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Features

Regulars

Cover Image: Thousands of Cars Stuck in Beijing Traffic Jam on 50-Lane Highway

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From the President and the Editor's

President's Column

Dear Members,

Spring time eh? Fantastic. Lovely time of year this, with all the budding new lifeforms in various categories of fauna and flora reaching up to feel the sun on their faces. My kids are certainly looking forward to weekends on their bikes and whooping around the neighbourhood sharing their noisy exuberance with others.

Have I ever mentioned how unnecessarily loud my children are? Well, I will one of these days. I guess it's like what they say about the plumbing in a plumber's house always being broken… I spend my days trying to make the world a quieter place, then come home to my kids. Bless 'em.

This brings me quite conviently (and not at all deliberately) to the topic I'd like to raise in this issue of Acoustics New Zealand: *The acoustic design of classrooms*.

Those who know me have probably been expecting for me to raise this for some time. From a professional point of view, this is one of my key areas of interest – in fact it was the topic of my Masters' thesis, way back when.

Acoustic design of classrooms is something that I'm sure everyone would be concerned about, if they took a moment to give it some thought… but not everyone does take that moment, so I ask you to do so now. Classrooms are our children's key learning environment. The place where the critical building blocks of knowledge enter their minds and become absorbed to form the foundations on which their future is built.

So, imagine if your kid can't undertand what their teacher and fellow pupils are saying because poor acoustic design has led to excess reverberation and high background sound levels. Worth thinking about right?

I'm raising this because the Ministry of Education (MoE) has come under fire recently (and publically) from top NZ schools who are pushing back against their policy of turning all traditional classrooms throughout the country into Innovative Learning Environments (ILEs) by 2021. ILEs are (for want of a better term) open plan spaces where multiple 'classes' operate under the same roof. Teachers cooperate with one another to task-share their lesson plans and the students can carry out set tasks in a range of environments including standing desks, IT hubs, bean bags or under the tree outside.

Acoustically we know that ILEs can work, but not unless three critical things happen:

1. They are packed to the gunwhales with acoustic absorption (to manage reverberant build up of activity noise).
2. There are ample break-out spaces to provide 'quiet, visually isloated spaces' for both small and large groups when they need them.
3. And this is MOST important – the teachers modify their methods and manage lessons to suit the space. Traditional teaching methods simply will not work.

I know this last point may not be an acoustic requirement, but I'd like to stress that even the most perfectly designed ILE won't work unless it's used properly. What worries me about the recent articles I've read in the news, is that if schools are resisting the change to ILEs… why is there such a big push towards getting them built? And if teachers are obliged to use them, will they know how to? Surely if there's any building where form should follow function, it's a classroom.

This is a very complex topic and I've barely scratched the surface here, just scattering a couple of seeds for thought. I'd be keen to hear what you think.

Yours faithfully,

James Whitlock

Editor's Column

Welcome to issue #3 (2015) of New Zealand Acoustics. This is a bumper, 44-page issue, full of your favourite regulars such as RMA.net and five articles to make you think. The first and last article are from last year's ASNZ conference and provide contrasting views on managing *reverse sensitivity* issues in New Zealand's transport network, well worth the read.

Adding to James' comments, the scope of the MoEs push to ILEs is much wide than classrooms as they "may include any designated place of learning such as science laboratories, distance learning contexts, libraries, tutoring centres, teachers' staffrooms, gymnasiums, and the interaction between these spaces", so the scope for poor acoustics has been significantly increased. What is not mentioned in this movement to ILEs is that this will significantly adversely affect the main-streaming of children with learning disabilities as many of these children will simply not be able to cope with these overstimulating environments.

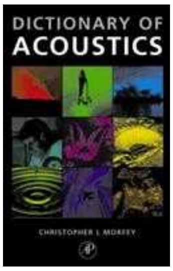
We have a new competition with a selection of five acoustics related books as prizes, so send us an email with your name in the subject line to be in to win.

Lindsay & Wyatt journal@acoustics.org

Book Competition

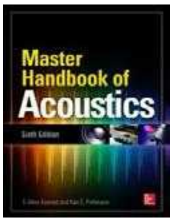
We are giving away five brand new books to readers of the Journal. All you have to do to enter the completion is email your name in the subject line to journal@acoustics.org.nz. You can enter only once and there is one winner per book. All entries must be received by 5.00pm, Monday 18th Janurary 2016. Winners will be notified by email and books couriered to them in the post. Winners will also have their names printed in the Journal.

First Place



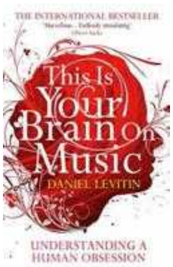
First Place is a copy of the *Dictionary of Acoustics*. This book provides in-depth and informative definitions of the terminology and concepts used in acoustics. The Dictionary of Acoustics is also a valuable reference for consultants, researcher's engineers, physicists, academia or any one who works in the field of acoustics.

Second Place



Second Place is a copy of the revised and updated, Sixth Edition of *Master Handbook of Acoustics*, which now includes the latest modern updates in audio technology and architectural design Master Handbook of Acoustics, acknowledged as the definitive volume and originally authored by one of the pioneers of the field, F. Alton Everest, is brought up to date by highly respected audio engineer and author Ken C. Pohlmann.

Runners Up



We have three copies of *This is Your Brain on Music* for runners up of the competition. The book offers a comprehensive explanation of how humans experience music and to unravel the mystery of our perennial love affair with it.

Journal Feedback and Comments

If you have any feedback on what you would like to see in future issues or even things you don't like to see, please share with us via email to **journal@acoustics.org**, we would like to hear from you! All comments and feedback is treated as confidential by the Editors.

The Acoustical Society of New Zealand

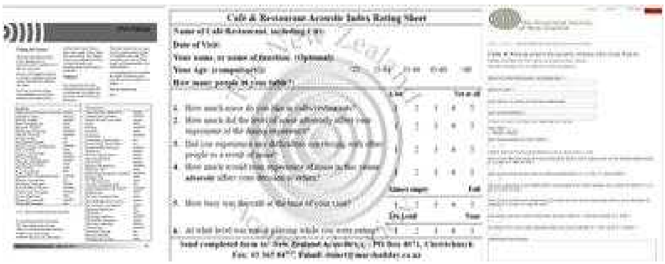
www.acoustics.org.nz

The ASNZ webpage contains a host of information including information on Membership, Journal Information and Journal Articles, Continuing Professional Development, Cafe and Restaurant Acoustic Index, Standards Committees and Standards, the Latest News and Discussion and Contact details of the Society.

Why not visit for yourself?

Cafe and Restaurant Acoustic Index (C.R.A.I.)

The Cafe and Restaurant Acoustic Index, C.R.A.I., is now completely online with all results and online forms able to be viewed and download from the acoustics.org.nz website under the C.R.A.I tab.



Cafe & Restaurant Acoustic Index Rating Sheet

Second Australasian Acoustical Societies Conference

The Acoustical Society of New Zealand and the Queensland Division of the Australian Acoustical Society are pleased to announce the Second Australasian Acoustical Societies Conference to be held 9-11 November 2016 at the Brisbane Convention and Exhibition Centre, Brisbane Australia. Put it in your diary and for more detail go to: www.acoustics2016.com.au

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Managing state highway reverse sensitivity effects

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Abstract

Port and airport companies have long been proactive in seeking and defending reverse sensitivity controls in district plans. These typically include control boundaries within which new noise sensitive activities around key infrastructure are either prevented or are subject to sound insulation requirements. Such controls are not currently in place for the most widespread environmental noise source in the country, the state highway network, and consequently the NZ Transport Agency frequently has to deal with actual reverse sensitivity effects. To avoid compounding these issues the Transport Agency developed a Reverse Sensitivity Policy in 2007, using a similar approach to that set out in the port and airport noise standards (NZS 6805, NZS 6807 and NZS 6809). However, the state highway network passes through nearly every district in the country and to date controls have only been implemented in a minority of district plans. Councils have often been resistant to including reverse sensitivity controls in district plans, and modifications have been made to standard provisions making them inconsistent around the country. This paper presents a review of these existing issues and introduces the Transport Agency's new draft guide for managing reverse sensitivity effects on the state highway network.

Originally published at the 22nd Biennial Conference of the Acoustical Society of New Zealand, November 2014

1. Introduction

The New Zealand Transport Agency operates, maintains and constructs New Zealand's state highway network. Na-tionally the state highway network makes up 12% of New Zealand's total roads. Despite this, almost 50% of all vehicle kilometres travelled and 70% of all freight kilometres travelled within New Zealand are on state highways [1]. The state highway network therefore provides strategic and often critical routes for transporting people and goods within and across regions. As a result the national state highway network passes through nearly every district and adjoins varying land uses. Some of the adjoining land uses are sensitive to the often unavoidable effects of state highway operation, maintenance and construction. For the Transport Agency this results in what is known as '*reverse sensitivity*' complaints or effects.

Reverse sensitivity is the legal vulnerability of an established activity to complaint from a new land use [2]. This can occur in situations where incompatible land uses/activities are located in close proximity to each other, resulting in conflict between the activities. For transport operators there is a risk that new activities (such as houses and schools) that choose to locate near to established roads or railways for example may object to the effects of the transport network (such as noise and vibration) and take action against the operator. As such, the term 'reverse sensitivity' generally relates to the effects of the development of a sensitive activity in an area that is already affected by established activities [3]. For the Transport Agency, reverse sensitivity effects have resulted in restrictions being imposed on the state highway network.

The Mana Esplanade section of State Highway 1, Wellington, provides an example of where reverse sensitivity effects have resulted in restrictions being imposed on state highway operation. Clearways operate along this 2 kilometre section of State Highway 1 to improve traffic capacity during peak travel periods. However, pressure from residents has resulted in heavy vehicle operators being asked to use the central traffic lanes during peak traffic periods to reduce noise and vibration effects on adjoining residents. In practice this compromises the peak capacity of State Highway 1, North of Wellington.

This paper explores reverse sensitivity effects arising from state highways in New Zealand and summarises the existing reverse sensitivity policy introduced by Transit New Zealand in 2007 [4]. Issues with the policy are discussed and a new draft guide to replace the policy is presented.

2. Examples

A common scenario where reverse sensitivity effects can arise is when new houses are built near to a state highway designation which does not yet contain a road. A designation can protect a route for a future road, and explicitly show the community the location so that other development can take account of that future road. However, houses are often built near to designations without taking account of the road-traffic noise that will occur, resulting in adverse reverse sensitivity effects. Two examples of this have occurred at the Ruby Bay Bypass and Transmission Gully.

2.1 Ruby Bay Bypass, Tasman District

The 10.7 km long Ruby Bay Bypass links Richmond and Motueka in the Tasman District, and was constructed between 2008 and 2010. The Notice of Requirement for the designation was lodged in 2000 and was confirmed subject to a number of conditions including three relating to road-traffic noise at houses existing in 2000. During the period between designation and construction, additional houses were built near the designation. Residents of some of the new houses were disturbed by road-traffic noise when the bypass was completed, particularly when the second-coat chipseal surface was laid. They requested a low-noise porous asphalt surface.

The Transport Agency spent significant resources investigating the complaints relating to the Ruby Bay Bypass and liaising with the residents. The noise levels were found to be reasonable and compliant with the designation conditions. A porous asphalt surface would be expensive and is not justified for this state highway in a rural area with approximately 5,000 vehicles per day. Ultimately, the residents remain dissatisfied with the noise effects they experience and the response of the Transport Agency. This situation could potentially have been avoided if appropriate reverse sensitivity controls had been in place.

2.2 Transmission Gully, Wellington

The Transmission Gully project has had a long gestation. A designation was completed in 2004 and then a new designation alignment was confirmed in 2011. Between 2004 and 2011 a number of houses were built near to the 2004 designation alignment. Despite the houses being built near a known future noise source, and even though the 2011 designation alignment did not come any closer, under the 2011 designation the Transport Agency was required to investigate mitigation for these houses.

Had reverse sensitivity controls been in place following confirmation of the 2004 designation then the subsequent houses would have been appropriately located and designed to mitigate future road-traffic noise. However, this was not the case and consequently the Transport Agency is now responsible for the cost of mitigation. This contrasts with another location along the Transmission Gully route where a subdivision between 2004 and 2011 was subject to reverse sensitivity controls and therefore did not require mitigation under the 2011 designation conditions.

2.3 Existing State highways

Reverse sensitivity effects can also arise where new houses are built near to established state highways.

The Transport Agency receives in the order of ten noise complaints each month from people living near the state highway network, throughout the country. A common request from residents is for the Transport Agency to install noise barriers or low-noise road surfaces. Both of these noise mitigation measures are costly to install and maintain, and it would not be practicable to retrofit the entire state highway network in all locations where they are requested. The Transport Agency spends significant resources investigating and responding to these noise complaints. In many cases where noise mitigation is not practicable residents continue to experience noise that they find disturbing or annoying.

A proportion of noise complaints are made by residents living in houses that have been recently built near to a state highway. If there were nationwide reverse sensitivity controls then this proportion of the complaints would not arise as the buildings would have been appropriately located and designed to avoid adverse noise effects. However, in the absence of controls residents often experience noise disturbance, and the Transport Agency expends resources measuring noise, and liaising with residents.

3. New Zealand Standards

New Zealand's airport companies were early to appreciate the need to manage reverse sensitivity effects. Internationally there are examples of airports that were originally located in relatively open space, but became surrounded by residential development, and consequently had operations constrained, such as by curfews. New Zealand Standard NZS 6805 [5] includes recommendations for land use planning controls to manage the location of residential development near to an airport. Specifically, NZS 6805 recommends inner and outer control boundaries are inserted into district plans to regulate sensitive land use close to airports.

Since NZS 6805 was published in 1992 it has been applied to all major airports through plan change processes, although with some variations made to the recommended procedures. Implementation of these reverse sensitivity controls now provides better certainty for the airport companies allowing forward planning and investment, while ensuring people moving into areas most affected by airport noise have their sleep protected through appropriate building location and design.

Following on from NZS 6805 for airports, NZS 6807 [6] was developed for helicopter landing areas. Comparably NZS 6807 provides similar procedures for managing land use planning. However, because helicopter landing areas are generally established through a resource consent process (as opposed to a plan change) there is no authority to impose planning controls on surrounding land as recommended by the Standard. Consequently, the authors are not aware of any examples where reverse sensitivity controls have been based on NZS 6807.

For ports NZS 6809 [7] sets out a similar framework to NZS 6805 for airports, including recommended land use planning controls to manage reverse sensitivity effects. This general approach has been applied to most ports in New Zealand.

Unlike NZS 6805, NZS 6807 and NZS 6809, which address both management of the noise source and land use planning, the road-traffic noise standard NZS 6806 [8] only addresses actions for designing new and altered roads. There are no New Zealand Standards for addressing reverse sensitivity effects for roads or railways.

4. Transit New Zeland Policy

To manage the reverse sensitivity effects outlined above, Transit New Zealand (now the New Zealand Transport Agency) published a reverse sensitivity policy in 2007. This policy sets out an approach with: a Buffer Area around state highways within which new buildings containing noise sensitive activities are avoided; and a wider *Effects Area* within which noise sensitive activities can be established but buildings may require acoustic treatment. This approach essentially mirrors the land use planning controls set out in NZS 6805, NZS 6807 and NZS 6809.

