BEFORE INDEPENDENT COMMISSIONERS

IN THE MATTER	of the Resource Management Act 1991 ("**RMA**")
AND	
IN THE MATTER	a submission by KiwiRail Holdings Limited (**"KiwiRail"**) on Proposed Te Tai o Poutini Plan (**"TTPP"**)

STATEMENT OF EVIDENCE OF STEPHEN CHILES ON BEHALF OF KIWIRAIL HOLDINGS LIMITED

NOISE AND VIBRATION

1. INTRODUCTION

1.1 My full name is Dr Stephen Gordon Chiles. I have the qualifications of Doctor of Philosophy in Acoustics from the University of Bath and Bachelor of Engineering in Electroacoustics from the University of Salford, UK. I am a Chartered Professional Engineer and Fellow of the UK Institute of Acoustics.

1.2 I am self-employed as an acoustician through my company Chiles Ltd. I have been employed in acoustics since 1996, as a research officer at the University of Bath, a principal environmental specialist for Waka Kotahi NZ Transport Agency (**"Waka Kotahi"**), and a consultant for Arup, WSP, and URS, Marshall Day Acoustics and Fleming & Barron. I am contracted as the principal advisor to provide the Environmental Noise Analysis and Advice Service to the Ministry of Health and Te Whatu Ora - Health New Zealand.

1.3 I have been involved in many situations relating to noise effects on new or altered sensitive activities around existing infrastructure. I was an Independent Commissioner for plan changes for Queenstown and Wanaka Airports and a plan variation for Port Nelson, which dealt particularly with noise effects. I have previously been engaged to advise Waka Kotahi and Auckland Transport (roads), KiwiRail (railways), Christchurch City Council (airport) and Environment Canterbury (port) on reverse sensitivity noise issues. I have presented acoustics evidence for Waka Kotahi and KiwiRail on numerous plan changes and plan reviews. I previously drafted potential environmental noise provisions for Clause G6 of the New Zealand Building Code for the Ministry of Business, Innovation and Employment.

1.4 I am convenor of the New Zealand reference group for "ISO" acoustics standards and a member of the joint Australian and New Zealand committee responsible for acoustics standards. I was Chair of the 2012 New Zealand acoustics standards review, Chair for the 2010 wind farm noise standard, and a member for the 2008 general environmental noise standards.

2. CODE OF CONDUCT

2.1 I confirm that I have read the Code of Conduct for Expert Witnesses set out in the Environment Court's Practice Note 2023. I have complied with the Code of Conduct in preparing this evidence and will continue to comply with it while giving oral evidence at the hearing. Except where I state that I am relying on the evidence of another person, this written evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this evidence.

3. SCOPE OF EVIDENCE

3.1 My statement relates to the TTPP, and in particular, to potential effects of railway noise and vibration on new and altered sensitive activities. I have prepared this statement for KiwiRail as network utility operator of the Westport, Stillwater – Ngakawau, Rapahoe, Greymouth, Hokitika, and Midland Lines, all of which extend through the West Coast.

3.2 I have been separately engaged by NZ Transport Agency Waka Kotahi and the National Public Health Service with respect to their submissions on the TTPP and will be providing separate evidence for those parties.

3.3 I have prepared general advice for KiwiRail on land use controls for railway sound and vibration nationally. I have attached that advice as **Appendix A** and make reference to it with respect to various matters I discuss in my evidence.

3.4 KiwiRail made a submission on the TTPP seeking:[1]

1 KiwiRail Submission on Proposed Te Tai o Poutini Plan, dated 27 October 2022.

(a) the inclusion of noise and vibration controls requiring acoustic insulation and ventilation to be installed in new (or altered) sensitive uses within 100 metres of the railway corridor; and

(b) controls within 60 metres of the railway corridor, for buildings containing new (or altered) sensitive uses to be constructed to manage the impacts of vibration.

3.5 The purpose of these provisions is to protect the health and amenity of occupants of those buildings, and to avoid or mitigate potential reverse sensitivity effects on KiwiRail's operations.

3.6 My evidence will address:

(a) noise and vibration effects arising from rail infrastructure;

(b) methods to manage adverse effects on new and altered buildings containing sensitive activities near existing infrastructure;

(c) the appropriateness of the relief sought by KiwiRail from an acoustics and public health perspective; and

(d) the evidence of Stephen Peakall for the West Coast Regional Council dated 19 July 2024 and the Section 42A report prepared by Ruth Evans, in relation to recommendations on the relief sought by KiwiRail.

4. NOISE AND VIBRATION EFFECTS FROM RAIL INFRASTRUCTURE

4.1 Sound and vibration from rail networks have the potential to cause adverse health effects on people living nearby. I address these effects for railway sound and vibration in **Appendix A**, sections 2 and 3.

5. METHODS TO MANAGE ADVERSE EFFECTS

5.1 I set out in **Appendix A**, sections 7 and 8, approaches to manage effects of railway sound and vibration. I have been involved in different activities undertaken by KiwiRail to manage and reduce this sound and vibration where practicable. These include installation of ballast mat, rail grinding and tamping, ballast cleaning and replacement, and automated monitoring of rolling stock wheel condition. However, even with practicable improvements implemented, the operation of the railway network can result in adverse effects which cannot be completely internalised within its typical designation boundaries, such as noise and vibration. These effects commonly occur within the railway network subject to normal maintenance and cannot be solely attributed to defects in track or rolling stock. In particular, vibration varies significantly depending on ground conditions and localised features such as buried services and structures. Even with "good" ground, track and rolling stock conditions, there is still inherent vibration from railways that can cause disturbance to activities in proximity to the rail corridor.

