East – West Rail: Phase 1

ATKINS

Chiltern Railways Company Limited

Plain Line Vibration Assessment and Mitigation

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Plan Design Enable

Notice

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Executive summary

Atkins is currently undertaking the detailed design of the proposed double-tracking of Oxford to Bicester Rail line (referred to as the 'Scheme' in this document). There are a number of vibration conditions which need to be discharged with the local planning authority before the Scheme can be built.

This report deals with vibration form the plain line, and vibration from switches and crossings will be considered in a separate report. The aim of this report is to present appropriate data and analysis, and based on the relevant vibration conditions, make recommendations on suitable form of mitigation measures, to support the application process.

There are 9 vibration-sensitive dwellings which have been considered in detail as part of this assessment. The assessments take into account the best available information on the number, type and speed of trains during day-time and night-time as well as the distance between individual tracks and vibration-sensitive dwellings.

A number of vibration measurements have been undertaken as part of this project to identify appropriate data for use in the assessments. Over the course of a number of site visits, data from 70 pass-by events have been captured. These included 51 passenger trains, 16 freight trains and 3 stone trains. The full details of each pass-by event including speed, vehicle type, number of wagons and distance from the track were noted.

Two different approaches were used to estimate Vibration Dose Value (VDV) based on information from vibration measurement surveys and other empirical analysis. The first approach was based on analysis of measured vibration acceleration levels, in dB, to identify vibration decay characteristics with distance at individual 1/3 octave band frequencies. The second approach used the measured data to derive appropriate vibration decay curves for distance attenuation, in single VDV figures, which could be used directly to assess compliance with project limits. The results from both approaches were found to be consistent.

The calculated VDVs at all 9 vibration-sensitive properties were shown to be below project VDV limits. The predicted night-time VDVs at Islip, Kareol (0.16 $m/s^{-1.75}$), which is the dwelling with the highest predicted level, was 20% below the project limits (0.2 $m/s^{-1.75}$).

Analysis of measured data indicated that the predictions incorporate sufficient factor of safety to demonstrate that the predicted VDVs are robust in determining compliance with project limit values. For passenger trains, predicted vibration levels were 3.5dB higher than the average values and 95% of all measurements were observed to be on or below the regression curve. For freight trains, the predicted vibration levels were 2.5dB higher than the average values and 90% of all measurements were shown to be on or below the regression curve.

As part of the assessment process, Edilon Sedra, suppliers of vibration isolation systems, were requested to provide an insertion loss prognosis for a sub ballast mat system, which was identified as a suitable form of mitigation from an engineering point of view. Although the subsequent analysis showed that project VDV limits would not be exceeded, potential mitigation measures were considered at Islip, Kareol. The details of the theoretical model, input assumptions and the findings of the assessments are described in this report, including the full mitigation parameters. If installed, this system could provide a further 23% reduction in the calculated VDVs. This would lower the predicted VDVs at Islip, Kareol to 0.13 $m/s^{-1.75}$. However on the basis of the assessments there is no requirement to implement mitigation measures at the dwellings.

1. Introduction

1.1. Atkins is currently undertaking the detailed design of the proposed double-tracking of Oxford to Bicester Rail line (referred to as the 'Scheme' in this document). There are a number of vibration conditions which need to be discharged with the local planning authority before the Scheme can be built.

1.2. This report deals with vibration form the plain line, and vibration from switches and crossings will be considered in a separate report. The aim of this report is to present appropriate data and analysis, and based on the relevant vibration conditions, make recommendations on suitable form of mitigation measures, to support the application process.

1.3. The structure of the report is as follows;

- Section 2 provides details of the project background and the main assumptions made.
- Section 3 gives details of vibration monitoring survey methodology and measured levels.
- Section 4 provides an analysis of measured vibration levels at a control position to identify the influence of track and to derive appropriate speed relationships with vibration.
- Section 5 provides an analysis of measured vibration levels, normalised for speed, to identify vibration decay characteristics, in dB, with distance at individual 1/3 octave band frequencies, for passenger and freight trains.
- Section 6 presents empirical relationships for deriving VDV adjustment factors for small variations in train speeds.
- Section 7 provides an analysis of vibration levels and derives decay relationships for VDVs with distance.
- Section 8 presents the findings of the assessment, both for current situation and for the proposed Scheme, using the two approaches described in Sections 5 and 7. The VDV estimates for the current situation are compared with measured VDVs reported in the Environmental Statement, where these are available for the receptor under consideration.
- Section 9 provides a summary of calculated VDVs, identifies dwellings which could qualify for mitigation and presents an analysis of a mitigation option.
- Section 10 provides a discussion of the main findings of the study.
- Section 11 contains the conclusions to the report.
- Section 12 makes recommendations regarding potential mitigation measures.

1.4. A glossary of technical terms is provided in **Appendix A**.

2. Methodology

Project Vibration Limits

2.1. The vibration limits, in Vibration Dose Value (VDV), which the Scheme is required to meet in occupied vibration-sensitive receptor buildings adjacent to the Scheme are summarised below;

- Day (0700 – 2300 hours) - 0.4 $m/s^{1.75}$
- Night (2300 – 0700 hours) - 0.2 $m/s^{1.75}$

2.2. Vibration Dose Value (VDV) is a measure of the accumulated level of vibration over a period, and, through the application of BS6472 [**1**], is a standard metric for predicting the likelihood of adverse comments from building occupants. According to the guidance contained in the standard, the probability of adverse comment at or below the described threshold VDV levels, as adopted by the Scheme, is low.

Background

2.3. Atkins prepared a Vibration Mitigation Strategy report (reference: 5114534-ATK-EWRP1-AV001) in December 2012, which has been reviewed in a report dated February 2013 by the Independent Expert (IE) appointed by the Local Authority. The main elements of the review which are relevant to the current assessments are summarised here for completeness.

Scheme Variables

- The assumptions made regarding the number of train movements as part of this study are reasonable;
- The 15m distance limit used for identifying properties at risk from vibration impacts is sensible and all such properties have been fully identified;
- The main parameters of concern due to double tracking and re-alignment are as follows; change of distance between track and property, change in line speeds and change in the number of trains during day and night;
- Other scheme wide changes, including train types, are not expected to result in significant changes in vibration levels.

Assessment

- It is reasonable to base the decay in vibration levels with distance from the track, provided suitable measurement information is available, from a site with the correct geotechnical conditions;
- It is reasonable to make corrections to RMS vibration data to allow for small speed adjustments;
- The assessments should use separate event VDVs for passenger and freight trains;
- The distance to each track from the properties at risk should be considered individually.

Vibration Monitoring

- Further vibration monitoring should be made at Oxford (Wolvercote) on the main line (DCL) where train speeds are closer to the operational speeds of the new line and the soil geology is representative of the study area. The measurements should provide vibration information at various distances and appropriate frequency information should be obtained to support the choice and design of mitigation measures. The information should relate to passenger and freight trains, separately.

General Approach

2.4. The preferred unit adopted for train speeds throughout this report is in miles per hour (mph), which is in line with the existing and design line speed convention provided in design coordination drawings.

2.5. As described above, the project limits are in VDVs. VDV is obtained by weighting the rms acceleration values as appropriate at one-third octave frequency bands and combining these together to obtain a single value. Therefore frequency characteristics are appropriately reflected in the definition of VDV. In this project acceleration has been the preferred unit of measurement for vibration levels. Where possible, the assessment has been based on true VDVs as obtained from direct measurements on site. In other instances, rms acceleration values have been converted to decibels (dB) for undertaking additional assessments, and then converted back to VDVs. Working in VDVs meant that compliance with project limits could be clearly demonstrated.

2.6. There are 9 No. vibration-sensitive dwellings which have been considered in detail as part of this assessment.

2.7. The assessments take into account the best available information on the number, type and speed of trains during day-time and night-time as well as the distance between individual tracks and vibration-sensitive dwellings. For each receiver, the full details of assumptions on distance from track, number, type and speed of trains are shown in **Appendix B**.

2.8. The estimates of vibration dose values (VDV) are undertaken based on information from targeted vibration measurement surveys and other empirical relationships. A number of technical sources have been used in this assessment and a list of technical references is provided in **Appendix C**.

2.9. VDVs are initially estimated for the existing situation at all 9 No. receivers. The estimates are then extended to the scenario which represents the expected operational characteristics of the Scheme in the future. Where the Scheme vibration limit values are exceeded, appropriate recommendations are made regarding the type of mitigation measures which may be appropriate and a performance specification for these is given.

Assumptions

2.10. Although part of the same Scheme, the only section not being double-tracked at this stage is between Woodstock Junction and North Oxford. However, when designing mitigation measures, potential impacts of this future double tracked section needs to be taken into account, as part of the planning application for the Scheme. Although the full details of the alignment of this section of the track are not known at this stage, the design is likely to follow a similar alignment to the proposed double-track in line with the rest of the Scheme being considered in this report. Assumptions have been made on an envisaged outline alignment to enable vibration impacts to be appropriately assessed.

2.11. Where a group of properties in a similar location is identified as being at risk of exceeding project vibration thresholds, the distance between the tracks and the nearest property have been used in the assessments. It is assumed that the choice of mitigation at that location would be dictated by vibration levels at the nearest property to the tracks.

2.12. The distances between existing track and dwellings have been measured using electronic Ordnance Survey maps. The distances between realigned and new track have been measured using the latest electronic design coordination drawings. The speed profile information is as shown on the coordination drawings. The number and type of trains are based on various project documentation including the Noise and Vibration Policy and Environmental Statement. On all track sections, an even split is assumed for the number of trains travelling in each direction.

2.13. The speed information shown on the speed diagrams are the maximum permitted. Due to the braking and acceleration patterns, the trains will not be at the maximum speed for the whole route. The assessment does not consider acceleration or braking or the resulting changes in speed profiles where these occur.

2.14. The so-called ‘stone train’ travels from various locations, but ultimately at present comes from the Oxford direction to the Banbury road sidings (east of Oxford Parkway station). This is expected to remain the same in the future. However during construction there may need to be temporary access arrangements from the East (Bicester end) between February 2014 and September 2014 (via Claydon jct) and between September 2014 and February 2016 (via the new chord line). The assessments have been based on the current and the future situations. The potential impacts of the temporary access arrangements are not considered in this report. The potential impacts of stone train are only considered at 3 Bladon Close and Quadrangle due to the current and anticipated future route of the train.

2.15. The assessments do not take into account the building response for any of the properties. It is assumed that the levels calculated outside the buildings will be representative of those measured on the floor inside the building.

2.16. This report does not consider any synergies with the noise assessments or mitigation measures specifically being developed to minimise potential noise impacts.

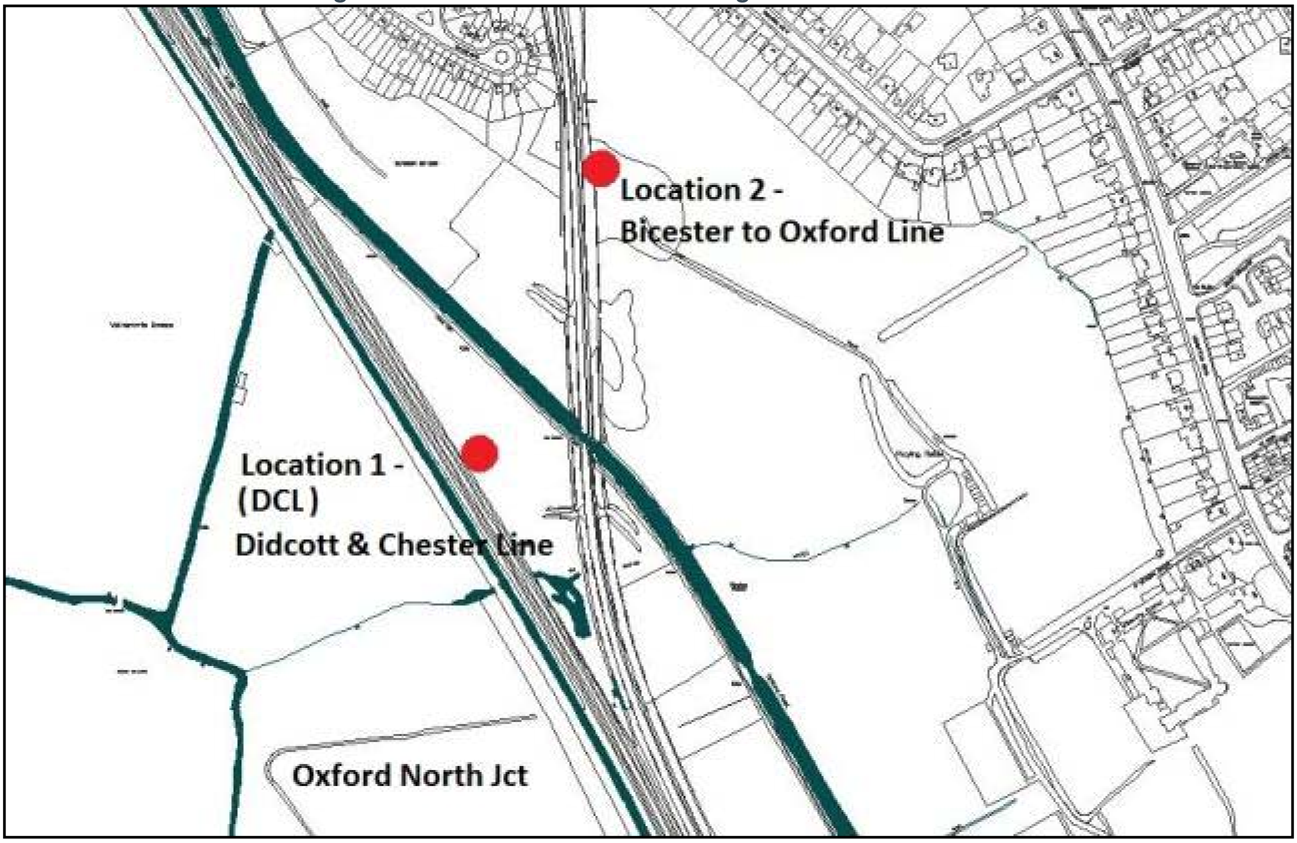
3. Vibration Monitoring Survey

3.1. Vibration measurements were undertaken by Atkins during three separate site visits on; Thursday 14th March; Thursday 25th April, and for two consecutive days on Wednesday 9th & Thursday 10th October, all in 2013.

Introduction

3.2. An initial desk-based investigation identified four potential vibration monitoring sites. A subsequent site visit by Atkins ascertained that none of these sites was suitable for the desired programme of monitoring. The main issues were noted as presence of a watercourse and a retaining wall next to the track, presence of former trackbed, lack of space for measurements and access issues. Following this site selection process, two new measurements sites were identified as suitable alternatives. The approximate location of the two measurements sites are shown on the Figure 1 below.

Figure 1. Vibration Monitoring Locations



3.3. The measurements along Bicester to Oxford Line (Location 2) were intended to capture data from the pass-by of a stone train, which is generally considered to generate a higher level of vibration compared with ‘conventional’ freight trains. The measurements on the DCL (Location 1) were aimed at obtaining data from faster moving trains approaching the design speeds of the trains on the proposed scheme.

3.4. The ground type in this general area is understood to be a substrate of Oxford Clay (un-weathered).

3.5. Measurement Location 1 was just outside the Network Rail boundary, at the bottom of the railway embankment, approximately 1.5 metres below rail head, in an area of grassland currently used as a small holding by the local school for keeping some animals.

3.6. Location 2 was within Network Rail land on top of the embankment, approximately 0.5 metres lower than the rail head. This area of made ground is thought to be of the same age as the railway construction.

3.7. Photos of the general measurement locations are presented in the figures below:

Figure 2. Location 1 – Oxford to Banbury (DCL) Line

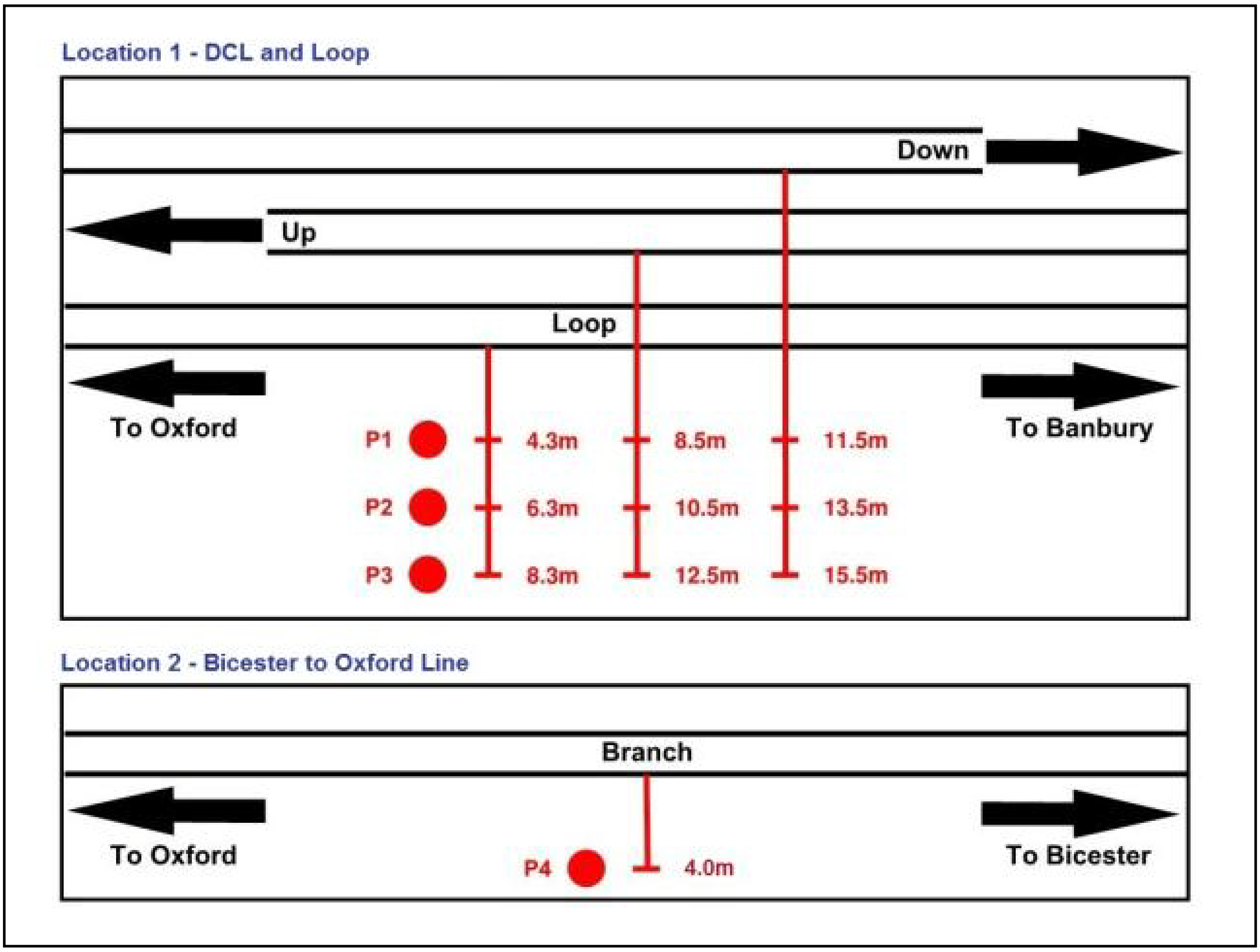
Figure 3. Location 2 – Bicester to Oxford (OXD) Line

Measurement Positions

3.8. At each location the ground was prepared for each measurement position by using a trowel to dig a shallow hole, approximately 50mm to 100mm deep, which was made level and any loose material removed. Plaster of Paris was mixed on site and poured into the hole, then a solid steel plate (100mm x 100mm x 15mm) was placed level into the plaster. This heavy metal platform was then used to mount the accelerometers.

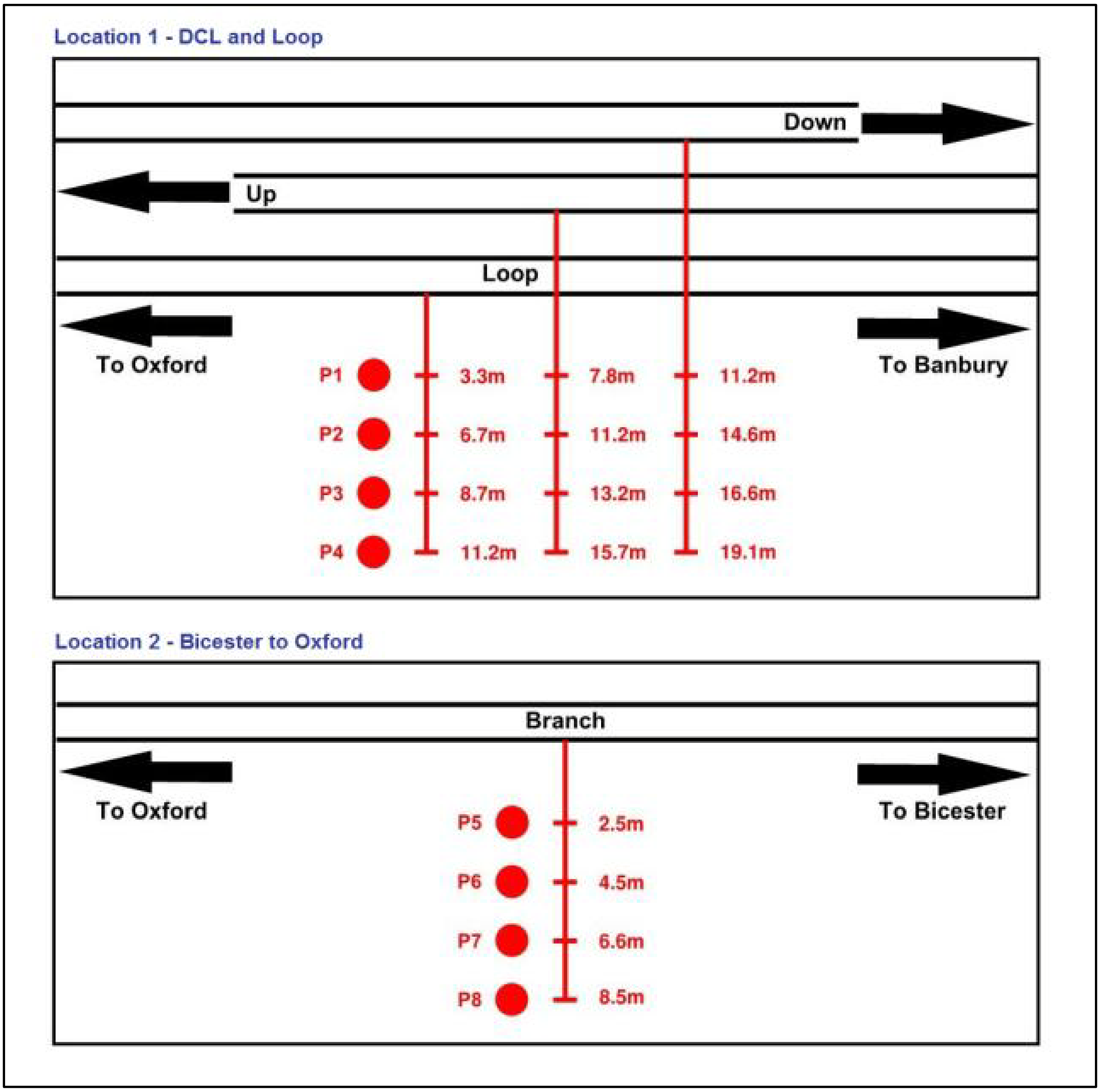
3.9. For the measurements taken on the 14th March and 25th April, at measurement Location 1 three measurement positions were set up at different distances, perpendicular to the track. At Location 2 only one measurement position was established due to the physical constraints of the site. The Figure 4 below shows the arrangement of measurement positions in relation to the track at this site.

Figure 4. Measurement Positions in Relation to Track (March/April)



3.10. For the measurements taken on the 9th and 10th October, four positions were set up at location 1 at sequential distances, perpendicular to the track. At location 2 four further positions were set up, again perpendicular to the track. Figure 5 shows the arrangement of measurement positions in relation to the track.

Figure 5. Measurement Positions in Relation to Track (October)



3.11. During the latter survey on the DCL and Loop lines, a control distance from each track was maintained. The measurement of distances between measurement positions and the tracks were further improved in accuracy with the use of a laser distance measurer.

3.12. At each position the orientation of the accelerometers in relation to the railway tracks was as follows:

- X axis (horizontal) – perpendicular to the tracks
- Y axis (horizontal) – parallel to the tracks
- Z axis (vertical) – vertical to the tracks

3.13. An example of the measurement position set up can be seen in the Figure 6:

Figure 6. Example Measurement Position Accelerometer Set Up

Equipment Set Up

3.14. All the instruments used to undertake ground vibration measurements were provided by Acoustic1 Limited. The general set up was a combination of tri-axial and mono-axial accelerometer sensors (between 3 to 12 channels), connected to NetdB, a multi-channel acquisition unit, which communicated real-time with the dBFA software suite. The software (dBTrig) recorded the signals and gave the opportunity for real-time analysis and checks on-site. This set up is demonstrated in Figure 7 below.