This reverse sensitivity policy has been applied extensively by Transport Agency planners since 2007, when approving and commenting on individual land use developments and subdivisions proposed near state highways. This policy has also been used to inform submissions by the Transport Agency on district plan changes and district plan reviews. Due to the timing of this policy being published in 2007 the controls were not incorporated into first generation district plans, but over recent years it has been used to inform some second generation district plans.

4.1 Issues

The implementation of the 2007 reverse sensitivity policy has led to a number of issues including:

- Controls have not been introduced into the majority of district plans across New Zealand. Where controls have been introduced they are inconsistent between districts.
- Councils have been reluctant to impose controls in district plans, mainly due to concerns about increased building costs for ratepayers.
- In constrained urban environments, a buffer area excluding noise sensitive activities might not be consistent with good urban design.
- The extent of the Buffer Area and Effects Area in the policy only has three distance steps based on broad categories of traffic volumes and speeds.
- Insufficient detail is provided on the need for ventilation when windows are closed for sound insulation.
- Outdated vibration criteria are referenced.
- Internal sound level criteria are not the same as specified in NZS 6806.

5. Draft Guideline

To address the issues listed above, the Transport Agency has prepared a draft guide which is intended to replace the reverse sensitivity policy once finalised. The draft guide maintains the same overall approach with a Buffer Area and Effects Area, but refines the implementation of the recommended controls in several respects.

Figure 1: Draft Transport Agency guide

In preparing the guide the Transport Agency has undertaken work to inform the approach recommended. This includes:

- A case study into the costs of acoustically treating new houses near to state highways.
- A review of the ventilation requirements and development of a new specification for systems to be installed when windows are required to be closed for sound insulation.
- Development of a more refined calculation method to determine the recommended extent of the Buffer and Effects Areas. Previously distances were based just on traffic flow and speed, but now are also based on the road surface and percentage of heavy vehicles.

- Generation of public web-based GIS maps showing the recommended Buffer and Effects Areas for the entire network.
- Development of standard district plan provisions and consent conditions.

This work is all detailed in the guide. Additional information and case studies are also included to provide better context for the controls recommended.

While the basic controls are similar to the current policy, it is now recommended that noise sensitive activities should be permitted in the Buffer Area for urban areas, but subject to additional controls (such as for vibration). This approach recognises that urban development densities often constrain the Buffer Area available and good urban design principles. While this is a significant change to the existing policy, in practice this approach has been taken in many cases.

5.1 District Plans

Consistent application of the Transport Agency's reverse sensitivity guide is still reliant on the controls being incorporated into individual district plans. The most effective approach for achieving this is through the statutory 10 year district plan review process. In practice it will therefore be many years before there is widespread adoption of the recommended land use controls.

The Transport Agency is interested in exploring further opportunities for nationally consistent guidance for managing reverse sensitivity effects. Should such an opportunity arise, a National Environment Standard or similar national guidance instrument would be a more effective method of managing reverse sensitivity effects on New Zealand's land transport networks.

5. Conclusions

Reverse sensitivity effects can arise from noise sensitive activities such as residential activity, establishing near to transport operations. Some transport operators such as airports and ports have implemented guidance in New Zealand Standards to manage reverse sensitivity effects. While starting over a decade later, Transit and now the Transport Agency have adopted a similar approach for reverse sensitivity controls for state high-ways. However, given that state highways span nearly every district, controls have not yet been achieved for most of the network.

The Transport Agency has now prepared a draft guide to refine its approach to reverse sensitivity. As part of the development of this guide, the Transport Agency is consulting to obtain external feedback.

Longer term, the approach in the guide should provide a consistent basis for managing reverse sensitivity effects into the future.

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2. Pardy, B. and Kerr, J. Reverse sensitivity – The common law giveth, and the RMA taketh away. NZ Journal of Environmental Law Vol 3. 1999.
3. Auckland Regional Council v Auckland City Council. A010/97
4. NZ Transport Agency. Planning Policy Manual, Appendix 5D Reverse sensitivity. 2007
5. NZS 6805:1992 Airport noise management and land use planning
6. NZS 6807:1994 Noise management and land use planning for helicopter landing areas
7. NZS 6809:1999 Acoustics – Port noise manage-ment and land use planning
8. NZS 6806:2010 Acoustics – Road-traffic noise – new and altered roads

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Strengthening New Zealand's standards system

The latest developments in the transition of the national standards body functions to the Ministry of Business, Innovation and Employment (MBIE), is the Standards and Accreditation Bill, which disestablishes the Standards Council and legislates for the new arrangements, has passed its third and final reading in Parliament. Once Royal Assent has been granted (expected to be soon), the Bill becomes the Standards and Accreditation Act 2015. The next step is recruitment of the Standards Approval Board which will approve standards and standards development committees in the new arrangements. Commerce and Consumer Affairs Minister Paul Goldsmith has issued a press release on the third reading of the Bill. While the transition process progresses, we continue to provide support for standards development, approval, maintenance, and access to standards. Standards New Zealand, the Standards Council, and MBIE are working together to ensure the transition goes as smoothly as possible.

If you would like to read more about the transition refer to: www.standards.co.nz

FAA gives Inglewood $8M grant to help insulate homes from noise near LAX

An article by mynesla has reported that Inglewood Airport will receive an $8 million grant from the Federal Aviation Administration to help insulate homes against noise from nearby Los Angeles International Airport, representative, Maxine Waters announced Monday. "Although Inglewood has previously received noise mitigation funds, not all residents have been covered and many have been waiting for years for soundproofing for their homes," said Waters, D-Los Angeles.

The funding, which will be provided through the city's Residential Sound Insulation Program, is expected to provide upgrades to 202 homes, according to Waters' office. "Noise from planes landing and departmenting from LAX is very disruptive for these families," Waters said. "This grant will bring relief to families in Inglewood who have to live with airport noise every day."

For further information see: http://mynewsla.com/government/2015/08/31/faa-gives-inglewood-8m-grant-to-help-insulate-homes-from-noise-near-lax

Birds sense speed limit when fleeing cars

An article by the zeenews website reports that a new study has found that Birds flee from the path of an incoming car on the basis of the posted speed limit, rather than the actual speed of the vehicle. Researchers captured 25 species in flight, looking at reaction distances for all species, and for the three most prevalent the results were similar. For further information see: zeenews.india.com/news/eco-news/birds-sense-speed-limit-when-fleeing-cars_870922.html.

Bleary-eyed residents have called noise control on contractors working on New Zealand's most expensive roading project

An article by TVNZ website reports that some residents have called noise control regarding construction noise from the construction of the Western Ring Route in Auckland. The project will eventually add 48 kilometres of new tunnels and roads to Auckland's growing motorway system. For further information see: www.tvnz.co.nz/one-news/new-zealand/noise-control-called-on-new-zealand-s-biggest-roading-project-6219855

Loopy rules report sparks talk of further Building Act amendments

In 2014 Local Government Minister Paula Bennett established a Rules Reduction Taskforce to meet with and take submissions from the public about frustrating and

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Modelling buildings to predict barrier effects in traffic noise models

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Abstract

As a result of the New Zealand Government's 'Roads of National Significance' programme, there has been a significant number of roading projects requiring large and complex traffic noise models to inform assessments of the potential impacts of traffic noise. For roading projects in built-up urban areas, screening by the front row of houses affects traffic noise levels at properties further away from the road. This paper explores different approaches to modelling the screening effects provided by these buildings using SoundPLAN and compares the results with measured noise levels.

Originally published at the 22nd Biennial Conference of the Acoustical Society of New Zealand, November 2014

1. Introduction

Since it was published in 2010, the New Zealand Standard NZS 6806:2010 "*Acoustics – Road traffic noise – New and altered roads*" (NZS 6806) has become the primary method of assessing noise from New Zealand public roads. When applied to large-scale projects, such as new motorways, bypasses and upgrades to major arterial routes, the study area can extend for kilometres, and include hundreds of potentially affected properties. Because of the multiple calculation points and sometimes complex geometries, calculations using simple methods, such as with a spreadsheet, are generally inefficient. As a result, 3-dimensional computer models are the preferred method of predicting traffic noise levels and developing noise mitigation options.

NZS 6806 requires predictions of traffic noise levels to be conducted in accordance with CRTN (Calculation of Road Traffic Noise) methodology [1]. This has been generally accepted as being the most appropriate method for predicting traffic noise in New Zealand, subject to adjustments for common road surfaces [2]. One element of the CRTN method is the barrier insertion loss, this being the reduction in noise at a receiver resulting from screening of the noise source by intervening terrain or structures. This is referred to in CRTN as the 'barrier correction'. The barrier correction is an important element of the overall calculation, as the reduction in noise level can be up to 20 decibels in extreme cases, significantly affecting the resulting traffic noise level.

Because predicted traffic noise levels are used to inform decisions regarding noise mitigation, incorrect modelling of barriers could result in inappropriate specification of noise mitigation measures. For instance, the under-prediction of the barrier loss (resulting in higher traffic noise levels at receivers) may lead to the specification of a low-noise road surface, and subsequent increased costs. On the other hand, over prediction of barrier loss could result in insufficient noise mitigation being included in the design of the project, leading to significant unanticipated adverse noise effects, unexpected costs and loss of goodwill.

For large scale projects, a standard approach to modelling buildings to accurately predict barrier loss is required to enable the acoustic consultant to provide accurate, timely and reliable advice.

Most residential buildings in New Zealand have relatively complex geometries, including pitched roofs. This paper explores methods for modelling of these more complex building shapes and covers the following:

- General overview of the CRTN traffic noise prediction method, with particular reference to how intervening structures are taken into account.
- An outline of four general approaches to modelling buildings in SoundPLAN, including an overview of the advantages and disadvantages from a modelling perspective, and a comparison of predicted noise levels for each method.
- Development of the flat-topped building approach to determine a standard building height.
- A comparison between traffic noise levels predicted using the flat-topped building approach and measured traffic noise levels at a location in Christchurch.

2. The CRTN calculation method

In essence, the traffic noise calculation method defined in the CRTN standard comprises three core parts:

- Calculating the basic noise level based on parameters affecting noise emissions including traffic flow, percentage heavy vehicles, traffic speed, gradient and

road surface.

- Determining appropriate corrections to the basic noise level to account for the propagation path including distance, intervening structures and ground cover.
- Adjusting for the specific receiving environment to take into account reflection effects and angle of view.

The calculation of the barrier correction term is included in the second part of the method described above, and is the only element of the CRTN method considered in this paper.

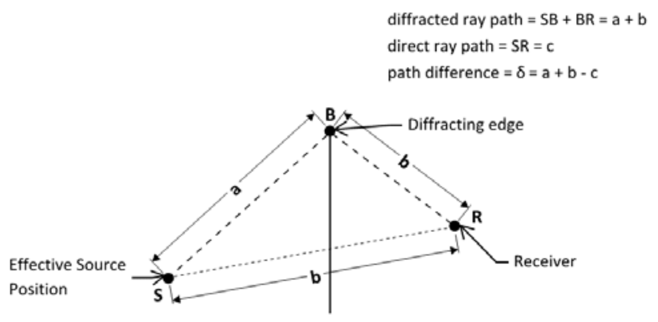

Figure 1: Geometry to evaluate the path difference for obstructed propagation

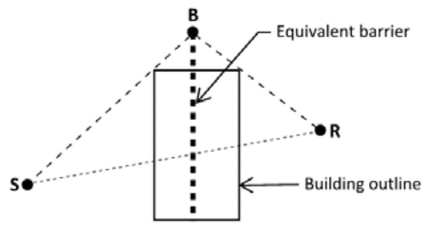

Figure 2: Equivalent barrier location used to calculate the barrier correction with a flat-topped building

Once the path difference is determined from the propagation geometry, the barrier correction, in decibels, is calculated using a polynomial expression 2.

3. 3-Dimensional modelling approaches

The tools most applicable to modelling buildings in SoundPLAN are the Building, Noise Barrier, and Floating Screen tools. These key aspects of how these tool work are:

- The Building tool creates a horizontal, flat-topped building with a user-entered footprint and vertical walls.
- The Noise Barrier tool creates vertical walls of a user-defined height.
- The Floating Screen is essentially a Noise Barrier that does not have to be vertical. It therefore can be used to create angled planes.

It is important to remember that SoundPLAN merely applies the selected calculation standard, in this case CRTN. Therefore, while complex geometries can be modelled in SoundPLAN, the accuracy of the predicted noise levels is still limited to how these geometries are interpreted by the calculation standard.

Four main modelling approaches using these tools were considered:

- Detailed modelling of the building including pitched roofs.
- Vertical wall parallel with the road axis representing the equivalent barrier/roof ridge height.
- Flat-topped building based on the actual footprint.
- A combination of flat-topped building with a noise barrier at the roof ridge.

These methods are described in the following sections, with brief comments regarding key issues from a modelling perspective. Note that some of the following comments with respect to modelling may only apply to SoundPLAN models, and may not be applicable to other computer noise modelling software packages.

3.2 Pitched roof building model

Buildings with pitched roofs can theoretically be input in SoundPLAN by a skilled user implementing a combination of tools.

From a modelling point of view, this method has some drawbacks when modelling on a large scale. Namely:

- The method is very time consuming, as the roof of each building must be constructed separately and in addition to the main building structure as described above. In some cases each individual roof plane would need to be entered separately.
- The method cannot be easily error-checked or modified on a large-scale, and has many possibilities for error.

The main advantage of this approach, from a modelling perspective, is that the Building tool, as well as defining the geometry of a structure, also provides options for the specification of receiver positions. That is, entering a building defines the receiver position at the same time. This streamlines the modelling process, ensures that calculation positions are in the correct position, and enables modifications to receiver positions at all positions to be made quickly.

3.3 Individual noise barrier

To model buildings with pitch roofs using this method, a noise barrier is placed with the top edge at the ridgeline of the roof.

From a modelling perspective, the key issues with adopting this approach stem from the requirement to enter additional receivers for every assessment position.

Namely:

- Entering receiver positions for every position of interest takes a significant amount of time for large

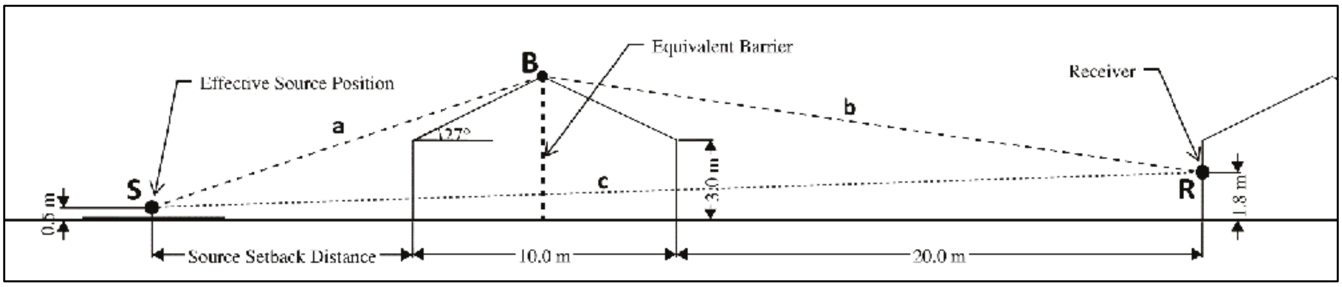

Figure 3: 2-dimensional geometry including ray paths and equivalent barrier position

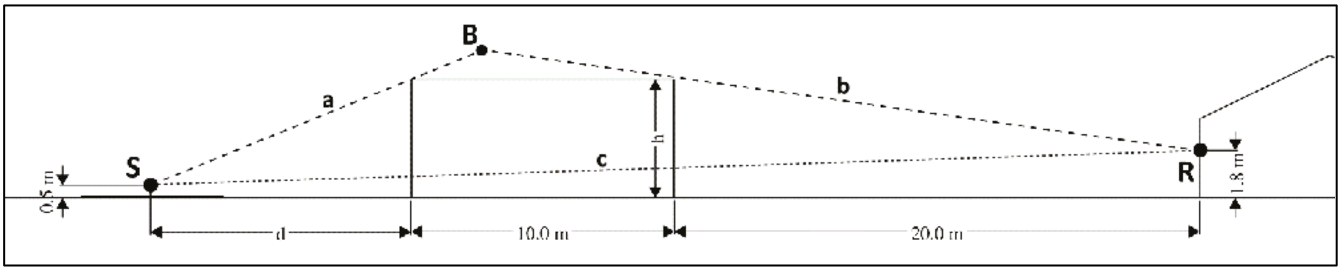

Figure 4: 2-dimensional geometry with flat-topped building ray paths

models.

