem;
- ▮ Plastics can be a fire hazard and should contain a fire retardant and UV inhibitor;
- ▮ Transparency can deteriorate through the build up of pollutants (angling panels away from the road can enhance natural cleaning from the rain);
- ▮ High maintenance e.g. cleaning;
- ▮ Transparency can be affected by weather and temperature changes e.g. dew;
- ▮ Typically more embodied carbon than timber on a per weight basis³⁴;
- ▮ Privacy of residential areas can potentially be compromised (frosting lower sections of transparent walls may be an effective way to allow both privacy and light); and
- ▮ Increased risk of bird strike (refer Section 4.3 - Environmental).



Figure 4.29 Transparent panels can be used on bridges to reduce the overall visual bulk of the noise barrier, Holland (Source: Forman Building Systems)



Figure 4.30 Transparent glass noise barriers are easily smashed by vandals, Tauranga Harbour Link

Table 4.5 Comparison of transparent materials used in noise barriers³⁵

Type of Barrier	Advantages	Disadvantages
Polycarbonate	<ul style="list-style-type: none"> ◀ Cost (initial and whole-of-life) ◀ Virtually unbreakable ◀ UV resistant ◀ Self-extinguishes when in contact with fire 	<ul style="list-style-type: none"> ◀ Prone to discolouration & yellowing ◀ Can be scratched ◀ Use of anti-etching films problematic ◀ Combustible (emits toxic gases such as carbon monoxide but is self-extinguishing) ◀ Permanent proprietary anti-graffiti coatings are expensive (manufacturers' warranties may be affected by use of non proprietary anti-graffiti coatings) ◀ Less established than other transparent materials
Acrylic	<ul style="list-style-type: none"> ◀ Impact resistance - comes with option of filament reinforcement. ◀ Scratches can be polished out. ◀ May be possible to flame polish. ◀ UV resistant ◀ Well established internationally for road-traffic noise barriers 	<ul style="list-style-type: none"> ◀ Easy to scratch ◀ Use of anti-etching films problematic ◀ Combustible (burns to completion unless extinguished) ◀ Permanent proprietary anti-graffiti coatings are expensive (manufacturers' warranties may be affected by use of non proprietary anti-graffiti coatings)
Glass	<ul style="list-style-type: none"> ◀ Harder to scratch than polycarbonate or acrylic ◀ Scratches can be polished out ◀ Not combustible ◀ More compatible with use of anti-etching film ◀ Established material for road-traffic noise barriers ◀ UV resistant 	<ul style="list-style-type: none"> ◀ Relatively easy to smash/shatter ◀ Expensive ◀ Manufacturers' warranties may be affected by use of non proprietary anti-graffiti coatings ◀ Fire may cause glass to shatter

4.5 MATERIAL SELECTION

Metal

Advantages

- ▶ Can be made relatively lightweight (especially sandwich panels) and easy to fix;
- ▶ Dual leaf sheet metal systems or panels can be used for absorptive barriers using a perforated metal front face and a solid unperforated metal rear face. The cavity can contain fibre glass or other noise absorbing materials; and
- ▶ Modular panel systems are available with the same advantages as modular concrete or timber panels.

Disadvantages

- ▶ Metallic surface finishes may not be visually suited to all locations, but can be assimilated more readily into an urban environment;
- ▶ Relatively heavy framing and fixing may be required for galvanised mild steel panels due to the likelihood of distortion during the galvanising process;
- ▶ High rate of expansion in hot weather may necessitate the use of expansion joints which can create an issue in regards to maintaining noise attenuation; and
- ▶ Lightweight panels are easily damaged and are thus readily vandalised. Coatings are not easy to repair.



Figure 4.31 Corrugated metal panels can be used as a barrier, Khyber Pass offramp, SH1, Auckland



Figure 4.32 Earth bunds can make use of excess fill from road construction, Rolleston

Earth bunds

Advantages

- ▶ Can make use of excess fill from road construction;
- ▶ Limited possibility for gaps developing, breakages or other acoustic integrity/maintenance issues;
- ▶ Bunds are often more aesthetically pleasing than walls; and
- ▶ Graffiti/vandalism is not an issue.

Disadvantages

- ▶ Earth bunds require a large amount of space compared with standard noise walls;
- ▶ On certain ground, settlement may become an issue due to bund weight, and if relevant should be allowed for when determining bund height; and
- ▶ Earth bunds may require more maintenance if grassed or inappropriately planted.

Absorptive surfaces

Advantages

- ▶ Reduce sound reflections; and
- ▶ Can be integrated into the same construction as the solid structure required to limit sound transmission (as opposed to using a “stick-on” absorptive facing). Examples include porous concrete panels, metal sandwich panels with one side perforated, or wood fibre products with one side set in a cement mix and the other side porous.

Disadvantages

- ▶ Additional elements will generally increase the cost; and
- ▶ Porous surfaces (e.g. wood fibre) are not always visually appealing, and their use needs to be carefully considered from an urban design perspective.



Figure 4.33 Absorptive porous concrete panels can be used to reduce sound reflection (Source: Forman Building Systems)



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5 PLANNING & PROCUREMENT

5.1 STATUTORY CONSIDERATIONS

This section provides a summary of the statutory approval requirements for the NZTA to install noise barriers alongside the state highway.

These statutory considerations could apply to retrospective noise barrier projects, for example those identified within the NZTA Noise Improvement Programme (refer Section 1.4), or for noise barriers included as part of new or altered roading projects.

Resource Management Act (1991)

This information has been primarily taken from the Auckland Motorway Alliance's "AMA Statutory Approval Strategy - Noise Barriers³⁶," which should be referred to for further discussion of statutory approval methods for installing noise barriers on state highways.

