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Report Number: AC16218 – 04 – F1

Selwyn District Plan Review: DW006 Vibration

Prepared for:

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3 October 2017

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Revision History

Reference	Status	Date	Prepared by	Reviewed by	Approved by
AC16218 – 04 – D1	DRAFT	1 September 2017	W. Reeve	C. Dykes	J. Trevathan
AC16218 – 04 – D2	DRAFT	12 September 2017	W. Reeve	J. Trevathan	J. Trevathan
AC16218 – 04 – F1	FINAL	3 October 2017	W. Reeve	J. Trevathan	J. Trevathan

Document Acceptance

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On behalf of Acoustic Engineering Services Limited
3 October 2017

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1.0 BACKGROUND

Acoustic Engineering Services (AES) have been engaged by the Selwyn District Council to undertake a preliminary review of a number of aspects of the current vibration provisions within the Operative Selwyn District Plan (the Plan), as part of the Plan review process.

At this stage, our brief is to identify key vibration sources, legislative requirements, provide recent case studies involving vibration management, identify appropriate management approaches and highlight the District Plan provisions in adjoining Districts.

The scope of work for this report is based on the following:

- Document titled *Project Scope of Work: Vibration*, as prepared by Selwyn District Council, and dated the 26th of April 2017.
- Email sent by Jeremy Trevathan of AES titled *Re: Further information required: Noise and vibration package of work*, sent on the 15th of June 2016.

The aim of this report is to cover the specific scope requested, and enable informed discussion moving forward. Consistent with discussions with the Selwyn District Council relating to the *Project Scope of Work: Vibration* document, we understand that our review and advice is to be technically focussed and high-level, and the decisions regarding any possible changes to the Plan and the specifics of rule wording and the like will be made at a later point in the process.

2.0 VIBRATION GENERATING ACTIVITIES

The most commonly encountered sources of man-made vibration are associated with transport, construction and industrial activity. These sources vary in terms of both character and duration, and are described in more detail below.

2.1 Transport networks

The operation of road networks is a key source of vibration, particularly busy roads or roads which accommodate heavy vehicles. The character and duration of the vibration will differ depending on the volume of traffic on the road. While the vibration caused by an individual vehicle movement is transient, for a road where there is heavy traffic then vibration may be continuous or quasi-continuous. In addition, for a low volume road where there are a high percentage of heavy vehicle movements (such as an access road for a quarry) higher vibration levels may be generated on a more infrequent basis.

We note that often vibration from the road network can be exacerbated by imperfections in the road surface (such as potholes or expansion joints on bridges) which result from poor maintenance or design.

The vibration generated by railway lines is typically transient; however, for a long freight train the period of vibration may be sustained for a greater period.

While airfields are identified as a potential source of vibration in the Selwyn District Plan, we consider that the setbacks required for the safe operation of an airfield are sufficient to mitigate vibration effects and therefore in practice vibration from airfields is typically not problematic.

2.2 Construction / demolition

There are a number of construction / demolition activities which can generate significant vibration. Common examples include piling, surface compaction, rock breaking, drilling and the movement of heavy vehicles and equipment on a site.

Vibration generated by construction will often vary over the construction/demolition process. Some activities such as the use of a drill or pavement breaker will result in periods of continuous vibration, while other activities will result in repeated periods of impulsive vibration, such as a pile driver or soil compaction.

Blasting is also a source of vibration which can be used during construction or demolition. We note that this causes a high level of vibration for a short period of time, and therefore is of a significantly different character to the other potential construction/demolition vibration that is induced on a site.

2.3 Industrial activity

Common industrial activities which can generate high levels of vibration are quarrying and mining. The main activities which generate vibration on these sites is heavy equipment movements, rock breaking and blasting.

We note that as above blasting has a unique character in terms of vibration effects. When blasting is used as part of an industrial activity the overall period in which blasting could occur is significantly longer than for construction / demolition.

Vibration may also be encountered from other heavy industrial processes such as forging or presswork.

3.0 VIBRATION EFFECTS

Vibration effects are typically considered in two ways – with regard to possible structural or cosmetic damage to buildings, and human response. Detectable vibration has the potential to impact on the quality of life and/or work efficiency of building occupants. Individuals can detect building vibration levels that are well below those required to cause any risk of damage to the building or its contents.

There are no New Zealand Standards which provide relevant guidance for vibration effects on people or damage to buildings. Previously, the ISO Standard 2631-2:1989 *Evaluation of human exposure to whole-body vibration* standard was commonly adopted. However this standard was superseded in 2003 by an informative standard which contained no vibration exposure limits. In April 2005 ISO 2631:1989 was subsequently withdrawn by Standards New Zealand. We have taken guidance in the following sections from international standards which are commonly referenced in New Zealand.

3.1 Human Response

The human response to vibration is complex and perception thresholds vary between people. In residential settings, adverse comment about building vibration may arise when vibration is only slightly in excess of perception levels (British Standard BS 6472-1:2008, *Guide to evaluation of human exposure to vibration in buildings*).

