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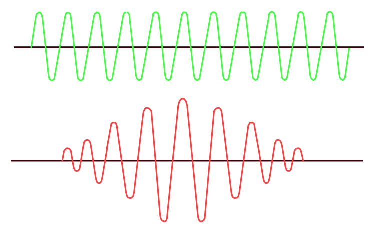
PASMINCO COCKLE CREEK SMELTER

– MASTER PLAN

Rail-Related Vibration Assessment



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Vipac Engineers & Scientists Ltd

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PASMINCO COCKLE CREEK SMELTER – MASTER PLAN

Rail-Related Vibration Assessment

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PREPARED FOR:	**PREPARED BY:**
PacLib Management Pty Ltd	VIPAC Engineers & Scientists Ltd
Suite 2, level 4, 65 Epping Road	Shop 5, Laycock Street
NORTH RYDE, NSW 2113	CAREY BAY, NSW 2283
Contact: Steve McLeod	Email: huntervalley@vipac.com.au
☎ 61 2 9490 2216	Phone: 61 2 4950 5833
Fax : 61 2 9490 2316	Fax : 61 2 4950 4276

AUTHOR:	Simon Ritchie Project Engineer	18th February 2008
REVIEWED BY:	Project Engineer	18th February 2008
APPROVED BY:	Ian Guy Manager, Newcastle Office	18th February 2008

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EXECUTIVE SUMMARY

This report provides the results, findings and recommendations arising from a vibration assessment of rail activities carried out within the boundaries of the Pasminco Cockle Creek Smelter site, Cockle Creek, NSW. The purpose of this assessment was to anticipate any adverse impact of rail-related ground vibration on future buildings located on site in terms of the following:

- Occupants discomfort; and
- Structural damage.

The vibration criteria had to conform to both standards BS 6472 and DIN 4150-3.

The future buildings proposed are residential, commercial and industrial.

This assessment highlights the following:

- Current rail-related vibration levels at the proposed development boundary, which is 18m from the rail track centreline, are well below the relevant criteria for structural damage and human perception;
- It should also be noted that vibration can be amplified in the upper floors of multi-storey buildings. This issue should be considered at design stage if such a building was to be constructed close to the rail line.

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1. INTRODUCTION

This report provides the results, findings and recommendations arising from a vibration assessment of rail activities carried out within the boundaries of the Pasminco Cockle Creek Smelter site, Cockle Creek, NSW.

The purpose of this assessment was to anticipate any adverse impact of rail-related ground vibration on future buildings located on site in terms of the following:

- Occupants discomfort; and
- Structural damage.

The future buildings proposed are residential, commercial and industrial.

2. VIBRATION CRITERIA

2.1 HUMAN PERCEPTION

As outlined in the Rail Infrastructure Corporation (RIC) guidelines, floor vibration levels in habitable rooms should comply with the criteria in British Standard BS 6472:1992 *Evaluation of Human Exposure to Vibration in Buildings (1Hz to 80Hz)*. This is the vibration standard recommended by Department of Planning (DoP) and Department of Environment and Climate Change (DECC) in the document *Assessing Vibration: A Technical Guideline (2006)*.

BS 6472 provides general guidance on human exposure to building vibration in the frequency range 1Hz to 80Hz. The standard defines curves of equal annoyance for humans for various types of building occupancy. **Figure 2-1**, **Figure 2-2** and **Table 2-1** detail BS 6472 criteria curves.

In addition to the above, BS 6472 introduces the concept of Vibration Dose Value (VDV), which addresses people response to the frequency of train movements. The VDV depends on acceleration levels and exposure time (relative to the number of train pass-by), and relate the severity of intermittent vibration to that for continuous vibration. **Table 2-2** outlines acceptable VDV values for various types of buildings, based on 16h days and 8h nights.

VDV frequency weightings to be applied to measured vibration data for human exposure analysis are detailed in BS 6841.

Figure 2-1: x-axis and y-axis criteria curves (BS 6472)

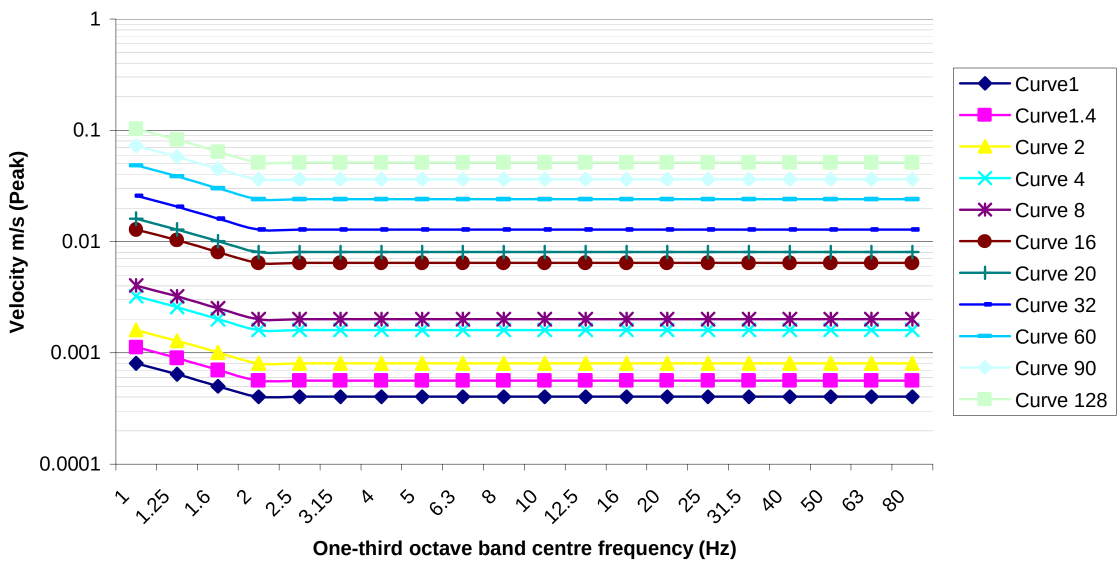


Figure 2-2: z-axis criteria curves (BS 6472)