- If reflections off noise barriers are included, the calculated noise level at the associated receiver(s) will not be a free-field level and cannot be simply adjusted.
- If reflections off noise barriers are excluded to enable free-field noise levels to be calculated, the effect of reflections on other receiver positions will not be taken into account, resulting in lower noise levels.

3.4 Flat-topped buildings

The footprint of a building can be defined in SoundPLAN by tracing the perimeter of the structure from a high definition aerial photograph, or by geo-located digital building footprints imported directly into the model. Building heights are usually set using one of the following three approaches:

- Building height set at eave height which does not take into account the pitched roof.
- Building height set at ridgeline height, essentially increased the height of the walls.
- Building height set at value between the eave and ridge height to approximate the effect of the pitched roof on screening of the source.

From a modelling perspective, this approach has the following advantages:

- Multiple buildings can be entered quickly when geo-located digital building footprints are available, avoiding the need to manually define each individual building based on aerial images.
- Height information is sometimes included in the building footprint data, assisting in the identification of multi-storey buildings and positioning receivers. This is especially useful where buildings overlook the road being assessed.
- Receiver positions for noise level calculations can be associated with buildings and do not need to be entered separately.

However, the most significant flaw in this approach is that the vast majority of residential buildings in New Zealand have pitched roofs. Therefore, the potential accuracy of this approach relies on closely matching the barrier correction calculated by the pitched roof approach.

3.5 Flat-topped building and noise barrier combination

This combination of modelling approaches capitalises on the significant advantages of the flat-topped building method, while also negating the main issues with both standalone approaches. The only real disadvantage to this method is the extra time required to input the noise barriers, which for large-scale projects may be significant.

4. Comparison of predicted noise levels

A simple scenario was modelled in SoundPLAN using a combination of the different modelling approaches.

Figure 3 shows the geometry of the scenario that was modelled. Figure 4 shows how this might be modelled by a flat-topped building. The lines marked a, b and c are the ray paths used to calculate the path difference, as shown earlier in Figure 1 and Figure 2.

The receiving position is 20 m behind the buildings closest to the road source. A 20 m distance is considered representative of the common scenario where houses are on opposite sides of a residential road, separated by small front yards, a footpath and grass verge on either side of the street, and the street itself. NZS 6806 defines the ground floor assessment position as between 1.2 m and 1.5 m above the floor level [3]. The receiver was located 1.8 m above the ground and therefore is valid for buildings with foundation heights between 0.3 m and 0.6 m.

A source setback distance of 50 m was used, with propagation over 100% hard (i.e sound reflecting), flat ground between source and receiver. Arbitrary traffic parameters were used, as these only affect the overall level, not the difference between each method. The predicted noise levels are shown in Table 1.

Table 1: Comparison of predicted noise levels

Predicted traffic noise level (dBA)				
Pitched Roof	Noise Barrier*	3 m High Flat-top	5.5 m High Flat-top	Combination Model**
50.5	50.3	53.4	49.2	50.4

* 5.5 m high barrier located at ridge position

** 3 m high flat-topped building and 5.5 m high noise barrier at ridge position.

In summary, the results for the simple model show the following:

- Predicted noise levels are similar for all modelling approaches which model the roof ridge (i.e. pitched roof, noise barrier and combination). As there are significant benefits, from a modelling perspective, associated with the use of the combination approach, the pitch room and noise barrier approaches were not developed further.
- Predicted noise levels for flat-top buildings vary by almost 4 dB depending on the height selected.

As a result of the above, the flat-topped building approach was progressed further in order to determine what height of building results in predicted noise levels in line with the more detailed approaches. This is discussed in the following section.

4. Developed flat-topped building model

As discussed, there are significant benefits to the modeller in adopting the flat-topped building model approach. On the basis that CRTN barrier correction calculation method correctly predicts the insertion loss of a structure when the correct geometry is modelled, the key challenge is therefore determining the building height that most accurately predicts the barrier correction calculated with the other, more geometrically correct, approaches. This section outlines the process by which this was determined.

4.1 Methodology

The simple scenario used to compare the modelling approaches was used to analyse a range of flat-topped building heights (refer to Figure 2), as follows:

- The barrier correction was calculated for setback distances between the source and front-row varying from 80 m to 5 m. The results therefore take into account the range of geometry that might be found in real life. For example, an upgrade to an existing urban road would most likely bring the road significantly closer to the front-row buildings than a new motorway located on the fringe of an urban area.
- As seen in Table 1, the barrier correction calculated for a pitched roof building is very similar to that calculated for a simple noise barrier. To determine which flat-topped building height was most accurate for the range of source distances, the predicted CRTN barrier correction for each building height was compared with the CRTN barrier correction for the equivalent barrier. This is a 5.5 m high barrier located at the building ridge position (refer to equivalent barrier in Figure 1).
- To restrict the models to realistic geometries, buildings between 3 m and 5.5 m in height were assessed. 3 m is the eave height of the theoretical building and therefore a reasonable minimum height. 5.5 m is the ridge height and therefore a reasonable maximum height limit.

4.2 Results

The calculated barrier corrections for the following three scenarios are presented:

- Scenario 1: 3 m high building, representative of models based on the building eave height.
- Scenario 2: 5.5 m high building, representative of models based on the building ridge height (5.5 m is the ridge height for the reference scenario).
- Scenario 3: 4.4 m high building, selected as the giving the best approximation of the reference scenario for the range of source positions modelled.

The results are presented in Table 2 and Figure 5, with a detailed data table contained in Appendix A.

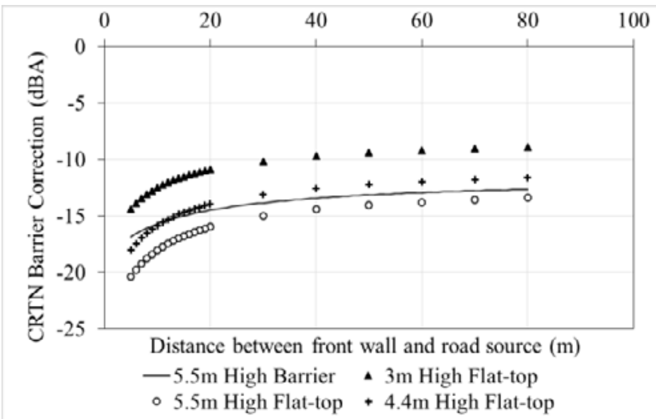

Figure 5: CRTN barrier correction for flat-topped buildings in reference scenario

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Table 2: CRTN barrier correction for flat-topped buildings in reference scenario

Source Setback (m)	CRTN Barrier Correction (dBA)			
	Reference Scenario	3 m High Flat-top	5.5 m High Flat-top	4.4 m High Flat-top
80	-12.7	-8.9	-13.4	-11.6
70	-12.8	-9.0	-13.6	-11.8
60	-12.9	-9.2	-13.8	-12.0
50	-13.1	-9.4	-14.0	-12.2
40	-13.4	-9.7	-14.4	-12.6
30	-13.8	-10.2	-15.0	-13.1
20	-14.5	-10.9	-16.0	-14.0
15	-15.0	-11.5	-16.8	-14.7
10	-15.7	-12.5	-18.0	-15.8
5	-16.8	-14.4	-20.4	-18.0

In summary, the results show the following:

- Calculated barrier corrections for flat-topped buildings modelled at eave height are typically around 3 dBA to 4 dBA smaller (i.e. less reduction in noise level) than the barrier correction for the reference scenario.
- The barrier correction with a 3 m high flat-topped building differs from the reference scenario barrier correction relatively consistently across the modelled range of source setback distances.
- Calculated barrier corrections for flat-topped buildings based on the ridge height are within 1 dBA of the reference scenario for source setbacks greater than 40m, and differ by more than 2 dBA for source setback distances less than 13 m. The difference is most significant with small setbacks, and the barrier correction is always larger (i.e. more negative), as would be expected.
- The calculated barrier correction for a 4.4 m high flat-topped building is within 0.5 dBA of the reference scenario for source setbacks between 20 m and 8 m, and within 1 dBA for source setbacks between 6 m and 80 m.

5. Traffic noise survey

To test the accuracy of the flat-topped building model, noise levels calculated by a SoundPLAN computer noise model for a section of QEII Drive (SH74) were compared with measured noise levels.

Traffic noise level measurements were conducted near QEII Drive (SH74) in Christchurch on the afternoon of 8 July 2014. Figure 6 shows the location of measurement

Figure 6: Measurement and calculation positions (Imagery: Google, 2012)

positions A, B and C.

A logging sound level meter was erected at Position A, recording one-second A-weighted average noise levels (L_{Aeq}) for the duration of the survey. Multiple short-duration L_{Aeq} measurements were recorded at Position B and C. The logger data was post-processed to determine the LAeq noise level at Position A that correlated to each measured noise level at Position B and C. The noise level difference between Position A and Position B or C was then calculated.

6. SoundPLAN traffic noise model

A 3-dimensional noise model was constructed in SoundPLAN [4]. The position of the buildings, road and solid fences were based on aerial images. The underlying terrain model was flat and 100% hard.

Free-field receivers were located at Positions A, B and C, shown in Figure 6. Additional receivers were also attached to the front façades of two buildings, at Positions D and E, to determine the calculated level difference at Position C compared to front-row buildings.

Traffic noise levels were calculated in accordance with the CRTN method, with arbitrary values set for traffic flow, average speed, surface correction and percentage heavy vehicles.

7. Results - Comparison with measured noise levels

Table 3 contains both the measured and calculated difference in traffic noise level at Position B and C, compared to Position A. Note that the level differences in Table 3 include factors such as distance from the road and reflections off nearby structures, and are not directly comparable to the CRTN barrier correction.

The results in Table 3 show that, for all building heights, the calculated level difference at Position B and C is smaller (i.e. less r) than the measured results.

Table 3: Difference in traffic noise level compared to Position A

Position	Measured level difference (dBA)	Calculated level difference (dBA)		
		3 m high buildings	5.5 m high buildings	4.4 m high buildings
B	-22.8	-15.4	-20.2	-18.4
C	-22.0	-15.6	-19.2	-17.9

8. Discussion

8.1 Approach to modelling buildings

The practical advantages associated with modelling single-storey dwellings as flat-topped boxes far outweigh the potential inaccuracies associated with the fundamental deviation from modelling the true shape of most buildings. It is therefore anticipated that future developments in 3-dimensional modelling of buildings for traffic noise modelling will be based around this approach.

A 4.4m high flat-topped building result in a CRTN barrier correction that most closely correlates to the reference scenario for source setbacks between 5 m and 80 m. 4.4 m may therefore be a reasonable default building height for traffic noise models.

It is interesting to note that SoundPLAN's recommended approach to modelling buildings is to use flat-topped buildings at the mean building height. If the ridge height is not known, SoundPLAN calculates this by adding half the floor height onto the overall building height. For a single storey building with a 3 m first floor height, this would give a building height of 4.5 m.

On some projects, aspects of the reference scenario geometry, such as eave height or roof pitch, may be clearly inapplicable. For example, areas of the country with the potential for high snowfall are likely to have steeper roofs, or a particular area may have consistently higher foundations due to potential flood risk. In this case, it would be possible for the modeller to fine-tune the building height by reproducing the calculations undertaken in this paper to derive the 4.4 m height. However, the impact of these geometric changes is unlikely to alter the building height by more than a few hundred millimetres, with a corresponding change in barrier correction of a few fractions of a decibel at most. Therefore, it is unlikely that this would be warranted for most projects, and the 4.4 m height will still provide a good level of correlation.

One aspect of traffic noise modelling not covered by the reference scenario is the potential impact on noise levels at multi-storey second-row dwellings behind single-storey front-row dwellings, or where buildings have the potential to overlook the main carriageway due to elevated terrain. The degree of shielding provided by the front-row buildings is likely to be a key factor affecting noise levels at the second row buildings and will be affected by how both the receiver position and front-row buildings are modelled.

8.2 Predicting noise levels for assessment

Even with flat-topped buildings with walls the same height as the ridge of the peaked roof, modelled noise levels are around 3 dBA higher than measured noise levels. This suggests that calculations performed using the CRTN method will over-predict traffic noise levels at receivers with significant intervening structures.

While it is generally preferable to err on the conservative side when predicting noise levels for any assessment of noise effects, the impact of incorrect predictions on an assessment under NZS 6806 are potentially significant, as discussed at the start of this paper.

9. Future work

Traffic noise modelling and comparison with measured levels at more sites need to be undertaken to confirm the apparent over-prediction of traffic noise levels and suggested 4.4 m building height.

The reference model used in this paper could be modified to consider situations such as multi-storey second-row buildings, significant terrain variations, and where screening is dominated by a noise barrier in front of front-row dwellings.

An in-depth investigation of the potential impact on NZS 6806 traffic noise assessments, taking into account other real-life scenarios and the complete assessment process applied to large-scale projects, would provide valuable information to acoustic consultants and other parties involved in roading projects. A review of recent major projects is one potential starting point.

10. Conclusions

Buildings in 3-dimensional traffic noise models are recommended to be modelled using flat-topped buildings. Adopting this approach will enable modellers to benefit from the expected quality and availability of digital data, which is only expected to increase, by increasing their modelling accuracy and efficiency.

Analysis of a reference scenario based on generic building geometry shows that flat-topped buildings with a height of 4.4 m for single-storey buildings give the best correlation with the CRTN barrier correction

Acknowledgments

I would like to thank my colleagues in the Marshall Day Acoustics Christchurch office, particularly Jon, Stuart, Rob and Aaron, for the many challenging and enlightening discussions about the vagaries of computer noise modelling.