Figure 7. Measurement Equipment Set Up

3.3.1 Table 1 details the vibration equipment details.

Table 1. Vibration Equipment Details

Equipment	Type	Serial Number
Multi-Channel Acquisition Unit and Analyser	01db – Net dB	LCF011500-142
Tri-axial Accelerometer	(Piezoelectric) PCB 356B18	LW133898
Mono-axial Accelerometer	(Piezoelectric) CTC – AC133-1D	1044
Mono-axial Accelerometer	(Piezoelectric) CTC – AC133-1D	1045
Mono-axial Accelerometer	(Piezoelectric) CTC – AC133-1D	1046
Mono-axial Accelerometer	(Piezoelectric) CTC – AC133-1D	1047
Mono-axial Accelerometer	(Piezoelectric) CTC – AC133-1D	799M11729
Tri-axial Accelerometer	MMF – KS823B	10074

Equipment	Type	Serial Number
Mono-axial Accelerometer	B&K 4507 002	10412
Mono-axial Accelerometer	B&K 4507 002	10413
Mono-axial Accelerometer	B&K 4507 002	10414

3.15. All vibration measurement equipment had been reference calibrated within the last two years. Calibration certificates for all accelerometers are provided in **Appendix D**.

3.16. Other equipment used on the site surveys included:

- Digital Camera
- Digital Video Recorder
- Tape measure
- Anemometer
- Trowel, Plaster of Paris & water
  Sound Level Meter – NorSonic 118

Survey Details for Main Line (Location 1)

14th March 2013

3.17. On this date the weather was warm, with clear skies and negligible levels of wind. The conditions were considered suitable for vibration measurements.

3.18. As shown in Figure 4, there were three measurement positions set up at this location, each 2 metres apart in a direct line perpendicular to the railway tracks. Details of each position are summarised in Table 2:

Table 2. Location 1 - Measurement Position Details (March)

Position (From Figure 4)	Accelerometer set up	Distance to nearest rail head of passenger loop (m)	Distance to nearest rail head of Main Up line (m)	Distance to nearest rail head of Main Down line (m)
P1	Tri-axial (x, y & z)	4.3	8.5	11.9
P2	3 x Mono-axial (x, y & z)	6.3	10.5	13.9
P3	2 x Mono-axial (x & z)	8.3	12.5	15.9

3.19. There were 15 pass-by events recorded which included 6 Cross Country passenger trains, 4 First Great Western passenger trains and 5 freight trains.

9-10th October 2013

3.20. On the 9th of October the weather was mild with clear skies but frequent cold gusts of wind. Conditions were similar on the 10th but with negligible levels of wind. The conditions were considered suitable for vibration measurements on both days

3.21. As shown in figure 5, there were four measurement positions set up at this location on these dates. The closest possible distance to achieve from the loop line was 3.3 due to the railway ballast. Details of each position are summarised in Table 3.

Table 3. Location 1 - Measurement Position Details (October)

Position (From Figure 5)	Accelerometer set up	Distance to nearest rail head of passenger loop (m)	Distance to nearest rail head of Main Up line (m)	Distance to nearest rail head of Main Down line (m)
P1	Tri-axial (x, y & z)	3.3	7.8	11.2
P2	3 x Mono-axial (x, y & z)	6.7	11.2	14.6
P3	3 x Mono-axial (x, y & z)	8.7	13.2	16.6
P4	Tri-axial (x, y & z)	11.2	15.7	19.1

3.22. There were 52 pass-by events recorded which included; 22 Cross Country passenger trains, 19 First Great Western passenger trains and 11 freight trains.

Survey Details for Bicester to Oxford Line (Location 2)

3.23. The main purpose of this survey location was to obtain vibration measurement of the stone freight train. This freight train was known to pass by the Location 2 measurement position at approximately 08:25.

25th April 2013

3.24. On this date the weather was warm, clear skies with negligible levels of wind. The conditions were considered suitable for vibration measurements.

3.25. The single measurement position was set up at 4 metres away from the nearest rail well before this time in order to be ready when the stone freight came

3.26. There were four pass-by events recorded which included 3 Chiltern Railways (2 Car) passenger trains and the stone freight train.

10th October 2013

3.27. On this date the weather was mild with clear skies and negligible wind. The conditions were considered suitable for vibration measurements.

3.28. As shown in Figure 5, there were four measurement positions set up at this location, each 2 metres apart in a direction perpendicular to the railway track. The closest achievable distance to the railway track was 2.5 metres. Table 4 summarises the details of each position.

Table 4. Location 2 - Measurement Position Details (October)

Position (From Figure 5)	Accelerometer set up	Distance to nearest rail head of branch line (m)
P5	Tri-axial (x, y & z)	2.5
P6	3 x Mono-axial (x, y & z)	4.5
P7	3 x Mono-axial (x, y & z)	6.6
P8	Tri-axial (x, y & z)	8.5

3.29. On all survey dates and locations, a digital video recorder captured each train pass-by and the speed of the trains was calculated by reviewing this video footage and applying the Speed = Distance/Time relationship. The video footage was recorded at 30 frames per second and derived speeds are considered to be estimates suitable for this study. The Sound Exposure Level (SEL) of each train pass-by was also measured for information purposes.

Permanent Way Inspection

3.30. Permanent way inspections were undertaken on 9 October 2013 on the Oxford to Bicester Line (OXD) and the Oxford to Anyho Junction Line (DCL). The results are contained in the Atkins technical note 5114534-ATK-GEN-TN-00044 which is included in **Appendix E**.

3.31. The scope of the inspection was to determine the overall condition of the permanent way and to identify factors that would unduly impact on the vibration results.

3.32. The inspections on both the OXD and DCL lines concluded that the track is in a good condition, with no evidence of "track pumping" or other issues that would be outside of the normal parameters for a well maintained line for the track category currently in service.

Measurement Results

3.33. The table in **Appendix F** provides a summary of the pass-by events observed at both measurement locations. Each pass-by event has a unique event number which are subsequently used to refer to the different events in this report.

3.34. Ignoring locomotives there were no two axle wagons. All wagons were four axle i.e. two axle per bogie. Videos are available for most pass by events which can be reviewed if more information is required.

3.35. The acceleration signal was measured for each pass-by event and this was processed as required to obtain the relevant outputs for this study. Before the weighted RMS acceleration and VDV/eVDV values could be determined, a fourth order high pass filter was used on all measured signals with a 1 Hz cut-off, in order to remove unwanted low frequency interference in the signal.

3.36. The VDV and eVDV values for all events during both site surveys are presented in **Appendix G** along with weighted RMS acceleration data for selected events. In accordance with the guidance of BS6472 Part 1:2008 – "Guide to evaluation of human exposure to vibration in buildings" [**1**], the measured acceleration has been frequency weighted using the following correction weightings for the different axes:

- X axis = Wd weighting
- Y axis = Wd weighting
- Z axis = Wb weighting

As defined in **[1]**.

3.37. From these the weighted acceleration values the VDV and eVDV values have been derived by the analysis software.

3.38. Table 5 presents the weighted rms acceleration and single event VDV for selected events.

Table 5. Selected Event Results

Event - Train	Estimated Speed (mph)	Event Duration (Seconds)	Distance from Source (m)	Z Axis Weighted (Wb) RMS Acceleration ms^{-2}	Z Axis Single Event VDV $ms^{-1.75}$
5 - Freight	38	33	11.9	0.008	0.040
11 - Freight	60	19	8.5	0.015	0.046
12 - Passenger	75	3.5	8.5	0.015	0.028
1B - Passenger	35	5	4	0.016	0.034
3B – Freight (Stone Train)	35	21	4	0.034	0.124

3.39. Frequency data has been extracted for the selected events by undertaking Fast Fourier Transform on the weighted acceleration signal in the time domain. Figures 8-12, show selected results for events 11 (freight 60mph), 12 (passenger 75mph) and 3B (stone train 35mph).

Figure 8. Acceleration 1/3 Octave Frequency Data - Freight (Z-Axis only)

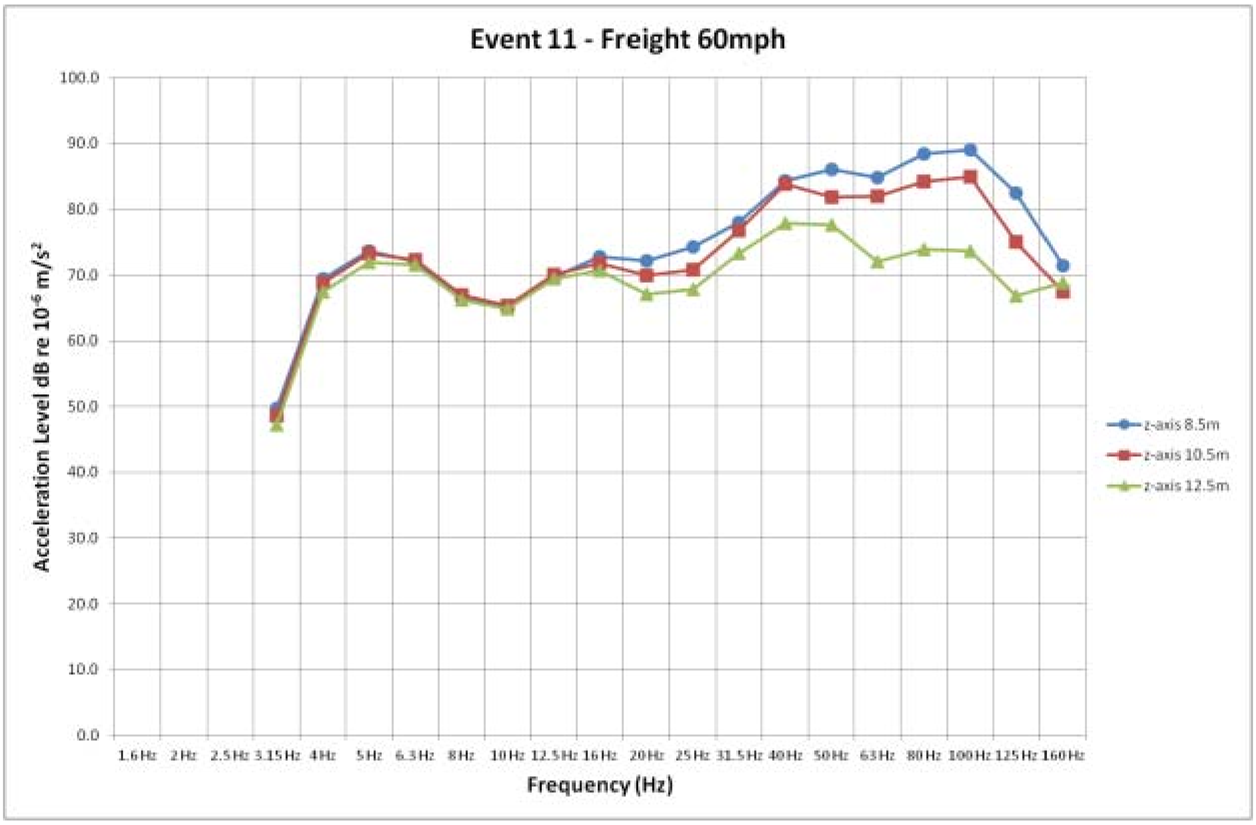


Figure 9. Acceleration 1/3 Octave Frequency Data - Freight (X, Y & Z - Axis)

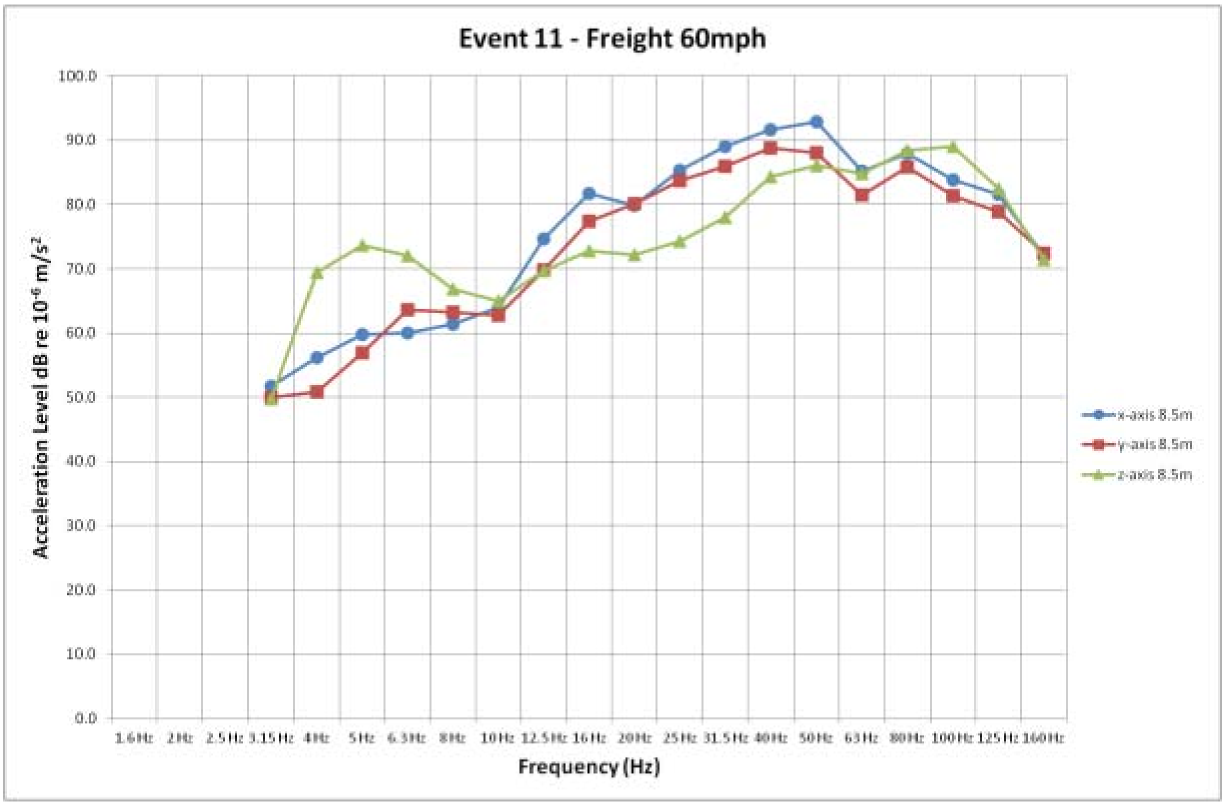


Figure 10. Acceleration 1/3 Octave Frequency Data – Stone Freight (X, Y & Z - Axis)

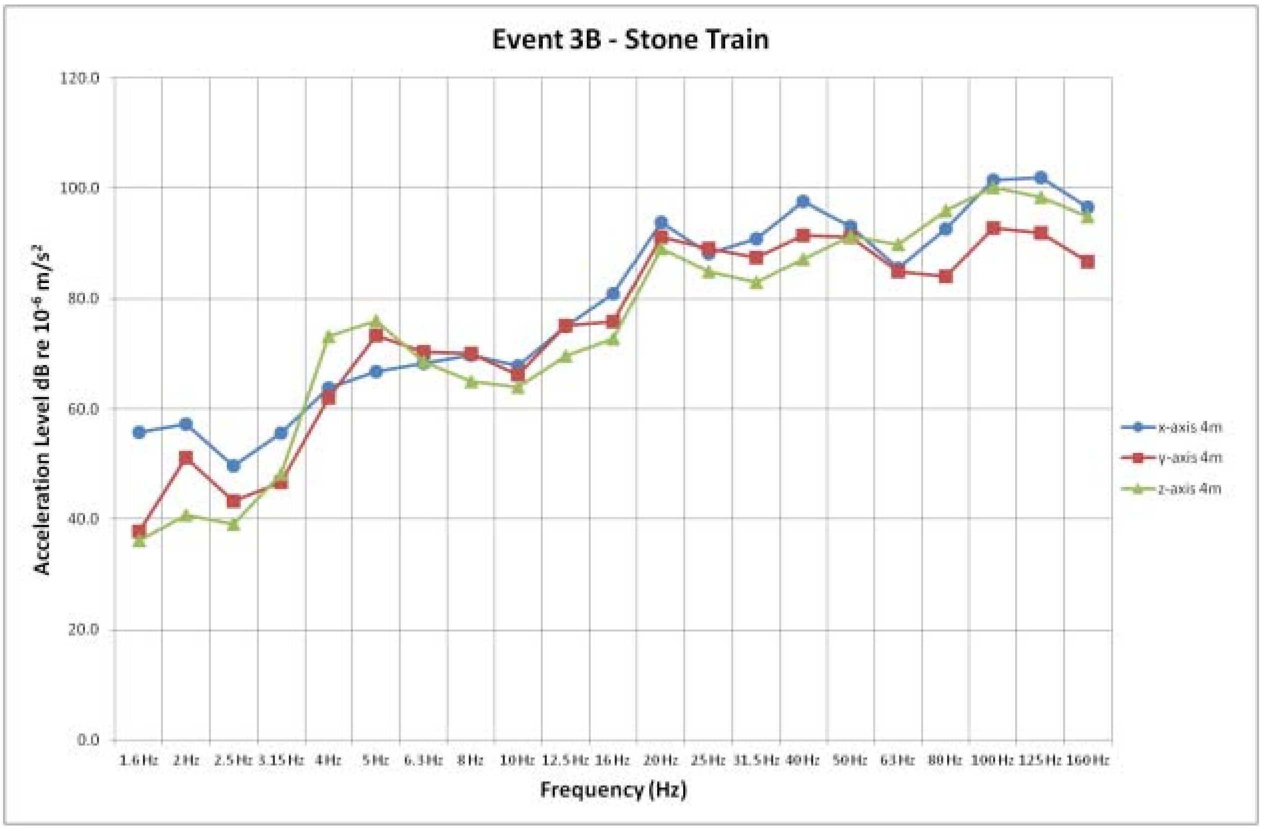


Figure 11. Acceleration 1/3 Octave Frequency Data - Passenger (Z-Axis only)

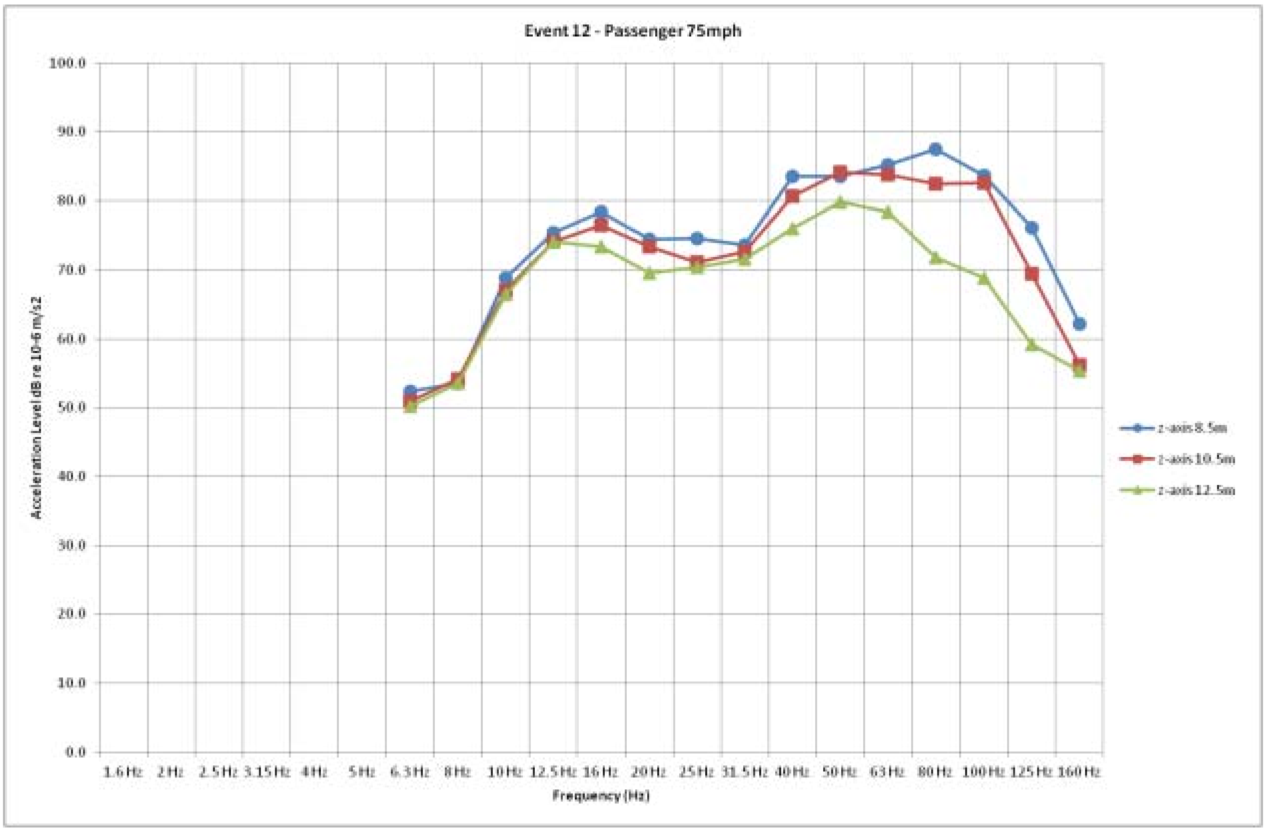
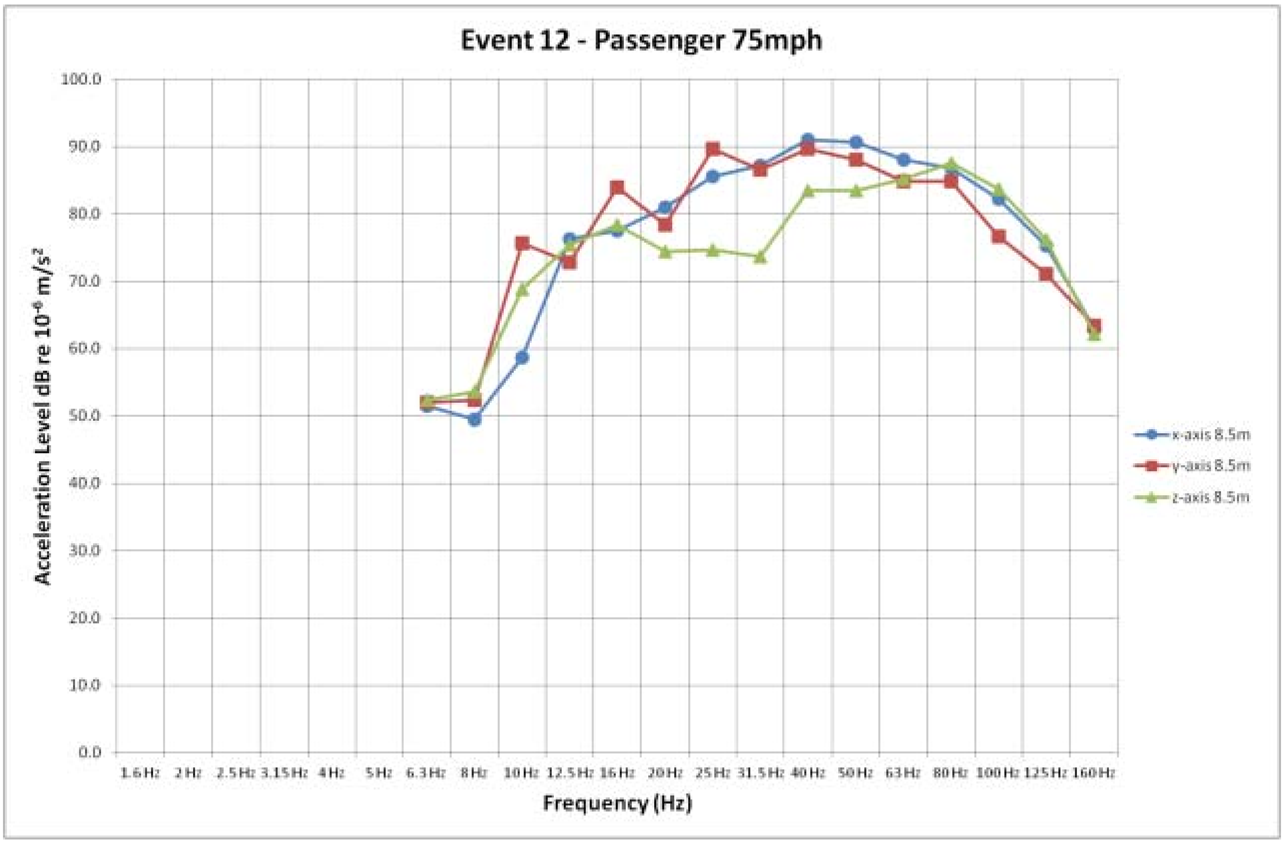


Figure 12. Acceleration 1/3 Octave Frequency Data – Passenger (X, Y & Z - Axis)



3.6.1 The next section presents an analysis of the results, for use in the assessments.

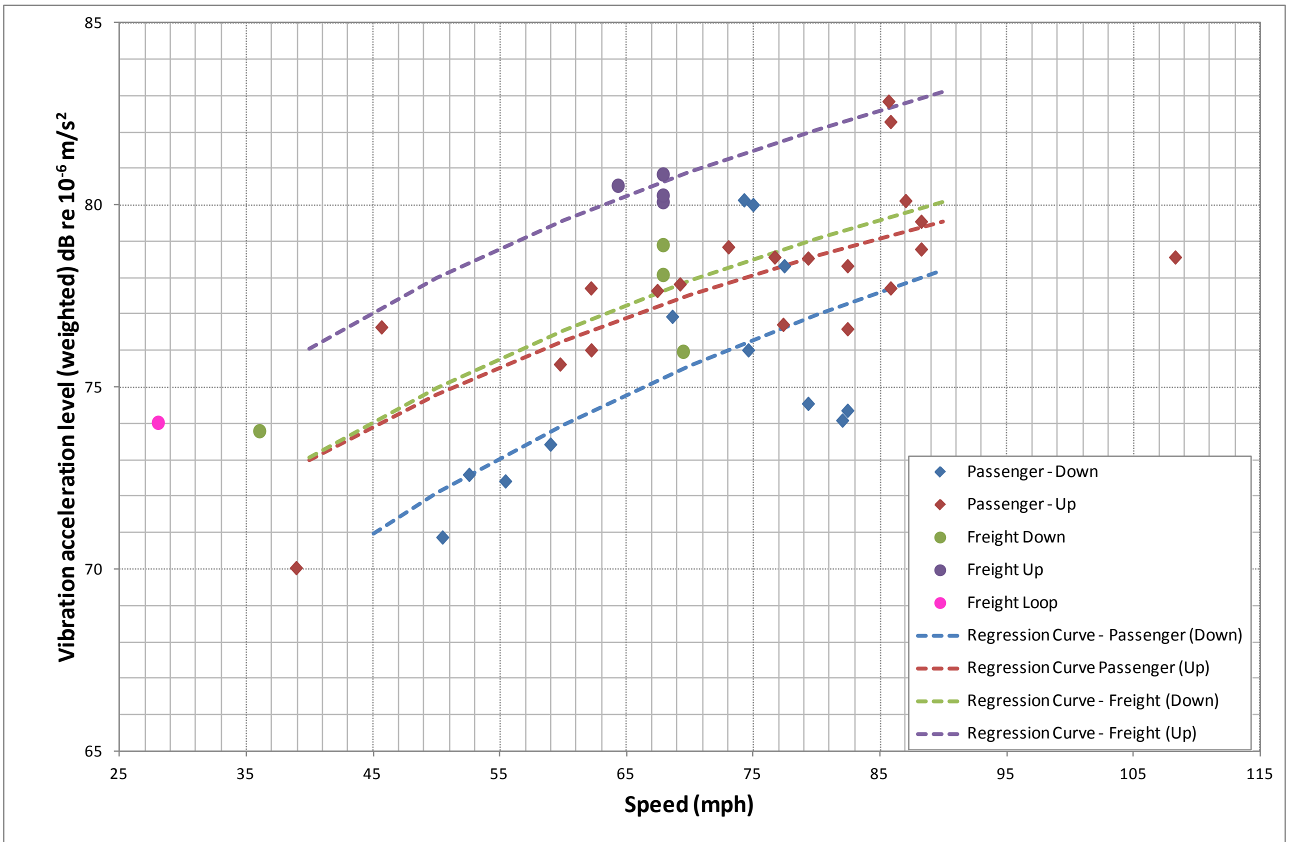
4. Measurements at Control Position

4.1. During the second set of site visits in October 2013, the measurement positions were selected in a way to provide a common distance from all track for a direct comparison of measurements at a control position. The spacing of the track (DCL up, DCL down and Loop line) and the closest practicable measurement distance to track (3.3m to loop line) determined this distance as 11.2m. Figure 5 in Section 3 illustrates the relative position of measurement points from the track.

