

Noise Mitigation Guideline



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Section 1

Overview

1.1 Why is this guideline required?

This guideline outlines the approach Roads and Maritime Services takes to the evaluation, selection and design of feasible and reasonable noise mitigation measures. It supersedes Practice Note (iv), (iv-a) and (iv-c) of the Environmental Noise Management Manual (2001).

This policy should be read in conjunction with the:

- Road Criteria Guideline
- Road Noise Policy, 2011
- Project Pack
- Noise Wall Design Guideline
- QA Specification R271, Design and Construction of Noise Walls.

1.2 Policy Statement

Roads and Maritime is committed to effectively managing impacts from its activities in an environmentally responsible manner. Roads and Maritime is committed to avoiding or minimising noise and vibration impacts from road traffic on all roads and traffic systems under our control.

Roads and Maritime recognises that considering noise at the outset of a project can minimise or avoid noise impacts and the cost of mitigating them.

Roads and Maritime will assess and provide feasible and reasonable noise mitigation measures for:

- Road projects in accordance with the NSW Road Noise Policy 2011
- Existing roads in accordance with Roads and Maritime's Noise Abatement Program.

Roads and Maritime prefers noise and vibration mitigation measures to be applied within the road corridor wherever practicable. Measures that need to be applied outside the road corridor such as at-property treatment of building facades will be limited to the circumstances described in this guideline.

1.3 Context

Policies such as the NSW Road Noise Policy 2011 (RNP) and Roads and Maritime's Noise Abatement Program (NAP) call for the application of feasible and reasonable measures to mitigate noise.

This guideline provides the detail needed to determine feasible and reasonable noise mitigation measures for road projects and to existing roads with an acute level of traffic noise.

This guideline will need to be considered for all road projects.

Noise impacts and mitigation measures need to be evaluated at various stages of a road project to inform the approval and design process. The evaluated outcomes reported during these processes also provide the required reference to assess post construction operational compliance.

When identifying feasible and reasonable noise mitigation the total noise level from all roads is always used. This includes when assessing against new road criteria. This is because it is not reasonable to provide noise mitigation unless it provides a reduction in noise level. This differs from the 2011 edition of the Road Noise Policy where only contributed noise levels are considered. This ensures that noise mitigation provides a benefit by reducing noise levels at a receiver rather than just noise levels coming from the new road. It also ensures that the noise from the new road can not unreasonably increase noise levels at a receiver without the receiver qualifying for noise mitigation.

1.4 Scope

This guideline provides a consistent approach to the evaluation, selection and design of the most appropriate mix of these further noise control options. This guideline is most relevant for:

- Project development managers
- Environmental staff
- Project implementation managers
- NAP managers
- Acoustical consultants.

This guideline will apply for:

- All new and redeveloped road projects managed by Roads and Maritime:
 - In the final stages of project concept design development and in the environmental impact assessment (including any REF)
 - During the project's detailed design
 - Following post-construction operational compliance noise monitoring and assessment, if re-evaluation of the project's noise treatments is considered necessary
- Minor works where noise levels increase by more than 2.0dBA (2.1dBA or more)
- Noise Abatement Program noise mitigation measures.

The guideline does not apply to:

- Ancillary facilities such as truck rest areas, bus layovers or heavy vehicle inspection stations. In these cases the NSW Industrial Noise Policy is applicable
- Road traffic on private roads.

Section 2

Definitions

Word	Definition
Acute noise level	A level of road traffic noise of 65 dB(A) or more for the day period of 7am to 10pm or 60 dB(A) or more for the night period of 10pm to 7am and measured as an equivalent continuous noise level (L_{Aeq}) 1 metre from the building facade.
At-property treatments	Includes building treatments and courtyard walls. Building treatments may include but are not limited to ventilation, glazing, window and door seals, sealing of vents and underfloor areas.
Closely spaced group of residences	Residences are generally considered closely spaced where the facades are separated by less than 20 metres.
Controlling criterion	Whichever of the day or night time L_{Aeq} criteria (Noise Criteria Guideline) is exceeded by the greatest amount.
Cumulative limit	A total noise level that is 5dBA or more above the Noise Criteria Guideline criteria in the build year. See Section 6.1 for further clarification.
Design barrier	Barrier where two-thirds of receivers that qualify for consideration of noise mitigation and receive benefit from the noise barrier no longer need at-property treatments. In some instances the height may be increased where the points weighting curve has a minimum value. See Section 8.4.
Equitable	Receivers and communities exposed to road project noise receive consistent outcomes.
Feasibility	Relates to engineering considerations (what can be practically built). These engineering considerations may include: <ul style="list-style-type: none"> • The inherent limitations of different techniques to reduce noise emissions from road traffic noise sources • Safety issues such as restrictions on road vision • Road corridor site constraints such as space limitations • Floodway and stormwater flow obstruction • Access requirements • Maintenance requirements • The suitability of building conditions for at-property treatments.
Isolated single residences and isolated groups of closely spaced residences	Single residences or closely spaced groups of residences in numbers of three or less are considered isolated where they are separated from other residences by more than 100 metres. Where residences are separated by between 20 metres and 100 metres they may be considered isolated but this depends on examining surrounding development more broadly. If for example the low density development comprises regular placement of residences at 20 metres to 100 metres separation then the residences are not considered isolated.
Low noise pavement	Low noise pavement is pavement that has an emission level 2dBA lower or more than dense graded asphalt.

Word	Definition
Maximum barrier design	The barrier height where there are no receivers behind the barrier that need at-property noise treatment other than those that are influenced by barrier end effects or noise from other non-project roads. See Section 8.2.
Modelling allowance	<p>A decibel amount added to predicted noise levels to artificially increase them. This may be used to provide conservatism to predictions where there is uncertainty in modelling input parameters. In engineering design this is commonly referred to as a safety factor.</p> <p>The modelling allowance should be applied to both the build and no build cases so that it does not affect the difference in noise levels between them.</p>
Project area	Please see Section 5 of the Noise Criteria Guideline for clarification.
Reasonable	<p>Selecting reasonable measures from those that are feasible involves judging whether the overall noise benefits provide significant social, economic or environmental benefits. The factors to be considered are:</p> <ul style="list-style-type: none"> • The noise reduction provided and the overall number of people that benefit from the mitigation • Existing and future noise levels, including changes in noise levels in the build and design year and the extent of any exceedance of the noise criteria • Potential for a mitigation measure to reduce noise during construction as well as from road traffic after the project is complete • The cost of mitigation, including the cost of noise mitigation measures as a percentage of the total project cost and the ongoing maintenance and operational costs • Community views and wishes (typically gathered at a number of stages including route selection, following concept design, community consultation process following the noise assessment and post opening in the operational noise report) • Visual impacts for the community surrounding the road project and for road users. These are typically identified in the environmental impact assessment • The wider community benefits arising from noise mitigation of the proposed road or road redevelopment • Relative weighting of treatments with respect to protection of outdoor areas or only internal living spaces.

Section 3

Policy

This guideline describes the principles to be applied when reviewing if noise mitigation is feasible and reasonable. It also describes procedures to assist in reviewing noise mitigation. The approach is staged giving preference to reducing noise during corridor planning and road design rather than through use of specific noise mitigation measures. The basis for this staged approach is given in NSW's Road Noise Policy (RNP).

The intention in all situations is to meet the following principles. Should circumstances arise where the procedures in this document do not appear to meet the principles below then the procedures may be varied through consultation with Roads and Maritime noise specialists. Note that the use of the procedures in this guideline does not guarantee that the principles will always be met and in cases where there is doubt then it is the principles rather than the procedures that are paramount.

The principles are:

1. Communities should receive reasonable and equitable outcomes
2. Noise mitigation should be designed to reduce noise levels to the criteria at qualifying receivers
3. Priority should be first given to reducing noise during corridor planning and road design where there may be greater opportunity to provide cost effective and integrated outcomes with better urban design
4. Following corridor and road design residual exceedences of noise criteria may be addressed at qualifying receivers using in order of preference (RNP Section 3.4.1) quieter road surfaces, barriers and at-property treatments
5. Incidental benefits from the noise mitigation designed for qualifying receivers should be recognised at all receivers within a community where noise levels exceed WHO guidelines¹
6. Noise barrier evaluation processes must:
 - a) Give preference to reducing outdoor noise levels and the number of at-property treatments, and
 - b) Provide efficient barrier heights and extents without disregarding lengths of effective noise barrier in front of eligible groups of receivers
7. Noise mitigation shall be evaluated and installed where feasible and reasonable.

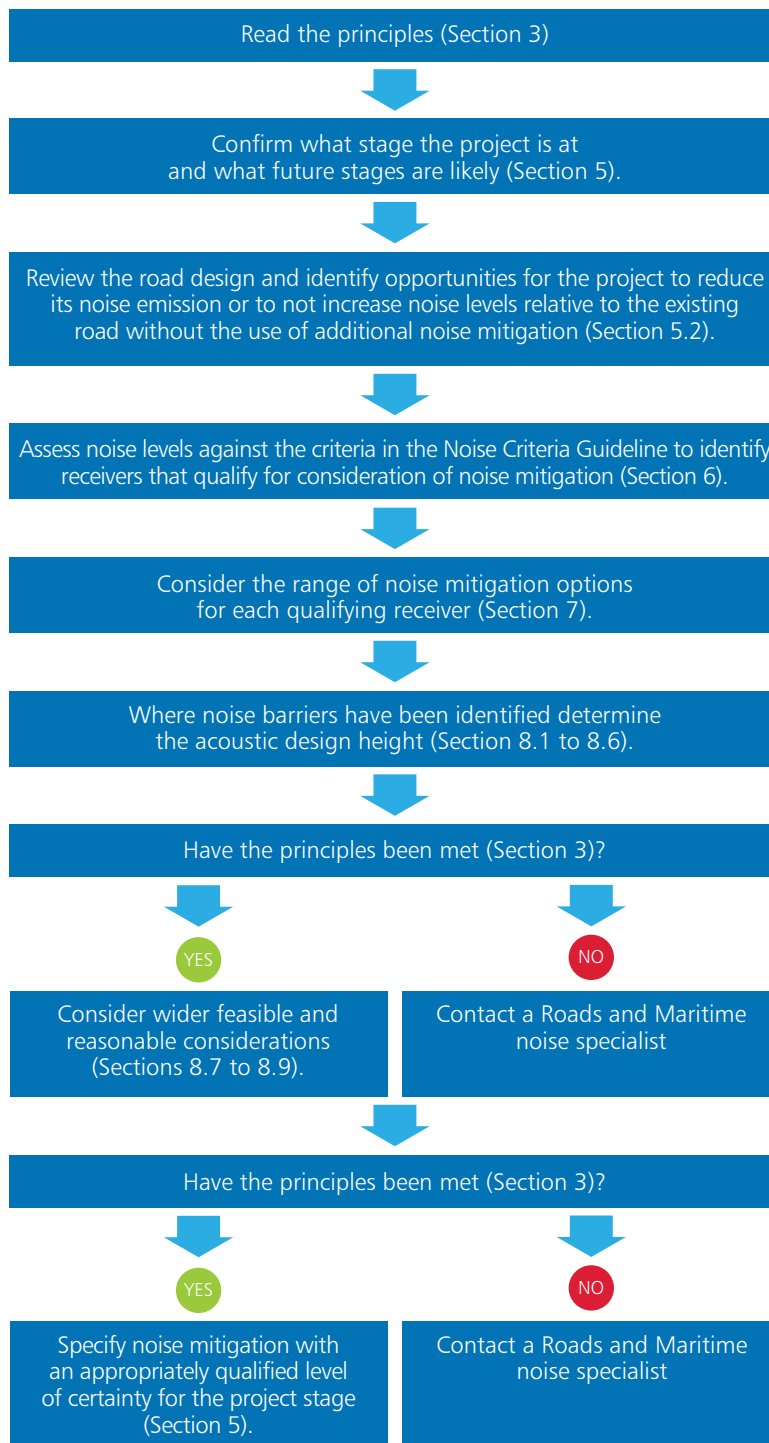
Note 1: Facade noise levels of 50dBA day and 45dBA night are considered representative of the World Health Organisation (WHO) Guidelines for Community Noise (1999) for outdoor areas and the WHO Night Noise Guidelines for Europe (2009) threshold levels.

