Blast and Vibration Impact Assessment

Train Support Facility

Pacific National

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APPENDICES

1. INTRODUCTION

Advitech Pty Limited was engaged by Monteath and Powys Pty Ltd to prepare a Blast and Vibration Impact Assessment (BVIA) of potential vibration impacts associated with the development of a Train Support Facility (TSF) at Greta, NSW. Pacific National proposes to construct and operate the facility to provide support to its coal haulage business in the Hunter Valley. The location of the proposed facility is provided in **Figure 1**. The site is currently zoned Rural 1a pursuant to the *Cessnock Local Environment Plan* (LEP) 1989 and is located between the existing Main Northern Railway and the proposed F3 freeway extension to Branxton. The purpose of this assessment is to provide an analysis of potential blasting and vibration impacts associated with the construction and operation of the TSF.

It should be noted that this report was prepared by Advitech Pty Limited for Monteath and Powys ("the customer") in accordance with the scope of work and specific requirements agreed between Advitech and the customer. This report was prepared with background information, terms of reference and assumptions agreed with the customer. The report is not intended for use by any other individual or organisation and as such, Advitech will not accept liability for use of the information contained in this report, other than that which was intended at the time of writing.

1.1 Site Location and Surrounding Land Uses

The site is located at Lot 300, DP1117342 Mansfield Road, Greta (**Figure 1**). The site has an area of approximately 46 hectares and is zoned 1(a) Rural pursuant to the Cessnock LEP (1989). The site surrounds include:

- mixture of rural and residential receivers;
- New England Highway to the north;
- Main Northern Railway corridor to the north; and
- proposed Hunter Expressway extension to the south.

Figure 1: Site Location

1.2 Project Description

Pacific National's intention is to establish the Greta site as a train support facility. The new facility is required to meet the expected growth in coal exports through the Newcastle Port and will allow Pacific National to not only achieve its business objectives but to also meet responsibilities within the Hunter Valley coal chain. The development is referred to as a Train Support Facility, which includes the infrastructure required to service trains as well as provide the administration and ancillary development associated with the project.

1.2.1 Train Support Facility

The facility will operate as a service point for Pacific National's existing trains that utilise the Main Northern Railway. On return trips from delivering commodities to the Port of Newcastle, empty trains will utilise the proposed Greta facility to be re-fuelled, maintained and when necessary change crews. The trains currently operate 24 hours a day, seven days a week, and as a result the facility needs to be available to service the trains on this basis. Once the trains have been re-fuelled and serviced, they will return to the Main Northern Railway for their intended destination. Minor planned maintenance works would also be undertaken at the facility.

The layout of the proposed development is provided in **Figure 2**.

1.2.2 Development Staging

Development of the facility will be undertaken in a construction stage and three (3) operational stages. These stages include:

- **Construction** – vegetation clearance, bulk earthworks, establishment of internal stabling roads and establishment of site buildings and ancillary infrastructure. Blasting would also be undertaken during this stage to remove rock from the site that is unsuitable for excavation;
- **Stage 1 Operations** – the facility will operate 24 hours a day, 7 days per week with approximately 10 trains serviced by the facility per day. The facility at this stage will have capacity to house 3 trains (totalling 9 locomotives and 273 wagons). Stage 1 operations are proposed to commence immediately upon commissioning of the facility.
- **Stage 2 Operations** - the facility will operate 24 hours a day, 7 days per week with approximately 15 trains serviced by the facility per day. The facility at this stage will have capacity to house 5 trains (totalling 15 locomotives and 455 wagons). Stage 2 operations are proposed to commence in 2014; and
- **Stage 3 Operations** - the facility will operate 24 hours a day, 7 days per week with approximately 25 trains serviced by the facility per day. The facility at this stage will have capacity to house 5 trains (totalling 15 locomotives and 455 wagons). Stage 3 operations are proposed to commence in 2018.

1.3 Sensitive Receivers

A number of potentially sensitive receivers were identified adjacent to the proposed development site, including residential receivers:

- to the east at Greta;
- to the south-east at Illalong;
- to the south off Tuckers Lane;
- to the west at North Rothbury;
- to the north-west at Branxton; and
- to the north off the New England Highway.

The location of potentially sensitive receivers adjacent to the development site is shown in **Figure 3.** The nearest sensitive receivers with potential to experience vibration impacts are located to the south of the site on Mansfield Road, Illallong.