5.2 As these effects cannot be completely internalised within the corridor, in my opinion there must be appropriate land use controls in place to manage sensitive development near these transport corridors. Land use controls to avoid or manage adverse noise and vibration effects on new sensitive activities or alterations to such activities are critical in protecting sensitive activities from adverse noise and vibration effects. Such controls, in turn, are fundamental to managing the potential for reverse sensitivity effects on the rail network. The location of incompatible sensitive activities in proximity to rail infrastructure can lead to noise and vibration effects on, and complaints from, sensitive users.

5.3 If it is not practicable to avoid sensitive activities near the rail corridor, for new buildings being constructed, or existing buildings being altered, it is relatively straight-forward to control internal sound and vibration through the building location, design and systems (like acoustic insulation and mechanical ventilation). In most cases, it is practical to achieve acceptable internal sound and vibration levels using such measures. Thus, with careful design of building location, orientation and materials, future occupants of the building can be protected from the most significant adverse effects associated with railway sound and vibration.

5.4 Rules in district plans commonly control the location and design of sensitive activities such as housing, where such activities seek to locate near existing sound sources such as roads, railways, airports, ports, quarries, industrial sites, industrial and business zones, gun clubs and motorsport facilities. As such, KiwiRail sought the inclusion of noise and vibration controls in the TTPP to ensure the safe and efficient operation of its rail network in the district.

6. RELIEF SOUGHT

Noise controls

6.1 KiwiRail seeks the inclusion of controls requiring acoustic insulation and ventilation to be installed in new (or altered) sensitive uses within 100 metres of the railway corridor. The 100 metres distance aligns with the assumed sound levels for rail volumes and one-hour average discussed in **Appendix A**, section 5. The 100 metres distance reflects a reasonable compromise to capture the most affected sites without requiring assessment where building treatment is less likely to be required.

6.2 There are a variety of sensitive activities that would be affected by the proposed controls. KiwiRail sought to apply different noise criteria to reflect the particular sensitivities of different activities.

Vibration controls

6.3 KiwiRail's submission also sought controls within 60 metres of the railway corridor, for buildings containing new (or altered) sensitive uses to be constructed to manage the impacts of vibration.

6.4 A relevant technical standard in this regard, NS 8176:2017 uses a 'Class C' criterion of 0.3 mm/s $v_{w,95}$. The measurement data shows that this criterion can routinely be exceeded at over 100 metres from railway tracks in New Zealand, but there is significant variation. Vibration levels generally exceed this criterion beyond 60 metres from the track.

6.5 For the application of land use controls, from a technical perspective, it would be preferable to assess all sites within 100 metres or more of rail corridors. However, KiwiRail has limited proposed controls to 60 metres in its submission on a pragmatic basis, also in recognition of the significant variability in vibration levels.

Ventilation requirements

6.6 KiwiRail's submission also seeks amendment to the ventilation controls to be applied to all buildings affected by rail noise, and for the requirements to provide thermal comfort so that windows do not need to be opened. The submissions also seek inclusion of requirements for user controls and limitations on ventilation system self-noise.

7. RESPONSE TO SECTION 42A REPORT

7.1 Mr Peakall and Ms Evans generally agree with the technical basis and need for the controls in NOISE-R3 for buildings for sensitive activities near the rail corridor.

7.2 Mr Peakall agrees that that NOISE-R3.1.c should be updated but he only considers a distance of 60 metres should be included.[2] Mr Peakall also accepts a construction table as an alternative compliance pathway.[3] I disagree with Mr Peakall with respect of the necessary distance for the reasons set out above and in my **Appendix A**. In my opinion, 100 metres is already a compromise. With respect to train volumes, it is also important to consider that the TTPP is not just addressing current rail traffic but the rail corridor for the life of the plan.

7.3 Mr Peakall and Ms Evans do not explicitly address the KiwiRail submission point regarding the use of different noise criteria depending on the nature of different sensitive activities. Ms Evans has recommended retaining the notified provision with a single 35 dB $L_{Aeq(1h)}$ criterion in NOISE-R3.1.c for all types of sensitive activity.[4] In its submission, KiwiRail only sought this as the most stringent criterion to be applied in sleeping spaces and critical listening environments. For other sensitive activities, KiwiRail sought more lenient noise criteria of 40 or 45 dB $L_{Aeq(1h)}$ depending on the nature of the particular activity. In my opinion the nuanced criteria sought by KiwiRail are preferable to a 'one-size-fits-all' criterion that is overly stringent and would impose unnecessary cost for some activities.

7.4 Mr Peakall, and in turn Ms Evans, have recommended the addition of a new appendix NOISE-APP1, setting out construction details that can be used as an option to result in compliance with noise and vibration limits.[5] Such tables are commonly used in other plans to provide alternative compliance pathways. In my experience, in practice, such tables often don't provide the 'simple' option intended as minor deviations from specified constructions invalidate the approach. However, if the constructions are suitably conservative, they can provide a useful option in some instances.

2 Statement of Evidence of Stephen Peakall dated 19 July 2024 at [53].
3 Statement of Evidence of Stephen Peakall dated 19 July 2024 at [50].
4 Te Tai o Poutini Plan – Section 42A Report NOISE, dated July 2024 at [173].
5 Statement of Evidence of Stephen Peakall dated 19 July 2024 at [47] – [48] and Te Tai o Poutini Plan – Section 42A Report NOISE, dated July 2024 at [173].

7.5 I have not reviewed the details of NOISE-APP1, but I note there appears to be a significant omission that no ventilation is specified. If NOISE-APP1 is retained then it should specify that ventilation is to be provided in accordance with NOISE-R3.1.f. The vibration component of NOISE-APP1 reflects KiwiRail's submission.