Section 4

How do I use this guideline?

The following flow chart provides an overview of how to use this guideline. Key aspects to note are that the guideline principles must be met and that each step in the flow chart is applicable at each project stage.

Figure 1: Overall approach for noise mitigation assessment



Section 5

Project stages

5.1 Designing to reduce and mitigate noise

When reviewing project noise the first consideration should be at what stage is the project and what the likely future stages are. The project stages are detailed in Sections 5.4 to 5.6.

The project stage and any subsequent stages determine the level of detail that is available and the certainty in which final mitigation measures may be specified.

For example, depending on the scale of the project, there may be one design stage which is used for the environmental assessment or further design refinements at different stages after the environmental approval. More complex projects may also have a route options analysis completed prior to the environmental assessment.

5.2 Integrated noise reduction measures

Each of the project stages (Sections 5.4 to 5.5) provides a review point at which opportunities to integrate noise reduction into decisions, corridor planning and fundamental design processes are available. This may require coordination of multiple design and planning disciplines at each stage and throughout the duration of the project.

The following road design features should be considered integral to corridor planning and road design. They may also provide greater benefits than just mitigation of noise:

- Adjustments to vertical and horizontal alignments
- Road gradient modifications
- Traffic management
- Utilisation of airspace above roads for acoustically designed land use developments
- Cost effective use of won project spoil to provide landscape mounds where there is suitable site footprint.

Integrated noise reduction measures should exclude the use of quieter surfaces during road design except for where they are used for another primary purpose.

As the stages progress towards the 'for construction' design the opportunities to integrate noise reduction measures into the design may reduce with increased reliance on specific noise mitigation measures to meet the criteria established for the project using the Noise Criteria Guideline (NCG).

5.3 Specific noise mitigation measures

Specific noise mitigation measures to meet the NCG criteria at qualifying receivers (Section 6) should only be included after opportunities for integrated measures have been investigated. Specific noise mitigation measures should be identified (Section 7) with an appropriately qualified level of certainty for each project stage.

Guidance on how to evaluate the most feasible and reasonable mix of noise mitigation is in Section 7 and 8. Detailed discussion of noise mitigation performance for pavements, barriers and property treatments are proposed to be contained in separate guidelines.

These specific measures should be reviewed at each stage of the project below (Sections 5.4 to 5.6).

5.4 Route options

During an options assessment various routes are investigated. Each route may have different opportunities to integrate noise reduction, different noise specific mitigation measures and a different potential noise impact. An important aspect in planning a new road and road corridor is to provide a buffer. This buffer aligns the road corridor away from sensitive receivers and also provides sufficient space for noise mitigation in the road corridor. This underlies the premise in the RNP that for a new road there is a greater potential opportunity to have lower noise levels than a redeveloped road.

5.5 Design

Each of the following steps represents an increase in the level of design detail:

- Environmental impact assessment (EIA)
- Environmental impact assessment review for scope of works or performance requirement documentation provided to contractor
- Tender design
- Detailed design stages (e.g.15, 80 and 100 per cent and 'for construction').

This improved level of detail (e.g.road location, topography) increases the level of certainty in modelling results and allows for refinement of mitigation measures. Where the level of certainty increases this may permit the modelling allowance to be adjusted.

Common examples of information that is refined as a project progresses are ground geology and ground height contours near the road and at receivers. These both influence vertical and horizontal road alignment and the corresponding noise propagation.

In all instances, any allowance added to predicted noise levels to address less than ideal information, should be applied after the difference between the 'build' and 'no-build' noise levels have been calculated or to both the 'build' and 'no-build' noise levels. This ensures that the allowance does not artificially increase the noise level difference. The effect of the allowance should be to only increase the number of receivers that are identified above the criteria.

Potential mitigation identified at all stages of assessment, particularly during the EIA phase should clearly state:

- If it is being presented as an option only subject to feasible and reasonable considerations or future design refinement
- If there are any uncertainties that may result in changes to the noise mitigation.

When recommending mitigation during the EIA stage it should be confirmed whether there is to be a detail design stage. If there are to be no further design stages then the level of detail in survey information used to prepare the EIA technical noise report should be appropriate for construction purposes.

For example, if there are no further design stages then input parameters such as ground height contour resolution should be confirmed to provide sufficient accuracy. Typically 1 metre contours inside 300 metres. For distances beyond 300 metres then 2 (preferred) to 5 (upper limit) metre contours are sufficient.

Any limitations and modelling uncertainty in the EIA reports should be documented in the technical report.

5.6 Post construction operational compliance

Please see ENMM Practice Note 8 and Roads and Maritime's additional clarification. Note that where the outcome of the compliance report is that further noise mitigation should be considered the processes in this guideline should be followed.

Section 6

When should additional mitigation be considered?

Once noise has been minimised by feasible and reasonable methods during the corridor planning and road design stages receivers with residual exceedances of Noise Criteria Guideline (NCG) criteria can be assessed to determine if they qualify for noise mitigation.

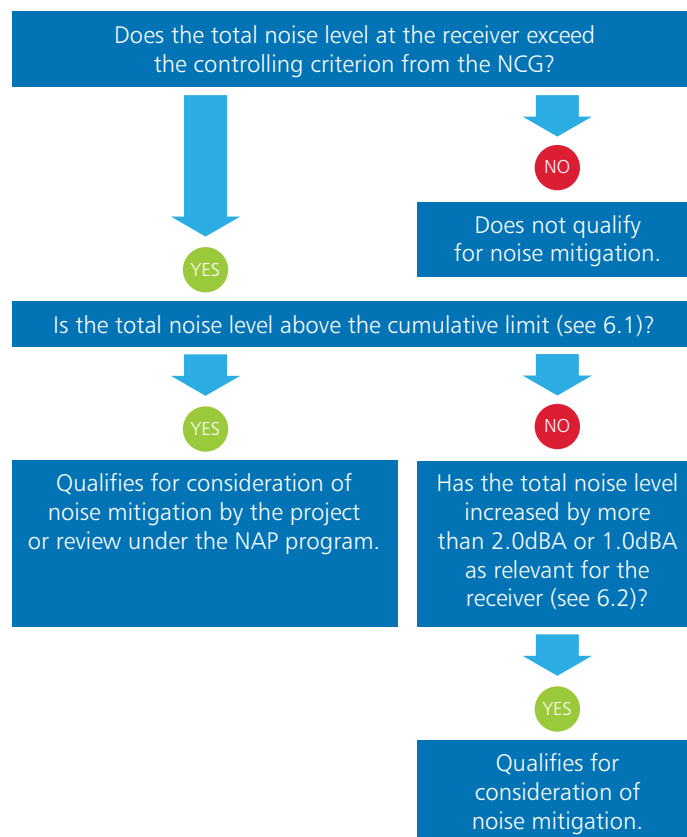
Noise levels and noise increases should be assessed at each affected facade noting that the biggest noise increase may not be at the noisiest facade.

Note that in all instances any modelling allowance added to predicted noise levels should be applied so that it does not affect the difference between the 'build' and 'no-build' noise levels.

When evaluating if a receiver qualifies for consideration of noise mitigation Roads and Maritime considers how far above the criterion the noise level is and also how much the noise level has increased by. These two considerations are detailed below and provide for a feasible and reasonable approach to identifying qualifying receivers and managing small noise increases.

A receiver may qualify for consideration of noise mitigation under the following situations in Sections 6.1 to 6.4. A summary of the process by which a receiver may qualify for consideration of noise mitigation is shown Figure 2 below.

Figure 2: Summary of qualifying process for a receiver



6.1 Cumulative limit

When the total noise level in the build year is 5dBA or more above the NCG criterion it is considered to have exceeded the cumulative limit. Receivers where the exceedance occurs qualify for consideration of noise mitigation.

The purpose of the cumulative limit is to prevent a receiver with an existing high noise level from remaining well above the criterion if the noise level did not increase significantly relative to the 'no-build' year. This meets the intention of the RNP where criteria have no allowance for high existing noise levels and still provides for a feasible and reasonable approach. Please see Appendix A for an example of a new and redeveloped road with a transition zone.

The cumulative limit does not apply if most of the noise causing the cumulative limit to be exceeded comes from a road that is not assessed as part of the project. This is defined as where the contribution from the road project at the affected facade adds less than 2.0dBA to the total noise level in the build year. Instead consideration should be given to whether the noise levels are acute at the receiver.

A receiver with noise levels at or above 65dBA $L_{Aeq, 15 hr}$ and 60dBA $L_{Aeq, 9 hr}$ may be referred to as acute. If the contribution from the road project is acute then the receiver qualifies for consideration of noise mitigation.

6.2 New roads, redeveloped roads, transitways and transition zones

Where the total noise level for the 'build' year exceeds the controlling criterion established using the NCG, and there is an increase of more than 2.0dBA (i.e. 2.1dBA or greater), relative to the 'no-build' year, then a receiver qualifies for consideration of noise mitigation. This includes the situation where the 'no-build' noise level is below the criterion value.

A receiver may also qualify for consideration of noise mitigation where the NCG criterion is exceeded with the project and the noise increase from the project is less than 2.0dBA. This may occur where there is potential for a noise reduction from the upgraded design moving traffic further away from receivers and this is not realised because of the introduction of a noisier pavement than the existing road surface. The two specific examples to be considered where road design may provide noise reduction benefits are shown in Figure 3 and Figure 4.

In the situations in Figure 3 and Figure 4 a receiver qualifies for consideration of noise mitigation where the total noise level for the 'build' year exceeds the criterion and there is an increase of more than 1.0dBA (i.e. 1.1dBA or greater), relative to the 'no-build' year. This meets the intention in the RNP which places greater emphasis on reducing noise levels during corridor planning and road design.