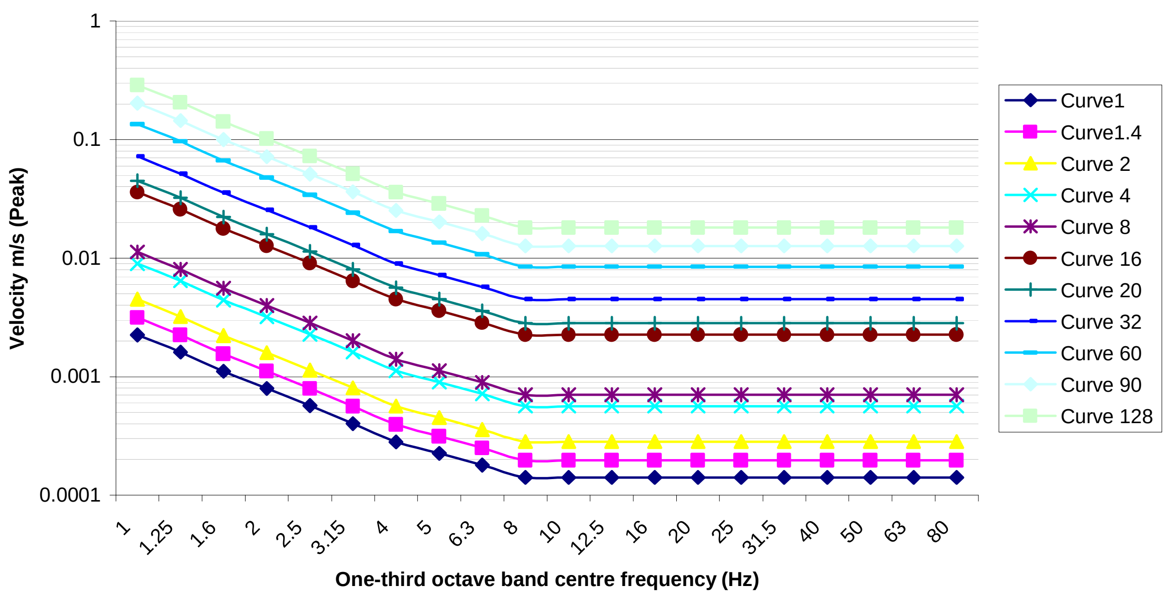


Table 2-1: Multiplying factors used to specify satisfactory magnitudes of building vibration with respect to human response

Place	Time	Multiplying Factors[1]	
		Exposure to continuous vibration (16h day, 8 h night)	Impulsive vibration excitation with up to 3 occurrences
Critical working areas (eg. precision laboratories)	Day	1	1
	Night	1	1
Residential	Day	2 to 4	60 to 90
	Night	1.4	20
Office	Day	4	128
	Night	4	128
Workshops	Day	8	128
	Night	8	128

Table 2-2: VDV ($m/s^{1.75}$) above which various degrees of adverse comment may be expected

Place	Time	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Critical working areas (eg. precision laboratories)	Day	0.10	0.20	0.40
	Night	0.09	0.18	0.36
Residential	Day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
	Night	0.13	0.25	0.51
Office	Day	0.40	0.80	1.60
	Night	0.36	0.73	1.46
Workshops	Day	0.80	1.60	3.20
	Night	0.73	1.46	2.91

2.2 STRUCTURAL DAMAGE

In the absence of any Australian Standard addressing the issue of structural damage from ground vibration, German Standard DIN 4150:1999 *Structural Vibration – Part 3: Effects of vibration on structures* is normally used as a reference. DIN 4150 recommends maximum peak particle velocity (PPV) vibration limits in mm/s for different frequency ranges to be associated with transient vibration sources. According to DIN 4150, if the recommended criteria are not exceeded, damage that reduces the serviceability of a building should not occur.

The minimum "safe limits" of for short –term vibration for different types of buildings and intermittent vibrations is presented in **Table 2-3** below.

[1] The multiplying factors lead to magnitudes of vibration below which the probability of adverse comments are rare.

Table 2-3: DIN 4150 – Minimum "safe limits"

Type of Structure	Peak particle velocity guide values PPV (mm/s)			
	At Foundation			At plane of floor of uppermost full storey (all frequencies)
	< 10 Hz	10 to 50 Hz	50 to 100 Hz * and above	
1.Buildings used for commercial purposes, industrial buildings or similar design	20	20 – 40	40 – 50	40
2.Dwellings and buildings of similar design and/or use	5	5 – 15	15 – 20	15
3.Structures that, because of their particular sensitivity to vibration do not correspond to those listed in 1 and 2 and are of great intrinsic value (e.g. buildings that are under a preservation order).	3	3 – 8	8 – 10	8

3. METHODOLOGY

Vibration measurements were taken on site along a straight section track, 5m from the rail centreline as shown in figure. The measurements were taken on the 4th of October between 1pm to 5pm and the 5th of October between 10am and 12pm.

