Good Practice Guidance for the Treatment of Noise during the Planning of National Road Schemes

March 2014

NRA
An tÚdarás um Bóithre Náisiúnta
National Roads Authority
Environment

ACKNOWLEDGEMENTS

To support the Environmental Integration Model (EIM), the National Roads Authority are undertaking post EIA evaluation research studies to monitor the actual impacts of national road scheme developments on the environment. Post EIA research evaluation entails the collection, structuring, analysis and assessment of information covering the impacts of road scheme projects that have been subject to environmental impact assessments (EIA). The results from these studies will assist in:

- facilitating better feasibility analysis of sites and projects,
- scoping EISs and supporting the prediction methodologies used in EISs,
- informing future environmental policy and best practice guidelines in relation to road infrastructure,
- building databases of actual impacts of road schemes on different ecosystems and revision of prediction methodologies, and
- assessing the effectiveness of mitigation measures at reducing significant adverse environmental impacts.

In a series of environmental research studies, the NRA are focusing on a range of individual issues that will initially target EIA assessments which will then lead to assessment of the performance of various mitigation measures used on the national road network.

In developing national road schemes, considerable efforts are made during the planning and construction stages to ensure that significant impacts on noise sensitive locations are avoided or significantly reduced. In order to assess the appropriateness of the methodologies adopted during the preparation of noise quality chapters for EISs of national road schemes, the NRA has prepared the following report outlining the findings of a two year research programme addressing post EIA evaluation noise studies and noise mitigation measures. In addition to this work, a research study was also commissioned by the Authority looking at the design of noise barriers with a view to developing an in-situ testing method for assessing the effectiveness of noise barriers on the Irish road network.

This post EIA evaluation work was undertaken by Atkins and the design of noise barrier work was undertaken by Dr. John Mahon of Trinity College Dublin on behalf of the National Roads Authority.

DISCLAIMER

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Preamble

The NRA commissioned Atkins Ireland to undertake a study of Environmental Impact Statements of national road schemes four years after the publication of the *Guidelines for the Treatment of Noise and Vibration in National Road Schemes, as revised in October 2004.* The study has also looked at Constraints Studies, Route Selection Studies, present practice in other countries both in Europe and beyond, and recently published revisions to the UK DMRB which contains advice on noise prediction.

The purpose of the review was to evaluate the effectiveness of the *Guidelines*, including the effectiveness of noise mitigation measures, in achieving the NRA's noise design goal as set out in the *Guidelines*. A further aim of the review was to identify good practice and potential deficiencies in current practice, and to provide advice on the practice to be adopted in the planning of national road development proposals.

In addition to the work undertaken by Atkins Ireland, the NRA commissioned a noise research study with Trinity College Dublin looking at the design of noise barriers and the development of a quick look method for assessing the effectiveness of noise barriers in-situ.

The present Good Practice Guide is based on the lessons learned from these two studies. It provides advice for the information and use by acousticians, which also has some relevance for traffic, motorway and pavement engineers. The advice amplifies and supplements the *Guidelines*, and should be read in conjunction with them.

The NRA *Guidelines* and the further guidance on good practice offered here constitute guidance in general. They do not constitute universal requirements which must be followed precisely on every scheme. The guidance is offered to encourage and facilitate good practice. It is not offered as a replacement for considered professional judgement in the context of each individual scheme. Each section of the guidance ends with a checklist. Ticking all the boxes is not the aim. The checklist is there to help the acoustician to make a positive contribution to the generation of noise-sensitive road schemes.

1. Introduction

1.1 The NRA's *Guidelines for the Treatment of Noise and Vibration in National Road Schemes*, as revised by the National Roads Authority in October 2004[1], are based on the Authority's phased approach to road scheme planning and development. They cover the Constraints, Route Corridor Selection and Environmental Impact Assessment stages.

1.2 The *Guidelines* also set out a "design goal" for noise to ensure that the current roads programme proceeds on a path of sustainable development.

1.3 The current design goal is that all national road schemes should be designed, where feasible, to meet a day-evening-night sound level of 60 dB L_{den} (free-field residential façade criterion), to be met both in the year of opening and in the design year.

1.4 The Authority accepts that it may not always be sustainable to provide adequate mitigation in order to achieve the design goal. Therefore, a structured approach should be taken in order to ameliorate, as far as is practicable within the particular circumstances of a given scheme, road traffic noise through the consideration of measures such as horizontal and vertical alignment, barriers, low noise road surfaces, etc.

1.5 This Good Practice Guidance is intended to expand and supplement the advice already provided in the *Guidelines* on these matters.

2. The Phased Approach to Acoustic Design

Introduction

2.1 The *National Roads Project Management Guidelines (2000)*[2] (NRPMG) allow a phased approach to be applied to developing a major road scheme, and the NRA's *Guidelines for the Treatment of Noise and Vibration in National Road Schemes* are based on this approach. The noise and vibration input into each of these phases should not be treated in isolation, but the findings arising out of each phase should provide the foundation for the next activity and collectively should assist in the final design of the scheme. The noise and vibration input into the Constraints Study and Route Corridor Selection should concentrate on the avoidance of impacts and the EIS should describe further steps to avoid impacts and to consider further mitigation of noise and vibration as necessary.

2.2 This *Good Practice Guidance* is intended to assist road design teams to ensure that noise and vibration is considered in appropriate detail in each phase, including the early stages where potential impacts can often be minimised in the most sustainable manner.

Constraints Study Phase

2.3 The specific objective of the noise input to the Constraints Study is to identify any receptors that may be deemed to be particularly sensitive to noise and/or vibration. The *Guidelines* list examples as including schools, hospitals, places of worship, heritage buildings, special habitats, amenity areas in common use and designated quiet areas. However, residential properties must not be overlooked, and it may be noted that some commercial or industrial uses can also be noise sensitive, for example, recording studios and research or manufacturing facilities using noise or vibration-sensitive equipment.

2.4 A desk-based study based on mapping or aerial/satellite photography will be an essential starting point. It is suggested that maps at a 1:50 000 scale is the minimum for good practice and a scale of 1:25 000 or larger is preferable. However, the desk study should be supplemented with a field visit by an experienced acoustician to provide an assessment of the potential noise sensitivity of the study area, to note particularly noise-sensitive properties and to provide a description of the ambient noise climate and of any significant existing noise sources within the study area. A textual description of the noise climate is normally sufficient and a formal noise survey is not usually necessary at this stage.

2.5 There is likely to be some indication of probable traffic volumes even at this early stage. While the different options may have differences in the precise traffic flows, an approximation will allow the zone of influence or "noise footprint" of the scheme to be estimated in terms of the distance between the road centre line and the location of a 60 dB L_{den} contour. The noise footprint cannot be marked at a particular position on the constraints map at this stage (because no route alignments will have been proposed). However, it would be possible to indicate its size by a scale line in an information box, possibly for different road configurations, such as "at grade", "in cutting", and "on embankment". For each configuration, the size of the noise footprint will be smaller if a low-noise road surface is used, rather than a hot rolled asphalt (HRA) surface. Including the two road surface options in the information box will alert the design team to the potential advantage to be gained from the use of a low-noise road surface. The acoustic consultant can generate the footprints, or the procedure described in Chapter 5 and the Charts in Appendix A could be used to obtain the required information.

2.6 Noise is not the primary consideration in every scheme, as compared with say ecology, archaeology or other environmental concerns. Where traffic volumes are expected to be moderate, the footprint will be smaller, and noise may not need such intensive attention. However, where high traffic volumes are anticipated, noise should be given due attention by all members of the design team at the earlier stages in the design process.

2.7 The field visit can also help in the early identification of opportunities for "free" mitigation provided by the local topography. It can also assist in developing cost-effective mitigation. For example, the provision of a single continuous barrier, which might be an earth bund, close to an urban-rural fringe could provide protection to many properties, as against the higher cost of providing multiple barriers for a number of isolated properties.

2.8 These issues are discussed in more detail in Chapter 5 which addresses the acoustic design of roads and the amelioration and mitigation of noise.

Route Corridor Selection Study Phase

2.9 The Constraints Study helps the project design team to refine the broad study area into a small number of route corridor options. The noise element of the Route Corridor Selection Study is to evaluate the relative noise impact of each option, both against other options and against other considerations.

2.10 The *Guidelines* advise that the noise impact should be determined by counting the number of noise-sensitive properties within 300 m of the centreline of each corridor, subdivided into distance bands of 0 to 50m (Band 1), 50 to 100m (Band 2), 100 to 200m (Band 3) and 200 to 300m (Band 4). The count in each band is multiplied by a rating factor according to distance. Band 1 (the closest) has a factor of 4, Band 2 has a factor of 3, Band 3 has a factor of 2 and Band 4 has a factor of 1. The weighted totals are then summed to give a Potential Impact Rating (PIR) for each option.

2.11 The *Guidelines* acknowledge that this process only allows a ranking of the route options in order of potential noise impact and that to provide an accurate assessment of likely impact, other factors such as the presence of embankments and cuttings, traffic flows and mitigation measures should be considered.

2.12 This is important advice, since in reality the route corridor selection process has the greatest influence on the cost and effectiveness of mitigation and on the residual noise impact of the scheme. Once the alignment is fixed, the acoustic engineer is left with few options in the design of the most appropriate local mitigation to achieve, or to come as close as practicable to achieving, the design goal at affected noise-sensitive receivers.

2.13 Modern noise mapping software has eliminated much of the requirement for the manual entry of data, as this can now be captured from digital mapping, including details of topography, existing roads and buildings. Even where a detailed road design is not available, a simple horizontal (plan) alignment of the road can be 'draped' over the existing topography (embankments and cuttings can be inserted with approximate heights and depths where known) and approximate traffic flows can be used. (It has been noted elsewhere that even if traffic flows are approximated by a factor of 2, the effect on noise levels will be only 3dB, the smallest normally perceptible difference in level.)

2.14 Where the required data sources are not available at this stage, then the method set out in Chapter 5 can be used to prepare a rough noise footprint.

2.15 It is therefore recommended that initial noise footprint maps showing the location of the 60dB L_{den} contour should be prepared at an early stage of the route corridor selection process, preferably using computer modelling. It is often the case that certain route options are eliminated from further consideration for non-acoustic reasons e.g. Natura 2000 sites, important archaeological remains, engineering practicalities, cost etc., and noise footprint maps need not be prepared for these, but should be prepared for the remaining practicable options.

2.16 At present, there is no formal method of evaluating noise footprint maps. Their value is as a design tool and not an assessment tool. They provide, to all members of the design team, a good indication of the locations where noise mitigation would be required in order to meet the design goal, and thereby suggest where adjustments to the alignments (both horizontal and vertical) could improve the situation. By providing this information at an early stage, there is more opportunity for the project design team to ameliorate the noise impact of the scheme, perhaps at reduced cost and in a more sustainable manner.

2.17 Moreover, noise maps will help to show the noise impact of the scheme in areas where the design goal is met: the choice of an option with fewer noise-sensitive receivers within the noise footprint, and/or a smaller footprint could lead to the adoption of a more sustainable route option. It will always be good practice to consult with the design team and engineers at this stage.

Worked example of route corridor selection

2.18 The NRA *Guidelines* emphasise that when considering route options, the PIR analysis is only part of the process and that to provide an accurate assessment of likely impacts, other factors such as the presence of embankments and cuttings, traffic flows and mitigation measures should be considered. This example shows how these factors might come into play. It is recognised that this is an idealised example, and that every scheme is different. Acousticians and scheme designers will need to consider the particular characteristics of each scheme.

2.19 Figure 2.1 shows two possible options for a bypass of an urban area that has a busy road passing through it. Option A passes just to the east of the urban fringe, and thus has a high PIR count. Option B is further from the urban fringe, and although it passes a few isolated properties, it has a low PIR count. On this basis, it appears to be the preferred option for noise.

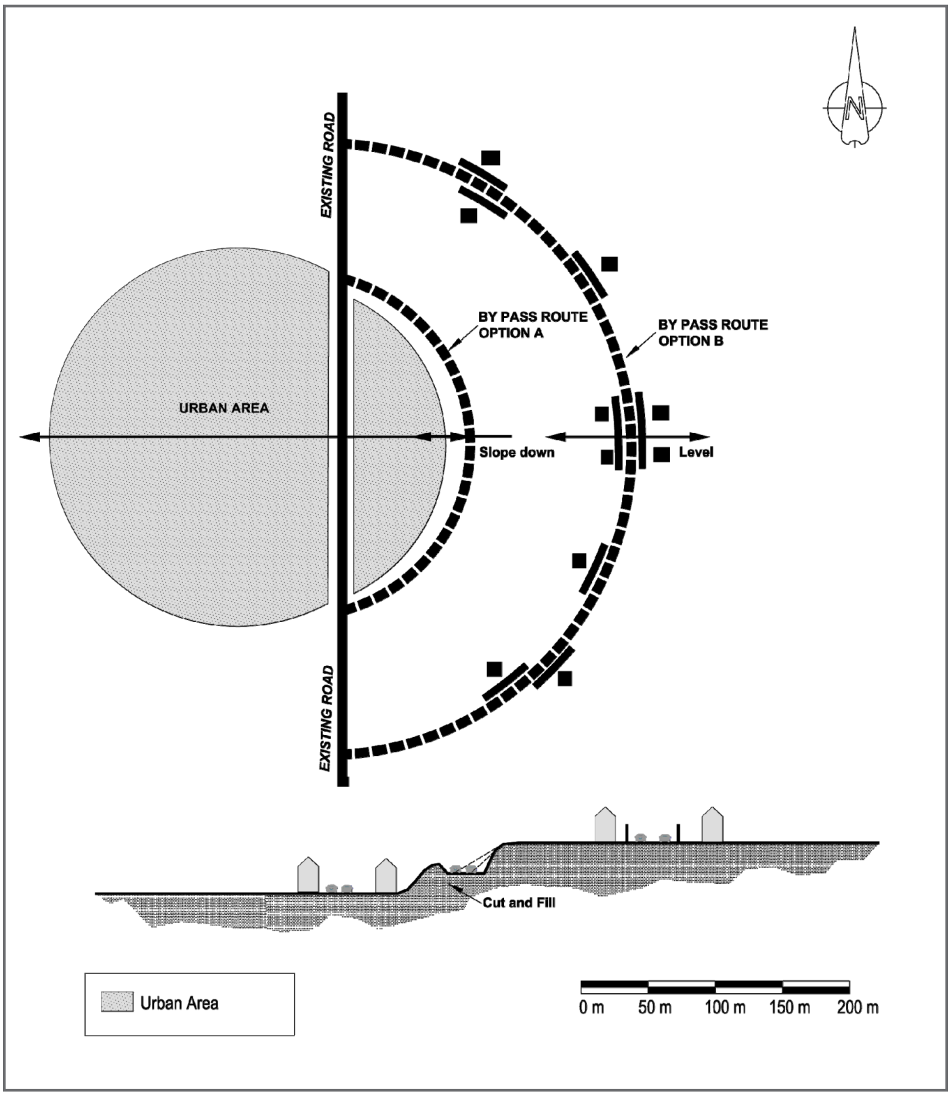
2.20 However, using the design charts or by means of a simple noise model, it is known that because of the traffic flow, some of the isolated properties affected by Option

B will exceed the design goal, and it will be necessary to consider local mitigation to reduce their noise levels. Clearly, it would be expensive to place the whole length of this route into cutting, and moreover because of the proximity to properties, it may be impracticable to place the road into a false cutting or to provide a bund alongside the road. Since many of the properties are isolated, a number of separate panel barriers will be required, which will be both visually intrusive and expensive.

2.21 Returning to option A, this is located on rising ground close to the urban fringe. However, it is quite feasible to provide a cut and fill construction along the sloping ground, such that the cut protects housing to the east of the alignment and the embankment fill protects housing to the west of the alignment. No additional local mitigation may be required.

2.22 Furthermore, it may be noted that Option A also has the merit of keeping traffic noise to the area already influenced by urban noise, whereas Option B would spread traffic noise into a currently quieter area, even if the design goal is met.

Figure 2.1 - Example of bypass options



EIS Phase

2.23 If the preceding guidance has been followed, the detailed route alignment will have been evolved with knowledge of where noise-sensitive receivers are located and where additional mitigation will be needed to meet the design goal.

2.24 In the EIS phase, a detailed noise impact assessment is required. This will involve:

Checklist for noise impact assessment

- ✓ Establishing the prevailing noise climate through noise monitoring.
- ✓ Preparing and validating a traffic noise prediction model.
- ✓ Preparing Do-minimum and Do-something noise levels for opening and design years.
- ✓ Comparing Do-something noise levels with the Design Goal and the three conditions that must be satisfied before additional local mitigation measures are deemed necessary.
- ✓ Assessing and specifying additional local mitigation.
- ✓ Assessing construction impacts and mitigation.
- ✓ Assessing vibration.

2.25 The remaining sections of this document provide guidance on good practice in these matters.

3. Monitoring

Reasons for noise monitoring

3.1 It is essential to establish baseline noise levels in areas that will be directly affected by a road scheme and in those areas where indirect impacts are anticipated by significant changes in traffic flows on existing roads consequent of the proposed road scheme.

3.2 Baseline noise levels can be established by noise modelling and prediction in areas dominated by road traffic noise, but noise surveys are needed to determine noise levels in areas influenced by non-traffic noise sources. However, without undertaking noise monitoring, it is difficult to identify the extent of such areas. Noise surveys are also invaluable in providing public reassurance over the noise modelling and prediction process and to assist in the verification of that process.

3.3 For these reasons, the *Guidelines* require baseline noise monitoring to be carried out.

3.4 An indirect benefit of undertaking noise surveys is that personnel must visit the sites in question, and it is good practice to use the site visits to identify features that may not be easy to notice from a desk-based study. This includes detecting the presence of extraneous noise, for example from leisure facilities, industrial or agricultural establishments, other transportation sources such as railways and airports, and natural sources such as wind in trees and rapidly-running water.

3.5 It is good practice to use the site visit to verify the location of noise-sensitive buildings, and to note the presence of substantial walls and other features that can form noise barriers or affect noise propagation in other ways. Maps, though sufficient for the Constraints Study and the Route Selection Study, may not be fully up-to-date and there may be newly-constructed dwellings on the ground. Buildings shown on maps may not all be noise-sensitive. Barns on farms will not require local mitigation. The Local Planning Authority should be consulted so that noise-sensitive developments for which planning permission has already been granted are included in the assessment.

Requirements of noise monitoring

3.6 The *Guidelines* state that a good geographic spread of noise measurements is required to establish noise level variation along the entire length of a scheme, to establish maximum and minimum levels, indicative of noise levels at worst-case locations.

3.7 An example of the process for selecting noise measurement locations is given in Figure 2 of the *Guidelines*. Experience suggests that it should not be necessary to co-locate two separate sets of equipment to determine a short-term measurement and a 24-hour measurement, since the individual hourly noise levels can be extracted from the 24 one-hour readings at the 24-hour site. Furthermore, it is not necessary to co-locate two sets of equipment as a checking procedure, since it is better practice to check the equipment using an acoustic calibrator as described later in this chapter.

Site selection process

3.8 Each of the existing traffic routes affected by the scheme should have at least one 24-hour measurement site on it. Generally, these points should be chosen to represent noise levels at a noise-sensitive receiver (NSR) close to the route concerned, but as far as possible in a location free from extraneous noise, such as local industry, car parking, neighbour activity, gardening, leisure sources or agricultural activity. The 24-hour measurement sites will be used to establish the variation of noise throughout the various parts of the day and night (the diurnal cycle) and it is important that these are not 'contaminated' by noise events that are not associated with the road in question. It is also important that these measurements are not made when wind speeds are too high or road surfaces are wet. The sites must also be secure so that the equipment is not tampered with or vandalised when left unattended.

3.9 Each 24-hour measurement can be supplemented by a number of short-term measurement sites. These are used to determine noise levels at other NSRs affected by the same road as a 24-hour site. It will be particularly useful to take measurements within clusters of housing where properties set further back from the road may be screened, fully or partly, by properties or noise barriers closer to the road.

3.10 Noise measurements are also required in areas that are expected to be affected by a new road. Firstly, it will be necessary to establish the location of any 24-hour measurement sites. In many cases, a site visit will establish that the background noise level is largely determined by road traffic noise, and if a 24-hour measurement is made close to the road in question, short-term measurements will provide an acceptable indication of the noise climate at other locations affected by the same section of road.

3.11 At other locations, there may be very little road traffic noise at present, in which case baseline levels will be governed by natural sounds, such as wind noise, wildlife, and by human activity. Extrapolation from short-term measurements may not be reliable if this is based on the typical diurnal cycle for road traffic, which is not the dominant noise source at these locations. In such cases, it will be necessary either to make a 24-hour measurement, or to compare the short-term measurement with a similar 24-hour site where the noise sources, and thus the diurnal variation of noise, is considered to be essentially the same.

3.12 Many measurement points will be made on private property, for which permission for access will need to be obtained. This can sometimes be difficult, and therefore some flexibility will be needed in the final choice of sites, which will have to be made by the survey team when on location. It is therefore important that those undertaking the survey understand the principles of site selection so that they can make rapid decisions where necessity dictates changes. It may be easier to choose publicly-accessible sites for short-term measurements, as there will be no disturbance to occupiers on return visits, and, moreover, access should be available for any post-construction measurements that might be required.

3.13 The baseline noise level should be established for every noise-sensitive building or group of buildings where traffic noise levels are likely to change significantly as a result of the scheme. This includes areas where traffic flows are reduced by 20% or more, and where existing flows are increased by 25% or more. Traffic noise will also change where traffic parameters other than total flow volumes are changed.

An increase in the percentage of heavy vehicles, or in traffic speed, will also lead to increases in traffic noise. It is sufficient to calculate the Basic Noise Level with and without the scheme to determine whether there would be a difference of 1dB or more.

3.14 The aim is to select sufficient locations to summarise the ambient noise climate rather than to measure the noise level at every individual property. Where a group of buildings is affected by the same noise source, and the buildings are all roughly the same distance from the source, then a single measurement point will suffice. Where the group of properties is quite large, so some properties are much closer to the source than others, or screening varies significantly, or where they are exposed to different noise sources, then the selected measurement points should represent this variation.

3.15 Long-term measurement locations need to be chosen very carefully, because they are normally made with unattended data-logging meters. They must be located securely where they cannot be tampered with or stolen. This will usually mean placing them in private grounds where the presence of residents is more likely to deter intruders. However, they also need to be located where extraneous noise (such as from children playing, gardening equipment, farm machinery) is less likely to contaminate the measurements.

3.16 Usually, residents will need to be informed of the purpose of the measurements, the nature of the information recorded (i.e. sound levels but not an audio recording); and the need for them to avoid making loud noises close to the microphone. It has been known for residents to interfere with measuring equipment either inadvertently or deliberately, for example by placing a blanket over the microphone or by playing loud noises into it. Checks will need to be made during analysis of the recorded data to detect any obvious anomalies in the results.

Worked example - Selection of measurement locations

3.17 This worked example shows how noise measurement locations might be chosen for a small town which is being bypassed. The same principles would apply equally to much longer new routes. This example is given to illustrate the guidance provided above, but it is up to each acoustician to select measurement locations suitable and appropriate for each particular road scheme.

3.18 Figure 3.1 gives a diagrammatic representation of the area of interest. The group of properties at the northern end of the existing road may not need to be included in the survey, as the NRA design goal requires a contribution of noise of at least 1 dB from the new road and it is assessed that these properties are too far from the new route to qualify for additional local mitigation. If the scheme is likely to lead to an increase in traffic on the existing road, then a survey of their existing noise exposure would be appropriate.

3.19 The noise survey strategy is to establish ambient noise levels in sufficient detail to give an adequate baseline whilst keeping the amount of noise measurement time to a practicable level.