4.2. Figure 13 shows the vibration acceleration levels (weighted) (re 10^{-6} m/s^{-2}) in dB at the control position for passenger and freight trains in the up and down directions. Regression curves having the general shape m Log(speed) + C have been plotted through the measured vibration levels for passenger trains on the up and down lines. The number of freight trains observed at the control position was limited and a 20 Log (speed) + C relationship has been used. Similar relationships were shown to apply to the individual 1/3 octave band frequencies. The resulting regression equations are summarised below;

- Passenger up; 18.6 log (speed) + 43.2
- Passenger down; 24 log (speed) + 31.3
- Freight up; 20 log (speed) + 44
- Freight down; 20 log (speed) + 41

Figure 13. Measurements at Control Position



4.3. It is shown that the general trend of the regression lines is similar. The speed dependence of different types of trains travelling on different track was approximately 2dB increase in vibration levels per 10miles/hour increase in speeds.

4.4. The vibration levels are generally lower for passenger trains travelling on the down main line, compared with passenger vehicles on the up line. The average difference is 3dB at low speeds, reducing to 1.5dB at the higher speeds. Similar observations can be made for freight trains on the down line, which result in lower levels of vibration compared with freight trains on the up line, even though there is limited data available for the latter.

4.5. The observed differences between vibration levels from traffic on up and down directions are likely to be due to track. The vibration levels in the down line travel through a greater proportion of embankment and ballast compared with those on the up line. It is noted that the scatter in data is such that levels could vary by as much as +/- 4dB from the 'best fit' regression curve for passenger trains and +/- 3dB for freight trains. For example it can be seen that at 75 mph, the down line generates the higher levels of vibration from passenger trains, even though it is further away from up line.

4.6. The speed relationships are used in the next section to normalise the measured vibration levels for speed.

5. Vibration Decay Curves with Frequency

5.1. This section provides analysis of measured vibration levels to identify vibration decay characteristics with distance at individual 1/3 octave band frequencies, for passenger and freight trains. The vibration levels have been normalised for speed using the relationships described earlier in report, to minimise the influence of train speed in the variation observed in the data. The reference speeds used for normalising data from passenger and freight trains were 100mph and 70mph, respectively, which correspond to the line design speeds with the scheme. The levels have not been corrected for the influence of track due to variable nature of track influence.

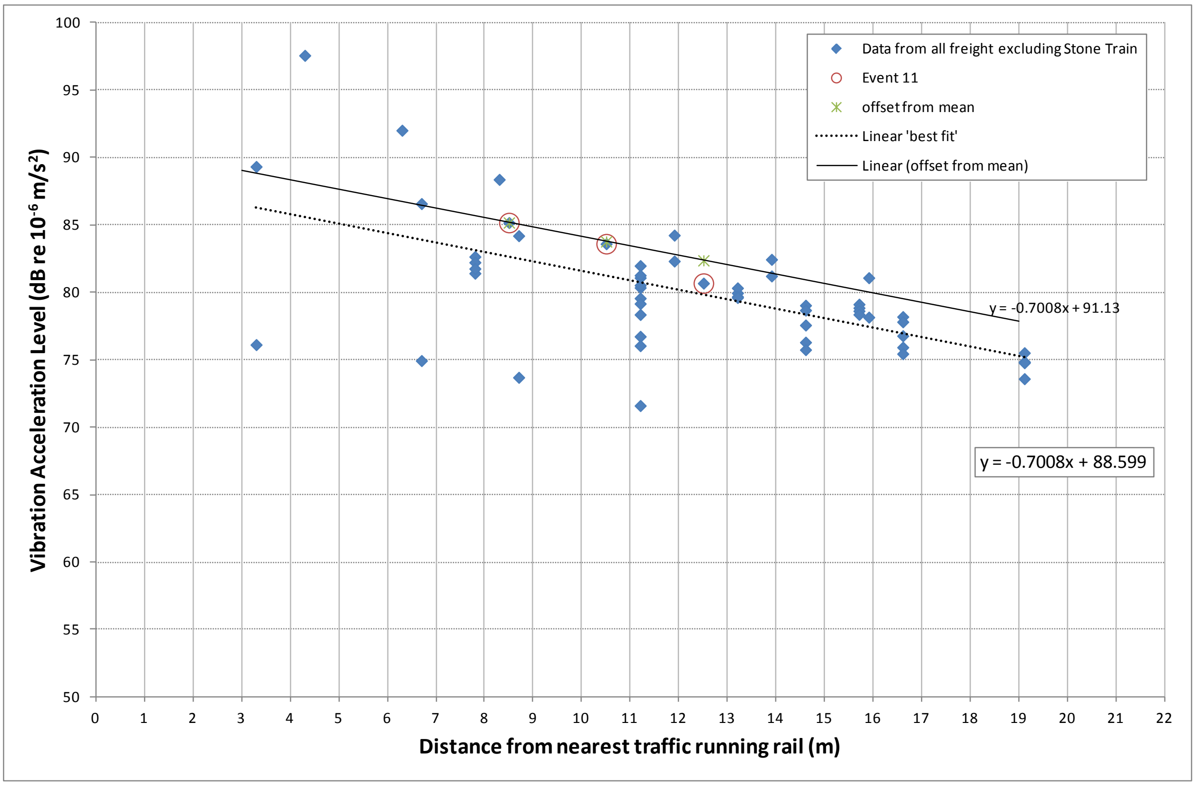
5.2. The graphs in **Appendix H** show linear (unweighted) vertical vibration acceleration levels in dB La (re 10^{-6} m/s^2) plotted against distance in m, for each 1/3 octave frequency band of interest, for all passenger and conventional freight pass-by events observed on site. A decay curve is shown for each frequency band considered in the assessment, using data for all trains. In addition, specific events are identified which are used as reference or base case in the assessments. These correspond to selected pass-by event travelling at a representative speed are (event 11 for freight and event 12 for passenger).

5.3. The decay curves have the general shape, y = -mx + C where m is the vibration decay rate/ m, in dB, and C is the vibration level, in dB, at origin (i.e. at the track), and y is the resulting vibration level, in dB, at a distance x from the track.

Freight Trains

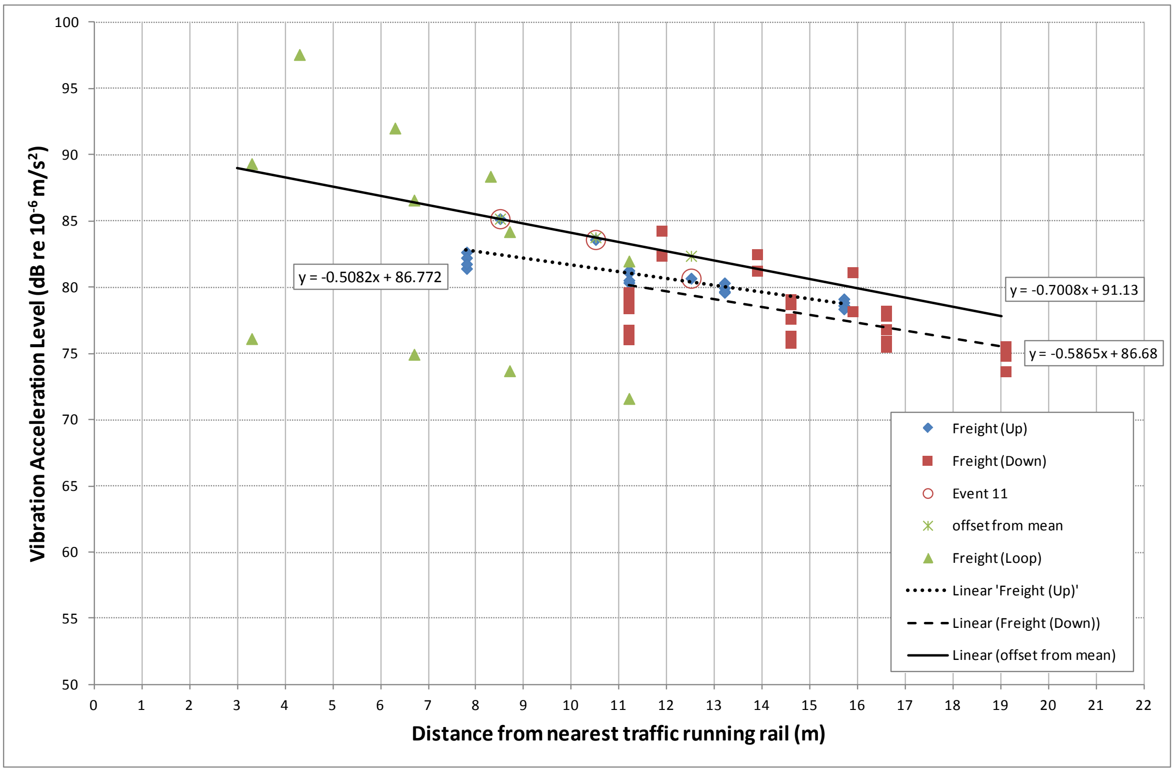
5.4. The overall vibration levels for freight pass-by events are shown in Figure 14. Full set of vibration decay curves at each 1/3 octave band frequency between 3.15Hz and 160 Hz are shown in **Appendix H-1**. The selected reference curve (event 11, at 8.5m from track) is shown to be 2.5dB higher than the global decay curve, with approximately 90% of all data points shown to be on this curve or below it.

Figure 14. Freight train decay characteristics, overall vibration levels



5.5. The influence of track on vibration levels from freight trains is illustrated in Figure 15. On average, the nearer track (up direction) generates higher levels of vibration compared with the further track (down direction). Freight pass-by data observed on the loop line resulted in the highest scatter in the data. The reference curve is a conservative representation of the measured data from both tracks on the main line.

Figure 15. Freight train, influence of track on overall vibration levels



5.6. In order to illustrate the influence of track at different 1/3 octave frequencies, the decay relationships at 40Hz and 63Hz are shown in Figures 16 and 17 respectively for freight trains.

Figure 16. Freight train, influence of track at 40Hz

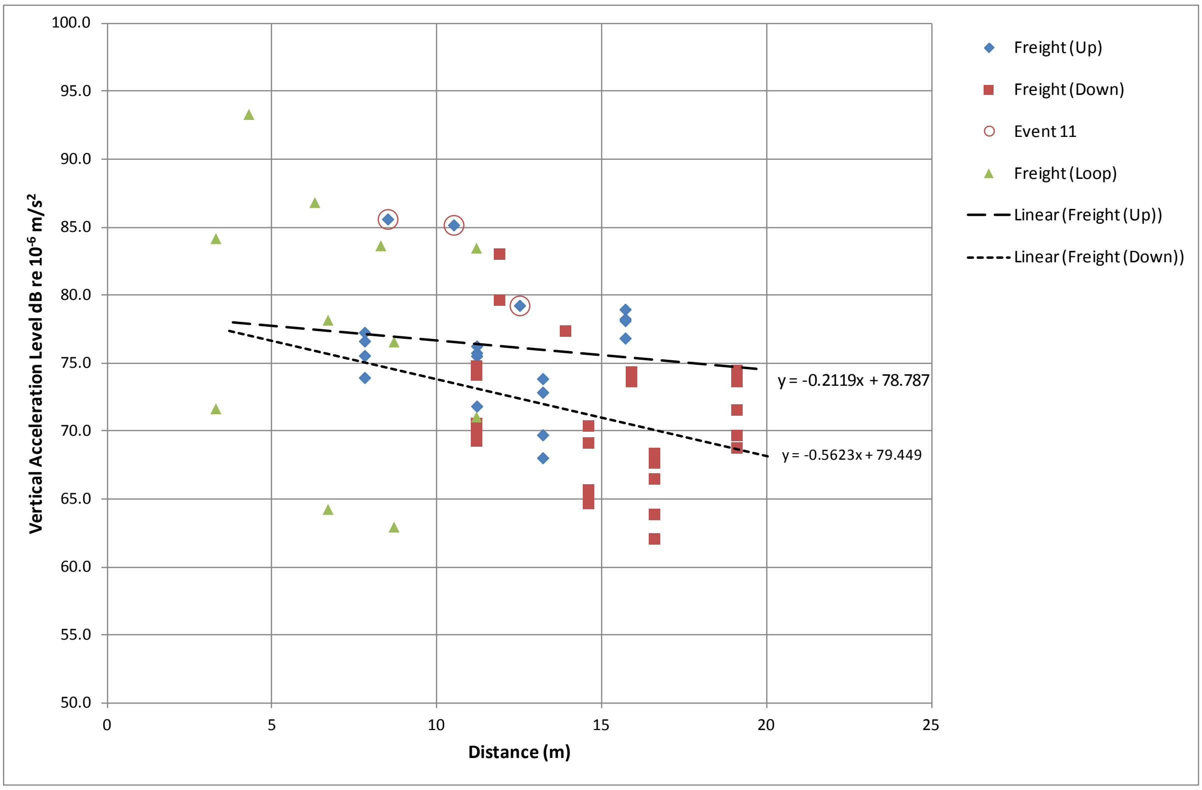
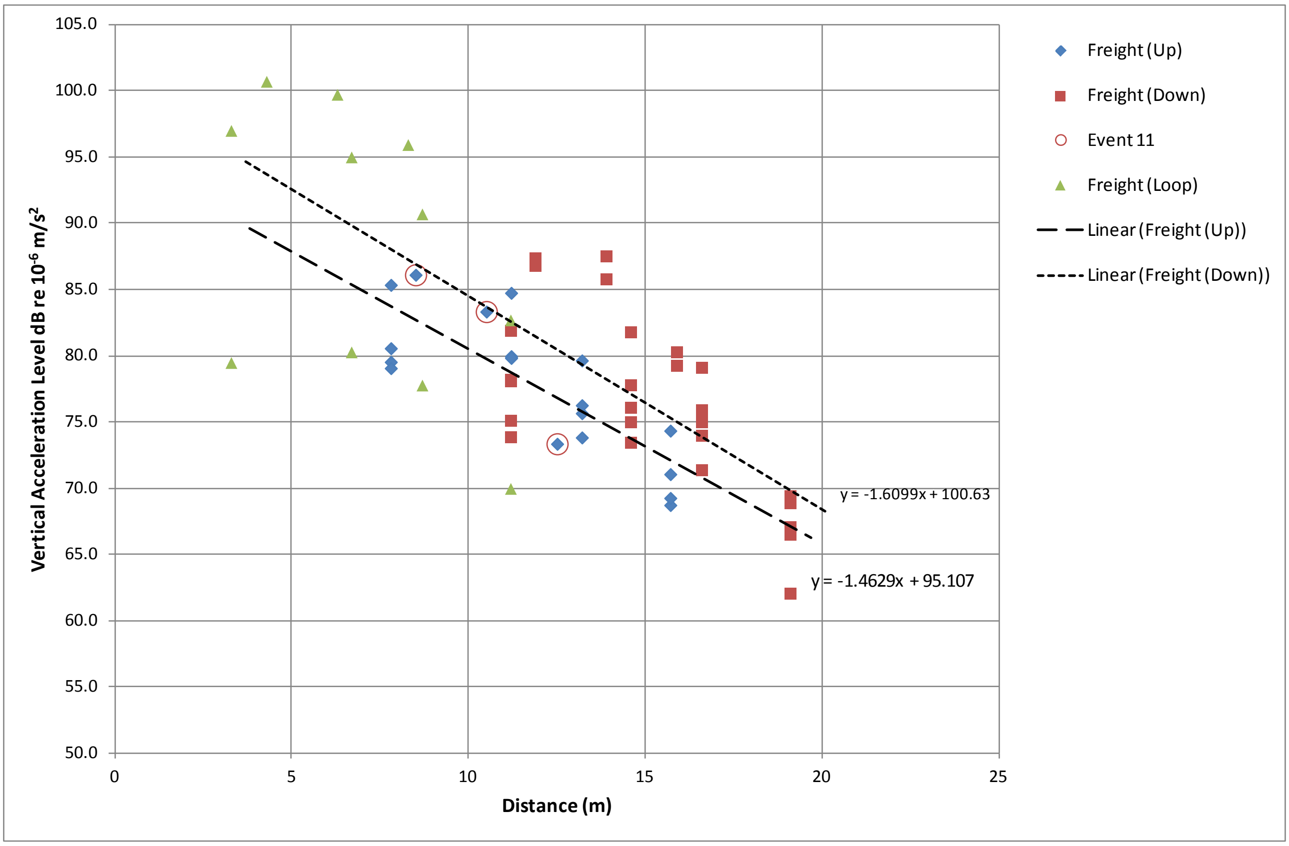


Figure 17. Freight train, influence of track at 63Hz

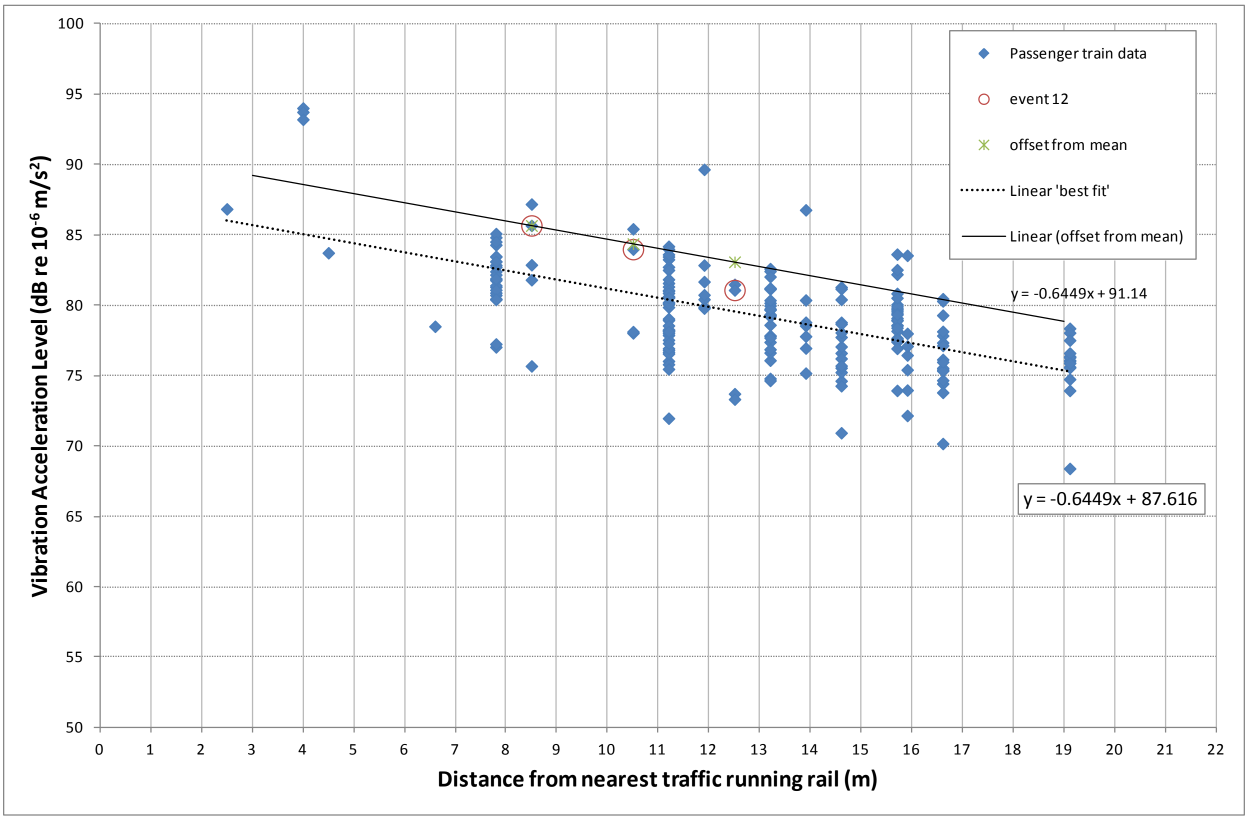


5.7. At 40Hz, the vibration levels from the nearer track (up direction) are higher, in line with the observed differences in overall vibration levels. The selected decay curve results in levels which are up to 10dB higher. At 63Hz, the track which is further away results in higher vibration levels and the selected decay curve is consistent with the higher of the two decay curves.

Passenger Trains

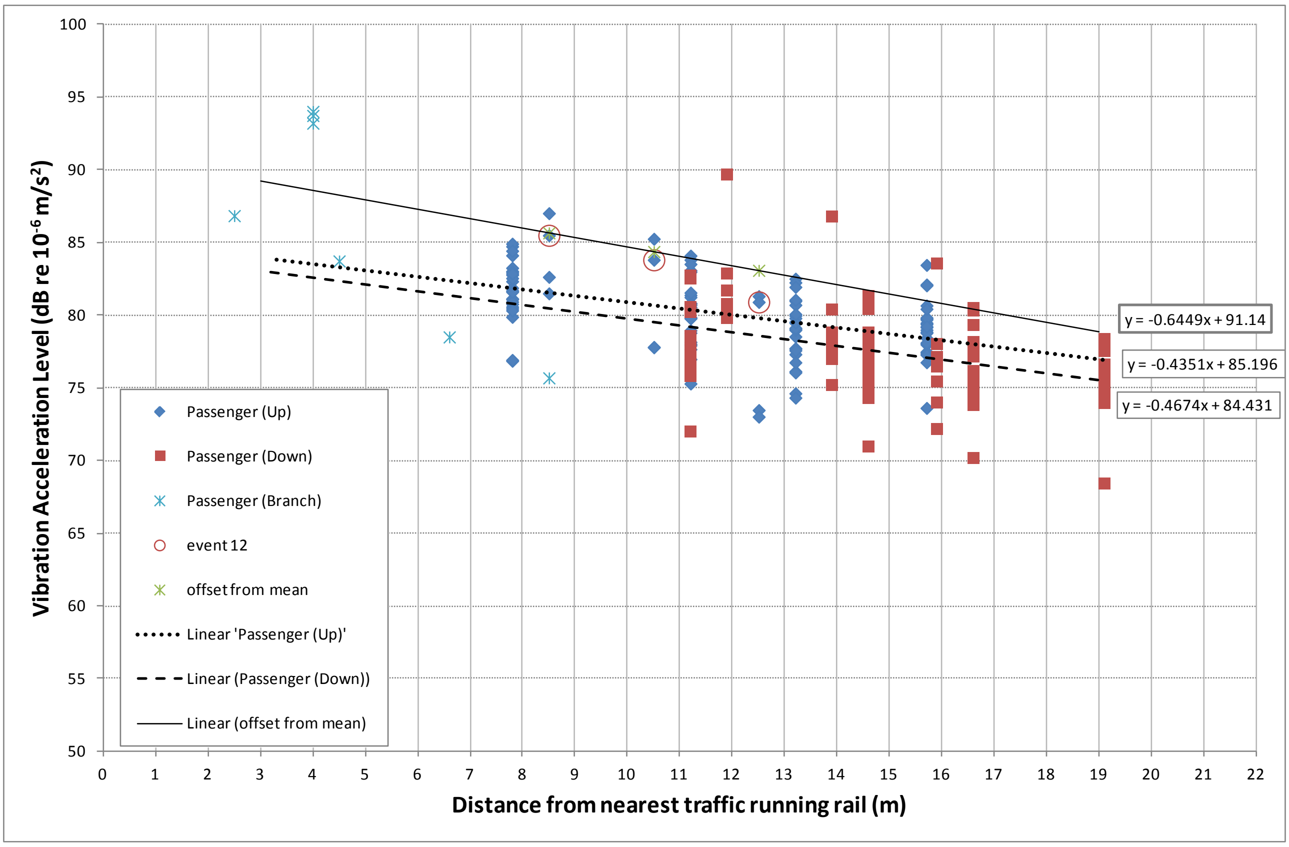
5.8. The overall vibration levels for freight pass-by events are shown in Figure 18. Full set of vibration decay curves at each 1/3 octave band frequency between 6.3Hz and 160 Hz are shown in **Appendix H-2**. The selected reference curve (event 12, at 8.5m from track) is shown to be 3.5dB higher than the global decay curve, with approximately 95% of all data points shown to be on this line or below it.

