Waikato Expressway: Hamilton Section
Ruakura Interchange
Assessment of Vibration Effects

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Waikato Expressway: Hamilton Section

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Assessment of Vibration Effects

Peter Cenek
Executive Summary

The New Zealand Transport Agency (the Transport Agency) proposes to alter the existing designation for the Hamilton Section of the Waikato Expressway (Hamilton Section) and obtain resource consents (if required) from Waikato Regional Council (WRC) in order to construct, operate and maintain the Ruakura Interchange and connecting roads.

A desk study therefore was undertaken to examine vibration effects arising from the construction and operation of the Ruakura Interchange and associated connecting roads. The desk study combined previously measured vibration source levels during road construction activity and traffic operating on state highways and local roads with soil attenuation coefficients derived from scalpenetrometer readings made along the route of the Hamilton Section of the Waikato Expressway between Percival Road and Morrinsville Road (i.e. SH26). These two roads are on either side of the Ruakura Interchange.


The principal conclusions arising from this assessment of ground vibrations generated by the construction and operation of the Ruakura Interchange are as follows:

1. Vibration levels generated by construction are likely to be higher than those from operation but would be temporary and of a limited duration.

2. There is the potential for adverse effects from construction but these can be appropriately mitigated through a Construction Vibration Management Plan as the mitigation measures relate to selection of equipment and processes, the location and operation of the equipment and the sequencing of operations. Therefore, it is recommended that the requiring authority shall implement a Construction Vibration Management Plan for the duration of the construction period of the Project as this will be sufficient to mitigate the identified vibration effects of the designation to a minor level or less.

3. Any construction activity associated with local road connections, specifically Ruakura Road, Ryburn Road, Vaile Road, Silverdale Road and SH26 (Morrinsville Road) must be addressed by the Construction Vibration Management Plan, given the potential for structural damage because of the closeness of the designation boundary to residential and educational buildings bordering these roads.

4. Areas of peaty soil have the potential to generate problematic vibrations during construction of the Ruakura Interchange and once it is operational. Therefore, there is a need for these areas to be identified so that appropriate measures can be put in place to limit the disturbance of occupants of nearby buildings.

5. There is the potential for cumulative effects at dwellings in Ryburn Road. Therefore, care will need to be taken in scheduling construction activities in the vicinity of Ryburn Road that generate large ground vibrations, such as piling and compaction, to ensure they do not occur concurrently at the Ruakura Interchange project, the Ruakura PPC development (inland port and logistics hub) and the Waikato Expressway, Hamilton Section project.
6. All existing residential properties are sited 8 m or more away from the closest trafficked lane. This is considered a sufficient separation distance to ensure building occupants will not be disturbed by ground vibrations resulting from the operation of the Ruakura Interchange. Therefore, no specific mitigation of traffic-induced vibrations is considered necessary.
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1 Introduction

The New Zealand Transport Agency (the Transport Agency) proposes to alter the existing designation for the Hamilton Section of the Waikato Expressway and obtain resource consents from Waikato Regional Council (WRC) in order to construct, operate and maintain the Ruakura Interchange and connecting roads.

This report presents the findings of a desk study undertaken to examine vibration effects arising from the construction and operation of the Ruakura Interchange and associated connecting roads. The desk study combined previously measured vibration source levels during road construction activity and traffic operating on state highways and local roads with soil attenuation coefficients derived from scala penetrometer readings made along the route of the Hamilton Section of the Waikato Expressway between Percival Road and Morrinsville Road (i.e. SH26). These two roads are on either side of the Ruakura Interchange.

The expected vibration levels were calculated in terms of ground vibration velocities and compared with guideline values specified in current international standards and also Appendix I of the Waikato District Council’s (WDC) operative District Plan and Chapter 25 of the Hamilton City Council’s (HCC) proposed District Plan. This comparison highlighted the need or otherwise for conditions to ensure reasonable ground vibrations.

The procedure adopted for assessing vibration effects is identical to that used for the Hamilton Section of the Waikato Expressway, which was endorsed by Christian Vossart of Styles Group, who was engaged by the two local authorities, Waikato District Council and Hamilton City Council to provide independent specialist noise and vibration advice.

The report has been structured as follows:

- Section 2 describes the project and its background.
- Section 3 details the criteria by which the measured vibrations were evaluated from the perspectives of human comfort and cosmetic building damage.
- Section 4 provides the relationships used for deriving soil attenuation coefficients and for scaling measured vibration levels to a specified receiver distance.
- Section 5 summarises the key results from the measurement programme, in particular the critical separation distances required to ensure no disturbance of building occupants and no structural damage.
- Section 6 provides suggested conditions for managing vibrations generated during the construction and operation of the Project.
- Section 7 summarises the main conclusions resulting from the assessment.
2 Project Description

2.1 Background

2.1.1 Roads of National Significance

In May 2009, the Government Policy Statement on Land Transport Funding (GPS) was released, which identified seven Roads of National Significance (RoNS), which are considered by the Government to be New Zealand’s most important transport routes requiring significant development to reduce congestion, improve safety and support economic growth. The Waikato Expressway is one of the seven RoNS.

The purpose of listing particular roads as nationally significant was to ensure these priority roading projects are fully taken into account in the development of the National Land Transport Programme. The Government expects that planning for the future development of the land transport network should reflect the importance of these roads from a national perspective and the need to advance them quickly.

2.1.2 Waikato Expressway

The Expressway will extend from the Bombay Hills in the north to just south of Cambridge. The Expressway has been divided into 12 sections. It is expected the Expressway will:

- Improve economic growth and productivity for Auckland, Waikato and Bay of Plenty through more efficient movement of people and freight between Auckland, Hamilton, Tauranga and Rotorua;
- Improve the reliability of the transport network by providing a more robust and safer road network between Auckland, Hamilton, Tauranga and Rotorua;
- Reduce travel times between Waikato and Auckland; and
- Support the growth strategy for the central Waikato.

2.1.3 Hamilton Section

The Hamilton Section is located on the eastern side of the city of Hamilton. The Hamilton Section adjoins the recently completed Ngaruawahia Section to the north, and the existing Tamahere Interchange to the south. It is approximately 22km in length. Figure 2-1 shows the scope of the Hamilton Section.

2.2 Context

2.2.1 Current Designation and Resource Consents

The Hamilton Section was first designated in 2005, following an appeal before the Environment Court in 2004. In October 2013, the Transport Agency lodged Notices of Requirement (NORs) to alter the designation in a number of discrete locations. Applications for resource consent to construct, operate and maintain the Hamilton Section were lodged at the same time. The NORs and resource consent applications were heard by independent commissioners in April and May 2014.
The commissioners’ decision was notified on 1 July 2014 with respect to the resource consents. The decision is that the consents sought are granted subject to conditions. A recommendation from the commissioners was released on 30 June 2014 with respect to the notices of requirement, in accordance with s171 RMA 1991. The recommendation is that the notices of requirement be granted subject to a set of recommended conditions.