7.6 Mr Peakall and Ms Evans have not explicitly addressed the KiwiRail submission point to include an alternative compliance pathway based on a minimum 50 metre distance from a railway and line-of-sight screening to the height of a locomotive. The provision sought by KiwiRail would avoid specialist assessment and any treatment in cases where it is not warranted, because of reduced noise exposure.

7.7 A minor issue is that Mr Peakall, and in turn Ms Evans, have amended NOISE-R3.1.f.v to state a noise limit applies "at least" 1 metre away from any grille or diffuser.[6] In my opinion, the noise limit should be specified at 1 metre to ensure it is achieved at all potentially occupied locations. The wording recommended by Ms Evans provides a loophole that would result in excessive noise from the ventilation system. I recommend retaining NOISE-R3.1.f.v as notified.

8. CONCLUSION

8.1 Sound and vibration from rail corridors can give rise to adverse health and amenity effects on sensitive land uses located nearby. The research and guidelines relating to these effects are widely accepted internationally and applied in New Zealand.

8.2 KiwiRail continuously works to reduce existing sound and vibration exposure and to manage the effects of their operations on existing sensitive activities. However, due to the nature of its operations, KiwiRail (as with many large infrastructure providers) is unable to internalise all noise and vibration effects associated with its activities.

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6 Statement of Evidence of Stephen Peakall dated 19 July 2024 at [71] and Te Tai o Poutini Plan – Section 42A Report NOISE, dated July 2024 at [173].

8.3 Adverse effects on new and altered to buildings for sensitive activities can be avoided and managed through well understood controls in district plans. As above, in my opinion, the current TTPP controls do not provide an appropriate level of protection to manage adverse health effects on sensitive activities in new and altered buildings near railway lines.

Stephen Chiles

6 August 2024

KiwiRail

APPENDIX A

Chiles Ltd

Project: **Land use controls for railway sound and vibration**

Report: **Acoustics advice**

Client: KiwiRail

Reference: 130418g

Date: 9 June 2023

Author: Stephen Chiles

Contents:

1. Introduction

1.1. KiwiRail is undertaking an analysis of potential controls for existing/permitted railway sound and vibration from its national network, affecting new and altered sensitive land uses nearby. Chiles Ltd has been engaged by KiwiRail to provide advice on associated acoustics details to inform that analysis. This report sets out: effects of sound and vibration on people and buildings, indicative sound and vibration levels at different distances from railway tracks, methods to reduce sound and vibration, and recommendations for land use controls.

1.2. In normal acoustics usage the term "noise" describes unwanted airborne "sound", although some people use the words interchangeably. However, under the Resource Management Act (RMA) "noise" is defined as including vibration; presumably ground-borne. Notwithstanding that in practice "noise limits" in rules and conditions under the RMA refer exclusively to airborne sound. The term sound has been used in this report to distinguish airborne sound from ground-borne vibration in an RMA context where both are defined as noise.

1.3. A fundamental input when assessing railway sound and vibration is the type, volume and timing of railway traffic to be assumed on a particular section of the network. For comparison, when considering roads in New Zealand, road traffic volumes often gradually increase or remain steady, such that acousticians can sometimes use existing measured road traffic volumes as a reasonable baseline for future design. However, for railways in New Zealand, railway traffic volumes and times can change significantly, such that existing railway traffic may not be a reliable baseline when considering effects associated with new neighbouring houses that will exist for many decades. Therefore, appropriate assumptions for railway traffic types, volumes and times are an essential input that should be considered alongside the following acoustics information in this report.

1.4. Both sound and vibration have complex varying characteristics which are only approximated by metrics representing levels as a single number. There are compromises with whichever metrics are used. In the case of railway sound and vibration in New Zealand the choice of metrics is particularly challenging because often there are a relatively small number of intense events. In this situation, use of average values might under-represent adverse effects and use of maximum values might over-represent effects. The extent of under or over representation varies depending on the rail traffic in any location, which in turn relates to the comment above on railway traffic volumes. Metrics and objective analysis can still be valuable to focus interventions in the most effective places, but the limitations of the metrics require consideration when evaluating potential land use controls. This issue is discussed further in section 4.

2. Effects of sound

2.1. The World Health Organisation ("WHO") has periodically reviewed and collated evidence of health effects caused by environmental sound including from railways.[1] The most recent publication was by WHO Europe ("2018 WHO Guidelines"),[2] which was based on systematic

[1] World Health Organisation, Guidelines for community noise, 1999; World Health Organisation, Burden of disease from environmental noise, 2011.

[2] World Health Organisation, Environmental noise guidelines for the European region, 2018.

reviews of a large number of published studies. There have been numerous other discrete studies of these issues, but the 2018 WHO Guidelines provides a robust synthesis of available information and its findings with respect to railway sound appear to be widely accepted.

2.2. From preceding studies, the 2018 WHO Guidelines found moderate quality evidence that railway sound causes adverse health effects in that it increases the risk of annoyance and sleep disturbance in the population. Various other potential health effects were examined but evidence was not available to determine a relationship for them with railway sound. Based on the information available the 2018 WHO Guidelines made "strong" recommendations that external railway sound levels should be reduced below 54 dB L_{den} and 44 dB L_{night}. The 2018 WHO Guidelines found there was insufficient evidence to recommend one type of intervention over another to reduce levels.