Figure 18. Passenger train decay characteristics, overall vibration levels



5.9. The influence of track on vibration levels from passenger trains is illustrated in Figure 19. On average, the nearer track (up direction) generates higher levels of vibration compared with the further track (down direction). Passenger pass-by data observed on the branch line (i.e. stone train measurement site) resulted in the highest scatter in data. However the base curve is representative of the measured levels on the site from both tracks on the main line.

Figure 19. Passenger trains, influence of track on overall vibration levels



5.10. Figures 20 and 21 show the influence of track on vibration levels from passenger trains at 40Hz and 63Hz respectively.

Figure 20. Passenger train, influence of track at 40Hz

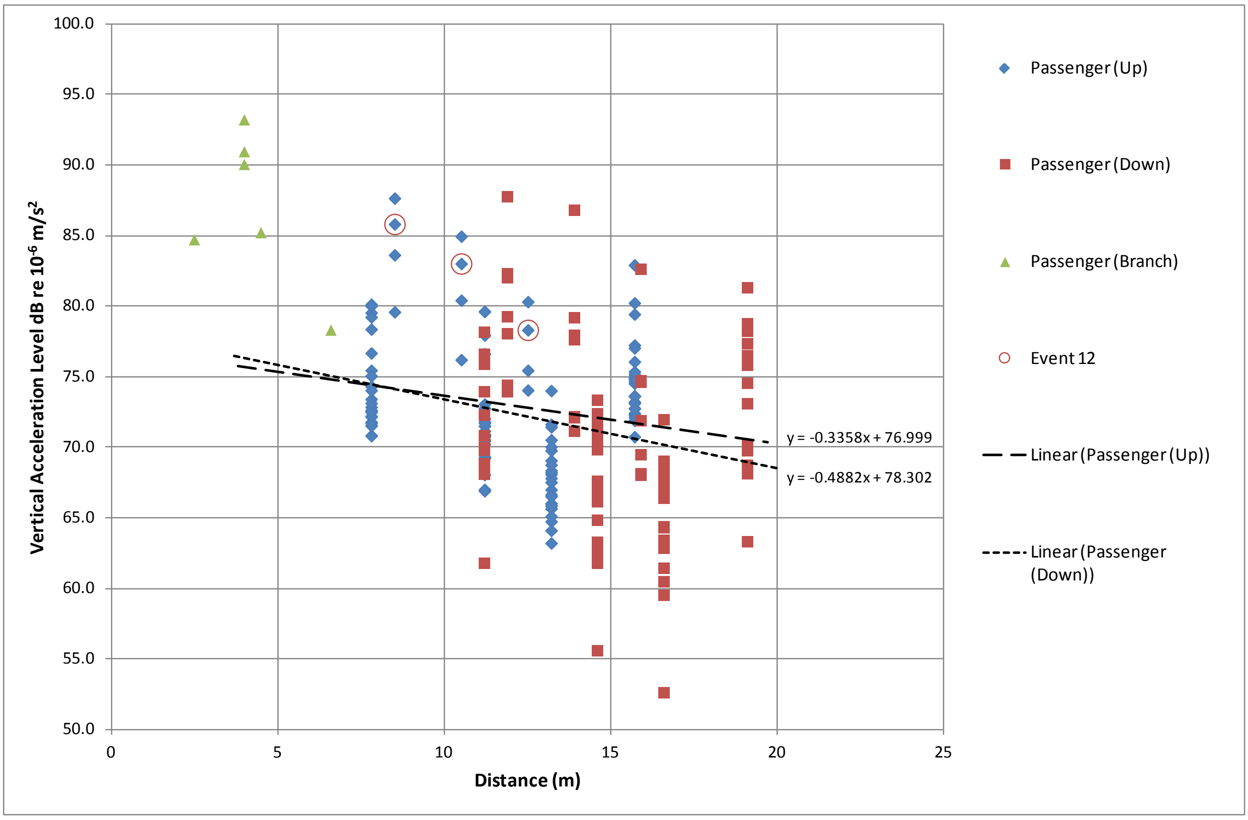
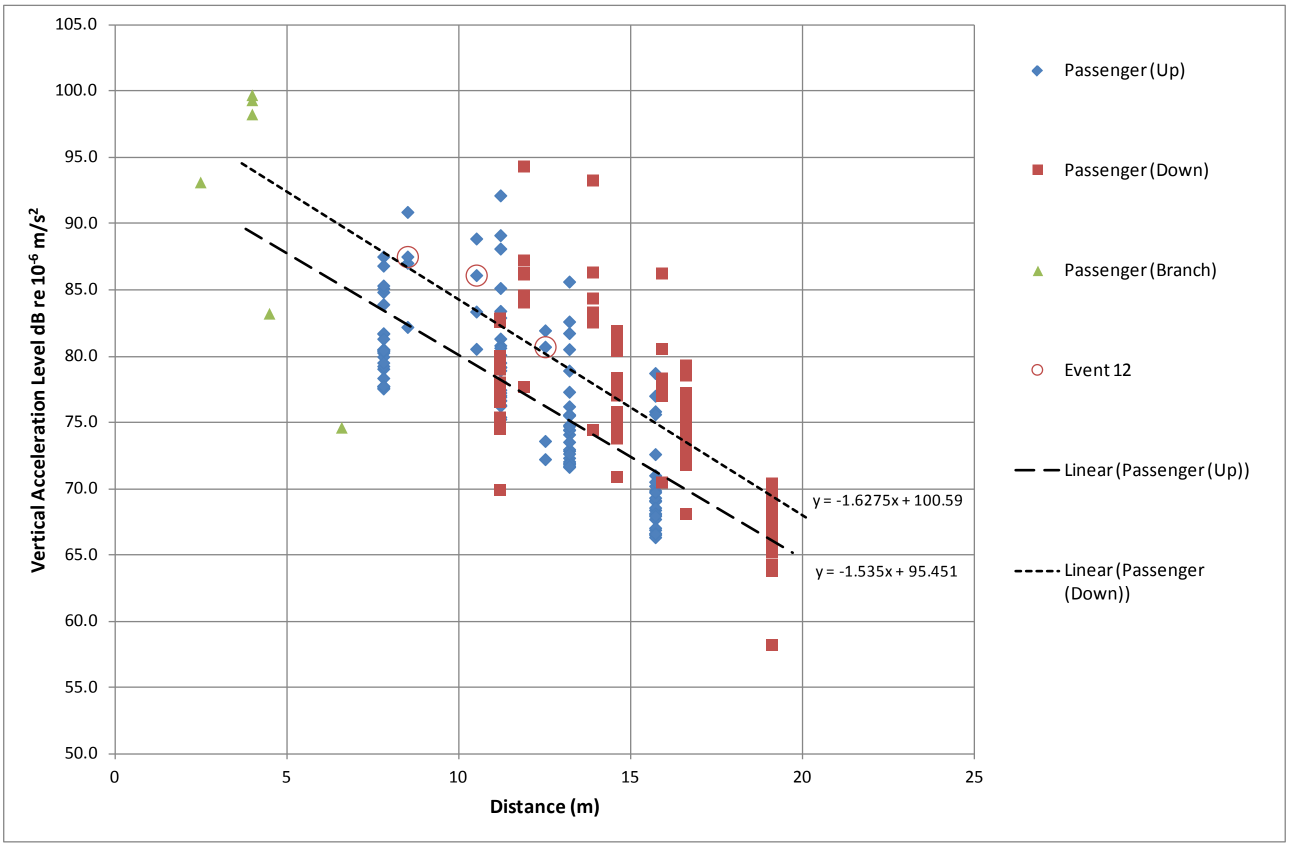


Figure 21. Passenger train, influence of track at 63Hz



5.11. At 40Hz, the contributions from both track are similar and the selected decay curve results in higher levels of vibration (by up to 10dB) compared with average levels from each track individually. At 63Hz, the track in down direction (further away) results in higher vibration levels, and this is reflected by the selected base curve.

Decay Constants

5.12. A summary of decay curve constants for specific passenger and freight trains are tabulated below. The decay rates are expressed in the form (-m) for direct use in the decay curve having the general shape of y = -m + C. Decay constants C have been rounded to nearest dB, and the decay constants m are shown to nearest 1 decimal point.

5.13. As discussed later in this report, the VDVs predicted using these decay constants provide a good correlation with VDVs predicted using an alternative prediction approach which relies on measured VDVs.

Table 6. Decay Curve Constants

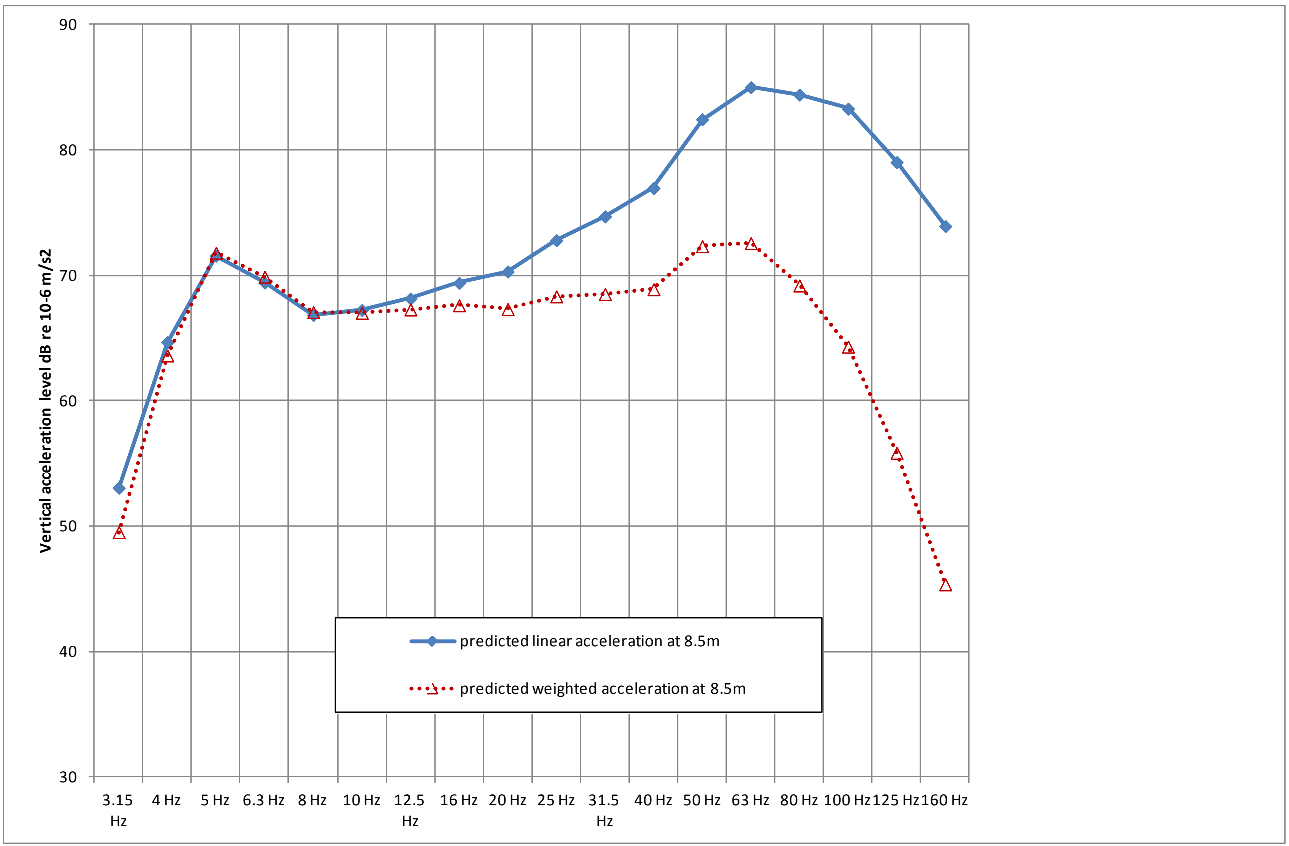
1/3 octave band frequency	Freight trains		Passenger trains	
Hz	-m Decay rate/ m, dB	C linear vertical vibration acceleration levels in dB La (re 10^{-6} m/s^2) at origin	-m Decay rate/ m, dB	C linear vertical vibration acceleration levels in dB La (re 10^{-6} m/s^2) at origin
3.15	-0.5	57	-	-
4	-1.2	75	-	-
5	-1.1	81	-	-
6.3	-0.4	73	-0.8	64
8	-0.2	69	-0.5	66
10	-0.5	71	-0.6	75
12.5	-0.3	71	-0.5	76
16	-0.2	71	-0.4	77
20	-0.3	73	-0.8	84
25	-0.3	76	-0.5	80
31.5	-0.5	79	-0.4	78
40	-0.7	83	-0.7	82
50	-1.2	93	-0.9	88
63	-1.5	98	-1.3	95
80	-1.6	98	-1.5	95
100	-2.0	100	-1.8	97
125	-2.1	97	-2.2	97
160	-1.5	86	-1.4	84

Application of Decay Curves

5.14. In this section, the application of decay curves is discussed.

5.15. The predicted vibration levels are illustrated below for a typical freight train (event 11) at 8.5m from track, both in linear dB and with the Wb weighting applied to illustrate the effect of weighting at higher frequencies. In determining the VDVs, hence assessing project compliance with limits and designing mitigation, this becomes an important consideration since VDVs are based on weighted acceleration levels.

Figure 22. Influence of weighting at higher frequencies



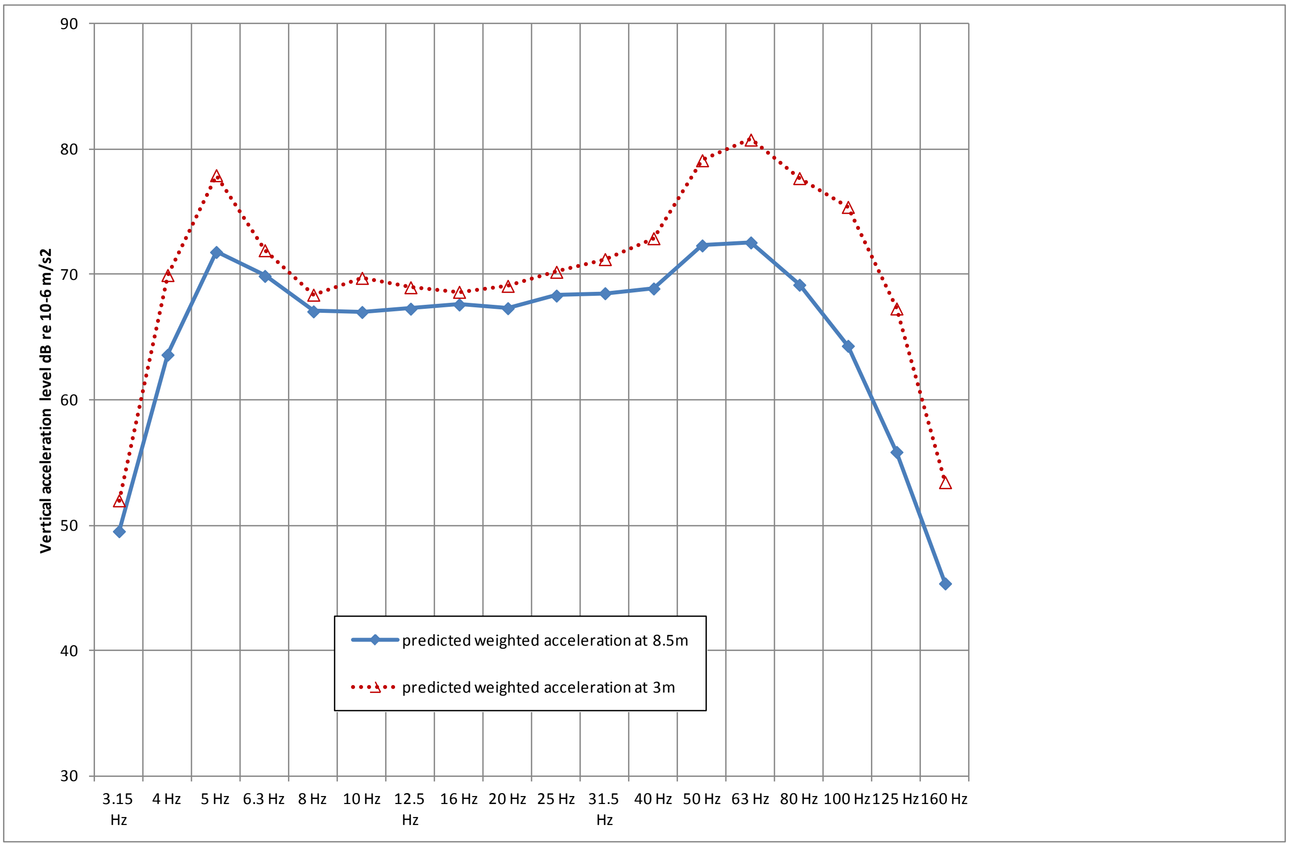
5.16. Typically, the decay rates were noted to be less than 1dB/ m at low frequencies (<=40Hz), and varied between 1dB/m and 2dB/m at higher frequencies. Using the decay curve relationships, the resulting vibration levels, for example, at 3m from the track could be expected to be as follows;

Table 7. Example showing expected variation in vibration levels for a typical freight train

Frequency	Reference weighted vibration level in dB at 8.5m from track	Decay rate/m in dB	Change in levels, dB (moving 5.5m towards track)	Predicted weighted vibration level at 3m from track
6.3Hz	70	-0.4	2	72
25Hz	68	-0.3	2	70
63Hz	73	-1.5	8	81

5.17. The table above illustrates that low frequencies could be expected to be affected by a smaller margin when moving closer to the track, however, the higher frequencies would be increased more substantially. The predicted weighted acceleration levels for event 11 are shown below for the full frequency spectrum of interest, at 3m from track.

Figure 23. Predictions undertaken using the decay curves through event 11 data



5.18. The following section of the report identifies speed relationships for use with vibration decay in single VDV figures, which can be used directly to assess compliance with project limits.

6. Speed Relationships for VDVs

6.1. This section presents assessments to derive adjustments for small speed corrections for use with VDV decay curves.

6.2. Empirical relationships are relied upon to assess the implications of small speed variations on vibration levels.

Stone Train

6.3. The operator DB Schenker Rail (UK) advised that it would be very unusual for a loaded train of stone or any other bulk materials (as opposed to containers or cars) to be authorised to run at more than 60 mph, as the gross weight of a worthwhile load in every wagon would tip the scales at over 25 tonnes per axle.

6.4. In the immediate surroundings of the siding at Water Eaton or Banbury Road, by definition the train would be approaching a red signal at the new Water Eaton station, which would change to give a “subsidiary” indication of 2 white lights at the last minute as the train approaches it to allow a slow speed (max 15 mph) entry into the siding. Generally speaking, it is understood that the drivers of freight trains are advised not to exceed 20 mph after passing the yellow signal which gives warning that the next one is at red and that can be approximately 1 km away (or more).

6.5. In some instances, the overall maximum speed of heavily loaded wagons of 60 mph could be further reduced by additional instructions which impose lower speed limits over known weaker bridges and viaducts and in some cases longer stretches of line where the underlying soil conditions are regarded as sub-standard or naturally “spongy”. In the vicinity of Oxford and the terminal, it is understood that there are no additional speed restrictions applicable to the loaded wagons. Therefore the normal maximum speed in ‘heavy’ and ‘empty’ mode would apply. DB Schenker Rail (UK) advised that currently the trains typically include JYA wagons, which are restricted to 45 mph loaded and empty, but other types include JNA, which is allowed to go up to 60mph in both states of loading. The trains themselves are timed at a maximum speed of 45 mph, but for “future-proofing”, it is reasonable to assume 60 mph.

6.6. As to likely attainable speeds, currently Oxford North Junction, 1 mile north of Oxford station, is restricted to 20 mph for trains bound for Bicester, so freight trains to Water Eaton (another two miles away) would only cover a short distance before slowing for the entrance to the terminal as explained above. It is understood there are active plans to improve the diverging speed at Oxford North Junction to 60 mph, but in view of the relatively short distance between this point and the terminal, the train would need to be slowing down most of the way. For reasons of fuel economy and concerns about the risk of broken couplings and shifted loads, freight train driving style is different from that applicable to passenger rolling stock, with drivers actively seeking to “smooth out” the speed profile where possible without excessive loss of time. In good rail conditions (i.e. no heavy rain or greasy rail from tree sap in adjacent hedges and woodlands) 60 mph may well be attainable with the empty train in just over a mile after the last wagon leaves the exit points from the siding, but the probability of that happening will also be dictated by the aspect shown by the signals at the major junction ahead, as the train will have to be filtered in among the frequent passenger and freight services using the Banbury - Didcot main line.

6.7. Therefore it is unlikely that a fully loaded stone train will travel at the line speeds of 70mph. The highest maximum speeds for an unloaded train, under ideal conditions, would be expected to be 60mph. As explained above, the attainable speeds in reality would be further limited by a number of physical and operational constraints associated with the network and the trains. As part of the vibration assessments, it is assumed that the stone train could travel at 60mph with the scheme, which is a conservative assumption.

6.8. In addition to above, there is some uncertainty in the speed adjustments for the stone train at the assumed new speed of 60mph, since the current vibration measurements correspond to a speed of 35mph. The technical paper entitled ‘Ground Vibrations from Heavy Freight Trains’ (Dawn 1983) **[2]** investigated the measured vibration levels from a loaded test train consisting of 16 no.

of 50t bulk powder carrying vehicles over a range of speeds. The speeds varied between 23kph (14mph) and 88kph (55mph). Vibration measurements of 22 pass-by events were undertaken at a distance of 25m from the track. The ground at the test site was river gravels and sand to a depth of 6m with an underlying Keuper Marl and was at grade with the track. It was found that the vibration levels generated by heavy freight trains have a weak dependence on speeds above 30kph (19mph). The increase in vibration velocity level (dB) measured between train speeds of 56kph (35mph) and 88kph (55mph) was shown to be around 1dB.

6.9. It is considered that the use of an empirical speed relationship for the stone train over the speed ranges of 35mph to 60mph is likely to result in an overestimate of the impacts from this type of train. This is retained as a further factor of safety in the calculations. The potential impact of this assumption on the assessments is discussed later in the report.

Passenger and Freight Trains

6.10. According to **[3],** in most cases, the changes in vibration levels are proportional to 13-30Log (speed), typically 20Log (speed). Similar relationships are given elsewhere **[4],** whereby vibration level in dB is noted to be proportional to 20Log (speed/$speed_{ref}$) and that sometimes the vibration with speed has been observed to be as low as 10 to 15Log (speed/$speed_{ref}$). Although **[3]** does not make the distinction, **[4]** applies the adjustments derived in this way to a vibration velocity base curve, rather than to vibration acceleration values.

6.11. In this assessment, vibration acceleration values have been used, since these provide a more direct link to the VDV values, than the vibration velocity values. The approach adopted was to apply the 20Log (speed) dependence to the weighted acceleration signal. The calculation steps are described in **Appendix I.**

6.12. The analysis described in **Appendix I** provides a relationship for rms vibration levels for small changes in train speeds. It is found that a speed increase of 5mph, for example from 75mph to 80mph (6.7% increase) would be expected to result in the same percentage increase in rms vibration levels for a 20Log (speed) dependence.

6.13. This speed corrected weighted acceleration and time is then used to determine an eVDV. The true VDV is determined from the eVDV by using an eVDV to VDV correction factor obtained from measurements, as derived from the same signal. The calculation steps are described in **Appendix I**.

6.14. Strictly the rms acceleration values can only be used to obtain an estimated VDV, or the eVDV, and the true VDV values are a function of rmq (root-mean-quad) acceleration. According to ANC guidelines **[5]**, where the crest factor of the signal is low, for example in the case of non-impulsive vibration, the rmq (root mean quad) acceleration may be expected to be about 1.4 times the rms acceleration.

6.15. The common experience of measurements of ground vibration from trains **[5]** appears to be that eVDV does not differ from true VDV by more than a factor of two. In **[5]** it is explained that the eVDV can be higher or lower than the true VDV.

6.16. For the measurements described in this report, the ratios of VDV/eVDV were found to vary approximately between 0.92 and 1.77. The relationship between the two indicates that the VDV at these sites is, on average, 1.1 times higher than the eVDV. The relationships applied in this assessment are specific to measured events, type of train and its speed used in the assessments.

6.17. The resulting speed correction factors used in the assessments are summarised in Table 8;

Table 8. Summary of Speed Correction Factors

Event No.	Type	Measured Speed (mph)	Proposed Speed (mph)	Speed Factor	Comment
12	passenger	75	100	1.24	Used to derive a speed correction for passenger trains on new main line
	passenger	75	70	0.95	Used to derive a speed correction for passenger trains on new main line at Woodstock Jnc, near Qaudrangle
	passenger	75	60	0.85	Used to derive a speed correction for passenger trains on new main line near 3 Bladon Close
1B	passenger	35	40	1.11	Used to derive a speed correction for passenger trains on existing main line as well as the new chord
11	freight	60	75	1.18	Used to derive a speed correction for freight trains on new main line
	freight	60	70	1.12	Used to derive a speed correction for freight trains on new main line at Woodstock Jnc, near Qaudrangle
5	freight	38	40	1.04	Used to derive a speed correction for freight trains on existing main line
41	stone train	28	40	1.31	Used to derive a speed correction for stone trains on existing main line
	stone train	28	60	1.77	Used to derive a speed correction for stone trains on new main line

7. Vibration Decay Curves using VDVs

7.1. This section presents an analysis of measured data to derive appropriate vibration decay curves for distance attenuation, expressed in VDVs.