Appendix A - Detailed CRTN barrier correction

Table A1: CRTN barrier correction

	Reference Scenario	3m High Flat-top		5.5m High Flat-top		4.4m High Flat-top	
Source Setback (m)	Calculated CRTN Barrier Correction (dBA)	Calculated CRTN Barrier Correction (dBA)	Deviation from Reference Scenario (dBA)	Calculated CRTN Barrier Correction (dBA)	Deviation from Reference Scenario (dBA)	Calculated CRTN Barrier Correction (dBA)	Deviation from Reference Scenario (dBA)
80	-12.7	-8.9	**3.8**	-13.4	**-0.8**	-11.6	**1.0**
70	-12.8	-9.0	**3.8**	-13.6	**-0.8**	-11.8	**1.0**
60	-12.9	-9.2	**3.8**	-13.8	**-0.8**	-12.0	**1.0**
50	-13.1	-9.4	**3.7**	-14.0	**-0.9**	-12.2	**0.9**
40	-13.4	-9.7	**3.7**	-14.4	**-1.0**	-12.6	**0.9**
30	-13.8	-10.2	**3.7**	-15.0	**-1.2**	-13.1	**0.7**
20	-14.5	-10.9	**3.6**	-16.0	**-1.5**	-14.0	**0.5**
19	-14.6	-11.0	**3.6**	-16.1	**-1.5**	-14.1	**0.5**
18	-14.7	-11.1	**3.5**	-16.2	**-1.6**	-14.2	**0.4**
17	-14.8	-11.2	**3.5**	-16.4	**-1.6**	-14.4	**0.4**
16	-14.9	-11.4	**3.5**	-16.6	**-1.7**	-14.5	**0.3**
15	-15.0	-11.5	**3.5**	-16.8	**-1.8**	-14.7	**0.3**
14	-15.1	-11.7	**3.4**	-17.0	**-1.9**	-14.9	**0.2**
13	-15.2	-11.8	**3.4**	-17.2	**-2.0**	-15.1	**0.2**
12	-15.4	-12.0	**3.3**	-17.4	**-2.1**	-15.3	**0.1**
11	-15.5	-12.2	**3.3**	-17.7	**-2.2**	-15.6	**0.0**
10	-15.7	-12.5	**3.2**	-18.0	**-2.3**	-15.8	**-0.1**
9	-15.9	-12.8	**3.1**	-18.4	**-2.5**	-16.2	**-0.3**
8	-16.1	-13.1	**3.0**	-18.8	**-2.7**	-16.5	**-0.4**
7	-16.3	-13.4	**2.9**	-19.2	**-2.9**	-16.9	**-0.6**
6	-16.6	-13.9	**2.7**	-19.8	**-3.2**	-17.4	**-0.9**
5	-16.8	-14.4	**2.4**	-20.4	**-3.5**	-18.0	**-1.2**

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4. SoundPlan 7.3, Braunstein + Berndt GmbH

Non-destructive assessment of wood properties in tree stems using acoustic imaging

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Abstract

There is significant interest in non-destructive testing of trees and felled logs. One way of imaging the interior of tree stems is using acoustic techniques. This paper describes a study which investigates the potential of acoustics for au-tomatic detection of knots in felled logs for optimising the value that can be achieved during sawmilling. Pulses of sound, in the audio frequency range, were excited at one end of a log using an air coupled transducer. The sound emitted from the log was then detected at a range of positions along the log using a single microphone in contact with the log and then using a non-contact acoustic camera. Initial results are presented which indicate that this technique may have potential as a means of automatically detecting knots. Results from current research, including the development and use of high power ultrasound will be presented. Future research plans will then be outlined..

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1. Introduction

The ability to predict the properties of a tree stem or felled log can have a significant effect on the profitability that can be achieved [1]. One factor that can affect the structural properties of wood is knots. Identification of the location of knots in saw milling processing plants is often performed using manual inspection. It would be desirable to have an automatic method of detecting knots.

The acoustic wave propagation in wood is anisotropic, having different velocities and attenuation rates in the longitudinal, radial, or tangential directions. The highest velocity and lowest attenuation rate is in the longitudinal (along the grain) direction [2,3]. This has been used to measure the grain direction in living trees and lumber [4,5]. In lumber, it has been reported that an ultrasonic signal follows the grain and propagates around knots [6,7]. An ultrasonic signal transmitted at the base of a log follows the grain and tends to come to the surface of the log with a higher amplitude at the knots [8,9]. Few details are provided in these references but the suggestion is that this phenomena may be used as a method of detecting knots in logs.

This paper presents initial work performed, with funding from SWI , to investigate the use of acoustics for detecting the location of knots in logs. In a similar manner to that suggested by [8,9], speakers were attached to the base of logs. Audio frequency signals, which have lower attenuation than ultrasound, were used. RMS measurements of the signal propagating through the wood was obtained using microphones which were in contact with the surface of the log. A microphone phased array (acoustic camera) was then used to image the sound coming from knots.

2. Contact mirophone technique

2.1 Experimental Procedure

Experiments were performed to investigate if an acoustic signal excited at the base of a log resulted in increased acoustic emission at knots. Figure 1 shows the experimental setup used. Excitation signals were created using MatLab. These were Hann windowed, tone bursts in the audio frequency range. These were converted to an analogue signal using a DAC channel of a Data Translation DT9836 board with a sampling rate of 225 kHz. This was amplified using a commercial audio power amplifier and used to excite one or more tweeter speakers attached to the end of logs.

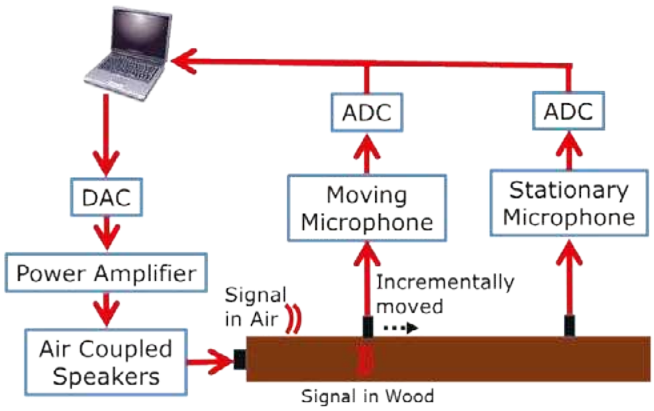

Figure 1: The experimental set-up used to measure RMS values as a function of position on a log for knot detection

The resulting signal was measured using two low noise GRAS microphones which were in contact with the surface of the log. This was amplified using the GRAS low noise preamplifier and sampled using analogue inputs of the DT9836 board using a sampling rate of 225 kHz and a resolution of 16 bits. One microphone was kept stationary, while the other was moved along the log in steps of 25 mm.

An AIC picker algorithm [10] was used to detect the first arrival of the signal, see Figure 2. A RMS value was then obtained from a set number of samples following this first arrival time. This was assumed to be the signal emitted from the wood before the first arrival of the signal through air. This was repeated for each measurement point along the log. The stationary microphone signal was optionally used to normalise the moving microphone RMS signal.

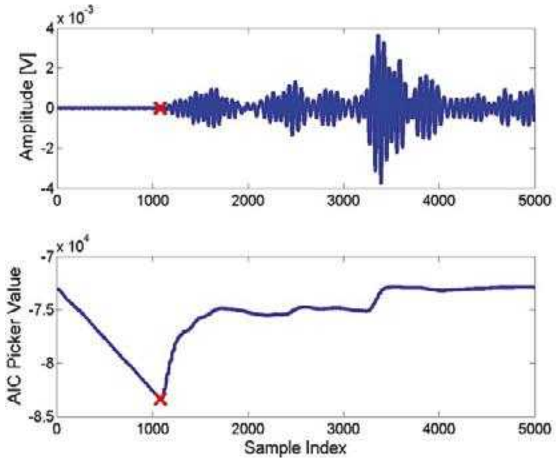

Figure 2: Example of the use of AIC picker algorithm output used to obtain time of arrival for pulse.

2.2 Lab Measurements

Initial measurements were made in the acoustics lab of the Physics Department of the University of Auckland. Figure 3 shows the wooden post used for these lab measurements. This post was a retaining wall post which was 2.4 m long and 130 mm in diameter.

Figure 3: Photo of experimental set-up in the lab for contact microphone measurements

RMS measurements were calculated for a range of transmit frequencies (see Figure 5 for several example plots).

There appeared to be a correlation with RMS peaks and the size and location of some knots. This correlation appeared to occur even if the measurement location was offset circumferentially from the knot location. However, this varied with transmit frequency and individual knots.

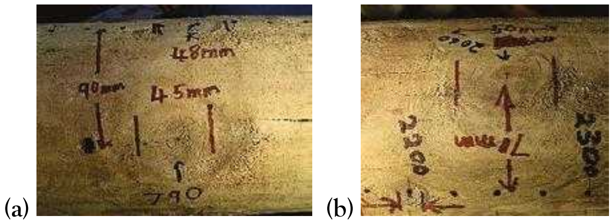

Figure 4: Photos of the two main knots which corresponded to peaks in the RMS measurements at (a) 790 mm and (b) 2200 mm. The dots show the contact microphone measurement locations

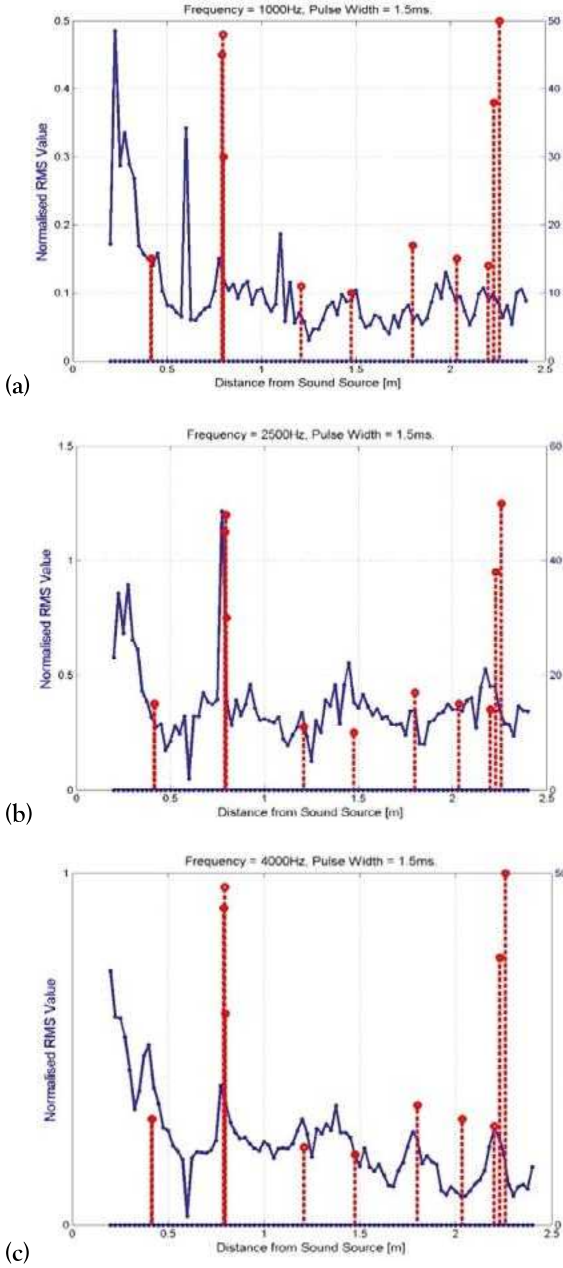

Figure 5: Lab measurement signal RMS values (blue) as a function of distance from source for 1, 2.5, and 4 kHz. Also shown on the plots (red) are the knot location and size (right hand axis). For some transmit frequencies, such as in (b) and (c), peaks in the RMS signal appeared to correlate to the location of knots.

2.3 Field trials

RMS contact microphone measurements were also performed on larger logs with higher moisture content in field trials at a site in Rotorua. The attenuation in these logs was much larger than had been observed in the post used for lab measurements. Therefore, an array of speakers was used for excitation, as is shown in Figure 6(a). However, the received signal from the wood was still relatively low. The excitation signal was a 3 kHz Hann windowed tone burst signal.

(a)

(b)

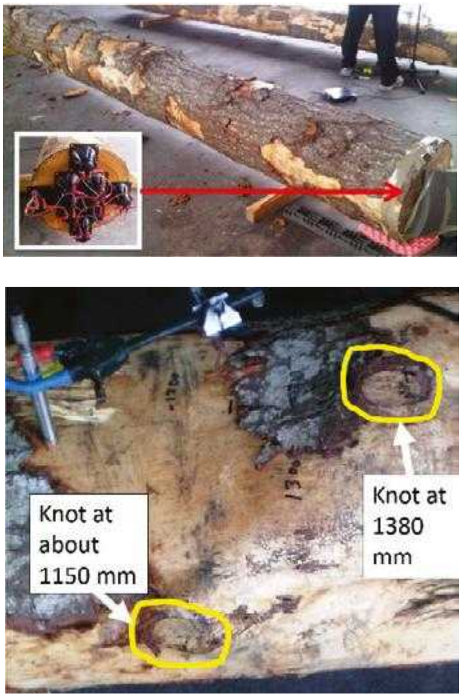

Figure 6: Photo (a) shows the logs used for field measurements with the speaker array used to excite the logs. Photo (b) shows the main knots.

The contact microphone measurement locations were orientated on the log so that they passed through a main knot located at 1380 mm from the sound source, see Figure 6(b). RMS values, were obtained using the AIC picker technique, see Figure 7. There is a strong peak in the plot which appears to correlate with the location of the main knot at 1380 mm.

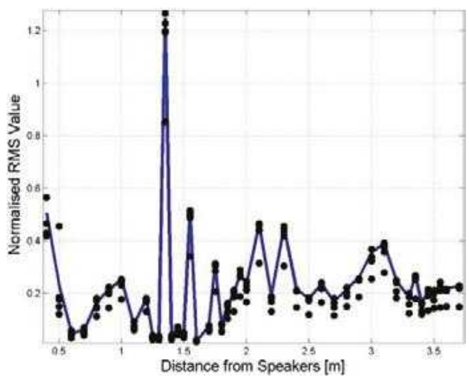

Figure 7: Plot of the RMS values for the field trial contact microphone measurements obtained using AIC picker algorithm

3. Phased array measurements for knot detection trials

The contact microphone measurements indicated that more sound was being emitted at the location of some knots. However, a non-contact method of detecting knots would be desirable. A microphone phased array, often called an acoustic camera, is a device that enables the sound emitted from an object to be imaged as an acoustic plot over a camera image. Experiments were performed to try to see if an acoustic camera had potential for detecting knots.

3.1 Experimental procedure

Figure 8 shows the experimental setup used to image the sound emitted by the log. The excitation signal used for lab measurements was a 3 kHz Hann windowed signal. A microphone phased array, built at the Physics Department of the University of Auckland [11,12], was used to measure the signal emitted from the log. The sampling rate used was 90 kHz with a resolution of 16 bits.

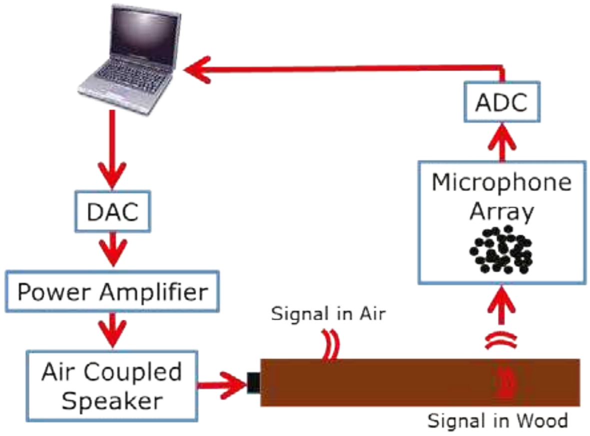

Figure 8: The experimental set-up used for microphone phased array measurements to try to image knots

Beamforming was used to generate acoustic maps. Beamforming maps contain blurring artefacts referred to as side lobes. To sharpen the image, the CLEANSC algorithm [13] was used to remove these artefacts and try to more accurately image the sound source distribution on the logs.