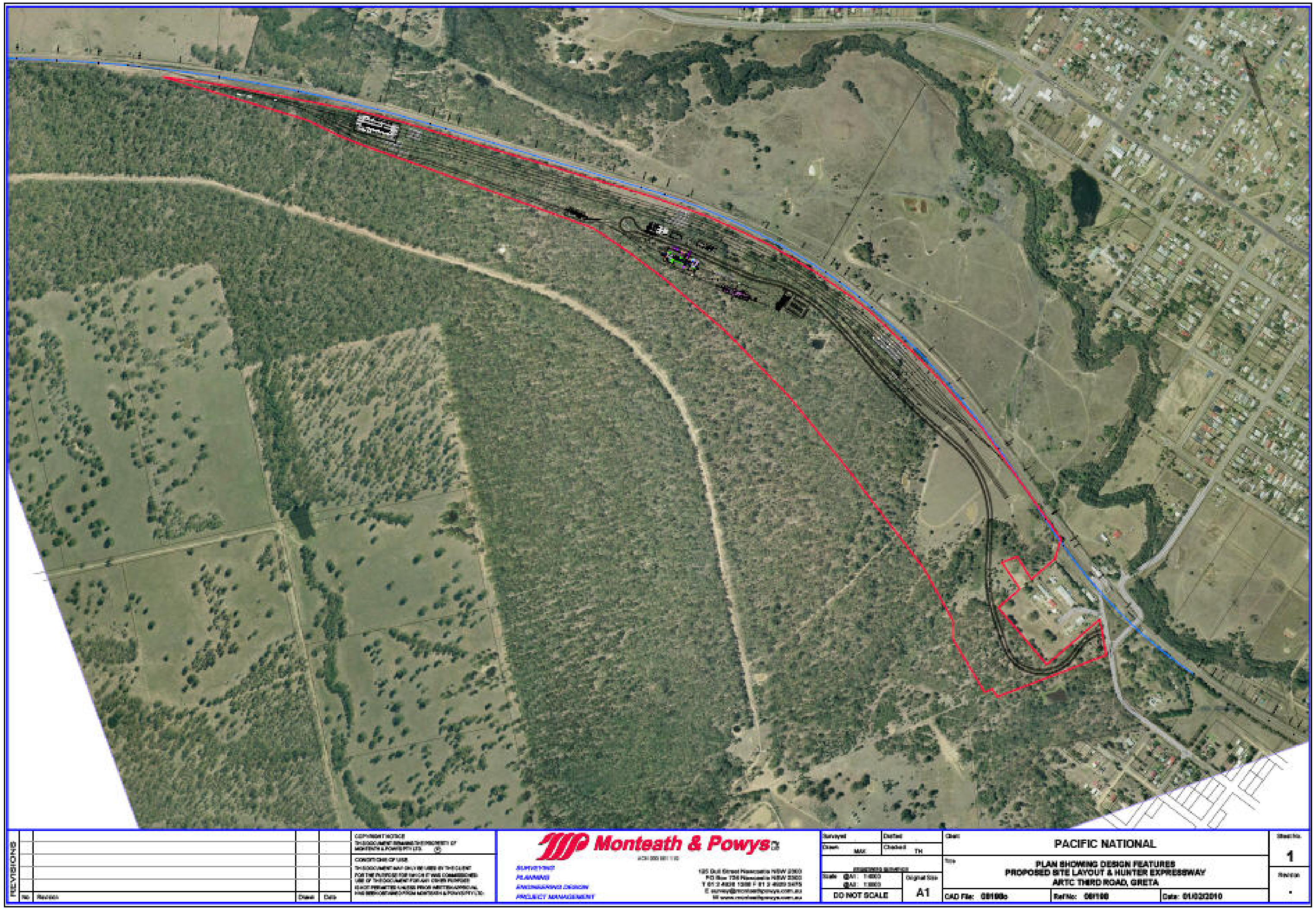


Figure 2: Site layout

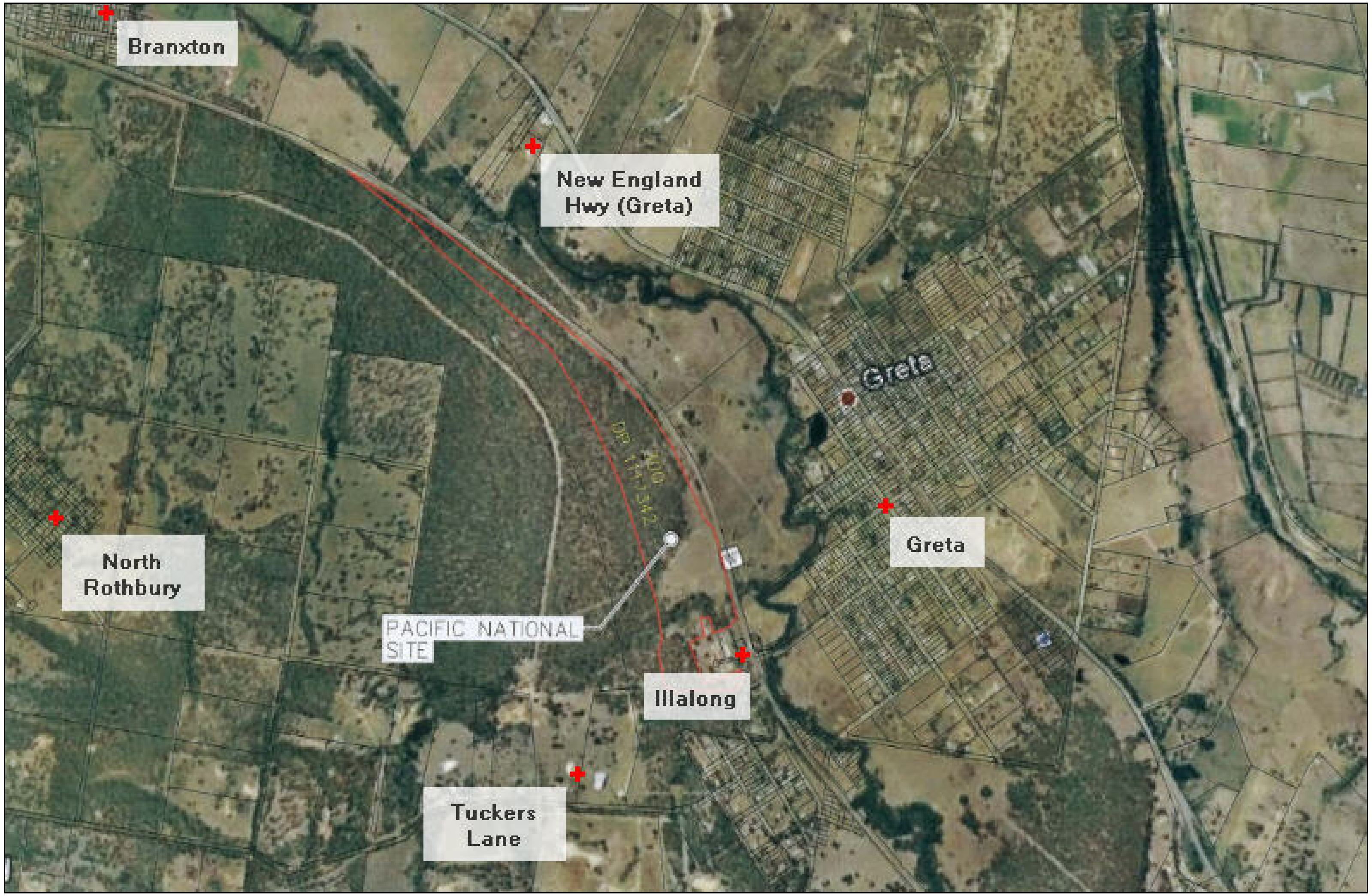


Figure 3: Location of Sensitive Receivers

2. REFERENCES

The following information was used in the preparation of this report:

1. ANZECC (1990). *Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration*, Australian and New Zealand Environment Council;
2. AS2187.2-2006 *Explosives – Storage and use Part 2: Use of Explosives*;
3. AS2670.1:2001 *Evaluation of human exposure to whole body vibration, Part 1: General Requirements;*
4. Department of Environment and Climate Change (2009). *Interim Construction Noise Guideline*, Department of Environment and Climate Change, Sydney*;*
5. Department of Environment and Conservation (2006). Assessing Vibration: a technical guideline, Department of Environment and Conservation, Sydney;
6. GHD (2009). *Report on ARTC Minimbah Third Track Environmental Assessment: Noise and Vibration Impact Assessment*, Australian Rail and Track Corporation;
7. GHD (2009). *Noise and Vibration Impact Assessment for Maitland to Minimbah Third Track Project*, Australian Rail and Track Corporation;
8. Heggies (2007). Blasting Noise and Vibration Assessment: Modification to Development Consent for Glendell Coal Mine;
9. Heggies (2005). Construction, Operation and Transportation Noise and Blasting Impact Assessment, Wilpinjong Coal Project;
10. Hansen, CE, Towers, DA and Meister, LD (2006). *Transit Noise and Vibration Impact Assessment*, US Federal Transit Administration, Washington; and
11. NSW Roads and Traffic Authority (2001). *RTA Environmental Noise Management Manual,* NSW RTA, Surry Hills.

3. ASSESSMENT CRITERIA

3.1 Construction Stage Blast and Vibration Criteria

3.1.1 Assessment Criteria for Human Annoyance

The NSW Department of Environment, Climate Change and Water (DECCW) advises that impacts associated with blasting be assessed in accordance the Australian and New Zealand Environment Council (ANZEC 1990) *Technical basis for guidelines to minimise annoyance due to blasting overpressure and vibration*. The guideline establishes the following criteria to minimise annoyance associated with blasting:

- Air-blast Overpressure:
  - the recommended peak maximum level for air blast overpressure at sensitive receivers is 115 dB(Lin);
  - the maximum air blast overpressure level should not exceed 115 dB(Lin) during more than 5% of blasts in any 12 month period, and should never exceed 120 dB(Lin).
- Ground Vibration:
  - the recommended maximum peak particle velocity (PPV) value of 5 mm/s;
  - the maximum PPV should not exceed 5mm/s during more than 5% of blasts in any 12 month period, and should never exceed 10 mm/s.
- Timing:
  - blasting should be restricted to the hours 9.00am to 5.00pm, Monday to Saturday;
  - blasting should not take place on Sundays or public holidays.

3.1.2 Assessment Criteria for Structural Damage

Currently no published guideline or Australian Standard establishes a vibration criterion for the assessment of structural or cosmetic damage to buildings or permanent infrastructure caused by blasting. Review of published literature indicates that German Standard DIN 4150-3: 1999 *Structural Vibration – Part 3: Effects of vibration on structures* provides an effective guidance criteria of 80mm/s for rail infrastructure (Heggies 2005, 2007).

AS2187.2-2006 cites more conservative guideline values from British Standard (BS) 7385-2 *Evaluation and measurement for vibration in buildings; Part 2: Guide to damage levels from ground-borne vibration* for cosmetic and minor structural damage to residential and commercial structures. **Table 1** presents vibration criteria for commercial and residential buildings.

Table 1: BS7385-2 Transient vibration guide values for cosmetic damage[1]

	Peak component particle velocity	
Type of Building	**4Hz to 15Hz**	**15Hz and above**
Reinforced or framed structures. Industrial and heavy commercial buildings	50mm/s at 4Hz and above	
Unreinforced or light framed structure. Residential of light commercial type buildings	15mm/s at 4Hz increasing to 20mm/s at 15Hz	20mm/s at 15Hz to 50mm/s at 40Hz and above

Note 1: Reproduced from Appendix J of AS2187.2-2006

3.2 Operational Stage Vibration Criteria

The NSW Department of Environment and Conservation (DEC) document *Assessing Vibration: a technical guideline* is identified as the appropriate guideline for the assessment of vibration impacts from new industrial and transportation developments. The guideline identifies three specific types of vibration:

- continuous;
- impulsive; and
- intermittent.

Rail induced vibration is identified as presenting an intermittent impact in accordance with the following definition:

> *Interrupted periods of continuous (e.g. drilling) or repeated periods of impulsive vibration (e.g. piling works), or continuous vibration that varies significantly in magnitude. It may originate from impulse sources or repetitive sources, or sources which operate intermittently, but which would produce continuous vibration if operated continuously (including intermittent machinery, railway trains and traffic passing by).*

3.2.1 Assessment Criteria for Intermittent Vibration

The DEC guideline identifies the Vibration Dose Value (VDV) as the appropriate indicator for the assessment of intermittent vibration impacts. The VDV provides an assessment of accumulated vibration impacts experienced over the duration of the assessment period. The DEC guideline adopts the assessment methodology from BS6472-1992 *Guide to evaluation of human exposure to vibration in buildings* for determination VDVs. The acceptable VDVs for intermittent vibration are reproduced in **Table 2**.