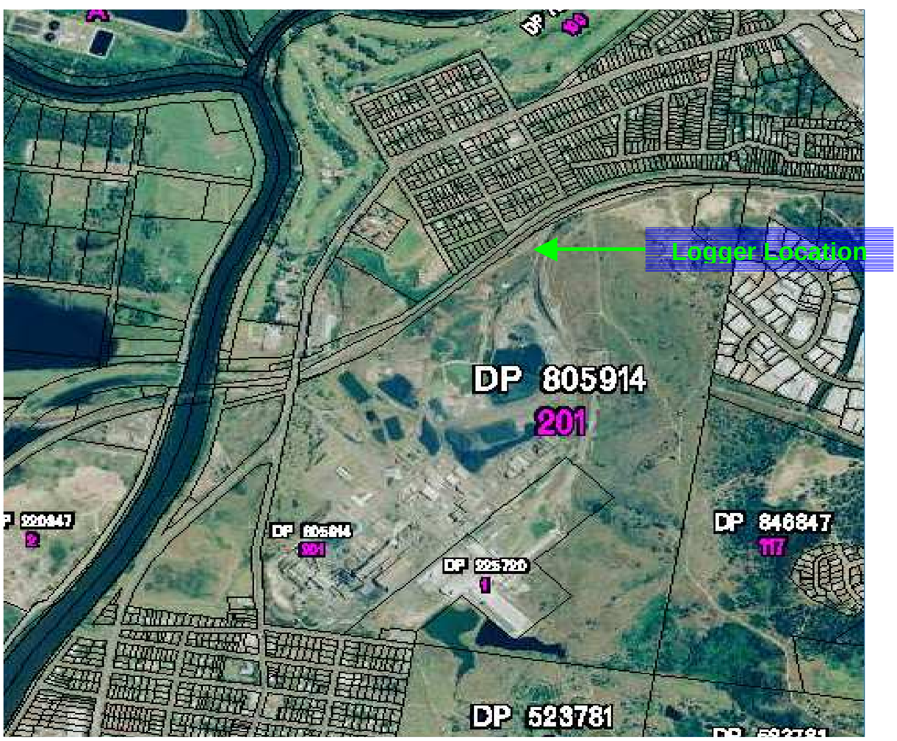


Figure 3-1. Aerial photo of site showing location of logger. *Map taken from iplan.australis.net.au*

The following train pass-by's were monitored:

Table 3-1: Monitored Pass-by's

Date	Time	Train ID	Direction	Train Description
Oct 4 /07	13:27	27	North	Freight
Oct 4 /07	13:37	28	North	3 car Passenger
Oct 4 /07	13:38	29	South	2 car Passenger
Oct 4 /07	13:44	30	North	8 car Country Link
Oct 4 /07	13:50	31	South	4 Car Passenger
Oct 4 /07	14:34	1	South	8 car Country Link
Oct 4 /07	14:36	2	South	6 car Passenger
Oct 4 /07	14:48	3	North	2 car Passenger
Oct 4 /07	14:53	4	South	5 car Country Link
Oct 4 /07	14:56	32	North	Freight 42 cars
Oct 4 /07	15:22	6	South	2 car Passenger
Oct 4 /07	15:23	7	North	72 car Freight
Oct 4 /07	15:38	8	South	2 car Passenger
Oct 4 /07	15:45	9	North	4 car Passenger
Oct 4 /07	15:55	11	South	72 car Freight
Oct 4 /07	16:14	12	North	2 car Passenger
Oct 4 /07	16:34	13	South	2 car Passenger
Oct 5 /07	10:37	16	North	8 car Passenger
Oct 5 /07	10:38	17	South	2 car south
Oct 5 /07	10:49	18	South	4 car Passenger
Oct 5 /07	10:51	19	North	2 car Passenger
Oct 5 /07	10:56	20	South	> 50 car Freight
Oct 5 /07	11:20	21	North	Empty Coal Train
Oct 5 /07	11:37	22	North	4 car Passenger
Oct 5 /07	11:39	23	South	2 car Passenger
Oct 5 /07	11:46	24	North	2 car Passenger
Oct 5 /07	11:48	25	South	8 car Passenger
Oct 5 /07	11:53	26	North	42 car Full Coal Train

Measurements were conducted with 2 Instantel Minimate Plus (Serial No.12000, 11828).

The Instantels were set up to measure instantaneous particle velocity levels once an attendant had manually started them.

The monitor was used to measure the velocity in 3 directions. Data signals were recorded digitally at a sample rate of 1024 and 2048Hz and Instantel Blastware Software was used to analyse the data.

Data processing and analysis followed the sequence below:

- Analysis of the velocity time waveforms and conversion of particular events in the frequency domain using fast Fourier transforms (FFT);
- Differentiation of the velocity time waveforms into acceleration time waveforms;

- FFT analysis of the acceleration waveforms to identify the measurements frequency content and comparison against BS6472 criteria curves. FFT analysis was conducted on sections of the time signal showing outstanding peaks.
- The Instantel Blastwave software was used to calculate the VDV levels for human exposure analysis. The frequency weightings outlined in BS 6841 were applied using the Wb weighting curve for vibration in the vertical direction and the Wd weighting curve for transverse and lateral vibration.
- The daily VDV was calculated for the worst-case scenario. The highest VDV for each train type was applied to a list of worst-case daily train volumes and summed to calculate the daily VDV. Train volumes were gathered from a review of CityRail passenger service timetables and freight train movements on the Main Northern Railway.

Table 3-2: Worst-Case Daily Train Volumes

Train Type	Worst Case Daily Train Volume
Heavy Rail (Freight, Coal)	43
Passenger	32
Total	75

To provide a measure of conservatism, all Freight trains were assumed to consist of a diesel locomotive dragging 50-70 freight cars with a pass-by time of 80 seconds and the highest acceleration levels occurring for 10% of the time, as witnessed on site with the larger trains.

4. RESULTS & DISCUSSION

4.1 STRUCTURAL VIBRATION

The figures below present the velocity waveforms for the two trains that produced the highest peak particle velocity values. The waveforms are shown in all three directions (relative to the rail line axis).