3.20 **Location 1 - The School** – this is likely to be affected by both the existing road and the new road, so the measurement point is chosen to acknowledge this. However, a sample measurement is used because noise from playgrounds and playing fields should be avoided. Also, noise outside school hours is not relevant for a school.

3.21 **Location 2 - Place of Worship** – similar considerations to those at the school means that a sample measurement is appropriate. Note that the measurement point has been chosen to be roughly the same distance from the road as the actual building façade, but far enough from any vertical surfaces that façade reflections are avoided.

3.22 **Location 3 - Residential** – this location is affected by the existing road and will also be affected by the new road in future. Since a secure location is available at this residential property, it is appropriate to use it for a long-term measurement. In the baseline, it is affected by the same length of existing road as Locations 1 and 2, so will act as a good basis for comparison with these and other short-term sites.

3.23 **Location 4 - Residential** – this site has been chosen because it is on the opposite side of the road from Location 3, at a slightly different distance from the existing road, and the topography means that the screening of this point is slightly different. However, it is affected by the same traffic as Location 3, which will provide a suitable long-term comparison.

3.24 **Location 5 - Residential** – this is at the edge of an open green area and is set further back from the existing road than other nearby sites, so a measurement is deemed desirable here.

3.25 **Location 6 - Residential** – this is near the road junction where congestion is noted, so a measurement is deemed desirable here.

3.26 **Location 13** is in a similar location to Location 6 on the opposite side of the road, but as it is also adjacent to the branch road, additional short-term monitoring is desirable here.

3.27 **Location 12** has a secure position for a long-term measurement, which will provide comparisons for Locations 6 and 13. Given its proximity to location 13, it might be reasonable to omit that location if resources are limited.

3.28 **Locations 7 and 11** represent exposure on opposite sides of the road at the end of the built-up area where there is less congestion.

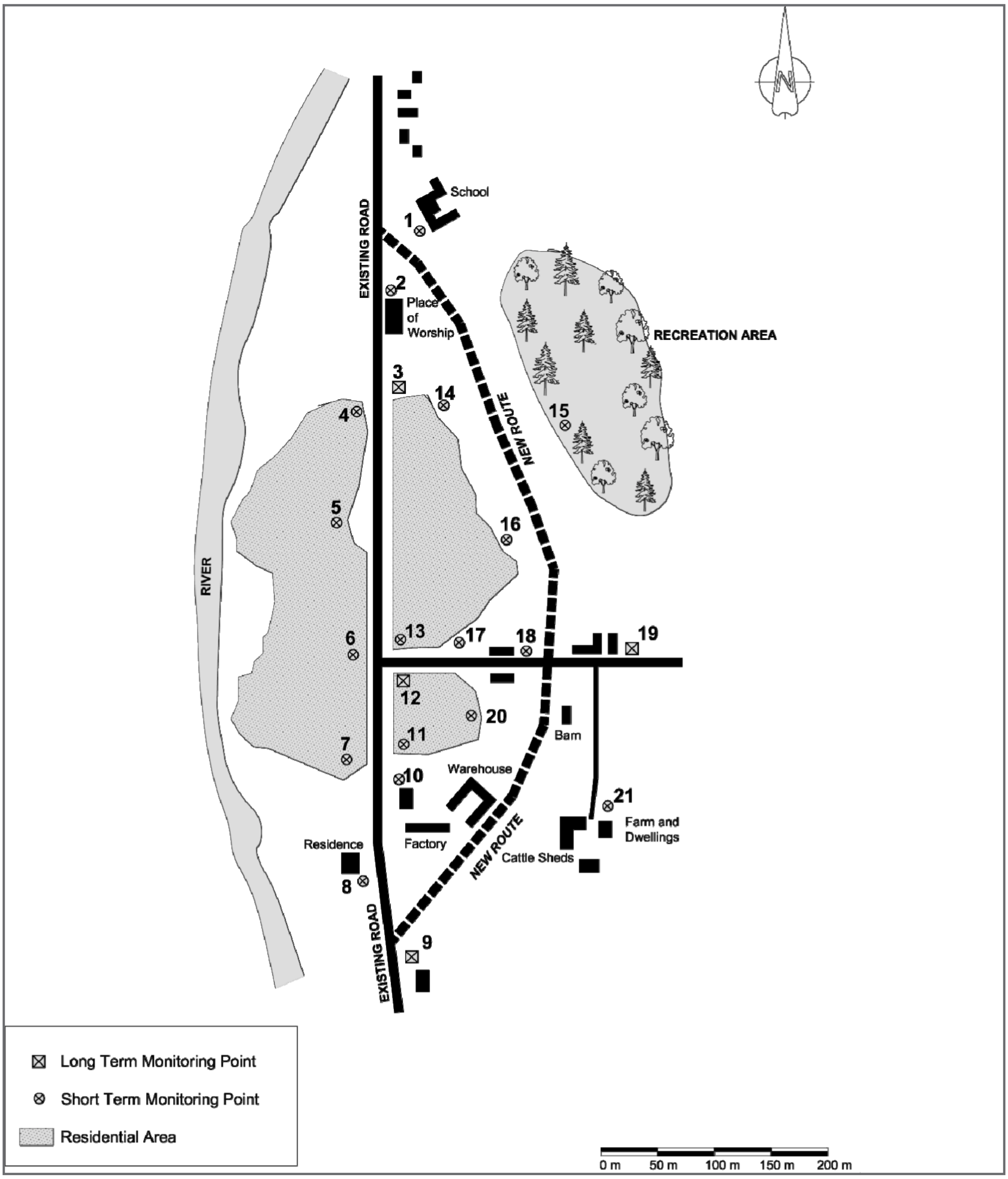
3.29 **Locations 8 and 10** represent individual isolated properties.

3.30 **Location 9** is selected as a long-term site because it is secure and represents traffic noise levels at the edge of the town.

3.31 Locations 9 or Location 12 both provide long-term comparisons for the short-term sites towards the south of the town, so it will be desirable to compare the noise pattern at both these locations and to use some judgement as to which is chosen, or to interpolate between them.

3.32 **Turning to the new route**, measurements are required along the eastern edge of the residential areas, but in the baseline, much of this is affected only by distant road traffic noise.

Figure 3.1 - Selection of measurement locations



3.33 **Locations 14 and 16** represent the extremities of the northern residential area, and intermediate locations can be interpolated from them.

3.34 **Location 17** is chosen to represent receivers affected by the branch road.

3.35 Measurements are made at **Locations 18 and 19** to represent these isolated properties.

3.36 **Location 19** is chosen as a location for long-term measurement as it responds to the pattern of traffic on the branch road, as is a secure location unaffected by extraneous noise.

3.37 The new route will affect an isolated group of buildings consisting of a farm and dwellings to the south-east. A site visit shows that one of these buildings is a barn and some of the others are cattle sheds. Accordingly, **Location 21** is chosen to represent the residential parts of the site. Although noise levels here are affected by both the existing main road and the branch road, it is judged inappropriate to make unattended long-term measurements here because of the uncertainly of extraneous noise from farm machinery and livestock.

3.38 It is noted that the new route runs past some industrial buildings at the southern end of the town, but because these are not considered to be noise-sensitive, they are not measured.

3.39 The Recreation Ground is considered to be noise-sensitive, but noise generated by users of the Recreation Ground is judged not to be relevant to the assessment of noise impact from the new road. This means that an attended measurement is needed so that noise sources can be noted. It is judged that baseline noise levels do not vary much throughout the Recreation Ground, so a single measurement will be sufficient. **Location 15** is chosen as representative of noise levels in the parts likely to be most affected by the new road. There are a number of different background sources that affect noise levels in the Recreation Ground – mainly distant traffic on the existing main road and on the existing branch road, but there is also noise from the residential area. This means that long-term Locations 3 and 19 can provide comparators.

3.40 Although it might be possible to set up an alternative secure long-term site in the nearby housing area, the inevitable intrusion of neighbourhood noise means that it may not provide a better comparator for noise levels in the Recreation Ground than the other suggested comparator sites.

Measurement Procedure

3.41 The *Guidelines* refer to 24-hour measurements (called long-term in this Guide) which should be read as 24 consecutive measurements of 1 hour each. It is convenient if these hour-long samples commence "on the hour" and most data-logging sound level meters can be set to do this. Start and end times will need to overlap to ensure that 24 complete hours are recorded.

3.42 The *Guidelines* suggest that short-term measurements should consist of three samples each of 15-minute duration taken in any three consecutive hours between 10:00 and 17:00 hours and these should normally be on weekdays. It is simpler for comparison with the long-term sites if the samples do not cross hourly boundaries and that they are totally contained within a particular hour. Short measurement samples are prone to errors arising from short variations in traffic flow or caused by unusual noise events, such as a vehicle with a damaged exhaust. Where one of the three measurements is out-of-line with the other two, it can be replaced by a fourth measurement, and the replacement reported.

3.43 Measurements should be taken at a height of 4m above ground to represent dwellings that are two or more stories in height, and at 1.5m above ground level to represent single-storey dwellings or in open land. The microphone should be mounted with the diaphragm horizontal, on a pole supported on a strong tripod base, connected by an extension cable to the data-logging sound level meter. The equipment must be 'weatherproof' to provide protection from unexpected wind and rain and the microphone protected by a windshield. Suitable 'outdoor' equipment is available from specialist suppliers. The equipment should meet the specifications of Type 1 in EN 61672-1:2013[3].

3.44 The whole equipment chain must be field-calibrated (including the extension cable but excluding the windshield) before and after each measurement. Any calibration drift should be investigated, as it could be a symptom of an equipment fault. Internal clocks and batteries should be checked before leaving equipment, as considerable time and effort could be wasted, particularly if the results from a long-term comparison site are lost.

3.45 Periodically, at least once every two years, all equipment should be calibrated at a recognized laboratory to EN 61672-3:2013[4] for periodic tests.

3.46 It is generally accepted that noise measurements should not be taken when there is precipitation (rain, snow or hail), when there is a significant wind, or when road surfaces are wet. BS 4142[5] (which actually addresses industrial and not traffic noise) suggests that windshields are generally effective in providing protection against wind-induced noise in microphones at wind speeds up to 5m/s. It is preferable to avoid wind speeds in excess of 2m/s at microphone height, as these may be associated with greater wind speeds at greater heights which may induce noise as the wind passes through trees. In all situations, it is advisable to measure the meteorological conditions that prevailed throughout the measurement campaign.

3.47 Where a receiver is particularly noise sensitive and it is considered that noise levels may not have been typical, either because a normal noise source was not present, an abnormal source was present, unusual weather conditions or because of apparently aberrant results, then the measurement should be repeated.

3.48 Noise measurements have been commonly limited to baseline conditions before the road is built. However, it would be valuable to undertake additional noise monitoring six to nine months after the scheme has been opened to the public. The measurements of multiple schemes would constitute a valuable data bank for future development of predictive techniques and could build confidence in the accuracy of predictions. However, the actual value of such a data bank would be dependent on the adequacy of administrative procedures for collecting, maintaining and disseminating the information.

Information to be recorded

3.49 It is essential that the location of the measurement microphone is reported unambiguously. It should be marked as accurately as possible on a scale map and the microphone height should be clearly stated. A photograph is also helpful, especially if it shows the microphone in its actual location, as there may be objects nearby that are not recorded on the map. However, a photograph in isolation is not likely to be sufficient to determine the measurement position – for example it may not unambiguously show which façade of a building is being viewed, especially to a reader who is not familiar with the locality.

3.50 Although the *Guidelines* require measurements to be free-field, i.e., away from any vertical reflecting surfaces, it is recognised that in some circumstances, for example in the middle of towns, it may not be possible to find a location which is clearly free of reflections. In such cases, it would be preferable to position the microphone exactly 1 m from a suitable façade and to record this fact clearly. A façade reflection factor can then be subtracted during data processing.

3.51 The noise indexes to be recorded include as a minimum, $L_{Aeq,T}$, $L_{A10,T}$, $L_{A90,T}$, for each 1-hour or 15-minute sample period as appropriate. To avoid doubt, it should be clearly stated whether or not the measurement is in the 'free-field'. Derived measures, including $L_{A10,18\ hour}$, L_{night}, L_{day}, $L_{evening}$ and L_{den} should be reported for 24-hour measurements. Extrapolations for $L_{A10,18\ hour}$ and L_{den} should also be reported for short-term measurements, together with a specification of how the extrapolations have been conducted. Guidance on conducting the extrapolations is given in the following Chapter.

3.52 All the equipment (including serial numbers) and its calibration status should be detailed in an Appendix, so that if any measurement anomalies or equipment problems are found at a later time, there is a paper trail and those anomalies can be investigated.

3.53 Meteorological conditions must be recorded, in particular wind speed and direction. Consideration should be given to the use of a data logging weather station which has the capability of recording wind speed, direction and rainfall, particularly for long-term measurement. If precipitation occurs after a long-term measurement has been started this should be noted, and the measurement should normally be repeated when conditions are better. Short-term measurements should not be undertaken in such conditions.

3.54 Enquiries should be made to ascertain that traffic flows were 'normal' on any dominant road and not affected by road works, other disruption or local events, and this should be recorded. Where it is intended to use a noise survey to 'verify' a noise prediction model, then it is desirable to record traffic flows (including percentage of heavy vehicles) on the dominant road during the noise survey period.

Analysis of results

3.55 In addition to reporting the measured noise levels, weather conditions and noise sources as described above, it is important that the noise levels are reviewed to detect any obvious errors or anomalies.

3.56 It is to be expected that at any particular location, each of the readings will be slightly different. If they are all almost exactly the same (e.g. differing by less than 1dB) this could indicate the presence of a continuous extraneous noise, such as flowing water or a ventilation unit, or possibly an equipment fault. In either case, these problems could show up as a 'noise floor', where loud noises can be seen as creating a peak of noise, but at quieter times, the readings bottom out at the same fixed level.

3.57 The converse problem can be unexpected peaks of noise that cannot be related to obvious noise events. A particular peak is produced by the 'dawn chorus' of birdsong which can be very marked particularly in spring.

3.58 Other occasional peaks can be produced by bird scarers, aircraft, animals, passers-by and so on. Occasional peaks of noise are likely to affect the L_{Aeq}, but not the L_{A90} value. These should be recorded during attended measurements and reported. The survey team should be aware that extraneous noise can affect the reliability of unattended measurements. It is advised that long-term measurements should be plotted as a time-history graph, which should be examined for any of the above effects.

3.59 As a record of baseline levels, the measurements should be reported as found. However, for verification of the noise model, which relates purely to road traffic noise, anomalous readings will need to be excluded.

3.60 For long-term measurements, the $L_{A10,18\ hour}$, L_{night}, L_{day}, $L_{evening}$ and L_{den} can be calculated directly from the measurements made over the relevant time periods. For the statistical indexes (L_{A10}, L_{A90}, etc) this is done by taking the arithmetic average of the hourly readings. For the L_{Aeq} based indexes, the energy-average must be used. More information is presented in Paragraph 3.1 of the *Guidelines*.

3.61 Short-term measurements require the L_{den} to be derived from the sample of measurements taken on that day. Firstly the $L_{A10,18\text{-}hour}$ should be calculated by calculating the arithmetic average of the 3 samples taken at the site, and subtracting 1dB. Then the L_{den} should be calculated by using Method B in Paragraph 3.1 of the *Guidelines*.

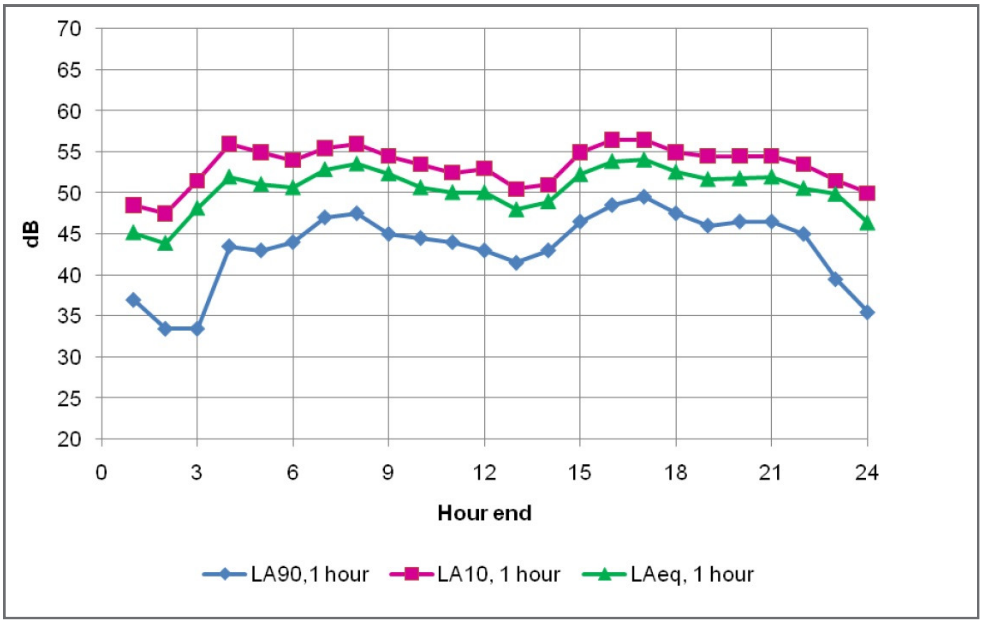
3.62 Where traffic flows differ very significantly from the normal daily pattern (as set out in Appendix A of the *Guidelines*), or where traffic is not the dominant noise source, then the normal correction cannot be applied to convert the 15-minute samples (taken between 10:00 and 17:00 hours) to an 18-hour value. However, it may be possible to derive a site-specific correction from a nearby long-term site affected by the same noise sources. If there is no comparator site, a short-term measurement is inappropriate and a 24-hour measurement will be required.

Worked example - Analysis of measurement results

3.63 This worked example shows some typical noise readings and shows how a plot of noise levels could be used to check a noise measurement. It is up to each acoustician to make an appropriate analysis in each case and to develop their own scheme-specific conclusions.

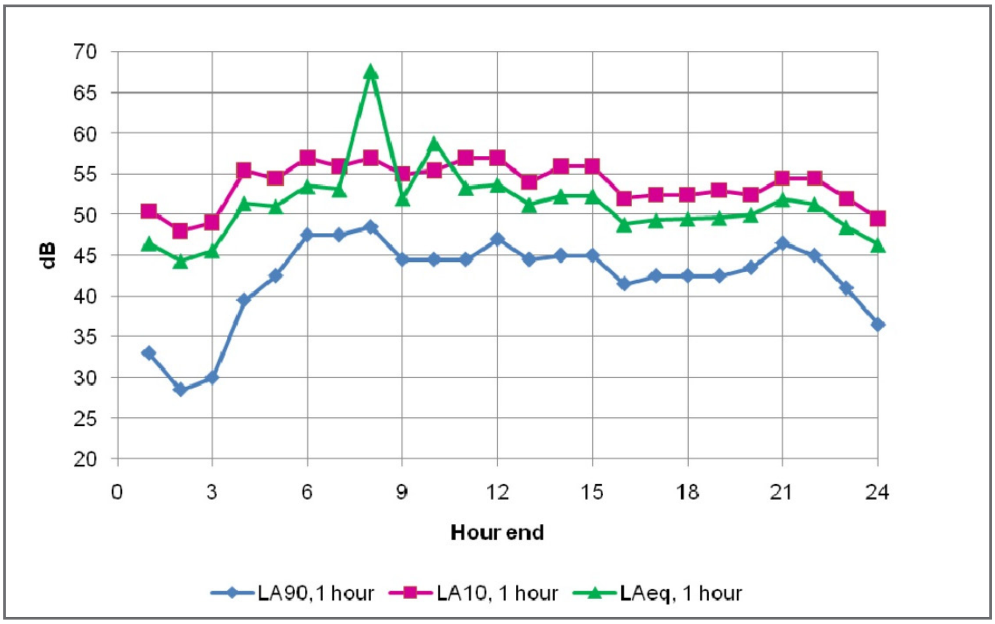
3.64 Figure 3.2 shows a typical plot of noise levels alongside a commuter route. The morning and evening peak periods are clearly visible, as is the dip in the small hours of the night, although there was clearly a busy period at 4 am. L_{Aeq} readings are consistently around 3 dB below the L_{A10} readings. The Background L_{A90} readings clearly follow the pattern of the other parameters, showing that traffic noise was dominant at all times of day, and there is no evidence of extraneous noise or unexplained noise events.

Figure 3.2 - Location 1 - Commuter route



3.65 In the above example of a road with a continuous flow of traffic, the L_{Aeq} readings are consistently below the L_{A10} readings. However, it may be noted that in cases of low, intermittent traffic flows (especially at night) it is possible for the L_{Aeq} readings to be above the L_{A10} readings.

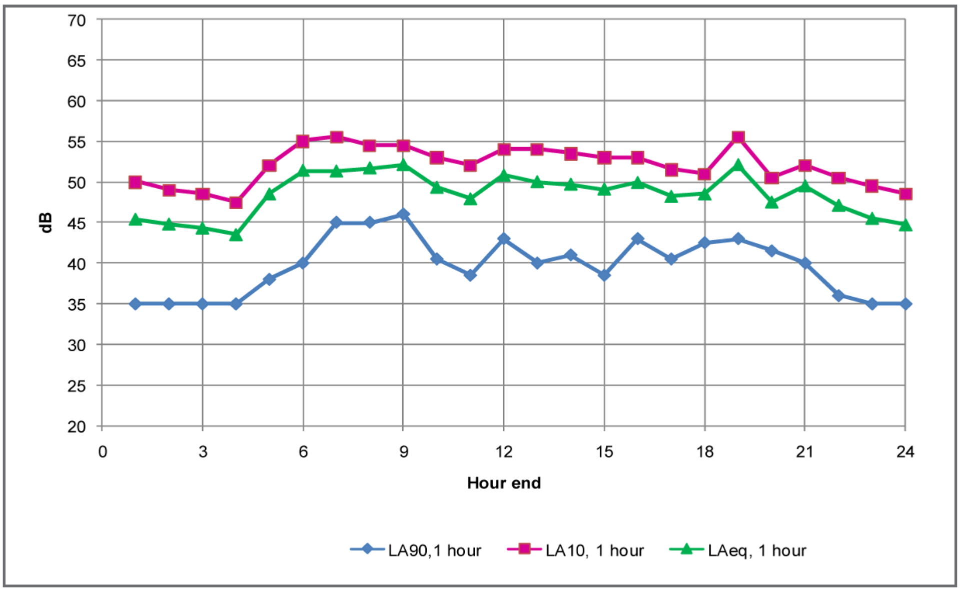
Figure 3.3 - Location 2 - Motorway



3.66 Figure 3.3 shows the results of measurements taken at a location which is a short distance from a motorway. It shows a very different daily variation of noise levels from the commuter route, typical of a steady flow of long-distance traffic. A clear dip is seen in the small hours, but there are no morning and evening peaks. L_{Aeq} readings are consistently around 3dB below the L_{A10} readings, as on the commuter route, except for an unexplained peak at 08:00 and a smaller one at 10:00. These do not affect either the L_{A10} or L_{A90} readings, so must be short, intense events, possibly the local resident leaving and returning by car, and passing close to the microphone. Clearly, this event would not be included in a noise model and should be excluded from any validation of a noise prediction for this location.

3.67 Figure 3.4 shows some inconsistency in the difference between the various noise indexes which may be due to the effects of extraneous noise. The influence of extraneous noise can be seen in the L_{A90} levels, particularly the noise floor of 35dB that occurs between 23:00 and 05:00, which was found to be caused by ventilation plant in a nearby warehousing facility. This facility is also likely to have caused the loud noise at 19:00. Although this reading may accurately represent the ambient levels at this location, because some of it arises from non-traffic sources it would not provide an accurate verification of a traffic noise model. In a post-construction assessment, however, it would show that the design goal had been achieved.