Under the Resource Management Act 1991 (RMA) Territorial Authority (TA) or Regional Council approvals may be required to install noise barriers beside roads. A range of influences such as land ownership, availability of space, existing designation conditions, and future widening programmes will determine the approvals appropriate for each specific noise barrier site.

The process in Figure 5.1 outlines the recommended sequence for identifying RMA approvals required for installing noise barriers alongside the NZTA roading network.

Understanding council plans, and conditions attached to a road designation is an important part of the RMA approval strategy and will significantly influence the selection of approval mechanisms. Most noise barriers will be located on or within the existing NZTA designation boundary except in sections where road widening is planned or where conditions specifically require barriers in other locations. Alternatively, physical site constraints may mean the noise barrier cannot be located within the boundaries of the existing designation.

Table 5.1 summarises the different RMA approval mechanisms that may be used to authorise the installation of noise barriers, and outlines the pros and cons associated with each of these mechanisms.

Fencing Act (1978)

The Fencing Act (1978) sets out the rights and responsibilities relating to boundary fences between neighboring properties. The Fencing Act does not apply to any motorway, limited access road, street, access way, service lane, or other public highway. As such in most situations this Act is not applicable to the construction of noise barriers by the NZTA. Please refer to Section 4.4 (Maintenance) of this guide for further information on the NZTA and boundary issues in relation to noise barriers.

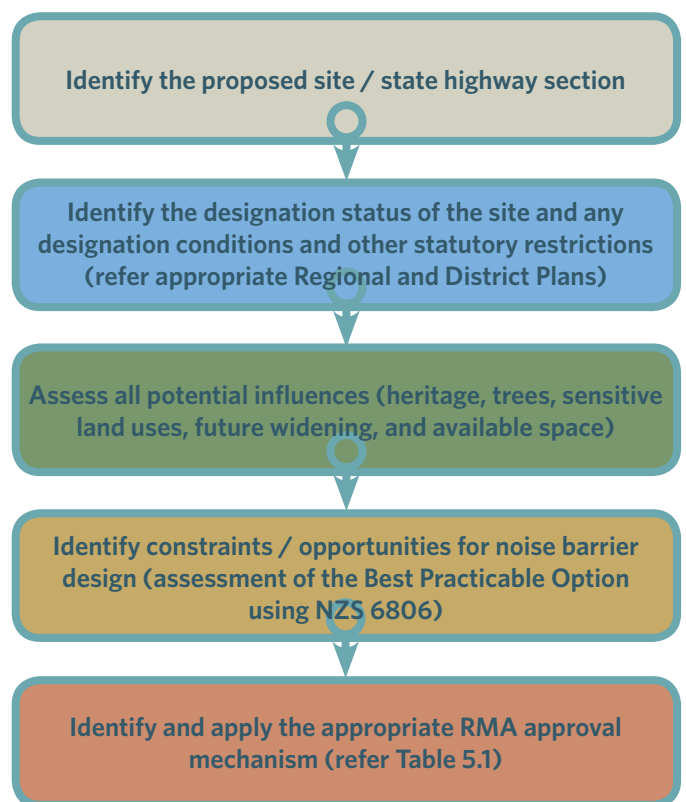


Figure 5.1 Process to identify RMA approvals

Table 5.1 Assessment of Resource Management Act approval mechanisms

Approval Mechanism	Pros	Cons	Comments
New Designation RMA s168 or Alteration to Designation RMA s181	<ul style="list-style-type: none"> ◀ can cover a large area ◀ does not have to comply with District Plan rules or standards unless those standards are included as a condition ◀ can be used to secure long-term interests (e.g. if widening is proposed as part of the roll-out or at a later date) ◀ subsequent works/maintenance may be undertaken via OPW 	<ul style="list-style-type: none"> ◀ longer timeframes than works within an existing designation ◀ might be notified or limited notified 	<ul style="list-style-type: none"> ◀ OPW still required prior to works (unless waived or sufficient detail in NOR and AEE) ◀ ensure appropriate time frames are specified if for future works
Outline Plan of Works (OPW) RMA s176	<ul style="list-style-type: none"> ◀ available where noise barrier can be accommodated within existing designation ◀ shorter timeframe than new consent or designation ◀ TA cannot determine conditions only request changes ◀ does not have to comply with District Plan provisions 	<ul style="list-style-type: none"> ◀ high level of information maybe required by TA ◀ cannot introduce elements that are not within the scope of designation ◀ TA requests can result in changes to barrier design if NZTA accepts them and possible appeal if it does not 	<ul style="list-style-type: none"> ◀ early communication with TA required as design progresses to avoid changes under OPW process ◀ landscape plan generally a basic requirement of an OPW for noise barriers ◀ may be subject to Urban Design review, but requested changes must still be within OPW framework
Outline Plan of Works waiver RMA s176A(2)(c)	<ul style="list-style-type: none"> ◀ no formal approvals are required ◀ can be obtained in short timeframe 	<ul style="list-style-type: none"> ◀ uncertainty: decision is subject to TA discretion 	<ul style="list-style-type: none"> ◀ early consultation needed with TA ◀ in practice generally a written request needed
Permitted Activity, or Certificate of Compliance (CoC) RMA s139	<ul style="list-style-type: none"> ◀ if no CoC sought no consenting delay/costs 	<ul style="list-style-type: none"> ◀ will be subject to all District Plan provisions (permitted activity) ◀ obtaining CoC can be as onerous as an application for resource consent 	<ul style="list-style-type: none"> ◀ may be suitable in place of an OPW if the activity is permitted in the district plan
Resource Consent RMA Part 6	<ul style="list-style-type: none"> ◀ moderate timeframes ◀ potentially non-notified or only limited notified ◀ site does not have to be owned by the NZTA or designated ◀ if granted, some detailed information can be provided at a later date 	<ul style="list-style-type: none"> ◀ may be notified ◀ may be declined (if not a controlled activity) ◀ conditions can be added to consent that may be onerous, or restrict future use of the site 	<ul style="list-style-type: none"> ◀ may be subject to Urban Design review
Existing use rights RMA s10,10B & 139A (if there is already an existing fence)	<ul style="list-style-type: none"> ◀ if no existing use certificate sought no consenting delay/costs 	<ul style="list-style-type: none"> ◀ existing fence may not be lawfully established under s10B RMA and it may not be possible to positively establish that it was lawfully established under s10 RMA ◀ existing use certificate (s139A) can be as onerous as application for resource consent ◀ cannot rely on existing use rights if you change the character, intensity and scale of the effects of the fence 	