Figure 4-1: Country Link, South Bound 2:34, 4/10/2007

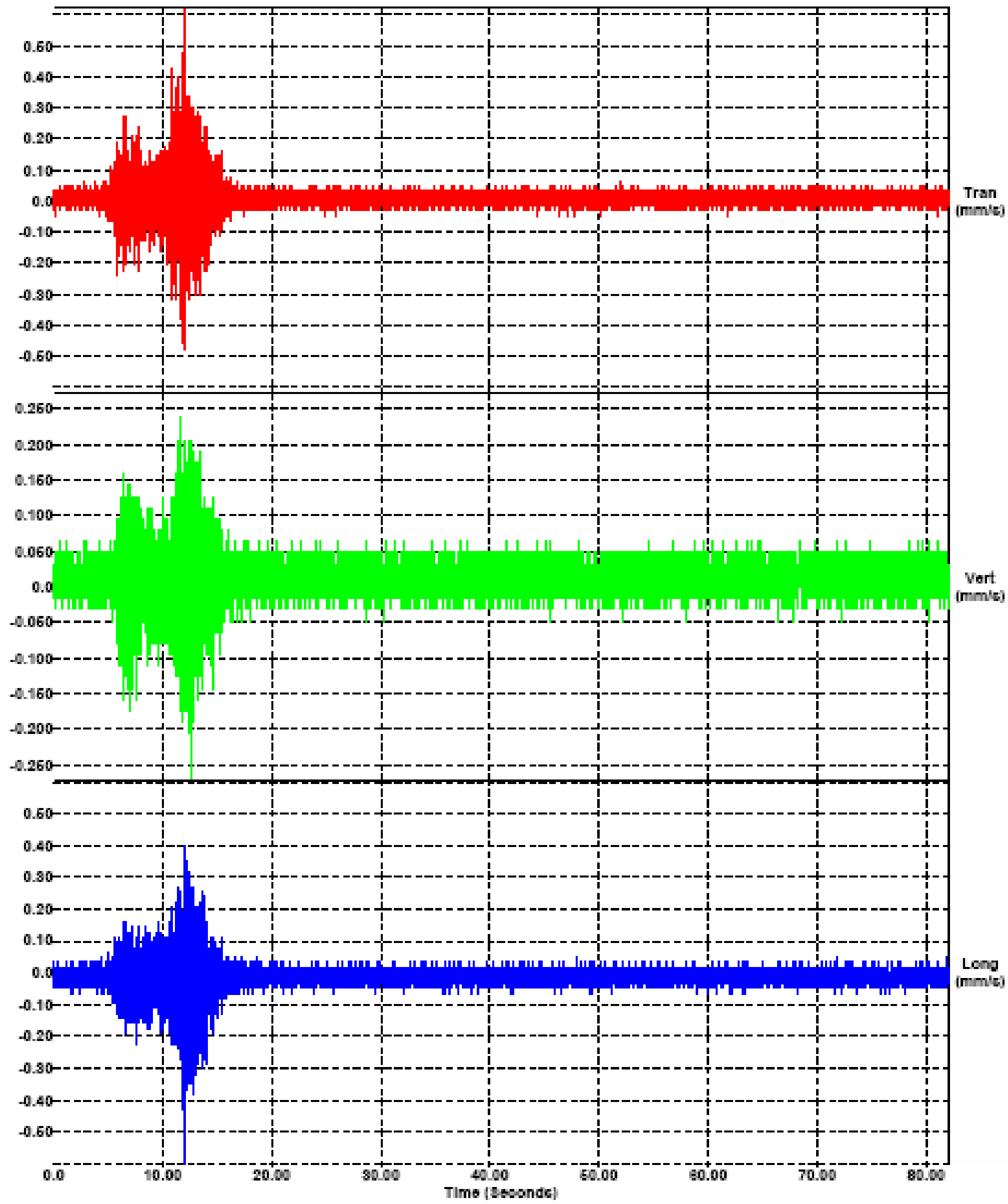


Figure 4-2: Freight Train, North Bound, 3:23pm 4/10/2007

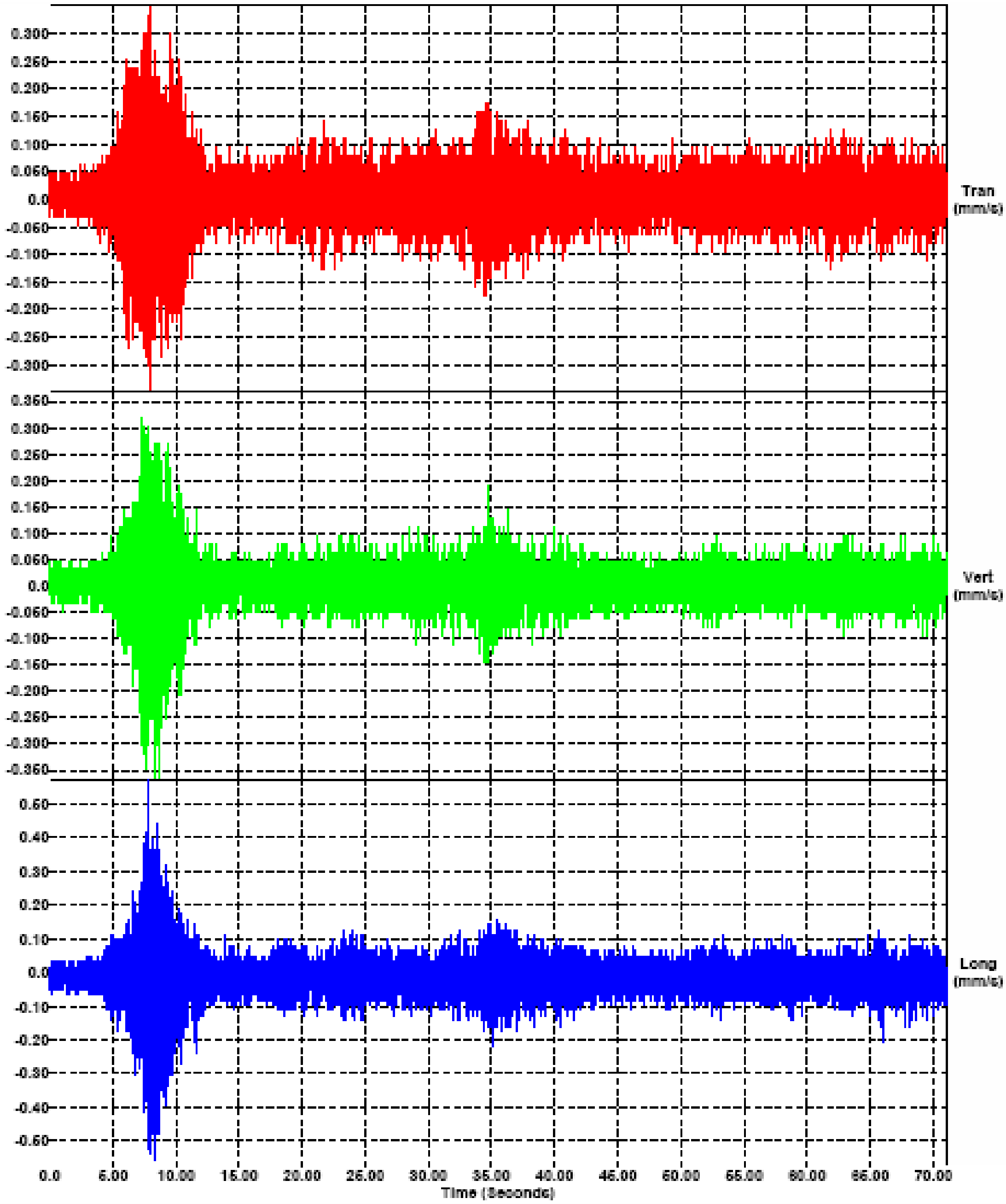


Table 4-1: Summary of Peak Particle Velocity for all Trains, Sorted by PPV.

Train Type	No. Cars	Direction	Time	Date	Tran Peak (mm/s)	Vert Peak (mm/s)	Long Peak (mm/s)	PVS (peak vector sum)
Country Link	8	South	14:34	4-Oct	**0.619**	0.27	0.603	0.791
Freight	72	North	15:23	4-Oct	0.349	0.365	0.571	0.613
Freight	>50	South	10:56	5-Oct	0.444	0.381	0.571	0.594
Freight	-	North	13:27	4-Oct	0.46	0.46	0.492	0.581
Freight	72	South	15:55	4-Oct	0.397	0.238	0.397	0.477
Country Link	8	North	13:44	4-Oct	0.302	0.27	0.429	0.436
Country Link	5	South	14:53	4-Oct	0.302	0.159	0.365	0.379
Passenger	6	South	13:50	4-Oct	0.27	0.175	0.333	0.352
Empty Coal Train	42	North	11:20	5-Oct	0.19	0.19	0.254	0.289
Coal Train Full	42	North	11:53	5-Oct	0.238	0.159	0.254	0.288
Passenger	8	South	11:48	5-Oct	0.238	0.143	0.222	0.274
Freight	42	North	14:56	4-Oct	0.206	0.175	0.238	0.272
Passenger	4	South	10:49	5-Oct	0.159	0.143	0.222	0.242
Passenger	2	South	15:38	4-Oct	0.175	0.127	0.206	0.239
3 car north & 2 car south		-	13:37	4-Oct	0.175	0.127	0.206	0.223
Passenger	2	South	16:34	4-Oct	0.206	0.111	0.222	0.223
Passenger	6	South	14:36	4-Oct	0.206	0.143	0.175	0.212
Passenger	2	South	15:22	4-Oct	0.143	0.111	0.19	0.203
8 car north & 2 car south		-	10:37	5-Oct	0.127	0.111	0.175	0.181
Passenger	2	South	11:39	5-Oct	0.127	0.111	0.159	0.166
Passenger	4	North	15:45	4-Oct	0.143	0.0952	0.127	0.163
Passenger	4	North	11:37	5-Oct	0.127	0.0794	0.127	0.153
Passenger	2	North	14:48	4-Oct	0.0952	0.111	0.127	0.143