Distance Decay Relationships

7.2. The decay in vibration levels with distance from the track, have been based on the measured VDV information, which was gathered on soil conditions representative of the study area. The decay curves are valid for distances of between 3m and 19m from the nearest traffic running rail head. This is representative of the range of distances where properties at risk were identified as part of this project.

7.3. A number of regression relationships were derived from various vibration data. The general form of the resulting equation is as follows;

$$y = C.e^{-k.x} \qquad \text{(Equation 7-1)}$$

where;

y is the VDV(z) in $m.s^{-1.75}$

C and *k* are constants derived from regression curves

x is the distance from nearest edge of traffic running rail, m

7.4. The magnitude of VDV1 (or y1) and VDV2 (or y2) at any given distance x1 and x2, using the same regression curve, can be expressed as follows;

$$y_1 = C.e^{-k.x1} \qquad \text{(Equation 7-2)}$$

$$y_2 = C.e^{-k.x2} \qquad \text{(Equation 7-3)}$$

7.5. The ratio of equations 5-3 and 5-2 provides the VDV scale factor for distance, as follows;

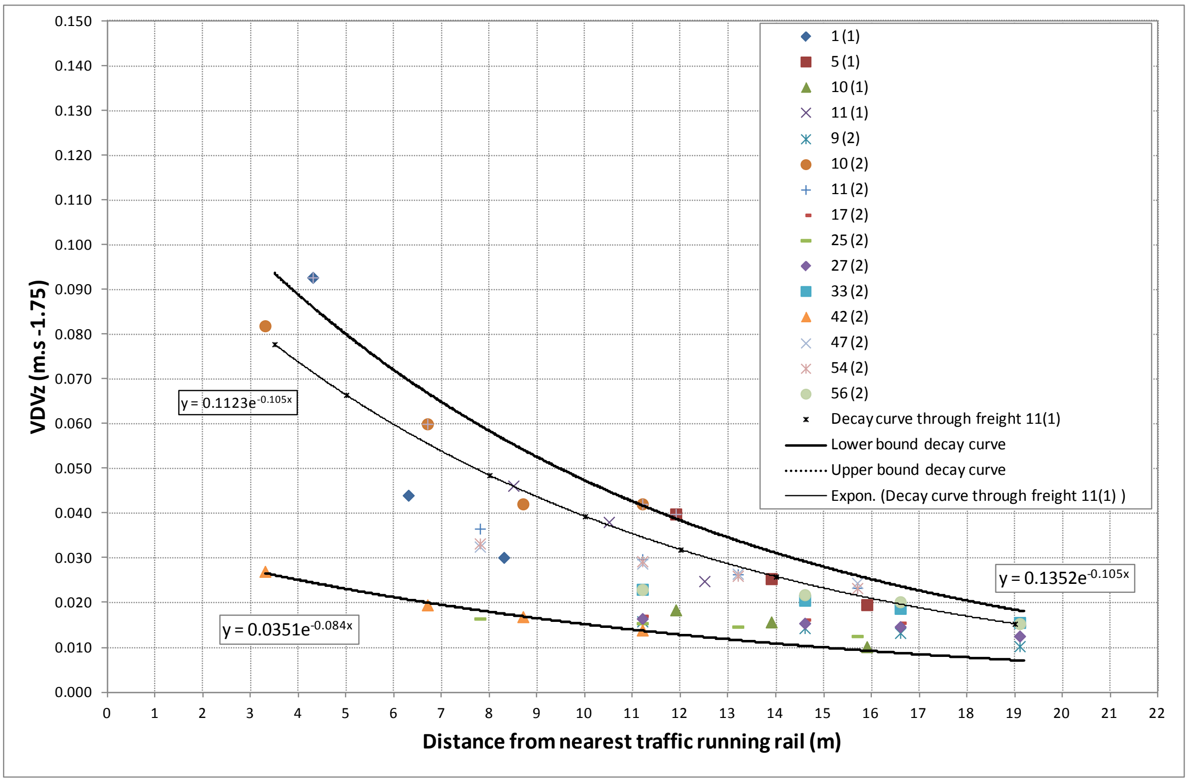
$$\frac{y_2}{y_1} = e^{-k(x2-x1)} \qquad \text{(Equation 7-4)}$$

7.6. This relationship is then used to factor up or down VDV1 (or y1) measured at a known distance of x1, to derive a VDV2 (y2) at a new distance x2. The distance dependence relationship is different for the different types of train and so each train type is considered separately.

Freight Trains

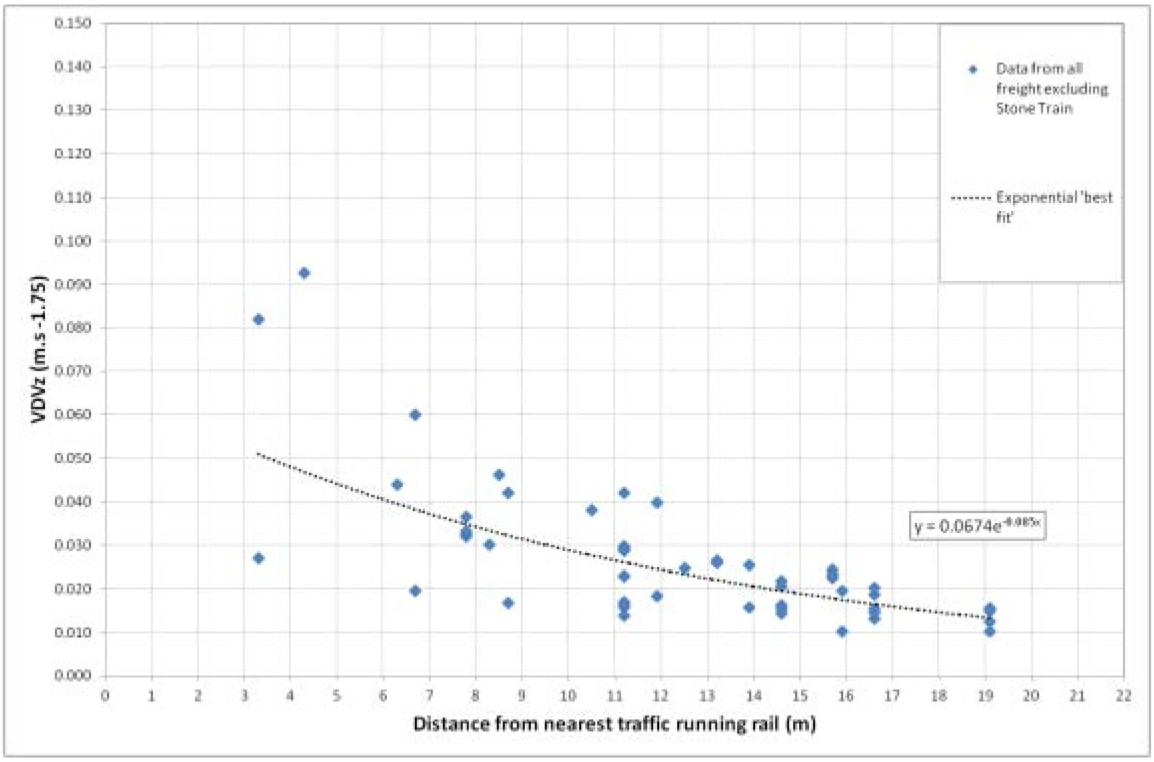
7.7. The VDV (z) measurements in $m.s^{-1.75}$ from freight trains at various distances from the nearest traffic running rail are summarised in Figure 24. The graph shows an ‘upper bound’ and a ‘lower bound’ decay curve which demonstrates the potential uncertainty at distances considered. The upper decay curve has been offset to represent a similar decay through the reference pass-by event (event 11 at 8.5m from track), which is used for predicting VDVs in this assessment. The details of individual pass-by events are given in **Appendix F**.

Figure 24. Summary of VDV(z-axis) values for Freight



7.8. The graph in Figure 25 shows the best-fit regression curve through all measurements corresponding to conventional freight vehicles. At 5m from the track, the decay curve through the reference pass-by event (event 11 at 8.5m from track) results in levels which are 50% higher than the average values (factor of 1.5). Approximately 80% of all measured VDVs are on or below this curve.

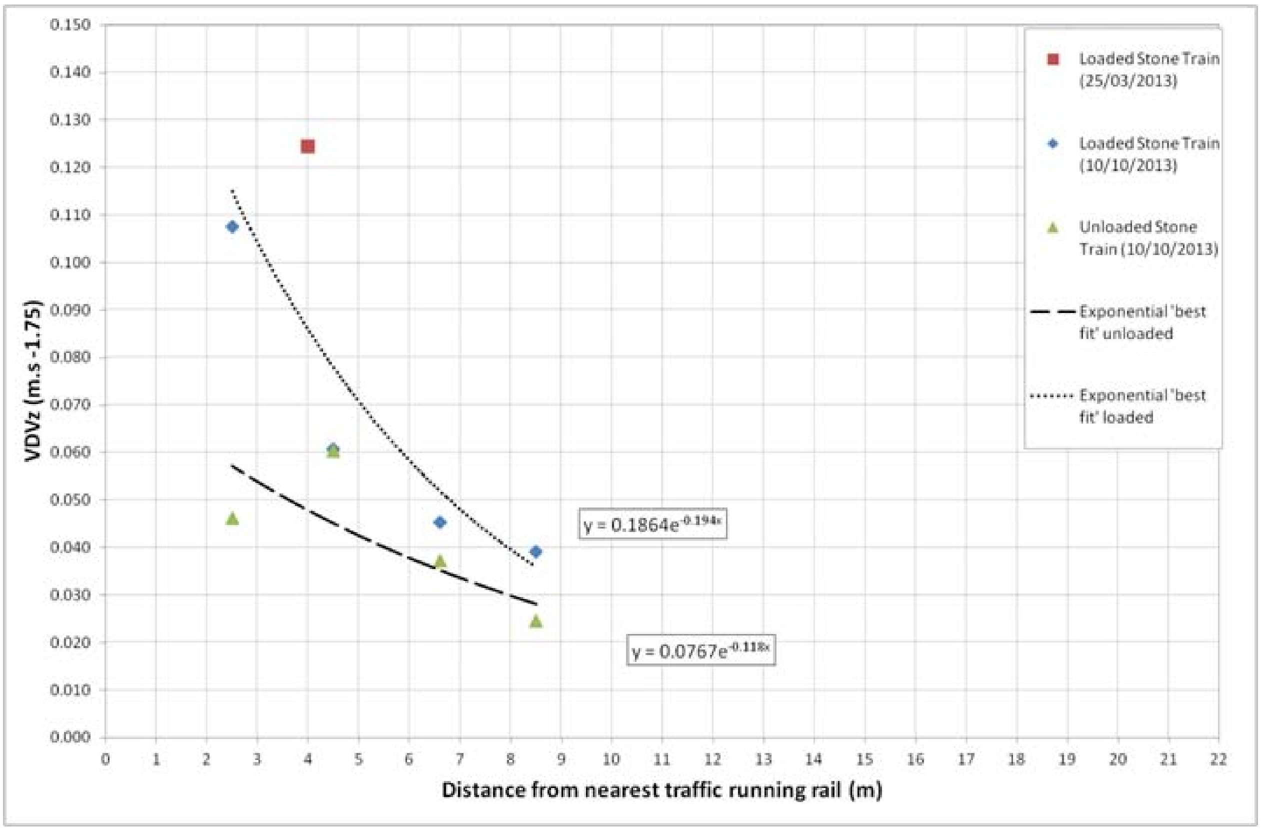
Figure 25. VDV(z-axis) Freight Vs Distance – Best Fit Curve



Stone Train

7.9. In addition to a measurement of a loaded train at a single location in March 2013, measurements in October 2013 included that of a loaded and unloaded stone train at 4 distances from the track. Figure 26 below shows the regression curves through data where multiple measurements were undertaken of the same pass-by event.

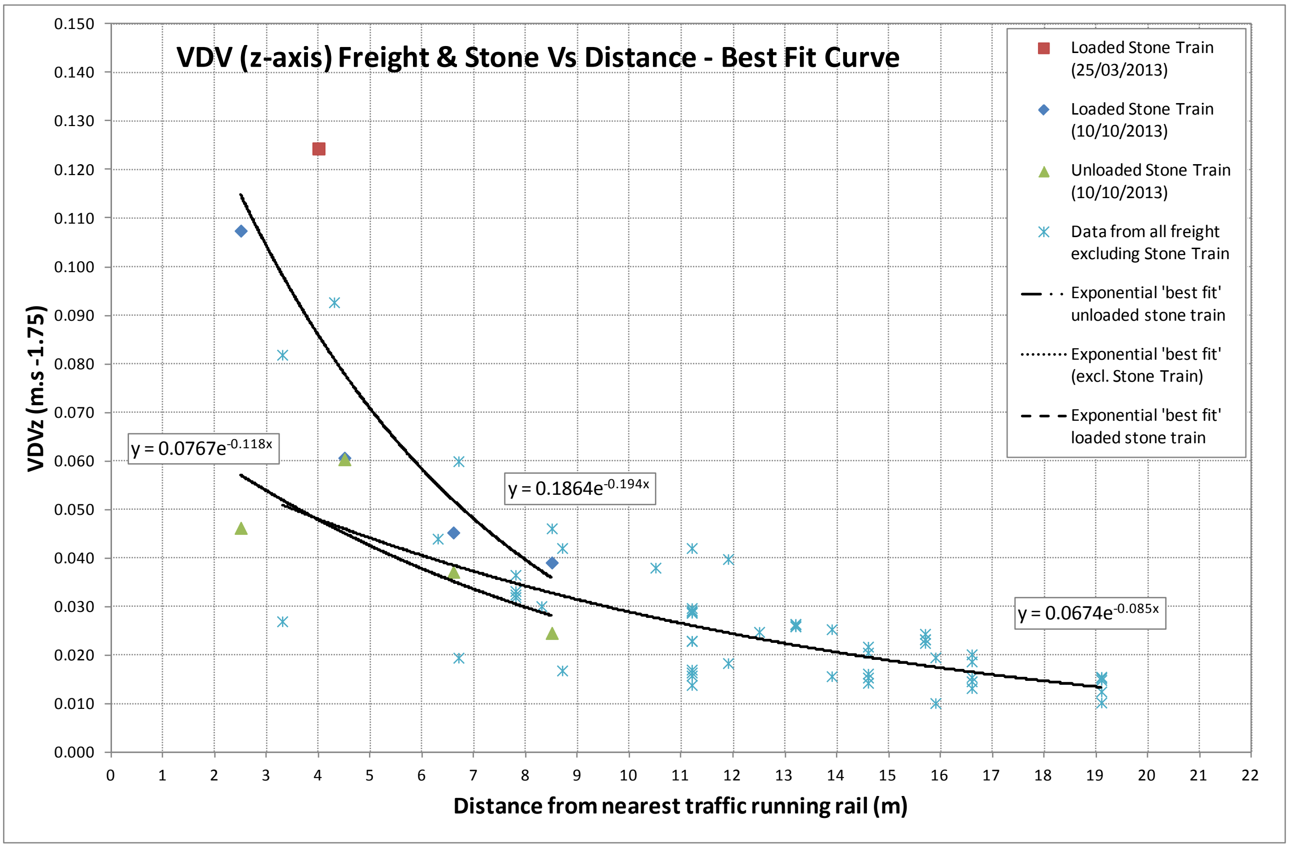
Figure 26. VDV(z-axis) Stone Train Distance Regression Curve



Combined Freight and Stone Train

7.10. The measured vibration levels from conventional freight trains and stone trains are compared below.

Figure 27. VDV(z-axis) Combined Freight and Stone Train Regression Curve



7.11. It is shown that the vibration levels from the unloaded stone train are consistent with the regression curve for the conventional trains. Although the loaded stone train is shown to generate higher vibration levels than an average freight train, the levels are mainly within the upper bound regression curves illustrated earlier. The levels appear to decay faster, becoming consistent with the rest of the measured levels at around 9m from the track.

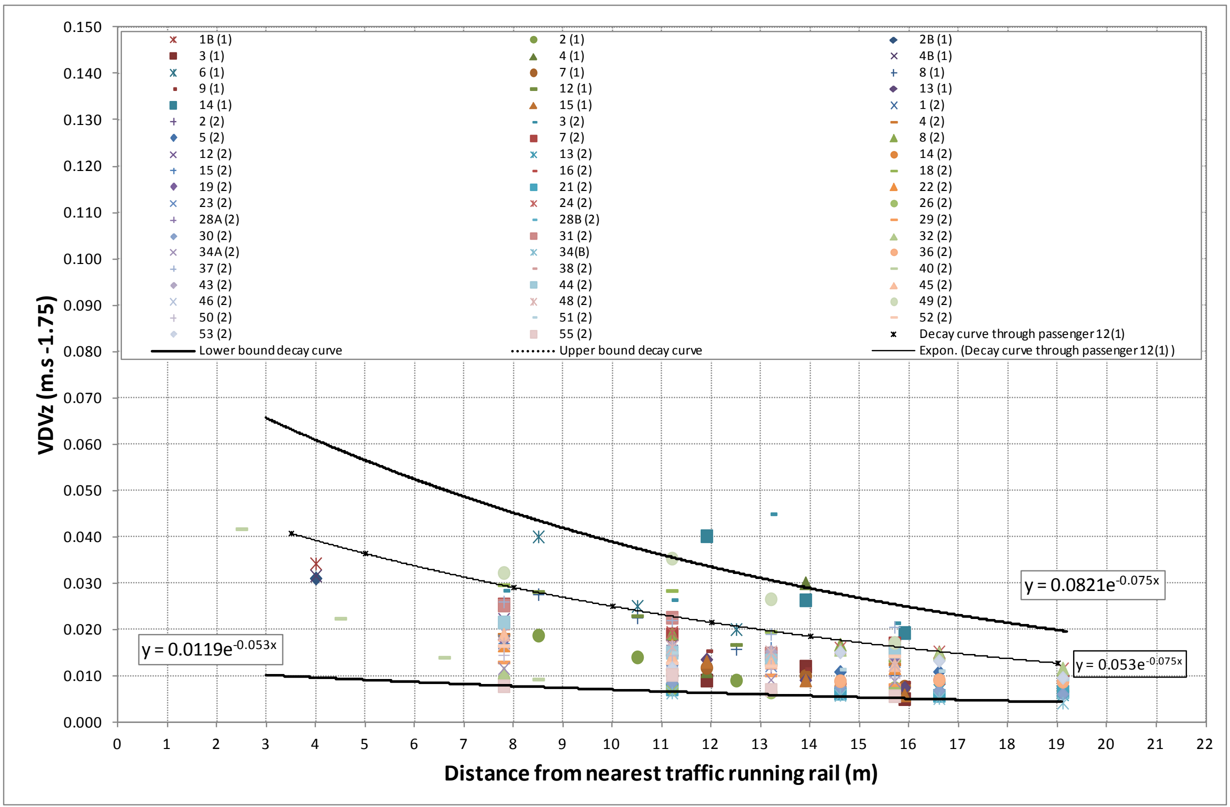
7.12. On the basis of this evidence, it is reasonable to assume that unloaded stone train could generate similar levels of vibration as the conventional freight trains. The loaded stone trains should be treated separately.

Passenger Trains

7.13. The VDV (z) measurements in $m.s^{-1.75}$ from passenger trains at various distances from the nearest traffic running rail are summarised in Figure 28. The graph shows an ‘upper bound’ and a ‘lower bound’ decay curve which demonstrates the potential uncertainty at distances considered. The upper decay curve has been offset to represent a similar decay through the reference pass-by event (event 12 at 8.5m from track), which is used for predicting VDVs in this assessment. The details of individual pass-by events are given in **Appendix F**.

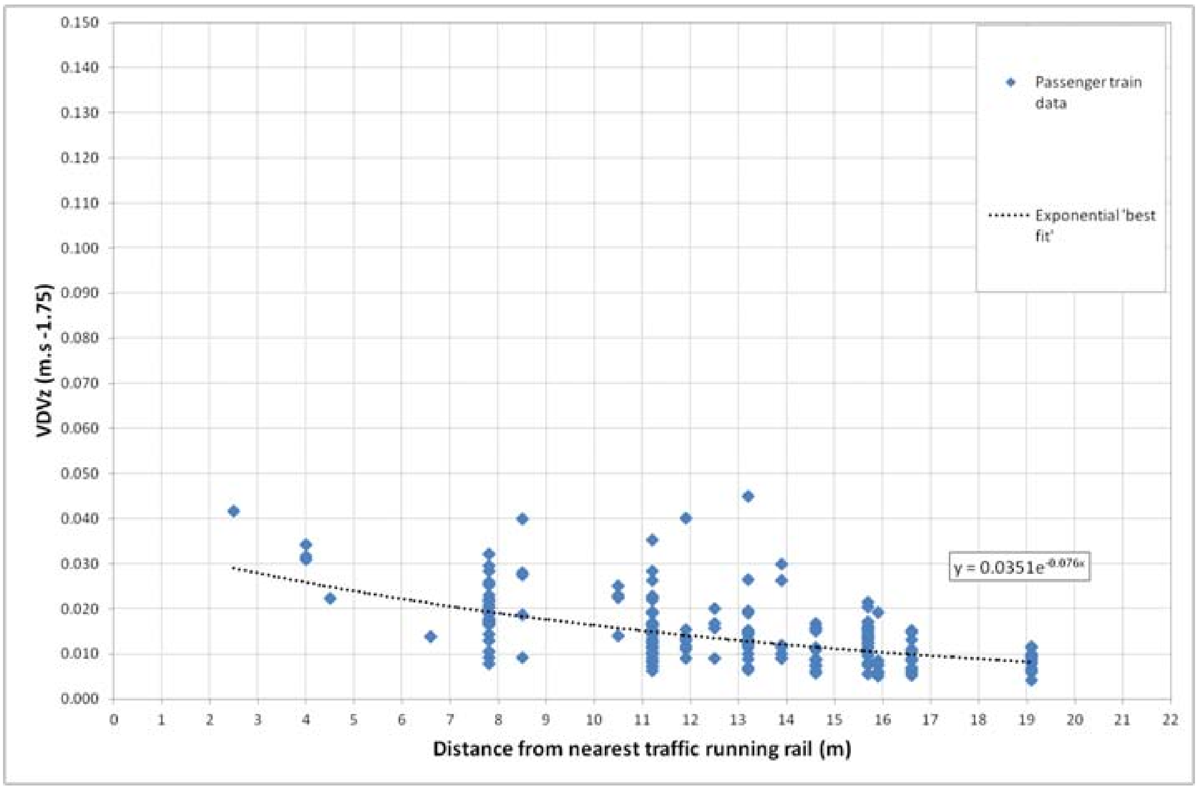
7.14. For ease of comparison with the freight train data, the same graph scales have been applied. As expected the vibration levels generated by passenger trains are lower than those caused by freight trains.

Figure 28. Summary of VDV(z-axis) values for Passenger



7.15. The graph in Figure 29 shows the best-fit curve through all measurements corresponding to passenger vehicles. At 5m from the track, the decay curve through the reference pass-by event (event 12 at 8.5m from track) results in levels which are 50% higher than the average values (factor of 1.5). Approximately 93% of all measured VDVs are below this curve.

Figure 29. VDV(z-axis) Passenger Vs Distance – Best Fit Curve



Choice of Decay Curves

7.16. For the prediction of VDVs, the decay curves having the following general shape have been used.

$$VDV1 = VDV1\ x\ e^{-k(x2-x1)} \quad \text{(Equation 7-5)}$$

7.17. Where;

- VDV1 is the measured VDV corresponding to the reference pass-by event
- x1 is the distance between the track and the position at which the reference pass-by event was measured
- x2 is the distance between the track and the vibration sensitive receiver
- k is the VDV decay rate

7.18. The VDV decay rates, k, are summarised below for different train types.

Table 9. Distance Decay Curves for VDVs

Proposed Scheme	VDV decay rate, k
Passenger trains	0.075
Freight trains	0.105
Loaded Stone Train (applies to 3 Bladon Close and Quadrangle only)	0.194
Unloaded Stone Train (applies to 3 Bladon Close and Quadrangle only)	0.118

8. Assessment of Plain Line Vibration

8.1. This section identifies predicted vibration levels, in VDV, and compares these against project limit values. Where limits are met, no further action is required. Where limits are exceeded, mitigation measures need to be considered.

8.2. As described above, the project limits are in VDVs. Working in VDVs ensures that compliance with project limits can be clearly demonstrated. The predicted VDVs have been derived using two different approaches.