2.3. The above 2018 WHO Guidelines recommendations are in terms of long-term (annual) average sound levels. One of the metrics relates just to the night period (L_{night}) and the other (L_{den}) is for a 24-hour average including penalties for sound occurring in the evening (+5dB) and at night (+10dB). By necessity, this use of long-term averages is a pragmatic approach given that potential health effects generally relate to exposure over extended periods and are determined from consideration of the community/population rather than specific individuals. Other research into health effects, such as relating to awakenings from sleep, has previously referenced maximum sound levels, but sleep disturbance as a health effect is only assessed in terms of average levels in the 2018 WHO Guidelines.

2.4. The 2018 WHO Guidelines were based on international research from a wide range of countries. There was no available data from New Zealand at that time. Subsequent research published in 2019 specifically addressed the applicability of international data on railway sound annoyance of the New Zealand population.[3] This included a survey of people living in the vicinity of the North Island Main Trunk line in South Auckland, using the same general methodology as most international studies. The research found that international noise annoyance response curves are generally applicable for the New Zealand population.

2.5. There is current New Zealand and international research that may further refine the understanding of health effects caused by railway sound. However, the existing 2018 WHO Guidelines already establishes there are adverse health effects that warrant intervention.

2.6. In New Zealand, railway sound criteria have commonly been defined in terms of one-hour average levels (see section 4). Values of 35 dB $L_{Aeq(1h)}$ inside bedrooms and 40 dB $L_{Aeq(1h)}$ inside other habitable spaces have previously been applied for protection from health effects. Accounting for the different metrics, these values are slightly higher (more lenient) than the 2018 WHO Guidelines for regular sound events but would be more stringent for infrequent events. This comparison relates only to average sound levels, but corresponding relationships with health effects for different frequencies of railway events are uncertain/unknown. Therefore, currently there is no evidence base available that would support significantly more or less

[3] Humpheson D. and Wareing R., 2019. Evidential basis for community response to land transport noise, Waka Kotahi Research Report 656. https://nzta.govt.nz/resources/research/reports/656/

stringent railway sound criteria than 35 dB $L_{Aeq(1h)}$ inside bedrooms and 40 dB $L_{Aeq(1h)}$ inside other habitable spaces for protection of health.

2.7. There is a lack of information on the combination of indoor and outdoor living conditions in relation to health effects. Even if indoor conditions are controlled, there may still be residual health effects arising from outdoor conditions. In a New Zealand context, based on criteria applied for other sources, reasonable conditions in outdoor living spaces might be achieved with railway sound levels of 55 dB $L_{Aeq(1h)}$.

3. Effects of vibration

3.1. Adverse effects of railway vibration can include annoyance and sleep disturbance for building occupants and damage to buildings. Damage to buildings (even cosmetic damage) occurs at greater vibration magnitudes than those which can cause annoyance.

3.2. Internationally, there has been less research into transportation vibration effects on people compared to research on transportation sound effects. However, the evidence that does exist on adverse health effects caused by railway vibration indicates they are material, and as such the relative paucity of research is not an indicator of the degree of effects. There is international research ongoing in this area. Research is also investigating health effects arising from the combination of railway sound and vibration.

3.3. Norwegian Standard NS 8176[4] summarises research of human response to transportation vibration and provides exposure response curves in terms of the percentage of people who would perceive or experience degrees of annoyance from vibration. The current version of the standard (2017) discusses the inherent uncertainty in the data, including that it does not account for varying traffic volumes, although notes no other studies addressing that factor were found.

3.4. NS 8176 defines four categories of vibration exposure in residential buildings, with Class A representing the best vibration conditions and Class D (or below) representing the worst. The Class C criterion has previously been applied in New Zealand for habitable spaces in new buildings. This corresponds to a vibration level at which about 20% of people would be expected to be highly or moderately annoyed by vibration. The Class C criterion is defined as a $v_{w,95}$ of 0.3 mm/s (vibration metrics are explained in section 4).

3.5. For vibration effects on buildings, a ppv criterion of 5 mm/s is often used in New Zealand as a threshold at which there is potential for cosmetic damage to new buildings. While the 5 mm/s ppv criterion has been taken from guidance in an overseas standard, it does not relate specifically to railway vibration and is generally regarded as a cautious value. There is a knowledge gap as to the actual likelihood of cosmetic damage from railway vibration in New Zealand. However, all potential criteria for vibration effects on people are substantially more stringent, such that for buildings containing sensitive activities, cosmetic building damage might not require separate consideration.

[4] Norwegian Standard NS 8176:2017 Vibration and shock - Measurement of vibration in buildings from land-based transport, vibration classification and guidance to evaluation of effects on human beings

4. Methods

Sound level metrics

4.1. As discussed in section 1, for railway lines with intermittent traffic in New Zealand, use of an average sound level over any time period can cause inconsistencies between the level and the corresponding human response or health effect.

4.2. The noise provisions which have been sought by KiwiRail in plan changes around New Zealand to date have adopted a one-hour average ($L_{Aeq(1h)}$) for railway sound in their standards. This approach was initially proposed by Marshall Day Acoustics in a review undertaken in 2009 of appropriate noise criteria for district planning rules.[5] This report considered the utilisation of one-hour averaging as against broadscale setbacks and average / maximum or day / night averages. The one-hour average allows for a degree of averaging compared to single events, but still represents periods of activity when disturbance from railway sound is occurring. In the New Zealand context an alternative metric with longer averaging times (e.g. L_{den}/L_{night}) would be likely to significantly under-represent adverse effects from maximum/event sound levels over much of the network.

4.3. Neither one-hour averages or maximum levels however have an established, researched relationship with the health effects correlated to the external long term average sound level criteria recommended by the 2018 WHO Guidelines. This represents a knowledge gap and currently necessitates a broad judgement to determine criteria using the one-hour average (or another metric like maximum levels).