5.1 STATUTORY CONSIDERATIONS

Building Act (2004)

The Building Act (2004) sets the regulatory framework for ensuring building quality and performance in New Zealand. The construction of a noise barrier structure will require building consent under the Building Act 2004 unless it is exempt under Schedule 1 of the Act, e.g.:

- ❖ Schedule 1 (b), the barrier is a simple structure (e.g. an earth bund) owned or controlled by network utility operator e.g. NZTA; and/or
- ❖ Schedule 1 (c), the barrier is a retaining wall less than 1.5 metres in height and does not support any surcharge or load additional to the load of the ground; and/or
- ❖ Schedule 1 (d), the barrier is not a retaining wall and is less than 2 metres height above the supporting ground.

Where a building consent is required for a noise barrier, compliance documents should be used. It should be noted that the Compliance Document for the New Zealand Building Code Clause B2: Durability, requires the building elements of the noise barrier that are difficult to access or replace to be designed and constructed to satisfy the performance requirements of the Building Code for the specified intended life of the noise barrier (if that is less than 50 years) or for 50 years. “Difficult to access or replace” applies to building elements where access or replacement involves significant removal or alteration of other building elements. Examples in relation to noise barriers are works involving the removal of masonry or concrete construction (e.g. concrete piles and foundations) or structural elements (e.g. beams or columns). The Compliance Document should be referenced for further information.

CASE STUDY

AUCKLAND BOTANIC GARDENS

In 2001, a noise barrier was erected beside SH1 to reduce road-traffic noise levels in the Auckland Botanic Gardens. The wider community living on the opposite side of SH1 was not consulted about the barrier. The Manukau City Council granted resource consent for the barrier on a non notified basis, as noise reflection was predicted to be a less than minor issue for houses opposite the gardens.

The barrier was a large visually obtrusive structure made of steel faced panels, as typically used in industrial premises. It was 500 m long and 3.5 m high.

A number of residents opposite the barrier complained about adverse noise effects. The residents asserted that they were experiencing significantly increased noise and a different character of noise, due to reflections from the barrier. This matter proceeded to the Environment Court, which issued an enforcement order for the barrier to be removed.

Noise measurements made before and after

removal of the barrier showed no significant change in noise level or character. Therefore, the negative response by residents is not explained by the change in noise environment.

While the root cause of the complaints is difficult to determine, it is likely that the limited consultation and the visual appearance of the barrier were contributing factors. This case therefore provides a good illustration of the potential negative outcome that can result from a lack of effective stakeholder engagement and also inadequate consideration of the visual appearance of barriers.



Noise barriers outside the Auckland Botanic Gardens were later removed after residential opposition

5.2 STAKEHOLDER ENGAGEMENT

The primary purpose of any stakeholder engagement is to ascertain community views and opinions to identify issues and achieve a better outcome. This includes the engagement of affected parties so that people are kept informed, and are provided with appropriate opportunities for input into the decision making processes.

The potential negative impacts of noise barriers on neighbouring properties include issues such as the disruption of views, community severance, reducing sunlight and creating a potential negative focal point towards the NZTA.

Initial stakeholder engagement with regard to noise may include discussions with affected property owners/occupiers about the project intent as well as any possible noise mitigation such as noise barriers. Specific details such as the visual effect of the barriers and the process undertaken to install and maintain noise barriers (issues such as site constraints, maintenance, graffiti and construction management) may also be discussed. In some cases more formal agreements may be sought or required from property owners for resource consent applications and property acquisitions.

When different barrier options are compared during the design process, further stakeholder engagement may include feedback from the affected property owners/occupiers. This could relate to the barrier appearance, colours and plant species relating to individual sites. This may provide an understanding of the potential effects of the noise barriers to residents and either avoid, or provide appropriate mitigation to minimise, effects on residents.

Finally, public involvement may be requested once noise barriers have been built to seek opinion on the success of the noise barriers for use in future projects.

Other key stakeholders such as local community boards may also have an interest in the project and it may be appropriate to include them in any stakeholder engagement. Additionally, local authority liaison will probably be required from the outset of the project, especially in relation to statutory matters.

Framework

Public Engagement Manual

The NZTA has a Public Engagement Policy and Guidelines Document³⁷. This document provides guidance for deciding when and how to engage the public. When applying the public engagement policy and guidelines users should use professional judgement and take into account local circumstances and context. The guidelines are advisory and are provided as an aid to planning and decision-making for noise barrier projects.

Land Transport Management Act 2003 (LTMA)

Consideration should be given to the requirements of the LTMA when undertaking noise barrier works as the NZTA is required to exhibit a sense of social and environmental responsibility (LTMA s96), which includes:

- avoiding, to the extent reasonable in the circumstance, adverse effects on the environment.