Figure 3: Duplication with additional carriageway further away from receiver

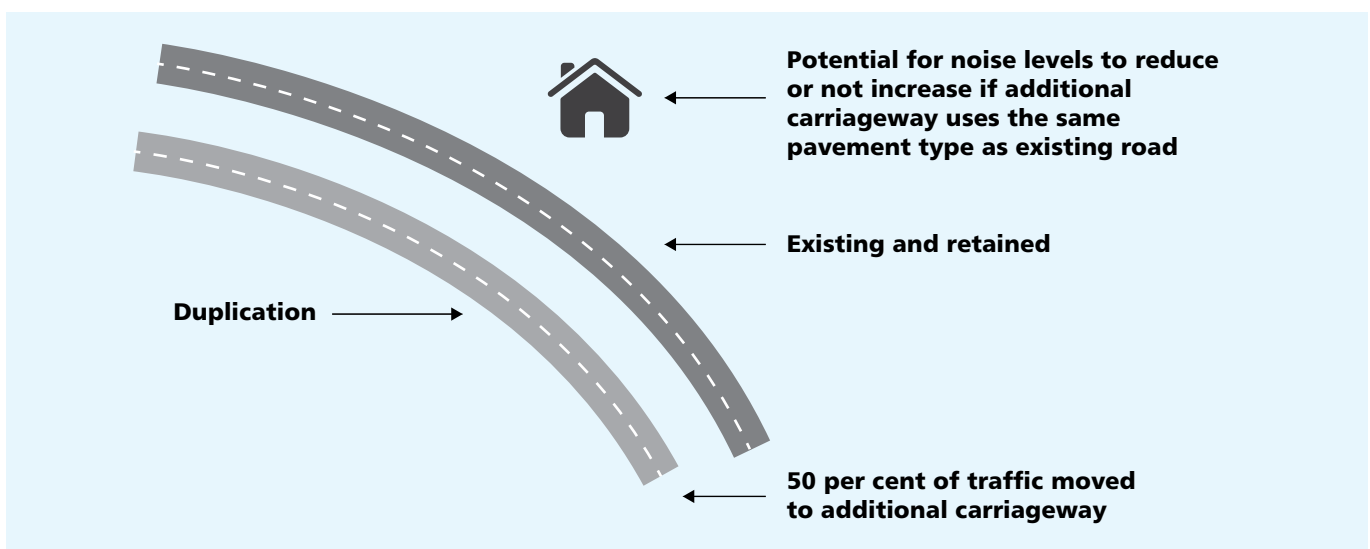
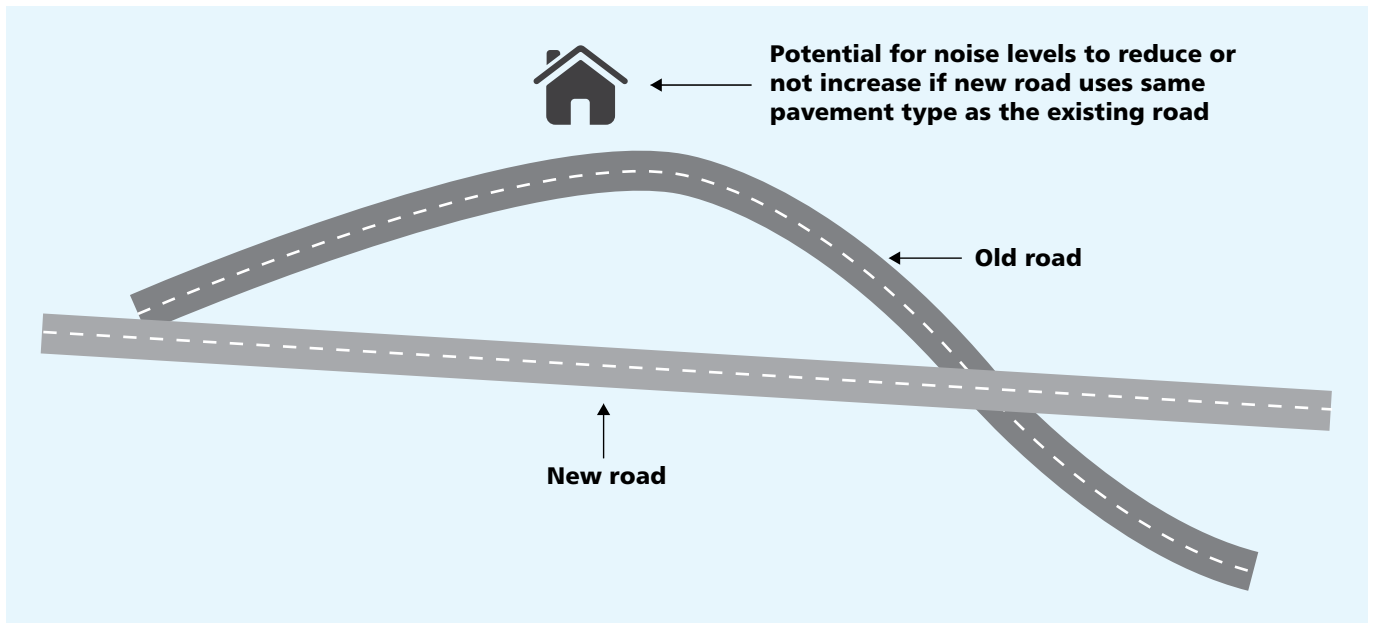


Figure 4: New road further away from receiver



Mitigation should also be considered when the mitigation measures are relatively inexpensive. For example a minor adjustment to the length of barriers or to a length of pavement treatment that has already planned may improve equity at receivers adjacent to qualifying receivers. Another example is the use of small barriers that are relatively inexpensive to install (such as so called “New Jersey” style kerbs).

6.3 Minor works

For minor works Roads and Maritime applies the criteria from the NCG if noise levels increase by more than 2.0dBA at the worst affected receiver.

When this is demonstrated, all sensitive receivers must be assessed where the noise levels exceed the controlling criterion within the minor works study area (NCG). Where the total noise level for the ‘build’ year exceeds the criterion and there is an increase of more than 2.0dBA (ie 2.1dBA), relative to the ‘no-build’ year, then the receiver qualifies for consideration of noise mitigation. This includes the situation where the ‘no-build’ noise level is below the criterion value(s).

6.4 Noise Abatement Program

If a receiver has been identified as being acute under the Noise Abatement Program then it qualifies for consideration of noise mitigation under the procedures in Section 7 and 8 of this document and in accordance with the Program.

Section 7

Identify the noise mitigation measures

For receivers that qualify for consideration of additional noise mitigation measures, identify potential noise mitigation measures from the list below. Options for noise mitigation measures are listed below in the order of preference for application given in the RNP:

1. Quieter pavement surfaces
2. Noise mounds
3. Noise walls
4. At-property treatments.

Community views should be considered when evaluating and selecting noise treatments as should the wider community benefits arising from noise mitigation of the proposed road or road redevelopment. Community views may be identified through a range of community engagement activities including visits to individual affected receivers.

For it to be considered reasonable to provide quieter pavement surfaces, noise mounds and noise walls there needs to be four or more closely spaced receivers that benefit. Where there are four or more closely spaced receivers the specific combination of noise mitigation measures is subject to further evaluation.

7.1 Quieter pavement

A quieter pavement surface is the preferred form of noise mitigation as it reduces source noise levels. This provides protection to both outside recreational areas and internal noise levels and also has the least visual impact.

A quieter pavement surface should be considered where there are groups of four or more receivers that exceed the criteria and before the use of noise barriers.

Quieter pavements may provide noise benefits to receivers at greater distances than noise barriers. This may occur where receivers at greater distances already have shielding from rows of houses near the road or topography.

7.2 Noise barriers

Noise mounds and noise walls

A noise mound or noise wall provides similar benefits to those provided by a quieter pavement surface through reducing both external and internal levels of noise.

In terms of visual impact a noise wall has a higher visual impact than a quieter pavement or noise mound under most situations. However, a noise wall is often more feasible than a mound as the site footprint can be much smaller.

Often barriers comprise a mound with a wall on top. Combinations with both mounds and walls may be visually more appealing than a wall alone and also cost less than a wall of equivalent total height. A detailed guideline on how to identify noise barrier height is described in Section 8.

Noise barriers should be considered where there are four or more closely spaced receivers.

Projects with existing noise barriers

The benefit provided by existing noise barriers (walls and mounds) must be taken into account when determining if a residence qualifies for consideration of treatment. Where road widening has expanded over the existing noise barrier footprint then the top of barrier height should be moved to an adjacent and suitable new barrier location as part of the no-build scenario.

If four or more closely spaced residences qualify then noise barrier design identified using Section 8, should be completed assuming that the existing barrier does not exist.

Where residences qualify for consideration of treatment, the aim is to conduct a full barrier design assessment with height ranges between 0 metre and the maximum height and assuming that the existing barrier does not exist. This avoids situations where consideration is only given to incremental benefits from extending the height of the existing barrier.

If the outcome of the assessment is a barrier height greater than the existing barrier then the additional noise reduction provided needs to be evaluated. If the barrier has been relocated due to widening then the higher barrier should be recommended. Otherwise where the additional noise reduction is greater than 2.0dBA then an increase in barrier height is considered to be reasonable as it achieves a noticeable reduction in noise level.

Any replacement or augmented barrier must as a minimum provide the same noise reduction for L_{Aeq} and L_{Amax} noise sources as the existing barrier.

Where higher barriers are identified as feasible and reasonable then supplementing the existing barrier heights should be examined and considered before the removal and replacement of the existing barriers. Issues such as wind loading, suitability of footings and visual aspects are important considerations to the possibility of supplementing existing barriers. Reuse and recycling of existing material is encouraged.

7.3 At-property treatment in place of barriers

At-property noise mitigation measures such as facade treatments and localised screens may replace at-road mitigation, subject to a reasonable and feasible assessment, only in the following circumstances:

- Isolated single residences or isolated groups of closely spaced residences
- Where the affected community expresses a preference for at-property treatment and the cost is less than a combination of a barrier and at-property treatment
- Where noise barriers cannot achieve the level of noise mitigation (insertion loss) required
- Where the only applicable noise criteria are internal (e.g. places of worship, hospitals or schools and child care facilities where play areas meet external criteria)
- Where other noise mitigation measures have been shown not to be feasible or reasonable.

These treatments are generally limited to acoustic treatment of the building elements and the installation of acoustic screen walls close to the receiver where they also protect outdoor living spaces.

The NCG external noise level targets are the design guide for the level of noise reduction by external screen walls.

Building element treatments are more effective when they are applied to masonry structures than lightly clad timber frame structures. Caution should be exercised before providing treatments for buildings in a poor state of repair, as they may be less effective in these cases and may not provide any appreciable noise reduction benefit.