Figure 2-1 Waikato Expressway Hamilton Section
2.2.2 Ruakura Structure Plan (RSP)

Boundary changes between Hamilton City Council (HCC) and Waikato District Council (WDC) have meant that a significant area of land at Ruakura is now within the jurisdiction of HCC. The development of this land is identified in a number of high level documents including: the Hamilton Urban Growth Strategy, the Access Hamilton Transport Strategy and the Waikato Proposed Regional Policy Statement.

To enable the progressive development of this area, the Ruakura Structure Plan (RSP) was developed and notified as part of the Hamilton City Proposed District Plan (PDP) in December 2012. The RSP (as notified) includes an inland port, freight and logistics hub and other industrial land. The inland port as proposed in the RSP has an intermodal facility so that freight can be transferred to and from road and rail. The RSP also provides for research and innovation activities, and residential areas for an eventual population of approximately 1,800 households, including the development of a neighbourhood centre.

Submissions and further submissions have been received on the RSP, however hearings and a decision have been deferred, pending the outcome the Ruakura Private Plan Change (PPC).

2.2.3 Ruakura Private Plan Change (PPC)

Tainui Group Holdings Limited (TGH) is the predominant landowner affected by the RSP. It was identified that rules in the Hamilton District Plan: Waikato Section (as transferred over from the WDC’s District Plan) prohibit any application being made for urban development within this area. Given that the WDC rules are currently operative, they continue to apply until the PDP (including the RSP) is made operative. Given the potential for lengthy delays, TGH have sought a PPC for what is known as the Ruakura Development, through the Environmental Protection Authority (EPA). The PPC affects some, but not all, of the land subject to the RSP.

The PPC does not re-zone any land, rather it proposes to adopt mechanisms providing an overlying ‘schedule’. This allows a range of activities to be undertaken in identified areas, as well as existing rural activities.

The key aspects of the PPC are as follows:

- A new ‘Schedule 25H Ruakura’ inserted into Chapter 25: Rural of the PDP, which provides a Ruakura Logistics Area (incorporating the Inland Port), Ruakura Industrial Park Area, Knowledge Area, Residential Areas and Open Space Areas along with indicative roads (refer to Figure 1-2 below).
- Amendments to the Prohibited Activity rules to enable the planning and development of the land covered by Schedule 25H, including the future roading network.

On 31 July 2013, a ministerial direction was released, referring the PPC request to a Board of Inquiry (BOI) which was held over a number of weeks during May/June 2014. On 5 August 2014, the BOI issued its draft decision approving the PPC, subject to a number of amendments to the proposed objectives, policies and rules, as they would apply to the Ruakura Development. Comments on the draft decision close during the week commencing 1 September 2014, and a final decision is due on 11 September 2014.

The PPC will enable development to occur in the interim, but it is intended that the PPC will also be incorporated into the framework of the PDP, once the PPC has been confirmed. According to the
RSP contained within the notified PDP is likely to be superseded by the Board’s decision on the PPC.

2.3 Proposal

2.3.1 NOR – Alteration to Designation

The Transport Agency is now proposing to alter the designations for the Hamilton Section to include an interchange at Ruakura, and encompass associated connecting roads (being the diverted and existing Ruakura Road). The scope of the designation sought is shown in Figure 2-2 below.
Figure 2-2   Ruakura Schedule Area
Figure 2-3 shows the alteration to the designation that is proposed.

The altered designation includes the following:

» Widening of the existing Expressway designation to accommodate the Ruakura Interchange ramps, connecting roundabouts, and stormwater wetland;

» Closure of the existing Ruakura Road either side of the Expressway and consequently shortening of the proposed bridge over the East Coast Main Trunk (ECMT) rail line;

» Retention of the existing Ruakura Road either side of the closure at the Expressway in order to provide continued property access to residents on Ruakura Road, including access to Percival and Ryburn Roads as currently provided;

» Relocation of Ruakura Road between the Ruakura Road/Silverdale Road intersection and the existing Ruakura Road near the Vaile Road intersection to connect with the proposed Ruakura Interchange, including:
  • Existing Ruakura Road/Silverdale Road intersection closed, with Silverdale Road terminating in a cul-de-sac (road retained for access) and creation of a new signalised relocated Ruakura Road/Silverdale Road intersection that will also provide a key access point to the Ruakura Development Logistics Area;
  • New relocated Ruakura Road/Existing Ruakura Road (west) priority controlled tee intersection;
  • A signalised intersection along the relocated Ruakura Road to provide a second key access point to the Ruakura Development Logistics Area;
• Provision of a tee intersection where the relocated Ruakura Road meets the existing Ruakura Road (east);
• Upgrading the existing Ruakura Road, largely within its existing boundaries, between the new intersection with the relocated Ruakura Road (east) and the Ruakura Road/SH26 intersection (this will include shape correction of the roadway, carriageway widening, provision of a footpath and drainage improvements);
• Extension of the designation to cover the existing Ruakura Road (from the intersection with the relocated Ruakura Road up to SH 26) so upgrading works can be undertaken;
• Provision for the relocated Ruakura Road to pass either over or under the Expressway; and
• Provision for stormwater attenuation and disposal from the relocated Ruakura Road and Ruakura Interchange.

Detailed designation plans are provided as Appendix C to the NOR.

Subject to the Ruakura Interchange proceeding, the proposed north facing ramps where the Expressway passes under SH26 would not be required. Accordingly, a condition is proposed that would result in the north facing ramps being removed from the Waikato Expressway, once the Ruakura Interchange is under construction.

The relocated Ruakura Rd west of the Expressway will become a local road, whereas the link formed by the relocated and existing Ruakura Roads east of the Expressway as far as State Highway 26 will become state highway.

2.3.2 Resource Consents

The Transport Agency is also seeking additional resource consents from the WRC to construct, operate and maintain the connecting roads (being the relocated and existing Ruakura Road). The interchange ramps and associated earthworks are covered by the existing consents granted 1 July 2014. Water and discharge permit applications will be lodged with the WRC shortly.

2.3.3 Existing Environment

The Resource Management Act 1991 (RMA) requires an assessment of the actual and potential effects on the environment of allowing the activity (s104(1)(a)). This report forms part of that assessment. Consideration therefore needs to be given to what defines the existing environment, as this is what the effects of the proposal will be assessed against.

2.3.3.1 Waikato Expressway

The Hamilton Section of the Waikato Expressway designations pass to the east of Hamilton City in a generally north-south direction and enable the construction of a four-lane Expressway and associated on/off ramps to connect with the local road network (excluding the Ruakura Interchange). The development of the Expressway is also supported by a number of consents granted by the WRC. For the purpose of assessing this NOR, the Expressway as currently designated is considered part of the existing environment.