4.4. As set out in section 2, the 2018 WHO Guidelines recommend annual average criteria of 54 dB L_{dn} and 44 dB L_{night} applying outside buildings. These values assume windows may be open, resulting in internal sound levels around 15 dB lower than the criteria (with windows ajar for ventilation): 39 dB L_{den} and 29 dB L_{night}. In a situation where there are regular railway sound events, it could be appropriate to directly take the long-term average L_{den} and L_{night} criteria to apply as one-hour criteria (the L_{den} would also need a -10dB adjustment if applying at night). However, for irregular or infrequent events a higher one-hour criterion could be appropriate. It might also be appropriate to adjust criteria if there are no events at night.

Vibration level metrics

4.5. Internationally there are a range of different metrics used to quantify vibration affecting humans, with no accepted standardisation for this application. The "statistical maximum value of weighted velocity" ($v_{w,95}$) metric has been used previously in New Zealand for both road and railway vibration affecting people, and has the advantage that is corresponds to the exposure response curves in Norwegian Standard NS 8176.

4.6. For vibration effects on buildings and structures, the "peak particle velocity" (ppv) metric is in widespread use in New Zealand. This metric is mandated by the Noise and Vibration Metrics National Planning Standard for construction vibration affecting structures.

[5] Marshall Day Acoustics, *Ontrack rail noise criteria reverse sensitivity guidelines*, 22/10/09

4.7. In this report, vibration is presented in terms of the $v_{w,95}$ with respect to effects on people, and in terms of the ppv with respect to effects on buildings/structures.

Railway traffic characteristics

4.8. The above railway sound levels and effects depend on the timing, type and frequency of train movements at a particular location. As discussed in section 2, the proposed one-hour average sound criteria are generally less stringent than international daily average values for lines with more frequent movements. This was acknowledged by the original Marshall Day Acoustics report, which noted the application of one-hour averages are likely insufficient for lines with greater than 20 train movements a day, and the use of day / night averages or maximum levels would be more protective.

4.9. At the other end of the spectrum, for lines with very infrequent movements the proposed one-hour average criteria might be considered too stringent. With the numerous factors involved and the underlying knowledge gaps relating to sound effects, it is not possible to precisely define a lower railway traffic volume at which one-hour average sound criteria might become unwarranted. Any such consideration should not just include current rail volumes, but potential future rail volumes to which newly established activities may be subject to in the future.

4.10. Railway vibration levels and effects also depend on the traffic characteristics. However, the vibration criteria discussed in section 3 relate to levels from individual events rather than average levels. As such, the criteria are independent of the number of movements. Under the specified standard (NS 8176) the vibration criteria relate to the type of train at a particular location that generates the highest vibration levels, which will generally be freight trains. Therefore, the proposed criteria could be applied to all lines regardless of traffic characteristics.

5. Sound levels

5.1. Different options for sound level metrics are discussed in section 4 with respect to effects and criteria. In this section, example railway sound levels are presented in terms of average values over one hour ($L_{Aeq(1h)}$).

5.2. Railway sound levels are dependent on train types/condition, traffic volumes, speeds, track geometry/condition, terrain and various other factors. As discussed above, when considering average levels the assumed railway traffic volumes are a critical input.

5.3. With full geospatial details and information on railway activity, various standard acoustics computer modelling packages are available to predict railway sound levels for a specific situation. There is currently no standardised approach to this modelling for railway sound in New Zealand or consistent use of a particular calculation algorithm. Consequently, even with the same input data, predictions are likely to vary when made by different practitioners.

5.4. The following provides an illustration of typical railway sound levels based on an assumption of approximately two freight train movements in a one-hour period, in a flat area without screening. This is based on data summarised by Marshall Day Acoustics.[6] More recent

[6] Marshall Day Acoustics, *Ontrack rail noise criteria reverse sensitivity guidelines*, 22/10/09

(unpublished) measurements for various New Zealand train types confirm these sound levels are in a realistic range.

Distance from track	Sound level
10 metres	71 dB $L_{Aeq(1h)}$
20 metres	68 dB $L_{Aeq(1h)}$
30 metres	66 dB $L_{Aeq(1h)}$
40 metres	64 dB $L_{Aeq(1h)}$
50 metres	62 dB $L_{Aeq(1h)}$
60 metres	60 dB $L_{Aeq(1h)}$
70 metres	59 dB $L_{Aeq(1h)}$
80 metres	58 dB $L_{Aeq(1h)}$
90 metres	56 dB $L_{Aeq(1h)}$
100 metres	56 dB $L_{Aeq(1h)}$

5.5. In the Marshall Day Acoustics report which generated the above levels, this sound level assumption of 2 freight train movements in a one-hour period was originally proposed as being approximately equivalent to the sound level from lines with regular passenger trains. It was not intended to apply in settings which actually experienced two freight train movements per hour across a day (as noted in section 4 above, where there were more than 20 movements a day, a one-hour average was considered inadequate to address the likely effects). Instead the intention of the average is to provide an approximation of both the effects of a single event, and a generalised average of noise from the corridor. The report considered a single measurement would enable simpler application of the rule framework by landowners (compared to an average/maximum approach which was considered to add extra complication without significant benefits in effects management given the variability of single train pass-bys).

5.6. Based on this assumption the proposed sound criteria are likely to be appropriate for all urban lines with passenger trains and any lines with at least say six daily freight movements and/or freight movements at night (including where this level of activity may be required in future). This threshold of six freight movements is tentatively suggested based on a hypothesis that the one-hour average criteria would not be unduly stringent at this frequency of effect.