- Use of frequency decay curves in appropriate 1/3 octave band frequencies (Section 5 of the report)
- Use of decay curves obtained directly from true VDVs as obtained from measurements on site (Section 7 of the report)

8.3. Both approaches consider the following separately;

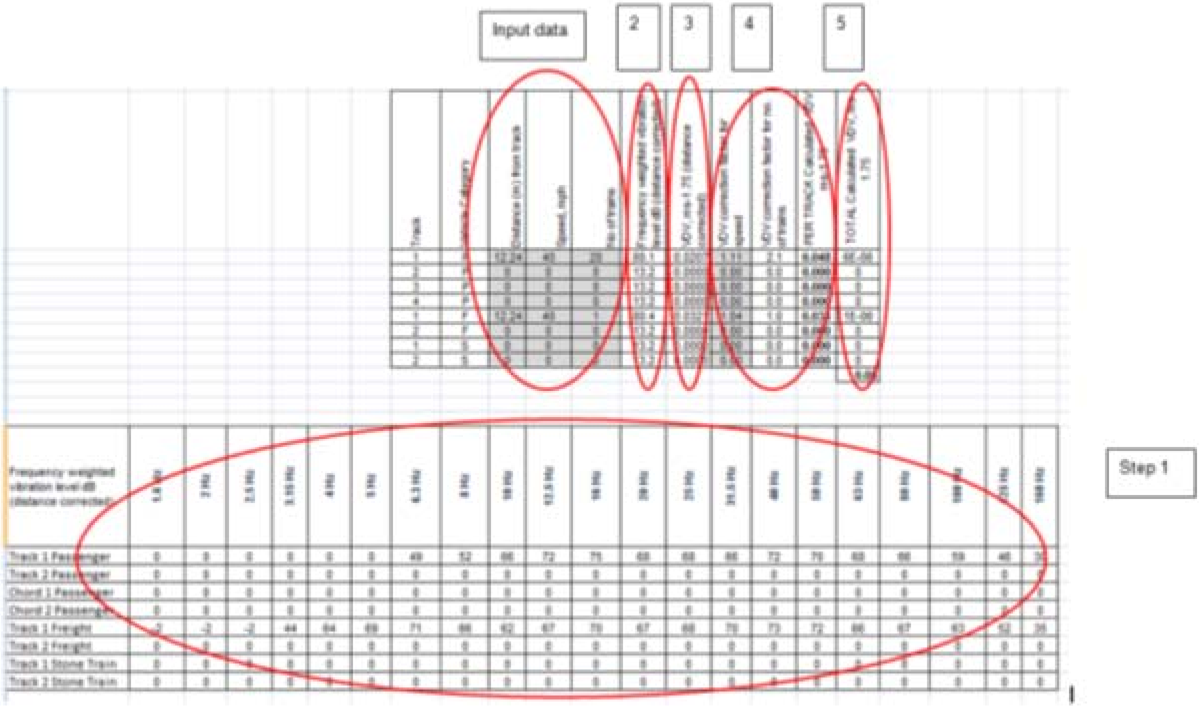
- Day and night time levels
- Passenger, freight and, where available, stone train
- Each individual track
- Existing and Proposed scenarios

Approach 1 - Frequency Decay Curves

8.4. The details of all calculations are shown in **Appendix J-1**. Calculations have been undertaken with the aid of spreadsheets. The calculations use frequency decay curves in appropriate 1/3 octave band frequencies. The decay rates described in Table 6, Section 5 are applied to the base curves for representative pass-by events at known distances. Base vibration data from high-speed freight and passenger events (events 11 and 12), and a loaded stone train (event 41) were used for assessing the impacts of the proposed Scheme.

8.5. In each frequency band, the weighted rms acceleration values, La, have been converted to decibels (dB) using the equation 20 log (La / 10^{-6}). The single figure levels L1, in dB, are derived by logarithmic addition of each 1/3 octave band dB level. Each base case also has a measured VDV1 associated with the event. Figure 30 below is used to explain how the calculations are arranged.

Figure 30. Frequency Decay Calculations in dB



8.6. Step 1 - Using the decay rates shown in Table 6 of Section 5, the vibration levels are calculated at the receiver distance, relative to the selected base curves, for each track and train vehicle type.

8.7. Step 2 - The distance corrected and frequency weighted vibration levels in each 1/3 octave frequency band (shown in Step 1) are logarithmically added to derive a single figure at the receiver position. This is undertaken separately for each track and train type.

8.8. Step 3 – Each vibration level L2, in dB, is converted to an intermediate VDV value termed VDV2 (int) (which at this stage has not been adjusted for number of trains or speeds) using the relationship below. As explained earlier, L1 and VDV1 are values associated with the base data.

$$L1 - L2 = 20 \log \left(\frac{VDV1}{VDV2(int)} \right) \qquad \text{(Equation 8-1)}$$

8.9. Step 4 - Appropriate correction factors are applied to the VDV(int) for speed, S and for number of trains, N. Speed corrections are tabulated in Table 8 of Section 6. The correction for number of trains uses the simple relationship (no of trains 2/ no of trains 1)$^{0.25}$. In these calculations, the ‘number of trains 1’ is always 1. This step gives calculated VDVs per track per vehicle type at the receiver position as follows VDV(2), ms$^{-1.75}$ = VDV2(int) x S x N.

8.10. Step 5 - Each VDV per track per vehicle type is added to give an overall VDV at the receiver position, using the following;

$$VDVtotal = (VDVi^4 + \cdots + VDVn^4)^{0.25} \qquad \text{(Equation 8-2)}$$

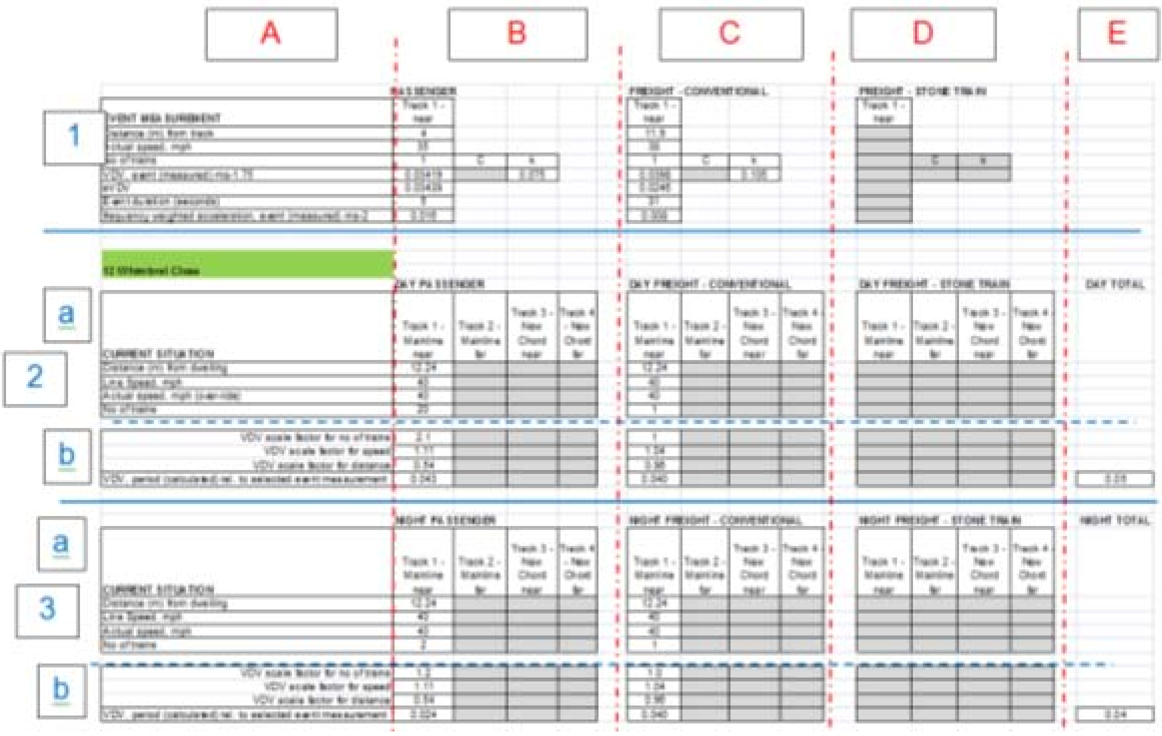
Approach 2 - Single Figure VDVs

8.11. The details of all calculations are shown in **Appendix J**. Calculations have been undertaken with the aid of spreadsheets. Figure 31 below is used to explain how the calculations are arranged.

8.12. Each table in **Appendix J-2** shows the results of assessment undertaken at a selected receiver, the name of which is indicated in the table, and for a given scenario (i.e. current situation or proposed situation). Therefore there are 2 consecutive tables associated with each receiver to describe assessments for current and proposed scenarios.

8.13. The information is arranged in 3 main horizontal parts (labelled 1 to 3) and 5 main vertical parts (labelled A to E), as follows;

Figure 31. Single Figure VDV Calculations



8.14. Top third (1) of the table shows the assumed base vibration data. The second (2) and third (3) parts of the table show details of the day-time and night-time calculations respectively. The second and third parts are further sub-divided into two. The parts (a) show the input assumptions made as part of the calculations (distance from dwellings, speeds, number of trains) and the parts (b) describe the correction factors and the calculated VDVs. The calculation steps and the input assumptions are described in column A. Columns B, C and D contain details of assessments for passenger, freight and stone trains respectively, at each individual track. Column E gives the results of total VDVs, with contributions from all tracks and all passenger types summed up. Where cells are shown in grey, these parts of the calculations are not applicable to the assessments.

8.15. The selection of 'base' vibration data for undertaking the assessments has been determined by the train type (passenger, freight or stone train) and the train speed of interest. Base vibration data from low-speed events (1B, 5 and 41) were used for calculating the VDVs for current situation, where the relative speed adjustments to VDVs would be relatively small. Similarly, base vibration data from high-speed events (11 and 12) were mainly used for assessing the impacts of the proposed Scheme. On the proposed chord line, event 1B has been used to account for the speed limit of 40mph with minimal speed adjustment. This is reflected in calculations at 12 Whimbrel Close.

8.16. The calculation steps are explained below with the aid of a sample calculation (12 Whimbrel Close, passenger train, day-time, nearest track).

Table 10. Sample Calculation (12 Whimbrel Close, passenger train, day-time, nearest track)

Variable	Case 1	Case 2	Assessment	Adjustment Factor
Distance (m)	x1 = 4m	x2 = 12.2m	Input parameter	n/a
VDV scale factor for no of trains, N	1 no. of daytime passenger trains	20 no. of daytime passenger trains	$(20/1)^{0.25}$	2.1
VDV scale factor for speed, S	Speed1 = 35mph	Speed2 = 40mph	Use Table 8 (passenger train)	1.11
VDV scale factor for distance, D	x1 & x2 as above. k = 0.076 (from Table 9)		Use Equation 7-5	0.53
Calculated VDV	VDV1 = 0.03419 $ms^{-1.75}$	Calculate VDV2	VDV2 = VDV1 x N x S x D	n/a

8.17. At a given receiver, assessment period (day or night) and a scenario (i.e. current situation or proposed scheme), the above calculation steps are repeated for each track and for each vehicle type (passenger, freight, stone train) separately, as appropriate. The resulting VDVs are summed up using Equation 8-2 above.

Site Assessments

8.18. The VDVs at each receiver have been calculated for the current and future operation of the railway and results are set out in Tables 11 to 28.

8.19. The tables showing current VDV's include, for reference, the measured VDVs reported in the Environmental Statement (ES), where these are available. Normally, it would be expected that external ground borne vibration levels would be similar to those measured on the floor within the building, however in this instance comparisons between these levels are limited for the following reasons. The data presented in the ES was obtained from unattended monitoring within occupied buildings, for which there was no record of either monitoring locations within the buildings or traffic flows during the monitoring period.

8.20. The location of each dwelling under consideration is shown on a plan relative to existing and proposed tracks. The existing track is shown in black and the proposed tracks are shown in red. In a number of cases, the new track follows closely the alignment of the existing track, and may make it difficult to visually differentiate different tracks.

Receiver – 12 Whimbrel Close

Table 11. Summary of VDVs for Current Situation – 12 Whimbrel Close

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.05	0 - 0.01	ES values based on continuous measurements over 4 days
	Approach 2	0.05		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.04	0 - 0.01	ES values based on continuous measurements over 5 nights
	Approach 2	0.04		

8.21. There is currently no stone train in this area. Night-time VDV levels are dominated by freight trains. Both passenger and freight trains make similar contributions to the overall day-time VDV levels.

Table 12. Summary of VDVs for Proposed Situation– 12 Whimbrel Close

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.13	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.12		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.09	0.2	
	Approach 2	0.08		

8.22. According to the project understanding of the current and expected future train movements, no stone train is expected in this area in the future. Contributions are noted from both passenger and freight trains, however, the resulting VDVs are below project limits.

Receiver – 53 London Road

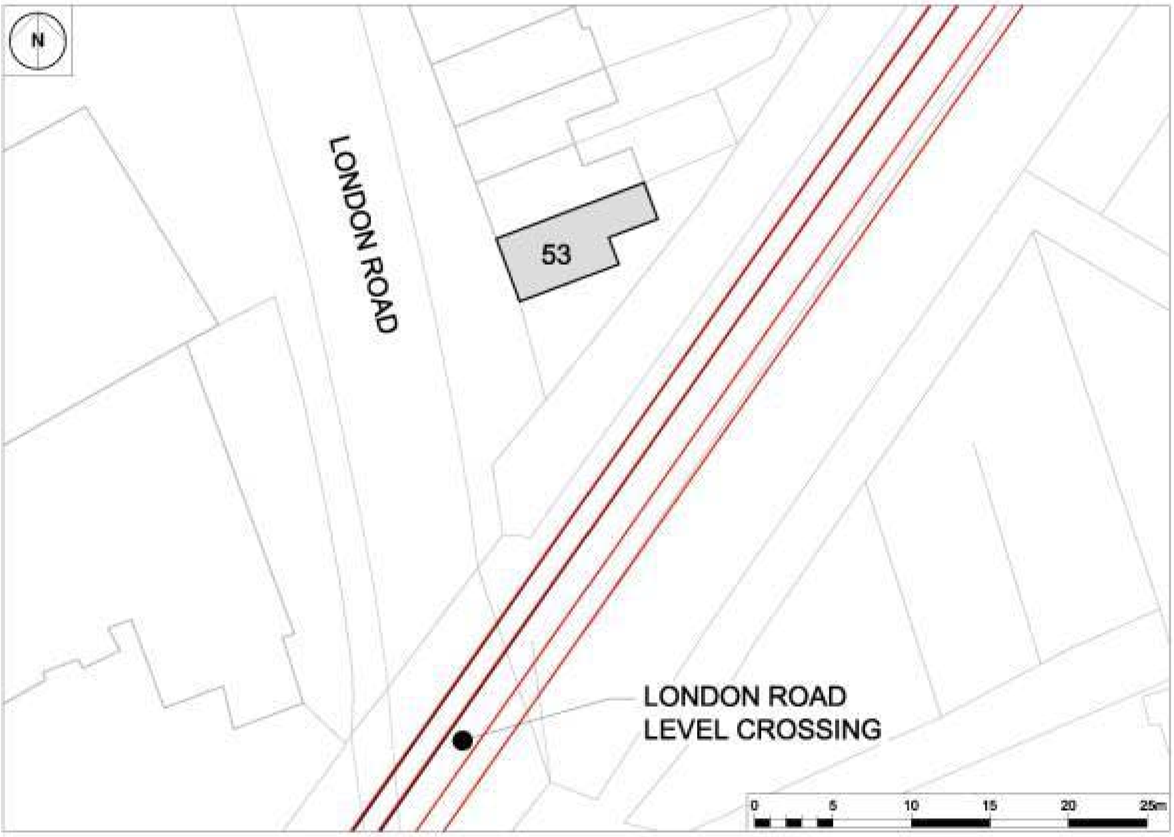


Table 13. Summary of VDVs for Current Situation - 53 London Road

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.08	n/a	-
	Approach 2	0.08		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.06	n/a	-
	Approach 2	0.07		

8.23. There is currently no stone train in this area. Night-time VDV levels are dominated by freight trains. Both passenger and freight trains make similar contributions to the overall day-time VDV levels.

Table 14. Summary of VDVs for Proposed Scheme - 53 London Road

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.16	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.16		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.11	0.2	
	Approach 2	0.11		

8.24. According to the project understanding of the current and expected future train movements, no stone train is expected in this area in the future. Contributions are noted from both passenger and freight trains, however, the resulting VDVs are below project limits.

Receiver – 21 Nuthatch Way

Table 15. Summary of VDVs for Current Situation – 21 Nuthatch Way

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) m.s$^{-1.75}$	Approach 1	0.04	n/a	-
	Approach 2	0.03		
Night-time VDV(Z) m.s$^{-1.75}$	Approach 1	0.03	n/a	-
	Approach 2	0.02		

8.25. There is currently no stone train in this area. Night-time VDV levels are dominated by freight trains. Both passenger and freight trains make similar contributions to the overall day-time VDV levels.

Table 16. Summary of VDVs for Proposed Scheme – 21 Nuthatch Way

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) m.s$^{-1.75}$	Approach 1	0.09	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.09		
Night-time VDV(Z)	Approach 1	0.06	0.2	

$m.s^{-1.75}$	Approach 2	0.06		

8.26. According to the project understanding of the current and expected future train movements, no stone train is expected in this area in the future. Contributions are noted from both passenger and freight trains, however, the resulting VDVs are below project limits.

Receiver – 5 Westholme Court

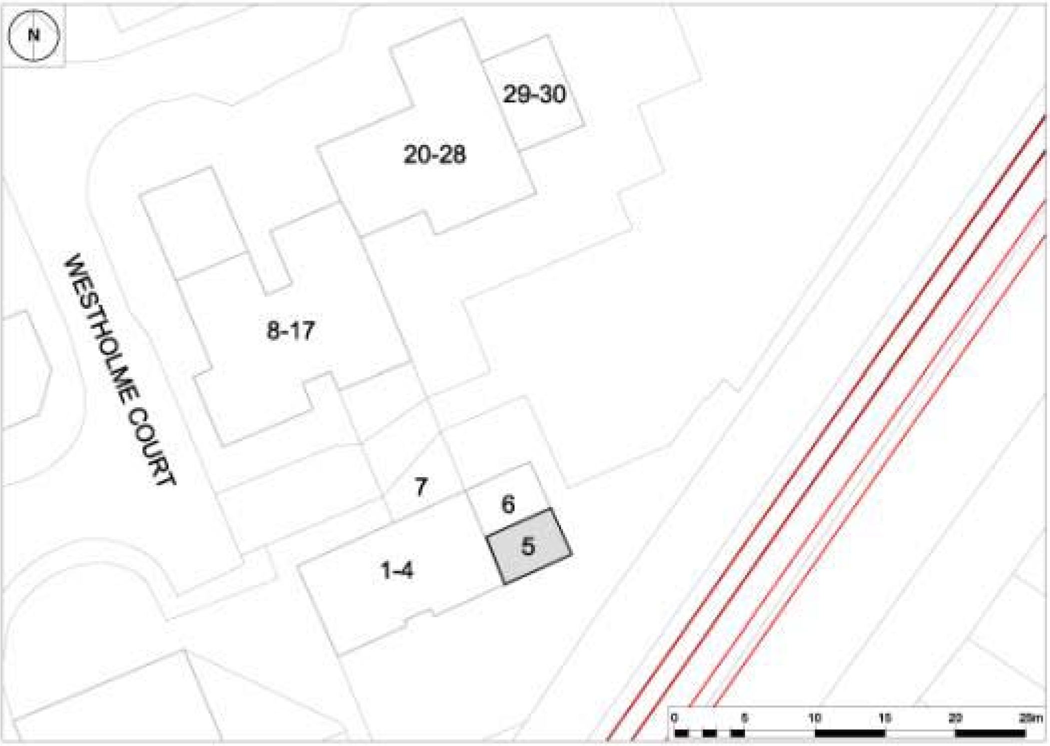


Table 17. Summary of VDVs for Existing Scheme – 5 Westholme Court

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.06	n/a	-
	Approach 2	0.06		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.05	n/a	-
	Approach 2	0.05		

8.27. There is currently no stone train in this area. Night-time VDV levels are dominated by freight trains. Both passenger and freight trains make similar contributions to the overall day-time VDV levels.

Table 18. Summary of VDVs for Proposed Scheme – 5 Westholme Court

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.12	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.12		

Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.08	0.2	
	Approach 2	0.08		

8.28. According to the project understanding of the current and expected future train movements, no stone train is expected in this area in the future. Contributions are noted from both passenger and freight trains, however, the resulting VDVs are below project limits.

Receiver – Kareol, Islip Crossing

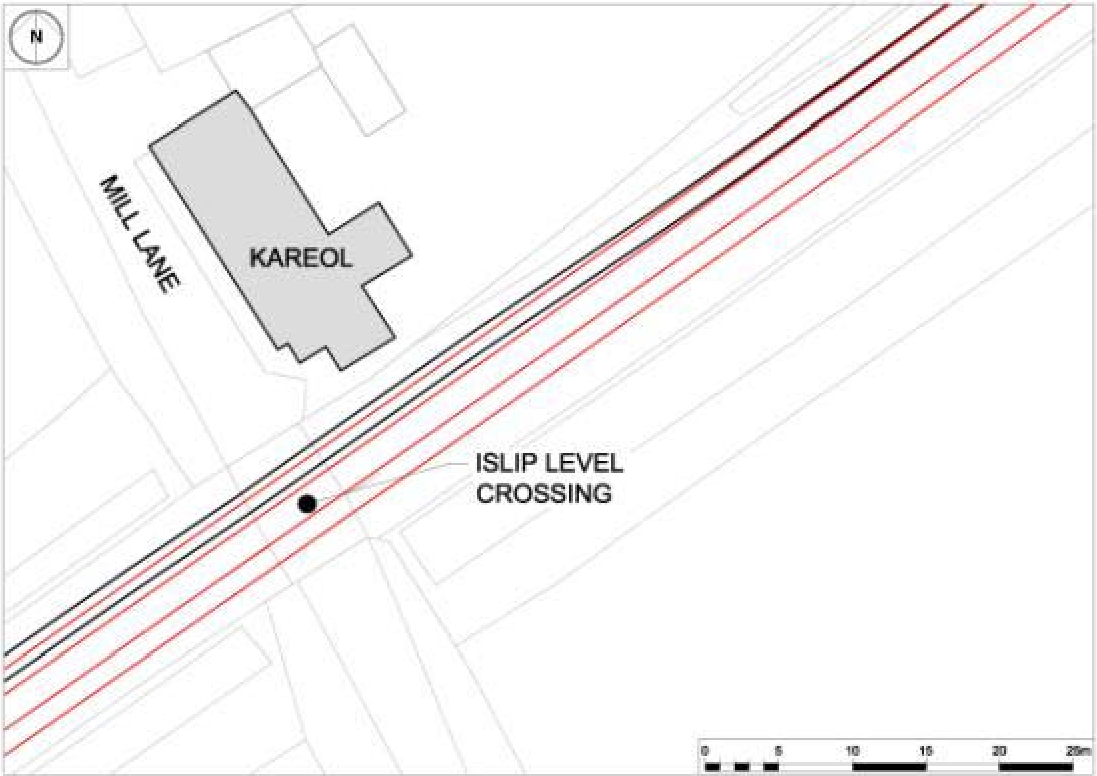


Table 19. Summary of VDVs for Existing Situation - Kareol, Islip Crossing

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.15	0.05	ES values based on continuous measurements over 1 day
	Approach 2	0.15		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.10	0.05 – 0.06	ES values based on continuous measurements over 2 nights
	Approach 2	0.11		

8.29. There is currently no stone train in this area. Both day and night-time VDV levels are dominated by freight trains.

Table 20. Summary of VDVs for Proposed Scheme - Kareol, Islip Crossing

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.22	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.20		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.16	0.2	
	Approach 2	0.15		

8.30. According to the project understanding of the current and expected future train movements, no stone train is expected in this area in the future. The estimated VDVs are dominated by freight trains both during the day and at night.

Receiver – Oddington Crossing

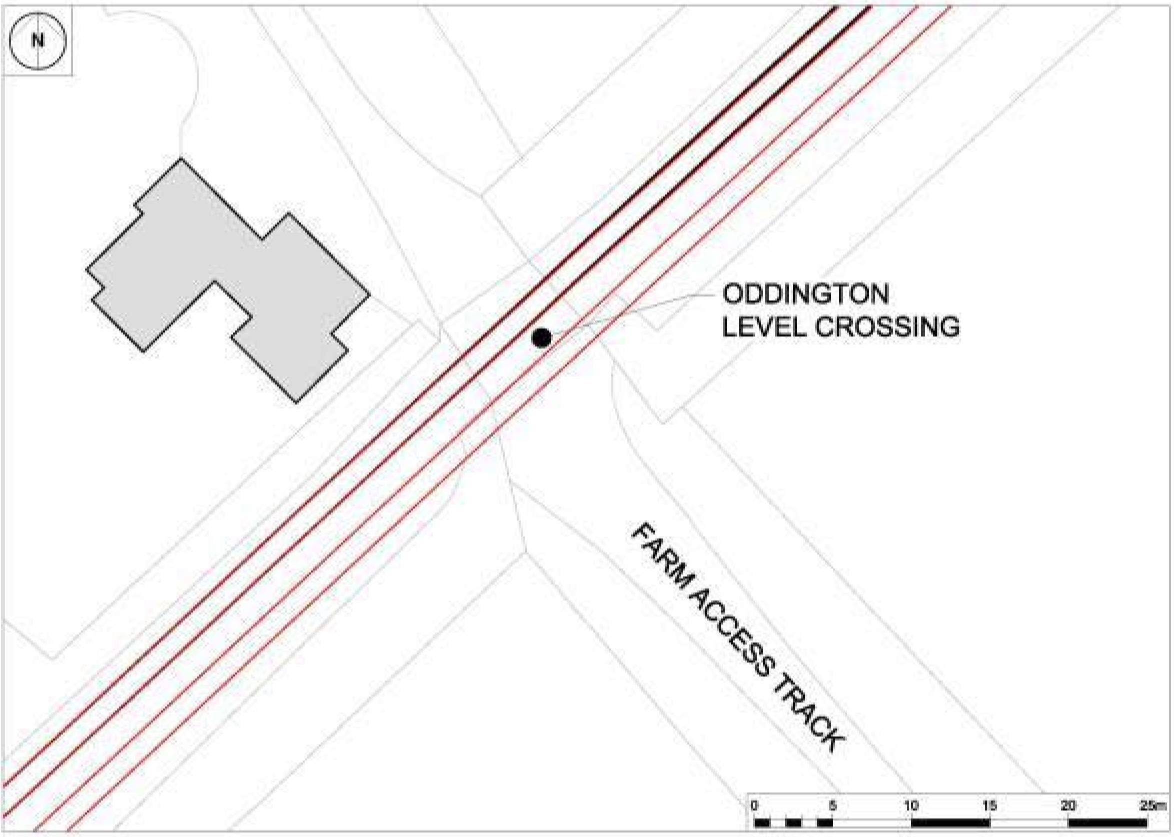


Table 21. Summary of VDVs for Existing Situation – Oddington Crossing

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.11	0.16 – 0.24	ES values based on continuous measurements over 6 days
	Approach 2	0.12		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.08	0 – 0.13	ES values based on continuous measurements over 7 nights
	Approach 2	0.09		

8.31. There is currently no stone train in this area. Both day and night-time VDV levels are dominated by freight trains.