Figure 3.4 - Location 3 - Motorway with warehousing facility in distance



3.68 Tables 3.1 and 3.2 present suggested tables for recording the results of long-term and short-term monitoring, the conditions under which the measurements were taken, and the equipment used. This detailed data can be placed in an Appendix to the EIS text. Copies of Certificates confirming that the equipment has been subject to periodic laboratory calibration should also be included in an Appendix. The main text of the EIS should summarise the results, and explain any apparent anomaly.

Worked Example - table layout presenting long-term monitoring results

Table 3.1 - Layout of typical table presenting long-term monitoring results

Location Number	Location Name	Free Field/Facade	Start Date/Time	End Date/Time
Wind speed	Wind direction	Temperature	Surfaces wet/dry	Microphone height
Equipment type	Serial number	Microphone type/serial	Calibrator type/serial	Operator

Hour End	$L_{A90,1\ hour}$	$L_{A10,\ 1\ hour}$	$L_{Aeq,\ 1\ hour}$	Observed noise sources where known
1	37	48.5	45.2	
2	33.5	47.5	43.9	
3	33.5	51.5	48.2	
4	43.5	56.0	52.0	
5	43.0	55.0	51.1	
6	44.0	54.0	50.7	
7	47.0	55.5	52.9	
8	47.5	56.0	53.6	
9	45.0	54.5	52.4	
10	44.5	53.5	50.7	
11	44.0	52.5	50.1	
12	43.0	53.0	50.1	
13	41.5	50.5	48.0	
14	43.0	51.0	49.0	
15	46.5	55.0	52.3	
16	48.5	56.5	53.9	
17	49.5	56.5	54.1	
18	47.5	55.0	52.6	
19	46.0	54.5	51.7	
20	46.5	54.5	51.8	
21	46.5	54.5	52.0	
22	45.0	53.5	50.6	
23	39.5	51.5	49.9	
24	35.5	50.0	46.4	
Derived Measurements				
$L_{A10,\ 18\ hour}$		54		
L_{den}			57	

Worked Example - layout of a typical table presenting short-term monitoring results

Table 3.2 - Layout of typical table presenting short-term monitoring results

Location Number	Location Name	Free Field/Facade	Date	End Date/Time
Wind speed	Wind direction	Temperature	Surfaces wet/dry	Microphone height
Equipment type	Serial number	Microphone type/serial	Calibrator type/serial	Operator

Measurement start time	Measurement end time	$L_{A90,T}$	$L_{A10,T}$	$L_{Aeq,T}$	Observed noise sources
10.45	11.00	44.0	52.5	50.1	
11.45	12.00	43.0	53.0	50.1	
12.45	13.00	41.0	50.5	48.0	
Derived Measurements					
Average			52		
$L_{A10, 18 hour}$			51		
L_{den}				54*	

* Calculated from $L_{A10,18 hour}$ by formula on Page 18 (Method B) of the *Guidelines*

Checklist for Noise Monitoring

- ✓ Select monitoring locations where the road will go and where the road will result in alterations to existing traffic flows.
- ✓ Select sufficient locations to summarise the ambient noise climate rather than to determine the existing noise climate at every individual property.
- ✓ Include locations which will allow validation of a noise model by a comparison of predictions for the Opening Year Do Minimum scenario with the measured values.
- ✓ Provide information that identifies the location of each measurement position sufficiently clearly so that someone else can later take a measurement at the same location, including height, knowing whether it was a free-field or a facade measurements and, if relevant, which facade.
- ✓ Report the dominant sources of noise at each location.
- ✓ Report the time and date of measurements and weather conditions.
- ✓ Avoid surveying when there is rain, wet roads, wind or unusual traffic conditions.
- ✓ Report measured $L_{Aeq,T}$, $L_{A10,T}$, $L_{A90,T}$ levels and other paramters as available and informative.
- ✓ Report $L_{A10,18hour}$ and L_{den} as measured directly or specify how they were derived from short-term measurements.
- ✓ Report the instrumentation used, the calibration conducted in the field and the date of the most recent laboratory calibration.
- ✓ Check that the measured levels are coherent, in terms of the relative values of different parameters, the variation between day, evening and night levels, and the difference between locations. Explain any significant deviations from normal expectations.
- ✓ Present the measured data in tables. Avoid extensive repetition of tabulated values within the text. The text should summarise the table contents and provide additional information that helps to explain the content.
- ✓ Do the noise surveys, as reported, give the decision-maker a clear and accurate summary of the ambient noise climate throughout the area in which both positive and negative impacts could occur?

4. Noise Predictions

Requirement for noise predictions

4.1 The future noise level, in both the year of opening and in the design year, should be established for every noise-sensitive building where noise levels are likely to change significantly as a result of the scheme. This includes areas where traffic flows are reduced, as well as areas where new flows are introduced or existing flows are increased.

4.2 Future noise levels are established by noise prediction (i.e. calculation) using the procedure set out in *Calculation of Road Traffic Noise* (CRTN). At the EIS stage this will almost always be done with the use of a computer-based noise model using a proprietary software package. Experience shows that using such a system will produce results that compare well with good-quality measurements, provided the model has been carefully checked to avoid input data errors and that the theoretical assumptions made in the model closely resemble the actual situation on the ground.

4.3 However, it is recognised that, particularly where the design team wishes to get a rough appreciation of potential noise impact in the early phases of a project, a broad-brush approach may be sufficient and the method set out in Chapter 5 may help in achieving this. Nevertheless, it may be noted that the efficiency of noise modelling packages has increased considerably in recent years and it may be advantageous to commence basic noise modelling much earlier in the planning phase than initially undertaken.

4.4 The last major revision to CRTN was in 1988 and recent enhancements have been advised, in particular to deal with modern road surfacing materials and to deal with predictions over longer distances than the original method was designed for. These are covered later in this Chapter.

Creating computer-based noise models

4.5 Although many factors affect the accuracy of a noise model, the principal inaccuracies arise from incorrect assumptions about screening and traffic flows. Correct assessment of the type and condition of the road surface is also important. It is essential that adequate topographical data is obtained; this is now becoming readily available as a result of advances in remote sensing techniques and can be easily incorporated into computer-based noise models.

4.6 Adequate details of the road alignment are required, particularly of the vertical alignment (i.e. the varying height of the road along its length). The height of a road relative to its surroundings makes a considerable difference both to the screening of the road and the spread of noise from the road. The alignment of most roads is designed using software that produces horizontal and vertical alignments that can be read automatically by noise modelling packages. Where there are areas of housing, these can usually be taken directly from digital mapping, although this does not normally contain the building height. This will need to be added manually, perhaps by assuming a given height per building storey.

4.7 A more difficult task is the inclusion of existing walls and other objects that function as noise barriers in the noise model. These cannot usually be picked up by remote sensing methods and it may be necessary to rely on site visits, perhaps during the noise survey.

4.8 Traffic data can be another source of error. Baseline data is difficult to gather and future estimates depend on complex assumptions. It is suggested that the traffic data assumed in the noise model should be presented in the noise chapter of the EIS, perhaps in the form of a diagram that makes it clear which flow applies to which segment of road. This can be a useful way of checking that data supplied by the traffic engineer has been correctly interpreted. By doing this, the traffic assumptions will be clear in the future should it be necessary to verify the post-construction noise levels.

Verifying a noise model

4.9 The *Guidelines* advise that a noise model should be validated to ensure that critical features have been correctly incorporated into the model. The *Guidelines* leave the exact method of validation to the discretion of the Acoustic Engineer.

4.10 Clearly, it is essential that the details mentioned in the preceding section are correctly entered and are verified. Noise modelling packages provide many ways of doing this, including the ability to produce cross-sections, 3-dimensional perspective views, and colouration of the model to show features such as heights, traffic flows, road surface types and so on. These should always be used, and the verification should be described in the noise chapter of the EIS report, along with full details of the noise modelling package that was used.

4.11 For existing roads, it would be possible to compare noise predictions against noise survey data, although this cannot verify the model of the proposed new scheme when the EIS is prepared. For example work undertaken by the EU[6] to improve noise prediction models suggested that 'ambition levels' for the discrepancies between predictions and measurements should be ≤ 2 dB for flat terrain up to a distance of 2 km, and ≤ 5 dB for hilly terrain and up to 2 km or in urban areas. However, it is recognised that it would be extremely difficult to replicate such levels using CRTN.

4.12 Where a model has been checked for accuracy but large discrepancies remain, it should be noted that the measurement can be just as likely to suffer from errors as the prediction, and it may be necessary to repeat the measurement, taking care to count traffic flows (including speed and percentage of heavy vehicles) and perhaps to take measurements of the road surface noise by means of a measurement close to the road in question, comparing this with the Basic Noise Level as predicted by CRTN.

4.13 The tools and methods of checking a noise model will depend on the software package used, but the user will need to verify the modelling of at least the following items:

Checklist for verifying a noise model

- ✓ The road geometry, including the vertical alignment, corresponds with the modelled situation.
- ✓ The correct road surface type and texture depth is assigned to each segment of road.
- ✓ The correct traffic flow, percentage of heavy vehicles and speed is assigned to each segment of road.
- ✓ Adequate modelling of topography.
- ✓ Adequate modelling of existing and proposed noise barriers.
- ✓ Buildings have been entered with appropriate heights so that screening is adequately modelled.
- ✓ Receiver points are at the correct height and at the correct facade.
- ✓ Areas of hard and soft ground are adequately represented.
- ✓ Comparison with measurements (if available) and discussion of discrepencies.
- ✓ Report the verification process.

Prediction Locations

4.14 Prediction points should be established for every noise-sensitive building or group of buildings where noise levels are likely to change significantly as a result of the scheme. This includes areas where traffic flows are reduced, as well as areas where new flows are introduced or existing flows are increased and there is a significant contribution of noise from the new road as well. This should include all measurement locations if practicable.

4.15 It is particularly important that there are predictions for all properties which would fall within, or close to, the 60dB L_{den} contour. It is good practice to consult the local Planning Authority and to include any property for which planning permission has been granted within the 60dB L_{den} contour. A representative selection of properties outside the 60dB L_{den} contour should also be included.

4.16 All properties where the predicted level under a Do Something scenario exceeds the design goal at 4m should be considered further. If a property is single-storey the prediction should be repeated at a height of 1.5m. If the level at 1.5m does not exceed the design goal this should be noted, and the property can then be eliminated from further consideration.

4.17 The predictions should be free-field, at the position of the most exposed façade under the Do Something scenario, which means that any reflection from the local façade is to be ignored. However, that façade may act as a screen to noise from other road links, and this should be represented within the noise model as a barrier. This may be pertinent where a new alignment is provided but an existing alignment is kept open. A property which is between the two alignments will receive noise from both, but on different facades and this should be reflected in the predictions. A similar consideration arises where a property has the major dimension at right-angles to a road, and the façade facing the road has no windows, e.g. a blank gable wall.

4.18 The location of each prediction point should be described clearly and shown graphically, as for the measurement locations, including its height above ground, confirming whether or not it is a free-field prediction and if not, the façade to which it relates.

Road Surfaces

4.19 The road surfaces assumed for the predictions should be described and the road surface corrections reported.

4.20 There is wide variation in advice on the amount of noise produced by different types of road surface, and on the amount of noise reduction that can be obtained from various types of low noise road surface, particularly as this can vary over the maintenance life-cycle. Difficulties are caused by variation in the measured noise produced by the same material in different locations, and a lack of international standardisation in measurement. New commercial products are also being produced.

4.21 In the current state of knowledge and until best practice is established, it is recommended that where site-specific surface noise measurements are not available the corrections shown in Table 4.1 are made for road surface noise, for all traffic speeds and compositions, in preference to the advice provided in Paragraph 16 of CRTN. This table shows the benefit of a low noise road surface without unduly exaggerating its effectiveness over the maintenance life cycle. Where site-specific surface noise measurements have been made alternative corrections may be used.

Table 4.1 - Recommended correction for road surface type

Surface type	Correction
Normal hot-rolled asphalt (HRA) surface	0dB
Low-noise road surface	2.5dB

Traffic Data

4.22 Traffic data is the basis on which noise predictions are constructed. It is therefore important that the traffic data used in the predictions is reported in an accessible location. While this may result in some repetition, the traffic data should be reported in the noise section, even if it is reported in a Traffic Appraisal. The traffic data reported in the noise section should be that which is input to the noise predictions, which may be hourly values or data for the CRTN 18-hour period. The Traffic Appraisal is most likely to report the Annual Average Daily Traffic (AADT) over a 24-hour period. This may be used to generate the hourly traffic parameters using the default diurnal traffic pattern within the Revised *Guidelines*, or it may be used to generate the 18-hour count used as input in the CRTN procedure. (It should be noted that although CRTN refers to the use of annual average weekday traffic (AAWT), this is to meet the requirements of the UK Noise Insulation Regulations. Calculation of L_{den} is based on the annual average daily traffic, as defined in the EU Environmental Noise Directive).

4.23 The *Guidelines* require predictions to be reported for the Opening Year, and for a

Design Year, 15 years after opening. In many cases the traffic data for the Design Year differs from the Opening Year only by a common growth factor which applies to all road links in the study area. In this situation, noise levels in the Design Year differ from those in the Opening Year by the same amount at all locations. This means that there will be no property that meets the requirements for mitigation in the Opening Year that does not also meet them in the Design Year.

4.24 Where this is applicable, it is only necessary to table the predictions for the Design Year and to report the (constant) difference between the Design and the Opening Year levels. This will reduce the volume of data presented in the noise report. It also avoids the need to consider mitigation for two different years, as any mitigation which is adequate for the Design Year will also meet the requirements of the Opening Year.

4.25 Noise models require the input of traffic speeds for each road segment, and this information should be obtained from the traffic engineer. The focus of attention for a traffic engineer may be on congestion, and their data may relate to traffic speeds during peak hours, whereas the average over 18 hours is more appropriate for noise calculations. Care should be exercised where traffic speeds of less than 20km/hr are predicted. At such low speeds, according to CRTN, traffic noise increases as traffic speed decreases, at an exponential rate. It is good practice to set a minimum traffic speed of 20km/hr for noise models using CRTN.

Updated advice on using CRTN

4.26 CRTN was last fully revised in 1988 at a time when traffic noise predictions were often carried out by hand or with simple computer programs. It incorporated a number of short-cuts and simplifications necessary to make the method practicable. The UK roads authorities have kept the methodology under review and in August 2008 they issued additional advice on the use of CRTN procedures[7].

4.27 In summary, the following modifications to CRTN procedures should now be adopted:

Dual carriageways - each carriageway should be modelled as a separate source line, irrespective of the number of lanes, or their relative vertical or horizontal alignment. *(CRTN 88 advises that a single source line can be used unless there is a wide horizontal or vertical separation of the carriageways.)*

Median barriers - a solid median barrier can screen receivers on the far side of the road, but could reflect noise back to those on the near side of the road. It is advised that median barriers should be modelled, but any reflection back to the nearside can be ignored if the barrier is less than 1.5m high (which is generally the case) or if the barrier sides are sloping.

Vehicle classification - the new advice in DMRB is that light vehicles should be redefined as those with an unladen weight of less than 3.5 tonnes. This advice appears to be related to a general increase in the weight of vehicles since the classification originated in 1975 and perhaps a reduction in noise emissions of vehicles, but no research evidence is presented in the revisions to DMRB. Accordingly, there seems to be no justification to change the current method of classifying light and heavy vehicles in Ireland.

Vehicle speeds - CRTN para 14.2 provides a table of 'prescribed speeds' that depend on the road type and speed limit. DMRB recommends that 'TUBA off-peak traffic speeds' should be used for noise predictions. It is advised that traffic speeds should relate to the off-peak situation and not to peak hour conditions.

Road surface noise - CRTN advises on road surface noise corrections based on the road surface material and its texture depth. There have been many practical problems in applying this; furthermore new surfacing materials and many changes to vehicles and tyres are not covered. New advice in DMRB takes a conservative view of the benefits of quieter surfaces, and restricts it to a maximum reduction of 3.5 dB. For Ireland, this current guidance recommends using the values in Table 4.1.

Extrapolation of attenuation beyond 300m - DMRB states that the CRTN procedures can be reliably extrapolated to 600m, but beyond that distance, the additional effects of soft ground attenuation diminish. Beyond 600m, no additional soft ground attenuation should be applied. **In practice, this change is unlikely to have any significant effect as the design goal of 60dB L_{den} will rarely be exceeded at this distance, and where barrier effects dominate, soft ground attenuation is ignored.**

Absorptive barriers - DMRB cites research that found almost no overall benefit from using absorptive barriers, and this is attributed to over-estimates of the effects of reverberation made when testing barrier materials. Reverberation is much more likely between the wing walls of bridges and in retained cuttings. **It is recommended that professional judgment be exercised in the decision to recommend an absorptive barrier.**

Reflection from opposite facades - CRTN provides a method of estimating the magnitude of this effect, but it does not specifically allow for the distance of the opposite façade from the source or receiver. DMRB provides advice on allowing for this, but it requires implementation in a computer. It is recommended that such a software implementation should be used where available. However, the effect of the change will generally be very small, as the maximum effect of reflection from an opposite façade is 1.5 dB.

Shortened measurement procedure - DMRB advises that research shows the use of a shortened measurement procedure is still a valid way to determine 18-hour levels, and confirms that **a 1 dB correction is still applicable.**

L_{A10} to L_{den} Parameter Conversions

4.28 The *Guidelines* provide three methods for converting L_{A10} values to L_{den}. Method A has two parts: the first (herein called Method A1) is based on a scheme-specific knowledge of the traffic flow in each hour of the day, and should therefore be the most accurate method. However, traffic engineers rarely predict the flow in each hour and the *Guidelines* deal with this by providing a pair of generic hourly traffic profiles that can be applied to the AADT and the percentage of heavy vehicles to generate the flow in each hour (herein called Method A2).

4.29 The *Guidelines* provide a further method, Method B, which can be used to convert the $L_{A10,18\ hour}$ output from CRTN (omitting the façade reflection) into an L_{den} value. A subsequent study confirmed that when applied to typical roads in Ireland, Method B provides an acceptable level of accuracy[8].

4.30 Recent research suggests that there is a small error in the prediction of night-time noise levels using Method A1 or A2 when traffic flows are very low, but when aggregated to L_{den}, the error is very small and results in a very slight over-estimate of noise levels.

4.31 It is now considered that, where the distribution of traffic flows throughout the diurnal cycle is atypical, perhaps because a road feeds a port with night-time loading and unloading, or because a road is subject to a curfew for heavy vehicles, Method B should not be used. The only option in these cases is to seek scheme-specific traffic data from the traffic engineer and Method A1 should be used.

4.32 The conclusion in the *Guidelines* is that Method A is the preferred method, however, should the user consider it more appropriate to use Method B, they should consult with the Authority in advance of using this methodology to justify the rationale for its selection.

Checklist for Noise Prediction

- ✓ Prepare noise models for the Do Something and Do Nothing scenarios in the Design Year.
- ✓ Prepare an audit checklist which works with the software used and pass the model through this checklist, checking that the model is coherent, comprehensive and correct.
- ✓ Generate the 60dB L_{den} contour at 4m.
- ✓ Set up a prediction location for every property with noise levels above, or close to the 60dB L_{den} contour. Add a selection of prediction locations representative of properties where noise levels are likely to be below the design goal.
- ✓ Conduct a walk-over survey to chect that all properties within or close to the L_{den} contour are included and all non noise-sensitive properties are omitted.
- ✓ Note any dwellings that are single-storey and re-run the models for them at 1.5m.
- ✓ Check with the Local Authority for recently permitted residential developments.
- ✓ Report the location of prediction points clearly and graphically.
- ✓ Report the traffic data as input to the noise model. Where assessments for opening year scenarios are omitted, this should be justified.
- ✓ Report the road surface type and any consequent correction.
- ✓ Consider whether, given the pattern of the diurnal traffic flows (and possible low traffic flows) Method A or Method B is to be used to convert a L_{A10} to a L_{Aeq} parameter.
- ✓ Report the road surface type and any consequent correction.

5. Acoustic Design, Amelioration and Mitigation

Noise Amelioration and Noise Mitigation

5.1 The aim of this guidance is to encourage and facilitate the positive acoustic design of road schemes which minimise the need for local mitigation, often with timber barriers, at a late stage in the design process.

5.2 Noise amelioration is that which takes place at an early stage in the design process, when a wider range of options are still open. Local noise mitigation may still be required at a later stage, but at a smaller scale. Thus, amelioration is part of the scheme design, whilst mitigation is an add-on to address the residual problems that the scheme creates.

5.3 Low-noise road surfacing may be specified to deal with local problems and to that extent can be considered to be a mitigation measure. However, using a mix of road surfaces may complicate both original construction and future maintenance, and if an early decision is made to adopt a low noise road surface throughout the length of a scheme, then this could bring widespread benefits and its use could be considered to be amelioration.

Noise Amelioration

5.4 The importance of optimising the road configuration during the Constraints Study and the Route Selection process has already been emphasised. This can be regarded as mitigation intrinsic to the basic route design and is perhaps best distinguished by using the term amelioration.

5.5 This guide aims to provide the design team with a ready means of appreciating the effect of road configuration – including horizontal and vertical alignment and selection of road surface type - on the spread of noise.

5.6 Appendix A contains a set of graphs which can be used at an early stage to give an indication of the magnitude of the footprint for a particular road.

5.7 This section provides information on the source to receiver distance at which the design goal would be met with various road configurations. It should be used with caution, as it cannot take into account all local variations in propagation conditions, and does not replace the detailed calculations of CRTN. It should be noted that noise levels change quite slowly with distance from the road, particularly beyond 100 m, and so small variations in propagation conditions can cause the design goal distance to change significantly. Designers should therefore be aware that the charts are not appropriate for assessment of precise separation distances.

5.8 The graphs represent four different vertical configurations:

- At grade
- Deep cutting
- False cutting
- High Embankment

5.9 For the At grade, False cutting and Deep cutting configurations there are four separate graphs covering different receiver heights and different traffic speeds, thus:

- 4m high and 120km/h
- 4m high and 100km/h
- 1.5m high and 120km/h
- 1.5m high and 100km/h

5.10 For the Embankment configuration, two separate scenarios are considered: (i) a road on an 8m Embankment and (ii) a road on an 4m Embankment. For both scenarios four separate graphs are provided covering different receiver heights and different traffic speeds, thus:

- 4m high and 120km/h
- 4m high and 100km/h
- 1.5m high and 120km/h
- 1.5m high and 100km/h

5.11 Finally, each of the 20 graphs present four curves, one each for:

- 15% heavy vehicles and a HRA road surface
- 5% heavy vehicles and a HRA road surface
- 15% heavy vehicles and a Low Noise road surface
- 5% heavy vehicles and a Low Noise road surface

5.12 A correction of 3.5dB is applied to the assessments involving low noise road surfaces. This assumes the correction has been validated with site specific measurements. None of the configurations include barriers other than those which are intrinsic to the configurations themselves. Thus, the lip of a deep cutting will have a barrier effect for most properties, as will the edge of an embankment for some properties. These effects are intrinsic to the configuration and are taken into account in the graphs.

5.13 A conscious decision has been taken not to include graphs with additional panel barriers. One of the objectives of the graphs as design tools is to assist road engineers in producing early designs with a minimised requirement for additional local mitigation by barriers.