2.3.3.2 West of the Expressway

The land immediately to the west of the Expressway is currently zoned Rural in the Hamilton District Plan: Waikato Section. This area adjoining the Expressway is in pasture, with scattered dwellings
and farm buildings. The Waikato University is located to the west of Silverdale Road, and is surrounded by residential development. There is also residential development to the east of Silverdale Road, which juts out towards the Expressway and is bounded by a gully (Nevada Road). North of Ruakura Road is an area of land zoned Country Living, which contains a cluster of approximately 30 rural residential dwellings.

The environment immediately to the west of the Expressway is subject to a PPC, which a BOI has approved in its draft decision. Consideration of this NOR by the territorial authority should be in the context of the future development enabled by the PPC. The need for the Ruakura Interchange is a direct result of development occurring in this area in accordance with the PPC. Without the PPC proceeding, the Agency would revert back to the approved north facing ramps at SH26, unless an alternative justification was provided for establishing an interchange at Ruakura.

It is reasonable to assume that the existing environment for the purpose of assessing the effects of this NOR will consist of the land use activities indicated in Figure 1-2 of this report, and supported by the BOI decision. The BOI has already heard evidence in relation to the associated effects of these land use activities and their ruling on the PPC has taken such effects into consideration. It is for this reason that for the purposes of the overall effects assessment the PPC has been adopted as the existing environment.

2.3.3.3 East of the Expressway

The land to the east of the Expressway is zoned Rural in the Waikato District Plan (WDP). The portion of land between the ECMT and Davison Road is characterised by large open paddocks and scattered buildings, including some dwellings. From Davison Road south, there is significantly more rural-residential development. The Dairy NZ/LIC site is located on the corner of Ruakura Road and SH26. Ruakura Road itself is identified as an Arterial Road in the WDP. The function of Arterial Roads is described in the WDP as roads that:

- Form a strategic network of regional importance
- Provide for the collection and distribution of goods significant to the regional economy
- Rural roads that typically provide for more than 2,500 vehicle movements per day
- Include rest areas; and
- The through traffic function predominates.
3 Assessment Criteria

3.1 Background

While district plan vibration related rules do not directly apply to the designation, they provide guidance as to the community's expectations of what is reasonable vibration and so can be useful in framing acceptable conditions on the designation.

With respect to human perception levels for ground vibration, the following general guidance is provided in Appendix I of the Waikato District Council's Operative District Plan (WDCODP):

- Vibration level less than 0.5mm/s – imperceptible (threshold of perception)
- Vibration level of 0.5mm/s to 2.0mm/s – slightly perceptible (barely noticeable)
- Vibration level greater than 2.0 mm/s – distinctly perceptible (noticeable)

Vibration levels in excess of 5.0mm/s have the potential to compromise amenity values.

The vibration conditions in Appendix I of WDCODP relate to blasting, which will not be employed on the Ruakura Interchange project.

Chapter 25 of the Hamilton City Councils (HCC) Proposed District Plan (Rule 25.8.3.3)\(^2\) contains the following construction vibration provision:

25.8.3.3 Construction Vibration

a) Construction vibration received by any building on any other site shall comply with the provisions of and be measured and assessed in accordance with German Standard DIN 4150‐3:1999 Structural vibration – Effects of vibration on structures.

Any standards based criteria used to evaluate the significance of the calculated maximum probable ground vibrations in the vicinity of the Project should ideally be consistent with the vibration related rules contained in the WDCODP and the HCC proposed District Plan.

Current standards considered appropriate in assessing the effects of vibration caused by the Project from the perspectives of human comfort and damage to buildings are discussed below. These standards state ground vibration in terms of peak particle velocity (PPV) with no requirement for frequency weightings, which simplifies their application to output from predictive models.

3.2 Human Comfort

3.2.1 Peak Vibration Levels

The British Standard, BS 5228.2, 2009, “Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration,” is a current standard that is commonly adopted in New Zealand to provide guidance on the response of humans to vibration levels. This is reproduced below as Table 3-1 for ready reference.

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\(^1\) [http://www.waikatodc.govt.nz/CMSFiles/54/546796c4-19b0-4fac-88b1-880f91755123.pdf](http://www.waikatodc.govt.nz/CMSFiles/54/546796c4-19b0-4fac-88b1-880f91755123.pdf)

Table 3-1: Guidance on effects of vibration levels (from British Standard BS 5228-2:2009, Annex B)

<table>
<thead>
<tr>
<th>Vibration level</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.14 mm/s</td>
<td>Vibration might be just perceptible in the most sensitive situation for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.</td>
</tr>
<tr>
<td>0.3 mm/s</td>
<td>Vibration might be just perceptible in residential environments.</td>
</tr>
<tr>
<td>1.0 mm/s</td>
<td>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.</td>
</tr>
<tr>
<td>10 mm/s</td>
<td>Vibration is likely to be intolerable for any more than a very brief exposure to this level.</td>
</tr>
</tbody>
</table>

The vibration levels in Table 3-1 are in terms of PPV, which is the vibration parameter routinely measured when assessing potential building damage.

Although BS 5228–2:2009 is concerned with construction related vibrations, it is valid to apply the guidance on effects of vibration levels given in this standard to traffic vibrations. This is because most vibration frequencies associated with construction and traffic are greater than 8 Hz eliminating any frequency dependency effects. As a result, there is complete agreement between the withdrawn New Zealand standard, NZS/ISO 2631 (1989): “Evaluation of Human Exposure to Whole Body Vibration, Part 2: Continuous and Shock Induced Vibration in Buildings (1 to 80 Hz),” which has been incorporated in a number of District Plans, and BS 5228–2:2009 for vibration levels that are just perceptible in the most sensitive of situations (0.14 mm/s PPV) and just perceptible in residential environments (0.3 mm/s PPV).

3.2.2 Exposure to Vibration

The Project is expected to maintain the maximum traffic-induced vibrations levels as at present if the speed limits and road maintenance practices remain as now. However, their frequency of occurrence will increase on Ruakura Road due to the projected increase in HGV traffic to between 500 and 700 HGV per day by 2041.

British Standard BS 6472–1:2008 “Guide to evaluation of human exposure to vibration in buildings – Part1: Vibration sources other than blasting” allows the impact of this increased exposure on building occupants to be determined.

BS 6472–1:2008 is not widely adopted in New Zealand, but is attractive for use in assessment of intermittent vibration effects due to its dose-response metric, Vibration Dose Value (VDV). VDV is defined in Equation 3-1.

\[
VDV = \left( \int_0^T a^4(t) dt \right)^{0.25}
\]

Equation 3-1

where: \( VDV \) = Vibration Dose Value \( (m/s^{-1.75}) \)

\( a(t) \) = frequency-weighted root-mean-square (r.m.s) acceleration \( (m/s^2) \)

\( T \) = total period of the day or night (in seconds) during which vibration can occur
The use of the fourth power method makes VDV more sensitive to peaks in the acceleration waveform. VDV accumulates the vibration energy received over the day-time and night-time periods. Acceptable values of vibration dose for intermittent vibrations are presented in Table 3-2.