Resource Management Act 1991 (RMA)

Notification may be a requirement when applying for a resource consent or seeking a designation for state highway activities. However, the RMA specifically provides that applicants for resource consent and requiring authorities seeking a designation, do not have a duty to consult under the RMA (s36A). However the NZTA commonly undertakes stakeholder engagement in relation to applications/Notices of Requirement.

5.3 DESIGN PROCESS

In addition to the provision of the required noise reduction and basic engineering considerations, the design and assessment process for noise barriers should address the needs of all affected parties, as well as any environmental/sustainability concerns. Affected parties might include road users, Iwi, neighbouring residents and businesses, local interest groups, pedestrians/cyclists and local authorities. As such the design process for noise barriers may involve a range of specialists, and integrated design is the key to achieving a good outcome.

A noise barrier design process is presented in Figure 5.2 which outlines steps in reaching a preferred barrier solution.

A. Determine noise reduction objectives

Confirm the need for a noise barrier before processing further (NZS 6806 provides further guidance on assessing alternative noise mitigation options). Determine options for locations and heights of noise barriers that would achieve the target noise reductions (in line with council plans, consent/designation conditions or other targets).

B. Identify site considerations

Property - Undertake surveys to determine the state highway/third-party property boundaries and designation boundaries. Identify any adverse occupation of the road reserve and report to the NZTA property teams to rectify. Identify affected property owners ready to begin consultation as required.

Flood risk - Check council files for overland flow paths and storm flood levels.

Services - Locate existing services within the possible alignments of the noise barrier options.

Geology - Assess the geology of the area.

Vegetation - Where effects on vegetation are likely to be an issue a specialist (e.g. arborist) could inspect the possible barrier alignments to assess the potential impact on surrounding vegetation/trees. Could the works affect the drip line of trees? Might trees need to be removed? A resource consent may be required in order to remove the trees (particularly if they are located on third party land), and property owners should

be contacted.

Landscape/townscape character - Identify the main features and character of the locality which could influence the range of noise barrier solutions considered i.e. wall, bund.

Access - Determine access requirements through or along the noise barrier alignment.

Heritage/Archaeology - Determine if noise barrier will affect or impact historic sites or buildings.

Cultural/Iwi issues

C. Start barrier design

Develop noise barrier design taking into consideration all the relevant issues and consulting with any required specialists. Consider different forms of barrier (earth bund or noise wall), different materials as well as location.

D. Start regulatory process

Determine requirement for any regulatory approvals e.g. outline plan of works, building consent, resource consent. Consider whether the noise barrier position, height and length can be adjusted to negate the need for consent without unduly compromising noise reduction.

E. Compare barrier options

Compare the effectiveness of alternative barrier solutions and determine whether or not target reductions in noise would be achieved by each option. Consider advantages/disadvantages for each option. Compare the characteristics of options including constructability, availability of materials and suppliers, and maintenance costs in order to decide upon a preferred option.