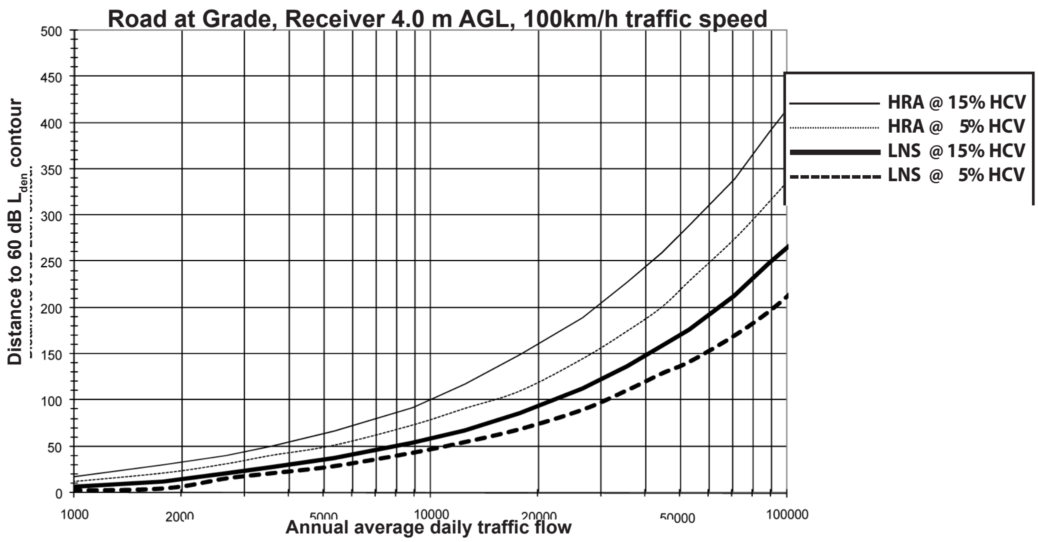
Example of using noise footprint graphs

5.14 An example of a noise footprint graph is presented in Figure 5.1.

5.15 This example is for a situation in which the road is at grade, and the traffic speed is 100km/h. Curves are presented for flows with 5% and 15% heavy vehicles, and for a HRA road surface and a low noise road surface (abbreviated to LNS). It is applicable where the dwellings are two-storey, so the prediction height is set at 4m.

5.16 The traffic flow is known and the graph can be read from the x-axis which is arranged on a logarithmic scale. (We will assume a flow of 20,000 vehicles). Assuming that the road surface is HRA and there are 15% heavy vehicles in that flow the upper curve indicates that the distance from the edge of the nearest running lane to the point at which the L_{den} value has declined to 60dB L_{den} is some 160m. Any two-storey property which is within that distance is likely to require a decision on local mitigation at a later design stage. Conversely any property which is further than 160m away is unlikely to require that local mitigation be considered.

Figure 5.1 - Sample Noise Footprint Graph



5.17 One design option may be to adjust the horizontal alignment of the road so that the actual distance to properties becomes greater than 160m. Thus the properties are no longer likely to be exposed to a level above 60dB L_{den}, and local mitigation is no longer likely to be required. Of course there must be proportionality in pursuing such an option, balancing the number of properties and the degree of benefit against any consequent increase in costs.

5.18 Another design option may be to specify a low noise road surface. The distance to the 60dB L_{den} contour falls to some 90m. A property which is between 90 and 160m from the edge of the nearside running lane which would require consideration of local mitigation where the road surface is HRA, but would not require local mitigation if a low noise road surface is used.

5.19 A third design option may be to use a different vertical configuration, for example to increase the land take to accommodate a false cutting.

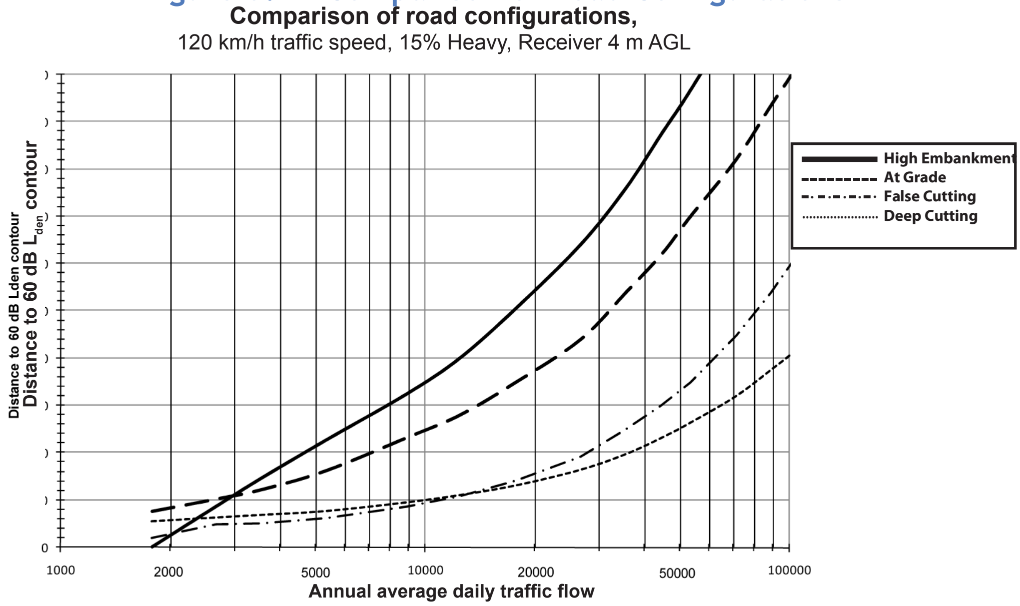
5.20 Figure 5.2 shows the different consequences of different road configurations. (For present purposes the Figure assumes 15% heavy vehicles at a traffic speed of 120km/hr, a HRA road surface and a receiver height 4 m above local ground level).

5.21 As can be seen, the different road configurations result in significantly different noise footprints. It is clear that a high embankment results in a relatively large footprint. Obviously high embankments are not introduced other than where the local topography necessitates that they be used. However, where the graph indicates that properties would fall within the 60dB L_{den} contour there is an early indication that local mitigation is likely to be required and the embankment width could be adjusted to accommodate that mitigation.

5.22 Compared with the at-grade configuration a false cutting shows a significant benefit, which gets larger as traffic flow is increased. Even at flows below 10,000 per day the reduction in the footprint from around 100m to around 50m may result in a considerable reduction in the number of properties which will later require consideration of local mitigation. A deep cutting performs even better than the false cutting at higher traffic flows.

5.23 Figure 5.2 shows some discontinuities for flow values of less than about 3,000 vehicles per day, where the 60dB L_{den} contour will be close to the road. In the case of an embankment and false cutting, this is because the embankment/bund edge screens the property from the source line, and so the 60dB L_{den} contour becomes very close to the edge of the road. However, in the case of a deep cutting, a property close to the edge of the cutting may have a direct view down into the cutting, so noise levels are rather higher, which keeps the 60dB L_{den} contour further from the edge of the road. It should be noted that the graphs presented in this document are for indicative purposes only and they do not eliminate the need to undertake detailed modelling.

Figure 5.2 - Comparison of Road Configurations



Road configuration assumptions for Graphs in Appendix A

5.24 In preparing the indicative graphs presented in Appendix A, various assumptions have been made.

5.25 It has been assumed that the HRA road surface would be bituminous (black-top macadam) with a 2mm surface texture, for which CRTN advises that the road surface noise has a reference value of 0dB. This is the road surface noise correction recommended for this road surface in this guidance. New road surfaces are commonly laid with a nominal surface texture of 1.5mm, which could therefore be marginally quieter than this assumption, although there is such a wide variation even in newly-laid surfaces that the assumption of 2mm is reasonable and may provide a small margin of safety.

5.26 The charts also include a case where a low-noise road surface is used. It has been assumed that this surface will be 3.5dB quieter than standard bitumen.

5.27 All distances are measured from the nearside kerb or the edge of the nearest running lane. In all cases it is assumed that the intervening ground is level and acoustically soft, i.e., grassland, cultivated or wooded ground cover.

5.28 The traffic flows shown in the graphs are in terms of 18-hour flows which are the basis of noise predictions made using CRTN. Annual average daily traffic (AADT) flows are commonly used by traffic engineers. 18-hour flows are usually about 95 % of the AADT flows, but within the tolerance of the graphs, they can be treated as being the same (the actual difference is about 0.2dB).

5.29 The vertical road configurations are as follows:

- **At-grade** – the road is level with the surrounding ground.
- **False cutting** – the road is cut into the surrounding ground to a depth of 1m and has a bund of 2m above ground level running alongside it. The side-slopes of the cutting and bund are 'natural' i.e. not strengthened, and so have a slope of one in three. This fixes the position of the top of the cutting and top and bottom of the bund, relative to the road.
- **Deep cutting** – the road is cut into the surrounding ground to a depth of 5m and has a natural side-slope of one in three. This fixes the distance of the top of the cutting from the road.
- **High embankment** – the road is on an embankment which is 8m above the surrounding ground and separately on an embankment which is 4m above the surrounding ground. The embankment has a natural side-slope of one in three, which fixes the position of the bottom of the embankment from the road.

5.30 Charts have been produced for a height of 4m above local ground and for a height of 1.5m above local ground. The receiver height influences the amount of screening produced by cuttings and bunds, and also the amount of ground absorption that occurs. Noise levels will therefore normally be lower at a 1.5m receiver than at a 4.0 m receiver at a given distance from the road as can be read from the graphs.

5.31 The graphs are generated for traffic speeds of 100 and 120km/h.

5.32 The position of the closest receiver is affected by the road configuration. For example, the foot of an 8m embankment with a one-in-three side-slope is 24m from the edge of the road (in practice, the width of the embankment is likely to be greater to provide access and safety features).

5.33 The graphs also assume that the vertical configuration is constant over a significant chainage. In practice this may not be true. Where the alignment of a road varies from cutting to at-grade and then to embankment, the width of the footprint will change, in this case getting wider and wider. It is still possible to use the graphs to get an early indication of the approximate shape of the footprint, by smoothing out the transitions between the different distances taken from different graphs. A design margin can be built in by assuming that the footprint remains at its greatest extent until after the end of the configuration that generates that extent, and tapers down to the lower extent within the length of the adjacent configuration.

5.34 There are limits to their applicability. As simple tools that are unable to deal with such things as complex junctions. They should not be used in urban areas where much screening will be provided by existing buildings.

5.35 A word of caution is in order. The graphs are not presented as a detailed design tool. They in no way replace the predictions that will still have to be produced using sophisticated noise software. They are offered to give the road design team an early indication of the magnitude of any noise impact that may arise from a proposed scheme, so that they are assisted in the production of noise-sensitive road designs. (They might also be used as a simple "reality check" on the output of noise models.)

Additional Local Mitigation

Road surface

5.36 While there are other considerations that may affect the choice of road surface, there can be no doubt that a low noise road surface is almost always the preferred solution for noise control. The only exception would be where there is no noise-sensitive property in the area capable of benefiting from the noise reduction. It is understood that contractors do not like to change road surfaces along the length of a road. As such, if there is benefit to be gained in any one stretch, a low noise road surface is preferred on acoustic grounds throughout.

5.37 In almost any noise control exercise reduction of noise at source is the preferred option, and that generalisation includes roads. Achieving a reduction of around 3dB by other means, such as approximately doubling the distance to the road, or increasing the dimensions of a barrier, will seldom be preferred, on acoustic grounds, to the use of a low noise road surface.

5.38 It might be argued that a low noise road surface should only be used where traffic volumes exceed a certain threshold. However noise exposure depends not only on the traffic volume, but also on proximity, road configuration and all the other factors which are addressed in CRTN. It would be inequitable to include mitigation on grounds of traffic volumes, but to exclude it where proximity is a major factor in creating high levels of exposure. NRA standards have been revised to include the use of polymer modified stone mastic asphalt surface coatings (Clause 942).

Screening

5.39 After adopting a noise-sensitive horizontal and vertical alignment, and after considering the use of a low noise-road surface, it may be that some predicted levels are still above the NRA design goal of 60dB L_{den} and further local mitigation must be considered. The only remaining option may be screening.

5.40 Noise barriers are generally most effective for receivers close to the road, but barriers must be high enough to cut the line of sight between the road surface and the receiver. This makes it difficult to screen properties which are on high ground overlooking the road. In some European cities, barriers that overhang the road have been used.

5.41 Attempts have been made to design barriers with special diffracting top edges in an attempt to increase the noise reduction that they provide, but at this time, these have had limited success and have not been adopted into general use in Ireland or other countries. This should not discourage future innovation in barrier design.

5.42 Barriers are also relatively ineffective at screening properties at some distance from the road (say more than 100m) as the barrier effect is **not** additional to the effect of attenuation by the intervening soft ground: instead the barrier replaces this component of noise attenuation. This means that many schemes have been designed with very long and very high barriers that achieve little effect. It is questionable whether this is a sustainable approach.

5.43 In many situations the benefit to be gained by the insertion of a barrier is limited. Research has shown that about half the barriers specified in recently-produced EISs result in a noise reduction of 3dB or less, and 3dB is widely acknowledged to be the smallest change that will give a reliable difference in public response.

5.44 In normal circumstances, the acoustic performance of a barrier is limited by the sound travelling through, around and over the top of the barrier. The amount of sound travelling through the barrier can be neglected if the barrier has sufficient superficial mass. Thus, a barrier required to give 10dB of screening should have a superficial mass of not less than $3kg/m^2$. However, it should be noted that ISO 9613-2[9] (1996) specifies a minimum density of $10kg/m^2$.

5.45 The form of the barrier does not affect the amount of acoustic screening it provides. The significant parameter is the amount by which the diffracting edge (the top of the barrier) cuts through the line of sight between the source and the receiver. Screening can be achieved equally effectively by earth bunds or by panel barriers. Provided space and material is available, bunds are usually the preferred option. Where space is more limited, then a panel barrier can be surmounted on an earth bund, a system used effectively in some other countries. Landscaping can then disguise the presence of both the bund and the panel barrier. It should be noted that trees and shrubs, in normal depth and density, provide no significant noise reduction.

5.46 If space is not available for bunding, or a bund is not considered to be locally appropriate, a panel barrier may be used. The material used for panel barriers has little effect on attenuation, provided it has sufficient superficial mass and integrity, as required by NRA Circular 11/2006 revised. Noise barriers are required to meet the performance specified in the EN 1793[10] and EN 1794[11] series. EN 1793 addresses the acoustic performance of panel barriers in terms of insulation and where appropriate absorption. The NRA requires that all panel barriers to be used on national roads should have been tested according to these standards, and to have attained the required level of performance.

5.47 EN 1794 addresses non-acoustic considerations. These include resistance to brushwood fires, the elimination of danger from falling debris if a panel is damaged, a demonstration that there would be no environmental pollution from the breakdown of materials used in the panel, provisions for escape through doors in the barrier and the detailing of those doors. A garden fence will not meet these requirements.

5.48 EN 1793-3, EN 1793-4 and EN 1793-5 are currently under revision. A new part, EN 1794-3 Reaction to Fire, and a new topic on Sustainability, are also being prepared.

5.49 When specifying panel noise barriers it is important that consideration be given to acoustic performance being maintained throughout the design life and the means by which that performance can be maintained. This may affect the choice of materials.

5.50 Research by Watts and Godfrey[12] shows that reflections from noise barriers have a very small effect on noise levels and it is recommended that the situation should be carefully analysed before specifying noise-absorbent barriers.

5.51 In some cases, transparent materials have been used for barriers, but they are often subject to graffiti and other vandalism which is expensive to repair.

5.52 The choice of material should be appropriate to the local context. Timber barriers may be appropriate in a rural area, particularly if they surmount a noise bund, or their visual impact is reduced by planting. However, in urban areas, masonry walls may provide a greater resistance to vandalism.

5.53 In an urban area the early stages of design may have made it clear that noise is a highly significant issue, and extensive barriers are likely to be required. This is an early signal that the barrier treatment is going to have significant visual impacts. Space for landscaping is unlikely to be available. The design team should therefore consider what architectural treatment would be appropriate, reduce any adverse visual impact, or even add attractive features in the local context.

5.54 Apart from the above guidance, it is difficult to provide general advice on optimising the location, height and length of a noise barrier in order to meet the design goal. In general, a shorter, higher barrier will be found to be more cost-effective than a longer, lower barrier to protect a property, but above a height of about 3m, a barrier becomes a significant structure, requiring engineering to be considered. This does not rule out the use of higher barriers, but it may be necessary to use professional judgement to compare the increasing cost of the barrier against perhaps limited acoustic gains.

5.55 Appendix B presents a Good Practice Guide for noise barrier design.

Proportionality

5.56 A review of recently produced EISs noted that barriers of several hundreds of metres long and up to 4m high are not unusual, sometimes for the protection of one or two noise-sensitive properties. It is reasonable to question whether the benefit gained is proportionate to the cost and visual intrusion of the mitigation measure.

5.57 The *Guidelines* recognise that in some cases the attainment of the design goal may not be possible by sustainable means.

5.58 Good practice should seek to reduce the need for barriers by the early attention to noise amelioration which is inherent in the scheme. Where the design goal is still exceeded, and there is no better option, barriers should be considered in an attempt to reduce noise exposure to the design goal, (or to the noise level which would exist at the same time under a Do Nothing scenario if this is higher). But after an optimal barrier design has been arrived at on acoustic grounds it should be tested against other criteria of reasonableness or proportionality.

5.59 One such test would be whether the barrier dimensions can be significantly reduced in footprint, length or height without the predicted level being materially increased. There are no formal definitions of a 'significant' reduction in barrier dimensions or a material increase in sound level. For the purposes of the present Guidance, in terms of barrier dimensions, it would be relevant to consider land take, visual intrusion and engineering practicalities in addition to construction costs. In terms of a material increase in noise level, it is noted that the *Guidelines* require a 1dB increase in the relevant noise level as one condition for local mitigation and they also define 1dB is the smallest difference that can be detected in a controlled laboratory situation. A significant decrease in barrier dimensions which would result in an increase of 1dB or less, may be reasonable. Conversely, it may be unsustainable to increase barrier dimensions significantly where the result would be a reduction of 1 dB or less, as such a reduction would be close to imperceptible in a laboratory situation, and would not result in a difference in public response in the real-world environment. A number of other countries go further and preclude the use of barriers where the effect of the barrier would be a reduction of less than 3, even 5dB.

5.60 The result may be that the predicted noise level, with mitigation, is above, often marginally above, the design goal. The NRA *Guidelines* allow for that to occur. The judgement in a particular case that it is reasonable not to increase barrier dimensions when there are diminishing returns is a legitimate professional judgement, which should be made clear and can be tested at Oral Hearing.

Checklist for acoustic design and mitigation

Early Design and Amelioration

- ✓ Draw the attention of the Design Team, to the noise footprint in the Constraints Study. Is noise a major or minor concern in this scheme?
- ✓ Graphs of distance to 60 L_{den} contour. Explain how they can be used.
- ✓ Generate the noise footprint graphically and consider whether the initial alignment should be altered.
- ✓ Consider the use of a low noise road surface.
- ✓ Consider where there are properties within the 60 dB L_{den} contour whether land take would be sufficient for bunds or a false cutting could be justified.

Additional Local Mitigation

- ✓ Where local mitigation is required can bunds be used, or are panel barriers the only available option?
- ✓ What is the locally appropriate material?
- ✓ Determine the optimal barrier dimensions.
- ✓ Check that the recommended barriers are proportional to the benefits achieved. Could the barrier size be reduced without a material increase in noise exposure?
- ✓ Ensure that the recommended barrier location, length and height is clearly defined on a map. Ensure that the reference level for the height of each barrier is clear, e.g. 3.5m above local ground, 2.5m above local road level, etc., especially when engineering work may change local ground or road heights.
- ✓ Prepare a table specifying the recommended barriers, the properties that benefit from those barriers and the magnitude of that benefit.
- ✓ Explain the reasons why the design goal cannot be achieved without disproportionate mitigation at specific locations.

6. Construction Noise and Vibration

Construction noise

6.1 Table 1 of the NRA's *Guidelines* sets out the following indicative levels of acceptability for construction noise, with the comment that more stringent limits might be appropriate in areas where pre-existing noise levels are low.

Table 6.1 - Maximum permissible noise levels at the façade of dwellings during construction

Days and Times	$L_{Aeq\ (1\text{-hour})}$	$L_{pA(max),\ slow}$
Monday to Friday 07:00 to 19:00 hrs	70	80
Monday to Friday 07:00 to 19:00 hrs	60	65
Saturday 08:00 to 16:30 hrs	65	75
Sundays and Bank Holidays 08:00 to 16:30 hrs	60	65

6.2 Except for emergency work, construction activity on Monday to Friday evenings, on Sundays and on Bank Holidays, and work outside the times indicated above, will normally require the explicit permission of the relevant local authority.

6.3 There is limited information available on construction methods, plant and equipment before the appointment of Contractor, which usually happens after an EIS has been prepared and accepted. This limits the scheme-specific information that can be incorporated into an EIS.

6.4 Nevertheless, it should be possible to address the way in which construction impacts will be assessed and how they will be dealt with, including potential forms of mitigation and any code of practice or construction noise management plan that will be applied. In the absence of an Irish or international standard relevant to construction noise, reference can be made to BS 5228: Part 1: 2009[13].

6.5 Estimates of the overall duration of construction works and the proposed hours of working should be available. Any locally applicable limits on construction noise should be noted. The location of major earthworks or blasting should also be noted and the locations where particularly noisy activities such as piling and ground consolidation are to be expected.

6.6 Any areas or activities that require night-time working should also be reported.

6.7 It is well-recognised that good communication with the general public will reduce the incidence of complaints, and this should be addressed.

Construction vibration

6.8 The NRA's *Guidelines* point out that there are two separate considerations for vibration during the construction phase: that which affects human comfort and that which affects cosmetic or structural damage to buildings. There is a third category: that which affects sensitive equipment or processes, which could include installations concerning gas, water, electricity and telecommunications.

6.9 The *Guidelines* suggest that human tolerance for daytime blasting and piling, two of the primary sources of construction vibration, limits vibration levels to a peak particle velocity (ppv) of 12mm/s and 2.5mm/s respectively.

6.10 To avoid the risk of even cosmetic damage to buildings, the *Guidelines* suggest that vibration levels should be limited to 8mm/s at frequencies of less than 10Hz, to 12.5mm/s for frequencies of 10 to 50Hz, and to 20mm/s at frequencies of 50Hz and above.

6.11 In practice, this means that for occupied buildings, human tolerance is normally the factor which limits vibration acceptability. However, some types of sensitive equipment could have even less tolerance than humans.

6.12 It is difficult to predict the magnitude of vibration that a construction activity will generate, as this depends not only on the activity itself, but also on the nature of the intervening ground, the type of building foundations, and way that the building is constructed.

6.13 Moreover, it is acknowledged that the availability of information on construction activity is inevitably limited at the time that the EIS is prepared. Nevertheless, efforts should be made to report any scheme-specific information that is available.

6.14 This should including noting where vibration-causing activities may be used, such as impact piling, vibratory compaction and blasting. The applicable limits for vibration should be stated, and any management plan to limit the adverse impact of vibration should at least be outlined.

Checklist for construction noise and vibration

- ✓ Provide a generic discussion of construction noise and vibration.
- ✓ Set out a table of construction noise and vibration limits.
- ✓ Scheme-specific information on major noise-generating works, their location and likely duration and the plan managing these.
- ✓ Identify and describe any vibration-inducing construction activities and the plan for managing these.

7. Operational Vibration

7.1 Ground vibration produced by road traffic is unlikely to cause perceptible structural vibration in properties located near to well-maintained and smooth road surfaces. Therefore this aspect should not generally constitute an issue and a generic discussion will usually be sufficient.