The acoustic treatments provided by Roads and Maritime are limited to:

- The installation of courtyard screen walls
- Fresh air ventilation systems that meet building code of Australia requirements with the windows and doors shut (Note; in certain circumstances air conditioning that includes fresh air intake may also be considered, particularly where adverse climate conditions prevail)
- Upgraded windows and glazing and solid core doors on the exposed facades of substantial structures only (e.g. masonry or insulated weather board cladding with sealed underfloor). These techniques would be unlikely to produce any noticeable benefit for light frame structures with no acoustic insulation in the walls
- Upgrading window and door seals and appropriately treating sub-floor ventilation
- The sealing of wall vents
- The sealing of the underfloor below the bearers
- The sealing of eaves.

Upgraded windows and doors must have a minimum sound reduction index (R_w) of 30 based on the performance of the entire door or window set. Higher performance may be required in some instances and consideration given to traffic spectrum corrections to the sound reduction index.

As at 2014, in most cases \$30,000 is the limit per residence of funding provided by Roads and Maritime for courtyard screen walls and/or building treatments for individual dwellings. This is reviewed annually.

Additional funding may be provided, however, only where exceptional site specific circumstances exist that justify a variation.

Due care must be taken in the design and selection of acoustic treatments for which funding is provided. In particular, gaps around window and door frames must be properly sealed to prevent significant degradation in performance of doors and windows. Accordingly post treatment assessment will be limited to ensuring that the construction meets relevant building standards and industry best practices. It is recommended that inspection of the installation occur before the fitting of architraves or weather strips to ensure adequate sealing. Photographs of the installation before the fitting of architraves or weather strips need to be taken. No post treatment noise monitoring of internal noise levels is done. Financial compensation will not be offered in lieu of undertaking treatments.

7.4 Noise Abatement Program

The Noise Abatement Program implements noise mitigation measures where road noise levels have been identified as being acute and where there are no road projects adjacent to the residence proposed in the short term, that will influence noise levels.

In the absence of a road project, noise mitigation is generally limited to what is feasible within the constraints of the existing road corridor (no additional land acquisition). This generally includes:

1. Noise barriers
2. At-property treatments.

Heights of noise barriers should be identified using Section 8 in the same way as for road projects.

Feasible and reasonable noise barrier construction under the Noise Abatement Program is more constrained than for noise mitigation measures provided during road projects. Additional feasible and reasonable considerations include:

- Local Government planning objectives
- Cost of relocating services already within the existing road corridor such as gas, electricity, communications, water and sewerage.

Section 8

Assessment of barrier height

8.1 Overview

The process in this section is to be used to design noise barriers for receivers that have been identified as qualifying for consideration of noise mitigation under Section 6. The process aims to meet the following policy principles during barrier design:

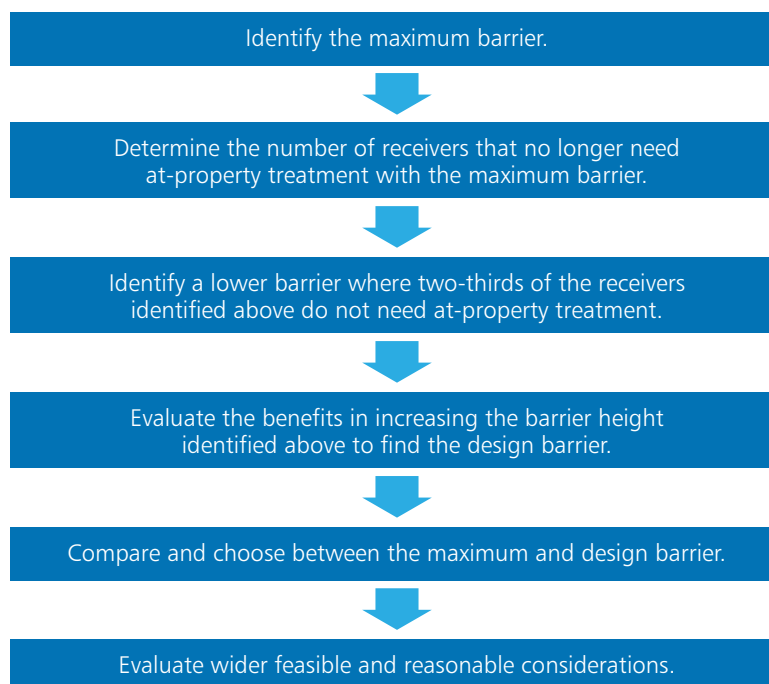
1. Communities should receive reasonable and equitable outcomes
2. Noise mitigation should be designed to reduce noise levels to the criteria
5. Incidental benefits from the noise mitigation designed for qualifying receivers should be recognised at all receivers within a community where noise levels exceed WHO guidelines¹
6. Noise barrier evaluation processes must:
 - a) Give preference to reducing outdoor noise levels and the number of at-property treatments, and
 - b) Provide efficient barrier heights and extents without disregarding lengths of effective noise barrier in front of eligible groups of receivers.
7. Noise mitigation shall be evaluated and installed where feasible and reasonable.

Noise barrier designs can vary in height along the barrier length, subject to urban design and community views. However if a barrier is to vary in height along its length it must be demonstrated that it achieves a better noise outcome for the community than a constant height noise barrier.

Before assessing barrier height the location of the barrier should be reviewed to ensure it provides the best opportunity to use the topography and road geometry to maximise shielding. Consideration should also be given to future road widening and maintenance access. For example, where additional lanes are planned at a future date to accommodate traffic growth then the location of the noise barrier and the size of footings should be made to allow the noise barrier to be added to in the future where this is likely to be more cost effective than replacing the barrier with a new one when additional lanes are added.

Noise barrier siting and design should be consistent with Roads and Maritime's Noise Wall Design Guideline and Specification R271.

Figure 5: Overall barrier design process



8.2 Maximum barrier height

The maximum barrier height is the barrier height that results in noise criteria being met at all receivers. However, other factors need to be considered before a final barrier height can be identified such as, impact on visual amenity, shading of properties, engineering constraints and available resources. Barrier heights above 8 metres will not be considered.

Sometimes it will not be feasible to meet the noise criteria (NCG) with a noise barrier at all receivers because the length of the barrier can not be increased or because of road traffic noise from other roads coming from different directions. In this situation the maximum barrier height is the height that will result in the lowest noise level that can be feasibly achieved, taking account of limitations to barrier length or traffic noise from other roads which are not part of the proposed road project.

No further investigation of barrier height and at-property treatment is necessary where it is considered reasonable to construct a maximum barrier with acceptable visual impact and where community views have been taken into consideration. However, it may be more reasonable to investigate the benefits from a combination of barrier height and at-property treatment. This process is described below.

Note, if the maximum barrier height is assessed as needing to be greater than 8 metres then use a height of 8 metres for the maximum barrier height when evaluating combinations of barrier height and at-property treatment. Analysis must also ensure that the maximum barrier height is not greater than 8 metres due to limitations in barrier length or traffic noise from other roads.

8.3 Combination of noise barrier and at-property treatment

A combination of noise barrier and at-property treatment can provide the most reasonable overall noise reduction for an affected community when consideration is given to cost, urban design, shadowing and engineering constraints with the maximum barrier. The process of deriving the most effective combination of noise barrier height and at-property treatment considers:

- The additional benefit of noise barriers in reducing external noise levels
- Noise reductions that occur to the broader community beyond only those receivers affected by traffic noise above the NCG noise criteria.

The preference for reducing outdoor noise levels is achieved by the relative point weighting given to barriers compared to at-property treatments. Benefits to the broader community are accounted for by including any residences that receive noise reductions of more than 2dBA (benefiting residence) from the presence of the noise barrier.

The process starts by incrementally reducing the height or area of the maximum barrier and identifying how this influences noise levels across the community behind the barrier as a whole.

To account for incidental benefits to the broader community noise reductions are counted at all benefiting residences until the noise levels are reduced to the lower of 50dBA daytime and 45dBA night time.¹ Exceptions to these lower limits are where:

- It can be demonstrated that noise levels from other traffic sources that are not being assessed as part of the road project are greater than 50dBA daytime or 45dBA night time.¹ Under this situation the noise level from other traffic sources becomes the lower limit where benefits are assessed
- The relative increase criteria from the NCG is more stringent. Under this situation the relative increase criteria becomes the lower limit for where benefits are assessed.

8.4 How to identify the design barrier height

The design barrier is the barrier height that is used in combination with at-property treatment to give the most reasonable noise benefits. An initial design barrier height is identified as the height at which two thirds of affected receivers that could meet the criteria with the maximum barrier no longer need at-property treatment. This sets the initial design barrier height.

A value of two thirds has been chosen as further increases in barrier height typically have diminishing benefits per increase in height increment. This is investigated further in the next step for the remaining one third of receivers. Weightings are then applied which consider cost and the benefits the barrier provides to the wider community. A low point in the weighting curve between the maximum barrier and in the initial design barrier height corresponds to the most reasonable barrier height.

The steps to identify the design barrier height are:

1. Identify and plot the number of receivers that would receive at-property treatment for each height increment (usually 0.5 metre or 0.6 metre) of noise barrier. Start at the maximum barrier height and reduce to 0 metre (Figure 1). Note that the average height may be used if the barrier height is not constant and that a two storey residence would be counted as two receivers.
2. Identify the number of receivers that would still require at-property treatment with the maximum barrier height and subtract this from the number of receivers that would need at-property treatment without a barrier. This identifies the maximum number of additional receivers that qualify for consideration of noise mitigation that could meet noise criteria using only a noise barrier.
 - 2.1. Of this maximum number of additional receivers identify the barrier height where two thirds could meet the noise criteria without at-property treatments. Subject to further feasible and reasonable considerations this is the minimum design barrier height.

3. Calculate the total points² at each barrier height from the barrier area (height times length), number of at-property treatments and exceedences of 50dBA day or 45dBA night. Only include the benefiting receivers behind the barrier. The points are:

- 1 point per square metre of wall or vertical cross section for mounds (outdoor noise reduction)
- 40 points for each at-property treatment where criteria are exceeded by less than 10dBA (internal noise reduction only)
- 120 points for each at-property treatment where criteria are exceeded by greater than or equal to 10dBA (internal noise reduction only)
- 4 points per dBA exceedance of 50dBA¹ day or 45dBA¹ night at each residence behind the barrier (note that where the barrier does not provide at least 2dBA of noise reduction then the number of points is the same as without the barrier).