Table 2: Acceptable vibration dose values for intermitten vibration ($m/s^{1.75}$)

	Daytime[1]		Night-time[1]	
Receiver Type	Preferred	Maximum	Preferred	Maximum
Critical areas[2]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Note 1. Daytime is defined as the period 7am to 10pm. Night is defined as the period 10pm to 7am.

Note 2. Examples of critical areas include hospital operating theatres and precision laboratories where sensitive operations are occurring.

These are the values above which disturbance to occupants of a building may be expected. Adverse reactions may be expected where vibration impacts approach the maximum values. These criteria relate to human comfort and annoyance and are the criteria against which both operational and construction stage impacts may be assessed.

3.2.2 Assessment Criteria for Structural Damage

Currently no guideline or Australian Standard establishes a vibration criterion for the assessment of structural or cosmetic damage to buildings. The US Federal Transit Administration guideline *Transit Noise and Vibration Impact Assessment* (1995) provides some guidance on the establishment of vibration damage criteria for structures adjacent to transport corridors. The FTA suggested building damage criteria are reproduced in **Table 3**.

Table 3: Structural damage criteria

Building Type	Peak Particle Velocity (mm/s)
Reinforced concrete, steel or timber (no plaster)	12.7
Engineered concrete and masonry (no plaster)	7.6
Non-engineering timber and masonry buildings	5.1
Building extremely susceptible to vibration damage	3.1

4. EXISTING ENVIRONMENT

4.1 Background Monitoring

Vibration monitoring was undertaken on 1 February 2010 in order to characterise ambient vibration impacts at the site of the proposed development. Monitoring was undertaken using a Texcel UMX (S/N:721) vibration analyser. The monitoring location is provided in **Figure 4**. A detailed plan of the monitoring layout is provided in **Figure 5**.

4.2 Methodology

The monitoring location was approximately 12 metres from the Pacific National site boundary and 22 metres south-west of the nearest track. Setback of the monitoring location from the nearest track was consistent with separation distances between the rail corridor and the closest sensitive receivers at Mansfield Street, Illalong.

Operator attended monitoring was undertaken between 12:30 and 14:00 on 1 February 2010. The monitoring unit provided a continuous record of Peak Particle Velocity (PPV) vibration impacts in 3-axes during this period, with assessment of rail pass-by induced impacts undertaken on the basis of operator observations.

4.3 Monitoring Results

While coal trains present the dominant contribution to rail traffic on the Main Northern Railway, freight and commuter trains also utilise this corridor. A total of eight (8) rail pass-by events were observed during the monitoring period, comprised of:

- 3 northbound un-laden coal trains (near track);
- 1 northbound commuter train (near track); and
- 4 southbound laden coal trains (far track).

A summary of the monitoring results are presented in **Table 4 to Table 6**.

Table 4: Summary of pass-by events

Event / ID	Pass-by Duration (s)	Description
T1N	105	Northbound Coal (unladen)
T2N	50	Northbound Countrylink passenger train
T3N	120	Northbound Coal (unladen)
T4N	180	Northbound Coal (unladen)
T5N	160	Southbound Coal (laden)
T6N	90	Southbound Coal (laden)
T7N	135	Southbound Coal (laden)
T8N	105	Southbound Coal (laden)

The pass-by times presented in **Table 4** represent the interval between the passage of the first and last component (locomotive or wagon) of the train at the monitoring location. Assessment of the range of measured PPV values in each axis are presented in **Appendix I**. The data provided in **Table 5** summarises the range of Root Mean Square (RMS) acceleration values from monitored pass-by events.