5.7. Internal sound levels with windows ajar for ventilation will typically be around 15 dB less than the external levels set out above. As such, at 100 metres from a track with 56 dB $L_{Aeq(1h)}$ outside, there is still potential to exceed internal criteria of 35 and 40 dB $L_{Aeq(1h)}$ (section 2). A 35 dB internal criterion in particular could be exceeded significantly beyond 100 metres from the track, potentially to around 200 metres. However, at progressively further distances from the track the actual sound level is more likely to be affected by topography and localised screening such that there will be greater variability in sound levels.

5.8. For land use controls, the appropriate method to determine railway sound levels for a particular site (specified values, modelled, measured) depends significantly on the approach to information on train types, volumes and times. This is discussed further in section 9 with respect to recommended controls.

6. Vibration levels (ground-borne)

6.1. The following table summarises various railway vibration measurements (and associated predictions) in New Zealand from a range of sources, generally ordered from lowest to greatest magnitude (other than the first row which uses the ppv metric rather than $v_{w,95}$). Where the data relates to a private development or complaint, a generic source reference is given. Not all measured values are directly comparable due to issues such as differences in measurement positions (ground/building) that would require adjustments.

Data source	Vibration levels
Marshall Day Acoustics, *Ontrack rail noise criteria reverse sensitivity guidelines*, 22/10/09 *(secondary reporting of Marshall Day Acoustics 2006 assessment for Marsden Point)*	Based on measurements: 2 to 3 mm/s ppv at 30m 0.5 to 1 mm/s ppv at 60m
AECOM, *Bayfair to Bayview – Rail Relocation Post Construction Noise and Vibration Monitoring*, 6/3/17	Measured: 0.56 mm/s $v_{w,95}$ at 7m From measurement and distance correction: 0.19 mm/s $v_{w,95}$ at 100m 0.26 mm/s $v_{w,95}$ at 50m 0.37 mm/s $v_{w,95}$ at 25m
Marshall Day Acoustics, *Wiri to Quay Park third main rail line noise and vibration assessment*, 10/7/20	Measured: 0.6 mm/s $v_{w,95}$ at 9.5m
URS, *Maunganui-Girven Road Intersection -Rail Vibration Assessment*, 14/4/14	Measured: 26.5 mm/s^2 $a_{w,95}$ at 17m *(this $a_{w,95}$ value has different units and is not directly comparable to a $v_{w,95}$ value)* From measurement and distance correction: 0.34 mm/s $v_{w,95}$ at 100m 0.47 mm/s $v_{w,95}$ at 50m 0.67 mm/s $v_{w,95}$ at 25m
URS, *Operational noise and vibration assessment Peka Peka to North Ōtaki Expressway Project*, 12/2/13	Measured: 0.58 mm/s $v_{w,95}$ at 60m
Marshall Day Acoustics, *assessment in relation to a complaint near Hamilton*, 28/11/12	Measured (on a deck structure): 0.42 mm/s $v_{w,95}$ at 140m
Marshall Day Acoustics, *assessment for development in Napier*, 6/2/20	Measured: 1.2 mm/s $v_{w,95}$ at 10m
URS, *Ground-borne vibration measurements at Hornby, Christchurch,* 12/9/14	Measured before renewal: 2.2/2.9 mm/s $v_{w,95}$ at 8.4m Measured after renewal: 0.5/0.4 mm/s $v_{w,95}$ at 8.4m

6.2. The data in the above table illustrates the significant variation that is inherent in railway vibration. Vibration levels often vary even within a localised area and cannot be reliably predicted, such as in the same manner as airborne sound. Hence, measurements are generally required to assess ground-borne vibration.

6.3. With respect to effects on people, a vibration criterion of 0.3 mm/s $v_{w,95}$ is discussed in section 3. The measurement data shows that this criterion can routinely be exceeded at over

100 metres from railway tracks in New Zealand, but there is significant variation. Vibration levels exceeding this criterion occur beyond at least 50 metres from the track in most cases.

6.4. With respect to effects on buildings, a vibration criterion of 5 mm/s ppv is discussed in section 3. The vibration measurement data indicates that vibration levels might exceed this criterion within approximately 20 metres of the track. The implications of this are discussed further with respect to recommended controls in section 9.

7. Approaches to manage effects of railway sound

Source

7.1. Routine rolling stock and track maintenance undertaken by KiwiRail contributes to reducing sound at source. There might be incremental improvements if more stringent maintenance service standards were adopted.

7.2. Locomotives can be designed with sound reducing features, such as attenuators and silencers. Generally, these need to be integrated at the time of initial design/manufacture. Retrofitting measures to existing locomotives may be constrained and would be likely to constitute a major rebuilding. Locomotives with alternative power systems such as battery power can have reduced sound, although significant sound still arises from the track/wheel interface. Unpublished research[7] included measurements that show the sound levels set out in section 5 remain representative for the current locomotive fleet, including the newer DL class locomotives. It is understood that KiwiRail has existing workstreams to renew its rolling stock (including the locomotives) overtime. This workstream is focused on alternative power systems, and as a multi-year project to explore (and where supported) upgrades/renewals of its stock, as opposed to retrofitting of existing or old stock.

7.3. Specific sound sources such as wheel squeal, can sometimes be reduced through treatment of rolling stock.

7.4. If older track is not continuously welded, implementing this measure can reduce sound.

Pathway

7.5. Barriers such as formed by earth bunds or walls can reduce railway sound. A barrier providing effective screening could typically reduce railway sound levels by around 5 dB. However, this is often impracticable because any noise barrier would typically need to be in the order of 5 metres high to achieve effective screening of locomotive sound sources that are several metres above the tracks, which in turn are often raised above local ground level. Sound screening might also be provided by intervening buildings or the terrain. As barrier performance is limited by sound passing over the top, typical barriers generally do not provide sufficient sound reduction for receivers close to the railway (within around 50 metres).