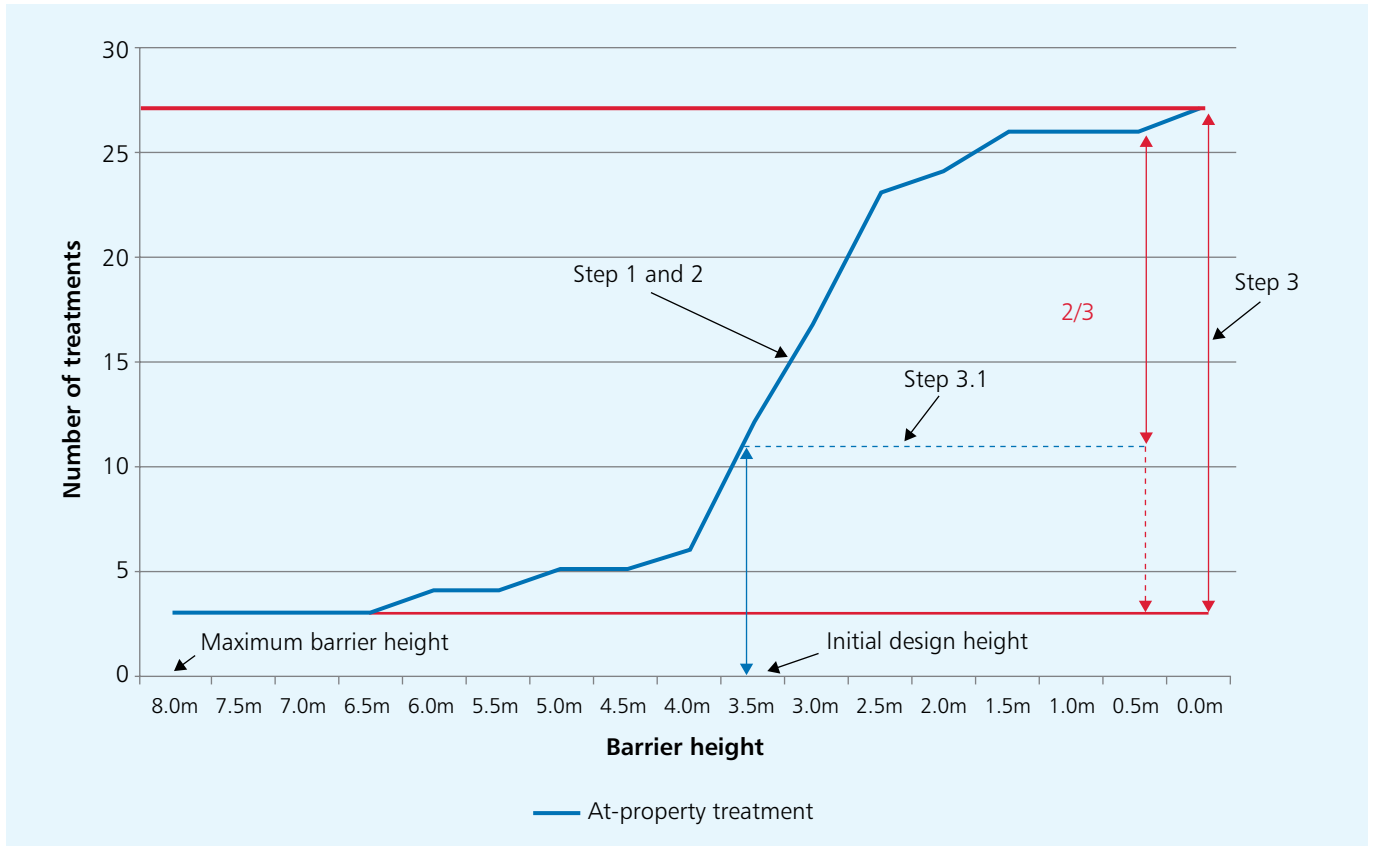
4. Plot the total number of points for each barrier height (Figure 2) increment. Note instead of height the average barrier height or total increment in height relative to the maximum barrier may be used.
5. Dips in the points curve highlight designs with potentially higher overall community benefit and reduced weighted cost. Identify the barrier height with the lowest total points between the maximum barrier height and the initial design barrier height from 2 above. Subject to further feasible and reasonable considerations this is the design barrier height (Figure 2).

Examples of these steps are shown in Figures 1 and 2 using total height for a barrier with constant height along its length. Detailed examples including calculation and plotting of points may be found in Appendix B.

Note 1: Facade noise levels of 50dBA day and 45dBA night are considered representative of the World Health Organisation (WHO) Guidelines for Community Noise (1999) for outdoor areas and the WHO Night Noise Guidelines for Europe (2009) threshold levels.

Note 2: Points are calculated at the first two floors of a receiver only. The calculation point is fixed throughout the entire assessment at the worst affected façade of each floor when the barrier is zero metres in height.

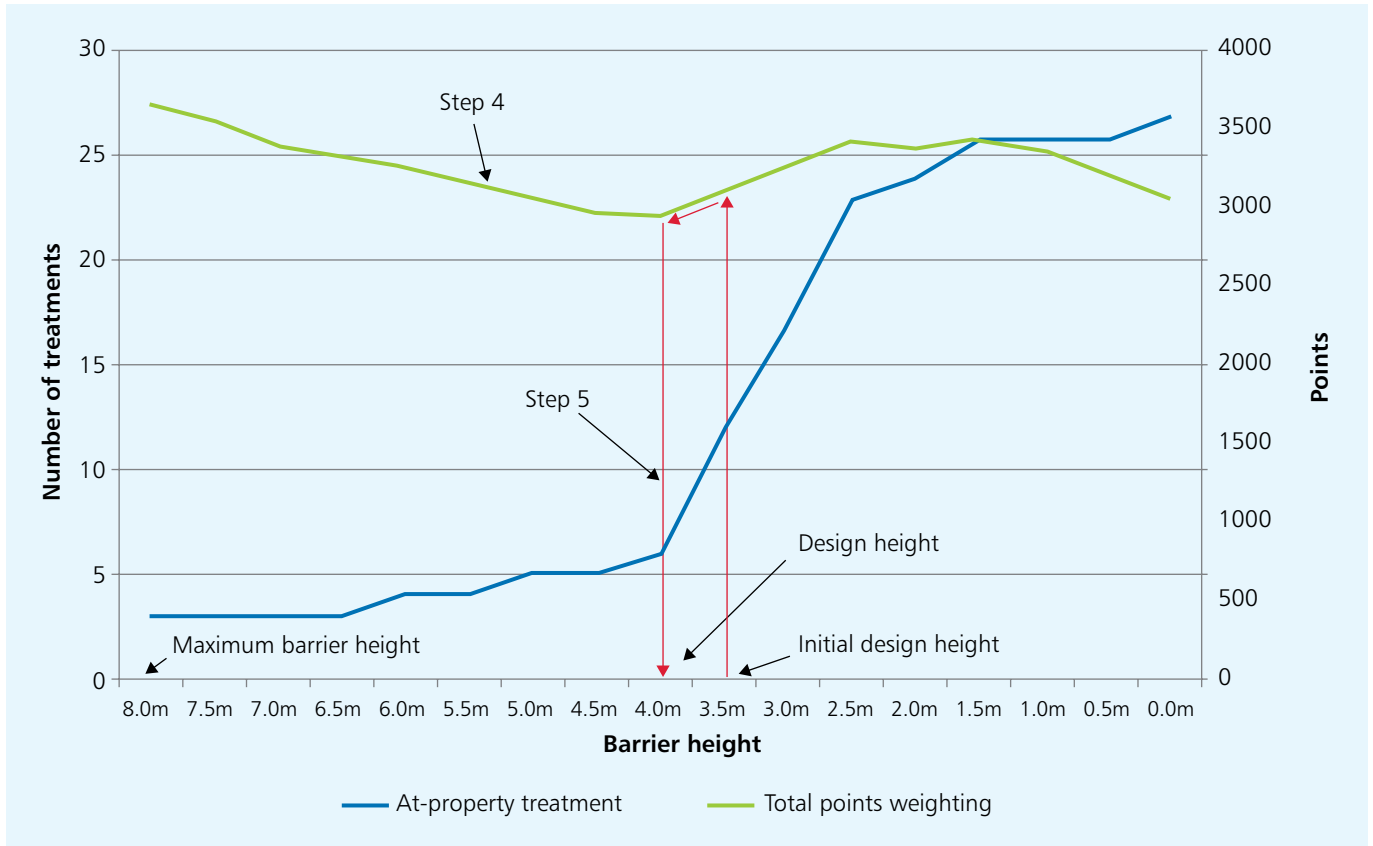
Figure 1: Initial design barrier height



Step 3: There are 27 receivers that qualify for consideration of noise mitigation for a wall height of 0 metres. 27 minus the 3 receivers remaining at the maximum barrier height gives a total of 24 additional receivers that could potentially meet the noise criteria with the maximum barrier height of 8.0 metres.

Step 3.1: Two thirds of 24 is 16. 27 minus 16 leaves 11 receivers. The wall height where 11 receivers still require at-property treatment is 3.5 metres. The initial design barrier has a height of 3.5 metres.

Figure 2: Design barrier height from points weighting curve



Step 5: The initial design barrier height is 3.5 metres. There is a low point at 4.0 metres in the total weighting curve between the initial design height and the maximum barrier height. The design barrier height is 4.0 metres.

8.5 Notes on optimisation

Advanced optimisation processes including the use of software may be helpful when designing barriers with varying height along their length and reduce the need for breaking the corridor up into arbitrary adjacent noise catchments. This may produce a number of different design options that may be plotted against average height and the number of points.

Before recommending noise barriers that vary in height in front of a group of receivers, or between groups of receivers, consultation will be required with urban design and the wider project team.

Note however that care should be taken to avoid situations where the software provides less than ideal outcomes at some receivers. An example would be where a low density area of housing lies between two high density areas of housing. It is possible that an optimisation process may give a barrier height of 0 metres to the low density area and assign all barrier material to the high density areas. This may not align with the barrier height assigned if the low density area was assessed separately. Thus barrier optimisations that result in parts of a barrier being assigned a height of 0 metres must be rejected and a closer analysis completed.

8.6 Selecting the design barrier or maximum barrier design

If the maximum barrier design has a height of less than 8 metres apply the following process to identify the preferred barrier height.

Where the difference in life cycle cost is not significant (i.e. cost for the maximum barrier is within 125 percent of the design barrier cost) the maximum barrier design is preferred if it gives a noise reduction of at least 2.0dBA above the design barrier. Otherwise the design barrier is to be preferred.

Life cycle costs should as a minimum consider:

- Combinations of a noise wall and mound or mounds instead of noise walls
- Cost effective use of excess or additionally won project fill and temporary stockpiles
- Maintenance
- Provision for height augmentation if future road upgrades are considered likely
- Provide a detailed break down of the costs.

8.7 Consideration of community views

Sometimes an outcome of community consultation is that the community deems the preferred noise barrier height to be too high. In deciding the height of the noise barrier consideration should be given to:

- Community views and wishes. These are typically gathered at a number of stages including route selection, following concept design, the period of community consultation following the noise assessment and post opening in the operational noise report
- Visual impacts for the community surrounding the road project and for road users. These are typically identified in the Environmental Impact Assessment.

When considering community views reference should be made to the Roads and Maritime's Stakeholder Engagement Manual which details Roads and Maritime's policies on effective communication and engagement and provides guidance on how this can be achieved.