BS 6472-1:2008 outlines factors which can modify subjective response to vibration. These include the vibration event duration, frequency of vibration and direction relative to the receiver. Whether the person is moving about, standing, seated on a chair or lying in a bed will influence how they are coupled to the structure and perceive vibration. Parallel effects such as structure-borne or airborne noise received at the same time as the vibration can also influence the response.

Guidance on the levels which affect humans can be taken from British Standard BS 5228 - 2:2009, *Code of practice for noise and vibration control on construction and open sites – Part 2 Vibration* as follows:

Table 3.1 – Guidance on vibration effects from BS 5228-2:2009

Vibration level	Effect
0.14 mm/s	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3 mm/s	Vibration might be just perceptible in residential environments.
1.0 mm/s	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents.
10 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level.

The Norwegian Standard NS 8176.E:2005 *Vibration and shock – Measurement of vibration in buildings from land based transport and guidance to evaluation of its effects on human beings*, outlines how the presence of vibration is detected by people in a number of different ways. For example, someone may notice that the building is vibrating, that things rattle or shake or are displaced, or the vibration may simply be felt in the body. Of these varying possible noticeable manifestations of vibration, it is the movement of buildings which most commonly draws people’s attention to elevated vibration levels. The most frequently reported vibration nuisance with respect to rest or daily activities is disturbance to the use of radio or television. However, other reported effects include sleep disturbance and difficulty falling asleep, and disturbance during conversations, including on the telephone.

3.2 Damage to buildings

The effect of vibration on buildings is influenced by the nature of the excitation, the geology of the area, the type of building foundation, and the structural response of the building.

The German Standard DIN 4150-3:1999 outlines criteria to ensure that there will not be an adverse effect on the serviceability of a structure. DIN 4150-3:1999 provides vibration levels in peak particle velocity (PPV), which enables easy comparison with the values in table 3.1 above.

Table 3.2 – Short-term vibration limits from DIN 4150-3:1999

Line	Type of structure	Guideline values for velocity, vi, in mm/s			
		Vibration at the foundation at a frequency of			Vibration at horizontal plane of highest floor at all frequencies
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz*	
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under preservation order)	3	3 to 8	8 to 10	8
* At frequencies above 100 Hz, the values given in this column may be used as minimum values					

Table 3.3 – Long-term vibration limits from DIN 4150-3:1999

Line	Type of structure	Guideline values for velocity, vi, in mm/s, of vibration in horizontal plane of highest floor, at all frequencies
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	10
2	Dwellings and buildings of similar design and/or occupancy	5
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under preservation order)	2.5

As these tables demonstrate, buildings which are subjected to ongoing vibration are more likely to suffer damage, so the appropriate limits in a particular situation also depend on the vibration duration.

As described in DIN 4150-3:1999, the most common damage which may begin to be evident in buildings subjected to vibration includes the formation of cracks in plastered surfaces of walls and the enlargement of existing cracks. Higher levels of vibration may lead to partitions becoming detached from loadbearing walls or floors and the impairment of the stability of the building and its components.

The levels shown in tables 3.2 and 3.3 for building damage are higher than the levels that are likely to cause complaint in a residential setting (1 mm/s). This illustrates the fact that complaints may occur at a vibration level that is not likely to cause building damage.
We note that DIN 4150-3 also provides guidance on limits to avoid damage to buried pipes and infrastructure. These limits apply on the surface of the pipe and are higher than the limits shown in tables 3.2 and 3.3 above (50 – 100 mm/s for short-term vibration or 25 – 50 mm/s for long-term vibration).

4.0 LEGISLATIVE REQUIREMENTS AND OPERATIVE PLAN PROVISIONS

The National Environmental Standards for Electricity Transmission Activities (2009) outlines a condition in *Noise and vibration from construction activity, 37 Permitted activities* as follows:

> *(3) The vibrations from the construction activity must comply with the peak particle velocity limits in table 1 of German Standard DIN 4150-3:1999 Structural Vibration – Effects of Vibration on Structures.*

These limits are reproduced in tables 3.2 and 3.3. The other National Environmental Standards do not appear to contain reference to vibration.

As summarised in the *Project Scope of Work: Vibration* document, generic references are also made to vibration as an environmental effect on surrounding land uses and communities throughout the current Selwyn District Plan in relation to:

- The operation of transport networks, railway lines, and airfields
- The construction, maintenance, and repair of roads
- Heavy vehicles travelling through rural townships and in Business zones adjoining Residential zones
- The take-off and landing of aircraft
- Preparing land for subdivision (earthworks) and installation of utilities - construction

Policies within the Plan which mention vibration include:

- Township Volume, Part B, 3. People's Health, Safety and Values, Quality of the Environment – Policies and Methods, Zones: Policy B3.4.15 – *Avoid, remedy or mitigate adverse effects caused by excessive or prolonged vibration associated with people's activities.*
- Rural Volume, Part B, 3. People's Health, Safety and Values, Quality of the Environment – Policies and Methods, Rural Character, Noise and Vibration: Policy B3.4.15 – *Avoid, remedy or mitigate adverse effects caused by excessive or prolonged vibration.*

Rules within the Plan which mention vibration include:

- Rural Volume, Part C, 9.16 Activities and Noise, Permitted Activities – Blasting: 9.16.4.1 – *Vibration from any site due to blasting shall not exceed a peak particle velocity of 5mm/sec measured in the frequency range 3-12 Hz at the notional boundary of any dwelling, rest home, hospital or educational facility classroom.*
- Rural Volume, Part C, 9.17 Activities and Blasting and Vibration, Permitted Activities – Activities and Blasting and Vibration: 9.17.1 – Any activity which involves blasting and/or vibration shall be a permitted activity if all of the following conditions are met: 9.17.1.1 – *Any activity which involves noise vibration from blasting complies with AS 2187.2-1993 Explosives – Storage, Transport and Use, Part 2 Use of Explosives, and ANZECC guidelines*
- Rural Volume, Part C, 9.17 Activities and Blasting and Vibration, Permitted Activities – Activities and Blasting and Vibration: 9.17.1 – Any activity which involves blasting and/or vibration shall be a permitted activity if all of the following conditions are met: 9.17.1.2 – *Except for blasting, any activity which involves vibration from any other source complies with New Zealand Standard 2631:1985-89 Parts 1-3*.

As also described in the *Project Scope of Work: Vibration* document, these rules will need to be revised as AS2187.2-1993 has been superseded, the ANZECC guidelines are over 25 years old and NZS2631:1985-89 has been withdrawn.

5.0 VIBRATION ASSESSMENT CASE STUDIES

As requested, we have reviewed recent projects and identified four relevant case studies which have involved vibration assessments to illustrate the type of situations where vibration effects are of concern in practice, and the current best practice approach to managing these effects.

5.1 Case Study 1 - Vibration associated with construction activity

AES were involved with the building design work associated with a high density, multi-level, multi-building residential development in Christchurch City. An assessment of construction vibration was not requested or provided during the Resource Consent process; however, when the finalised Resource Consent conditions were circulated, they contained the following condition relating to construction vibration drafted by Christchurch City Council:

“The work shall be undertaken in accordance with German Standard DIN 4150 Structural Vibration Part 3: Effects of vibration on structures (1999) with regard to vibration from truck movement, construction machinery, pile driving station, etc. The immediate adjoining properties (built structures) shall be continuously monitored in terms of potential effects from vibrations and appropriate action taken immediately to mitigate effects if necessary. No work shall start on site without a proper list of measures ready to mitigate the effects from vibration.”

No work had been done prior to determine if this condition could realistically be complied with, and there had been no discussion as to the suitability or purpose of the particular limits proposed. It was also unclear whether the continuous monitoring referred to in the condition related to vibration measurement, or visual monitoring of crack propagation etc. With either approach the practical issue of access to the interiors of neighbouring buildings to complete these tasks did not seem to have been considered.

As described in section 3.2, DIN 4150 provides guideline values for vibration that will not result in damage or affect building serviceability. Presumably this was therefore the intent of the condition, as opposed to the prevention of annoyance.

Vibration associated with piling activity at the site was deemed to have the highest risk of non-compliance with the limits identified in the condition. AES undertook measurements of test piling activity at the site in order to determine the areas of the site where there was the potential for the limits to be exceeded. During the test piling, a tenant of an adjoining commercial building approached the team on site, and expressed the strong view that the levels of vibration generated in his building by the test piling were unacceptable.

Our measurements indicated that if the short-term limits outlined in DIN 4150-3 were applicable, then compliance would likely be achieved in all scenarios. However, if the long-term limits were relevant, then AES identified an area near the boundary of the site where a heightened risk of non-compliance may be associated with piling.

It was unclear whether the short or long term limits applied to vibration associated with piling. AES recommended that a structural engineer be engaged to confirm which limits were applicable. We also noted that if the long-term limits applied, then vibration measurements within the neighbouring buildings would ultimately be required to demonstrate compliance when piling in these areas. The possible meaning of ‘continuous monitoring’ was discussed with the contractor, who requested a quotation for continuous vibration monitoring during the piling. The possible meaning of “a proper list of measures ready to mitigate the effects from vibration” was also discussed, as the piling methodology could not realistically be modified. We suggested that consultation and ongoing communication with neighbours, scheduling the piling work outside sensitive times identified by neighbours, and offering to temporarily relocate neighbours may be the only practicable mitigation measures. However, if the issue is building damage not annoyance, none of these measures would actually target that effect.

We had no further involvement with that aspect of the project, but observed that the piling work was completed shortly thereafter over a relatively short period (1 – 2 weeks). As far as we are aware further vibration measurements were not completed. We do not know if further feedback was received from neighbours during this period, or whether the Christchurch City Council were involved further with the process. There were no obvious signs of damage to neighbouring buildings.