**Table 3-2: Vibration Dose Value ranges which might result in various probabilities of adverse comment within residential buildings (reproduced from BS 6472-1:2008)**

<table>
<thead>
<tr>
<th>Place and time</th>
<th>Low probability of adverse comment ($m/s^{-1.75}$)</th>
<th>Adverse comment possible ($m/s^{-1.75}$)</th>
<th>Adverse comment probable ($m/s^{-1.75}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential buildings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 hr day</td>
<td>0.2 to 0.4</td>
<td>0.4 to 0.8</td>
<td>0.8 to 1.6</td>
</tr>
<tr>
<td>Residential buildings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 hr night</td>
<td>0.1 to 0.2</td>
<td>0.2 to 0.4</td>
<td>0.4 to 0.8</td>
</tr>
</tbody>
</table>

*NOTE: For offices and workshops, multiplying factors of 2 and 4 respectively should be applied to the above vibration dose value ranges for a 16 h day.*

BS 6472-1:2008 states that the VDV values in Table 3-2 represent the best judgement currently available and may be used for both vertical and horizontal vibration, provided that they are correctly weighted.

It will be noted that the VDV criteria have been presented as ranges rather than discrete values. This stems largely from the widely differing susceptibility to vibration evident among members of the population, and also from their differing expectation of the vibration. Therefore, some judgement has to be exercised when applying the VDV criteria.

With reference to Table 3-2 adverse comment is not expected for VDV values less than 0.2 ($m/s^{-1.75}$) during the day-time and 0.1 ($m/s^{-1.75}$) during the night-time. Conversely, adverse comment is extremely likely for VDV values above 1.6 ($m/s^{-1.75}$) during the day-time and 0.8 ($m/s^{-1.75}$) during the night-time.

### 3.3 Building Damage

The German Standard DIN 4150-3 (1999) “Structural vibration – Part 3: Effects of vibration on structures” provides guideline vibration levels which, “when complied with, will not result in damage that will have an adverse effect on the structure’s serviceability.” For residential buildings, the standard considers serviceability to have been reduced if:

- Cracks form in plastered surfaces of walls.
- Existing cracks in the building become enlarged.
- Partitions become detached from load bearing walls or floors.

These effects are deemed ‘minor damage’ in DIN 4150-3.

The DIN 4150-3 (1999) guideline values for evaluating short-term and long-term vibration on structures are given in Table 3-3 where short-term vibrations are defined as those that do not occur
often enough to cause structural fatigue and do not produce resonance\(^3\) in the structure being evaluated and long-term vibrations are all the other types of vibration.

With reference to Table 3-3, the German Standard DIN 4150-3 (1999) recognises commercial buildings can withstand higher vibration levels than residential and historic buildings. Also, the guideline values for short-term vibration increase as the vibration frequency increases.

**Table 3-3: Vibration guidelines from DIN 4150-3:1999 for assessing effects of vibrations on buildings**

<table>
<thead>
<tr>
<th>Type of Structure</th>
<th>Vibration Thresholds for Structural Damage, PPV (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At Foundation</td>
</tr>
<tr>
<td></td>
<td>0 to 10 Hz</td>
</tr>
<tr>
<td>Commercial/industrial</td>
<td>20</td>
</tr>
<tr>
<td>Residential</td>
<td>5</td>
</tr>
<tr>
<td>Sensitive/Historic</td>
<td>3</td>
</tr>
</tbody>
</table>

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

It should be noted that vibration related conditions placed by HCC on the Hamilton Eastern Arterial Project, colloquially known as the Hamilton Ring Road, are based on German Standard DIN 4150-3(1999). These conditions are reproduced below for ready reference:

“If vibration levels measured at the designation boundary in accordance with the vibration standard DIN 4150-3:1992-02 exceed 5 mm/s peak particle velocity, then vibration levels in selected ‘critical’ buildings shall be monitored, and pre-construction/post construction building condition surveys shall be undertaken in accordance with DIN 4150. ‘Critical’ buildings shall generally be dwellings and other vibration sensitive structures located within 20 m of the outer edges of the Hamilton Eastern Arterial carriageway. If any damage to such buildings or structures is detected, which is primarily attributable to excessive construction vibration levels, then such damage shall be repaired at the expense of the Requiring Authority.”

### 3.4 Vibration Guidelines Used by the Transport Agency

#### 3.4.1 Construction Related Vibrations

For recent Transport Agency roading projects, vibration criteria given in the State Highway Construction and Maintenance Noise and Vibration Guide (NZTA, 2013) have been used as a basis to manage construction related vibrations. These criteria are derived from BS 5228.2, 2009 and DIN 4150-3 (1999).

As an example, construction vibration criteria to be used on the Basin Bridge project in Wellington have been tabulated in Table 3-4.

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\(^3\) Resonance is the condition occurring when a vibrating system is subjected to a periodic force that has the same frequency as the natural vibrational frequency of the system. At resonance, the amplitude of vibration is a maximum.
Table 3-4: Construction Vibration Criteria for the Transport Agency’s Basin Bridge Project

<table>
<thead>
<tr>
<th>Receiver</th>
<th>Details</th>
<th>Category A</th>
<th>Category B</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupied dwellings</td>
<td>Daytime 6:00 am to 8:00 pm</td>
<td>1.0 mm/s PPV</td>
<td>5.0 mm/s PPV</td>
<td>Inside the building</td>
</tr>
<tr>
<td></td>
<td>Night time 8:00 pm to 6:00 am</td>
<td>0.3 mm/s PPV</td>
<td>1.0 mm/s PPV</td>
<td></td>
</tr>
<tr>
<td>Other occupied buildings</td>
<td>Daytime 6:00 am to 8:00 pm</td>
<td>2.0 mm/s PPV</td>
<td>10.0 mm/s PPV</td>
<td></td>
</tr>
<tr>
<td>All buildings</td>
<td>Transient vibration</td>
<td>5.0 mm/s PPV</td>
<td>BS 5228.2</td>
<td>Building foundation</td>
</tr>
<tr>
<td></td>
<td>Continuous vibration</td>
<td></td>
<td>Table B2 values</td>
<td></td>
</tr>
<tr>
<td>Underground Services</td>
<td>Transient vibration</td>
<td>20 mm/s PPV</td>
<td>30 mm/s PPV</td>
<td>On pipework</td>
</tr>
<tr>
<td></td>
<td>Continuous vibration</td>
<td>10 mm/s PPV</td>
<td>15 mm/s PPV</td>
<td></td>
</tr>
</tbody>
</table>

To assist with the reading of Table 3-4, table B2 from BS 5228.2 has been reproduced as Table 3-5.