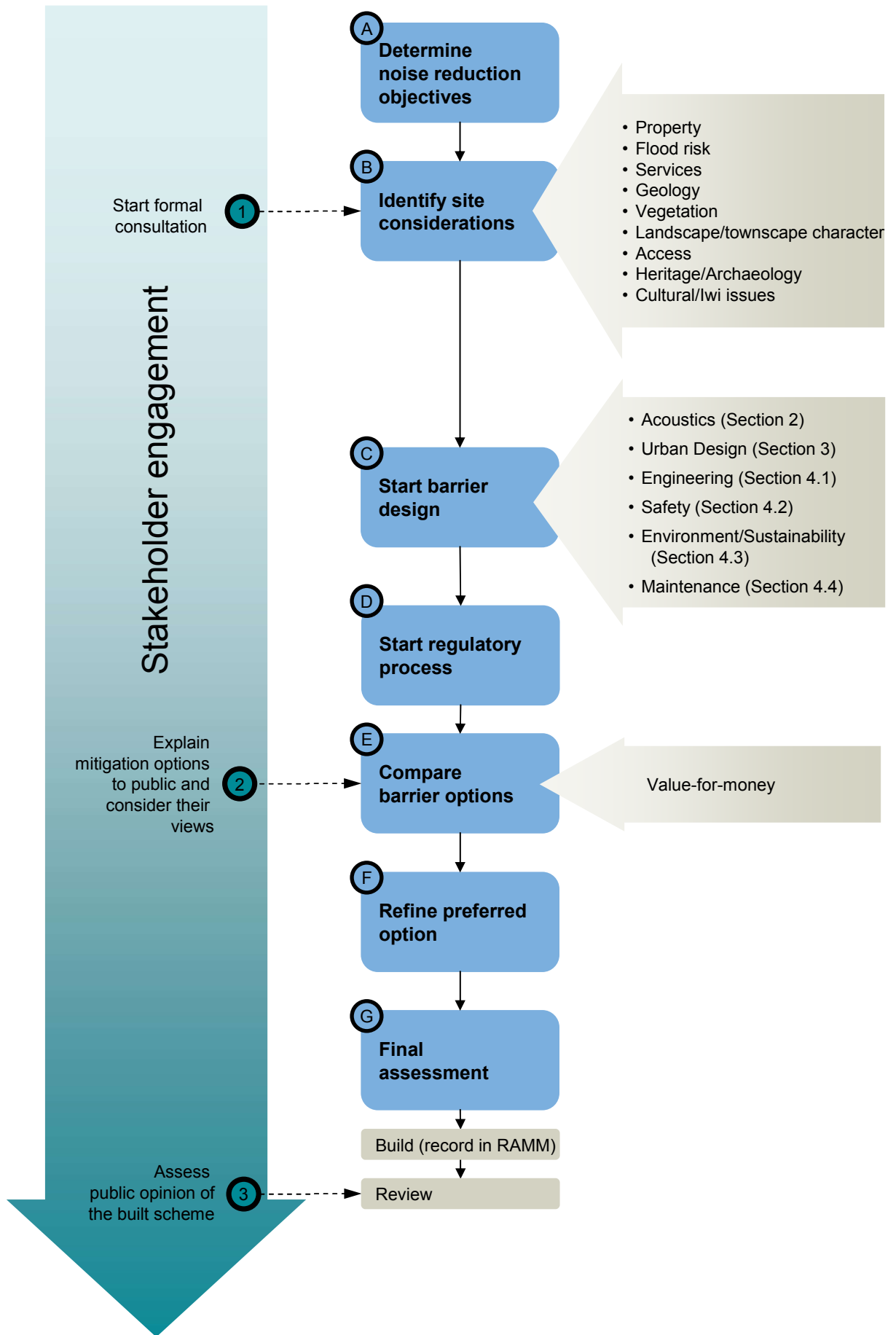
F. Refine preferred option

At detailed design stage refine the preferred option to optimise urban design principals, as well as acoustic and environmental benefits. Undertake detailed acoustics calculations if necessary. Multiple reflections should be assessed and absorptive materials specified where appropriate.

G. Final Assessment

Assess whether all relevant noise specification criteria will be met, and if necessary, make adjustments to the design.

Figure 5.2 Noise barrier design process



CASE STUDY

NOISE BARRIERS ON THE AUCKLAND MOTORWAYS

Following complaints from residents adjacent to SH1 in South Auckland, noise monitoring was undertaken at selected problem sites to determine whether intervention was required. This resulted in submissions for funding under the NZTA Noise Improvement Programme to construct retro-fit noise barriers at three selected sites – Otahuhu, East Tamaki and Penrose. Funding was approved for construction of noise barriers over the 3 years 2007/08 to 2009/10. The project was delivered by the Auckland Motorway Alliance (AMA).

After an initial investigation it was decided that post and panel wall construction offered the best options for development of alternative



Otahuhu noise barrier locations

products and finish details for panels, over other wall construction types (such as timber or living walls). Further investigations were made into the different material options that could be used for the post, and the panel, as well as the painting and decal variations. This also included consideration of construction and maintenance (whole-of-life) cost comparisons, as well as other issues such as sustainability.

The performance of different post materials (steel, concrete, polyurethane, plastic) was assessed based on availability of materials, ease of installation, versatility, and whole-of-life performance. It was considered that steel I-section (hot dip galvanised) provided the best overall performance of all of the materials considered. Steel also provided the opportunity to use a number of different panel materials as well as having the potential for the height of the noise wall to be increased at a later date if necessary.

Initially marine plywood panels, which had been successfully installed on Hobsonville, SH18, were used as the base option in design. Research was undertaken to identify panel materials (steel, aluminium, concrete, composite materials). Most of these panel options were proprietary products that would need to be imported, thus the landed cost was high and there was a lost opportunity

	Steel I-Post & Plywood Panels	Steel I-Post & LiteCrete Concrete Panels	Smart Wall	Lime Green Barrier
New				
Specification for cost comparison	2,5m high UB 150 18.0 Hot dipped Galv. I-beam posts at 2.4m centres. 1.5m embedment into 500dia. hole with 25Mpa concrete. 300 x 200mm concrete maintenance strip.	Note: No existing noise wall photograph available of this product 2,5m high UB 150 18.0 Hot dipped galvanised I-Beam posts at 4.0m centres. 1.5m embedment into 500 mm diameter hole with 25Mpa concrete. 400 x 200mm concrete maintenance strip.	2,5m high UB 150 18.0 Hot dipped galvanised I-Beam posts at 2.9m centres. 1.5m embedment into 500mm diameter hole with 25Mpa concrete. 300 x 200mm concrete maintenance strip.	Note: No existing noise wall photograph available of this product 2,4m high UB 150 18.0 Hot dipped galvanised I-Beam posts at 8.0m centres. 1.5m embedment into 500mm diameter hole with 25Mpa concrete. 400 x 200mm concrete maintenance strip.
Panel Type	Marine plywood panels Panel size 2400 x 1200 x 25mm	Light weight concrete panels Single panel 4000m x 2500m x 125mm	Laminate of polystyrene and fibre cement outer skins Panel size 2900 x 1200 x 75mm	Hollow core concrete Single panel 8000 m x 1200m x 135mm
Whole of life Maintenance Cost Est.	Plywood panels would need to be replaced after approximately 20 years. What is the % cost over 100 years??	No maintenance or replacement required up to 100 years. Indestructible by vandals. Can be water blasted to clean, and painted if required. Colour can be added to panels during manufacture (red, brown, or green oxide)	Can be water blasted to clean. Panels can be replaced if vandalised. Can be painted over	No maintenance or replacement required up to 100 years. Indestructible by vandals. Can be water blasted to clean, and painted if required. Colour can be added to panels during manufacture (red, brown, or green oxide)

Example of a noise barrier comparisons assessment undertaken by the AMA

for local economic gain. Accordingly focus shifted to finding a locally manufactured product, or a product that could be locally manufactured under licence from the parent company overseas. A search of locally available panel types uncovered several different possible products, although some were considered unsustainable due to their material type and were discounted. The options were then narrowed down to the following wall types:

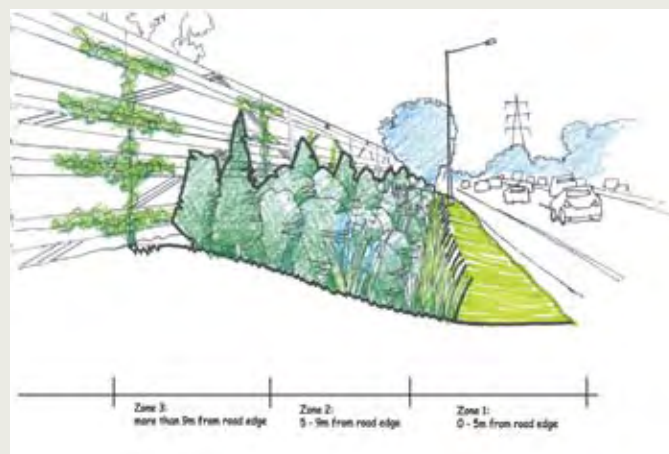
- ❖ Steel I-section post with plywood panels
- ❖ Steel I-section post with concrete LiteCrete panels
- ❖ Steel I-section post with Smart Wall concrete panels
- ❖ Steel I-section post with Lime Green Barrier concrete panels

The various requirements for noise barrier performance criteria such as whole-of-life maintenance, sustainability and costs were determined, and each of the above four wall types assessed against these criteria.

Overall, the Lime Green Barrier (LGB) panels were found to offer the best whole-of-life cost performance out of the various options, as both material items (steel and concrete) are expected to provide in excess of 50 years life span, without requiring maintenance or replacement. Additionally, the LGB panels were claimed to provide additional environmental benefits (reduction in noise reflection and air pollution, constructed from recycled products and itself recyclable) that other products did not provide, and it could also be installed with plain concrete finish, or painted, stencilled, and graffiti protected. As it was manufactured locally, it would also benefit the local economy, and could be made at short notice without any plant set-up costs. As such, AMA recommended that steel I-section posts with LGB panels be adopted as the minimum standard for a noise wall product on the Auckland Motorways, with optional variations of surface texture, decal, paint, and graffiti protection.

A comprehensive landscaping plan was proposed to support the new noise barrier design. In line

with AMA's aim to keep whole-of-life costs down, as well as meeting environmental objectives, the landscape plan includes the use of native New Zealand plant species that are hardy, require minimal maintenance, with a life span of at least 20 years, and also meet the NZTA's road safety requirements. The landscape plan includes the planting of 3 specific successional zones on the road verge, and includes the use of the native climbing plant species - the Three Kings Vine and Carmine Rata up the noise wall surface, providing graffiti prevention. Additionally, vegetation that is removed from the site during construction of noise barriers will be chipped for re-use as mulch when the new vegetation scheme is planted. This not only reduces environmental waste disposal impacts from the project, but also decreases costs through savings in disposal and new mulch costs.



Noise barriers planting plan

5.4 COSTS

Indicative construction costs for the most common types of New Zealand noise barriers are shown in Table 5.2³⁸ below. This table should only be used for initial cost assessments, and should be updated to take account of inflation from the base year of the table (2008). It should be remembered when undertaking noise barrier cost assessments, that to achieve value-for-money, construction costs are only one component of the overall cost of installing a noise barrier. Without a full consideration of all the issues discussed in this guide, it is likely that costs (particularly whole-of-life) relating especially to property, public engagement/communications and maintenance may escalate considerably.

Table 5.2 Indicative noise mitigation costs (planning, design, and construction (2008))

Barrier type	Material	Indicative cost/Unit	Unit
Safety	Test level (TL) 4 concrete barrier (810 mm high)	\$400	linear metre
	TL 5 concrete barrier (1070 mm high)	\$430	linear metre
Noise wall - 2 m	timber*	\$240	linear metre
	concrete	\$350	linear metre
	acrylic	\$1,650	linear metre
Noise wall - 3 m	timber*	\$400	linear metre
	concrete	\$480	linear metre
	acrylic	\$2,500	linear metre
Noise wall - 4 m	timber*	\$450	linear metre
	concrete	\$650	linear metre
	acrylic	\$3,300	linear metre
Noise wall - 5 m	timber*	\$500	linear metre
	concrete	\$1,000	linear metre
	acrylic	\$5,000	linear metre
Noise bund	non-structural recycled earth	\$15	m ³
	non-structural imported earth	\$25	m ³
	structural recycled earth	\$20	m ³
	structural imported earth	\$35	m ³

*Assuming "standard" pine planks.

Please refer to the NZTA acoustics website (www.acoustics.nzta.govt.nz) for updated costs, and an online noise barrier cost calculator.

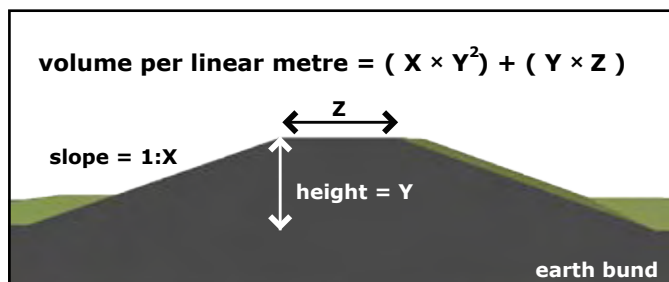


Figure 5.3 Material volumes (per linear metre) can be calculated using slope gradient and bund height

Table 5.3 Approximate material volumes in bunds

Bund height	Material volume per linear metre
1 m	4 m ³
2 m	14 m ³
3 m	30 m ³

Table 5.4 Indicative noise barrier maintenance costs

Barrier type	Material	Comparative Maintenance cost	Maintenance Considerations
Noise wall	timber	Moderate	Inspection/repair, periodic treatment
	concrete	Low	Inspection/repair, periodic cleaning
	polycarbonate	High	Inspection/repair, periodic cleaning/treatment
Noise bund	earth	Low to moderate	Grass cutting, planting maintenance

When estimating the cost of an earth bund, the material volumes in Table 5.3 can be used for an initial estimation for a bund on flat ground. Alternatively the calculation shown in Figure 5.3 can be used to work out material volumes per linear metre.