Table 22. Summary of VDVs for Proposed Scheme - Oddington Crossing

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.18	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.17		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.13	0.2	
	Approach 2	0.13		

8.32. According to the project understanding of the current and expected future train movements, no stone train is expected in this area in the future. The estimated VDVs are dominated by freight trains during the night. Both passenger and freight trains make similar contributions during the day.

Receiver - Alchaster House, Langford Lane Crossing

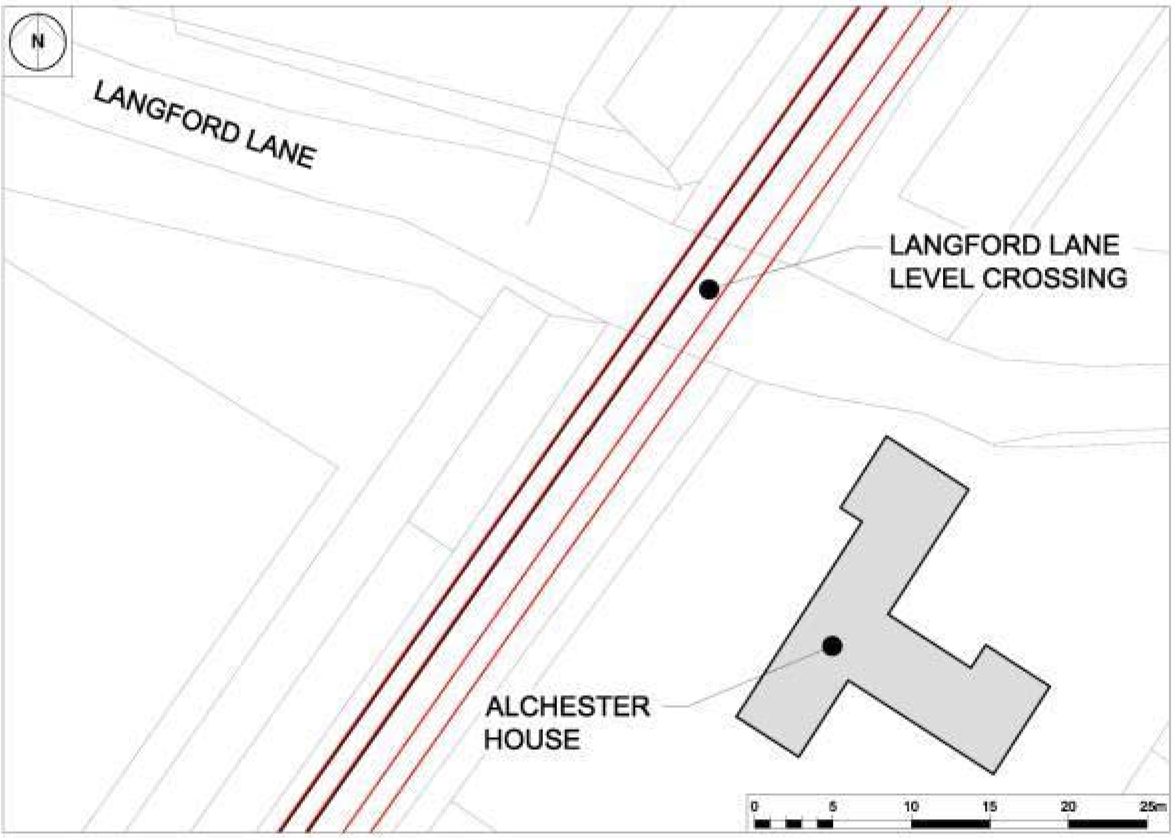


Table 23. Summary of VDVs for Existing Situation – Alchaster House

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.04	n/a	-
	Approach 2	0.04		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.03	n/a	-
	Approach 2	0.03		

8.33. There is currently no stone train in this area. Night-time VDV levels are dominated by freight trains. Both passenger and freight trains make similar contributions to the overall day-time VDV levels.

Table 24. Summary of VDVs for Proposed Scheme – Alchaster House

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.09	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.09		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.07	0.2	
	Approach 2	0.06		

8.34. According to the project understanding of the current and expected future train movements, no stone train is expected in this area in the future. Contributions are noted from both passenger and freight trains, however, the resulting VDVs are below project limits.

Receiver - 3 Bladon Close

Table 25. Summary of VDVs for Existing Situation – 3 Bladon Close

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.07	n/a	-
	Approach 2	0.05		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.03	n/a	-
	Approach 2	0.03		

8.35. The freight trains are the dominant component of VDVs during both day and night.

Table 26. Summary of VDVs for Proposed Scheme – 3 Bladon Close

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.11	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.07		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.06	0.2	
	Approach 2	0.06		

8.36. The main contributions to VDVs during the night are from freight trains. During the day, both freight and passenger trains provide a similar contribution to VDVs. The resulting VDVs are below project limits.

Receiver – Quadrangle, St Peter's Road

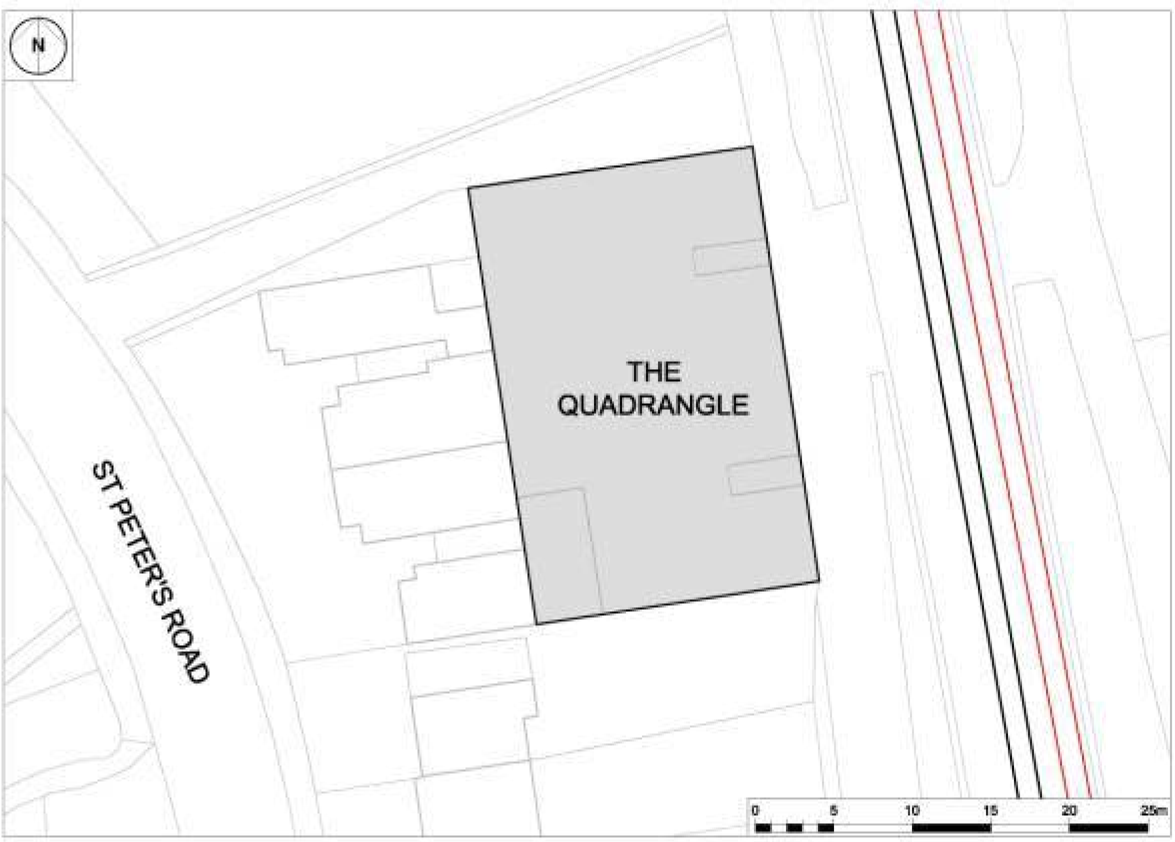


Table 27. Summary of VDVs for Existing Situation - Quadrangle

Assessment Period	Calculation Method	Calculated (open ground)	ES Measured (inside property)	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.09	0.03 – 0.04	ES values based on continuous measurements over 2 days, 2^{nd} storey
	Approach 2	0.08	0.04	ES values based on continuous measurements over 1 day, basement
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.05	0.02 – 0.04	ES values based on continuous measurements over 3 nights, 2^{nd} storey
	Approach 2	0.06	0.03 – 0.04	ES values based on continuous measurements over 3 nights, basement

8.37. The freight trains are the dominant component of the higher day time VDV estimates. Both the freight trains and the stone train contribute similarly to lower day time VDV estimates. The night-time VDVs are dominated by freight trains.

8.38. It is understood that the measurements undertaken in the basement level of the property include a measurement of a stone train. It is likely this is reflected in the day-time VDV values.

8.39. The observations on PPV (Peak Particle Velocity) levels indicate that measurements undertaken at the second storey level are in the region of twice the magnitude of those measured at the basement level. However the observed amplification factor of 2 in the PPV levels at Quadrangle does not appear to be reflected in the measured VDVs. On this basis, and the fact that predicted VDVs in this assessment were generally shown to be higher than those measured inside the properties, no additional adjustments have been applied to the calculations at this property to account for potential attenuations or amplifications due to the presence of the building and its elements.

Table 28. Summary of VDVs for Proposed Scheme - Quadrangle

Assessment Period	Calculation Method	Calculated (open ground)	Project Limits	Comment
Day-time VDV (Z) $m.s^{-1.75}$	Approach 1	0.15	0.4	VDVs lower than limit values. Mitigation not required.
	Approach 2	0.12		
Night-time VDV(Z) $m.s^{-1.75}$	Approach 1	0.09	0.2	
	Approach 2	0.09		

8.40. All train types make contributions to resulting VDVs during the day. At night, freight trains provide the dominant VDV component. However, the resulting VDVs are below project limits.

9. Vibration Mitigation

9.1. This section identifies the locations which could qualify for vibration mitigation, and where appropriate, provides an acoustic specification and a potential solution to meet this specification.

Quantification of Uncertainty

9.2. All calculated VDVs were shown to be higher than the average values observed in measurements, due to factors of safety employed in the calculations. The scheme impacts are calculated using appropriate regression curves through representative reference pass-by events which result in higher vibration levels than average. The observed factors of safety in the calculations are summarised below.

Table 29. Estimated factors of safety in VDV calculations

Prediction method	Passenger trains	Freight trains
Approach 1 – Decay curves in dB for each 1/3 octave band frequency linearly offset to represent appropriate reference case	Predicted vibration levels are 3.5dB higher than average 95% of all measurements are on or below the regression curve	Predicted vibration levels are 2.5dB higher than average 90% of all measurements are on or below the regression curve
Approach 2 – VDVs predicted from upper regression curves offset to represent appropriate reference case	Predicted VDVs at 5m from track are higher than average by a factor of 1.5 93% of all measurements are on or below the regression curve	Predicted VDVs at 5m from track are higher than average by a factor of 1.5 80% of all measurements are on or below the regression curve

Properties Qualifying for Mitigation

9.3. The night-time vibration levels were shown to be the critical levels in determining the need for mitigation. The day-time vibration levels are included for completeness. The appropriate VDVs are summarised below to determine whether the project VDV limits are exceeded or met.

Table 30. Summary of Project Compliance with VDV Limits

Receiver	Predicted VDV, $m/s^{-1.75}$		Project VDV Limit, $m/s^{-1.75}$ (D =0.4, N=0.2) Met or Exceeded?
	D	N	
12 Whimbrel Close	0.13	0.09	Met
53 London Road	0.16	0.11	Met
21 Nuthatch Way	0.09	0.06	Met
5 Westholme Court	0.12	0.08	Met
Islip, Kareol	0.22	0.16	Met
Oddington	0.18	0.13	Met
Alchaster House	0.09	0.07	Met

Receiver	Predicted VDV, m/s$^{-1.75}$		Project VDV Limit, m/s$^{-1.75}$ (D =0.4, N=0.2) Met or Exceeded?
	D	N	
3 Bladon Close	0.11	0.06	Met
Quadrangle	0.15	0.09	Met

9.4. The predicted vibration levels indicated that the calculated VDVs at all 9 vibration-sensitive properties were below project VDV limits.

9.5. The predicted night-time VDVs at Islip, Kareol, which is the dwelling with the highest predicted level, is 20% below the project limits. For passenger trains, predicted vibration levels were 3.5dB higher than the average values and 95% of all measurements were observed to be on or below the regression curve. For freight trains, the predicted vibration levels were 2.5dB higher than the average values and 90% of all measurements were shown to be on or below the regression curve. Therefore it is considered that the predictions incorporate sufficient factor of safety to demonstrate the predicted VDVs are robust in determining compliance with project limit values.

9.6. Although the assessments indicated that project VDV limits would not be exceeded, potential mitigation measures are considered below, at Islip, Kareol where predicted night-time VDVs were predicted to be 0.16 m/s$^{-1.75}$.

Predicted Insertion Loss Values

9.7. Edilon Sedra, suppliers of vibration isolation systems, have been requested to provide an insertion loss prognosis for a sub ballast mat system, which was identified as a suitable form of mitigation from an engineering point of view.

9.8. The details of the theoretical model, input assumptions and the findings of the assessments are shown in **Appendix K**. These reports include the mitigation parameters such as rail type, sleeper properties, soil properties, ballast properties as well the properties of the assumed sub ballast mat properties (TRACKELAST SBM/RPU/Blue/20-2GF). The model is based on Edilon Sedra's TRACKLAST SBM Selector software, which is routinely used to undertake theoretical assessments of potential mitigation measures. Scheme specific information has been supplied by Atkins in the form of response to questionnaires.

9.9. The track will be provided with a 0.25m capping layer under a 0.25m ballast layer. In order to approximate this in the model, two cases have been examined. First one considered a 0.25m thick ballast layer and the second one, a 0.50m thick ballast layer. The actual performance of the track is expected to be somewhere between the two cases.

9.10. The choices of vehicle types were a Class 66 with wagons to represent a typical heavy freight vehicle, and a DMU 168 to represent a light passenger vehicle. All other vehicles are expected to perform within this range. It should be noted that stone trains were not specifically considered in this assessment, since these trains are not expected to operate along the sections of the railway near Islip, Kareol which is the dwelling identified to be at highest risk from vibration.

Assessment of Mitigation Effectiveness

9.11. Using the insertion loss curves provided by Edilon Sedra, the effectiveness of the proposed mitigation measures are assessed below at Islip, Kareol for the following cases;

- soil stiffness of $E = <80$ MN/m^2 to represent a soft soil and a 0.25m thick ballast layer
- soil stiffness of $E = <80$ MN/m^2 to represent a soft soil and a 0.5m thick ballast layer

9.12. It was confirmed by the project engineers that that the assumed soil stiffness parameter was representative of the ground conditions found near the properties at risk from vibration. The insertion loss spectra have been applied to each track and train type separately in each 1/3 octave band frequency of interest (distance corrected and frequency weighted). This is then used to derive VDVs as described in Section 8 (Approach 1, steps 1 to 6).

Figure 32. Islip Kareol, No Mitigation

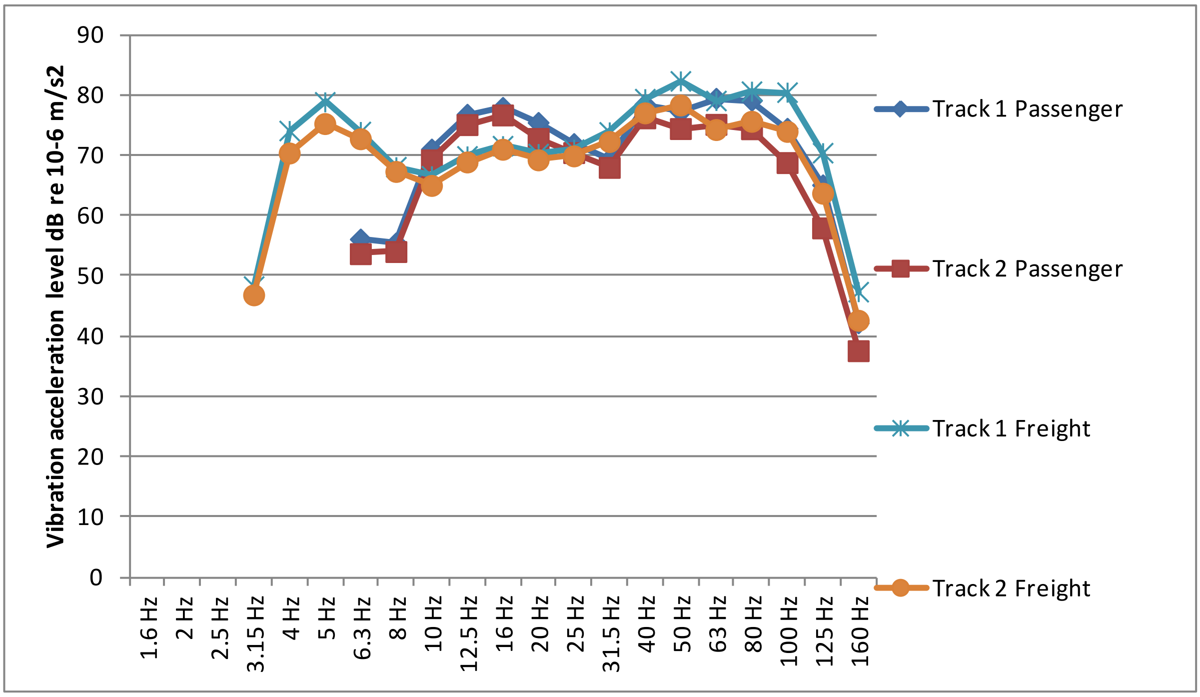


Figure 33. Islip Kareol, With Mitigation, 0.25m thick ballast layer, soft soil

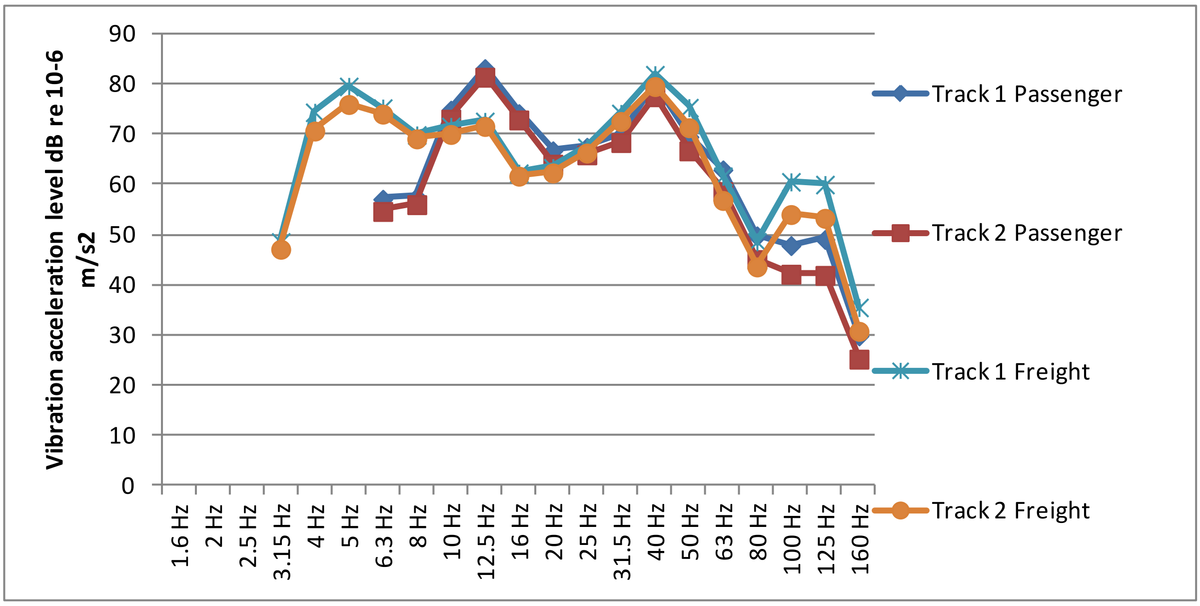
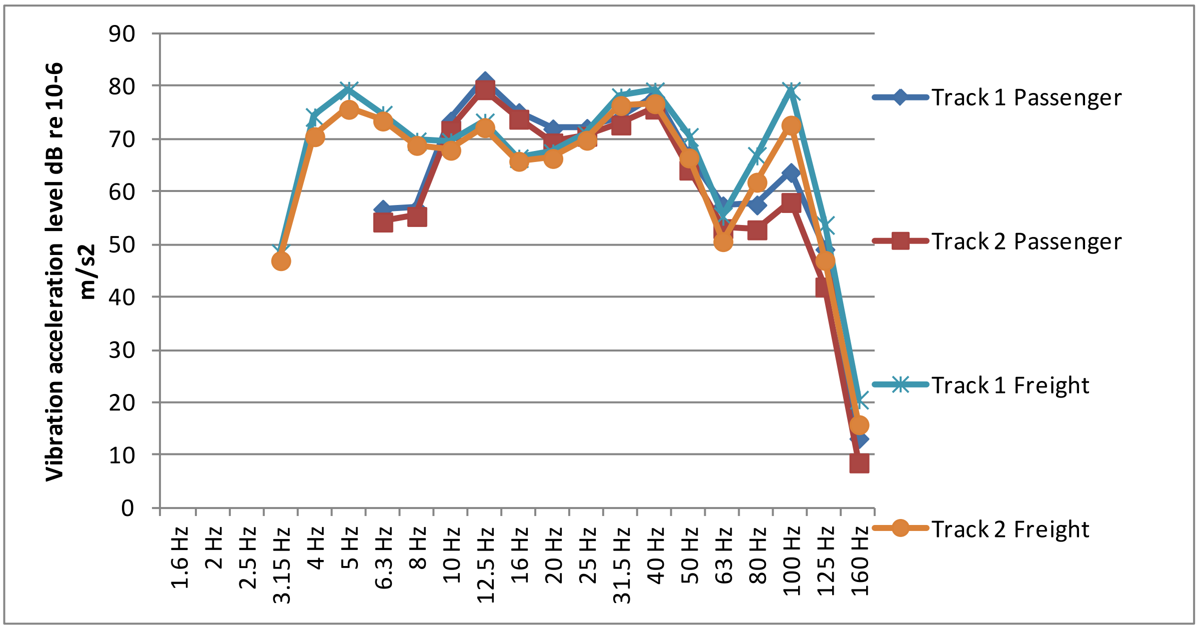


Figure 34. Islip Kareol, With Mitigation, 0.5m thick ballast layer, soft soil



9.13. The freight trains travelling on the near track (i.e. track 1) were found to be the dominant component of the resulting VDVs at night. With the application of the aforementioned sub ballast mat as part of the 0.25m thick ballast case, the higher frequencies are attenuated more effectively. In the case of freight trains, this exposes 5Hz and 40Hz as the main 1/3 octave band frequencies which limit the effectiveness of mitigation. As part of the 0.5m thick ballast case, vibration levels at 40Hz are reduced further for freight trains on the nearest track, however an additional peak is introduced at 100Hz. Over the full frequency range, the performance of both the 0.5m thick ballast case and the 0.25m thick ballast case is similar.

9.14. The calculated VDVs as well as the percentage reductions in VDVs are shown below at Islip, Kareol.

Receiver	Predicted Night-time VDV in m/s$^{-1.75}$ (% reduction in brackets)		
	No Mitigation	With mitigation 0.25m thick ballast	With mitigation 0.5m thick ballast
Islip, Kareol	0.16	0.13 (23%)	0.13 (23%)

10. Discussion

10.1. This section presents a general discussion of the results.

Project Limits and Assumptions

10.2. There are 9 No. vibration-sensitive dwellings which have been considered in detail as part of this assessment.

10.3. The vibration limits, in Vibration Dose Value (VDV), which the Scheme is required to meet in occupied dwellings adjacent to the Scheme are summarised below;

- Day (0700 – 2300 hours) - 0.4 $m/s^{1.75}$
- Night (2300 – 0700 hours) - 0.2 $m/s^{1.75}$

10.4. Therefore assessments are undertaken in the unit of VDVs to be able clearly demonstrate compliance with project limits and to assess the need for mitigation measures.

10.5. **Section 2** provides further specific information and assumptions related to the scheme, which have shaped the assessments. This includes best available information on the number, type and speed of trains during day-time and night-time as well as the distance between individual tracks and vibration-sensitive dwellings.

Vibration Measurements

10.6. A number of vibration measurements have been undertaken as part of this project to identify appropriate data for use in the assessments. Over the course of a number of days, data from 70 pass-by events have been captured. These included 51 passenger trains, 16 freight trains and 3 stone trains. The full details of each pass-by event including speed, vehicle type, number of wagons and distance from the track were noted.