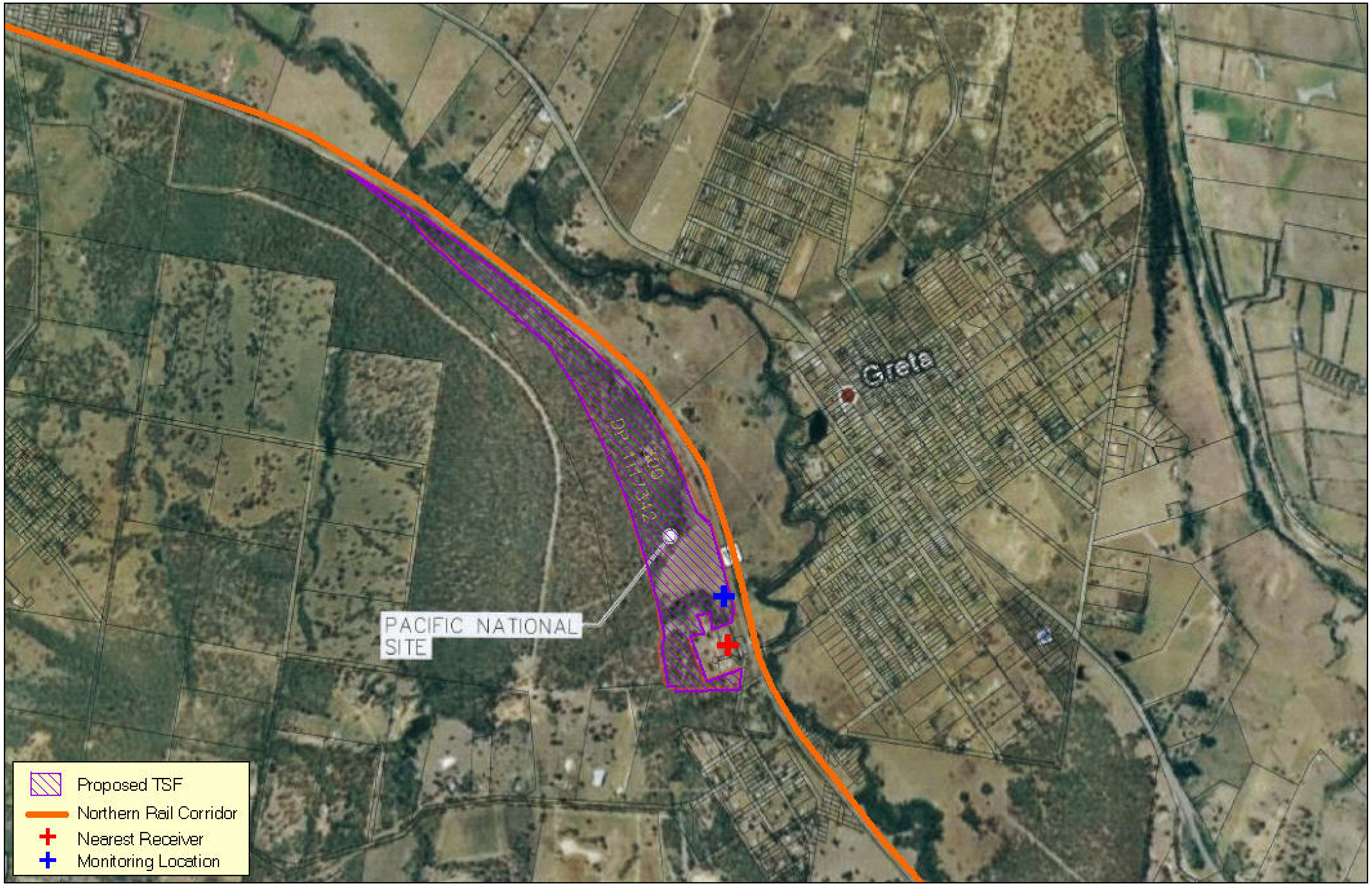


Figure 4: Vibration monitoring location

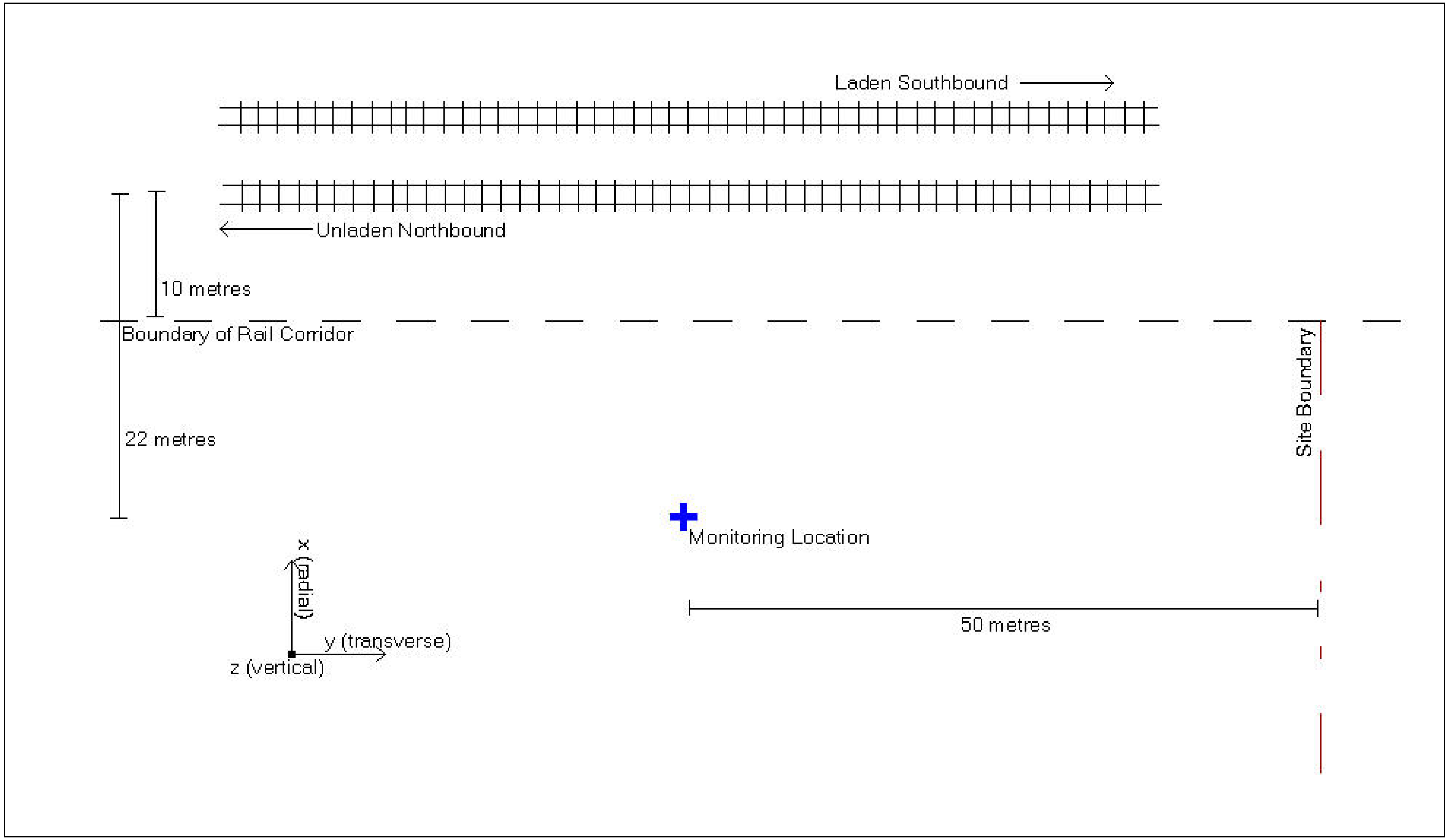


Figure 5: Detailed layout of vibration monitoring location

Table 5: Summary of existing vibration levels

		RMS Acceleration (ms^{-2})		
Range of Values		Radial	Transverse	Vertical
Northbound (unladen)				
	Minimum	0.0006	0.0006	0.0003
	Maximum	0.0112	0.0116	0.0225
Southbound (laden)				
	Minimum	0.0006	0.0006	0.0003
	Maximum	0.0094	0.0100	0.0091
Background				
	Minimum	0.0006	0.0006	0.0003
	Maximum	0.0009	0.0006	0.0006

The PPV were converted to an RMS velocity value assuming a typical crest factor of 4 for groundborne vibration from trains (FTA 2006). The RMS acceleration values presented in **Table 5** were then evaluated using the methodology presented in Appendix B2 of the DEC (2006) guideline:

$$a_{rms} = 2 \times \pi \times f \times v_{rms}$$

Where: a_{rms} = acceleration in ms^{-2}
f = frequency in Hz
v_{rms} = velocity in ms^{-1}

Review of the noise and vibration impact assessment for the ARTC Minimbah Third Track expansion indicates the dominant frequency for rail pass-by events is approximately 30 Hz (GHD 2008). For the purposes of calculating RMS acceleration from RMS velocity results at the Greta monitoring location, the dominant frequency was assumed to be 30 Hz.

Energy average RMS acceleration values for each of the pass-by events was calculated using the method described in equation B.4 of AS2670.1:2001 *Evaluation of human exposure to whole body vibration, part 1: General Requirements*:

$$a_{we} = \left[\frac{\sum a_{wi}^4 \times T_i}{\sum T_i} \right]^{\frac{1}{4}}$$

Where: a_{we} = equivalent vibration magnitude in ms^{-2}
a_{wi} = vibration magnitude for exposure duration T_i

AS2670.0:2001 provides an alternative method for the evaluation of energy equivalent vibration magnitude, however equation B.4 (presented above) was found to provide a more conservative evaluation of vibration impacts and was applied for the purposes of this assessment.

Based on calculated vibration magnitudes on each axis, the estimated partial VDV (eVDV) for each of the pass-by events was determined in accordance with the method presented in Appendix A of the guideline:

$$eVDV = 1.4 \times a_{rms} \times t^{0.25}$$

Where: eVDV is the estimated Vibration Dose Value ($ms^{-1.75}$)
a_{rms} = acceleration in ms^{-2}
t = duration of exposure in seconds

The total eVDV for each of the pass-by events was then evaluated using the equation provided in Section 2.4.1 of the DEC (2006) guideline for the summation of individual vibration doses:

$$eVDV = \left[\sum_{i=1-N} eVDV_i^4\right]^{0.25}$$

Where: eVDV is the total Vibration Dose Value ($ms^{-1.75}$)
$eVDV_i$ is the individual dose value (for x, y, z axis) ($ms^{-1.75}$)

The eVDV values for each of the monitoring rail pass-by events are presented in **Table 6**. Bold values indicate the axis on which maximum eVDV were observed.

Table 6: Summary of passby events ($ms^{-1.75}$)

		Partial eVDV		
Event / ID	Total eVDV	Radial	Transverse	Vertical
T1N	0.02	0.016	**0.021**	0.013
T2N	0.02	0.018	**0.020**	0.018
T3N	0.05	0.028	0.029	**0.052**
T4N	0.02	0.018	**0.019**	0.015
T5N	0.04	**0.030**	0.027	0.029
T6N	0.02	0.014	0.011	**0.016**
T7N	0.03	0.025	**0.028**	0.020
T8N	0.03	0.021	0.020	**0.021**

4.4 Assessment of Monitoring Results

The monitoring results presented in **Section 2.3** indicate the range of existing vibration impacts does not differ significantly for laden and unladen rail pass-by events. Vibration dose values associated with unladen train pass-by events were typically greatest in the transverse axis. The greater RMS acceleration and eVDV results presented for pass-by event T3N should be interpreted with caution as a large shudder was reported by the operator as the last wagon of the train passed the monitoring location. The reported vibration exposure for this event is likely to be more representative of a worst case impact associated with a damaged wagon than a typical exposure level. Measured PPV values associated with this event were in the order of 0.5 mm/s in the vertical axis. This impact is well below the vibration damage criteria for all building types presented in **Section 3.2**.

Background vibration levels were well below that of rail pass-by events and could not be attributed to any obvious industrial or transportation source.

5. ASSESSMENT OF POTENTIAL VIBRATION IMPACTS

5.1 Blasting Overpressure and Vibration Impacts

Preliminary geotechnical investigations undertaken by Pacific National indicate areas exist within the proposed development site that requires blasting to enable final site levels to be achieved. Blasting will be required to excavate approximately:

- 40,000m^3 of rock between chainages 211250 and 211650; and
- 10,000m^3 of rock between chainages 213250 and 213450.

The location of the proposed blasting areas is provided in **Figure 6**. Minimum separation distances between the proposed blast area and sensitive receivers or critical infrastructure are provided in **Table 7**.