5.2 Case Study 2 – Vibration associated with a gold mining operation

AES were engaged to provide advice in relation to an application for Resource Consent for the establishment and operation of an alluvial gold mine in the Marlborough District. The Marlborough District Council had requested an assessment of vibration from the operation of the gold screen and excavator. We are unaware of why they expected that vibration from these sources may have been problematic, but understand neighbours may have expressed concerns regarding potential vibration issues directly to the Council.

For the purposes of our assessment, guidance regarding acceptable levels of vibration when measured on the foundation of a residential dwelling were sourced from British Standard BS 5228-2:2009 *Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration*.

To adequately mitigate noise effects, it had already been determined that the mining operation could not occur within 20 metres of the site boundary (along with the use of significant temporary screening). Neighbouring dwellings were set back a further 5 to 30 metres from the site boundary.

In order to determine whether any additional setbacks or mitigation would be required to meet the vibration criterion at the neighbouring residential sites, AES undertook vibration measurements of a similar operation on the West Coast of the South Island. These measurements revealed that the only aspects of the activity capable of generating vibration levels exceeding the BS 5228-2:2009 criteria at 20 metres were when large rocks (> 300 mm) were dropped from large heights (> 3 m) or when the excavator occasionally manoeuvred using the bucket and boom to lift / swivel its tracks instead of normal smooth tracking.

The differences between the operation on the West Coast, and that proposed in Marlborough were then considered. In particular:

- The rock sizes in the Marlborough mine area were considerably smaller than on the West Coast. In addition, a different conveyor system was proposed, which would ensure that rocks were not dropped from heights over 1 metre, and;

- Management and training of excavator operators was proposed, to minimise rough manoeuvring in the vicinity of dwellings.

When considering these factors, it was concluded that compliance with the BS 5228-2:2009 criteria was likely to be achieved without increasing the proposed setback beyond that already proposed to mitigate noise effects. This analysis was presented in evidence at the Council hearing. In the s42A report the Council Officer had also confirmed that based on his experience he did not expect vibration effects associated with the activity to be significant.

5.3 Case Study 3 – Reverse sensitivity effects arising from vibration associated with a State Highway

AES were involved with the building design work associated with a significant high density residential development in Christchurch located in close proximity to State Highway 76. As part of the Resource Consent process, New Zealand Transport Association (NZTA) requested an assessment of the likely levels of vibration within the proposed units, generated by vehicles on the State Highway. The NZTA were concerned that this vibration may lead to reverse sensitivity effects.

The NZTA suggested that their document *Guide to the management of effects on noise sensitive land use near to the state highway network* would provide a suitable framework for the assessment.

This document provides maximum surface vibration levels within bedrooms and living areas of residential units. The surface vibration levels are based on NS 8176.E:2005 *Vibration and shock – Measurement of vibration in buildings from landbased transport and guidance to evaluation of effects on human beings*. If the limits in this standard are met then the NZTA state that they expect that potential reverse sensitivity effects associated with road traffic vibration will be adequately mitigated.

AES initially undertook a series of vibration measurements on compacted ground in multiple locations around the site, approximately in line with the location of the closest façade to the State Highway. The NS 8176.E:2005 methodology calls for measurements to be completed during 15 heavy vehicle drive-bys. This data is then used to undertake a statistical analysis to establish the 95^{th} percentile heavy vehicle vibration level.

These initial measurements revealed that there was an area of the site where vibration levels in the ground exceeded the NZTA criteria. It appeared that this was likely to be due to a combination of imperfections and other features in the road surface, and ground conditions which favourably supported the propagation of vibration. However, the criteria relate to vibration levels within bedrooms and living areas of residential units – not within the ground. Vibration levels will be modified as the energy is transferred from the ground into a building's foundations and structure. Generally, energy will be lost as it is transferred from the ground into heavy foundations. However, for a light-weight multi-storey building, vibration levels may also increase at upper levels, depending on building behaviour. The magnitude of any changes to vibration levels during any of these transitions is not easily predicted.

The outcomes of this initial testing were discussed with the NZTA, noting that:

- The primary vibration generation mechanism appeared to be imperfections and features of the State Highway surface itself, which the NZTA has some control over, but the Applicant did not.
- The Applicant had no realistic ability to modify the ground conditions between the Highway and the proposed dwellings, nor was it commercially or practically viable to set back the dwellings further on the site.
- A significant concrete foundation system was proposed. The vibration levels would likely be reduced as the energy was transferred into this floor structure, at least on the ground floor. However, this could not be accurately predicted.

It was determined that an empirical approach may be the only practicable way forward. Accordingly, a test foundation was constructed in a worst-case location close to the State Highway. Repeat vibration measurements were carried out on the test foundation, and the measured levels were found to comply with the limits outlined in NS 8176.E 2005. While this still leaves the question of potential vibration levels on the upper floors of the buildings unanswered, we understand the NZTA accepted this analysis as adequate demonstration that vibration reverse sensitivity effects would not be significant.