3.2 Lab measurements

Figure 9 shows the phased array setup in front of the log in the acoustics lab. Measurements were made at different positions along the log. Due to the separation of the phased array from the log, knots on the log near the source were not imaged, since the signal coming from the log could be merged with the direct signal through the air.

Figure 10 shows a beamforming and CLEANSC map for a knot that showed peaks that correlated with the location of a knot. These peaks were consistently seen for this knot for different positions of the microphone array relative to the knot. For other knots, such as that shown in Figure 11, no correlation was observed with the CLEANSC peaks and location of the knots.

Figure 9: Photo of the microphone phased array experimental setup used in the lab to image the location of knots

(a) (b)

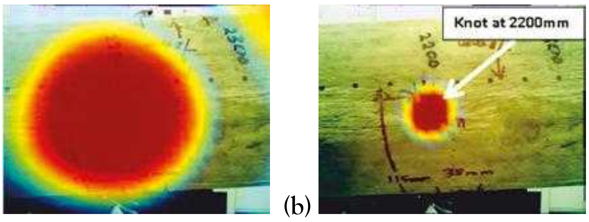

Figure 10: Microphone phased array (a) beamforming and (b) CLEANSC plots imaging the sound coming from the wooden pole in the lab. The plots show peaks in the vicinity of a knot, located 2200 mm from the source.

(a) (b)

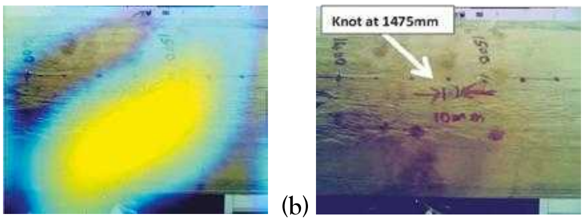

Figure 11: Plots showing an example where the microphone phased array (a) beamforming and (b) CLEANSC plots did not show any peaks in the vicinity of a knot, located at 1475 mm for the wooden pole in the lab

3.3 Field trials

Microphone phased array measurements were also performed for the larger logs. As in the case of the contact microphone measurements, the amplitude of the measured signal from these logs was low. Figure 12 shows the experimental setup used for the microphone phased array. Beamforming and CLEANSC acoustic maps were generated.

Figure 12: Photo of microphone phase array setup used for field measurements to investigate knot detec-tion imaging

Figure 13 shows an example where a peak in the beamforming map was obtained which correlated closely with a knot location.

(a) (b)

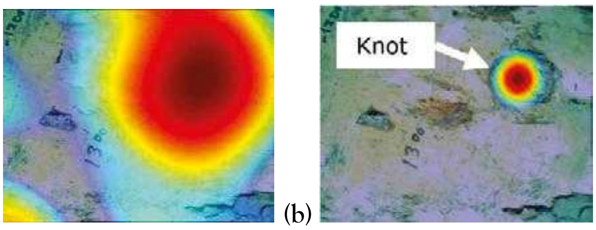

Figure 13: Microphone phased array (a) beamforming and (b) CLEANSC plots imaging the sound coming from a log in field measurements. The plots show peaks in the vicinity of a knot, located 1380 mm from the sound source. The excitation source was a 3 kHz Hann windowed tone burst.

However, Figure 14 shows an example, for the same knot but a different transmit frequency, which did not show this correlation of peak and knot location. Figure 15 shows an example, for a larger knot on a different log, which illustrated a tendency for the CLEANSC peaks to be located at the edges of the knots.

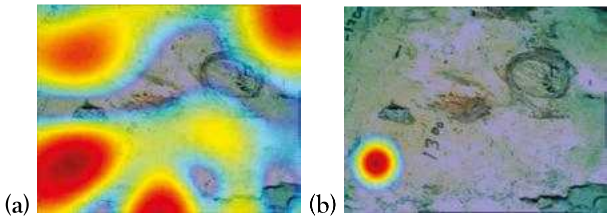

Figure 14: Plots showing an example where, for a different transmit frequency (6 kHz), the microphone phased array (a) beamforming and (b) CLEANSC plots did not show peaks in the immediate vicinity of the same knot that was imaged in Figure 13.

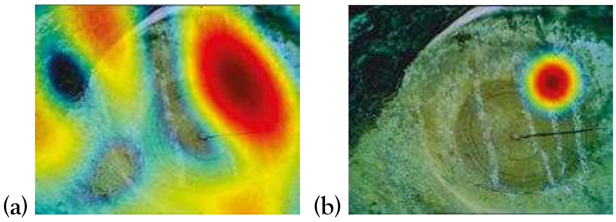

Figure 15: An example plot showing that often the peaks in the microphone phased array (a) beamforming and (b) CLEANSC plots appeared to occur at the edge of a knot on the same side as the sound source.

4. Conclusions and remarks

The individual microphone results show that there is an increased acoustic signal emitted from the vicinity of some knots when an acoustic signal was transmitted at the base of the log. For the individual microphone measurements, and for those with the acoustic camera, the challenge was to get a sufficiently strong signal. Improved coupling of the acoustic signal into the end of a log and improved hardware was required. Knots were able to be detected but not with the consistency required for commercial application. There were variation between individual knots and different transmit frequencies. More work was required to understand why this variability occurred.

This work is being continued in a subsequent project with Scion under the Growing Confidence in Forestry Future program . Improved excitation of the log is being investigated using contact ultrasonic transducers and high voltage power amplifiers. Potential benefits of using ultrasound are smaller wavelength, better coupling into wood, reduced effect from background noise, and reduced noise traveling through the air to the sensor. In addition, ultrasonic guided wave techniques can be used to provide better control of the signal being excited. The mechanism of acoustic emission at knots will also be investigated in more detail.

Acknowledgments

The authors would like to thank SWI for providing the funding for this project. Especial thanks to Keith Mackie of SWI and Wayne Miller of Tennon for their help and advice.

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SOUND
ADVICE

We have two decisions to share with you this issue and we are back to the Environment Court with the Te Rere Hau windfarm for further consideration of some of the remaining issues in this long run proceeding concerning the audible characteristics of the farm's turbines and then up to Auckland for an application for retrospective resource consent for the use of commercial units for residential purposes.

Full decisions and further information can be found on the RMA Net website at: www.rma.net

In the Environment Court

PALMERSTON NORTH CITY COUNCIL - Applicant

NEW ZEALAND WINDFARMS LIMITED - Respondent

[2015] NZEnvC 070, 20p, [66] paras, 21 April 2015

Summary of Facts

In 2011 the Council made an application for a series of declarations concerning the operation of the Te Rere Hau windfarm (TRH) near Palmerston North, owned by New Zealand Windfarms Limited (NZWL). In total the Council sought nine declarations, five of which were considered in decision [2012] NZEnvC 133. The remaining declarations remained alive and the Council sought consideration of the remaining issues which were renumbered 1.1-1.4. The Council's declarations were concerned with whether or not TRH was operating in accordance with its resource consent and conditions, in particular in relation to turbine special audible characteristics (SAC), especially tonality. The Court heard further evidence and considered each of the remaining declarations in turn.

Declaration 1.1 - That the noise emissions from the respondent's wind turbine generators (WTG's) at Te Rere Hau wind farm have known special audible characteristics.

Acoustic witnesses all agreed that the sound emissions from the WTGs at TRH contained tones and measurements taken at a distance of 50m from the turbine, as required by IEC 61400-11, identified tonal audibility exceeding 6.5dB. As such the Court held that the TRH WTGs indisputably produced SACs when measured close to the turbines and therefore made Declaration 1.1 as sought by the Council.

Declarations 1.2 and 1.3 were dealt with together being concerned with related issues.

Declaration 1.2 - That a penalty of +5dB is to be applied to the measured sound level for the reference sites as measured in MDA report of 18 February 2011 either based on the operating or "operational" or "fully operational" data sets.

Declaration 1.3 - That for the purpose of undertaking an objective test for tonality in accordance with Condition 5(1) of the Resource Consent:

(a) The assessment technique contained in IEC 61400-11 (2002) is to be used; and

(b) The assessment technique contained in IEC 61400-11 (2002) requires measurements and assessments to be undertaken at location close to the wind turbine generator.

The Court noted that these declarations must be undertaken in context of Condition (5) of the consent which dealt with measurement and control of sound levels at TRH together with Condition 5(1) which dealt with tonal noise. The central matter in dispute was the position where Condition 5(1) required the assessment of tonality to be undertaken for the purposes of imposition of the penalty. NZWL contended the position was at various sites identified in the consent, while the Council held the point was 50 metres from the WTGs as required by IEC 61400-11. The Court noted the distinction was highly significant for TRH which was running close to the noise limits imposed by its consent approximately 20-30% of the operating time.

The Court found that the relevant standard (NZS6808:1998) made it clear that as a general proposition the standard was directed at addressing the effects of WTG noise on recipients of the noise and that sound measurements were to be taken at receptor locations. The presence of SACs in the near field was no guarantee that they would be experienced in the far field and having measurement and assessment points at the same receptor locations was a logical approach agreed to on a practical level by all the acoustic witnesses. As such the Court noted there was an inconsistency between the Standard which was directed at assessing the effects of WTG noise at receiver locations in the far field and IEC 61400-11, as listed in Condition 5(1), which required a near field process. The Court's view was that Condition 5(1) lacked the required measure of certainty and was incapable of application for enforcement purposes. As such the Court declined to make the Declarations 1.2 and 1.3.

Lastly the Court assessed Declaration 1.4

Declaration 1.4 - That the respondent is not (even without special audible characteristic penalty) complying with noise limits of its resource consent in three sites with specific wind and speed directions.

The Court found the declaration was not confirmed for five of the listed instances and there was uncertainty in

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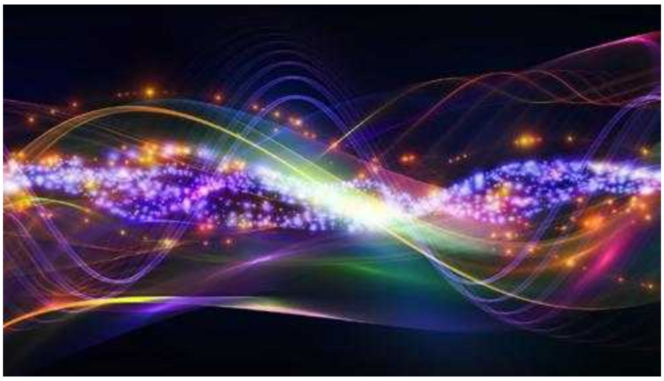
ineffective property rules. An example of what has been published in the report included comments from the public such as "Converting a shop into a two-bedroom residential unit required a reduction in noise levels from 70 dB to 35 dB. We tested the required noise levels in our brand new home; the only place that complied was the wardrobe". The report notes other issues raised by submitters include noise and the Resource Management Act. The Taskforce's Report entitled 'The loopy rules report: New Zealanders tell their stories' can be found at: www.dia.govt.nz/vwluResources/Rules-Reduction-Report/$file/Rules-Reduction-Report.pdf

Proposed International Year of Sound



The International Year of Sound will be a global initiative to highlight the importance of sound and related sciences and technologies as well as the contrast for quietness and peace in the lives for all in society. The International Year of Sound will consist of coordinated activities on regional, national and international levels. These activities will aim to stimulate the understanding throughout the world of the important role that sound plays in all aspects of our society. As well, these activities will also encourage an understanding of the need for the control of noise in nature, in the built environment and in the workplace.

The International Year of Sound is planned for 2019. For further information see: www.acoustics.asn.au/forms/IYS_PROSPECTUS-Draft-7July2015.pdf

North Korea resumes loudspeaker propaganda warfare with South Korea

The International Business Times website has reported on 17th August that North Korea has started blasting propaganda messages across the heavily militarised border with South Korea in response to similar messages from the South being resumed, officials in Seoul said. The article states that South Korea resumed the psychological warfare broadcasts after 11 years when two soldiers were injured by a landmine allegedly laid by North Korea earlier in August. Pyongyang denied planting the mines and threatened to launch rocket attacks to blow up the South Korean loudspeakers. The International Business Times article reports that North Korea's own propaganda broadcasts began on 17 August in a section of the eastern

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the sixth case sufficient for it not to make the declaration.

The Court made a final comment that in its initial decision it found the Council was entitled to conduct a review of the TRH consent conditions for reasons pertaining to the inaccuracies in the AEE provided by NZWL in support of its application. It noted that those findings stood and in the Court's view were expanded by the findings of the current decision. This reinforced the Court's view that there was a need to review Condition 5(1).

Court held:

Declaration 1.1 made.

Declarations 1.2 - 1.4 declined.

Costs reserved in favour of Applicant.

In the Environment Court

STRATA TITLE ADMIN BODY CORPORATE 176156 - Appellant

AUCKLAND COUNCIL - Respondent

AOTEAROA FISHERIES LIMITED, COROMANDEL MUSSEL KITCHEN, HANNAH HOLDINGS LIMITED, Z ENERGY LIMITED - Section 274 parties

[2015] NZEnvC 125, 51p, [196] paras, 23 July 2015

Summary of Facts

The Body Corporate appealed a decision by Council Commissioners refusing a retrospective resource consent application to use a building comprising 14 units situated at 255 Browns Road, Manurewa for residential purposes. The land was zoned Business 5 which enabled residential use in some circumstances, but the building was consented for use as commercial offices despite being used residentially since the early 2000s. The main issue related to the potential for adverse effects to arise from the residential use of the units within a suburban shopping centre with neighbouring industrial activities. The Court discussed the actual and potential effect of the units being used residentially which centred on the health, safety and wellbeing of the residents. Particularly relevant to the assessment of residential amenity the Court heard evidence on noise, natural light and ventilation and open space and landscaping.

The Court felt noise was a key issue in this case in terms of managing the effects of it on the residents from other business activities operating in and around the site. Also because that type of effect could precipitate complaint and result in reverse sensitivity effects on business operating lawfully nearby. Residents gave evidence that noise had not been a problem historically and they were happy with the current situation. District Plan Rule 14.11.7(a) required the average maximum noise level as measured at or within the boundary of any adjacent site zoned Business 5 should not exceed 65 dB L10, and that the maximum noise level (Lmax) should not exceed 90 dB. Rule 14.11.7 (b) stated household units should only be permitted in Business 5 zones where an acoustic design certificate was provided demonstrating that the accommodation was designed in such a manner as to comply with internal noise limits of 45 dB Ldn and Lmax of 55 dB.

Acoustic experts agreed that with suitable building treatments, the existing building envelope of the units could be upgraded to ensure that the internal noise levels complied with the District Plan, but that such work would approach the current limit of practicability. For the noise levels to be met all windows and doors would need to remain closed and mechanical ventilation would need to be provided. The exact costs of such upgrade work were not detailed, and due to the variability of the units each individual unit would probably require checking before acoustic certificates could be issued. The Court was satisfied however, that in broad terms noise levels in the District Plan could be met by the use of suitable building treatments.

In relation to other effects, the Court was not satisfied that sufficient natural light and ventilation was provided in all units and private open space was limited, with no landscaping at all around the units. The Court assessed the overall amenity to be at the lowest end of the scale and was not satisfied that the proposal provided appropriately for pedestrian safety which was contrary to Policy 14.4.9 of the District Plan.

The Court analysis of the potential for reserve sensitivity effects to arise if consent was grated concluded there was a real potential for the restriction on the future development of existing and future legally operating business in the immediate area, which was contrary to Policy 17 of the Auckland Regional Policy Statement. Overall the Court was not satisfied that the proposal satisfied the sustainable management of the Act.