Passenger	2	North	16:14	4-Oct	0.111	0.0952	0.0952	0.128
Passenger	2	North	10:51	5-Oct	0.0952	0.0635	0.0952	0.108
Passenger	2	North	11:46	5-Oct	0.0794	0.0635	0.0794	0.102

The above table and associated waveforms raise the following comments:

- The highest peaks are generally experienced when the train engine passes by the measuring equipment. Regardless of the frequency content of the waveforms, peaks are well below the most stringent criteria of 3mm/s for sensitive buildings .

- The highest peak particle velocity measured was 0.619mm/s.

- With reference to Table 2-3, the velocity waveforms show that vibration levels are well below the structural damage criteria for residential, commercial and industrial buildings at 5 metres from the track centreline. Vibration levels will decrease as the distance from the track increase. Provided that the train speed and weight of the trains does not increase significantly, it is our opinion that there is no risk for structural damage for buildings located at distances greater than 5 metres from the track. A train would have to produce PPV greater than 3mm/s (five times higher than the PPV measured during the survey) for it to approach the minimum safe limits for sensitive buildings;

- The structural damage criteria are based on instantaneous peak particle velocity levels and are therefore not dependent on the number of trains using the rail line over a given period. As a result, compliance with these criteria will not be affected should train volumes increase, as long as these trains are not significantly heavier or travel significantly faster than those measured.