Table 3-5 Transient vibration guide values for cosmetic damage after Table B2 from BS 5228-2:2009

<table>
<thead>
<tr>
<th>Type of Building</th>
<th>Peak component particle velocity in frequency range of predominant pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 Hz to 15 Hz</td>
</tr>
<tr>
<td>1. Reinforced or framed structures. Industrial and heavy</td>
<td>50 mm/s at 4 Hz and above</td>
</tr>
<tr>
<td>commercial buildings.</td>
<td></td>
</tr>
<tr>
<td>2. Unreinforced or light framed structures. Residential</td>
<td>15 mm/s at 4 Hz increasing to</td>
</tr>
<tr>
<td>or light commercial buildings.</td>
<td>20 mm/s at 15 Hz</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Values referred to are at the base of the building.

Note 2: For buildings under category 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) is not to be exceeded.

With reference to Table 3-4, if measured or predicted vibration levels exceed the Category A criteria then a suitably qualified expert shall be engaged to assess and manage construction vibration to comply with the Category A criteria. If the Category A criteria cannot be practically achieved, the Category B criteria shall be applied.

If measured or predicted vibration levels exceed the Category B criteria, then construction activity shall only proceed if there is continuous monitoring of vibration levels and effects on those buildings at risk of exceeding the Category B criteria by suitably qualified experts.

3.4.2 Operational Vibrations


The criterion for class C buildings is typically applied as it corresponds to the recommended limit value for vibration in new residential buildings and in connection with planning and building of new transport infrastructures. This criterion is in terms of statistical maximum value for weighted
velocity ($V_{w,95}$) and has a value of 0.3 mm/s. Weighted velocity is the root-mean-square value (r.m.s) of vibration velocity measured by using a frequency weighting filter corresponding to whole-body vibration in buildings, where the weighting is about 1 over the frequency range 1 to 80 Hz. The r.m.s integration time is 1 second and the statistical maximum is derived from the mean and standard deviation of a minimum of 15 single passes of a HGV at a measurement location.

For comparison with the BS 5228.2 guidance values, a $V_{w,95}$ value of 0.3 mm/s corresponds to a value of about 0.42 mm/s PPV.

NS 8176.E states that about 15% of the affected persons in class C dwellings can be expected to be disturbed by vibration.

### 3.5 Screening Criteria Applied to the Project

To identify where construction and operation of the Project may create significant adverse impact, the following criteria has been applied to the output of modelling used to provide estimates of ground-borne vibrations:

- 0.3 mm/s PPV for disturbance of building occupants
- 1 mm/s PPV for complaint by building occupants
- 2.5 mm/s PPV for damage to buildings arising from traffic (i.e. long term vibration)
- 3 mm/s PPV for damage to buildings arising from construction (i.e. short term vibration)

These criteria have been derived from BS 5228.2, 2009 and DIN 4150-3 (1999). The screening criteria pertaining to human perception have deliberately been made more stringent than the guideline values specified in the Waikato District Council’s Operative District Plan (refer Section 3.1) because they are being applied to modelled estimates of ground vibrations and not measured ground vibrations. This approach will yield slightly more conservative effects assessments, which is considered preferable.
4 Methodology for Estimating Vibrations

4.1 Background

The desk based methodology detailed in Transport Agency Research Report 485 “Ground vibration from road construction” (Cenek et al, 2012) was employed to obtain estimates of ground vibration magnitudes from construction activity and traffic along the Project. The advantage of this methodology is that it combines previously measured vibration source levels from road construction activity and traffic operating on state highways with scala penetrometer derived soil attenuation coefficients to allow the magnitude of ground vibrations to be estimated as a function of distance.

The key relationships are as follows.

1. The vibration level at distance from the source of interest is \( R_2 \) calculated from:

\[
V_2 = V_1 \left( \frac{R_1}{R_2} \right)^{0.5} e^{-\alpha(f)(R_2-R_1)} \quad \text{Equation 4-1}
\]

where:
- \( V_1 \) = the measured peak particle velocity (mm/s) at distance \( R_1 \) (m)
- \( V_2 \) = the peak particle velocity (mm/s) at distance \( R_2 \) (m) from source
- \( \alpha(f) \) = soil coefficient for the dominant frequency \( f \) (Hz)

2. The soil attenuation coefficient for a frequency of 5 Hz is calculated from the maximum scala penetrometer reading over the top 2 metres of soil using:

\[
\alpha(5Hz) = 0.0351e^{-0.236SCALA_{max}} \quad \text{Equation 4-2}
\]

where:
- \( \alpha(5Hz) \) = Soil attenuation coefficient (m\(^{-1}\)) for a frequency of 5Hz
- \( SCALA_{max} \) = Maximum scala reading (blows/50mm)

3. The soil coefficient for the dominant frequency \( f \) of the vibration source of interest is obtained by performing the following adjustment to \( \alpha(5Hz) \) calculated from Equation 4-2:

\[
\alpha(f) = \frac{\alpha(5Hz)}{5} \times f \quad \text{Equation 4-3}
\]

When retrospectively applied to measured ground vibrations, this methodology was shown to provide good estimates of how the vibration magnitude decays with distance. It can therefore be used with confidence to determine critical separation distances required for ground vibrations not to cause disturbance to building occupants or damage to buildings.

4.2 Source Vibration Levels

4.2.1 General Construction Activity

Table 4.1 in Transport Agency Research Report 485 “Ground vibration from road construction” (Cenek et al, 2012) summarises ground vibration data from construction sites throughout New
Zealand acquired for representative mechanised construction equipment operating on a range of soil types. The specific equipment monitored comprised three dozers, twelve rollers, one grader and one stabiliser. This table was used to identify the type of mechanical plant that would generate the highest magnitude vibrations when operating on soil types expected along the route of the Project.

For the Project, the source vibration representing construction activity, for use with Equation 4-1, was taken to be a Sumitomo SH120 Excavator, giving a vibration level of 5.4 mm/s PPV at a distance of 10 metres, with a frequency of 20 Hz. To put this source vibration level in context, it can be compared with ground vibrations generated by rollers, as rollers have a reputation for generating problematic vibrations.

With reference to roller vibration data presented in NZTA Research Report 485, there is only a 20% probability that a vibration level of 5.4 mm/s PPV at a distance of 10 m will be exceeded during compaction operations carried out by rollers. Therefore, use of this vibration level for general construction activity will provide an assessment of effects that will be on the conservative side.

4.2.2 Piling Operations

The relocated Ruakura Road will pass either over or under the Expressway. If piers are employed, piling may be required.

The two most likely methods of piling to be used are impact or recursive hammer, which works by dropping a large weight of several tonnes onto the end of the pile in order to drive the pile into the ground or vibratory hammer, which works by imparting a vertical vibration onto the pile through a system of counter-rotating eccentric weights, powered by hydraulic motors.

With reference to Transport Agency Research Report 485, the magnitude of ground-borne vibrations induced by vibratory hammers are typically a quarter to half those induced by impact hammers.