Court held:

Appeal dismissed.

Costs reserved.

Disclaimer - *This article has been provided to help raise an initial awareness of some recent cases involving acoustic issues. It does not purport to be a full listing of all decisions which have acoustic issues, nor does it replace proper professional advice.*

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part of the border, a South Korean defence ministry official told AP on condition of anonymity. A defence ministry official told South Korean news agency Yonhap that the purpose of the North Korean propaganda broadcasts was mainly to muffle the sound of those from the South.

For further information see: www.ibtimes.co.uk/north-korea-resumes-loudspeaker-propaganda-warfare-south-korea-1515788

Image Source: www.ibtimes.co.uk/north-korea-resumes-loudspeaker-propaganda-warfare-south-korea-1515788

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Ferrymead bridge replacement project – Construction vibration

[1]Stephen Chiles, [2]John Hannah and [3]Bernard Kopke

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[3]HEB Construction Limited, 21 Aerodrome Road, Mt Maunganui

Abstract

The replacement of the Ferrymead Bridge in Christchurch involved the installation of piles over a 15 month period. Due to the close proximity of both residential and commercial neighbours and as the substantial pile casings were to be driven in by a heavy impact and vibratory hammer, the resulting vibration received at the nearby buildings was identified as a potential impact at an early stage in the project. Specialist vibration advice was provided to the project team, and throughout the works the vibration issues were dealt with collaboratively and collectively by the client; designers; contractors; and the vibration advisors. This paper details the vibration assessment; monitoring; and management procedures that were used. The collaborative approach towards the management of vibration resulted in a number of positive outcomes for the project, including minimal complaints; no disruption to local businesses; and no lost construction time due to vibration issues..

Originally published at the 22nd Biennial Conference of the Acoustical Society of New Zealand, November 2014

1. Introduction

Before the February 2011 earthquake, the Ferrymead Bridge was in the process of being strengthened and widened but as liquefaction occurred in the riverbed and significant damage was caused to the existing structure during the Canterbury earthquakes, Christchurch City Council (CCC) decided to replace the bridge with a structure which fully met the current standards. This involved larger and deeper piles. The Ferrymead Bridge Replacement Project is currently in progress and is jointly funded by the CCC and the NZ Transport Agency, with HEB Construction Limited as the main contractor on the project, and design work undertaken by Opus International Consultants. Completion is due in mid-2015.

Extensive and detailed geotechnical investigations were undertaken in the locations of the new bridge piles and these showed that the underlying rock is extremely variable with some layers being weak. Thus the six 1.1 m diameter abutment piles and the four 2.4 m diameter pier piles for the new bridge are found-ed using a maximum length of pile of 31 m to enable adequate support. This piling work was expected to last approximately 15 months.

Figure 1 illustrates the location of the bridge and the surrounding area. The area to the west of the new bridge is predominantly commercial, with some mixed/residential use buildings. One of these commercial premises, Chiptech, designs and builds electronic devices and is located approximately 160 m from the bridge. A large number of residential dwellings are located to the

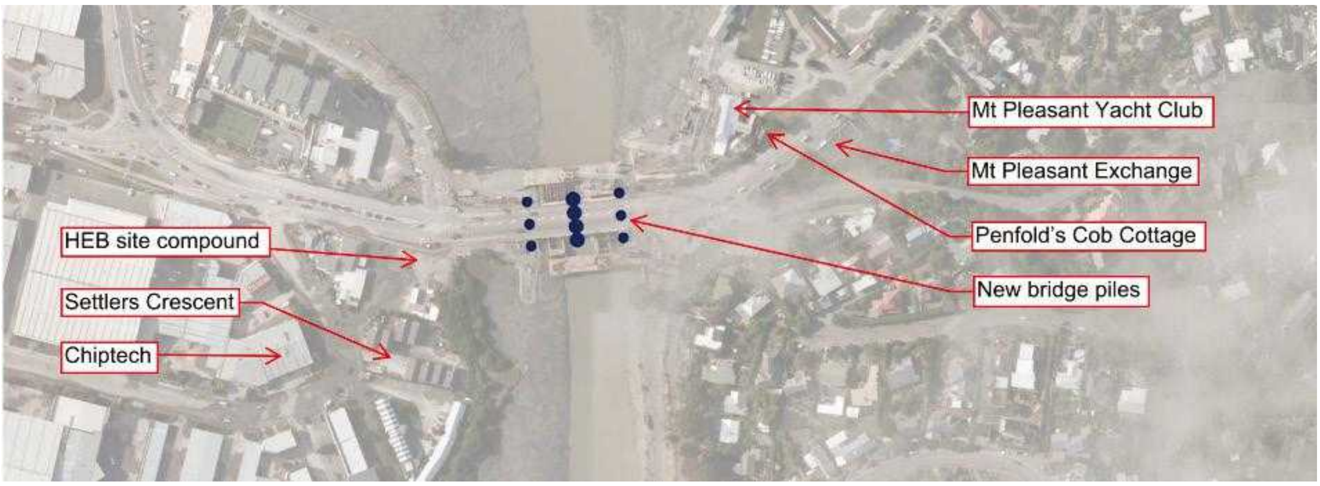

Figure 1: Ferrymead Bridge and surrounding area

south east. To the north east of the bridge is the Mount Pleasant yacht club and boat sheds, together with Penfold's Cob Cottage (a heritage-listed structure) and the Mount Pleasant telephone exchange.

Due to the close proximity of these neighbours and as the substantial pile casings were to be driven in by a heavy impact and vibratory hammer, the resulting vibration received at the nearby buildings was identified as a potential impact at an early stage in the project. Specialist vibration advice was provided to the project team by URS, and throughout the works the vibration issues discussed below were dealt with collectively by the client (CCC), designers (Opus) and contractors (HEB) with a collaborative approach.

This paper details the vibration assessment, monitoring and management procedures that were used for this project.

2. Inital Assessment

Prior to the piling work commencing the potential impacts of the piling vibration were assessed. Accurately predicting vibration from construction works is not straightforward as it is often difficult to quantify the energy transmitted from the pile into the ground and, most significantly, the propagation of the energy through the ground. The level and frequency content of the vibration that is propagated through the ground will depend on the dynamic properties of the soils, rocks etc and any layering in the ground structure. Therefore, without detailed knowledge of the propagation characteristics of the ground, empirical methods [1] were used to predict the level of vibration at a range of distances from the works. These predictions are typically conservative, i.e. an over-estimation of the actual vibration levels is made. The cost of this conservatism is generally less than the cost of more complex investigations (which would involve trial measurements of piling or another vibration source on the site) or the costs associated

Table 1: Vibration criteria

To assess	Threshold	Vibration level
Annoyance	Perception of daytime vibration in residential buildings	1 mm/s ppv
	Perception of daytime vibration in commercial buildings	2 mm/s ppv
Building damage	Cosmetic damage to structures	5 mm/s ppv
	Minor structural damage	15 mm/s ppv
Damage to underground services	Damage to plastic pipes	50 mm/s ppv

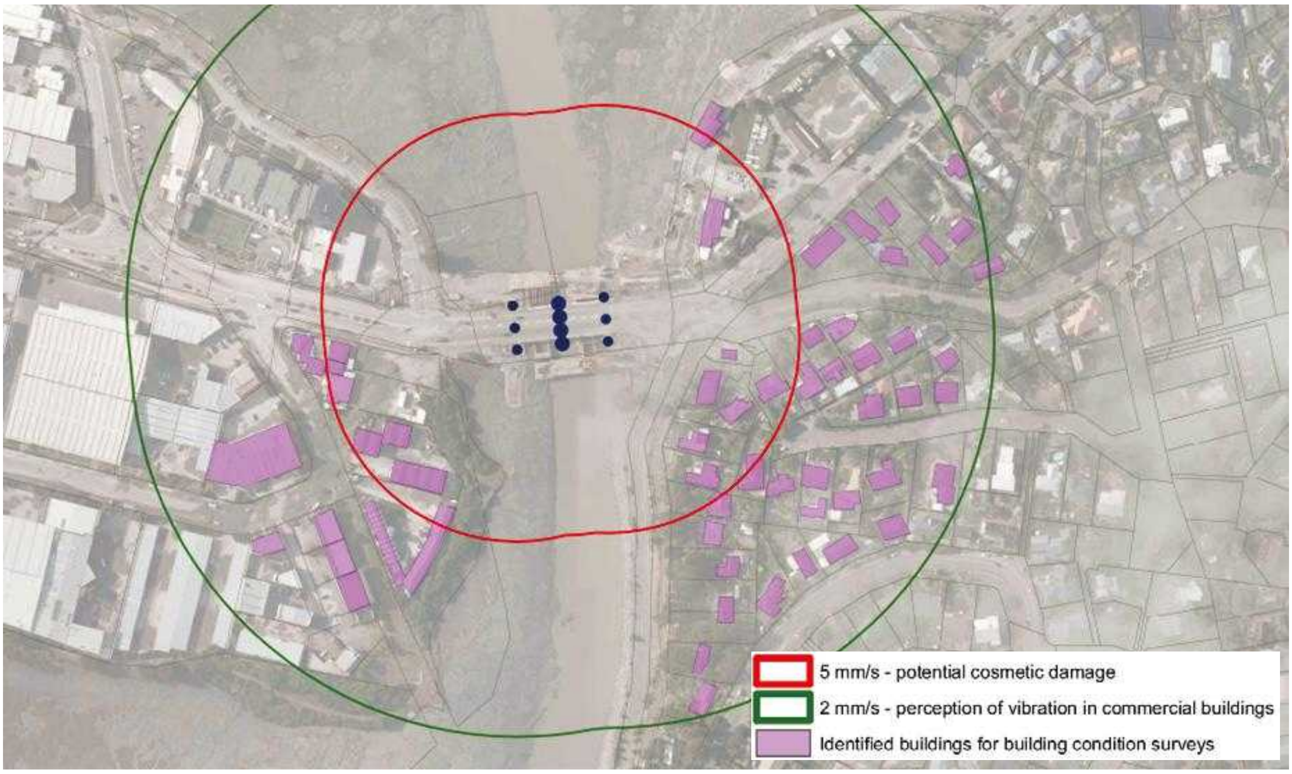

Figure 2: Predicted vibration levels and buildings to be surveyed

with halting the work once in progress.

Vibration criteria for the project were determined to assess annoyance, building damage (cosmetic or structural) and damage to underground services (Table 1). These are in terms of a peak particle velocity (ppv).

A comparison was made of the predicted levels with these criteria (Figure 2). This showed that the vibration would affect numerous buildings and showed a significant risk associated with the piling work. There was a risk of cosmetic damage (e.g. plaster cracking) to sixteen buildings and risk of disturbance from vibration in 56 buildings.

To manage this risk the project team decided to undertake the following:

- Inspection of buildings in the industrial area to identify any sensitive occupancy.
- Further assessment of the effects of vibration on Penfold's Cob Cottage.
- Further consultation with the neighbours of the project by means of a public meeting to describe the works and the likely effects of vibration. This included a comparison of the expected vibration from the construction works in comparison with that which occurred during the Canterbury earth-quakes.
- Pre- and post-work building condition surveys so that any effects of the piling vibration on the structures could be identified from any pre-existing damage.
- Inclusion of the piling vibration within the Construction Noise and Vibration Management Plan for the project. This incorporated:
  - Additional public liaison to forewarn neighbours of at the start of piling activity.
  - A vibration monitoring programme.

The vibration sensitivity of Chiptech (Settlers Crescent) was identified during the public meeting. As a result of this new information, the risk of disruption to their manufacturing process was subsequently minimised by the installation of anti-vibration mounts under the printed circuit board assembly line.

3. Monitorings

As part of the vibration management regime described above, monitoring was conducted to confirm the predictions made in the initial assessment. Vibration measurements were undertaken on the following occasions:

1. For the first abutment pile on each side of the bridge and the first pier pile:
   - As the casing was driven through the sediment layer,
   - As the rock chisel and grab was first operated within the casing, and
   - As the casing was driven into the rock layer/to depth.
2. During the installation of additional staging piling.
3. When a different piling technique or equipment was used.
4. As the result of any complaints regarding vibration.

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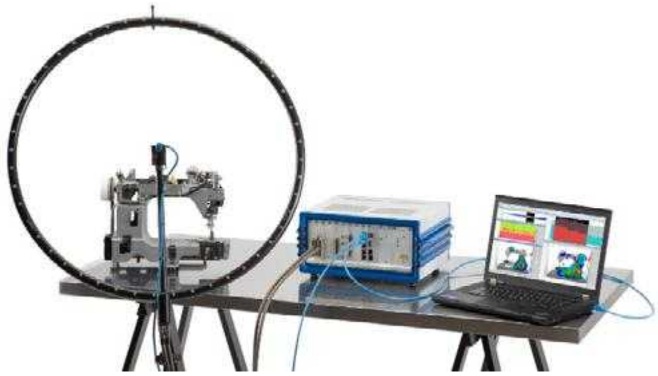
Invitation 2015 Workshop on Beamforming and array design



You are invited to a special Acoustical Society of New Zealand CPD Education Event: 2015 Workshop on Beamforming and Array Design. Please see Acoustical Society of New Zealand Webpage [www.acoustics.org.nz] and look under the heading tab 'CPD Education Event'. Members can download the pdf from the society page to register. Registration no later than November 15th 2015 to Magdalena Boeck at boeck@gfaitech.de with the registration form. Workshop Fees apply.

What: A workshop for academics and professionals who wish to learn more about beamforming and array design

When: Monday November 30th – Tuesday December 1st 2015

Where: University of Auckland (Auckland New Zealand)

We can now Simulate noise pollution levels before a road is even built?

Image Source: Marcin Szala via Wikimedia commons

An article by Jalopnik reports that Norway has a noise pollution problem - one so bad the World Health Organization (WHO) claims it is responsible for 150 cardiovascular-related deaths per year. A new group of researchers is looking to predict and map noise pollution before it even exists. Originally reported on Gemeni, researchers with SINTEF, the largest independent research organization in Scandinavia, have developed a new method of mapping noise pollution for a future roadwork project. Using a combination of sound-mapping and vehicle noise recording, the researchers can map out a future roadway in software and run a simulation of vehicles with the noise they produce, measuring the varying levels of noise penetration in the surrounding area.

This new project looks to prevent new infrastructure projects from taking a toll on the surrounding communities. The project began with measuring the various sounds emitted by passing vehicles. The noises were recorded with vehicles of varying sizes, traveling at varying speeds, and also while traveling in various road and weather conditions. The simulation also allows for the operator to insert deadening methods while running the simulation, like a wall or other shield often put up to minimize construction noises.

Researches have yet to define a specific use for their new system outside of testing, but they offer it as a way for engineers and planners to better assess the effects of their projects even before breaking ground. For further information see: http://jalopnik.com/we-can-now-simulate-noise-pollution-levels-before-a-roa-1727848191

TV sound system for the hard of hearing

Families often watch TV together, but what happens when one member has hearing difficulties? Usually the result is a compromise on listening volume that doesn't really satisfy anyone. To solve this problem, a University of Southampton researcher has developed a loudspeaker system to help people with hearing problems listen to television without affecting the sound for other viewers. For further information see: www.sciencedaily.com/releases/2014/11/141113085148.htm

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Forty-eight measurements were made between May 2013 and May 2014 covering the different piles and phases of piling, and at a range of locations, including:

- 3 Ferrymead Terrace
- 4/36 Settlers Crescent
- 5/36 Settlers Crescent
- Above the nearest underground services
- Chiptech, 11a Settlers Crescent
- HEB site compound (reference position, which is not subject to any vibration limits)
- Mount Pleasant Telephone Exchange
- Mount Pleasant Yacht Club
- Sand Bar, 1070 Ferry Road

The results are summarised in Figure 3 which plots the ppv of the ground vibration at the receivers listed above against the distance from the piling works. The reference position measurements are identified as grey circles and grey diamonds.