4.2 HUMAN PERCEPTION

VDV results for the monitored pass-by's are summarised in Table 4-2 below, showing the frequency weighted results for vertical, longitudinal and transverse directions. The table is sorted by vertical VDV in decreasing order.

Table 4-2: Summary of Peak Particle Velocity for all Trains, Sorted by PPV

Train ID	VDV Tran ($m/s^{1.75}$)	VDV vert ($m/s^{1.75}$)	VDV long ($m/s^{1.75}$)	RMS (m/s^2)	Train ID	VDV Tran ($m/s^{1.75}$)	VDV vert ($m/s^{1.75}$)	VDV long ($m/s^{1.75}$)	RMS (m/s^2)
27	0.00332	**0.0224**	0.00299	0.00688	9	0.00101	**0.00589**	0.00089	0.00175
7	0.00270	**0.0210**	0.00362	0.00492	18	0.00104	**0.00577**	0.00144	0.00232
20	0.00273	**0.0189**	0.00348	0.00390	28	0.00096	**0.00555**	0.00131	0.00149
11	0.00207	**0.0130**	0.00244	0.00437	8	0.00083	**0.00525**	0.00121	0.00283
30	0.00177	**0.0120**	0.00191	0.00632	13	0.00097	**0.00496**	0.00111	0.00175
21	0.00158	**0.0119**	0.00167	0.00239	16	0.00094	**0.00490**	0.00111	0.00158
1	0.00226	**0.0116**	0.00217	0.00261	23	0.00070	**0.00452**	0.00082	0.00129
32	0.00155	**0.0098**	0.00185	0.00262	6	0.00084	**0.00440**	0.00118	0.00254
31	0.00146	**0.0076**	0.00216	0.00208	3	0.00053	**0.00427**	0.00056	0.00090
25	0.00137	**0.0072**	0.00174	0.00296	22	0.00076	**0.00414**	0.00081	0.00135
4	0.00182	**0.0070**	0.00248	0.00364	12	0.00056	**0.00398**	0.00058	0.00097
26	0.00127	**0.0070**	0.00134	0.00224	19	0.00050	**0.00316**	0.00045	0.00082
2	0.00124	**0.0061**	0.00123	0.00147	24	0.00049	**0.00291**	0.00042	0.00091

The above table and spectra presented in appendix A raise the following comments:

- Spectra show that vibrational energy is consistently comprised between 15Hz and 80Hz, with negligible components at frequencies below 15Hz. With reference to the BS 6472 criteria curves, this frequency range corresponds to less stringent criteria regardless of the vibration direction.
- The highest RMS acceleration recorded was **0.00688m/s^2**, measured in the vertical direction.
- According to BS 6472, for comments or complaints about vibration to be rare, the vibration must be less than the values specified in the base curves represented in figure 2-1 and 2-2. Table 2-1 is used to determine which base curve is applicable for different building types.
- The vibrations recorded were well below even the most stringent criteria curves. As a result, it is our opinion that train vibration will not have an adverse impact on the occupants of future residential, commercial and industrial buildings on site.
- Estimated daily VDV for the site at the development boundary, 18m from the track under worst-case train vibration is**: 0.0659$m/s^{1.75}$**
- Estimated night-time VDV for the site at the development boundary, 18m from the track under worst-case train vibration is**: 0.0501$m/s^{1.75}$**

Results suggest that under BS 6472 human exposure criteria, adverse comments are a low probability for residential, commercial and industrial buildings located 18 metres from the track. On this basis, the distance from the track to the current development boundary provides a sufficient buffer zone between the track and the nearest buildings. Should plans arise to significantly increase the rail movements on the line, further assessment should be conducted to consider these increases. At present no increases are expected. Additionally, for the VDV to approach levels corresponding to possible/probable adverse comment, train movements would need to increase to unprecedented numbers.

5. CONCLUSION

This assessment highlights the following:

- Current rail-related vibration levels at 18m from the rail track centreline are well below the relevant criteria for structural damage and human perception;

- The low vibration levels are essentially due to the type of trains predominant on this line, the good condition of the track, the distance to the development, and the relatively short time of each train passby.

- The site is suitable for the construction of residential buildings provided that the 18-metre buffer remains from the track to the residence.