5.4 Case Study 4 – Vibration associated with heavy vehicles servicing a quarry travelling on a public road

AES were engaged as the Council peer reviewer for a proposed aggregate quarry in Christchurch.

Submitters raised the potential issue of vibration from quarry trucks on public roads travelling past residential dwellings. Heavy vehicles associated with a number of quarries in the area already travelled past the submitters dwellings, and they reported that:

- The heavy vehicles send vibrations "rattling through our home", and
- "Every truck that hurtles by is loud, intrusive and vibrates our home like a mini earthquake"

The neighbours houses were in the order of 22 metres from the edge of the road in question which is classified as a local road.

In terms of objective criteria against which to consider the situation, we suggested that the guidance regarding perceptibility and acceptable limits for vibration outlined in NS 8176.E:2005 would be relevant. However, due to various constraints, no objective investigation was able to be undertaken. This would have required, for example, access to the interior of the submitters houses at times when the dwellings were otherwise unoccupied.

Instead, a preliminary subjective investigation was undertaken, as it was possible to access land on the opposite side of the road to the submitters dwellings and observe the passage of heavy vehicles associated with the existing quarries.

At 3.5 metres from the road, perceptible vibration was observed. At 7.5 metres from the road edge, vibration levels approached the limit of perceptibility, and we were uncertain whether vibration could still be felt in the ground when heavy vehicles passed. At 22 metres (the distance to the closest dwelling), no perceptible vibration was observed.

We did note however that vibration levels are highly dependent on the condition of the road surface, with inconsistencies in the road surface from trenches or manholes, hollows or bumps, and seal joints expected to increase the level of vibration generated. While the road surface appeared to be generally in good condition, in theory improving existing minor inconsistencies in the road surface has the potential to reduce vibration levels. However, we also highlighted that localised work could also introduce further joints and variations which may offset the benefit achieved.

Overall, based on our subjective observations we concluded that the vibration levels received at the closest dwelling required no further mitigation, and were very likely to comply with the NS 8176.E:2005 criteria. The vibration expert engaged by the Applicant reached the same conclusion. We could not explain the difference between our site observations, and the situation the submitters described in their evidence.

6.0 MANAGEMENT OF VIBRATION EFFECTS

As the previous sections have demonstrated, the vibration levels received at a sensitive receiver are primarily determined by the distance from the source, ground conditions and the fundamental response of the receiving structure.

It is often not practical to alter the ground conditions or fundamental response of a structure significantly. Remaining physical mitigation options include isolating the source, changing the source, or increasing the distance between the source and the receiver. Whether these options are practical ultimately depends on the nature of the activity.

6.1 Construction / Industrial

For vibration caused by construction activities or industry, it may be practical to limit the duration and time of day when the vibration will occur to minimise effects on the sensitive receivers. In some cases, alternative construction techniques which generate lower levels of vibration may be practical (for piling for example).

For construction in particular, it is not practical to change the process or increase the distance from adjoining receivers. In this case, sufficient communication with affected parties along with assessments to catalogue any damage may be the only practical solution.

6.2 Transport networks

AES have reviewed the following documentation with regard to any identified mitigation to reduce the effects of vibration from road and rail:

- The NZTA's document titled *State highway environmental plan: improving environmental sustainability and public health in New Zealand* published in June 2008;
- The NZTA's document titled *State highway construction and maintenance noise and vibration guide*, published August 2013;
- The NZTA's document titled *Guide to the management of effects on noise sensitive land use near to the state highway network*, published September 2015;
- KiwiRail reverse sensitivity provisions. As far as AES are aware, these are not publicly available; however, we have received these based on involvement with various resource consents.

For vibration caused by road or rail sufficient distance between the source and sensitive receivers is often the only practical control measure. Ongoing maintenance of the road surface or railway tracks is also important to ensure that poor maintenance does not give rise to excessive vibration.

Vibration limits are provided in the majority of the documents reviewed (such as table 2.3 and table 2.4 of the NZTA's *State highway construction and maintenance noise and vibration guide*); however, mitigation measures to meet these limits are not discussed in any detail. Generally, the preferred option to reduce the effects of vibration from any source is to locate the receiver as far away from the source as possible. This is illustrated in the NZTA's document *Guide to the management of effects on noise sensitive land use near to the state highway network*, which outlines a 'buffer area' where no sensitive activities can be constructed.

We understand that Council's Transportation Consultants (Abley Transportation Consultants Ltd), consider that a setback from arterial roads and those anticipated to carry significant heavy traffic flow is critical.

The KiwiRail reverse sensitivity guidelines state that new, relocated or altered noise sensitive buildings within 60 metres of the rail corridor must achieve the Class C criterion (0.3 mm/s) in

NS 8176.E:2005 *Vibration and shock - Measurement of vibration in buildings from landbased transport and guidance to evaluation of effects on human beings*.