The maximum vibration level measured at a residential or commercial property was 1.0 mm/s ppv in the Chiptech building, at a distance of approximately 150 m from hydraulic impact piling on the west side of the bridge.

Also presented in this graph as black lines are the predicted levels of vibration both for the 14 T hammer envisaged before work commenced (and hence used in the vibration assessment) plus the 9 T hammer actually used on site. These predictions are higher than the levels measured, reflecting the conservatism of the prediction method.

The location and building-use specific project criteria are also included as green lines and demonstrate that vibration levels were below the criteria on all occasions. From the initial predictions it had been expected there would be widespread exceedance of the criteria.

The measurements show the vibration may have been felt in neighbouring residential properties (as the threshold for perception is approximately 0.3 mm/s ppv in such environments) but generally not at such a level to cause annoyance (1 mm/s ppv). There was negligible risk of cosmetic (or structural) building damage as a result of the piling works as the measured vibration levels are less than 5 mm/s ppv. These findings are consistent with the subjective observations received from the occupants of the Chiptech building.

One complaint was received from a residential dwelling in Settlers Crescent during the vibratory piling of the staging on the west side of the new bridge. The levels were monitored and assessed when the same works occurred again. It was concluded that although the vibration from these piling works may have been perceptible in the property, significant annoyance should not have been caused and there was no risk of building damage. No further complaints were received from the occupant.

A second complaint was received from a local commercial

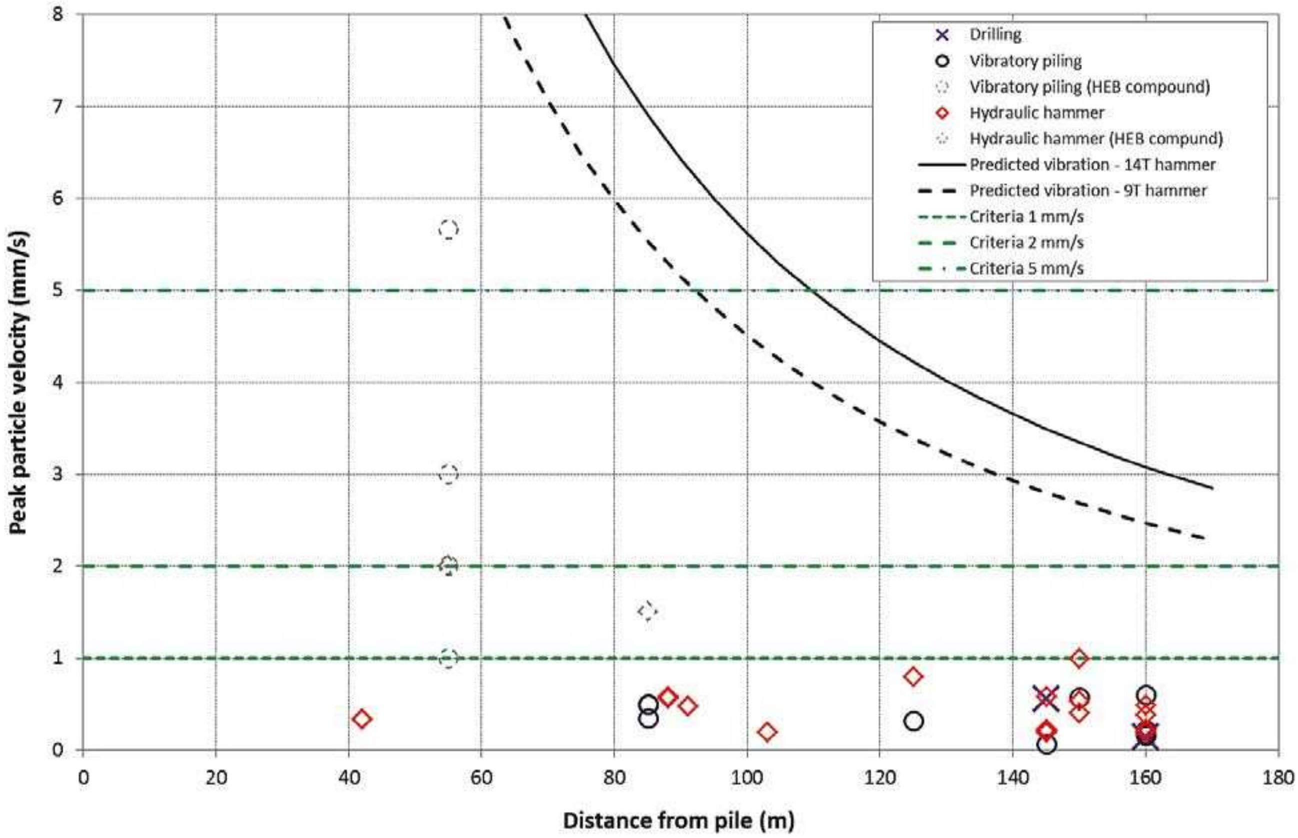

Figure 3: Measured and predicted vibration levels

property regarding some minor building damage. Using the pre-work condition survey, the project team were able to demonstrate that this damage pre-existed and therefore not caused by the bridge construction works.

4. Conclusions

The collaborative and proactive approach taken by the project team towards the management of construction vibration on the bridge replacement works has resulted in the following positive outcomes:

- Effective consultation and engagement with neighbours,
- Minimal complaints,
- No disruption to local businesses, e.g. Chiptech,
- No lost construction time due to vibration issues, and
- The value of pre-work building condition surveys has been illustrated.

An alternative approach to the management of construction vibration is a purely reactive process whereby the upfront vibration assessment and building condition survey work is avoided. This approach initially saves cost and time but with the risk that the works are slowed or even halted, together with associated delays and potentially significant cost, as a result of a complaint.

Without the consultation and engagement with the project's neighbours, no prior knowledge would have been gained of sensitive locations such as Chiptech (which was missed during the initial inspection of buildings in the industrial area) and residents would be more sensitive and anxious as a result of the vibration if they had not been forewarned. Once vibration can be felt, people tend to be concerned about damage to their properties, although the levels at which perception and damage occur are considerably different. These vibration levels were presented and explained during the public meeting, thus minimising concerns.

Acknowledgements

The authors wish to thank Christchurch City Council and HEB Construction for this permission to publish this paper.

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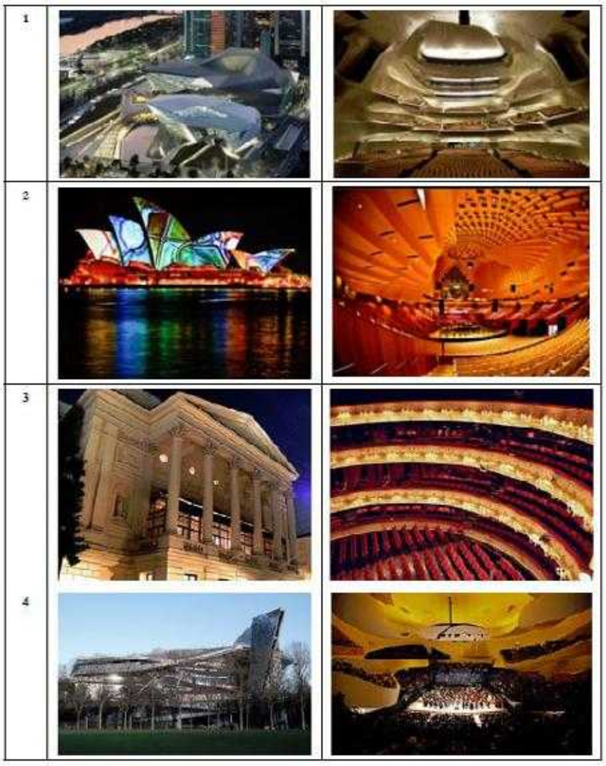
Acoustics Quiz Answers (Vol 28, #2)

Name these Opera Houses:

1. Guangzhou Opera House [China]
2. Sydney Opera House [Australia]
3. Royal Opera House [London]
4. Philharmonie de Paris [Paris]



Managing reverse sensitivity noise & vibration effects of rail and road transport in New Zealand

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Abstract

District and Regional Plans in New Zealand are a tool that can assist the functioning of a safe and efficient transport systems and assist in managing the environmental effects generated at transport nodes, and along transport corridors. This paper discusses reverse sensitivity measures intended to address noise and vibration from road and rail sources. The paper discusses whether applying land use restrictions beyond the designation corridor to address reverse sensitivity effects best serves the purpose and principles of the Resource Management Act if there are little or no efforts made by transport agencies to adopt the best practicable option to avoid, remedy or mitigate transport noise or vibration effects. Differences are highlighted between road and rail noise in this regard. The paper discusses the benefits of implementing planning measures that directly address effects of noise and vibration effects of land transport noise on people and communities for health and amenity reasons as a means of also dealing with reverse sensitivity effects on transport systems (if any). Finally, the paper outlines difficulties likely to be experienced by Council's implementing reverse sensitivity rules requested by the country's rail operator and by the state highway agency. Improvements are recommended that engender a balanced approach to managing direct and reverse sensitivity effects, based the relevant guidance from published New Zealand Standards and relevant international Standards.

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1. Introduction

Transportation noise can cause a range of impacts on people and communities from general interference with everyday activities through to more significant health impacts. Action to reduce environmental noise has had a lower priority than many other environmental issues, such as air, biodiversity and water, as noise has previously been regarded as an acceptable result of development [1]. As the impacts of noise are better under- stood transportation noise has now become a key environmental and social issue

Noise emissions are one of the more important impacts of Land Transport alongside other effects such as emissions to air, reduced water quality, landscape impacts, community severance and visual intrusions. Managing land Transport noise in New Zealand has been previously examined [2]. That report contains an evaluation of the total costs of Land Transport noise in New Zealand which has a value between 0.25% and 3.1% of GDP [2]. This estimate of the cost of Land Transport noise in New Zealand indicates the increasing impor- tance of Land Transport noise in terms of outcome for the environment.

2. Effects of transport noise

The impact of noise on human health have been widely researched [3,4,5 & 6]. Noise affects people in different ways and creates various reactions depending on the level of noise and the activities individuals are engaged in.

Noise in the environment, including from transport systems, creates stress-type responses in humans. No significant impacts on health are thought to occur at noise levels under 40 dBA during the day or 20 dBA at night. The effects rise with the level of noise and length of exposure. It is widely accepted that noise above 65 dBA is highly undesirable.

Sleep disturbance is a common complaint from people affected by noise. Sleep deprivation can have cumulative effects due to impairment of the rest and recovery functions of sleep [4].

3. Land use planning and noise

In New Zealand, land use planning is primarily implemented through the Resource Management Act, 1991 (RMA).

Part IV of the Act mandates territorial local authorities (Councils), through District Plans, to ensure the noise environment is managed in a sustainable manner and that adverse effects of noise generating activities are avoided, remedied or mitigated. The District Plan is therefore a key instrument for the control of adverse environmental effects, including noise.

Apart from District Plans, Council can control noise effects through such methods as:

- Conditions attached to resource consents or designations;

- Enforcement proceedings including: Abatement notices, enforcement orders and; excessive noise direction notices.

Apart from Council's, other key players in the management of the effects of transport noise include:

- The noise producers (RMA S16. Imposes a general duty on all landowners to avoid unreasonable noise);
- The receivers of noise (Developers and builders and designers are free to adopt methods that reduce noise received from transport corridors, although this on its own would not be likely to be a successful policy measure).

The over-riding requirement is for the noise-maker(s) to recognise the general duty to avoid unreasonable noise.

4. Mangaging land transport noise

4.1 Noise from road traffic

For road vehicles, the New Zealand Transport Agency (NZTA) determines certification requirements for new vehicles, including noise emissions. These requirements are based on 'type approval' testing for each vehicle model released in New Zealand. The allowable noise limit is based on a drive-by noise test (ISO 362). Land Transport (Road User) Rule 2004 provides for on-road enforcement of noise from vehicles in use. The police have a role enforcing these in-service vehicle noise requirements. Regarding exhaust noise, the requirement is for the vehicle to be "less than, or similar to" the noise output from the vehicle's original exhaust system at the time of the vehicle's manufacture". If necessary, the vehicle may be required to undergo a stationary exhaust noise test using a measurement pro- cedure based on ISO 5130 in order to prove a vehicle's exhaust noise levels are acceptable. Land Transport (Road User) Rule 2004 makes it illegal to operate a vehicle in a noisy manner, including noise from audio systems installed in vehicles.

Overall, New Zealand has a comprehensive suite of road vehicle noise controls that govern the output of new vehicles, the noise output of vehicles "in service" and controls over persons operating vehicles on a public road.

In addition, noise from land transport noise is controlled from new or altered roads via design measures through the application of NZ Standard NZS 6806:2010 Acoustics – Traffic Noise – Noise from New & Altered Roads. This Standard is often referred to within planning proceedings when designations are sought for new or altered roads as this Standard is only relevant to those situations.

There is no similar Standard applying to noise from existing roads. The 2008 Transit New Zealand Environmental Plan [7] and previous Transit documents recognise that outdoor noise levels above 65 dB LAeq(24 hr) are unacceptable. Section 2.1 of that Plan notes that if noise levels are above this threshold a noise improvement programme is available to fund retro-fitting of road noise mitigation. The fund for this is limited however and very few roading projects have been initiated to reduce noise from the existing network.

In addition, NZTA have developed "reverse sensitivity" noise guidelines to assist with managing noise from the existing state highway network. Developers and land owners seeking access to the state highway network are commonly requested by NZTA in return to agree to reverse sensitivity clauses where the development involves establishing noise sensitive activities such as residential subdivisions or apartments near state highway. An example of such a clause is set out as follows:

> The design and construction of the development shall;
>
> (a) Ensure that the following criterion is met in relation to noise from traffic on the road allowing for increases in noise arising from increased traffic growth during a period up to the year 2014 (Noise Performance Criterion);
>
> i. Noise from traffic on the road shall not exceed 35 dBA Leq(24 hour) in any bedroom and 40 dBA Leq(24 hour) in other Habitable Rooms (AS/NZ 2107:2000) within any Building.

Comments and observations on this approach to dealing with reverse sensitivity noise effects of the state highway network are discussed below.

4.2 Noise from rail activities

KiwiRail Holdings Limited (KiwiRail) is the State Owned Enterprise responsible for the management and operation of the national railway network. This includes managing railway infrastructure and land, as well as rail freight and passenger services within New Zealand. KiwiRail Holdings Limited is also the Requiring Authority for land designated "Railway Purposes" in District Plans throughout New Zealand. KiwiRail Network (ONTRACK) owns and manages New Zealand's rail network on behalf of the Crown, maintaining 4,000 kms of railway track, bridges and tunnels

KiwiRail operates around 100 diesel-electric locomotives, 22 electric locomotives, 3 railcars, and 103 shunting locomotives (Wikipeadia). There are also 19 diesel multiple units in Auckland operated by Auckland Transport and 71 electric multiple units owned by the Greater Wellington Regional Council. The author understands around 57 electric multiple units under construction for Auckland Transport.