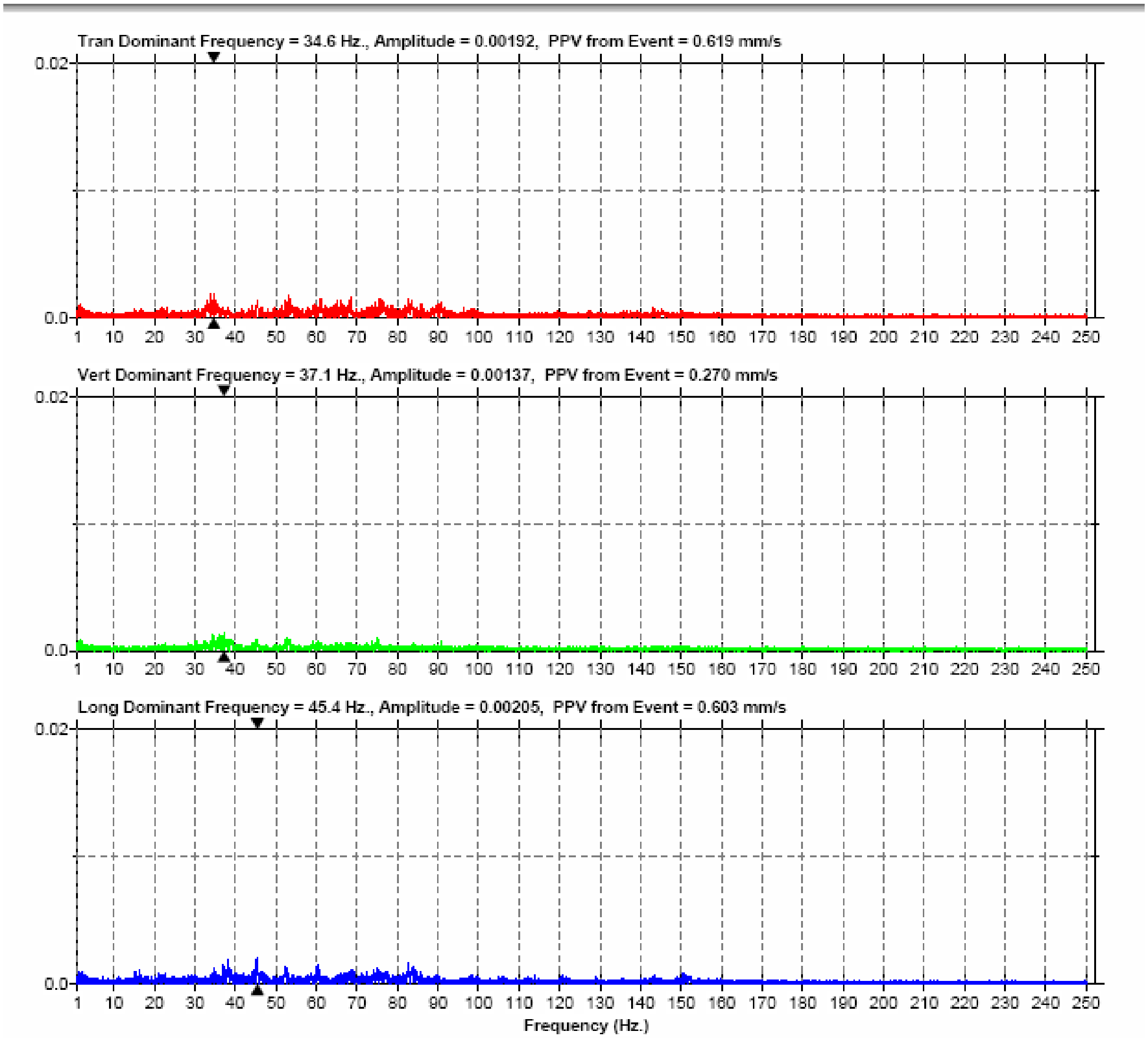
- It should also be noted that vibration can be amplified in the upper floors of multi-storey buildings. This issue should be considered at design stage if such a building was to be constructed close to the rail line.

APPENDIX A – PEAK PARTICLE VELOCITY IN TRANSVERSE, VERTICAL AND LONGITUDINAL DIRECTIONS WITH RESPECT TO FREQUENCY.

The following graphs show the peak particle velocity with respect to frequency for the four trains that showed the maximum vibration. For each train the vibration in the transverse, vertical and longitudinal directions is shown.