BS 5228:2:2009 provides an empirical equation, reproduced as Equation 4-4, for predicting the resultant PPV for vibratory piling operations that has a 5% probability of being exceeded.

\[
v_{res} = \frac{266}{x\delta}
\]

where:

- \(v_{res}\) = resultant PPV (mm/s)
- \(x\) = distance measured along the ground surface (m)
- \(\delta\) = 1.3 (all operations)

Upper-end estimates of ground vibrations generated from impact piling operations have therefore been calculated by multiplying \(v_{res}\) from Equation 4-4 by 2 i.e. \(2 \times v_{res}\) and 4 i.e. \(4 \times v_{res}\).

4.2.3 Traffic Induced Vibrations

Measurements of ground vibrations caused by vehicle traffic performed in the vicinity of the State Highway 29 realignment, Soldiers Road to Ngamuwahine Road, (Carpenter et al., 2011) were used to obtain an estimate of the magnitude of ground vibration representative of a truck travelling at the open speed limit on a road having the same expected characteristics as the Expressway.
The source vibration for use with equation 4.1 representing HCV traffic was 1.46 mm PPV at a distance of 5 metres, with a frequency of 13 Hz. This measurement was the maximum recorded for heavy commercial vehicles travelling at 90 km/h on a section of state highway with an average lane roughness value of 52 NAASRA counts/km. This roughness level is very close to NZ Transport Agency’s target roughness level of 50 NAASRA counts/km specified for new structural asphaltic concrete or other bituminous surfacings (TNZ, 2006), which are generally employed on RONS expressways.

By comparison, the probable maximum ground vibration at the road verge arising from traffic calculated using an approach developed for the US Federal Highway Administration (Rudder, 1978), is a value of 0.8 mm/s PPV at a distance of 2 metres from the edge of the road. This value of 0.8 mm/s PPV pertains to 54 tonne truck with conventional leaf spring/walking beam suspension travelling 90 km/h on a road surface with a roughness value of 100 NAASRA counts/km.

Therefore, the source traffic vibration level used for assessing the expressway can be considered conservative when compared to international guidance but representative of New Zealand conditions.

4.3 Scala Penetrometer Values

Data from Auger/Scala Penetrometer test reports contained in the Geotechnical Factual Report were applied to Equation 4-2 to obtain estimates of \( \alpha(5\text{Hz}) \) for the Ruakura Interchange.

The results are summarised in Table 4-1. For comparison purposes, values of \( \alpha(5\text{Hz}) \) and frequency independent soil property \( (\rho) \) for various soil types are provided in Table 4-2.

With reference to the column titled “Frequency Independent Soil Material Property” in Table 4-1, most of the values lie between \( 8 \times 10^{-4} \) and \( 1 \times 10^{-3} \), indicating from Table 4-2 that the soil along the route is made up of weak or soft soils. This means that for activities that transfer large amounts of energy to the ground, such as piling, large magnitude vibrations can be expected close to the source but they will attenuate quickly with distance.

<table>
<thead>
<tr>
<th>Location</th>
<th>Scala ID</th>
<th>Blows/50mm</th>
<th>Soil Attenuation, ( \alpha ), normalised for 5 Hz ((\text{m}^{-1}))</th>
<th>Frequency Independent Soil Material Property, ( \rho )(s/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percival Road – SH26</td>
<td>302</td>
<td>2.5</td>
<td>0.0194</td>
<td>1.24E-03</td>
</tr>
<tr>
<td></td>
<td>AST1</td>
<td>2.5</td>
<td>0.0194</td>
<td>1.24E-03</td>
</tr>
<tr>
<td></td>
<td>312</td>
<td>4.5</td>
<td>0.0121</td>
<td>7.73E-04</td>
</tr>
<tr>
<td></td>
<td>AST2</td>
<td>2</td>
<td>0.0218</td>
<td>1.39E-03</td>
</tr>
<tr>
<td>Average:</td>
<td></td>
<td></td>
<td><strong>0.0182</strong></td>
<td><strong>1.16E-03</strong></td>
</tr>
</tbody>
</table>
Table 4-2  Attenuation characteristics of various soil types (adapted from Amick, 1999)

<table>
<thead>
<tr>
<th>Class</th>
<th>Description of Soil</th>
<th>Attenuation Coefficient, $\alpha$, at 5 Hz (m$^{-1}$)</th>
<th>Frequency Independent Soil Property, $\rho$ (s/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Weak or soft soils (soil penetrated easily); loess soils, dry or partially saturated peat and muck, mud, loose beach sand and dune sand, recently ploughed ground, soft spongy forest or jungle floor, organic soils, topsoil</td>
<td>0.01 - 0.03</td>
<td>$6 \times 10^4 - 2 \times 10^3$</td>
</tr>
<tr>
<td>II</td>
<td>Competent soils (can dig with shovel): most sands, sandy clays, silty clays, gravel, silts, weathered rock</td>
<td>0.0003 - 0.01</td>
<td>$2 \times 10^4 - 6 \times 10^4$</td>
</tr>
<tr>
<td>III</td>
<td>Hard soils (cannot dig with shovel, must use pick to break up): dense compacted sand, dry consolidated clay, consolidated glacial till, some exposed rock</td>
<td>0.0003 - 0.003</td>
<td>$2 \times 10^5 - 2 \times 10^6$</td>
</tr>
<tr>
<td>IV</td>
<td>Hard, competent rock (difficult to break with a hammer): bedrock, freshly exposed hard rock</td>
<td>&lt; 0.0003</td>
<td>&lt; $2 \times 10^5$</td>
</tr>
</tbody>
</table>
5 Results

5.1 Critical Separation Distances

To assist the assessment, the separation distances required for (1) building occupants to perceive vibrations, (2) building occupants to complain about the vibration levels and (3) minor building damage to occur were calculated for various sections along the route for the three activities of interest, these being:

1. HCV traffic once the project is operational;
2. General road construction; and
3. Piling operations

The results of these calculations are given below.

5.1.1 General Construction and Operational Vibrations

The “Goal Seek” function in Microsoft Excel was used with Equation 4-1 to determine what distance from source would be required to achieve the assessment criteria values presented in section 3.5 using the source construction and traffic vibration values given in section 4.2 and the average attenuation coefficient tabulated in Table 4-1.

The results are summarised in Table 5-1.

Table 5-1 Critical separation distances for HCV traffic and general road construction

<table>
<thead>
<tr>
<th>Section along Waikato Expressway travelling north to south</th>
<th>Separation Distance from Vibration Source (m)</th>
<th>Operational</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Perception</td>
<td>Complaint</td>
<td>Damage</td>
</tr>
<tr>
<td>Percival Rd to SH26</td>
<td>22.5</td>
<td>8.0</td>
<td>2.2</td>
</tr>
</tbody>
</table>

It is clear from Table 5-1 that vibrations from construction have the potential to be more problematic than vibrations from traffic once the project is operational and so the construction plan will need to identify all buildings that are within 30 metres of the construction zones and cover appropriate control measures.

5.1.2 Piling Operations

Table 3-1 summarises separation distances estimated using Equation 4-4 for either impact or vibratory piling.