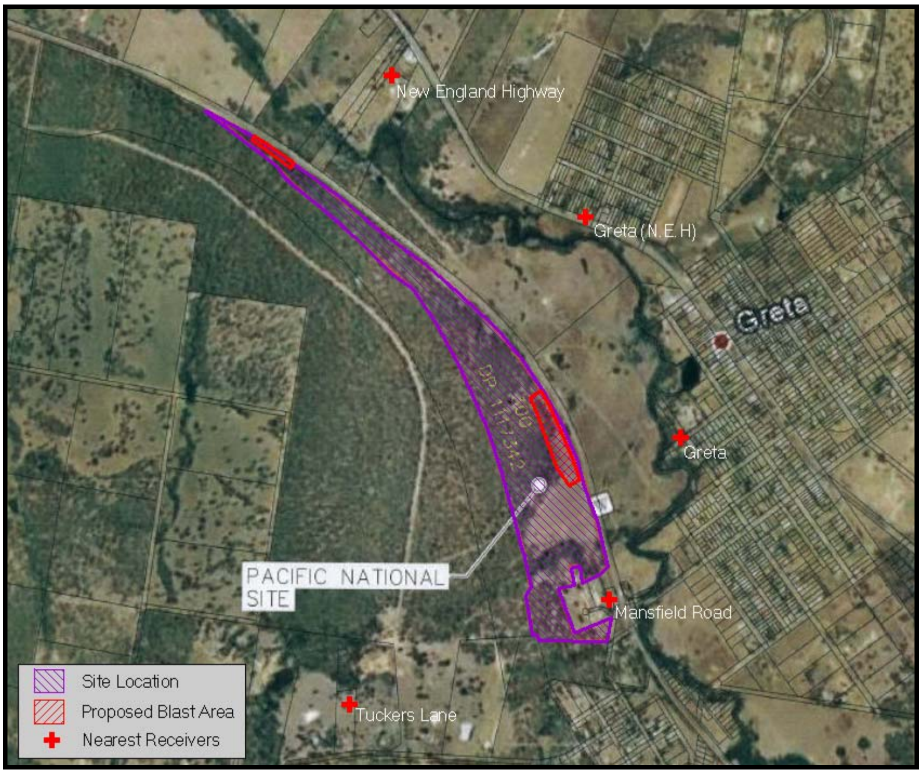


Figure 6: Areas subject to blasting

Table 7: Seperation distances between receivers and blast area

Receiver	Separation Distance (R), metres
Greta (nearest resident)	445
Mansfield Road (nearest resident)	390
Tuckers Lane	1360
North Rothbury	2050
Branxton	1690
New England Highway (nearest resident)	540
New England Highway (Greta)	730
Northern Rail Infrastructure (existing)	8

5.2 Preliminary Blast Design

Review of preliminary blast design has been undertaken for the purposes of understanding potential overpressure and ground vibration impacts. It should be noted information available at the time of the assessment is preliminary, and subject to minor adjustment following initial blast trials until such time as impacts associated with site specific characteristics are understood. Details relating to proposed blast design are provided in **Table 8**.

Table 8: Preliminary blast design

Blast Characteristic	Data
Number of Blastholes	30
Blasthole Diameter	89 to 102 mm
Blasthole Depth	2.5 to 4.0 m
Blasthole per Delay	1
Charge per Blasthole (Q)	4 to 6 kg

It is proposed that blasting would be undertaken every second day for approximately 3 months to excavate the estimated 50,000 m^3 of rock. Blasts would be undertaken between 9am and 5pm however timing would vary depending on the proximity to the Northern Railway and train schedules.

5.3 Assessment of Overpressure Impacts

5.3.1 Estimating Overpressure Levels

Appendix J7 of *AS2187.2-2006 Explosives - Storage and use. Part 2: Use of explosives* provides the following method for evaluating potential airblast overpressure levels:

$$P = K_a \left(\frac{R}{Q^{1/3}} \right)^a$$

Where: P is air pressure (Pa);
R is the distance between charge and point of measurement (m);
Q is maximum instantaneous charge (charge mass per delay) (kg);
K_a,is the site constant; and
a is the site exponent.

Additional detail contained in Clause J7.3 of AS2187.2:2006 provides the following values for the site constant and site exponent for confined blasthole charges:

K_a = range between 10 to 100;
A = -1.45

In lieu of further advice in AS2187.2-2006 relating to the application of site constants, the blast model was validated using data published in existing blast assessments that implement this methodology. The validated model applies a value of 10 for the site constant (K_a).

Equation J5.1 in AS2187.2:2006 allows for the expression of overpressure impacts in decibels:

$$SPL = 10 \times \log_{10}\left(\frac{P}{P_0}\right)^2$$

Where: P is estimated overpressure level (μPa); and
P_0 is the reference pressure of 20 μPa.

5.3.2 Assessment of Overpressure Impacts

A summary of assessed blast overpressure impacts is presented in **Table 10**. The results indicate that, based on observed separation distances, airblast overpressure levels are unlikely to exceed the human annoyance criteria presented in the ANZEC guideline at adjacent sensitive receivers. It should be noted the assessment applies minimum separation distances and hence presents a conservative assessment of potential impacts. **Figure 7** shows the area likely to experience overpressure impacts exceeding 115 dB(Lin).

Table 9: Assessment of blast impacts

Receiver (nearest resident)	Separation Distance (m)	Criteria	Airblast Overpressure (dB(Lin))
Greta	445	< 115dB(Lin) 95% of blasts Should not exceed 120dB(Lin) at any time	105
Mansfield Road	390		106
Tuckers Lane	1360		91
North Rothbury	2050		86
Branxton	1690		88
New England Highway	540		102
New England Highway (Greta)	730		98

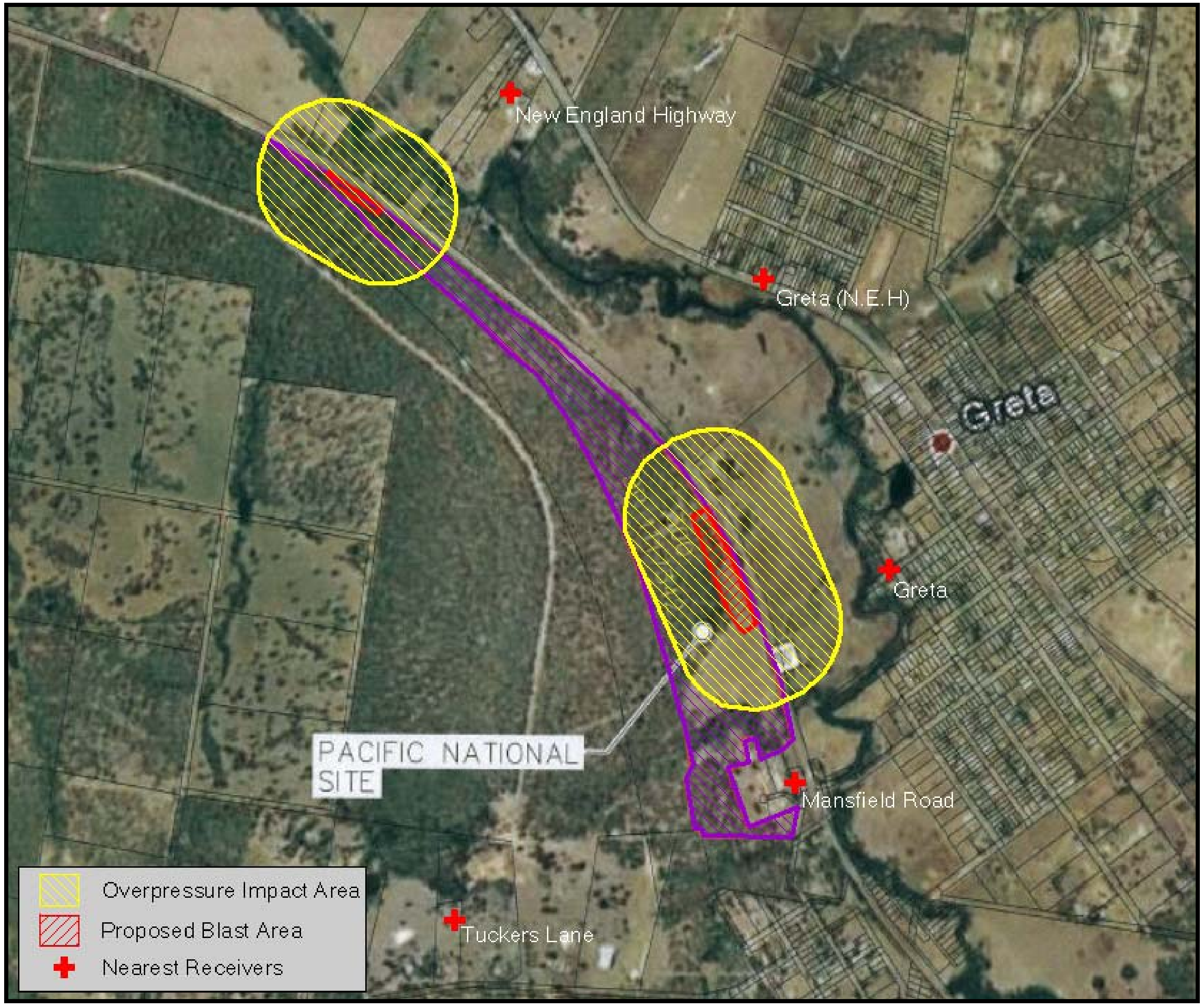


Figure 7: Blast overpressure impacts

5.4 Estimating Ground Vibration Impact

Appendix J7 of *AS2187.2-2006 Explosives - Storage and use. Part 2: Use of explosives* provides the following method for evaluating potential ground vibration levels:

$$V = K_g \left(\frac{R}{Q^{1/2}} \right)^{-B}$$

Where: V is ground vibration as vector peak particle velocity (mm/s);
R is the distance between charge and point of measurement (m);
Q is maximum instantaneous charge (charge mass per delay) (kg); and
K_g, B are constants related to site and rock properties for estimation purposes.

Discussion presented in Clause J7.3 of AS2187.2:2006 states that, in the absence of site specific constants the following values may be used to estimate vibration levels (50% probability of exceedence) in average conditions:

K_g = 1140
B = -1.6

In the absence of detailed understanding of site specific vibration propagation characteristics, the constants for average conditions are applied to this assessment.

5.4.1 Assessment of Blast Impacts

A summary of assessed blast impacts is presented in **Table 10.** The results indicate that, based on the observed separation distances, ground vibration levels are unlikely to exceed human annoyance or structural damage criteria at sensitive receivers adjacent to the blast site. Ground vibration levels may exceed the structural damage criterion established in DIN 4150-3: 1999, however consultation with ARTC to determine an acceptable impact criterion should be undertaken prior to commencement of construction works. Detailed blast designs would then be undertaken to ensure compliance with this criterion.

Table 10: Assessment of blast impacts

Receiver (nearest resident)	Separation Distance (m)	Criteria		Ground Vibration (mm/s)
		Annoyance	Structural Damage	
Greta	445	PPV < 5mm/s 95% of blasts PPV should not exceed 10mm/s at any time	>15mm/s	0.28
Mansfield Road	390			0.34
Tuckers Lane	1360			0.05
North Rothbury	2050			0.02
Branxton	1690			0.03
New England Highway	540			0.20
NEH (Greta)	730			0.13
Northern Rail Infrastructure	8		80mm/s	124

5.4.2 Mitigation of Blast Impacts

While the assessment indicates blasting activities are likely to comply with the relevant criteria, impacts may be perceived by sensitive receivers adjacent to the site. AS2187.2-2006 provides guidance on methods to manage blasting in such a way as to minimise ground vibration and overpressure impacts, including:

- reducing the maximum instantaneous charge;
- using appropriate delays;
- establishing blast times in accordance with prevailing meteorological conditions;
- keeping face heights to a practical minimum;
- optimising blast design;
- ensuring stemming types and lengths are adequate; and
- orienting blasts away from receivers (where possible).

It is also recommended a the construction contractor prepare a Blast Management Plan, and include provisions for:

- monitoring overpressure and ground vibration;
- feedback loops to modify blast design where monitoring indicates impacts are above the criteria; and
- receiving, investigating and responding to complaints.

5.5 Construction Plant Vibration Impacts

Due to the transient nature of the impact and the difficulty in evaluating a vibration dose for an activity that may vary significantly with time, the assessment focuses on reviewing potential impacts against the structural damage criteria. The US Federal Transit Administration guideline *Transit Noise and Vibration Impact Assessment* (1995) provides a methodology for the assessment of potential construction related vibration impacts. The FTA guideline recommends the following model for the evaluation of vibration impacts generated by construction activities:

$$PPV = PPV_{plant} \times \left[\frac{D_{ref}}{D_{sep}} \right]^{1.5}$$

Where: PPV is the Peak Particle Velocity at distance D_{sep} from the source;
PPV_{plant} is the reference PPV for a particular item of plant at reference distance $D_{ref;}$
D_{ref} is the reference distance.

Typical vibration levels generated by items of construction plant are sourced from the FTA guideline (2006) and the NSW RTA Environmental Noise Management Manual (2001). The typical range of vibration levels for common construction plant presented in these documents are reproduced in **Table 11**.

Table 11: Typical vibration levels for common construction activities

Construction Equipment	Peak Particle Velocity (mm/s)
FTA Guideline (reference distance = 7.6m [25 feet])	
Piling (impact)	16 to 39
Piling (sonic)	4 to 18
Vibratory Roller	5
Large Dozer	2
Drilling	2.5
Loaded Truck	2
Jackhammer	1
Environmental Noise Management Manual (reference distance 10m)	
Piling	12-30
Loader Breaking Kerb	6 to 8
15 Tonne Compactor	7 to 8
7 Tonne Compactor	5 to 7
Roller	5 to 6
Pavement Breaker	4.5 to 6
Dozer	2.5 to 4
Backhoe	1
Jackhammer	0.5

5.5.1 Construction Activities

It is estimated that the construction works associated with the proposed development will take 12 to 14 months. Detailed information relating to the construction program is not available at this stage of the design process however the following summary of works is provided:

- vegetation clearance and major earthworks;
- establishment of rail sidings and turnouts from Main Northern Railway;
- construction of buildings, tank farm and ancillary infrastructure;
- construction of internal roadways; and
- commissioning of site infrastructure.

Major earthworks and establishment of final site levels are identified as the major source of construction vibration impact given the potential requirement for rock breaking equipment and the significant volume of material to be cut. It is anticipated that cut material will be transported within the site only where it is required for use as fill or for construction of a noise barrier adjacent to sensitive receivers at the southern end of the site.

While it is acknowledged that the entire construction program is anticipated to last approximately 12 to 14 months, individual stages within the project will occur over shorter durations and are likely to be mobile in nature. For the purposes of this assessment construction works are considered in terms of two major components:

- Phase 1: Major earthworks and establishment of final levels; and
- Phase 2: Establishment of rail sidings, site infrastructure and ancillary services.

Phase 1 activities that may generate vibration impacts at receivers at the southern end of the site include rock breaking and construction of the noise barrier. Items of plant that may generate vibration impacts during this phase of the construction works include rock breaking equipment across the site and trucks and dozers used to emplace material and shape the noise barrier.

Phase 2 activities that may generate vibration impacts at receivers at the southern end of the site include construction of the internal roadway. Items of plant that may generate vibration impacts during this phase of the construction works include truck movements and the use of rollers to finish the road surface.

At the time of the assessment it was understood that blasting would not be undertaken as part of the construction phase of the development.

5.5.2 Assessment of Construction Vibration Impacts

The worst case vibration impacts during the construction stage of the development are likely to occur during construction of the noise barrier and internal roadway. During this stage of the development the separation distances between construction plant and privately owned structures is likely to be in the order of 20 metres.

At the time of this assessment any requirement for the use of rock breaking equipment during this phase of the construction works was unknown, however impacts associated with this item of plant represent the potential worst case vibration impact at these receivers. The equation presented in Section 5.2 was used to predict PPV levels at receivers assuming a separation distance of 20 metres.

This analysis assumes vibration levels generated by rock breaking equipment are consistent with those provided for kerb breaking operations provided in **Table 11**. The results of the assessment are presented in **Table 12**. The results of this assessment indicate predicted PPV impacts fall below the structural damage criteria presented in **Section 3.2** for all building types.