8.8 Barrier design aesthetic impacts

It is important that noise barrier design recognises the character of the road corridor, its environment and the views to and from the road. These issues are addressed in Roads and Maritime's Noise Wall Design Guideline 2006.

Some care needs to be exercised in the process of barrier design in respect of added costs. In particular aesthetic requirements from the noise affected community, such as requests for transparent barriers should be separated from aesthetic requirements applied by Roads and Maritime to improve the experience of road users. This is to allow the cost of noise mitigation measures assigned to the community impacted by road traffic to be identified separately from the cost of aesthetics for road users. Both of these things are important aspects of providing noise barriers, however in terms of identifying the cost of noise mitigation only the aesthetic requirements that derive from the noise affected community are to be included. If this is not done there is a risk that the cost of noise barriers may be increased to improve aesthetics for road users to an extent that they are not economic.

Local councils and projects may also have planning guidelines relating to visual amenity and urban design.

8.9 Consider further if the barrier is feasible and reasonable

Noise barrier benefit

As a guide noise walls or mounds are considered to be a reasonable noise mitigation option where they are capable of providing an insertion loss of:

- 5dBA at representative receivers for heights up to 5 metres high
- 10dBA at representative receivers for heights above 5 metres and up to 8 metres high.

Where a location exceeds the noise criteria by less than 5dBA this can lead to designing to achieve an insertion loss of less than 5dBA. Under these circumstances where two thirds of the residences no longer require at-property treatment a noise barrier would not be abandoned because it did not provide 5dBA insertion loss.

Where noise barriers greater than 5 metres do not provide 10dBA of noise reduction additional consideration needs to be given to the number of receivers that benefit, any unusual topography and whether the barrier placement could be improved. If it is not reasonable to provide a barrier with height above 5 metres then lower heights should be considered.

These insertion loss requirements are applicable to noise reduction provided by the full barrier height and should not be used to discount incremental changes in height to existing noise barriers.

Additional feasible and reasonable considerations for barriers

Consideration also needs to be given to engineering considerations (what can be practically built) about noise walls and mounds. These engineering considerations may include:

- Safety issues such as restrictions on road vision
- Road corridor site constraints such as space limitations
- Floodway and stormwater flow obstruction
- Access requirements for maintenance
- Maintenance requirements including ongoing costs
- Wind loading and ground conditions
- Shadowing
- Driveway access from residences to the noisy road.

Where issues of feasibility are identified that would prevent installation of a noise mitigation measure that had been identified for consideration, it is important to provide a well supported and objective case to support the feasibility issues cited.

Expert opinion in each particular area is helpful and for contentious locations the views of an independent expert are highly recommended. Quantitative information such as wind loading calculations, diagrams of site access, soil conditions, etc are needed to provide an objective basis.

If there is insufficient detail available at this point to present a quantified and definitive case then the issues and extent of information known should be presented together with a clear commitment to provide the missing information once the detailed design of the project is known.

It should also be clearly stated that it will only be at that stage (i.e. post detailed design) that a decision on what noise mitigation measures can be applied can be made.

The consideration of what is reasonable typically means looking at cost and equity considerations. There is no set monetary limit for noise mitigation provided for a road project however, there are some guiding principles to gauge whether costs are reasonable and equitable and the following points should be considered:

- Cost of mitigation measure
- Total cost of noise mitigation for the project
- Cost of mitigation measure and total cost of noise mitigation measures as percentages of total project cost
- Whether comparable noise mitigation measures have been provided at other locations in the project or for other similar projects and surrounding network.

Use this and other salient information that may be available to guide considerations as to whether the mitigation measure is reasonable or not.

Where feasible and reasonable considerations rule out the design barrier height then an alternative barrier height should be considered. The underlying principle in this document is to give preference to at-road noise mitigation measures over at-property measures. Except where isolated groups of dwellings occur in close groupings of three or less there is no provision to select at-property noise mitigation measures over at-road noise mitigation measures based solely on cost.

Appendix A:

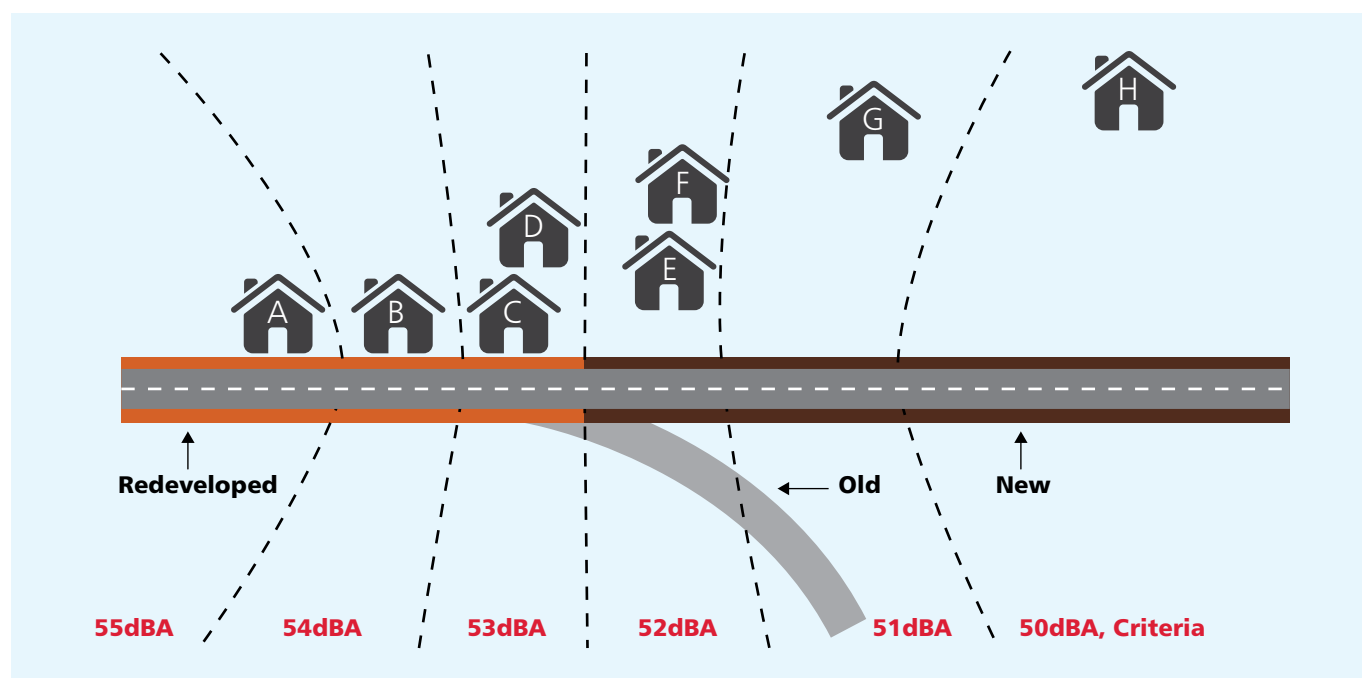
Example of cumulative limit in a transition zone

The cumulative limit provides a process that limits total noise level after applying a reasonable process to less than 5dBA above the criteria. Without the cumulative limit receivers with high existing noise levels and small noise increases may not qualify for consideration of noise mitigation unless they are acute which may be up to 10dBA above criteria.

The example below for a transition zone at night time shows how the cumulative limit is applied so that receivers either meet criteria or are less than 5dBA above criteria (NCG) following consideration of feasible and reasonable mitigation. Comparison is also made to outcomes at each receiver without the cumulative limit.

The cumulative limit realises the intention of a transition zone in providing a smooth change in criteria and corresponding noise levels between different road categories where transition zones are close to existing roads with high noise levels. The cumulative limit also meets the intention of the RNP more closely where no allowance is given for high existing noise levels when setting criteria.

Figure A1: Example transition zone



Example noise levels and outcomes are shown below and discussed in the following text.

Table A1: Night time noise levels with and without the cumulative limit (CL)

Receiver	A	B	C	D	E	F	G	H
Criteria Type	Redeveloped		Transition zone				New	
Criteria	55	54	53	53	52	52	51	50
Noise Level, $L_{Aeq,9hr}$ dBA								
Existing	63	62	60	59	58	57	55	52
Build	63.1	62.2	60.2	59.4	58.8	58	56.2	54.2
Increase	0.1	0.2	0.2	0.4	0.8	1	1.2	2.2
Build without CL and with mitigation	55	54	53	59.4	58.8	58	56.2	50
Exceedance without CL and with mitigation	0	0	0	6.4	6.8	6.0	5.2	0
Build with CL and with mitigation	55	54	53	53	52	52	51	50
Exceedance with CL and with mitigation	0	0	0	0	0	0	0	0

Without the cumulative limit receivers A, B and C are acute and are mitigated down to the criteria. Receivers D, E, F, and G exceed the criteria (new road and transition zone) by up to 7dBA but since the noise levels do not increase by more than 2dBA they are not mitigated. Receiver H which is the greatest distance from the existing road and with the lowest existing noise level receives mitigation as the noise level increase was greater than 2dBA. The resulting build noise levels are greatest in the transition zone at a number of adjacent houses where the criteria are exceeded.

Using the cumulative limit receivers A to H are mitigated down to the criteria. The outcome meets the intention of transition zones in the RNP by providing a smooth change in noise levels between adjacent receivers.

Appendix B1:

Example of barrier design

Example 1

The following example shows the steps to identify the design barrier height for five receivers behind a 100 metres long noise wall. Receiver D has a ground floor and also a second storey. The night time criterion is 55dBA. The Maximum barrier height is taken to be 8 metres as noise levels are still exceeded at 8 metres.

Step 1: Example 1

The noise levels are presented below. Noise levels highlighted in orange require double glazing and receivers in green exceed the criteria by less than 10dBA.