With reference to Table 5-2, a separation distance of at least 105 m will be required to ensure that no damage to nearby buildings will result from impact piling operations. This separation distance can be reduced to around 36 m if vibratory piling is employed.
Table 5.2  Critical separation distances for piling operations

<table>
<thead>
<tr>
<th>Piling Method</th>
<th>Separation Distance from Vibration Source (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Perception</td>
</tr>
<tr>
<td>Impact</td>
<td>316-538</td>
</tr>
<tr>
<td>Vibratory</td>
<td>185</td>
</tr>
</tbody>
</table>

5.2 Assessment of Vibration Effects

5.2.1 Existing Vibration Environment

No monitoring of existing traffic-induced vibrations in the vicinity of Ruakura Road has been carried out. However, Table 5-1 indicates that if a dwelling is located 22.5 m or further from the road, vibrations induced by passing HCV traffic are unlikely to be perceived by occupants. Furthermore, dwellings will need to be closer than 8 m from the road edge before traffic-induced vibrations will reach a level that will cause the occupants to complain.

As the existing residential buildings are sited more than 8 m away from the road edge, vibration conditions can be considered to be good at present, with occupants of buildings perceiving vibrations only as an exception. This exception will occur whenever a HCV encounters a localised irregularity in the road surface (e.g. pothole, uneven manhole cover etc.) at speed.

5.2.2 Construction Vibrations from the Project

5.2.2.1 General Construction

Occupied residences that are closest to the proposed Ruakura interchange travelling from west to east are as follows:

- 63 Ryburn Road (4.7 m from designation boundary and 39.6 m from road edge)
- 495 Ruakura Road (10.3 m from designation boundary and approximately 76 m from road edge)
- 3 Vaile Road (5.2 m from designation boundary and 11.2 m from road edge for Vaile Road frontage and 17.9 m from designation boundary and 23.7 m from road edge for Ruakura Road frontage)
- 588 Ruakura Road (16.1 m from designation and 22.4 m from road edge)
- 188a Morrinsville Road (SH26) (23.0 m from designation boundary and 27.4 m from road edge).
- 211 Morrinsville Rd (SH26) (15.8 m from designation boundary and 20.6 m from road edge)
- 212 Morrinsville Rd (SH26) (13.7 m from designation boundary and 17.8 m from road edge)
- 215 Morrinsville Rd (SH26) (15.9 m from designation boundary and 20.6 m from road edge)

Regarding significant commercial buildings, two are of interest. These are:
• The Facilities Management complex of The University of Waikato, which fronts onto Silverdale Road (13 m from the designation boundary and 17 m from road edge); and

• Waikato Institute of Leisure and Sport Studies, which is located near the intersection of Ruakura Road with Silverdale Road (11 m from designation boundary and 19 m from road edge).

With reference to Table 5-1, designation boundaries in all cases fall within either the complaint (27 m) or damage (16 m) separation distances for general road construction activity. Therefore, this brings a potential risk that if road construction takes place close to the designation boundary, building damage could result if control measures are not in place.

5.2.2.2 Piling

Regarding possible piling activity, the closest residential building is some 200 m away (310 Ruakura Road) and so although damage will be unlikely, there is the potential to annoy occupants leading to complaint if the resulting ground vibrations are not appropriately managed.

5.2.3 Operational Vibrations from the Project

5.2.3.1 Overview

Traffic induced vibrations once the Ruakura Interchange is operational is unlikely to be issue as in all cases the separation distance from the closest point of a dwelling to the road edge will be well in excess of the complaint threshold distance of 8 m. In fact, traffic induced vibrations are unlikely to be perceived at 495 Ruakura Road, 63 Ryburn Road and 188a Morrinsville Road.

5.2.3.2 Realigned Ruakura Road

By 2041, daily vehicle flows on the realigned Ruakura Road between SH26 and the interchange is projected to range between 4,300 and 6,600 vehicles of which heavy commercial traffic will comprise between 500 and 700 vehicles.

The majority of residential properties bordering the realigned Ruakura Road are located at least 20 m from the road edge, the closest being 22.4 m (no. 588). For the assumed source vibration level for HCV traffic of 1.46mm/s PPV at a distance of 5 metres, the maximum traffic-induced vibration level at a residential property is estimated to be 0.30 mm/s PPV. This estimate is based on the assumption that an open speed limit will apply and that the road roughness will be maintained to state highway standards.

With reference to guidance provided in British Standard BS 5228-2:2009, vibrations at a level of 0.30 mm/s PPV might be just perceptible in residential environments.

Also a value of 0.30 mm/s PPV corresponds to a weighted velocity (Vw,95) of about 0.21 mm/s and so is well below the criterion for class C buildings of 0.3 mm/s Vw,95 given in Annex B, table B.1 of Norwegian Standard NS 8176.E (2005). This criterion corresponds to the recommended limit value for vibration in new residential buildings and in connection with planning and building of new transport infrastructures.

The effect of an increase in the number of occurrences of traffic vibration events that result from the increase in heavy commercial traffic was also investigated using the vibration dose-response
metric defined in British Standard BS 6472-1:2008. This standard states that there is a low probability of adverse comment if the vibration dose value (VDV) over a 16 hour day period falls between 0.2 and 0.4 m/s$^{1.75}$. The VDV value calculated at the residence closest to Ruakura Road (number 588) is 0.13 m/s$^{1.75}$ for 500 HCV and 0.14 m/s$^{1.75}$ for 700 HCV. Therefore, increased traffic on the realigned Ruakura Road is unlikely to generate adverse comment from occupants of neighbouring residential buildings.

As a consequence, no specific mitigation of vibrations induced by heavy commercial vehicles using the realigned Ruakura Road is considered necessary.

5.2.4 Other Matters

5.2.4.1 Over and Under Interchange Options

From a vibrations perspective, there is no difference between the ‘over’ and ‘under’ interchange options as significant amount of earthworks is associated with either option. Therefore, irrespective of which option is chosen, construction activity will have to be appropriately managed through a construction vibration management plan (CVMP) to ensure mitigation of any vibrations that could be potentially damaging to nearby properties.

5.2.4.2 Peaty Soils

Some localised areas of peaty soils may be encountered during the construction of the interchange and local road connections. Water saturated peaty soils are vulnerable to consolidation and subsequent settlement. This can be caused by vibration. Therefore, there is the potential for problematic vibrations to occur during construction if equipment generating high impact loads is used in the area of the peaty soil. Problematic vibrations can also occur from HCV traffic if road corrugations result from seal joints or poor shape control in close proximity to the peaty soil. As a consequence, there is a need to identify where peaty soils are located so appropriate measures can be taken during the construction and operation of the Ruakura Interchange.

5.2.4.3 Cumulative Effects

The proposed designation alteration is occurring in addition to the Ruakura PPC development (i.e. Tainui Group Holdings (TGH) inland port and logistics hub) and also the existing Expressway construction. In order to contribute to a cumulative vibration impact, activities from these two projects would need to be located closely to the Ruakura Interchange project and happening at the same time.