7.2 Nevertheless, good practice would be to identify any areas at risk, particularly if there are unusual circumstances under which higher than normal traffic vibration levels may be expected. New road schemes can often reduce traffic flows through narrow streets with dwellings close by. These areas may benefit from the reduction or elimination of vibration, and this should be discussed. Where it is considered that there will be neither risks nor benefits, this should also be noted.

Checklist for operational vibration

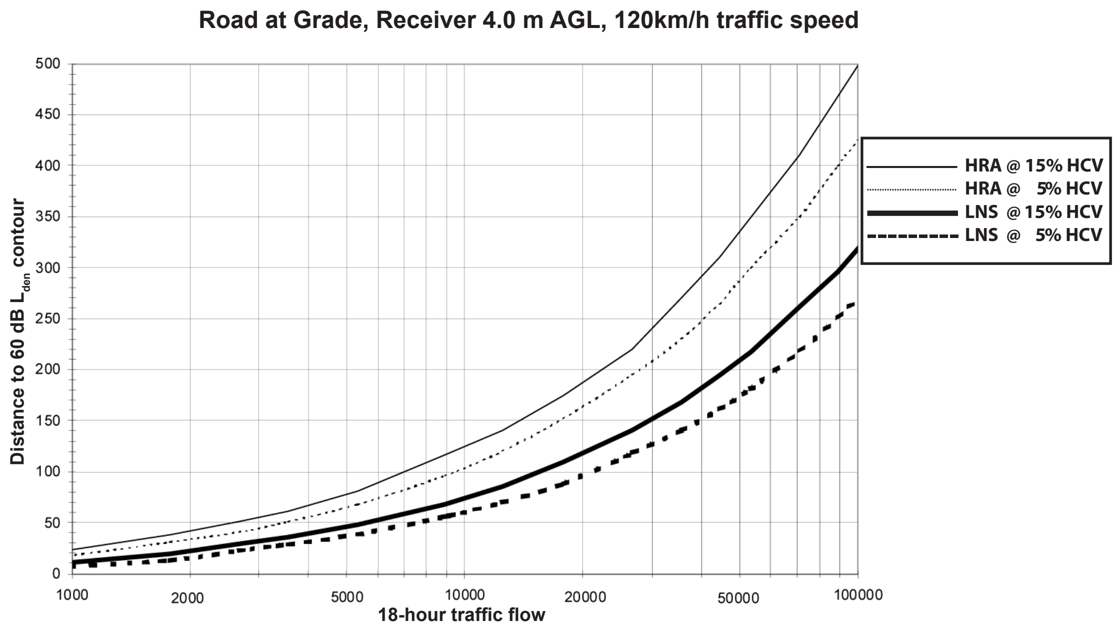
- ✓ Explain that vibration from road traffic on well-maintained roads should not give rise to concern.
- ✓ If there are unusual circumstances under which higher than normal levels of vibration or greater than normal sensitivity to vibration may occur, these should be addressed.
- ✓ Areas that may benefit from the reduced or elimination of vibration should be discussed.

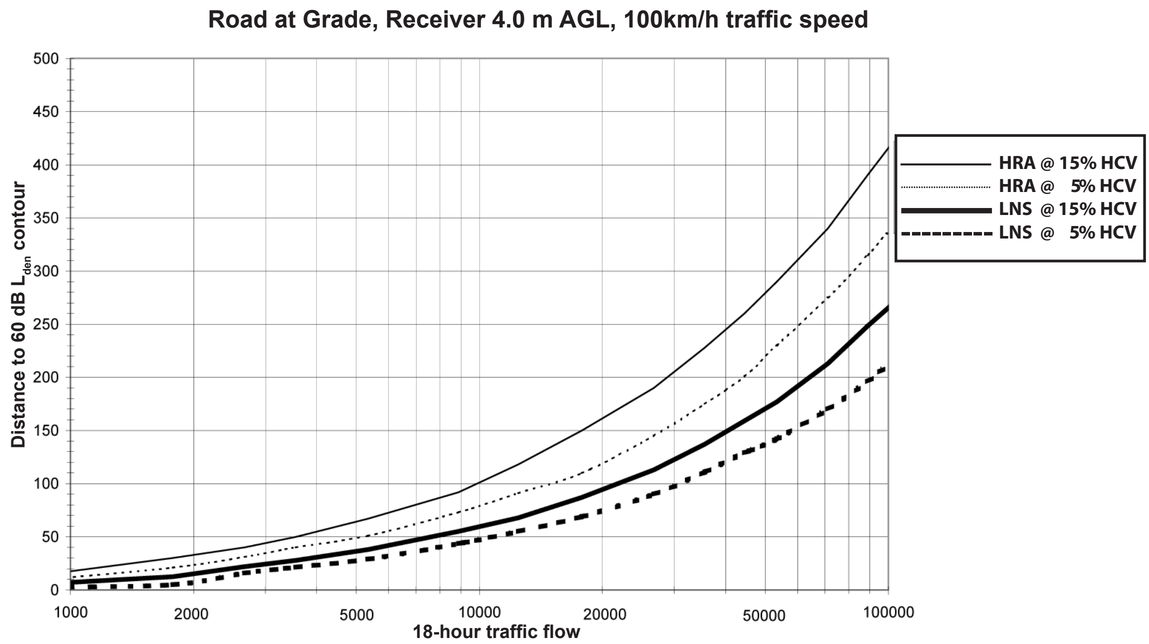
8. References

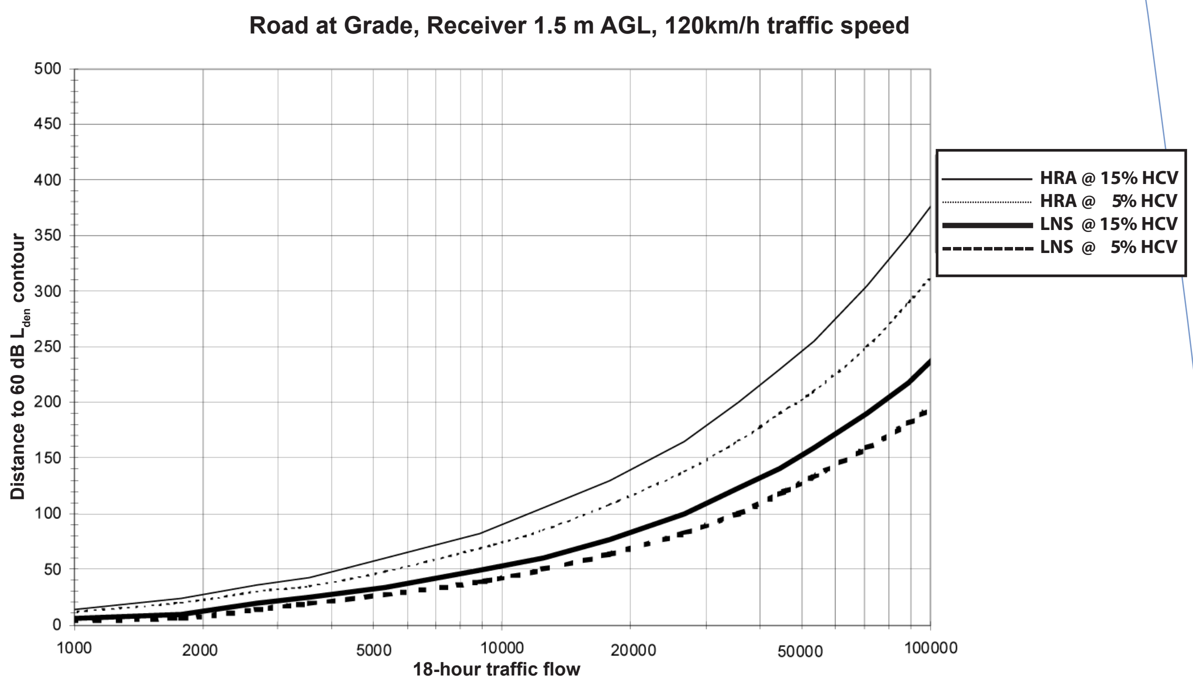
1. NRA Guidelines for the Treatment of Noise and Vibration in National Road Schemes. Revision 1, 25th October 2004.
2. National Roads Project Management Guidelines, 2000. National Roads Authority, Dublin. 2004
3. EN 61672-1:2013. Electroacoustics. Sound Level meters. Specifications
4. EN 61672-3:2016. Electroacoustics. Sound Level meters. Periodic tests
5. BS 4142:1997. Method for rating industrial noise in mixed residential and industrial areas.
6. Watts G.R. 2005 Harmonoise Prediction Model for Road Traffic Noise TRL Published Project Report PPR 034. July 2005
7. Design Manual for Roads and Bridges Revisions to Volume 11, Section 3 Part 7 UK Highways Agency HA 213/08: August 2008
8. O'Malley, V, King, E.A., Kenny, L, Dilworth, C (2009) Assessing methodologies for calculating road traffic noise levels in Ireland – Converting CRTN indicators to EU Indicators (L_{den}, L_{night}). Applied Acoustics Volume 70 (2009) pp. 284-296
9. ISO 9613-2 (1996) Attenuation of sound during propagation.
10. EN 1793 series European Standard for Road Traffic Noise Reducing Devices – Acoustic performance
11. EN 1794 series European Standard for Road Traffic Noise Reducing Devices – Non-acoustic performance
12. Watts, G R and Godfrey N S, 1999. Effects on roadside noise levels of sound absorptive materials in noise barriers. Applied Acoustics, Volume 58 1999 pp 385-402.
13. BS 5228-1: 2009. Code of practice for noise and vibration control on construction and open sites - Part 1: Noise.

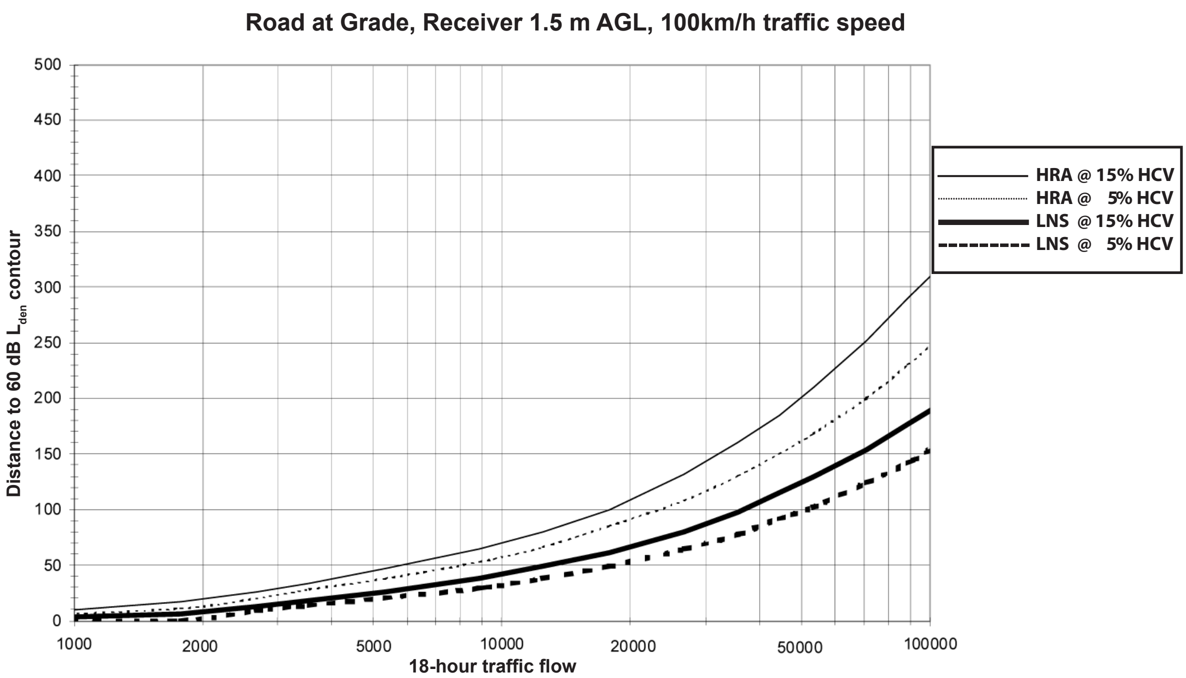
Appendix A – Intrinsic Amelioration

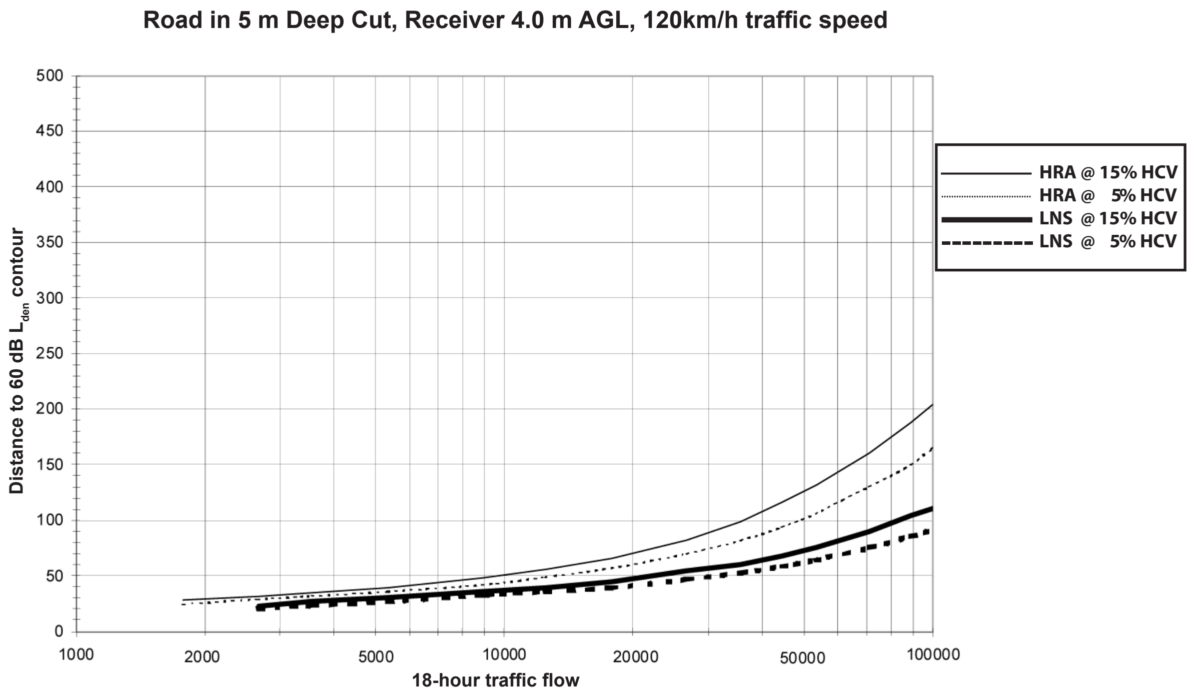
See Chapter 5 of this Guidance for advice on using these charts.

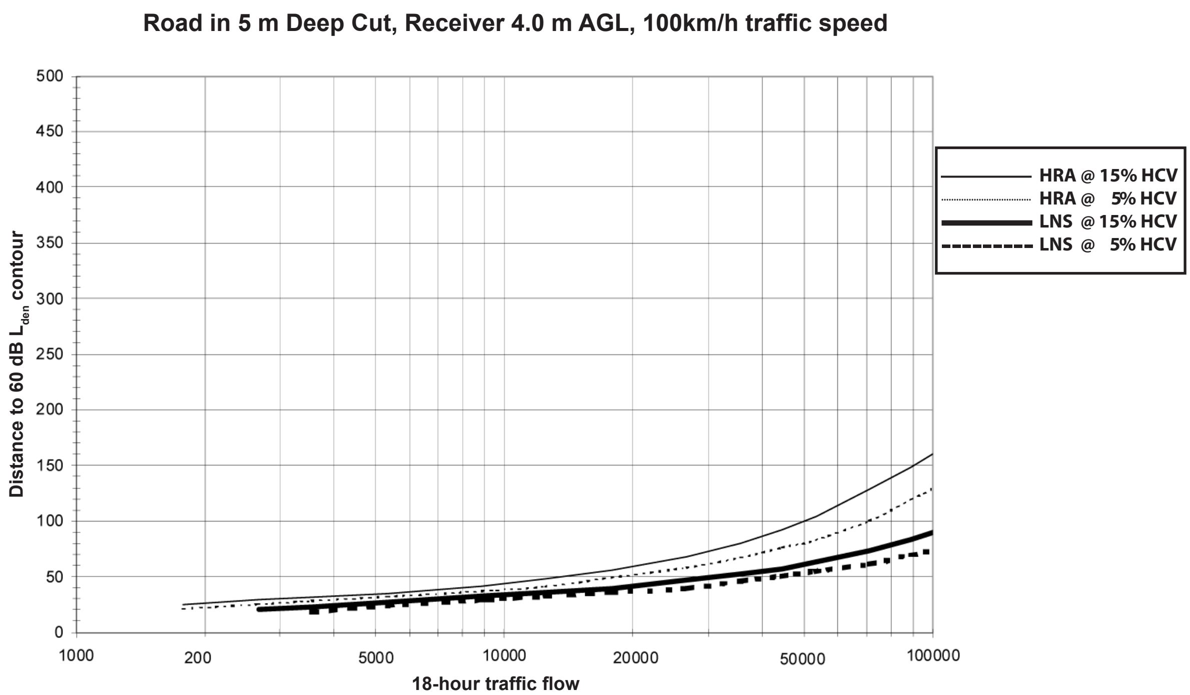


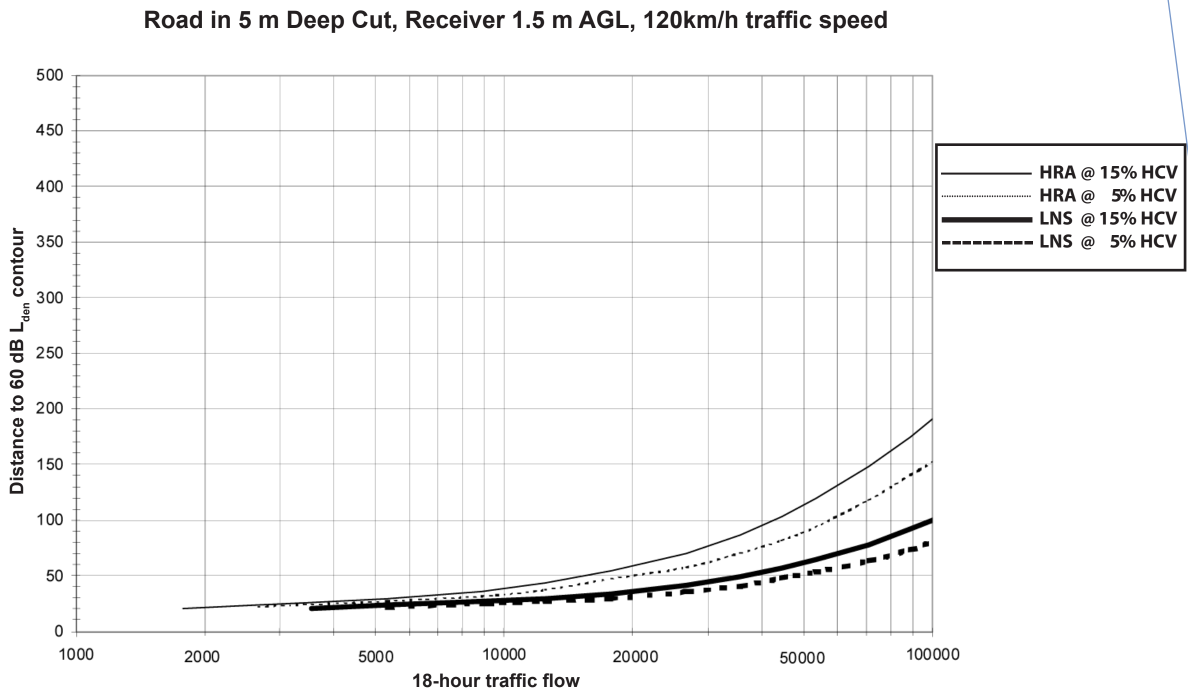


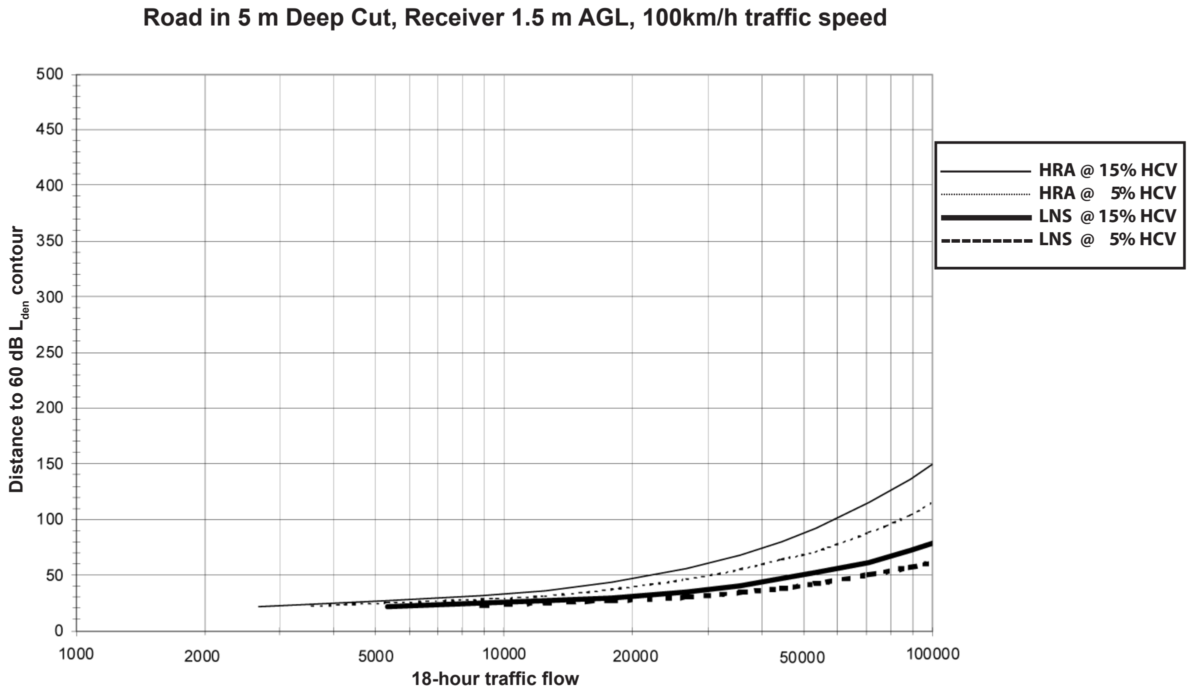

Road at Grade, Receiver 1.5 m AGL, 120km/h traffic speed
Distance to 60 dB L_{den} contour
18-hour traffic flow
HRA @ 15% HCV
HRA @ 5% HCV
LNS @ 15% HCV
LNS @ 5% HCV


Road at Grade, Receiver 1.5 m AGL, 100km/h traffic speed
Distance to 60 dB L_{den} contour
18-hour traffic flow
HRA @ 15% HCV
HRA @ 5% HCV
LNS @ 15% HCV
LNS @ 5% HCV