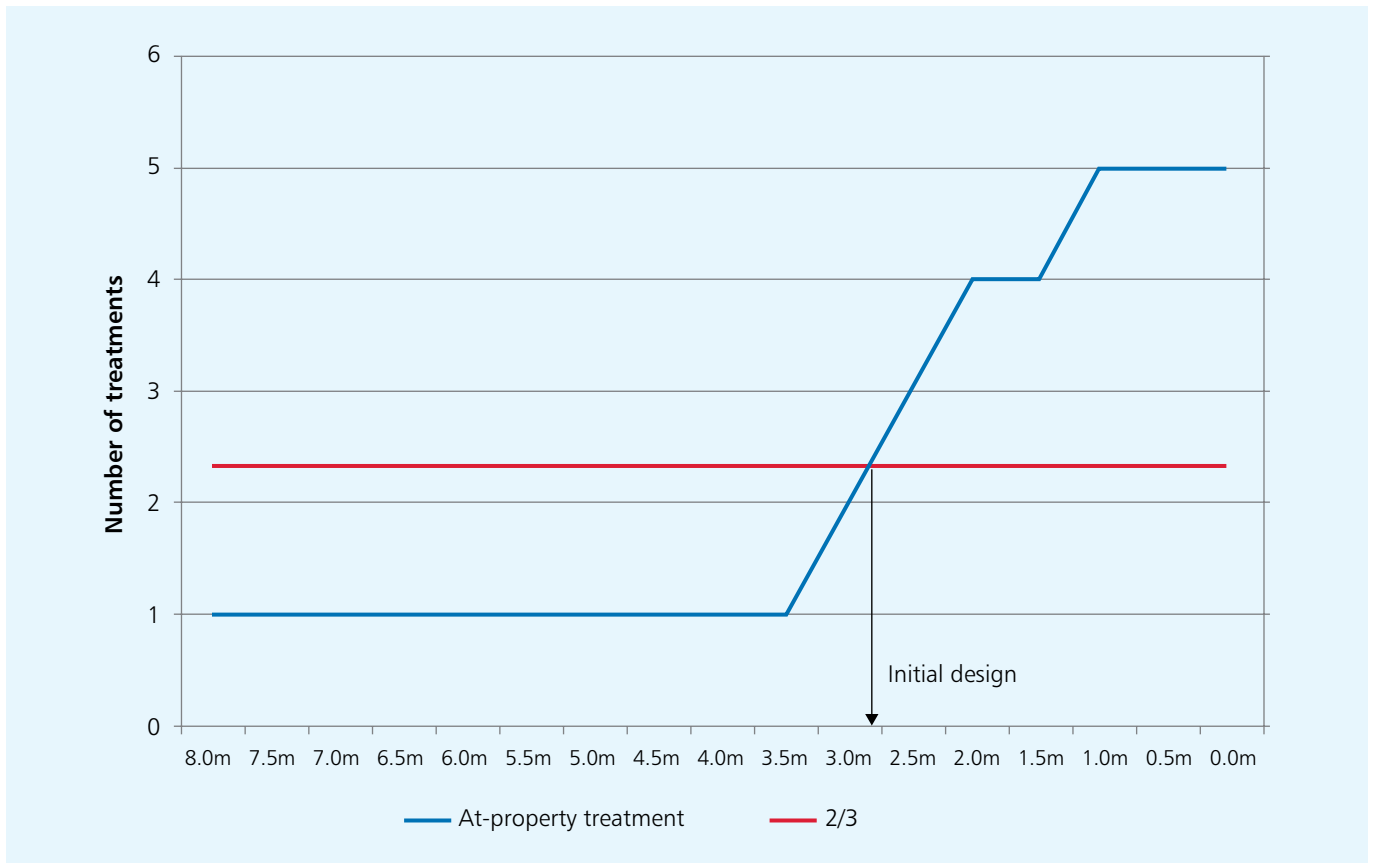
Table B1: Noise levels and number of at-residence treatments

Receiver	Wall height																	
	8.0m	7.5m	7.0m	6.5m	6.0m	5.5m	5.0m	4.5m	4.0m	3.5m	3.0m	2.5m	2.0m	1.5m	1.0m	0.5m	0.0m	
A	49	50	52	52	53	54	54.1	54.2	54.4	54.6	54.9	55.5	55.6	55.9	56.2	58	59	
B	57	58	59	60	61	62.9	63	63.2	63.4	63.8	65	65.2	65.3	65.6	66.1	66.6	68	
C	45	47	48	49	50	50.9	51.1	51.4	51.8	52.2	52.7	53.3	54	54.8	55.6	57	58	
D Ground	50	50	51	52	52	53.3	53.5	53.7	54	54.2	54.6	54.8	55.5	56.2	57	58.2	59.5	
D 2nd Storey	48	49	50	52	53	54	54.2	54.4	54.6	54.7	55.5	56	56.7	57.4	58.1	58.8	59.4	
E	40	41	42	44	44	45.3	45.5	45.7	46	46.2	46.6	46.9	47.2	47.5	47.8	48	48.1	
At-residences treatments																		
More than 10dBA above criteria (double glazing required)	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Exceed criteria by less than 10dBA (sealing of windows and vents etc)	1	1	1	1	1	1	1	1	1	1	1	1	2	3	3	4	4	4
Total At Resident Treatments	1	1	1	1	1	1	1	1	1	1	1	2	3	4	4	5	5	5

Step 2 and 3: Example 1

The figure below shows the number of at-property at each wall height and the wall height where two-thirds of receivers no longer need at-property treatment. The initial barrier design height is 3 metres.

Figure B1: Number of at-property treatments



Step 4: Example 1

The weightings at each wall height need to be calculated. First of all this requires the calculation of how much the noise levels exceed 45dBA night at each of the residences. This is shown in Table B2.

The exceedences in the cells highlighted in orange are within 2dBA of the exceedences with a wall height of 0 metre. Therefore the wall is not providing a significant benefit at receivers that exceed 45dBA night.

Table B2: Exceedance of 45dBA night

Receiver	Wall height																
	8.0m	7.5m	7.0m	6.5m	6.0m	5.5m	5.0m	4.5m	4.0m	3.5m	3.0m	2.5m	2.0m	1.5m	1.0m	0.5m	0.0m
A	4.0	5.0	7.0	7.0	8.0	9.0	9.1	9.2	9.4	9.6	9.9	10.5	10.6	10.9	11.2	13.0	14.0
B	12.0	13.0	14.0	15.0	16.0	17.9	18.0	18.2	18.4	18.8	20.0	20.2	20.3	20.6	21.1	21.6	23.0
C	0.0	2.0	3.0	4.0	5.0	5.9	6.1	6.4	6.8	7.2	7.7	8.3	9.0	9.8	10.6	12.0	13.0
D Ground	5.0	5.0	6.0	7.0	7.0	8.3	8.5	8.7	9.0	9.2	9.6	9.8	10.5	11.2	12.0	13.2	14.5
D 2nd Storey	3.0	4.0	5.0	7.0	8.0	9.0	9.2	9.4	9.6	9.7	10.5	11.0	11.7	12.4	13.1	13.8	14.4
E	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.7	1.0	1.2	1.6	1.9	2.2	2.5	2.8	3.0	3.1

The total weightings at each height are then obtained by multiplying results in Table B1 and B2 by the following factors in Table B3.

Table B3: Weighting

Weighting points	
1	per m ² of barrier
40	per receiver with exceedance NCG criterion less than 10dBA
120	per receiver with exceedance of NCG criterion greater than or equal to 10dBA
4 ¹	per dBA exceedance of 50dBA day or 45dBA at each receiver

Note 1: Where the barrier does not provide at least 2dBA of noise reduction then the number of points is the same as without the barrier at height 0.0 metre.

Step 4 continued: Example 1

Table B4 below summarises the points for the wall and each receiver by multiplying the data in Tables B1 and B2 by the points in B3. The points at each receiver include the points for the barrier, at-property treatment and also for exceedance of 45dBA night. Note that the points for the cells in orange use the 45dBA night exceedance for a wall height of 0.0 metre in Table B2. This is because the wall does not provide a significant benefit of 2dBA or more at the heights with orange cells.

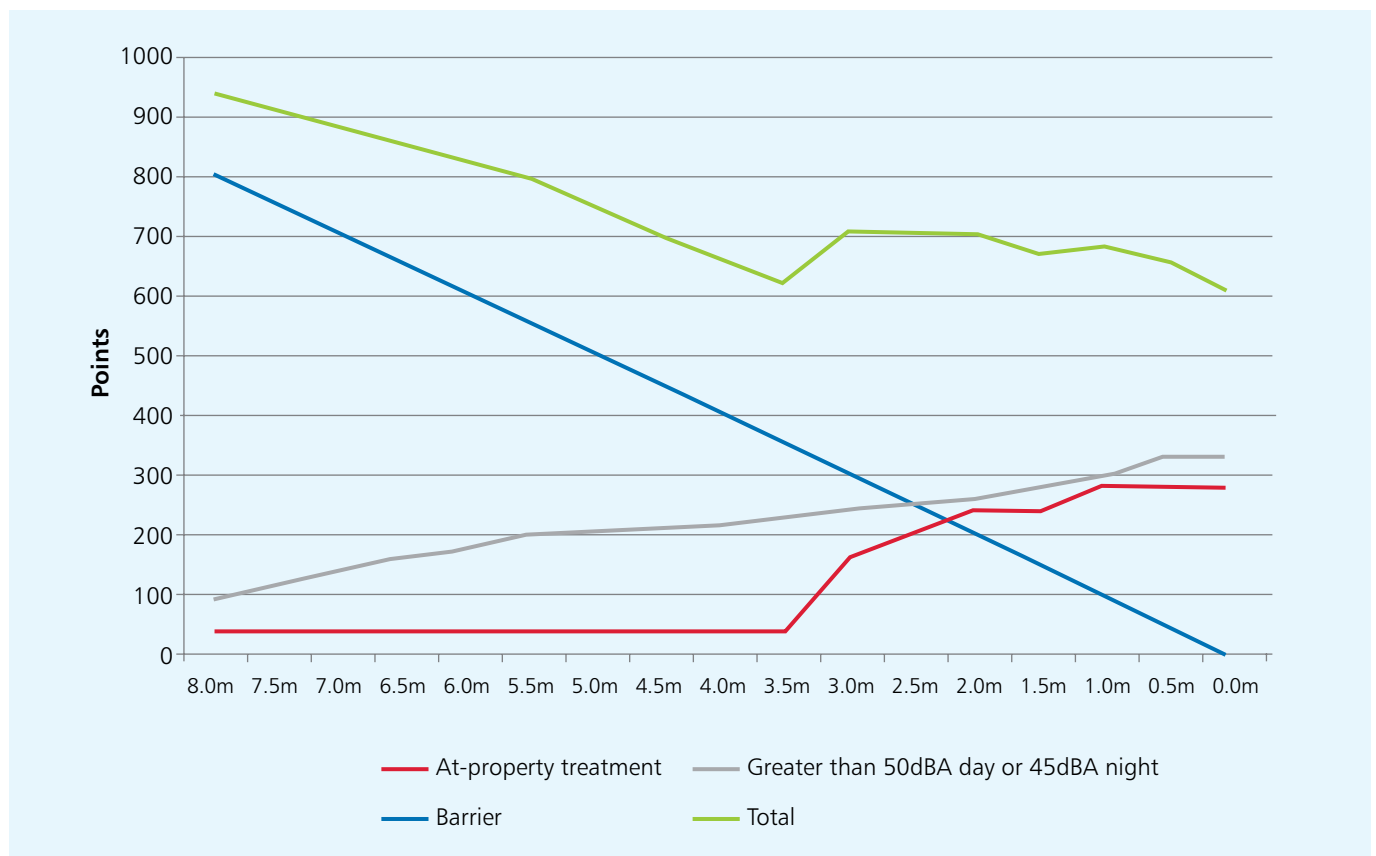
Table B4 – Weighted points

Item/Receiver	Points																
	8.0m	7.5m	7.0m	6.5m	6.0m	5.5m	5.0m	4.5m	4.0m	3.5m	3.0m	2.5m	2.0m	1.5m	1.0m	0.5m	0.0m
Wall	800	750	700	650	600	550	500	450	400	350	300	250	200	150	100	50	0
A	16	20	28	28	32	36	36	37	38	38	40	82	82	84	85	96	96
B	88	92	96	100	104	112	112	113	114	115	200	201	201	202	212	212	212
C	0	8	12	16	20	24	24	26	27	29	31	33	36	39	82	92	92
D Ground	20	20	24	28	28	33	34	35	36	37	38	39	82	85	88	98	98
D 2nd Storey	12	16	20	28	32	36	37	38	38	39	82	84	87	98	98	98	98
E	0	0	0	0	0	1	2	3	4	12	12	12	12	12	12	12	12
Total Points	936	906	880	850	816	792	746	700	657	620	703	702	701	670	677	658	608