The guidelines also state that all buildings within 20 metres of the rail corridor should be designed and constructed to ensure that vibration from trains shall not exceed the criteria in British Standard BS 7385-2 (a building damage standard).

We understand that the approach adopted by KiwiRail is for buildings which will be within 60 metres of a rail corridor, vibration measurements should be conducted at the site to determine whether additional measures are required in the building design to reduce vibration to achieve these criteria. As is illustrated in the case studies above, such an approach ignores the practicality of conducting detailed predictive analysis and design relating to the likely vibration response of a specific building and foundation design.

7.0 VIBRATION MANAGEMENT IN OTHER DISTRICT PLANS

AES has reviewed the Christchurch, Ashburton, Waimakariri and Hurunui Operative District Plans as requested. These four Districts are adjacent to the Selwyn District and provide an indication of vibration limits and controls which are typical in the Canterbury area.

Our review indicates that there is not a consistent approach to vibration control applied in these Districts. The only item that is relatively consistent is specific vibration limits for construction associated with major roading projects (in Christchurch, Ashburton and Waimakariri). Specific limits are typically outlined in the designation for these activities.

Other particular areas where specific vibration limits or standards are referenced are for blasting (Christchurch, Hurunui), earthworks (Christchurch) and earthquake rebuilding (Waimakariri).

The specific items identified in each District are described below.

7.1 Christchurch District Plan

- The policies in Chapter 8 *Subdivision, development, and earthworks* outline that earthworks could have an adverse effect resulting from vibration which should be avoided or mitigated. Vibration associated with earthworks including soil compaction is required to comply with DIN 4150:1999 to be considered a permitted activity.

- There are multiple designations outlined in Chapter 10 *Designations and Heritage Orders* which state vibration limits. These include:

    - State Highway 76, Southern Motorway Extension Stage 2. Construction vibration is required to be measured in accordance with DIN 4150.3:1999 *Effects of vibration on structures*, with the vibration limits outlined in table 7.4 below as described in DC.20 of Part P *New Zealand Transport Agency*.

Table 7.1 – Vibration limits for the Southern Motorway Extension Stage 2

Receiver	Details	Category A	Category B
Occupied dwelling	Night-time 2000h – 0630h	0.3 mm/s PPV	1 mm/s PPV
	Daytime 0630h – 2000h	1 mm/s PPV	5 mm/s PPV
Other occupied buildings*	Daytime 0630h – 2000h	2 mm/s PPV	5 mm/s PPV
All other buildings	Vibration – transient	5 mm/s PPV	BS 5228-2*1, Table B.2
	Vibration – continuous		BS 5228-2*1, 50% of Table B.2
* 'Other occupied buildings' is intended to include daytime workplaces such as offices, community centres etc., and not industrial buildings. Schools, hospitals, rest homes etc. would fall under the occupied dwellings category.			

    - For work associated with upgrades at Wigram Road / Magdala Place, a CNVMP is required before any construction activity starts. This includes vibration criteria set out in Part C9, of Chapter 10, that are required to be measured in accordance with ISO 4866:2010 and AS2187-2:2006. The vibration limits are reproduced in table 7.2 below:

Table 7.2 – Vibration limits for the Wigram Road / Magdala Place road upgrades

Receiver	Details	Category A	Category B	Location
Occupied dwellings	Daytime: 6:00am to 8:00pm	1.0 mm/s PPV	5.0 mm/s PPV	Inside the building
	Night time 8:00pm to 6:00am	0.3 mm/s PPV	1.0 mm/s PPV	
Other occupied buildings	Daytime: 6:00am to 8:00pm	2.0 mm/s PPV	10.0 mm/s PPV	
All buildings	Transient vibration	5.0 mm/s PPV	BS 5228.2 – Table B2 values	Building foundation
	Continuous vibration		BS 5228.2 – 50 percent Table B2 values	

Note: Tabulated Values are in terms of peak component particle velocity

- Chapter 13 *Specific Purpose Zones* outlines that vibration from port quarrying is not to cause significant adverse effects. This includes a vibration limit of 5 mm/s for blasting but none for typical quarrying or construction activity.

- The Christchurch District Plan expects that vibration caused by vehicles accessing sites may result in adverse environmental effects, reducing the amenity of adjacent residential units. This is outlined in Chapter 14 *Residential*, Chapter 17 *Rural,* and Chapter 18 *Open Space*.

7.2 Ashburton District Plan

- Vibration is discussed in the planning policy chapters of the Ashburton District Plan.

- Vibration is identified as a potential adverse effect from various activities in Chapters *3 Rural Zones, 4 Residential Zones, 5 Business Zones, 7 Aquatic Park Chapter, 8 Scheduled Activities, 9 Subdivision, and 10 Transport.* It is noted that vibration can decrease amenity of adjacent properties; however, no assessment criteria (vibration limits) are provided.