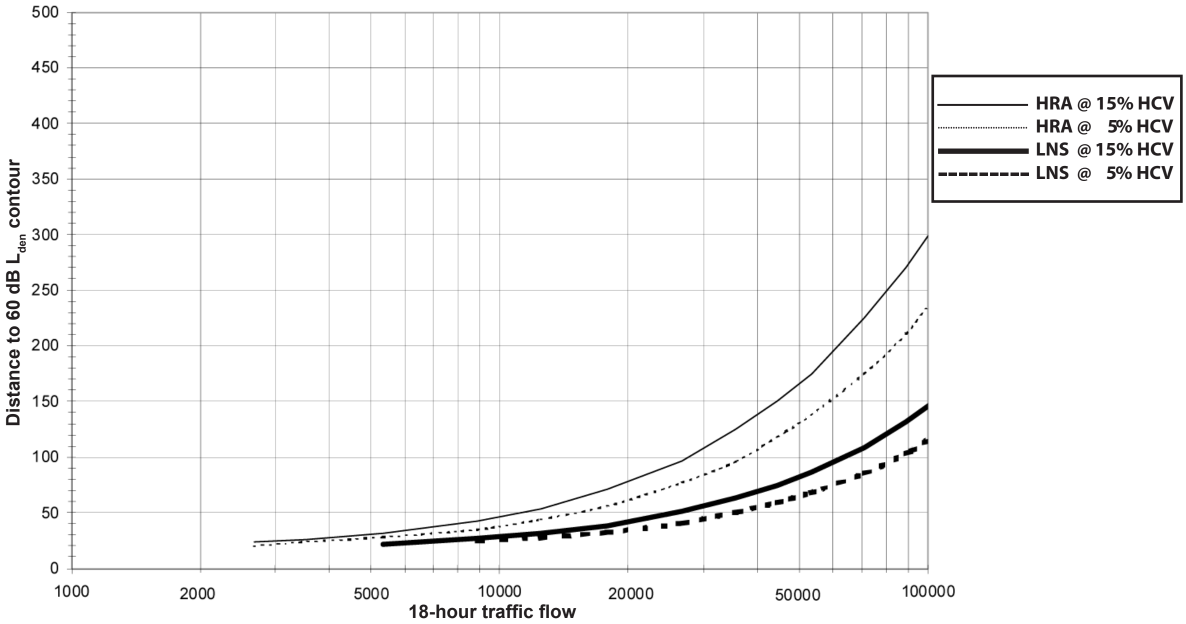

Road in 5 m Deep Cut, Receiver 4.0 m AGL, 120km/h traffic speed
Distance to 60 dB L_{den} contour
0
50
100
150
200
250
300
350
400
450
500
1000
2000
5000
10000
20000
50000
100000
18-hour traffic flow
HRA @ 15% HCV
HRA @ 5% HCV
LNS @ 15% HCV
LNS @ 5% HCV


Road in 5 m Deep Cut, Receiver 4.0 m AGL, 100km/h traffic speed
Distance to 60 dB L_{den} contour
0
50
100
150
200
250
300
350
400
450
500
1000
200
5000
10000
20000
50000
100000
18-hour traffic flow
HRA @ 15% HCV
HRA @ 5% HCV
LNS @ 15% HCV
LNS @ 5% HCV

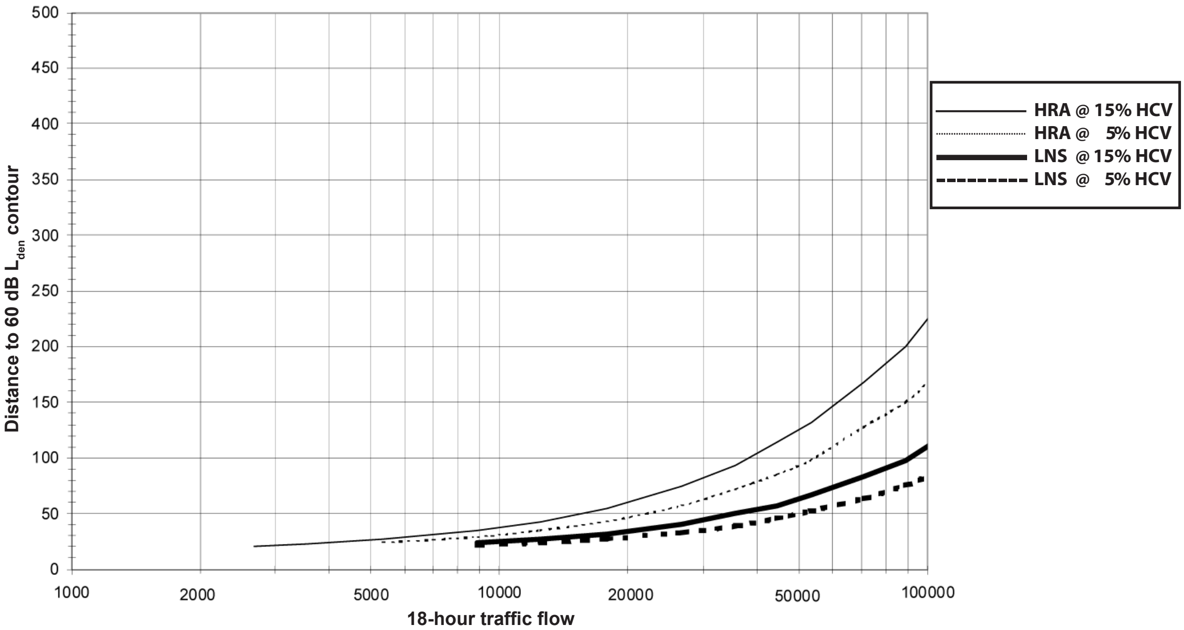

Road in 5 m Deep Cut, Receiver 1.5 m AGL, 120km/h traffic speed
Distance to 60 dB L_{den} contour
18-hour traffic flow
HRA @ 15% HCV
HRA @ 5% HCV
LNS @ 15% HCV
LNS @ 5% HCV


Road in 5 m Deep Cut, Receiver 1.5 m AGL, 100km/h traffic speed
Distance to 60 dB L_{den} contour
18-hour traffic flow
HRA @ 15% HCV
HRA @ 5% HCV
LNS @ 15% HCV
LNS @ 5% HCV

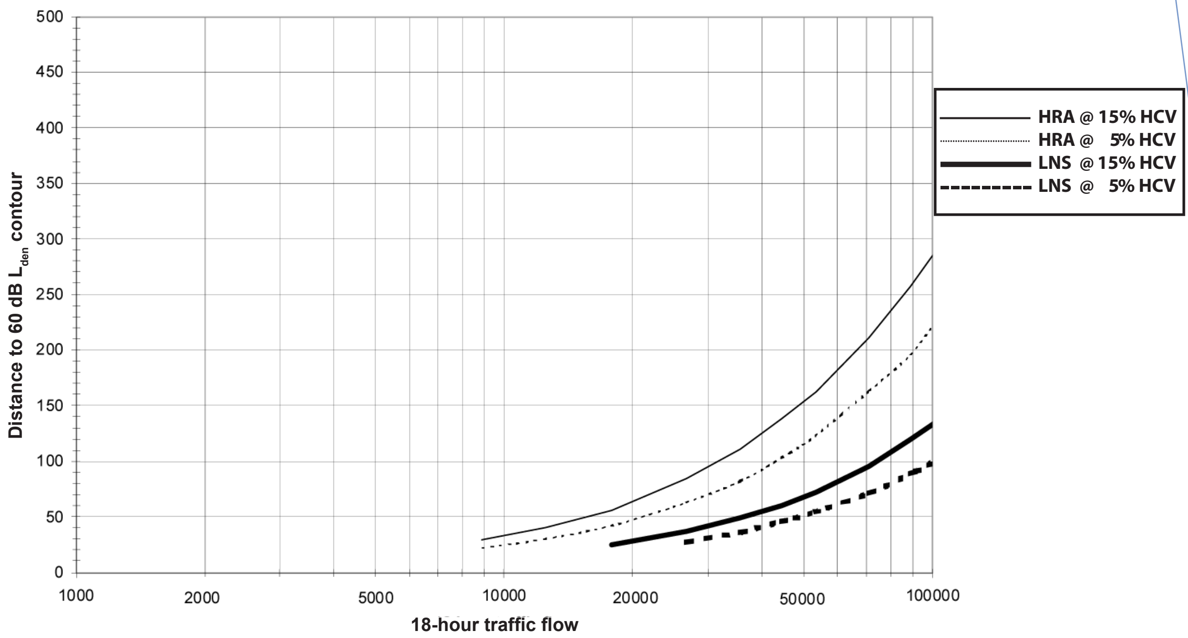
Road in False Cut, Receiver 4.0 m AGL, 120km/h traffic speed



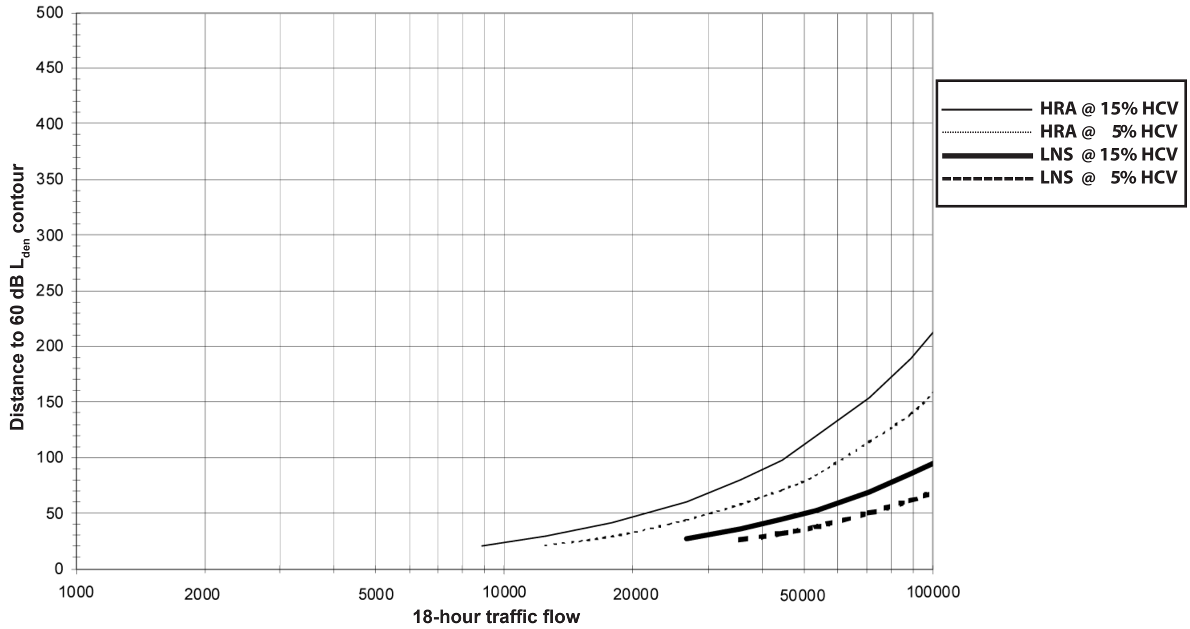
Road in False Cut, Receiver 4.0 m AGL, 100km/h traffic speed



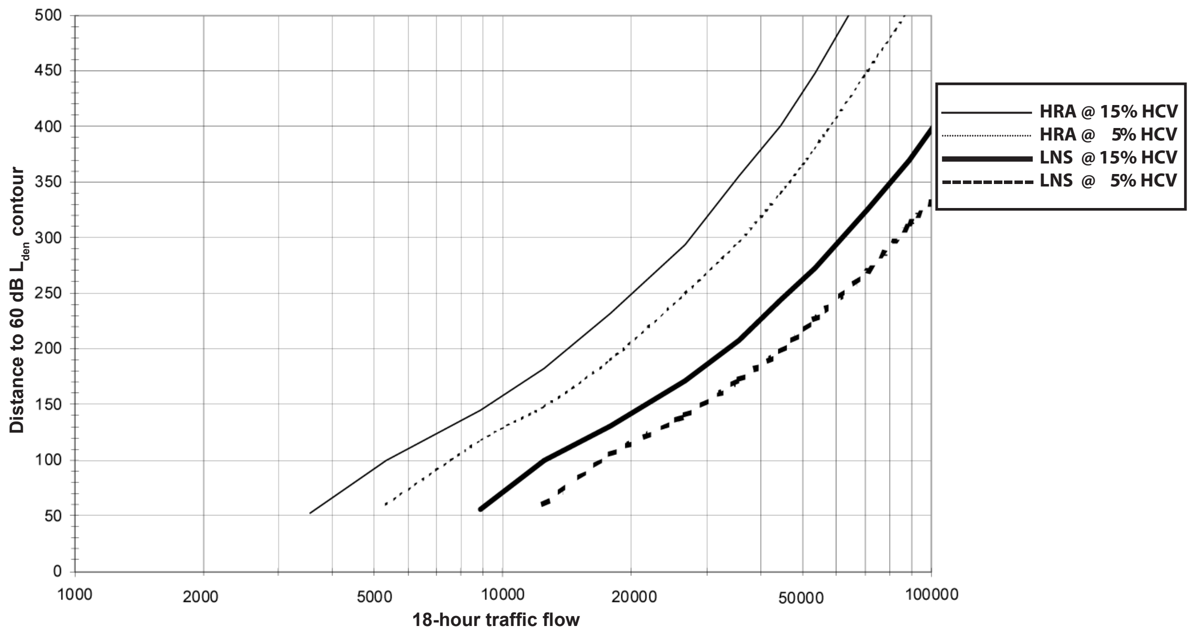
Road in False Cut, Receiver 1.5 m AGL, 120km/h traffic speed



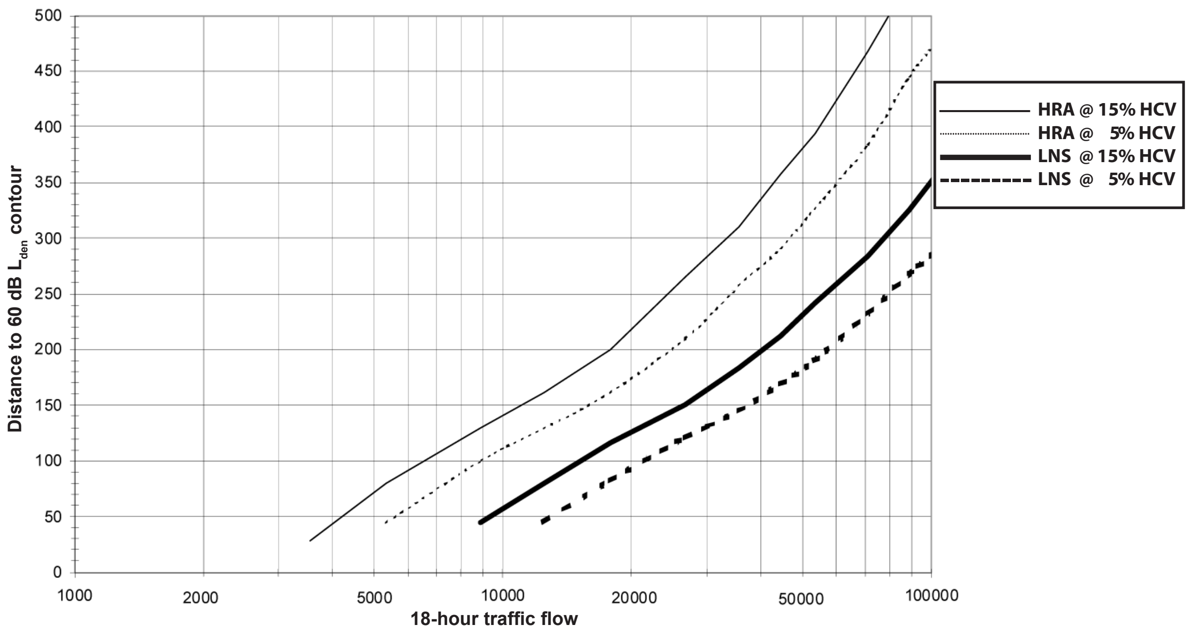
Road in False Cut, Receiver 1.5 m AGL, 100km/h traffic speed



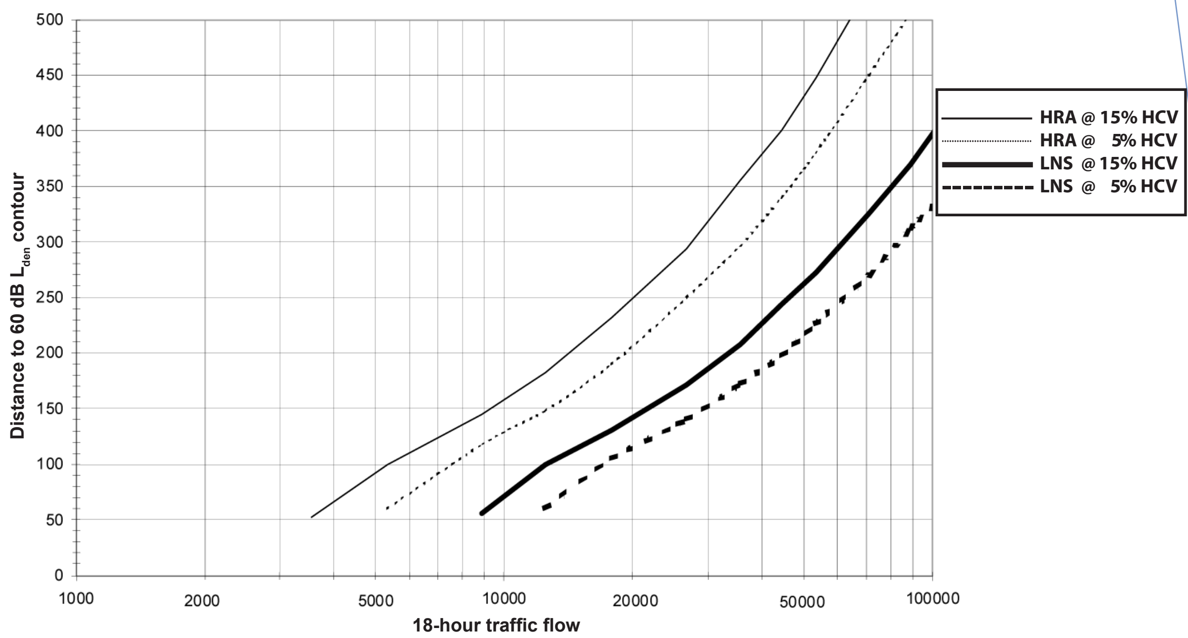
Road on 8 m Embankment, Receiver 4.0 m AGL, 120km/h traffic speed



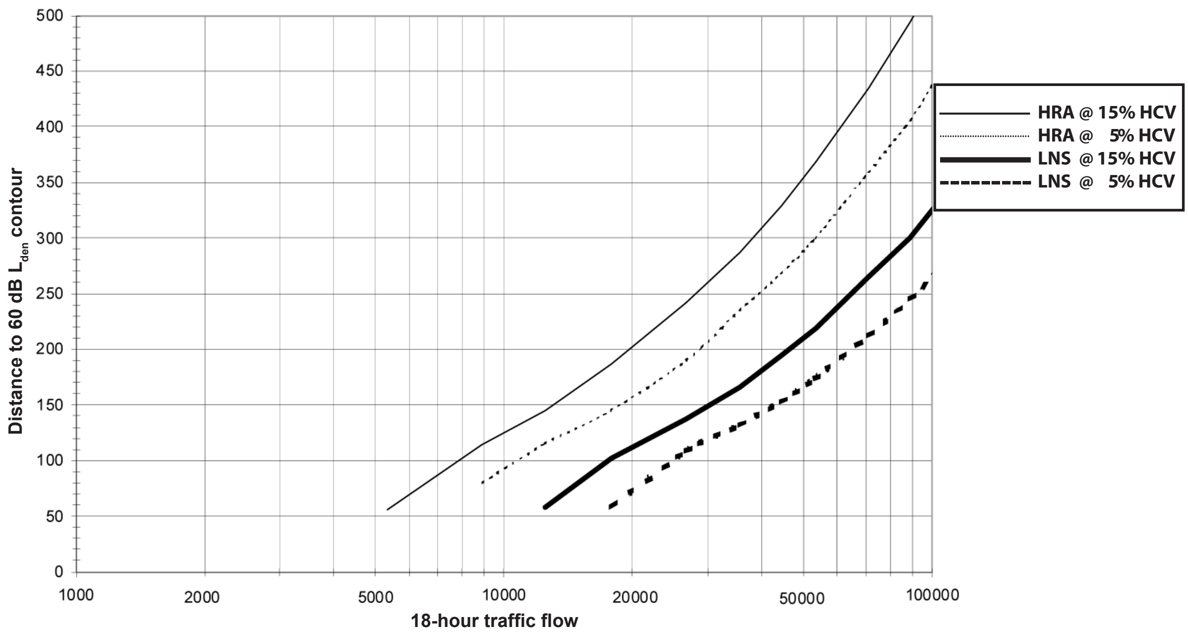
Road on 8 m Embankment, Receiver 4.0 m AGL, 100km/h traffic speed



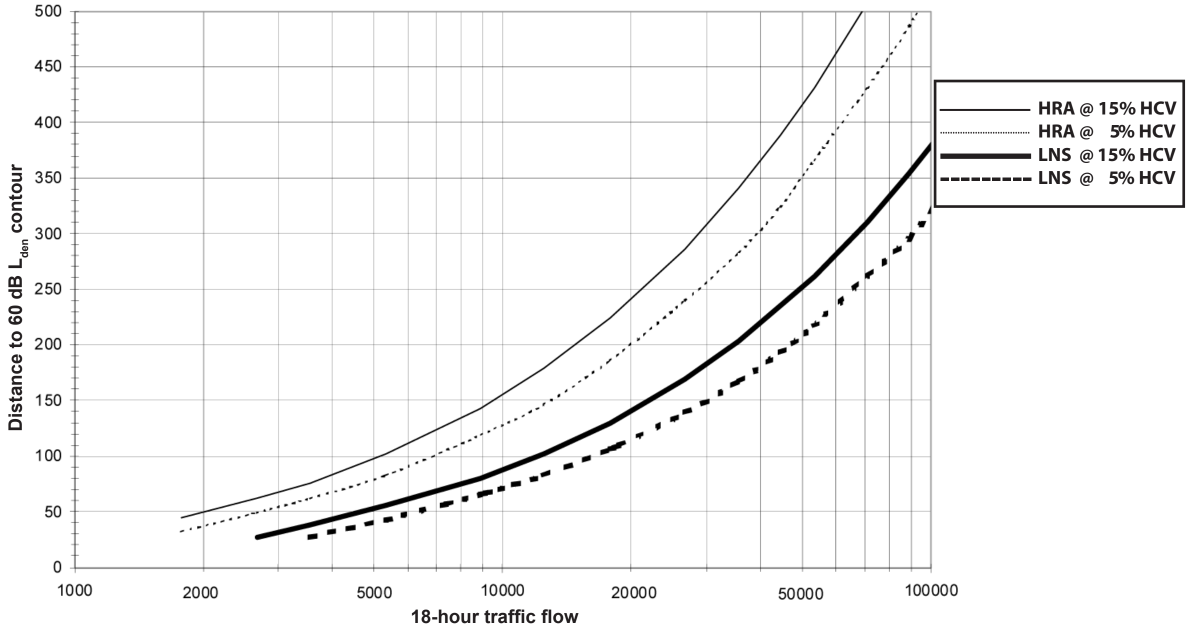
Road on 8 m Embankment, Receiver 1.5 m AGL, 120km/h traffic speed