[7] Waka Kotahi research programme. Social cost (health) of land transport noise exposure, https://www.nzta.govt.nz/planning-and-investment/research-programme/current-research-activity/active-research-projects/

7.6. Increasing the distance of the pathway reduces sound levels: i.e. separating the receiver from the source by a greater distance. As discussed previously, this measure in isolation may require separation of 100 to 200 metres.

Receiver

7.7. If habitable/sensitive spaces are orientated with no opening windows with exposure to railway sound then internal levels will be reduced. Hence the layout of a building can be used to manage railway sound. A practical approach can be to locate only ancillary, non-sensitive spaces such as garages and bathrooms on the side of the building facing the railway.

7.8. Where windows do have exposure to railway sound, closing those windows reduces internal sound levels. This typically provides a reduction in the order of 10 dB compared to when windows are open ajar for ventilation. However, if windows are required to be closed to reduce sound then an alternative (i.e. mechanical) ventilation and temperature control method is needed for occupants to maintain thermal comfort such that they have a genuine choice to leave the windows closed. For two older roading projects (SH20 Mt Roskill and SH1 Plimmerton) Waka Kotahi installed ventilation systems in 35 and 57 houses respectively with the intention that it would allow windows to be kept closed to reduce road-traffic noise.[8] However, those systems only provided ventilation and not temperature control (e.g. cooling) and for both projects residents reported the temperature being uncomfortable with windows closed. Therefore, if closed windows are to be considered as a noise reduction measure, temperature control should be included in any alternative ventilation system.

7.9. If greater reductions are required than can be achieved just by building layout or closing windows, then the building fabric can be upgraded. This typically requires thicker and/or laminated glazing of windows and in some cases additional/thicker layers of plasterboard wall/ceiling linings.

8. Approaches to manage effects of railway vibration

Source

8.1. As for managing sound, routine track and rolling stock (wheel) maintenance contributes to reducing vibration at source. Again, there might be incremental improvements if more stringent maintenance service standards were adopted. It is understood based on evidence previously provided by KiwiRail that it endeavours to undertake current maintenance best practice where practicable, and continues to invest in ongoing upgrades of its maintenance abilities. This includes the recent commissioning of a new wheel maintenance facility at its Hutt Workshops, which should contribute to improved wheel servicing and repair.

8.2. There are several different methods to treat railway track to reduce vibration. These include resilient clips fastening the rails to sleepers, resilient material under the sleepers or ballast, and tracks directly or on ballast on concrete slabs, "floating" on resilient or spring vibration bearings. These vibration treatments are generally "built into" the overall track formation, particularly for the better performing options. Some treatments can increase the height of the track, having

[8] Waka Kotahi, State highway guide to acoustic treatment of buildings, 2015

implications on clearances from bridges and overhead structures. As such, these measures are most commonly used for new tracks when the treatments can be integrated into and constructed as part of the overall design (e.g. on the Auckland City Rail Link). Retrofitting treatments over a wide area would require a major rebuilding of the tracks, beyond standard upgrading or maintenance.

Pathway

8.3. There are no standard pathway controls to reduce vibration. In some instances, depending on the dominant propagation route in the specific location, in-ground barriers can reduce vibration propagation. In addition to practical/space constraints (where the corridor is too narrow to construct an in-ground barrier), this is generally not something that could be applied broadly along a rail corridor as it would require analysis and design for specific locations.

8.4. Again, increasing the distance of the pathway reduces vibration levels: i.e. separating the receiver from the source by a greater distance.

Receiver

8.5. Depending on the specific propagation paths, use of different building foundation types (e.g. pile/pad) can result in reduced vibration entering a structure. Likewise, propagation through a structure will alter depending on its design (e.g. concrete/steel).

8.6. Buildings can be built on vibration bearings to reduce vibration from the foundations entering the building. (Some types of vibration bearing are similar to earthquake bearings.) Individual spaces within a building could be constructed as separate structures mounted on vibration isolators, but this is unlikely to be a practical solution in most cases compared to isolating the entire building.

9. Recommended land use controls

Form of controls

9.1. Extensive and widespread mitigation at source would generally only give relatively small incremental improvements and/or would require renewal/replacement of a substantial proportion of track and rolling stock. While (as set out at 7.2 above) there are programmes being undertaken by KiwiRail to renew its existing rolling stock, this confirms any improvements are likely to be incremental as fleets are gradually renewed. There are therefore unlikely to be practicable options for extensive mitigation at source to address sound and vibration effects on new and altered sensitive land uses seeking to establish near existing railways.

9.2. In terms of sound and vibration affecting people, the most robust control would be avoidance of effects by separating sensitive activities from railways. This could be achieved by defining an area around railways where new noise sensitive activities are not allowed. However, in addition to any non-acoustic impacts of such a control, if it contributed to larger and/or more dispersed urban areas then it might in itself cause increased transportation sound and vibration as the overall population travels greater distances. The following recommendations are therefore made on the assumption that avoidance of effects by separation alone is not a practicable option.

9.3. If new and altered sensitive activities are allowed near railways, then to manage potential health effects, controls are needed to result in appropriate design of buildings or effective screening and separation of those buildings from the railway.

9.4. Several different methods have previously been used in RMA plans. Two common approaches are:

a) setting internal sound and vibration limits; or

b) specifying building constructions directly or in terms of sound reduction performance.

9.5. The first approach requires a site-by-site assessment and tailored mitigation for each development, whereas the second approach requires the same mitigation for all developments. The first requires specialist acoustics expertise whereas the second does not if specifying building constructions directly.