- Chapter 11 *Noise* specifically states that the rail corridor needs protecting against reverse sensitivity issues from adjacent activities to ensure that the rail corridor can have unrestricted operation. However, there are no rules in the Ashburton District Plan regarding setbacks for vibration mitigation for the rail corridor.

- Specific vibration limits are provided relating to the construction of the Ashburton Second Bridge – Designation 208 (Chapter 14, Section 13). The construction vibration criteria for Designation 208 are outlined in table 7.3 below.

Table 7.3 – General construction vibration criteria for Ashburton Section Bridge, Designation 208

Receiver	Details	Category A	Category B	Location
Occupied dwellings	Daytime: 6.00am to 8:00pm	1.0 mm/s PPV	5.0 mm/s PPV	Inside the building
	Night time 8:00pm to 6.00am	0.3 mm/s PPV	1.0 mm/s PPV	
Other occupied buildings	Daytime: 6.00am to 8:00pm	2.0 mm/s PPV	10.0 mm/s PPV	
All buildings	Transient vibration	5.0 mm/s PPV	BS 5228.2 – Table B2 values	Building foundation
	Continuous vibration		BS 5228.2 – 50 percent Table B2 values	
Underground services	Transient vibration	20mm/s PPV	30 mm/s PPV	On pipework
	Continuous vibration	10mm/s PPV	15 mm/s PPV	

- Designation 208 (construction of Ashburton Second Bridge) also requires that an Outline Plan is submitted to the Council prior to construction which includes discussion on how to avoid, remedy, or mitigate the adverse effects arising from construction noise and vibration.

- Structural damage criteria are also provided for Designation 208 based on German Standard DIN 4150.3:1999. Section 14, Part 13 outlines the vibration criteria in part ix., and is reproduced in table 7.4 below.

Table 7.4 – Damage construction criteria for Ashburton Section Bridge Designation 208

Type of Structure	Vibration Threshold for Structural Damage, PPV (mm/s)				
	Short-Term				Long-Term
	At Foundation			Uppermost Floor	Uppermost Floor
	0 to 10 Hz	10 to 50 Hz	50 to 100 Hz	All Frequencies	All Frequencies
Commercial / Industrial	20	20 to 40	40 to 50	40	10
Residential	5	5 to 15	15 to 20	15	5
Sensitive/Historic	.	3 to 8	8 to 10	8	2.5

Note: When a range of velocities is given, the limit increases linearly over the frequency range

7.3 Waimakariri District Plan

- Vibration effects from Earthquake Recovery and Rebuilding activities are discussed in Chapter 12 *Health, Safety, and Wellbeing* and Chapter 23 *Land and Water Margin Rule.* These Chapters require that vibration from the earthquake rebuilding process is controlled to levels that will "*not create nuisance, damage structures, or adversely affect amenity values or the health and safety of people"* on adjacent sites. Chapter 31 *Health, Safety, and Wellbeing Rules* Section 31.12 *Noise* requires that vibration caused by Earthquake Rebuilding in Residential or Business Zones (Section 31.12.1.11 and 31.12.1.12) meets the vibration limits outlined in DIN 4150-3:1999 *Structural Vibration*.

- Chapter 35 *Designation – Rules* outlines vibration limits for the construction on the Notice of Requirement (NoR) for the Woodend Corridor, an eastern bypass of Woodend Township. Before construction works start a Construction, Environmental, and Social Management Plan is required to be submitted to the District Council. This Plan contains a Construction Noise and Vibration Management Plan (CNVMP). The vibration limits given in point 15 of Chapter 35, Appendix 35.7, requires vibration to be measured in accordance with ISO 4866:2010 *Mechanical vibration and shock – Vibration of structures – Guidelines for the measurement of vibrations and evaluation of their effects on structures*. These limits are reproduced in table 7.5 below.

Table 7.5 – Vibration limits for the NoR for the Woodend Corridor construction

Receiver	Details	Category A	Category B
Occupied dwelling	Night-time 2000h – 0630h	0.3 mm/s PPV	1 mm/s PPV
	Daytime 0630h – 2000h	1 mm/s PPV	5 mm/s PPV
Other occupied buildings	Daytime 0630h – 2000h	2 mm/s PPV	5 mm/s PPV
All other buildings	Vibration – transient	5 mm/s PPV	BS 5228-2[*1], Table B.2
	Vibration – continuous		BS 5228-2[*1], 50% of Table B.2

7.4 Hurunui District Plan

- Policy 10.9 in Chapter *Protection and Enhancement of Environmental Policy* explains that vibration can cause significant health effects so it is important to the amenity of the occupants of the District. This policy also explains controls are required for blasting near buildings and structures to ensure that structural damage is not caused as outlined in NZS 4403:1976 *Code of practice for the storage, handling and use of explosives (Explosives Code)*.

- Vibration limits for blasting are provided in Section A1 *Environmental Amenity*. A maximum vibration limit of 5 mm/s Peak Particle Velocity (PPV) is required to be met. However it also states that *"This level may be exceeded on up to 5 % of the total number of blasts over a period of 12 months. This level should not exceed 10 mm/s at any time."*.