Table 5.4 provides a comparative indication of maintenance costs. Only a comparison is given as site specific factors have a significant influence on the actual costs.

As discussed in Section 4.4 (Maintenance) the degree of maintenance required for noise barriers is dependent on a variety of issues e.g. materials, property/boundary, plant selection, design. When designing noise barriers, keeping whole-of-life maintenance costs low must be a key consideration from an overall cost perspective. Materials and construction costs are in many cases just the tip of the iceberg when it comes to the overall cost of a noise barrier.

Suppliers

The NZTA maintains a register of noise barrier related suppliers, contractors and specialists that have been identified by the NZTA Environment and Urban Design Team. The register can be found on the NZTA Transport Noise website (www.acoustics.nzta.govt.nz).

For acoustic performance specification clauses that could be included in noise barrier contracts with suppliers and contractors please contact the NZTA Environment and Urban Design Team, Email: environment@nzta.govt.nz

5.5 ACOUSTICS SPECIFICATIONS

Introduction

Historically noise barriers in New Zealand have not been subject to specific material acoustic performance specification, and often just the height and basic construction have been defined. Design for ongoing maintenance has often been neglected. This has resulted in numerous examples of poorly performing barriers, sometimes through incorrect installation but particularly with issues such as gaps in fences opening up over time.

All new state highway noise barriers should be subject to robust specification to ensure appropriate acoustic performance over the design life (NZS 6806 requires noise barriers to be designed in such a way that they retain the same noise reduction properties up to the design year). This is likely to require increased use of proprietary noise barrier systems, such as those in common use internationally.

Standards

A comprehensive suite of noise barrier standards has been developed in Europe, and these may assist in determining an appropriate approach for specification of noise barriers in New Zealand. These standards are outlined in Table 5.5.

EN 1793	Road-traffic noise reducing devices - Test method for determining the acoustic performance	
	EN 1793-1:1997	Part 1. Intrinsic characteristics of sound absorption
	EN 1793-2:1997	Part 2. Intrinsic characteristics of airborne sound insulation
	EN 1793-3:1997	Part 3. Normalized traffic noise spectrum
	EN 1793-4:2003	Part 4. Intrinsic characteristics - In situ values of sound diffraction
	EN 1793-5:2003	Part 5. Intrinsic characteristics - In situ values of sound reflection and airborne sound insulation
EN 1794	Road-traffic noise reducing devices - Non-acoustic performance	
	EN 1794-1:2003	Part 1. Mechanical performance and stability requirements
	EN 1794-2:2003	Part 2. General safety and environmental requirements
EN 14388:2005	Road-traffic noise reducing devices - Specifications	
EN 14389	Road-traffic noise reducing devices - Procedures for assessing long term performance	
	EN 14389-1:2007	Part 1. Acoustical characteristics
	EN 14389-2:2004	Part 1. Non-acoustical characteristics

Table 5.5 These European standards in relation to determining acoustic performance are being considered by the NZTA as formal specifications for installing noise barriers. At this stage, it is not proposed to adopt all the standards related to non-acoustic performance, although they may serve as a useful reference

Sound insulation

For noise barriers less than 2 metres high, the sound transmitted through the barrier is often negligible compared to the sound passing over the top. In that instance the material/construction used is not critical, providing the barrier is solid and of a certain mass. This type of low height barrier has often been used in New Zealand. However, more recent noise barriers are generally higher and often noise barriers are on embankments or bunds making the overall height significantly greater. In these instances the sound potentially passing through the barrier is more significant.

EN 1793-2 provides a test method for sound passing through barriers, and classifies results into categories B1 (least sound insulation) to B3 (most sound insulation). For high noise barriers, category B3 would often be appropriate.

Airborne sound absorption

As shown in Section 2.4 (Reflections) multiple reflections between barriers or between barriers and high sided vehicles can reduce or negate the benefit of a barrier. To avoid this situation absorptive noise barriers are commonly used internationally, but use of such barriers has not been standard practice in New Zealand. It is recommended that for new NZTA noise barriers, multiple reflections should be assessed and absorptive barriers considered where appropriate.