Step 5: Example 1

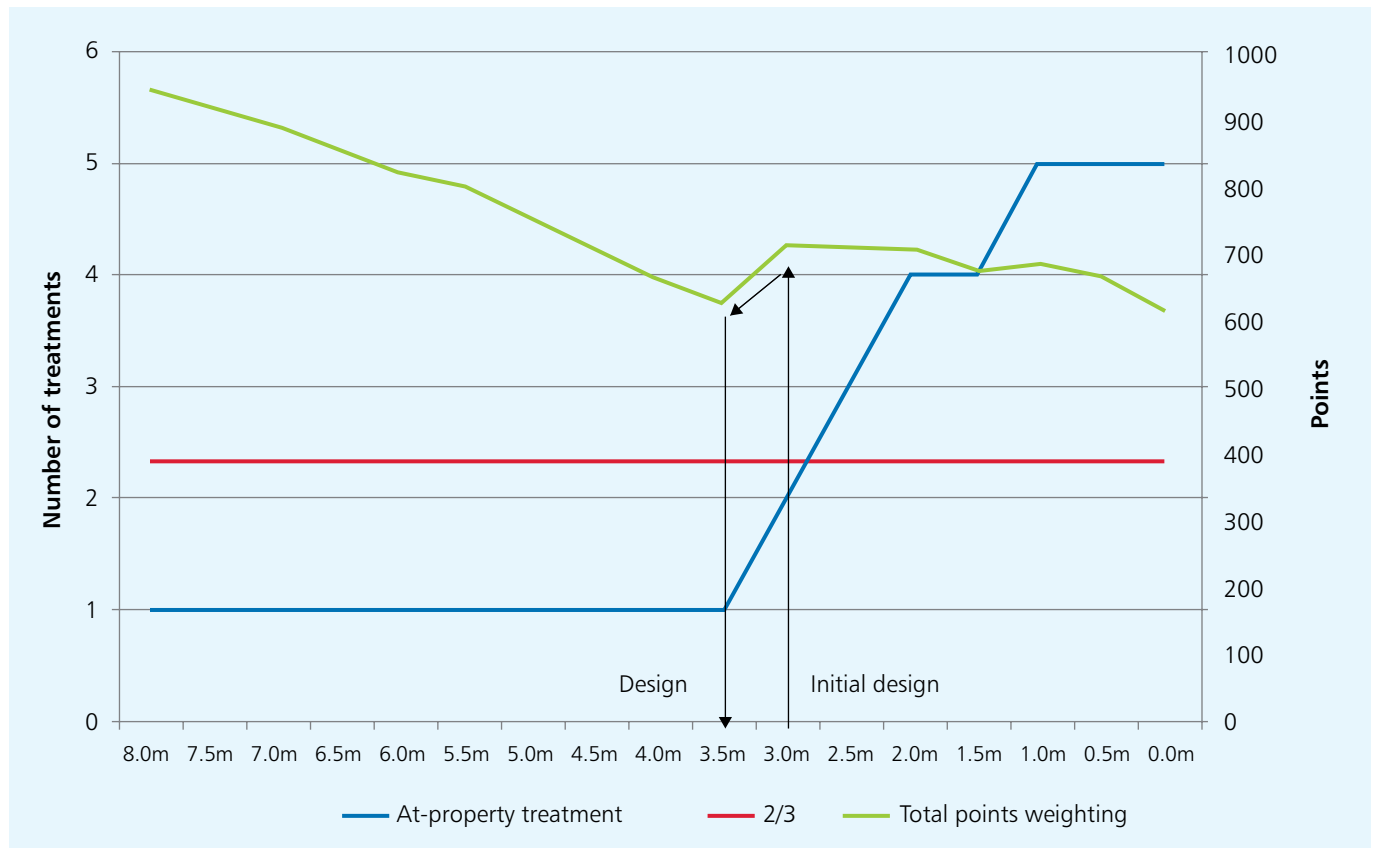
The figure below shows how the points for the property treatments and exceedences of 50dBA day or 45dBA night increase as the wall height reduces from 8 metres to 0 metre. In contrast the points for the wall decrease as the wall height reduces. The conflicting trends combine to give a low value in the Total Points curve at 3.5 metres.

Figure B2: Number of at-property treatments and total weighting curve



There is a minimum in the total points weighting curve between the initial design barrier height of 3.0 metres and the maximum barrier height of 8.0 metres. The minimum occurs at a wall height of 3.5 metres. The design barrier height is 3.5 metres.

Figure B3: Number of at-property treatments and total weighting curve



Appendix B2:

Example of barrier design with longer wall and reduced urban density

Example 2

Step 4: Example 2

This example is similar to Example 1, except that the barrier is 300 metres long rather than 100 metres. Table B4 has been updated below for a longer barrier length. Note that the weighted points for the cells in orange use the 45dBA night exceedance for a wall height of 0.0 metre in Table B2. This is because the wall does not provide a greater than 2dBA benefit at these heights.

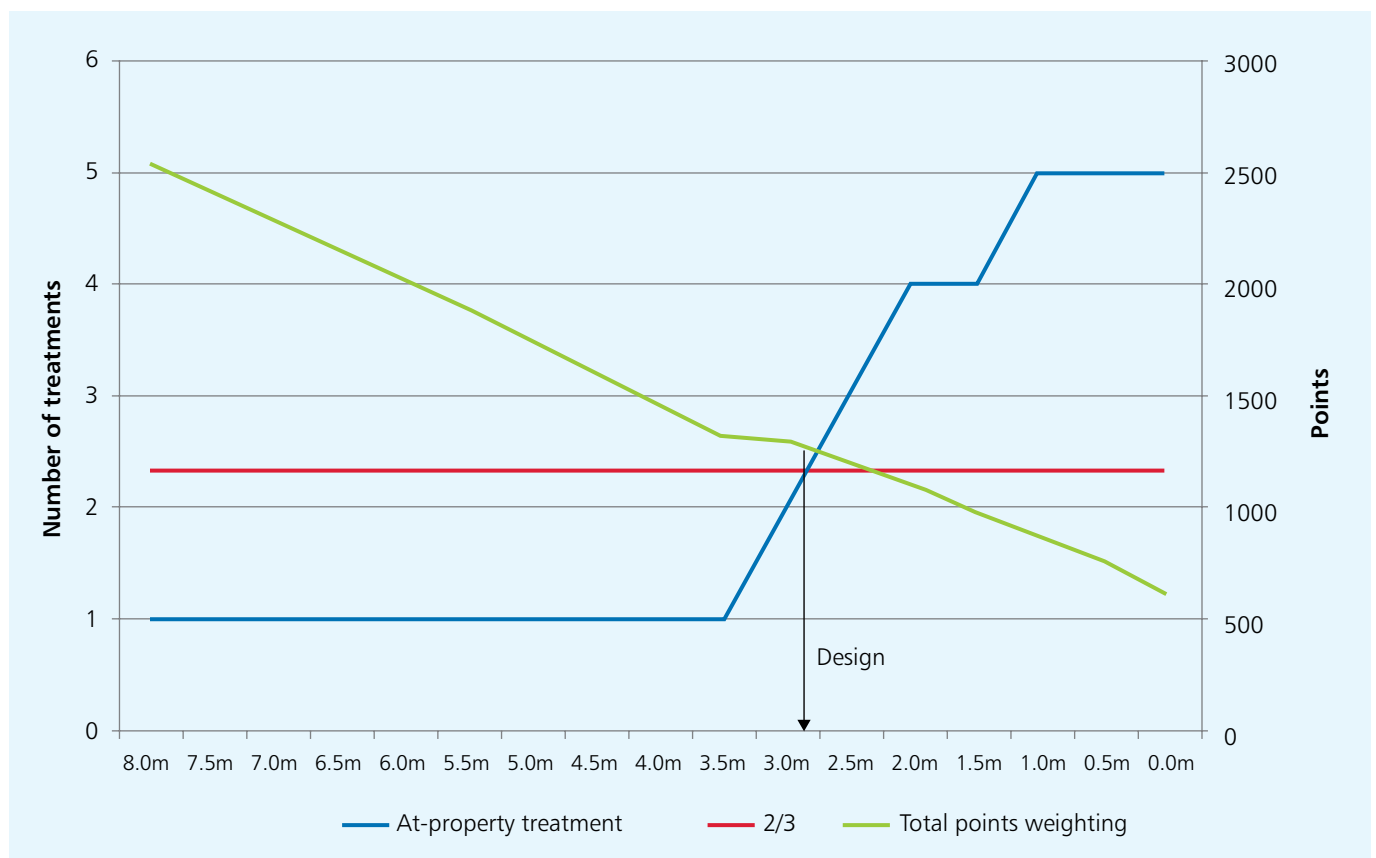
Table B5: Weighted points

Item/Receiver	Points																
	8.0m	7.5m	7.0m	6.5m	6.0m	5.5m	5.0m	4.5m	4.0m	3.5m	3.0m	2.5m	2.0m	1.5m	1.0m	0.5m	0.0m
Wall	2400	2250	2100	1950	1800	1650	1500	1350	1200	1050	900	750	600	450	300	150	0
A	16	20	28	28	32	36	36	37	38	38	40	82	82	84	85	96	96
B	88	92	96	100	104	112	112	113	114	115	200	201	201	202	212	212	212
C	0	8	12	16	20	24	24	26	27	29	31	33	36	39	82	92	92
D Ground	20	20	24	28	28	33	34	35	36	37	38	39	82	85	88	98	98
D 2nd Storey	12	16	20	28	32	36	37	38	38	39	82	84	87	98	98	98	98
E	0	0	0	0	0	1	2	3	4	12	12	12	12	12	12	12	12
Total Points	2536	2406	2280	2150	2016	1892	1746	1600	1457	1320	1303	1202	1101	970	877	758	608

Step 5: Example 2

There is no minimum in the total points weighting between the initial design barrier height of 3.0 metres and the maximum barrier height of 8.0 metres. The initial design barrier height of 3.0 metres is the design barrier height. This is because compared with Example 1 there are less receivers that benefit per metre length of wall.

Figure B4: Number of at-property treatments and total weighting curve





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