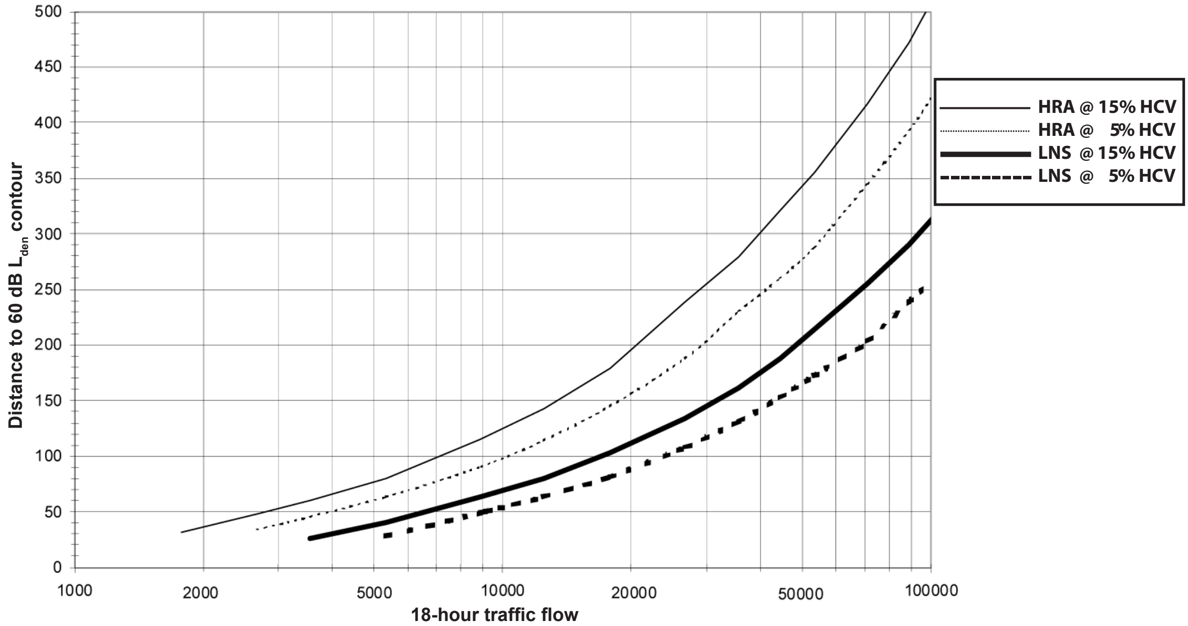
Road on 8 m Embankment, Receiver 1.5 m AGL, 100km/h traffic speed



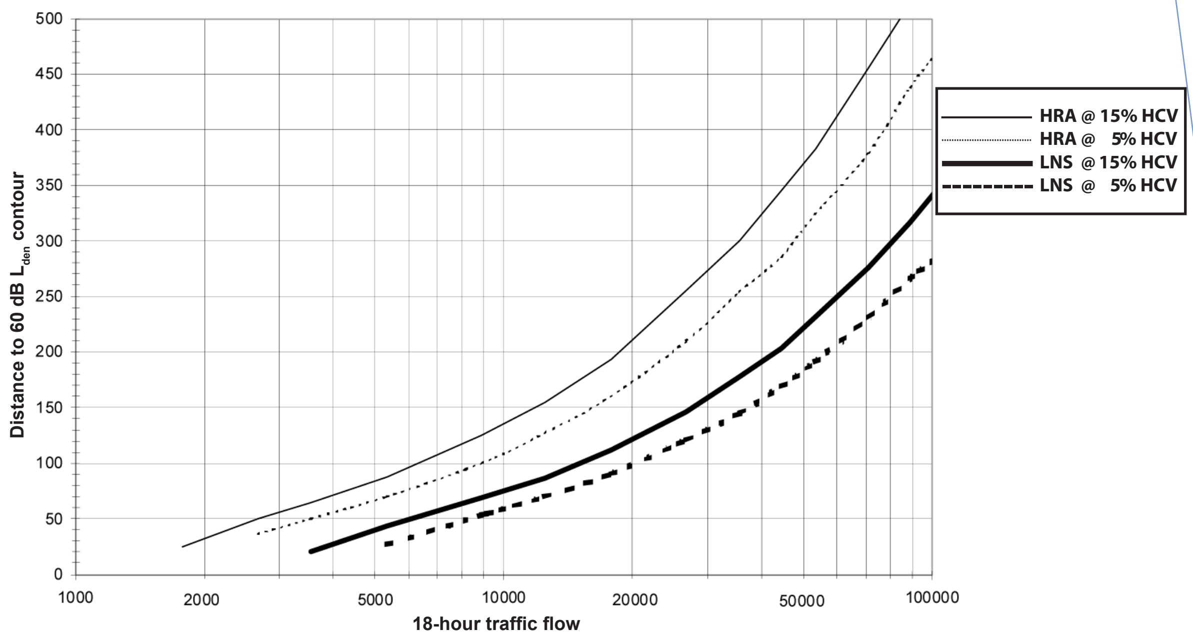
Road on 4 m Embankment, Receiver 4.0 m AGL, 120km/h traffic speed



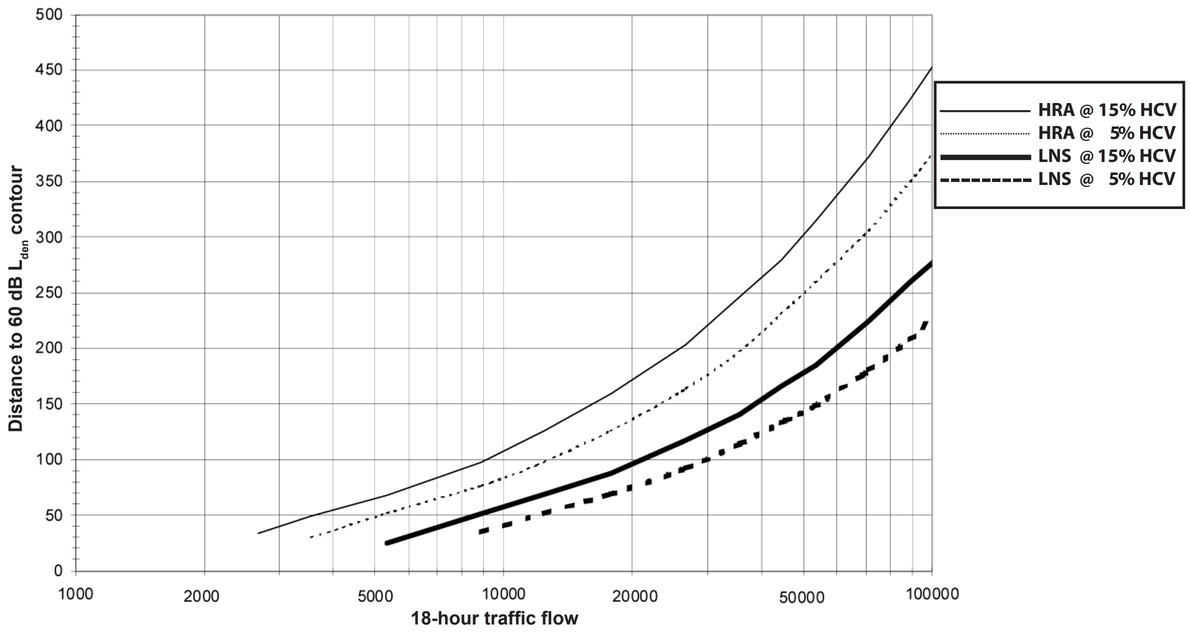
Road on 4 m Embankment, Receiver 4.0 m AGL, 100km/h traffic speed



Road on 4 m Embankment, Receiver 1.5 m AGL, 120km/h traffic speed



Road on 4 m Embankment, Receiver 1.5 m AGL, 100km/h traffic speed



Appendix B - Good Practice Guide for Noise Barrier Design

The post EIA evaluation study, that forms the basis for this document, identified that approximately 50% of all noise barriers proposed in the reviewed EISs resulted in a noise reduction of 3dB or less. This reinforced the need for improved noise barrier design in Ireland. As such, through the 2010 NRA Research Fellowship Programme, the NRA funded a post-doctoral research fellowship analysing the effectiveness of noise barriers in Ireland[1]. A deliverable of this fellowship was a Good Practice Guide for noise barrier design. This section presents observations on current noise barriers in Ireland along with suggestions for good practice in noise barrier design.

Road Traffic Noise Reducing Devices - EN 14388 (2005)

B.1 All current standards for road noise barriers are grouped together under the umbrella standard EN 14388 (2005) - Road Traffic Noise Reducing Devices - Specifications.

B.2 The standard covers the topics of acoustic, non-acoustic and long term performance, but not aspects such as resistance to vandalism or visual appearance.

B.3 Acoustic performance is covered under the EN 1793 suite. This suite includes the following parts:

- EN 1793-1: Intrinsic characteristics of sound absorption
- EN 1793-2: Intrinsic characteristics of airborne sound insulation under diffuse sound field conditions
- EN 1793-3: Normalized traffic noise spectrum
- EN 1793-4: Intrinsic characteristics in-situ values of sound diffraction
- EN 1793-5: Intrinsic characteristics in-situ values of sound reflection and airborne sound insulation
- EN 1793-6: Intrinsic characteristics in-situ values of airborne sound insulation under direct sound field conditions

B.4 Non-acoustic performance is covered under the EN 1794 suite. This suite includes the following parts:

- EN 1794-1: Mechanical performance and stability requirements
- EN 1794-2: General safety and environmental requirements

B.5 Long term performance is covered under the EN 14389 suite. This suite includes the following parts:

- EN 14389-1: Acoustical characteristics
- EN 14389-2: Non-acoustical characteristics

B.6 Revisions to the Specification and Acoustic Test Standards for Noise Barriers for use on European Highways have formally been approved and are due for publication in 2013/2014. The following parts are currently under revision:

- EN 1793-3
- EN 1793-4
- EN 1793-5

- EN 14389-1
- EN 14389-2

B.7 A new part to the EN 1794 suite; EN 1794-3 Reaction to fire, is also being prepared currently.

B.8 A new topic on Sustainability is also being prepared.

Series 300 of the NRA Specification for Road Works

B.9 All acousticians designing noise barriers for road schemes should be familiar with Series 300 of the NRA Specification for Road Works dealing with Fencing and Environmental Barriers. This document outlines the minimum technical requirements for environmental noise barriers. The main items are summarised as follows.

B.10 All noise barriers shall achieve performance criteria set out in the Contract Documents in accordance with:

- I.S. EN 1793-1
- I.S. EN 1793-2
- I.S. EN 1793-3
- I.S. EN 1794-1
- I.S. EN 1794-2

B.11 All noise barriers shall have a minimum insulation performance of B3 as classified in I.S. EN 1793-2 and all absorptive barriers shall have a minimum absorptive index of A3 as classified in I.S. EN 1793-1.

B.12 All noise barriers are to be designed to achieve a desired service life of 30 years and barriers are required to be vandal resistant. Any noise barrier vandalised within the first five years of installation shall be replaced by a length equal to the original unbroken total length of barrier involved. A noise barrier shall be deemed vandalised if it has been damaged in such a way that its integrity to perform as a noise attenuating device has been compromised. This means that timber barriers could be deemed a non-cost effective measure in urban areas where vandalism is likely to occur.

B.13 Where access gates are required, their design shall be such that they blend unobtrusively into the barrier. They shall open away from the nearest carriageway and leave no gap when closed. The gates shall be self-closing by the provision of a heavy-duty spring.

B.14 The barrier foundations play an important role in the integrity of a noise barrier. No gaps between barriers and foundations are permitted. Non-concrete barriers should sit on a concrete gravel board so that no part of the barrier is in contact with the ground. The gravel board should be not less than 150mm deep and shall have a thickness of not less than 50mm.

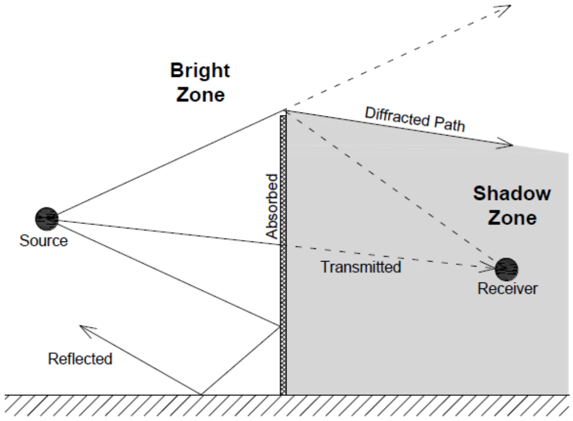
B.15 Series 300 of the NRA Specification for Road Works will be revised when the revisions to the Specification and Acoustic Test Standards for Noise Barriers for use on European Highways have been completed and approved.

Noise Barrier Design Basics

B.16 A properly designed noise barrier will reduce noise propagating from source to receiver through diffraction over the top of the barrier or around its edges. Some noise may also be transmitted through the barrier. The level of noise transmitted through the barrier depends on the material properties of the barrier, while the level of noise diffracted is dependent on the location and size of the barrier. For a barrier to be fully effective, the amount of sound passing through it must be significantly less than that diffracting over or around it.

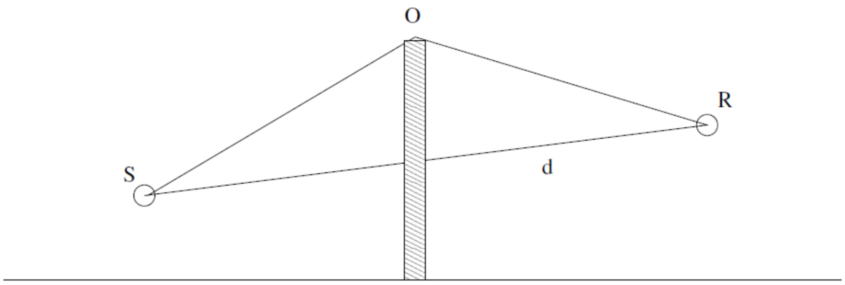
B.17 To function well the barrier should obscure the direct line-of-sight between the source and receiver. The region behind the barrier is known as the shadow region. Noise barriers attenuate higher frequencies more effectively compared with lower frequencies. This is due to the fact that higher frequencies are diffracted to a lesser degree; while lower frequencies are diffracted deeper into the "shadow" zone behind the barrier (Figure B.1). The occurrence of diffraction results in the benefits of the barrier decreasing as the receiver moves further away from the barrier.

Figure B.1 - Performance of noise barrier related to line of sight



B.18 An important parameter of diffraction is the path length difference, δ. The path length difference is the difference in length between the diffracted path from the source over the top of the barrier to the receiver, and the direct path from the source to receiver as if the barrier was not present (Figure B.2). This property governs the effectiveness of all noise barriers; in general, the greater the path length difference, the greater the barrier effectiveness.

Figure B.2 - Calculating the path length difference



$$\delta = SO + OR - d$$

B.19 Separate to diffraction, the level of sound insulation (or transmission loss) is also an important consideration. This is the amount of incident sound the barrier prevents from being transmitted through it. For the noise barrier to be effective, noise transmitted through the barrier should be minimal compared to the noise diffracted over and around the barrier. The barrier's sound insulation or transmission capacity should be 10dB greater than the desired noise reduction. For example, to achieve a noise reduction of 10dB, the barrier will require a transmission loss of greater than 20dB.

B.20 In practice, it is generally possible to achieve noise level reductions of 5-12dB at a receiver by installing noise barriers 2-4m high. Larger reductions can be difficult to achieve and may require the use of very high barriers. Reductions in noise levels of 20dB are extremely hard to obtain but have been reported where rail noise is the source and the high levels of attenuation are possible due to the location of the source.

Barrier Type

B.21 In general, noise barriers can be categorized as walls, earth berms or a combination of the two (Figure B.3). In rural settings, earth berm barriers are generally more attractive to both local residents and motorists as this type of barrier reflects its surroundings. However, earth berms require large amounts of space and are primarily used in countryside. Where space alongside the road is restricted, earth berms can be combined with wall barriers but care must be taken to integrate the two.

Figure B.3 - Combination of a wall and earth berm barrier

B.22 Other systems such as gabions, crib walls, anchored or reinforced earth can be used to support one or both faces of a barrier. Wall barriers can be reflective or absorptive and can be constructed from a range of different materials. Any barrier without added absorptive treatment is a reflective barrier by default.

Barrier Material

B.23 Noise barriers can be made from many different materials or a combination of materials but must be sufficiently durable and have low maintenance requirements. The barrier should be solid and the materials chosen should not form cracks or other leaks as a result of wear or weathering. Even small gaps in a noise barrier can significantly reduce the barrier performance. It is important that care is taken during the design and construction of a noise barrier to ensure sound leaks due to holes, slits, crack or gaps beneath a noise barrier are avoided.

B.24 Traffic noise must not cause the barrier to resonate since this would transfer the sound energy to the receiver side. Resonance is generally not an issue for solid barriers with a surface density greater than 20 kg/m^2. In general, the thickness of material required to provide structural rigidity exceeds the thickness needed to prevent resonance.

B.25 A single wall with a weight of approximately 20 kg/m^2 will normally have a sufficient transmission loss capacity (approximately 20-25dB).

Timber

B.26 Timber noise barriers are one of the most frequently installed types of barrier on the Irish road network. These barriers tend to resemble garden fence structures and have seldom developed a design identity of their own. A number of different species of wood have the potential for being used in the construction of a timber noise barrier (see IS 435-1 (2005) for more information). Timber barriers are generally considered as reflective barriers; however, an absorptive material can be fixed to barrier surface to improve the absorptive characteristics of the barrier.

B.27 There are a number of factors to consider with timber barriers:

- Timber barriers are susceptible to warping and shrinkage resulting in acoustic leaks. Barriers should be treated to ensure a service life of 30 years.
- Clause 311 of Series 300 (Specification for Road Works) provides minimum requirements for the preservation of timber.
- Timber barriers are also susceptible to combustion and smoke and emissions need to be considered.
- Timber barriers should be avoided across viaducts and bridges. The rustic character of the timber barrier is out of place on concrete and steel[2].

Sheet Metal

B.28 The most common types of sheet metal barriers are steel, stainless steel and aluminium. Aluminium is often chosen over steel as it is lightweight and does not rust. However, steel is the least expensive material. Sheet metal barriers can be either reflective or absorptive. For reflective barriers, the barrier façade is constructed from solid sheet metal. For absorptive barriers, the barrier façade is generally perforated with the internal space containing sound absorbing material. Metal panels have a weight advantage which makes them useful for installing on bridge structures. Sheet-metal barriers have been used extensively across Europe, nowhere more so than in Germany, where many have been in place for 15 years or more[2].

B.29 There are a number of factors to consider with metal barriers:

- Metal barriers can have an industrial appearance which is undesirable. Where steel is used, the barrier is susceptible to rusting.
- When choosing materials the non-compatibility of various metal combinations should be considered. In some instances when certain metals come into contact with each other, there may be an adverse effect e.g. corrosion.
- Metals are electrically conductive and should be avoided where barriers are to be installed near electrical power lines.
- Metal barriers are susceptible to glare and material finish should be considered.

Concrete

B.30 Concrete is one of the world's most common and versatile construction materials and there are many examples of concrete noise barriers in Ireland. Concrete can be cast on site or precast off site. Concrete lends itself be shaped, moulded, and textured whilst remaining rugged. Concrete is also able to withstand elements such as extreme temperatures, intense sunlight or precipitation. Concrete products also lend themselves well to colouring or tinting and can be either reflective or absorptive. To achieve absorptive characteristics, concrete is combined with either wood fibres or small cementaceous balls. Sound absorption is maximised by highly profiling the absorptive surface to increase the surface area of the façade and thus maximise sound absorption.

B.31 Although concrete is versatile and rugged, large flat areas of concrete should be avoided as this can appear dull and can be an eyesore on the landscape. Concrete is most effectively used where the surface is finished with patterns or texture combined with planting to soften and enhance the appearance of the barrier.

B.32 There are other factors to consider with concrete barriers:

- For precast panels, limitations on size and weight apply due to the logistics of shipping and handling.
- One must also consider the merits of cast versus precast panels. Precast panels can be erected quickly if crane and truck access are readily available. They also have the potential to be relocated and installed on another site. Cast-in-place concrete barriers flexibility of design, high structural strength, and resistance to vehicle impact damage mean they can be used on bridges and retaining walls.

Brick and Masonry

B.33 Brick and masonry barriers are often used as they merge with the surrounding architecture. These barriers require a foundation or concrete footing. Solid bricks are used to construct reflective barriers whereas perforated bricks are used for sound-absorptive barriers; either solution generally creates the impression of a conventional brick wall. Depending on the construction method deployed these barriers can be quite labour intensive.

Plastic

B.34 Barrier panels can be composed of polyethylene, PVC and fibreglass. The lightweight nature of plastic improves ease of handling both in the manufacturing plant and on site and makes it ideal for structure-mounted applications. In addition, as plastic recycling increases and these materials become more competitively priced and robust, it is likely that they will become more widely used[2]. Plastics are versatile and can be easily moulded so can be produced to mimic the aesthetics of almost any construction material available. Plastics can also appear eccentric, evoking strong colours and inventive moulded shapes. However, plastic barriers need not appear so eccentric for they can be moulded to imitate the character of other materials.

B.35 There are a number of factors to consider with plastic barriers:

- Plastic barriers are susceptible to combustion. Smoke, emissions and ash from such barriers should be considered toxic.
- Some plastics may be susceptible to shrinking and/or accelerated creep and deformation resulting in acoustic leaks.
- Some plastic products require ultraviolet protection as without it, rapid deterioration of pigments, surface appearance and material strength can occur. The deterioration of material strength can cause the plastic to become more brittle and susceptible to shatter.
- Plastic barriers may be susceptible to glare but this is dependent on the surface texture applied.
- Plastic barriers are also particularly susceptible to vandalism due to the nature of the material.

Transparent Barriers

B.36 Transparent noise barriers can be composed of toughened or reinforced glass or from plastics such as acrylics, polymers and polycarbonates. Both plastics and glass can be tinted and etched or given a frosty appearance. One of the big advantages of transparent barriers is their visual neutrality as they have very little visual impact on the surroundings. Glass and acrylic barriers may be used in most locations where the visual intrusion of traffic is not an overriding issue. Transparent material can be used when a barrier is located close to a building, where the use of a non-transparent barrier might significantly block or restrict the residents' view. Transparent barriers can also be used in the countryside to allow motorists to view or a landmark.

B.37 There are a number of factors to consider with transparent barriers:

- Transparent barriers are particularly susceptible to vandalism and graffiti. These barriers need to be cleaned regularly to prevent them from appearing soiled and dull.
- Transparent barriers may be susceptible to glare.
- Some transparent barriers are sensitive to ultraviolet light. Those without UV stabilizer additives or coatings will haze and discolour. Even with stabilizers, the barrier will eventually be affected by light. The ultraviolet light can also cause a deterioration of material strength and can cause the barrier to become more brittle and susceptible to shatter in the case of plastics. Glass on the other hand is not shatter resistant; even when the glass is tempered and/or laminated, the

panel will shatter.
- A final consideration with transparent barriers is the additional cost of the material.

B.38 Irrespective of the type of barrier material, all noise barriers should be installed by a competent individual, equipped with the necessary installation experience and expertise.

Noise Barrier Design Considerations

Barrier Height

B.39 The height of a noise barrier is an important parameter in terms of the barrier's acoustic performance. Increasing the height of a barrier increases the size of the shadow zone and improves insertion loss provided the sound insulation performance of the barrier is adequate. In Ireland, barrier heights of 3 – 4m are common. Barriers up to 10 metres in height have been used in other countries.

B.40 For a noise barrier to be effective the barrier has to cut the line of sight between source and receiver. A number of instances where this has not occurred have been observed, Figure B.4 shows such examples.

Figure B.4 - Noise Barrier installations where line of sight is not blocked

B.41 **Recommendation:** Noise barriers should be sufficiently tall so as to block the line sight (at the very minimum) between the source and receiver. It would be good practise to achieve a path length difference of at least 0.035m in order to ensure the line of sight is sufficiently blocked.

Barrier Length

B.42 Noise barriers should be long enough so that only a small portion of sound diffracts around the edges. In areas close to the end of the noise barrier, transmission loss diminishes because the sound propagates around the end of the barrier with degradations in barrier performance of up to 5 dB(A) less than the barrier's designed noise reduction. Figure B.5 shows an instance where the noise barrier blocks the line of sight but the barrier is not sufficiently long. As a result significant levels of noise will be diffracted around the edges of the barrier reducing the effectiveness of the noise barrier.