Table 12: Modelled construction vibration impacts

Construction Plant	PPV at 10m (mm/s)	PPV Vibration Level at Receiver(mm/s)
Rock Breaking (kerb breaking)	8	2.8
Dozer	4	1.4
Truck	2	0.7
Roller	6	2.1

5.5.3 Mitigation of Construction Vibration Impacts

While the assessment of construction vibration levels indicates that impacts are unlikely to exceed the structural damage criteria, construction works in close proximity to sensitive receivers at the south of the site may be perceptible to persons in this area. The *Interim Construction Noise Guideline* (DECC, 2009) identifies noise and vibration control practices that may be applied to minimise construction related impacts on the community. Examples of strategies and work practices that may be relevant management of potential vibration impacts include:

- Universal Work Practices:
  - ensure employees and contractors are appropriately trained in the use of equipment in ways to minimise generation of noise and vibration;
  - ensure site managers regularly check the site and nearby residences for problems such that solutions can be quickly applied.
- Consultation and Notification:
  - provide information to neighbours before and during construction;
  - maintain good communication between the community and project staff;
  - provide a contact telephone number for community enquiries during the works; and
  - have a documented complaints handling process, including a register of received complaints, actions and resolutions.
- Plant and Equipment:
  - ensure the correct plant is used for the purpose; and
  - ensure equipment is maintained in good working order.
- Work Scheduling:
  - schedule potentially high impact activities during less sensitive periods and provide periods of respite. An example of such scheduling may be to undertake high impact activities only between 9am to 12pm and 2pm to 5pm.
- At Residences:
  - undertake building condition surveys at potentially impacted dwellings prior to commencement of vibration generating works to provide a reference against which impacts may be assessed.

5.6 Operational Vibration Impacts

Section 4.6 of the DEC (2006) guideline identifies the difficulties in the prediction of vibration impacts due to the level of uncertainty that generally exists in the propagation medium. The guideline references the US Federal Transit Administration guideline *Transit Noise and Vibration Impact Assessment* (1995) as an appropriate methodology on which to base an assessment of potential vibration impacts. This document provides a staged approach to the assessment of vibration impacts:

- screening procedure;
- general assessment; and
- detailed analysis.

5.6.1 Screening Assessment

The procedure provides screening distances within which vibration associated with various activities have potential to generate vibration impacts. Table 9-2 of the screening procedure indicates the critical separation distance between residential receiver types and conventional railroad activities is on the order of 60 metres (200 feet).

The nearest residential receivers are located to the south of the TSF adjacent to the site access on Mansfield Street, Illalong. These receivers are located approximately 150 metres south of the junction of the Main Northern Railway and the arrival track for the TSF. This is the point at which the boundary between vibration impacts associated with the TSF and existing rail sources is defined.

While the screening level assessment indicates vibration impacts are unlikely to occur at receivers more than 60 metres from the vibration source, potential impacts on the Mansfield Street receivers are assessed in accordance with the General Assessment methodology presented in Chapter 10 of the *Transit Noise and Vibration Impact Assessment* (1995) guideline. Where it can be demonstrated that vibration impacts at the Mansfield Street receivers are acceptable, it is assumed that impacts at all other receivers more distant from the TSF are also likely to be acceptable.

5.6.2 General Assessment

The assessment presents a generalised model for the prediction of rail induced vibration impacts as a function of distance from the centreline of the track. The prediction curve for the locomotive powered freight and passenger trains is provided in Figure 10-1 of the FTA guideline, reproduced in **Figure 8**.

A trend line was fitted to this curve and the resulting equation used as a means of extrapolating the curve to evaluate vibration impacts at distances exceeding 100 metres. Validation of this model was undertaken by evaluating the impact at a distance 22 metres from the track centreline (the distance at which background monitoring was undertaken) and applying a correction to ensure the impact prediction was consistent with measured vibration magnitudes.

Comparison of modelled and measured impacts revealed that the FTA prediction curve presented an over-estimate of vibration impacts at the Greta site. As such, the model was corrected such that predicted impacts were representative of the higher end of the range of measured vibration magnitudes in order to present a conservative assessment.

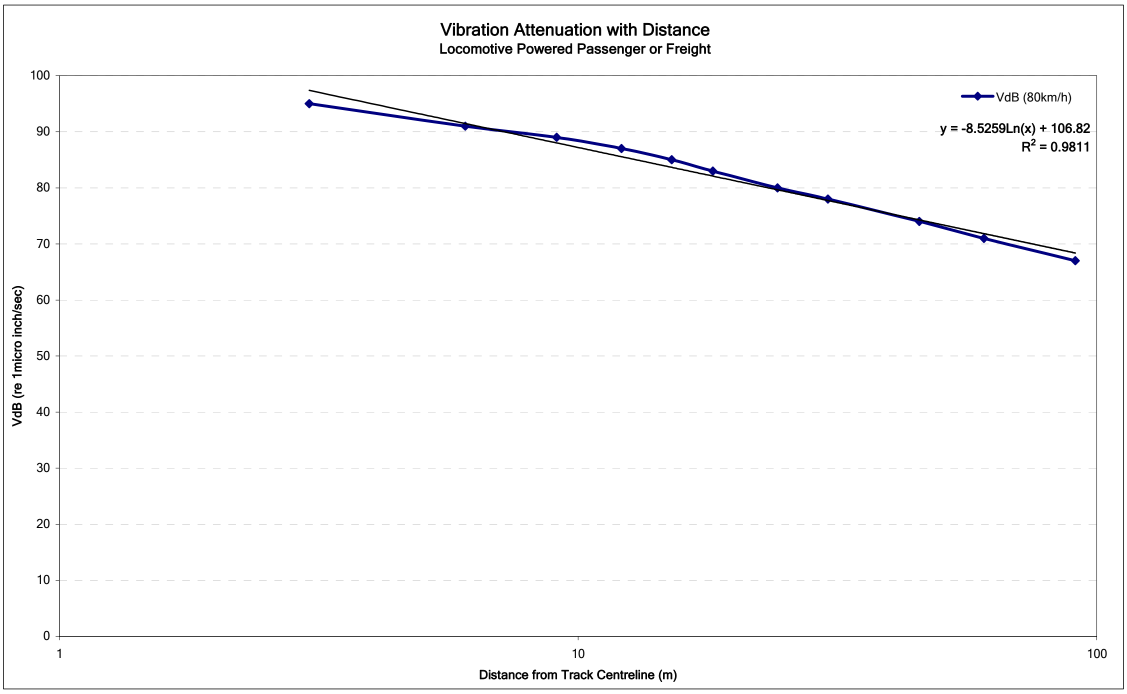


Figure 8: FTA impact prediction curve for locomotive powered rail vehicles

The curve presented in **Figure 8** was used to evaluate potential vibration impacts at residential receivers to the south of the TSF. Corrections were applied to the base curve in accordance with the methodology presented in Section 10.3 of the FTA guideline and parameters provided in **Table 13**.

Table 13: Modelling parameters and corrections to predicted impacts

Parameter	Variable	Correction	Reference
Vehicle Speed	45km/h	-5 VdB	Table 10-1
Vehicle Parameters	Worn Wheels	0 VdB	Table 10-1
Track Conditions	Special Trackwork	+10 VdB	Table 10-1

The adjustment for special trackwork relates to potential impacts generated as vehicles pass through junctions and turnouts with gaps or uneven joins in the rail. It is considered this impact may present where trains enter the TSF from the main line. The FTA guideline states that impacts associated with this variable are less significant at distant receivers, however a +10VdB correction is applied in order to conservatively assess potential impacts. No correction was applied for additional vibration generated by worn wheels as these impacts will be common to both the main rail corridor and the TSF and are considered to be represented in the existing vibration impacts presented in **Section 4**.

The impact predictions for the proposed development are presented in **Table 14**.

Table 14: Modelled vibration impacts

	Separation Distance (m)	Energy Average RMS Vibration Magnitude (ms^{-2})[1]
Measured Impact	22	0.0038 – 0.0117
Modelled Impact[2]	22	0.0116
	150	0.0031

Note 1. RMS acceleration values are calculated using the methodology presented in Section 3.3 and assumes a dominant frequency of 30Hz.

Note 2. Modelled impact is based on prediction curve adjusted to be representative of measured impacts.

5.6.3 Assessment of Impacts against Criteria for Intermittent Vibration

The results indicate that vibration impacts at residential receivers generated by trains entering the TSF are significantly lower than those generated by trains passing on the Main Northern Railway. **Table 15** presents the estimated vibration dose for receivers adjacent to the TSF based on the modelled vibration magnitude (RMS ms^{-2}) for trains entering the site.

Table 15: Modelled eVDV impact at residential receivers (ms^{-175})

Vibration Impact		Period	Pass-by Events	Period eVDV	Criteria
RMS Acceleration (ms^{-2})	0.0031	Day	16	0.032	0.2
Single Event eVDV[1]	0.016	Night	9	0.028	0.13

Note 1. eVDV value is presented for a single pass-by event using the methodology presented in Section 3.3 and assumes a pass-by time of 180 seconds

The results presented in **Table 15** are based on Stage 3 operations at the TSF and assumes the arrival of trains at the facility is equally distributed between the day and night assessment periods. The results indicate the predicted impact is below the vibration dose criteria for both the day and night periods. As the predicted vibration impact is compliant with the criteria at the nearest sensitive receiver, it is also considered to comply with the criteria at more distant receivers.