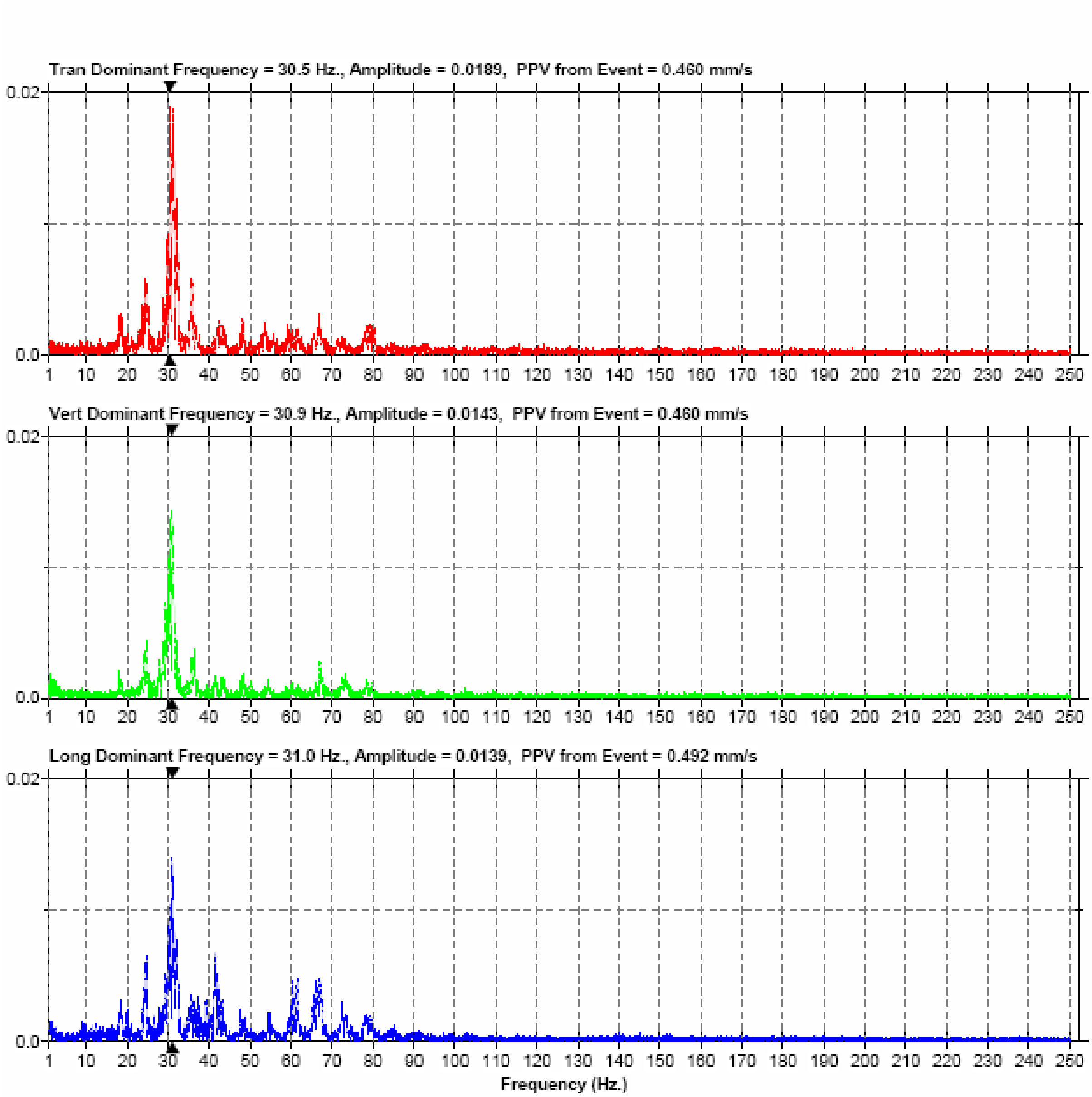
All charts in mm/s

8 car Country Link Passenger Train, South Bound at 2:34pm 4/10/2007



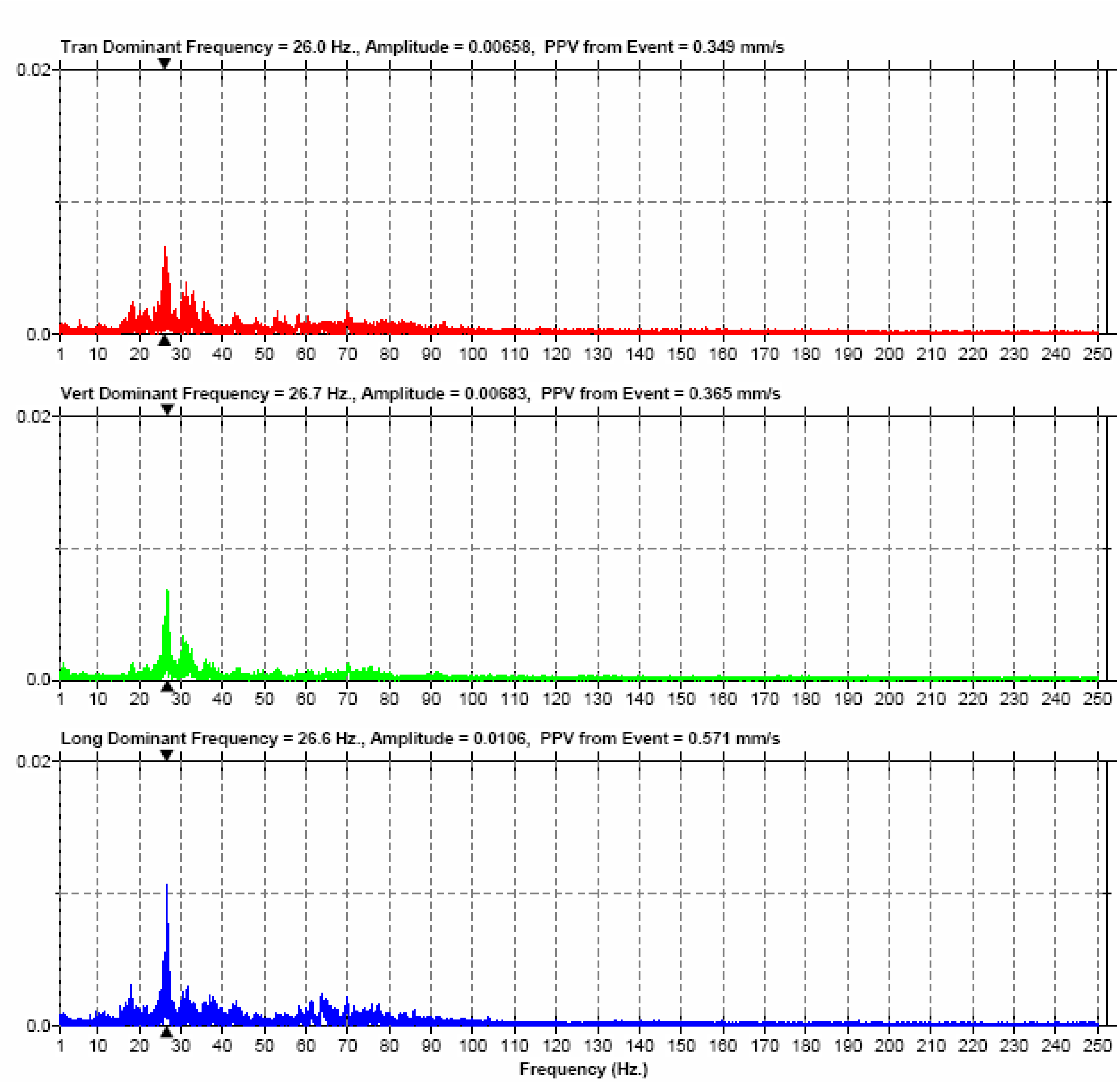
North Bound Freight Train, 13:27 4/10/2007

All charts in mm/s



North Bound Freight Train. 3:23 4/10/2007

All charts in mm/s



South Bound Freight Train, 10:56 5/10/2007

All charts in mm/s