The author has been unable to identify any rules or guidelines relevant to the control of noise from locomotives or rail vehicles in New Zealand. An ISO Standard (ISO 3095:20051) is available to guide on the procedures for obtaining reproducible noise levels emitted by all kinds of vehicles operating on rails, however there are no relevant rail noise limits applying in New Zealand.

KiwiRail has submitted on many District Plans to discourage "sensitive receivers" near rail corridors. This is to address so-called "reverse sensitivity" effects. As an example, the following wording of a reverse sensitivity rule was agreed among the parties to be inserted into the Tauranga District Plan (see *NZ Railways Corporation v Tauranga City Council: ENV-2011-AKL-00072*):

> Rule 4E.2.6 - The Rail Network - Managing Reverse Sensitivity Effects
>
> (a) For noise sensitive activities within the KiwiRail Reverse Sensitivity Plan Area shown on the Plan Maps (Part B):
>
> i. Any new dwelling shall meet an internal rail traffic design sound level of 40 dB LAeq(1hr) inside all habitable rooms except for bedrooms which shall achieve an internal rail traffic design sound level of 35 dB LAeq(1 hr)
>
> ii. All other noise sensitive activities shall meet an internal rail traffic design sound level of 40 dB LAeq(1 hr).

Below we set out observations and comments on the approach advocated by KiwiRail that require Councils and land owners and developers to implement measures ostensibly to protect the operation of the rail network.

5. Reverse sensitivity as an "effect"

Often Council's are asked by road and rail authorities to include within District Plans land use planning measures to address noise and vibration effects to address what are termed "Reverse Sensitivity" effects on the operation of the transport system. The measures sought in respect of both road and rail reverse sensitivity measures involve recommending no noise sensitive development take place within a land corridor adjacent to the transport corridor, with a recommendation for developers and landowners implementing mitigation within a wider "effects" corridor to ensure the levels of noise within habitable rooms in new buildings established within these areas are within what are considered reasonable limits recommended by the World Health Organisation (for example).

Existing case law establishes reverse sensitivity as an "effect" under the RMA. However, our search of the relevant databases has not been able to provide examples where a road or rail corridor has been affected by reverse sensitivity effects such as complaints by individuals or communities living within areas affected by noise from land transport noise.

Although the reverse sensitivity effect is widely touted at planning hearings as being a core concern of road and rail authorities, there are no examples evidencing where this effect has actually negatively impacted on the operation of any part New Zealand's transport system. While there are fears of such an effect, no actual effects of this nature appear to have surfaced.

6. Misuse of AS/NZS 2107:2000

NZTA's Reverse sensitivity guidelines have adopted the Australian and New Zealand internal noise standard AS/NZS 2107:2000 Acoustics - Recommended Design Sound Levels and Reverberation Times for Building Interiors. This Standard is said to have been adopted by NZTA because it is "an accepted industry standard" however there are some technical issues which remain unanswered regarding reliance on this Standard.

KiwiRail's reverse sensitivity guidelines typically seek insulation of buildings establishing within 40 metres from the rail track Dwellings so that rail noise does not exceed 40 dB LAeq(1hr) inside bedrooms or 45 dB LAeq(1hr) in other habitable spaces. The Guidelines seek rail noise levels within all other developments be "no greater than 5 dB above the recommended maximum design guidelines given in NZS 2107-2000".

Both road and rail reverse sensitivity guidelines rely on the recommendations of NZS 2107:2000. However, the author considers this to be a misuse of this Standard.

For example, NZS 2107:2000 refers to noise levels quantified using the Leq unit, however there is no reference within that Standard to the use of LAeq(24hr) or LAeq(1hr) units which have been adopted as the units within road and rail reverse sensitivity guidelines. Section 2 of the Standard specifically states the Standard was not developed to deal with rail noise and yet this Standard is quoted extensively within justifications provided for reverse sensitivity measures address rail noise. The Standard was developed to be used by architects and room designers and does not have a focus on recommending noise standards for land use planning purposes (which seems to be its main use in New Zealand over recent years).

According to enquiries undertaken by the author, no New Zealand transport agencies, environmental authorities or the Ministry of Health were consulted in the development of NZS 2107:2000. The author considers NZS 2107:2000 is being mis-applied to some extent from its original intended use as a guide to architects and building designers. This Standard appears to be currently misused to plug a void. It is clear to most of us involved that what is really needed is a purpose-developed NZ Standard which would be developed among all key stakeholders and would represent a "whole of government" approach, not simply the wishes of the agencies responsible for noise-making activities.

7. Acoustic insulation requirements

Acoustic insulation requirements contained within NZTA and KiwiRail requests for reverse sensitivity protection rely upon compliance with a stipulated limit of road or rail sound measured indoors. In practice, checking compliance on behalf of Council's or affected parties has proven very problematic. Relying on achieving a stipulated indoor sound level leads to unpredictable outcomes because:

(a) Acousticians and designers are not provided with guidance on expected outdoor sound levels against which to design the acoustic insulation of the building. This will often lead to an inconsistent design approach as different designers may assume (quite legitimately) differing levels of outdoor sound. Rail noise guidelines are said to be based on 65 dB LAeq(1hr) at 12 metres from the closest rail track. KiwiRail's submission on the Hauraki District Plan KiwiRail proposed that train noise shall be deemed to be 70 dB LAeq(1hr) at 12 metres from the closest rail track. The request to assume a certain outdoor sound levels for the purposes of calculation and design means the actual noise level occurring on the site is never known. This means an objective assessment of noise effects on the (such as Council's may undertake) cannot realistically be undertaken as no site specific information is provided.

(b) It is unclear how growth in noise levels is taken into account. The objective (to achieve adequately protected indoor environments) may be undermined if growth in noise levels in the long run is not adequately accounted for.

(c) The amount of noise reduction to be achieved by the building design may never be known and cannot therefore be tested or evaluated by Council's who are charged with implementing District Plans and overseeing enforcement (where required) with resource consent conditions.

(d) Should compliance need to be checked, measuring road or rail noise indoors within insulated rooms brings with it a host of problems. Simply measuring a 24 hour sound level to check traffic noise levels within insulated habitable rooms caused difficulties which have been outlined in evidence to the High Court in Invercargill (*P & J Tompkins v Wensley Developments 2011*). Not only was it not possible to avoid extraneous sounds (such as aircraft noise), but the speed limit was adjusted up- wards and road surface type changed after the insulated apartments were built and before they could be tested. For road noise, deviations in the normal percentage heavy vehicles and effects of a wet road surface can significantly alter measured sound levels within nearby rooms. For rail noise, the following questions arise for Council's when attempting to assess compliance with KiwiRail's reverse sensitivity measures:

    During which 1 hour period should compliance measurements be conducted?

    Measure compliance during daytime or night time?

    What about non-rail noise occurring during the measurement period?

It is worth noting that NZS 6806:2010 refers to insulation requirements for protecting against road traffic noise at clause 5.2.3.2 where it states the acoustic insulation performance of buildings should be rated using the 'standardised level difference' methods of ISO 717, not based around the "indoor LAeq(24 hr)" approach of the NZTA reverse sensitivity guidelines.

8. An issue of "Equity"?

While concerns raised above are important because it appears acoustic performance based on a received indoor sound level cannot be easily or simply checked by Council as consent authority, a further substantial issue is one of equity - Who would be responsible if a reverse sensitivity insulation rules was proven not have been properly complied with?

Quite clearly in this circumstance, the roading authority and rail agency (who are responsible for managing the transport noise at source) will not be around to assist. The Council would simply be trying to implement and assess compliance with the rule or resource consent condition and could not be blamed for the non-compliance. The building owner or developer would have taken appropriate acoustic advice at the time the building was designed (and all being equal, the builder built the building to specification), however any of the variables (a) to (d) above could easily cause non-compliance so that the owner or developer is left with a non-compliance which was really none of his or her making.

With these experiences in mind, the author considers it is inappropriate for councils and imposes unnecessary costs and risks for the building designer and owner where the outcome is based on the uncertain result of an indoor sound level measurement to determine the effectiveness of acoustic insulation.

There appears an inherent inequity in a system that enables the noise-making agency to request insulation rules based around an uncertain method for managing indoor effects of road or rail noise yet do not share in the technical and design risks in attempting to achieve compliance with the requested standards. This is aside from the difficulties

Councils must face in assessing compliance.

This is in addition to the questionable need for reverse sensitivity setbacks and insulation requirements where there are no known examples in New Zealand where the operation of a road or rail corridor has been adversely affected due to noise or vibration complaints from people living in high noise effects areas.

That is not to say there is no evidence of complaints. Most local authorities at one time or another will have fielded complaints regarding road or rail noise, however any organisation with an "embedded" network emitting noise 24 hours a day can expect to receive complaints and will be obliged to deal with them. The mere receipt and need to investigate complaints is often mistaken as a need to implement reverse sensitivity measures. However this seems to defy logic. The reverse sensitivity measures will not address the generation of noise or vibration complaints per se. It is normal for a transport organisation to have to investigate and report on noise and vibration complaints from time to time. Despite what some officials may say, this is not a policy driver for implementing reverse sensitivity measures

The lack of any operational noise or vibration emission limits coupled with the enabling provisions of the RMA (and inherent powers of any designations held) mean the road or rail agency will always prevail where any complaints or further actions arise. Realistically it is unlikely any individual or community has the ability to shut down or interfere with the operation of a road and rail corridor as often claimed as a rational basis for adopting reverse sensitivity measures within District Plans or resource consent conditions.

Granting rail noise reverse sensitivity measures in District Plans or resource consents worded as often sought within submissions by KiwiRail is particularly iniquitous. This is because this agency appears to make no attempt to manage noise from its rail and locomotive fleet in a manner consistent with the best practicable option requirement of the RMA. Rail noise has a large low-frequency component and can affect wide tracts of land, yet there appear to be no guidelines, rules or regulations in New Zealand requiring this noise to be managed at source.

For road traffic and vehicle noise it is clear a suite of controls are in place in New Zealand that (within reason) ensure cumulative noise from a road is no louder than necessary (setting aside for the moment improvements that could be achieved via introducing a noise-aware re-surfacing policy in residential areas). Rail noise is, and has always been, unfettered at source with KiwiRail continuing to be able to generate as much noise as it likes without impunity it seems

9. Recommended insulation standard

There are inherent advantages in acoustic insulation rules or consent conditions that stipulate the amount of acoustic insulation required of the building. This is achieved by specifying an acoustic rating of the building envelope using methods based on ISO 717-1:20132 such as stipulating Dtr,2m,nTw + Ctr. > 30. This means the building envelope or facade must reduce the outdoor sound level by 30 dB when tested in accordance with the prescribed (normalised) test method. Such an approach is superior in a number of ways because:

(a) Such rules provide greater guidance for architects and engineers to design to, and will result in a more certain outcome; and

(b) The performance standard to be achieved by the building fabric is established at the time the Plan or designation/consent hearing takes place (within a public process and being subject to scrutiny), or at the time the resource consent is decided. This can satisfactorily deal with issues such as how noisy the site is, how future growth in noise is to be taken into account and what sound spectrum to be assumed. Quite clearly, the "one size fits all" approach based on complying with a stated indoor noise limit does not work and leads to an imbalance between those whom benefit from measures that are said to protect road and rail corridors and those that must implement and administer the requested measures.

(c) While the use of an indoor sound level as a design target can be useful when setting the insulation standard to be achieved by the building, the actual process designing to achieve a stated indoor sound limit entails a great number of assumptions and can lead to uncertainty (not to mention the difficulties in determining compliance, as discussed above).

(d) For consent authorities and Council's, rules based on ISO 717-1:2013 are preferred because they can be readily checked using a simple test using a handheld sound level meter. The performance of a building can be estimated by simply measuring the difference between the sound level outdoors and the sound level measured indoors.

A full field test of facade transmission loss using ISO 16283-1:20143 can be conducted where an "evidential" type test result is desired.

10. Discussion and Summary

Council have a duty to manage noise effects in the district. This can often involve deciding upon submissions received that deal with reverse sensitivity noise and vibration effects from road and rail corridors.

...Continued on Page 44

2015

Workshop on Beamforming and Array Design. Auckland New Zealand, 30th November – 1st December 2015, University of Auckland. Please see the Acoustical Society of New Zealand webpage at www.acoustics.org.nz and look under the heading tab 'CPD Education Event'.

12th Wespac 2015. Singapore. 6th to 10th December 2015.
www.wespac2015singapore.com

Australian Acoustical Society Annual Conference. Pokolbin, Australia. 15th to 18th November 2015.
www.acoustics2015.com.au

2016

23rd International Congress on Sound and Vibration [ICSV23]. Athens, Greece. 10th to 14th July 2016.
www.icsv23.org

Inter-Noise 2016. Hamburg, Germany. 21st to 24th August 2016.
www.internoise2016.org

International Congress of Theoretical and Applied Mechanics [ICTAM]. Montreal, Canada. 21st to 26th August 2016.
www.ictam2016.org

22nd International Congress on Acoustics [ICA 2016]. 5th to 9th September 2016. Buenos Aires, Argentina.
www.ica2016.org.ar

International Workshop on Rail Noise [IWRN]. Terrigal, NSW, Australia. 12th to 16th September 2016.
www.iwrn12.acoustics.asn.au

2nd Australasian Acoustical Societies Conference. 9th to 11th November 2016, Brisbane Convention Exhibition Centre, Brisbane Australia.
www.acoustics2016.com.au

2017

Acoustics 2017 Joint meeting of the Acoustical Society of America and the European Acoustics Association. Boston, USA. 25th to 29th June 2017.
www.acousticalsociety.org

2018

175th Meeting of the Acoustical Society of America. Minneapolis, USA. 7th to 11th May 2018.
www.acousticalsociety.org

We question whether the need for such methods have ever been properly investigated in a "whole of government" approach that examines the full societal costs and benefits of adopting measures commonly requested. There appears to be no evidence of the operation of any road or rail corridor having been adversely affected by complaints from the public.

The primary need to manage the noise and vibration effects of road and rail activities are surely those based around protecting the health and well-being of exposed populations. It is a curious and disappointing observation that calls to protect the operation of roads and rail corridors due to reverse sensitivity concerns are more commonly raised within RMA proceedings compared to the relatively few submissions received from the Ministry of Health or primary health care agencies regarding the need to protect human health and welfare in these situations.

Councils may also be involved with compliance checking of acoustic insulation of dwellings and habitable rooms established within "noise affected" corridors adjacent to state highways or rail tracks. The above discussion establishes that acoustic insulation performance requirements based around meeting a stated limit of road or rail noise indoors has in practice to be neither practical nor workable. While indoor sound levels are important for ascertaining the appropriate standard of acoustic insulation to be implemented, as above, the actual acoustic performance standard should be based around the units set out within ISO 717:2013.

Setting acoustic insulation standards on a maximum level of road or rail noise to be received indoors is un-certain for Councils to enforce and impose unnecessary costs and risks for the building designer, builder and/or owner.

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7. State highway environmental plan: Improving envi- ronmental sustainability and public health in New Zealand. NZ Transport Agency, June 2008.

Publication Dates and Deadlines

New Zealand Acoustics aims to publish quarterly in March, June, September, and December.

The Deadline for material for inclusion in the journal is 1st of each publication month, although long articles should ideally be received at least 4 weeks prior to this.