- Issue 12 – *Amberley*, Policy 21.6 recognises that there is the potential of reverse sensitivity effects arising from the proximity of State Highway 1 / Carters Road to the adjoining residential properties. Vibration associated with the traffic on this road is proposed to be mitigated through the use of setbacks (primarily for noise).

- The Hurunui District Plan provides a chapter on the procedures on a Resource Consent (Section C1). Part C1.2.4 (d) *transportation* requires adverse effects to be considered where vehicles enter or leave a site to determine whether these are incompatible with the surrounding area. Section C1 provides a list of potential environmental effects which should be considered during a Resource Consent application (Table C1.3 – *Schedule of potential environmental effects*). Control measures identified which would be relevant for vibration are as follows; separation distances, limitation of hours of operation, number of people, number and types of vehicles, arrangement of activities on site and imposition of vibration and blasting limits.

7.5 Summary

DIN 4150-3:1999 *Structural Vibration* has been adopted as a relevant guideline in the Christchurch Plan for vibration from earthworks, and in Waimakariri for vibration associated with earthquake rebuilding. The NZTA vibration limits adopted for major roading projects in Christchurch, Ashburton and Waimakariri are also derived from DIN 4150-3:1999 (along with

BS5228-2 2009). This standard can therefore be considered as relevant guidance which is commonly used in Canterbury.

Both the Christchurch and Hurunui Plans show some similarity for blasting vibration limits. In Christchurch there is a 5 mm/s limit for vibration for blasting at the port. In Hurunui there is also a 5 mm/s limit for blasting although this may be exceeded on up to 5% of blasts over 12 months. Consideration of whether a specific blasting control is required in the Selwyn District, and if the 5 mm/s limit is appropriate may be relevant.

8.0 RECOMMENDATIONS

Selwyn District Council has requested recommendations for an approach to vibration management, including the necessity of provisions relating to State Highway roading construction and operation, electricity transmission construction, temporary military activities, blasting, quarrying and building construction.

As the above review demonstrates, there are no current New Zealand Standards which provide suitable guidance on management of these sources. If the Selwyn District Council determines that specific vibration limits for these activities are desired, then the standards which are most commonly used in New Zealand for vibration assessments of these sources are as follows:

For State Highway and building construction:

- British Standard BS 5228 - 2:2009, *Code of practice for noise and vibration control on construction and open sites – Part 2 Vibration* (amenity)

- German Standard DIN 4150-3:1999 *Structural vibration Part 3: Effects of vibration on structures* (building damage)

For State Highway operation:

- Norwegian Standard NS 8176.E:2005 *Vibration and shock - Measurement of vibration in buildings from landbased transport and guidance to evaluation of effects on human beings*.

For electricity transmission construction:

- German Standard DIN 4150-3:1999 *Structural vibration Part 3: Effects of vibration on structures* (building damage)

For blasting:

- British Standard BS 6472-2:2008 *Guide to evaluation of human exposure to vibration in buildings – Part 2: Blast-induced vibration.*

For quarrying:

- British Standard BS 5228 - 2:2009, *Code of practice for noise and vibration control on construction and open sites – Part 2 Vibration* (amenity)

For temporary military activities, we consider that with typical setbacks imposed, blast induced vibration is most likely to be the relevant effect. British Standard BS 6472-2:2008 *Guide to evaluation of human exposure to vibration in buildings – Part 2: Blast-induced vibration* could therefore be used to provide some relevant guidance.

We consider these standards to provide relevant guidance on acceptable limits for these vibration sources.

However, issues we have encountered when applying the provisions in these standards are:

- Determining whether a proposed development is likely to comply with the vibration standards is difficult. Predicting the transmission of vibration through the ground and into a structure, and then the behaviour of the structure, is the main issue. In the context of a typical Resource Consent process, this is not a process which is practicable due to complexity, cost and the typical state of development of the design of any project at Resource Consent stage. Determining whether compliance with these standards will be achieved is typically therefore based on a combination of empirical data and site measurements, which may not be accurate.

- If predictive analysis indicates that compliance may not be achieved, the mitigation options available are often rudimentary and limited – for example: increase setback distances or do not undertake the activity.

- If measurements after an activity is established indicate that compliance is not being achieved, options for remedial measures are similarly limited.

We also note that in the majority of cases, where the noise effects of a particular source are managed to an acceptable level, the vibration effects will also inherently be managed.

With this in mind, we note that for the operation of state highways (and busy arterial roads), an appropriate setback will be critical to control vibration effects and may be a more practical control than a specific vibration limit.

Overall, we consider that the current policies and rules in the District Plan relating to vibration can be improved, however it is unlikely that the introduction of wide-ranging vibration limits will be considered to be appropriate, on balance. Specific limits may be appropriate for certain activities – such as construction (building damage) and blasting.