9.6. The potential health effects discussed above have been shown to occur (or be more likely) above certain sound and vibration threshold levels inside buildings. As discussed previously, there are a large number of variables that determine external railway sound and vibration exposure and there are nuances with building siting/layout and design that affect the internal levels. Controls that require the same mitigation for all developments result in excess treatment in many cases and inadequate treatment for those developments most exposed (nearest to the railway). Technically, setting internal sound and vibration criteria and requiring a site-by-site assessment should be the most efficient and effective approach.

9.7. In the Christchurch District Plan, multiple compliance options were included for mitigating road and rail noise in buildings for new sensitive activities. On review of the controls the Council found that in most cases site-specific assessment was selected by developers rather than fixed mitigation (i.e. following a standard building design schedule or fixed sound reduction performance).[9] This was presumably as despite any specialist assessment costs the site-specific assessment provided a more efficient solution.

9.8. It is recommended that any land use controls should be based on achieving internal sound and vibration criteria and allowing for requirements for each site to be determined through individual assessment.

Sound and vibration criteria

9.9. For the reasons discussed previously, the following criteria are recommended to manage potential health effects. A range of sensitive activities have been included in this table, extending from the primary issue of residential units.

9.10. For all these building types the vibration criterion relating to health effects is more stringent than any separate control that might relate to building damage. For other building types a separate vibration criterion is included in the table, which could be used to avoid potential building damage.

[9] Christchurch District Plan, Plan Change 5E

Building type	Occupancy/activity	Sound criterion $L_{Aeq(1h)}$	Vibration criterion
Residential	sleeping spaces	35 dB	0.3 mm/s $v_{w,95}$
	all other habitable rooms	40 dB	
Visitor accommodation	sleeping spaces	35 dB	
	all other habitable rooms	40 dB	
Education	lecture rooms/theatres, music studios, assembly halls	35 dB	
	teaching areas, conference rooms, drama studios, sleeping areas	40 dB	
	libraries	45 dB	
Health	overnight medical care, wards	40 dB	
	clinics, consulting rooms, theatres, nurses' stations	45 dB	
Cultural	places of worship, marae	35 dB	
All	All occupancies/activities not specified above	-	5 mm/s ppv

9.11. As discussed in section 2, reasonable conditions should be achieved in outdoor living spaces if they are subject to a sound criterion of 55 dB $L_{Aeq(1h)}$.

9.12. The sound level criteria are based on intermittent rail activity. For the assumed rail activity discussed in sections 4 and 5, controls should specify that criteria are to be achieved for external railway sound of 70 $L_{Aeq(1h)}$ at a distance of 12 metres from the track, reducing at a rate of 3 dB per doubling of distance up to 40 metres and 6 dB per doubling of distance beyond 40 metres.

Extent of controls

9.13. Setting a distance for application of controls that includes most land affected by railway sound and vibration would extend for say 200 metres from railways, and would include a substantial area towards the periphery where on closer examination of specific developments no building treatments would be required. Previously, a distance of 100 metres has been used for the application of controls for railway sound. Technically this represents a reasonable compromise if the aim is to capture the most affected sites without requiring assessment where building treatment is less likely to be required. This aligns with the assumed sound levels applied for the rail volumes and one-hour average discussed at section 5 above.

9.14. For vibration, a distance of 60 metres has been used for controls previously. On the basis of the measurement data presented above, I have recommended this be increased to 100 metres consistent with the distance used for sound.

Ventilation

9.15. Where windows are required to be closed it is recommended that a mechanical system be required to provide thermal comfort so there is a genuine choice to leave windows closed.

Ventilation is outside the expertise of Chiles Ltd, but on the basis of work published by Waka Kotahi[10,11] the following system specification for residential and visitor accommodation habitable rooms may be appropriate:

i. provides mechanical ventilation to satisfy clause G4 of the New Zealand Building Code; and

ii. is adjustable by the occupant to control the ventilation rate in increments up to a high air flow setting that provides at least 6 air changes per hour; and

iii. provides relief for equivalent volumes of spill air;

iv. provides cooling and heating that is controllable by the occupant and can maintain the inside temperature between 18°C and 25°C; and

v. does not generate more than 35 dB $L_{Aeq(30s)}$ when measured 1 metre away from any grille or diffuser.

Alternative compliance pathways

9.16. Existing controls in district plans based on internal sound and vibration criteria, often include alternative compliance pathways that can be used in some cases to demonstrate that appropriate sound and vibration conditions will be achieved, without requiring specialist assessment or only requiring a reduced assessment. Essentially, these pathways allow for sites and buildings that are likely to have lower sound exposure, or that adopt conservative building designs, to face reduced assessment requirements. Alternative pathways have included:

a) Compliance with internal sound criteria demonstrated by external levels not exceeding the internal criteria by more than 15 dB (reduced assessment needed for external levels).

b) Compliance with internal sound criteria demonstrated by the building being at least 50 m from the railway and screened by a solid barrier, from all points up to 3.8 m above the tracks.

c) Compliance with internal sound criteria demonstrated by using prescribed building constructions.

d) Compliance with internal vibration criterion demonstrated by use of prescribed building base isolation system.

9.17. Technically, the alternative pathways are valid as they result in compliance with the sound and vibration criteria, albeit generally not in the most efficient manner. As discussed above, in the case of the Christchurch District Plan alternative pathways provided were generally not used and were found to make the plan more confusing for users and harder to administer for the Council.

[10] Acoustic Engineering Services, NZTA Ventilation specification review, 30 June 2020
[11] Beca, Ventilation systems installed for road-traffic noise mitigation, 26 June 2014