Figure B.5 - Noise Barrier installations where line of sight is blocked but barrier is not long enough to prevent diffraction around sides

B.43 **Recommendation:** Noise barriers should be continued some way past the noise-sensitive area. The length of the noise barrier should be long enough to cover an angle of at least 160 degrees from the receiver or, alternatively, the distance between the receiver and the barrier end should be at least four times the perpendicular distance from the receiver to the barrier (Figure B.6). In cases where there is not sufficient space to install a barrier long enough to provide the necessary attenuation, the introduction of curved ends may improve the barrier performance (Figure B.7).

Figure B.6 - Relationship between barrier length and sensitive receiver

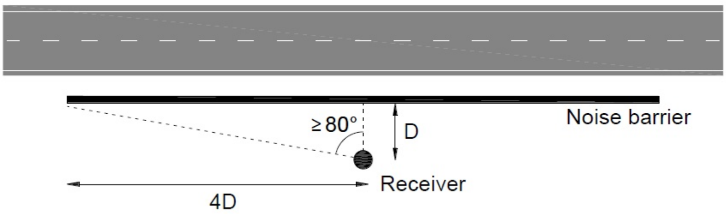
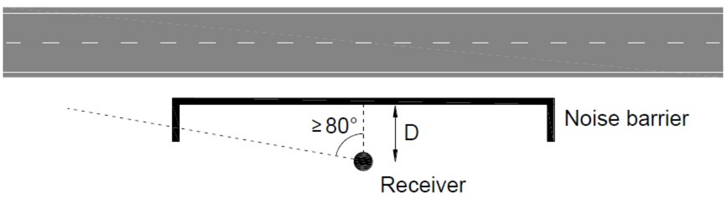


Figure B.7 - Noise barrier with curved ends



Barrier Continuity

B.44 The most effective barriers are solid and continuous. However, it is not always possible to maintain the continuity of the barrier as it is often necessary to introduce a break in the barrier to allow access for pedestrians or cyclists, emergency vehicles, or inspection and maintenance access. Some examples of inadequate noise barriers are presented in Figures B.8 and B.9. When this occurs the design team should develop alternatives to allow for these breaks.

Figure B.8 - Break in barrier for access to service

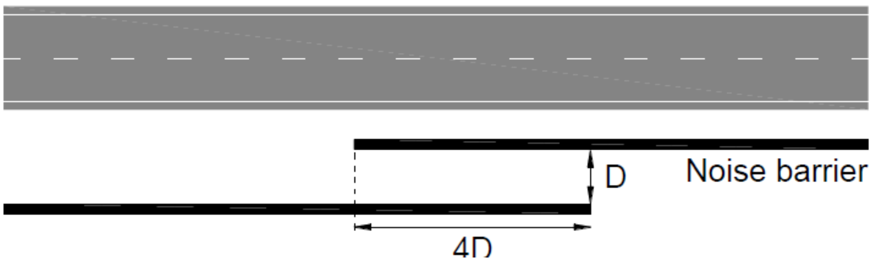
Figure B.9 - Break in barrier continuity at bridge section

B.45 Barrier materials should be carefully considered in overlap sections open to pedestrians, as these sections may be particularly susceptible to vandalism. Figure B.10 shows an absorptive barrier with protective metal grid.

Figure B.10 - Absorptive barrier with protective metal grid

B.46 **Recommendation:** Barriers should be designed to ensure continuity in acoustic performance. Gates should be provided where required and should be flush with the barrier leaving no gaps. Where a gate is not provided, but a gap is left for access, a length of barrier should be erected behid the gap or an overlap provided sufficient to maintain the acoustic performance of the barrier (e.g. Figure B.11).

Figure B.11 - Noise Barriers with gaps underneath



Noise Barrier Leaks and Gaps

B.47 Noise barriers should be solid and materials should not form cracks or other leaks as a result of wear. Even small gaps in a noise barrier can significantly reduce the barrier acoustic performance. The gaps can also be under the barrier. There are many instances on the national road network where gaps underneath the barrier may be observed. Figure B.12 shows two examples from different sites.

Figure B.12 - Noise Barriers with gaps underneath

B.48 A gap of 15mm under the noise barrier is not untypical. This equates to a gap of approximately 0.5% surface area for a 3m high barrier. Table B.1 presents the transmission loss at 500Hz with and without leaks for four cases describing a required transmission losses of 10, 15, 20 and 25dB[3]. Given that timber noise barriers can provide 20dB sound insulation performance, a 0.5% gap results in an approximate 4 to 5dB reduction in performance at a frequency of 500Hz.

Table B.1 - Reduction in Transmission Loss at 500Hz due to leaks

% Area occupied by leaks	Tranmission Loss without leaks at 500Hz			
	10dB*	15dB*	20dB*	25dB*
	Reduction in Transmission Loss [dB]			
50	10+	15+	20+	25+
25	10	15	20	25
13	8	12	17	22
6	5	10	14	19
3	4	7	11	16
1.5	2	5	9	13
0.78	1	3	6	10
0.39	1	2	4	8
0.20	0	1	3	5
0.10	0	1	1	4
0.05	0	0	1	2

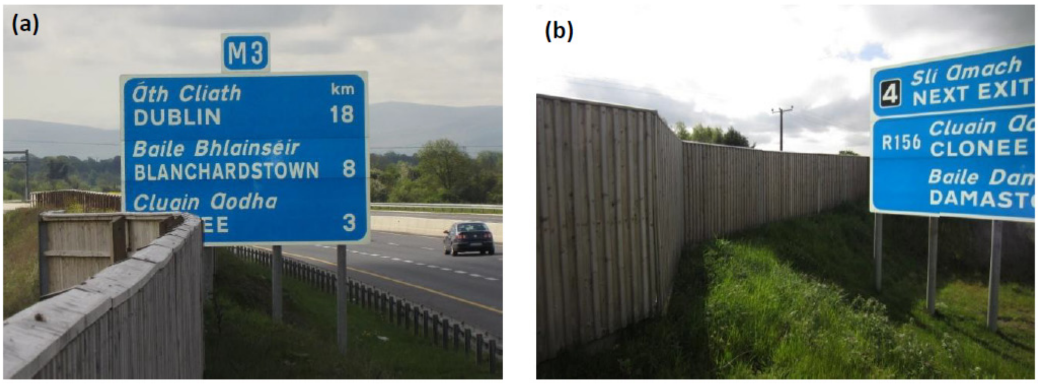
Source: *Guidelines on Design of Noise Barriers*, Highways Department, Government of Hong Kong (2003)[3]

B.49 **Recommendation:** It is important that gaps under the barrier are omitted to ensure the barrier performs as effectively as possible. Series 300 does not permit gaps in the foundation and recommends that the bottom of the barrier be buried (or overlapped) to a depth of at least 50mm. This should be considered a minimal depth.

Accommodation of Signs and Road Furniture

B.50 Where noise barriers are required to be installed in the vicinity of signs and other street furniture, sections of the noise barrier may need to be offset i.e. located further away from the noise source. One example is presented in Figures B.13. In this test case, the road (source) is 20m from the noise barrier with a height of 3m and the noise receiver is 35m behind the barrier. Using ISO 9613-2[4] the insertion loss at 1000Hz is 14.2dB. If the noise barrier is offset back an additional 3m from the road (source) to accommodate signage, the predicted insertion loss reduces to 13dB. In order to achieve the 14.2dB insertion loss for the offset section of noise barrier, the noise barrier height would have to be increased by 0.5m. Where the source and receiver distances are smaller, the degradation in acoustic performance may be further emphasised.

Figure B.13 - Noise barrier installation with accomodation of sign



B.51 **Recommendation:** If barrier positions must be altered to accommodate road signs the barrier should be reassessed to ensure it can perform as required. If necessary the height of the offset section of barrier may need to be increased to achieve the desired insertion loss.

Reflective or Absorptive Barriers

B.52 When a sound wave impacts upon the surface of a solid body, some portion of its energy will be reflected, some absorbed and the rest transmitted through the body. The relative proportion of each depends on the nature of the material impacted. A noise barrier which protects a noise sensitive receiver on one side of the road can also reflect noise back across it and increase the noise levels on the opposite side of the road. The screened effect for the reflected noise is not as effective as for the direct noise. The total noise reducing effect will be considerably diminished. The magnitude of the increase in noise level on the opposite side of the road will depend on site conditions, the height of the barrier and the barrier absorption characteristics.

B.53 Theoretically noise levels can be increased by up to 3dB due to reflections from a barrier. In reality measured noise levels would be expected to be lower. While an increase of up to 3dB is barely perceivable, the change in sound quality i.e. reflected sound has different frequency content, maybe be perceived by residents on the opposite of the road to the barrier.

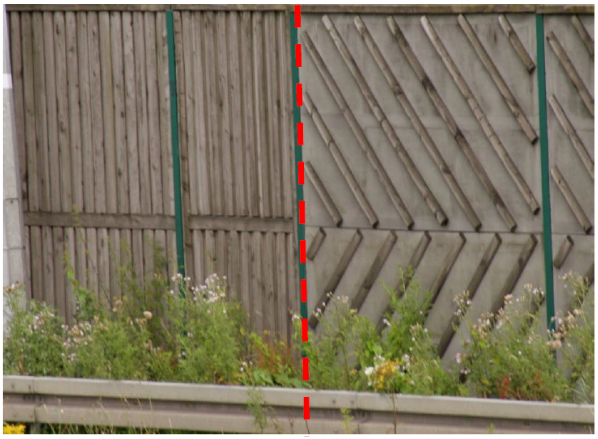
B.54 If two barriers facing each other on opposite sides of the road, sound reflected from each barrier may cause degradation in each barriers performance by up to 6 dB due to multiple reflections diffracted over the individual barriers. Hence, when parallel barriers are required, the ratio of the distance should be 10 times the average height of the barriers in order to minimise the degradation in performance.

B.55 The reflection problem can be improved by covering the noise barriers with sound absorbent materials. A range of sound absorption materials can be selected and chosen based on sound attenuation characteristics of the material and the acoustic signature of the noise source. Figure B.14 shows both reflective and absorptive barriers. The introduction of the absorptive barrier in this case was due to the installation of a barrier on the opposite side of the road and hence minimise the possible degradation in the barriers performance due to multiple reflections.

B.56 Another option to address the reflection problem is to erect the barrier at a slant so that the noise is reflected up into the air. However, the structure may appear visually unstable and impose on the residents' side of the barrier. For an earth embankment with sloping sides this will always be the case. If noise is reflected upwards, there is the possibility atmospheric effects will cause the noise to be refracted and increase the noise levels at distant receivers.

B.57 However, research by Watts and Godfrey[5] shows that reflections from noise barriers have a very small effect on noise levels and it is recommended that the situation should be carefully analysed before noise absorbent barriers are proposed.

Figure B.14 - Left Side: Reflective Barrier; Right Side: Absorptive Barrier



Other Factors to Consider

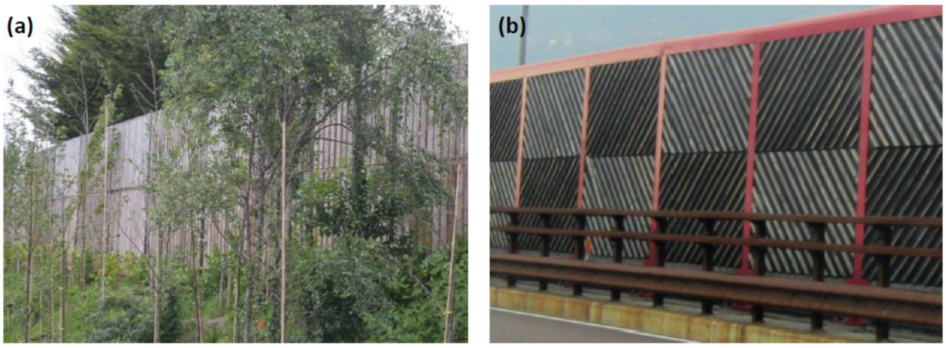
Barrier Surfaces

B.58 Surface finishes are very important from an aesthetic point of view. The visual quality of a barrier can be enriched through the use of colour, pattern and texture. The ability to add various effects and change the barrier aesthetics is also dependent on the material.

Barrier Colour

B.59 The choice of colour for a noise barriers installation can have a significant aesthetic impact on the barriers appearance with its surroundings. Depending upon the particular design philosophy adopted, the colour chosen can make the barrier become a striking addition to the environment or it can merge the barrier with the natural surroundings (Figure B.15).

Figure B.15 - (a) Noise barrier merging with surroundings and (b) Use of colour to highlight the structural form of the barrier



B.60 When adopting the design philosophy to merge the barrier with the surroundings and the backdrop consists of trees and vegetation, neutral to dark earth tone colours can help the barrier merge with the surroundings while lighter and non-earth tone colours can make the barrier stand out. When the barrier is viewed against an open backdrop such as the sky, lighter colours will make it less obtrusive.

B.61 The other design philosophy to make a noise barrier a conspicuous addition to the landscape requires the uses of colour to create a contrast with the natural surroundings. However, the use of vibrant colours to make a feature should be sparing and is most successful when restricted to key elements of the barrier, e.g. to highlight its structural form. Large areas of strong colour can have the opposite effect and result in a gaudy rather than attractive appearance.

B.62 The use of different colours can help break the monotony of long and high barriers. The visual effect of a high noise barrier can be toned down by painting lighter colours at the top and dark colours near the ground. This approach may be less effective when viewed at distance where the barrier appears in silhouette.

Pattern and Texture

B.63 Adding pattern or texture to a barrier is often regarded as a minor issue. However, pattern and texture are an important design consideration. Patterns if too simple can appear stark and contrived whilst the texture of the material should not affect the visual quality of the barrier except where close views are possible[2]. When incorporating pattern/texture, the speed of the motorist should be considered. The faster the motorists speed, the coarser the texture and the larger the pattern required for such treatments to be noticed and effective. The textures should be coarser and patterns should be deep enough to create shadow effects. The uses of pattern and texture can deter graffiti. Materials such as precast concrete can lend themselves to processes where texture and pattern can be incorporated into the surface finish (Figure B.16).

Figure B.16 - Concrete Barrier

B.64 Pattern and texture can also increase visual interest and can help break up the monotony of the barrier, helping to prevent inattentive drivers. Figure B.17 shows an example were a pattern can be implemented with timber noise barriers. This illustrates how the change in barrier style or the introduction of key patterns or features installed every couple of hundred meters can help break up monotony.

Figure B.17 -Absorptive barriers with vertical battens helping to break up monotony

B.65 Patterns can also help reduce the apparent size of the barrier. A smooth surface will be perceived as being larger than a textured surface. Horizontal patterns tend to reduce the visual impact of the barrier by compressing its height whereas vertical patterns can create the illusion that the wall is shorter than it actually is.

Landscaping and the Use of Vegetation

B.66 Although the attenuation properties associated with vegetation is minimal, a proper consideration of landscaping and vegetation can lead to a number of positive effects:

- Vegetation can be planted between the road and the barrier and can disperse noise before and after reflection. The amount of attenuation is generally small and is dependent on the size and density of the foliage as well as the frequency content of the noise.

- Planting can be used to soften and enhance the appearance of a barrier and its surrounds, providing variation from season to season and in different daylight conditions.
- Shielding from trees and other such vegetation typically has an "out of sight, out of mind" effect. That is, the perceived effect of traffic noise impact tends to decrease when vegetation blocks the line of sight to nearby residents.
- Vegetation can be used to enhance earth forming barriers.
- The monotony of long straight surfaces can be broke up using vegetation and planting along the base of the barrier can make it seem lower than it really is.
- Planting low vegetation in front and tall vegetation behind the barrier can reduce the dominance of the barrier.
- Well-designed planting is usually a visual asset. It also has the effect of enhancing the soil stability, the microclimate and the wildlife environment.

B.67 However, when using planting in a development a number of factors must be considered. For example:

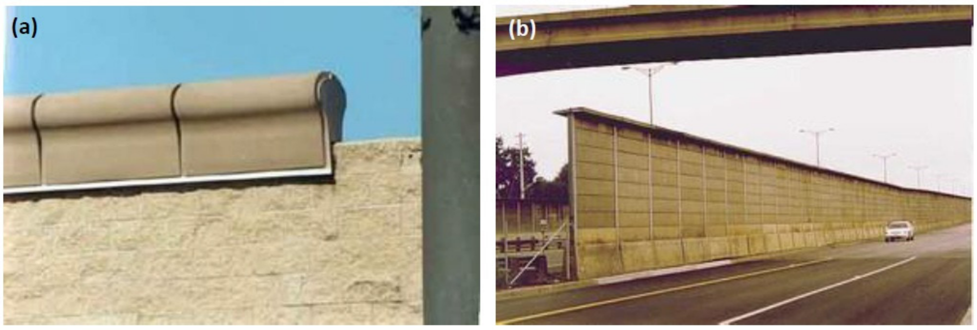
- The roadside is a harsh environment and plants need to be able to resist baking sun, buffeting by wind and, grit and salt spray in winter.
- Care must be taken that the barrier does not cause rain shadow, restricting the quantity of water reaching the plants' roots.
- Vegetation must have plenty of soil to grow in and access to sufficient water to promote good growth. At dry locations it may be necessary to install irrigating systems.
- Sufficient space should be allowed for growth and access to inspect and maintain the barrier.
- Vegetation can interfere with maintenance or emergency access features of a particular barrier design. It can also interfere with access doors or fire hose openings/valves or obscure the identification signs for these access features.
- Drainage under, along, or through the noise barrier needs to be considered when planting in the vicinity of a noise barrier.

Diffraction Edges

B.68 Novel barrier design should be encouraged. This may include altering the top diffraction edge of a barrier. Noise barriers with cross sections having rounded corners and curved shapes are not as effective at reducing noise as those with sharp edges. So a wall barrier (sharp edge at the top of the barrier) should be more effective than an earth mound (rounded top) of the same height. However, if the earth berm barrier has a flat top i.e. two diffraction edges, for a given site geometry, comparable barrier height and length and diffraction edges located same distance from the source, a berm barrier will typically provide an extra 1 to 3 dB(A) of attenuation.

B.69 Watts et al. reported on the insertion loss performance for T-shaped, multiple edge and double barriers over a simple plane barrier (2m high) with measurements at a range of distances (up 80m) behind the barrier[6,7]. A 1.4 to 3.6dB increase in insertion loss performance depending on design detail was observed. It was also reported that a 2.5m and 3m high simple barriers had an improved performance by 1.9 and 3.9dB, respectively. Hence, the merits of using diffraction edges must be thought of in the context of increasing the barrier height. Figure B.18 shows some examples of diffraction edges.

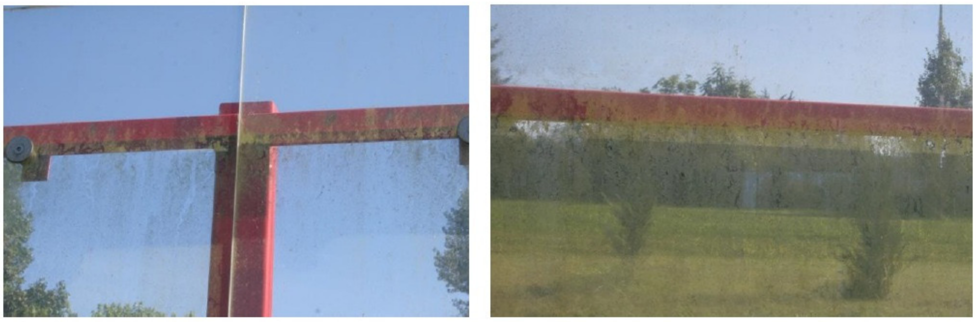
Figure B.18 -(a) Special top and (b) T-top diffraction edges



Barrier Maintenance

B.70 The need for future maintenance should be taken into account when deciding on the form of a noise barrier. Noise barriers should be designed so they require minimal maintenance. Concrete or masonry barriers require little or no maintenance with a service life of 40 years readily achievable whereas transparent sections need regular cleaning and may have to be replaced within their service life (Figure B.19). Resistance to the elements should also be taken into account e.g. resistance to ultra-violet light or expansion and contraction of materials where large temperature changes occur.

Figure B.19 - Sections of sullied transparent noise barrier



B.71 Access points for maintenance purposes or where barriers overlap are generally more vulnerable to vandalism and should be considered when choosing the barrier form and materials. It may also be useful to divide the noise barrier into modular sections so if vandalism occurs, it would be possible to easily replace the damaged elements.

B.72 In Ireland, timber barriers are one of the most common forms of noise reducing device. Timber barriers are prone to warping, shrinkage and cracking. Figure B.20 (a) – (e) present a collection images showing typical examples of damage and deterioration of timber noise barriers. Figure B.21 shows that the protective membrane in absorptive barriers is also prone to damage and/or degradation.

Figure B.20 (a)-(e) Damage to timber barriers due to warping, shrinkage and cracking

Figure B.21 - Damage/degraded protective membranes on absorptive noise barrier

B.73 Planting of vegetation may be used to minimise the visual effect of a noise barrier and integrate it with the surrounding landscape. However, vegetation was often found to be overgrown and as a consequence made access to noise barriers quite difficult. At several sites Ivy was growing and had adhered to the barrier, which may damage it (Figure B.22). In the case of concrete barriers which require very little maintenance, Ivy attaching to the barrier is desirable.

Figure B.22 - (a) Ivy attached to noise barrier; (b) Ivy protruding through noise barrier

B.74 Noise barriers are also susceptible to vandalism. Figure B.23 (a) – (d) shows a number of examples of damage caused to noise barriers due to vandalism. When selecting barrier type it is important to consider the likelihood of vandalism and selecting an appropriate barrier type accordingly.

Figure B.23 - Examples of damage to timber noise barriers due to vandalism

Sustainability and the QUIESST Project - an overview

B.75 Noise barriers are a growing part of Europe's transport infrastructure. Acoustic professionals and designers must be aware of the growing sustainability agenda for surface transport systems including supporting infrastructure such as noise barriers.

B.76 A key objective of the Commission of the European Communities' White Paper on European transport policy was to promote the sustainability of surface transport and its respective infrastructure, including noise barriers.

B.77 Noise barriers can have as much of an impact on the built environment as many other large built structures. For example, typical installations of noise barriers may be 300m, or 600m if both sides of the carriageway are treated. A typical height is 4m which means that the total area of the erected noise barrier is 2,400m^2.

B.78 Despite the fact that many Noise Reduction Device (NRD) projects, including the installation of noise barriers, are often conducted on a large scale, and can have substantial impacts on the environment, methods to accurately assess the sustainability of different devices have been historically lacking.

B.79 This need was recognised by the European Union through the Quietening the Environment for a Sustainable Surface (QUIESST) project[8].

B.80 The QUIESST Project aimed to merge the consideration of the NRD's intrinsic and extrinsic acoustic characteristics, together with their sustainability. This holistic approach aims to allow control of the actual global effectiveness, to reduce ground transport noise, to minimise the number of exposed people to noise, to reduce the level of noise exposure and to make NRD's more sustainable.

B.81 Within the framework of the QUIESST Project, sustainability was defined as the optimal consideration of technical, environmental, economical, and social factors during the design, construction, maintenance and repair, and removal/demolition stages of the NRD projects.

B.82 Researchers developed a tool for policymakers and industry professionals to aid decision-making and help evaluate the sustainability of different NRD options, including noise barriers.

B.83 Acoustic professionals and designers should be familiar with the findings of the QUIESST Project and pay due cognisnace to sustainability when proposing and designing noise barriers.

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