Most of the residential dwellings listed in section 5.2.2.1 as being closest to the proposed designation alteration are at least 400 m away from the inland port and Expressway. Therefore, as ground vibrations decay rapidly with distance, ground vibration levels at these dwellings will be dominated by construction and operation of the Ruakura Interchange.

Similarly the educational buildings identified in section 5.2.2.1 are at least 130 m from the inland port and 1500m from the Expressway so again their vibration environment will be dominated by construction and operation of the Ruakura Interchange.

The only locations where cumulative effects may possibly occur due to the close proximity of the Ruakura Interchange designation boundary to the inland port and Expressway are dwellings at 53A, 55, and 63 Ryburn Road. The shortest separation distance to the Expressway is 41 m and to
the inland port 100 m. Therefore, the only opportunity for a measurable cumulative effect is if construction activity for two or more of the projects takes place concurrently. This can be avoided by scheduling impact related construction activities in the vicinity of Ryburn Road, such as piling and roller compaction, so that they do not occur simultaneously at two or more of the projects.

Ground vibrations once the inland port and Expressway are operational will be of too small a magnitude to be perceptible at the Ryburn Road dwellings.

5.3 Suggested Mitigation Measures

5.3.1 Construction Vibrations

The operation of construction equipment causes ground vibrations that spread through the ground and diminish in strength with distance. Buildings and structures in the vicinity of the construction site respond to these vibrations with varying results ranging from no perceptible effects at the lowest levels, perceptible vibrations at moderate levels and slight damage at the highest levels (Hanson et al, 2006). Construction equipment that generate little or no ground vibrations are air compressors, light trucks, hydraulic loaders etc. whereas construction activities that typically generate the most severe vibrations are pile-driving, vibratory compaction, and drilling or excavation in close proximity to vibration sensitive structures.

With regard to the Project, the two construction activities that have the most potential to generate troublesome vibrations are piling associated with the construction of the interchange and general earthworks associated with formation of the road.

The analysis has shown that there is a real possibility of occupants of residential buildings bordering the new route being disturbed by vibrations generated by construction activity. Also, in two cases, the designation boundary is only 5 m away from a residential building (63 Ryburn Road and 3 Vaile Road), so damage to these buildings could occur if inappropriate earthmoving equipment is operated close to the boundary.

In addition, there is the potential for cumulative effects if impact related activities in the vicinity of Ryburn Road coincides with similar construction activity at either the Ruakura PPC development or the Waikato Expressway, Hamilton Section.

This analysis highlights that considerable care will need to be taken when selecting and operating construction equipment and in the scheduling of activities that generate large ground vibrations, such as piling and compaction. The recommended option for mitigating the excavation/construction related vibrations is the use of a CVMP to ensure vibrations resulting from construction of the project meet conditions imposed to ensure internationally accepted guidelines for human annoyance and building damage are not exceeded. Suggested requirements for the CVMP are discussed in greater detail in section 6.

5.3.2 Operational Vibrations

All existing residential properties are sited 8 m or more away from the closest trafficked lane. This is considered a sufficient separation distance to ensure building occupants will not be disturbed by ground vibrations induced by passing HCV traffic.

Furthermore, the Transport Agency has processes in place for managing roads to minimise the generation of vibrations. Firstly, the Transport Agency monitors the State Highway network for
‘smooth ride’ on an annual basis to ensure the targets that have been set are being met through the network management and maintenance contracts. Secondly, section 5.5 of the State Highway Control Manual (SM012) specifies procedures for dealing with vibration related complaints and their resolution. Therefore, no specific mitigation of vibrations induced by HCV traffic is considered necessary.

6 Suggested Conditions

Given the close proximity of existing residential buildings in Morrinsville Road, Ruakura Road, Ryburn Road and Vaile Road to the designation boundary, there will be a need to carefully manage ground vibrations from mechanised construction equipment. The most appropriate instrument for this is a construction vibration management plan (CVMP).

For consistency, it is recommended that the construction noise and vibration management plan related conditions proposed for the Waikato Expressway, Hamilton Section (i.e. conditions 2.2(vi), 2.4, 2.5, 2.6, 2.7, 2.8 and 2.9) also be adopted in their entirety for the Ruakura Interchange. These conditions were agreed to by the Transport Agency and council officers and their representatives.

However, to address the issue of potentially problematic vibrations occurring if localised areas of peaty soil are encountered during the construction of the interchange and local road connections, it is recommended that Waikato Expressway, Hamilton Section condition 2.7 (iii) be amended as follows:

*Identification of affected houses and other sensitive locations where noise and/or vibration criteria apply. For vibrations, this shall include all occupied buildings located within 50 m of general road construction activities, and 100 m of piling, where those activities are undertaken on peat.*
7 Conclusions

A desk based assessment of vibration effects resulting from the construction and operation of the proposed Ruakura Interchange has identified:

1. Vibration levels generated by construction are likely to be higher than those from operation but would be temporary and of a limited duration.

2. There is the potential for adverse effects from construction but these can be appropriately mitigated through a Construction Vibration Management Plan as the mitigation measures relate to selection of equipment and processes, the location and operation of the equipment and the sequencing of operations. Therefore, it is recommended that the requiring authority shall implement a Construction Vibration Management Plan for the duration of the construction period of the Project as this will be sufficient to mitigate the identified vibration effects of the designation to a minor level or less.

3. Any construction activity associated with local road connections, specifically Ruakura Road, Ryburn Road, Vaile Road, Silverdale Road and SH26 (Morrinsville Road) must be addressed by the Construction Vibration Management Plan, given the potential for structural damage because of the closeness of the designation boundary to residential and educational buildings bordering these roads.

4. Areas of peaty soil have the potential to generate problematic vibrations during construction of the Ruakura Interchange and once it is operational. Therefore, there is a need for these areas to be identified so that appropriate measures can be put in place to limit the disturbance of occupants of nearby buildings.

5. There is the potential for cumulative effects at dwellings in Ryburn Road. Therefore, care will need to be taken in scheduling construction activities in the vicinity of Ryburn Road that generate large ground vibrations, such as piling and compaction, to ensure they do not occur concurrently at the Ruakura Interchange project, the Ruakura PPC development (inland port and logistics hub) and the Waikato Expressway, Hamilton Section project.

6. All existing residential properties are sited 8 m or more away from the closest trafficked lane. This is considered a sufficient separation distance to ensure building occupants will not be disturbed by ground vibrations resulting from the operation of the Ruakura Interchange. Therefore, no specific mitigation of traffic-induced vibrations is considered necessary.
8 References


Carpenter, P., Cenek, P.D. and McIver, I.R. (2011) Vibration measurements in the Vicinity of the SH29 Realignment – Soldiers Road to Ngamuwahine Road, Opus Central Laboratories Report 11-29A048.01