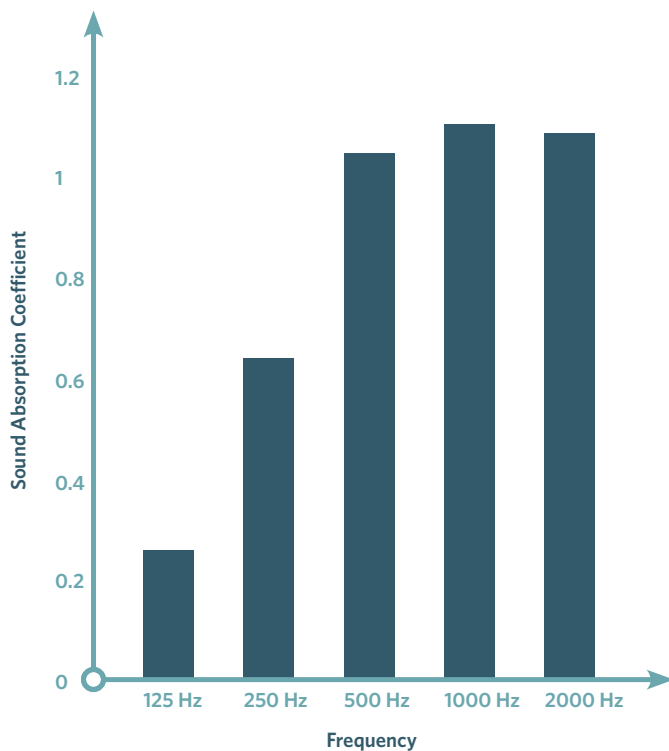


Figure 5.4 Example sound absorption coefficients based on 50 mm thick absorption (suitable for absorptive road barriers, provided adequate drainage)

EN 1793-1 provides a test method for the sound absorption coefficients of barriers and classifies the results into categories A1 (least absorptive) to A4 (most absorptive). Where absorptive noise barriers are required, category A3 would generally be appropriate. However, category A4 should be considered for particularly high barriers or parallel barriers close to the road.

Field testing

The tests described above from EN 1793-1 and EN 1793-2 are laboratory tests. It can also be advantageous to measure the actual installed (in situ) performance of a noise barrier, as in some instances such as with “living walls”, it is not practicable to conduct standardised laboratory testing. EN 1793-5 provides a procedure for in situ tests. As this is a relatively complex new procedure it is not recommended for general use in New Zealand at this time. However, it may be required in special circumstances.

Diffraction

Section 2.5 (Top shape) of this guide shows the benefit of different shaped diffraction devices at the top of noise barriers. Should they be used in future, their performance could be specified using EN 1793-4.

Durability

The design life of barriers constructed for the NZTA should be at least 50 years. The whole-of-life costs of barriers should be considered, and it may be appropriate to specify that barriers maintain their specified performance with minimal maintenance over the first 20 years. EN 14389-1 provides a standardised procedure for assessing the durability of a noise barrier over 20 years only.

GLOSSARY

Airborne sound insulation	The reduction in sound as it passes through a noise barrier, or into a building.
Altered road	An existing road that is subject to alterations of the horizontal or vertical alignment and meets criteria defined Section 1.5 of NZS 6806, including certain sound level thresholds.
AMA	Auckland Motorway Alliance.
Annual average daily traffic (AADT)	The vehicle count for an entire year in both directions past a point on the road, divided by the number of days in the year.
Best practicable option	<p>The best method for preventing or minimising the adverse effects on the environment having regard, among other things, to:</p> <ul style="list-style-type: none">- the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and- the financial implications, and the effects on the environment, of that option when compared with other options; and- the current state of technical knowledge and the likelihood that the option can be successfully applied. <p>When determining whether a noise barrier represents the best practicable option, the factors defined in Section 6.3 of NZS 6806:2010 (Acoustics - Road-traffic noise - New and altered roads) should be considered.</p>
Crime Prevention through Environmental Design (CPTED)	A framework for incorporating crime prevention within quality urban designs, by focusing on reducing the opportunity to commit crime, therefore lessening the motivation to offend.
decibel (dB)	A unit of measurement on a logarithmic scale which describes the magnitude of sound pressure with respect to a reference value (20 μ Pa).
Diffraction	The bending of sound waves around or over obstacles such as a noise barrier.
Existing road	A formed legal road existing at the time when road-traffic noise from a new or altered road is assessed using NZS 6806.
Free-field location	A location at least 3.5 metres from any significant reflecting surface other than the ground.
$L_{Aeq(24h)}$	The A-frequency-weighted time-average sound level over a 24 hour period, in units of decibels. $L_{Aeq(24h)}$ is the metric used in New Zealand to describe road-traffic noise.
LTMA	Land Transport Management Act 2003.
New road	Any road which is not an altered road and is to be constructed where no previously formed legal road existed.

Noise	Noise may be considered as sound that serves little or no purpose for the exposed persons and is commonly described as ‘unwanted sound’. If a person’s attention is unwillingly attracted to the noise it can become distracting and annoying, and if this persists it will provoke a negative reaction. However, low or controlled levels of noise are not necessarily unreasonable.
Noise barrier	A structure that at least blocks the line-of-sight from a noise source to a receiver to reduce the noise levels. In this guide “noise barrier” refers to both wall type structures and berms/bunds.
NZS	New Zealand Standard.
RAMM	Road Assessment and Maintenance Management database. A database used by the NZTA for storing state highway network and asset information.
Reflection	The redirection of sound by a reflecting medium such as a noise barrier, often back towards the source of that sound. The overall nature of a reflection varies according to the angle, extent, texture and structure of the reflecting surface
Reverse sensitivity	The vulnerability of an established activity to objection from a new sensitive land use.
RMA	Resource Management Act 1991.
TA	Territorial Authority.
TL3, TL4, TL5	Test Level e.g. TL3. Performance rating given to road safety barrier systems in accordance with the National Cooperative Highway Research Program Report 350: Recommended Procedures for the Safety Performance of Highway Features (NCHRP Report 350).
Treated timber	Timber that is treated to meet the approved chemical activity and the minimum concentrations (retained in the wood after treatment) required to meet a hazard class specification such as H1-6. Refer <i>NZS 640:2003 Chemical preservation of round and sawn timber</i> and <i>AS/NZS 1604:2004 Specification for preservative treatment</i> .
Tunnelling effect	Where structures such as noise barriers, run parallel to each other on either side of the carriageway. This can create confined views for the road user.

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For further information:
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