5.6.4 Assessment of Impacts against Criteria for Structural Damage

No detailed assessment of potential vibration damage to buildings was undertaken as monitoring data indicates PPV values generated by existing rail impacts on the Main Northern Railway are well below the damage criteria at separation distances exceeding 20 metres. Minimum separation distances between sources of vibration associated within the TSF and structures on adjacent properties are in the order of 170 metres. Assuming the intervening ground types are the same, the potential for vibration induced damage to structures is considered negligible.

6. CONCLUSION

Pacific National proposes to construct and operate a maintenance facility at Greta to provide support to its coal haulage business in the Hunter Valley. The site is located between the existing Main Northern Railway and the approved Hunter Expressway extension to Branxton. The purpose of this assessment was to undertake detailed assessment of potential vibration impacts associated with the construction and operation of the facility.

The results of background vibration monitoring indicate estimated vibration dose values associated with the passage of trains on the Main Northern Railway are on the order of 0.02 to 0.05 $ms^{-1.75}$. The maximum peak particle velocity result associated with train a pass-by event was 0.5 mm/s.

These results were used to calibrate the vibration impact prediction curve for locomotive powered freight and passenger rail impacts provided by the US Federal Transit Authority. Additional corrections were applied to this curve to account for lower speeds and special track work encountered as trains enter the TSF. The results of this model that receivers 150 metres to the south of the arrival track may experience eVDV on the order of 0.03 $ms^{-1.75}$, well below the 0.13 $ms^{-1.75}$ criteria for the night period. These results indicate TSF operations would comply with the criteria for both human comfort and annoyance and structural damage to buildings.

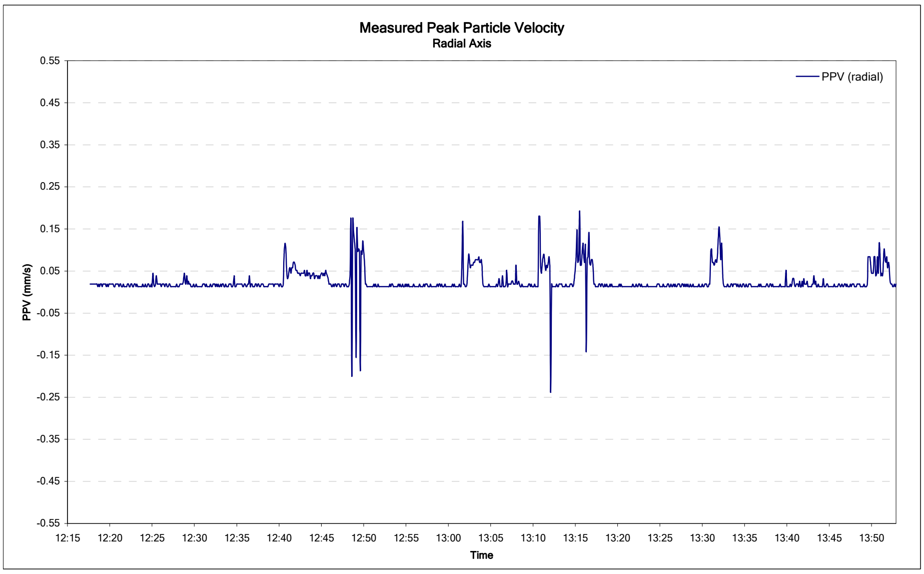
Due to the transient nature of the impact and the difficulty in evaluating a vibration dose for an activity that may vary significantly with time, assessment of potential construction vibration impacts focus on the structural damage criteria. In lieu of a published Australian Standard or guideline for this impact, assessment was undertaken against the building damage criteria presented in the US FTA guideline *Transit Noise and Vibration Impact Assessment* (1995). Analysis presented in **Section 5.2** indicates that construction vibration impacts will comply with the structural damage criteria for all building types at separation distances exceeding 20 metres.

Assessment of potential blast impacts was undertaken against the ANZEC guideline for human annoyance and BS7385-2 for damage to structures. While these results indicate overpressure and ground vibration impacts induced by blasting are likely to be well below the criteria, it is recommended a Blast Management Plan be developed to monitor impacts at receivers and allow for modification to blast designs as required.

Although considered compliant with the structural damage criteria, construction vibration impacts may remain perceptible by members of the community near to construction works. A range of potential mitigation measures outlined in the *Interim Construction Noise Guideline* (DECC, 2009) and AS2187.2-2006 *Explosives – Storage and use Part 2: Use of Explosives* may be applied to minimise vibration impacts and manage the response where impacts are perceptible by the community.

Appendix I

Vibration Monitoring: Logger Results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PPV (radial)
PPV (mm/s)
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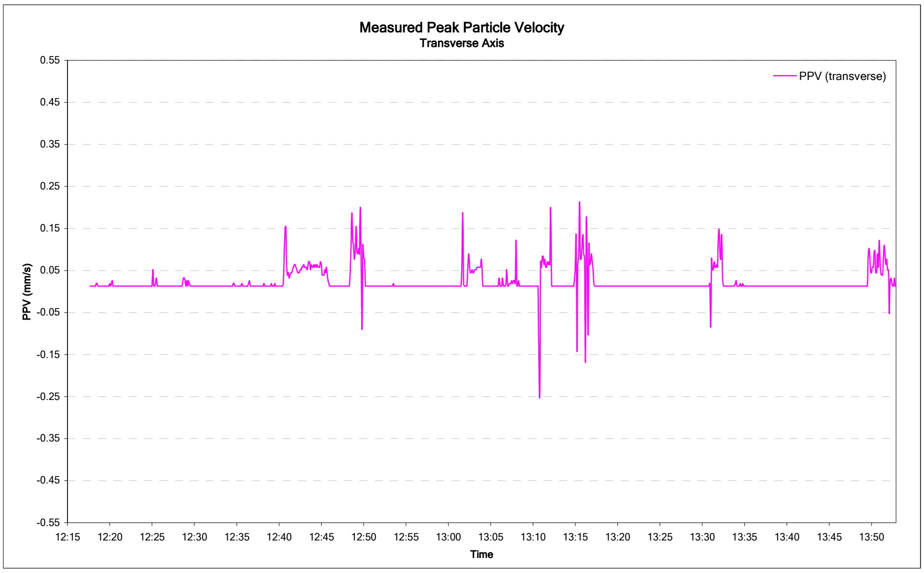
Time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PPV (mm/s)
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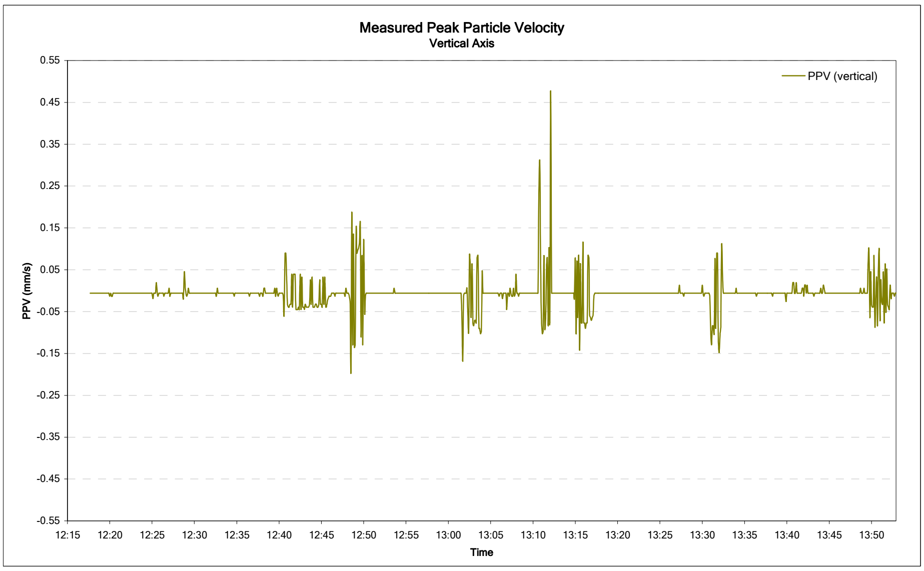
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