10.7. Full details of vibration monitoring methodology and results are described in **Section 3**.

Track Inspection

10.8. The existing permanent way was inspected at the vibration monitoring sites on the existing Bicester to Oxford line (ELR – OXD) and the Oxford to Anyho Junction line (ELR – DCL), to determine the (a) component type; (b) component condition; (c) overall condition of the permanent way; and to (d) identify factors that could unduly impact on the vibration results.

10.9. The inspection of both lines was undertaken by Julien Green, who is the project CEM, and a former Permanent Way Maintenance Engineer, on 9 October 2013. The report is attached in Appendix E.

10.10. It was identified that the track is in a good condition, with no evidence of “track pumping” or other issues that would be outside of the normal parameters for a well maintained line for the track category currently in service.

10.11. It was also advised by the engineers that the tamping regime of the Loop line is likely to be 6-12 months basis dependent on how the track holds up in service. Because of the track category (level 2), tolerance levels for quality of track will be fairly stringent and will need to be maintained in the good to very good quality band.

Analysis

10.12. The analysis of vibration measurement survey results are undertaken in **Sections 4 to 7**. The information gathered from measurement surveys were analysed and used for deriving appropriate vibration decay curves with distance and frequency. These were also used to identify the frequency content of the resulting vibration levels for assessing effectiveness of mitigation measures.

Semi-empirical Prediction Method

10.13. The predicted VDVs are shown in **Section 8**. The predictions of VDVs have been undertaken using two different approaches. The first one was based on analysis of measured vibration acceleration levels to identify vibration decay characteristics, in dB, with distance at individual 1/3 octave band frequencies, for passenger and freight trains. The second approach applied directly measured data to derive appropriate vibration decay curves for distance attenuation, expressed in VDVs.

10.14. Comparisons between the results obtained using the two approaches showed a very good correlation in the predicted VDVs, both in the existing situation and with the scheme. By definition, VDV is obtained by weighting the rms acceleration values as appropriate at one-third octave frequency bands and combining these together to obtain a single value. Therefore frequency decay characteristics are appropriately reflected in the definition of VDV.

10.15. This comparison showed that both approaches provide consistent results and it would be appropriate to use the directly measured VDVs or the individual frequency decay curves in dB at each 1/3 octave band frequency for the assessment of project compliance with VDV limits.

Compliance with Project Limits

10.16. The predicted VDVs were further summarised in **Section 9** and the calculated VDVs at all 9 vibration-sensitive properties were shown to be below project VDV limits. The predicted night-time VDVs at Islip, Kareol (0.16 $m/s^{-1.75}$), which is the dwelling with the highest predicted level, was 20% below the project limits (0.2 $m/s^{-1.75}$).

10.17. Analysis of measured data indicated that the predictions incorporate sufficient factor of safety to demonstrate the predicted VDVs are robust in determining compliance with project limit values. For passenger trains, predicted vibration levels were 3.5dB higher than the average values and 95% of all measurements were observed to be on or below the regression curve. For freight trains, the predicted vibration levels were 2.5dB higher than the average values and 90% of all measurements were shown to be on or below the regression curve.

10.18. Although the assessments indicated that project VDV limits would not be exceeded, potential mitigation measures were considered at Islip, Kareol. Section 9 presented the details of insertion loss prognosis undertaken by Edilon Sedra for a bespoke sub ballast mat system. The results of insertion loss figures are used to assess the effectiveness of mitigation at the property. It was found that this system could provide a further 23% reduction in the calculated VDVs. This would lower the predicted VDVs to 0.13 $m/s^{-1.75}$.

Stone Train

10.19. Detailed discussions associated with the maximum and attainable speeds of stone trains are provided in Section 6. Further assumptions on stone trains are described in Section 2.

10.20. The current and expected future movements of the ‘stone train’ indicate this train is only likely to affect 2 of the 9 receivers assessed. These are 3 Bladon Close and Quadrangle. Since no stone train is expected at night, and the day-time VDVs are well below the limit values, it was found that the project VDV limits would not be exceeded at either of these locations.

10.21. Currently, the stone train operates 2 days of the week. The assessments are based on a typical day when the stone train would be operational, and represents a conservative approach when assessing typical VDVs at the dwellings.

10.22. With the scheme, there would be an increase in the number of freight movements. However there is no positive indication that there would be an intensification in use of the stone train. As a conservative approach, it has been assumed that, with the scheme, there could be up to 2 fully loaded stone trains a day (1 on each track, since both tracks are designed to be bi-directional).

The total number of freight movements has therefore been proportionately reduced to allow for these movements.

10.23. Measurements of a loaded and unloaded stone train showed that when the stone train is not loaded, the vibration levels generated are comparable to the 'average' decay curve from freight trains. Therefore as part of this assessment it is reasonable for an 'unloaded' stone train to be treated as a 'conventional' freight train.

Summary of Uncertainty

10.24. There are a number of sources of uncertainties associated with the measurement and the prediction of vibration levels at the various receptors considered in the assessment. These sources of uncertainty are identified and described below with their potential effect on the assessment and how they have been taken into account.

10.25. The last column of the tables provide a traffic-light assessment whether each item has a potential adverse (red), neutral (orange) or positive (green) impact on the assessments.

Table 31. Sources of Uncertainty Associated with Stone Train

Item	Assumption or Uncertainty	Assessment of Risk	Potential Effect	Action
1	It is assumed that with the scheme, the loaded stone train can travel up to 60mph.	Advice from the operators is that this is the highest maximum speed which could be expected under ideal conditions. The attainable speeds in reality would be further limited by a number of physical and operational constraints associated with the network and the trains. Further details are provided in the report.	This could lead to a lower assumed speed correction for the stone train with the scheme (1.77), and make it more comparable to the speed correction without the scheme (1.131). Only affects part of scheme used by stone train.	This is a conservative assumption and represents a factor of safety in the assessments.
2	Empirical relationships are used for adjusting VDVs from stone trains for speed.	These relationships are suitable for adjustments for small variations in speed. However as part of this assessment, they are applied to stone trains to scale up vibration levels from speeds 28mph to 60mph.	This likely to result in an over-prediction, supported by previous work by others discussed in report. Only affects part of scheme used by stone train.	This is a conservative assumption and represents a factor of safety in the assessments.
3	It is assumed that unloaded stone train would generate similar levels of vibration as the conventional freight trains.	The measurements have shown that an unloaded stone train is expected to generate vibration levels which are similar to those from conventional freight trains.	Not expected to affect assessments.	This is a reasonable assumption supported by evidence.
4	The assessments are based on a typical day when the stone train would be operational.	Currently, the stone train only operates 2 week-days of a 7-day week.	This results in an over-prediction of typical vibration levels experienced at properties over a period of time. Only affects part of scheme used by stone train.	Represents a conservative approach.
5	Assumed an increase in the number of stone trains with the scheme.	There is no indication from the operators of the stone train that the number of trains in use would be increased in the future. It is understood this would depend on operational constraints and economic considerations. Any potential additional stone trains could be spread onto different days of the week, or there could be more slots for loaded stone trains within the same day.	The predicted vibration levels with the scheme are likely to be higher than those expected in practice, over-predicting scheme impacts. Only affects part of scheme used by stone train.	This is a conservative assumption and represents a factor of safety in the assessments.

Table 32. Sources of Uncertainty Associated with Semi-Empirical Prediction Method

Item	Assumption or Uncertainty	Assessment of Risk	Potential Effect	Action
1	Assessments are based on regression curves derived from measurements of in-service trains.	The assessment takes into account the effect of different vehicle types travelling at speeds representative of design speeds and on representative geology.	For passenger trains, predicted vibration levels were 3.5dB higher than the average values and 95% of all measurements were observed to be on or below the regression curve. For freight trains, the predicted vibration levels were 2.5dB higher than the average values and 90% of all measurements were shown to be on or below the regression curve.	This is a conservative assumption and represents a factor of safety in the assessments.
2	The maximum permitted speeds on the line have been used in the assessments.	Due to the braking and acceleration patterns, the trains will not be at the maximum speed for the whole route.	The calculated vibration levels are likely to be higher than those expected under operational speeds.	This is a conservative assumption and represents a factor of safety in the assessments.
3	Speed corrections for freight and passenger trains rely on empirical relationships.	This is consistent with standard literature on the subject.	This element of the assessment is not expected to affect the assessments significantly.	This is a reasonable assumption.

Table 33. Sources of Uncertainty Associated with Measured Vibration Levels

<table>
<tr><th>Item</th><th>Assumption or Uncertainty</th><th>Assessment of Risk</th><th>Potential Effect</th><th>Action</th></tr>
<tr><td>1</td><td>Variation in track roughness through the tamping cycle of track as well as along the route</td><td>This is a general source of uncertainty which is likely to result in variation in vibration levels.</td><td>Inspection of track at measurement positions identified that track is in good overall condition, and consistent with the rest of the network. Engineer’s report is included in the report.</td><td rowspan="7">Assessments are based on decay relationships through a number of distances, speeds and vehicle types and numbers. Potential uncertainty is demonstrated by appropriate ‘upper’ and ‘lower’ regression curves.

In estimating the scheme impacts, in VDVs, appropriate design curves have been used to account for general source of uncertainty.

On the basis of measurements undertaken, it is shown that this would ensure that a significant majority of observed vibration levels are well below the assumed design curves. This is quantified in Table 32.

Assessments indicate that there is a high probability that in practice the vibration levels would be lower than the calculated levels.</td></tr>
<tr><td>2</td><td>Local variations in geology within the study area.</td><td>This is a general source of uncertainty which is likely to result in variation in vibration levels.</td><td>Not quantified as part of this study. However assessments are based on similar type of geology and a large number of measurements to minimise risk.</td></tr>
<tr><td>3</td><td>Day-to-day variations in material properties.</td><td>This is a general source of uncertainty which is likely to result in variation in vibration levels.</td><td>The same site has been visited over a number of days. Potential day-to-day variation is reflected in the measured data.</td></tr>
<tr><td>4</td><td>The spread in measurements of different vehicles of same type travelling at speeds within a narrow band.</td><td>This is a general source of uncertainty which is likely to result in variation in vibration levels.</td><td>Variation has been investigated. Appropriate design curves are used for calculating scheme VDVs.</td></tr>
<tr><td>5</td><td>Lack of control distance for measurements.</td><td>Second round of measurements use a control measurement position at equal distance from all track.</td><td>Variation has been investigated. Appropriate design curves are used for calculating scheme VDVs.</td></tr>
<tr><td>6</td><td>Uncertainty associated with the number of pass-by events relied upon for deriving appropriate regression curves.</td><td>This is a general source of uncertainty which is likely to result in variation in vibration levels.</td><td>70 pass-by events measured, including 52 passenger trains, 15 freight trains and 3 stone trains, to minimise risk.</td></tr>
<tr><td>7</td><td>Variation in source terms for freight and passenger trains.</td><td>This is a general source of uncertainty which is likely to result in variation in vibration levels.</td><td>Assessment based on decay relationships through a number of distances, speeds and vehicle types and numbers.</td></tr>
</table>

11. Conclusions

11.1. Atkins is currently undertaking the detailed design of the proposed double-tracking of Oxford to Bicester Rail line (referred to as the 'Scheme' in this document). There are a number of vibration conditions which need to be discharged with the local planning authority before the Scheme can be built.

11.2. This report deals with vibration form the plain line, and vibration from switches and crossings will be considered in a separate report. The aim of this report is to present appropriate data and analysis, and based on the relevant vibration conditions, make recommendations on suitable form of mitigation measures, to support the application process.

11.3. There are 9 vibration-sensitive dwellings which have been considered in detail as part of this assessment. The assessments take into account the best available information on the number, type and speed of trains during day-time and night-time as well as the distance between individual tracks and vibration-sensitive dwellings.

11.4. A number of vibration measurements have been undertaken as part of this project to identify appropriate data for use in the assessments. Over the course of a number of site visits, data from 70 pass-by events have been captured. These included 51 passenger trains, 16 freight trains and 3 stone trains. The full details of each pass-by event including speed, vehicle type, number of wagons and distance from the track were noted.

11.5. Two different approaches were used to estimate Vibration Dose Value (VDV) based on information from vibration measurement surveys and other empirical analysis. The first approach was based on analysis of measured vibration acceleration levels, in dB, to identify vibration decay characteristics with distance at individual 1/3 octave band frequencies. The second approach used the measured data to derive appropriate vibration decay curves for distance attenuation, in single VDV figures, which could be used directly to assess compliance with project limits. The results from both approaches were found to be consistent.

11.6. The calculated VDVs at all 9 vibration-sensitive properties were shown to be below project VDV limits. The predicted night-time VDVs at Islip, Kareol (0.16 $m/s^{-1.75}$), which is the dwelling with the highest predicted level, was 20% below the project limits (0.2 $m/s^{-1.75}$).

11.7. Analysis of measured data indicated that the predictions incorporate sufficient factor of safety to demonstrate that the predicted VDVs are robust in determining compliance with project limit values. For passenger trains, predicted vibration levels were 3.5dB higher than the average values and 95% of all measurements were observed to be on or below the regression curve. For freight trains, the predicted vibration levels were 2.5dB higher than the average values and 90% of all measurements were shown to be on or below the regression curve.

11.8. As part of the assessment process, Edilon Sedra, suppliers of vibration isolation systems, were requested to provide an insertion loss prognosis for a sub ballast mat system, which was identified as a suitable form of mitigation from an engineering point of view. Although the subsequent analysis showed that project VDV limits would not be exceeded, potential mitigation measures were considered at Islip, Kareol. The details of the theoretical model, input assumptions and the findings of the assessments are described in this report, including the full mitigation parameters. If installed, this system could provide a further 23% reduction in the calculated VDVs. This would lower the predicted VDVs at Islip, Kareol to 0.13 $m/s^{-1.75}$. However on the basis of the assessments there is no requirement to implement mitigation measures at the dwellings.

12. Recommendations

12.1. The assessments showed that calculated VDVs at all 9 vibration-sensitive properties would be below project VDV limits and there is no requirement to implement mitigation measures.

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Appendices

Appendix A. Glossary of Technical Terms

Acceleration - The measure of the rate of change of particle velocity with respect to time, typically expressed in $m.s^{-2}$.

Weighted RMS acceleration is the root-mean-squared value of the frequency weighted acceleration, using W_b or W_d as appropriate.

Frequency (Hertz) - The number of cycles per second (Hertz) at which a structure will oscillate when either; driven by a "forcing frequency" or when excited and then allowed to come to rest naturally, "natural frequency".

Frequency Weightings - Different frequency weightings (value corrections) are required for different axes of motion because people perceive vibration differently depending on the frequency and the direction of movement. The frequency range concerned is 0.5 Hz to 80Hz for the thre axes. The weightings (Wb (for vertical motion) and Wd (for horizontal motion) are defined in BS 6841, "Guide to Measurement and evaluation of human exposure to whole-body vibration and repeated shock".

Peak Particle Velocity (PPV) - Instantaneous maximum velocity reached by a vibrating element as it oscillates about its rest position, typically expressed in $mm.s^{-1}$.

Vibration Dose Value (VDV) - Measure of the total vibration experienced over a specified period of time, expressed in $m.s^{-1.75}$. The VDV is derived from the weighted RMS acceleration in each axis and provides a consistent approach to the assessment of continuous, intermittent, occasional and impulsive vibration, which correlates well with subjective human response.

- **estimated Vibration Dose Value (eVDV) –** Is an approximation of the VDV and is sometimes appropriate to use where vibration is not time-varying in magnitude. It is over a specific time period and expressed in $m.s^{-1.75}$.

Appendix B. Design Assumptions

Table 34. Current Situation

Receiver	Track M - Mainline C - chord	Distance from existing track (m)	Time Period	Passenger		Freight	
			D=16hr Day N=8hr Night	Number	Speed, mph	Number	Speed, mph
12 Whimbrel Close	C1	-	-	-	-	-	-
	M1	12.24	D	20	40	1	40
			N	2		1	
	M2	-	-	-	-	-	-
53 London Road	M1	6.84	D	20	40	1	40
			N	2		1	
	M2	-	-	-	-	-	-
21 Nuthatch Way	M1	17.52	D	20	40	1	40
			N	2		1	
	M2	-	-	-	-	-	-
5 Westholme Court	M1	9.63	D	20	40	1	40
			N	2		1	
	M2	-	-	-	-	-	-
Islip	M1	2.87	D	20	40	3	40
			N	2		1	
	M2	-	-	-	-	-	-
Oddington	M1	5.09	D	20	40	3	40
			N	2		1	
	M2	-	-	-	-	-	-
Alchester House, Langford Lane	M1	16.00	D	20	40	3	40
			N	2		1	

	M2	-	-	-	-	-	-
3 Bladon Close	M1	14.34	D	20	40	5	40
			N	2		1	
	M2	-	-	-	-	-	-
Quadrangle	M1	8.97	D	20	40	5	40
			N	2		1	
	M2	-	-	-	-	-	-

Table 35. Proposed Scheme

Receiver	Track M - Mainline C - Chord	Distance from proposed track (m)	Time Period D=Day N=Night	Passenger		Freight	
				Number	Speed, mph	Number	Speed, mph
12 Whimbrel Close	C1	5.18	D	31	40	0	40
			N	4		0	
	M1	9.80	D	109	100	9	75
			N	18		4	
	M2	13.32	D	79	100	9	75
			N	14		4	
53 London Road	M1	6.84	D	140	100	9	75
			N	22		4	
	M2	10.28	D	79	100	9	75
			N	14		4	
21 Nuthatch Way	M1	14.03	D	140	100	9	75
			N	22		4	
	M2	17.52	D	79	100	9	75
			N	14		4	
5 Westholme Court	M1	9.80	D	140	100	9	75
			N	22		4	
	M2	13.17	D	79	100	9	75
			N	14		4	
Islip	M1	3.51	D	79	100	9	75
			N	14		4	
	M2	6.74	D	79	100	9	75
			N	14		4	
Oddington	M1	5.09	D	79	100	9	75

			N	14		4	
	M2	8.62	D	79	100	9	75
			N	14		4	
Alchester House	M1	12.25	D	79	100	9	75
			N	14		4	
	M2	16.00	D	79	100	9	75
			N	14		4	
3 Bladon Close	M1	12.92	D	79	70	9	70
			N	14		4	
	M2	13.62	D	79	60	9	60
			N	14		4	
Quadrangle	M1	10.89	D	79	70	9	70
			N	14		4	
	M2	7.49	D	79	70	9	70
			N	14		4	

Appendix C. References

[1] BS 6472-1:2008 Guide to evaluation of human exposure to vibration in buildings. Part 1: Vibration sources other than blasting, British Standards Institute, June 2008

[2] Ground Vibrations from Heavy Freight Trains, T.M. Dawn, Journal of Sound and Vibration, Volume 87, Issue 2, p351-356, 1983

[3] Transportation Noise Reference Book, P.M. Nelson, Butterworth, 1987

[4] Train-Induced Ground Vibration and Its Prediction, Mehdi Bahrekazemi, TRITA-JOB PHD 1005, ISSN 1650-9501, Stockholm, 2004

[5] Measurement and Assessment of Groundborne Noise and Vibration, ANC Guidelines, 2nd Edition, 2012

Appendix D. Equipment Calibration Records

The calibration certificates and sensitivities are provided below for the accelerometers used during the vibration surveys.

~ Calibration Certificate ~

Per ISO 16063-21

Model Number: 356B18

Serial Number: LW133898 (y axis)

Description: ICP® Triaxial Accelerometer

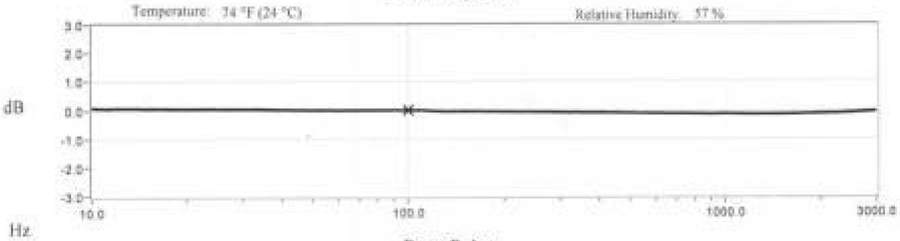
Manufacturer: PCB

Method: Back-to-Back Comparison AT-401-3

Calibration Data

Sensitivity @ 100 Hz	**962 mV/g**	Output Bias	11.4 VDC
	(98.1 mV/m/s²)	Transverse Sensitivity	2.4 %
Discharge Time Constant	1.3 seconds		

Sensitivity Plot



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
10	0.8	300	-0.9
15	0.7	500	-1.3
30	0.5	1000	-1.7
50	0.1	3000	-0.8
REF. FREQ.	0.0		

[illegible] Fixture Orientation: Vertical

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is NIST Traceable thru Project 681/280472 and PTB Traceable thru Project 10065.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 5-9 Hz; +/- 2.0%, 10-99 Hz; +/- 1.5%, 100-1999 Hz; +/- 1.0%, 2-10 kHz; +/- 2.5%.

Technician: Gary Oatis

Date: 6/25/2012

ACCREDITED CALIBRATION CERT #1862.02

PCB PIEZOTRONICS VIBRATION DIVISION

Headquarters: 3425 Walden Avenue, Depew, NY 14043

Calibration Performed at: 10869 Highway 903, Halifax, NC 27839

TEL: 888-684-0013 FAX: 716-685-3886 www.pcb.com

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~ *Calibration Certificate* ~

Per ISO 16063-21

Model Number: 356B18

Serial Number: LW133898 (z axis)

Description: ICP® Triaxial Accelerometer

Manufacturer: PCB

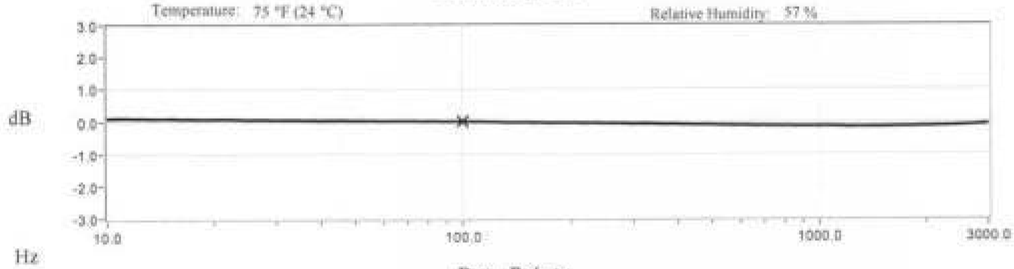
Method: Back-to-Back Comparison AT-401-3

Calibration Data

Sensitivity @ 100 Hz	**970 mV/g**	Output Bias	11.4 VDC
	(98.9 mV/m/s²)	Transverse Sensitivity	1.4 %
Discharge Time Constant	1.0 seconds		

Sensitivity Plot

Temperature: 75 °F (24 °C)   Relative Humidity: 57 %



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
10	1.1	300	-0.9
15	1.0	500	-1.4
30	0.6	1000	-1.9
50	0.2	3000	-1.1
REF. FREQ.	0.0		

Mounting Surface: Beryllium w/Silicone Grease Fastener: 10-32 Female Fixture Orientation: Vertical
Acceleration Level (pk)*: 1.00 g (9.81 m/s²)
*The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration Level (g) = 0.008 x (freq)²
²The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s²

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is NIST Traceable thru Project 681/280472 and PTB Traceable thru Project 10065.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 5-9 Hz; +/- 2.0%, 10-99 Hz; +/- 1.5%, 100-1999 Hz; +/- 1.0%, 2-10 kHz; +/- 2.5%.

Technician: Gary Oatis   Date: 6/25/2012

ACCREDITED
CALIBRATION CERT #1862.02

PCB PIEZOTRONICS
VIBRATION DIVISION
Headquarters: 3425 Walden Avenue, Depew, NY 14043
Calibration Performed at: 10869 Highway 903, Halifax, NC 27839
TEL: 888-684-0013 · FAX: 716-685-3886 · www.pcb.com

PAGE 1 of 1

~ *Calibration Certificate* ~

Per ISO 16063-21

Model Number: **356B18**

Serial Number: **LW133898 (x axis)**

Description: ICP® Triaxial Accelerometer

Manufacturer: PCB

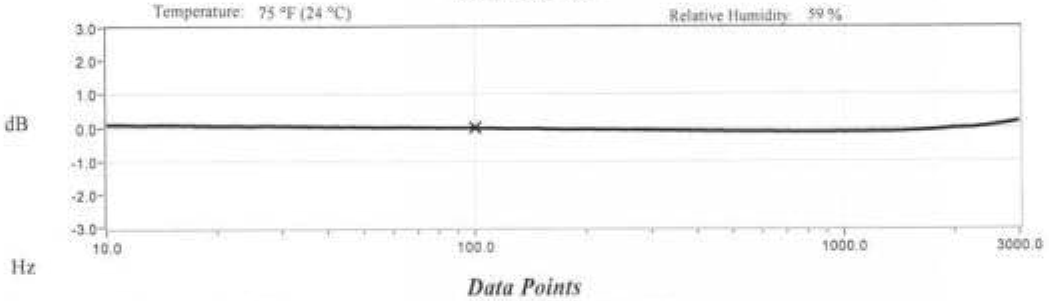
Method: Back-to-Back Comparison AT-401-3

Calibration Data

Sensitivity @ 100 Hz	**1013 mV/g**	Output Bias	11.7 VDC
	(103.3 mV/m/s²)	Transverse Sensitivity	0.6 %
Discharge Time Constant	1.0 seconds		

Sensitivity Plot

Temperature: 75 °F (24 °C) Relative Humidity: 59 %



Data Points

Frequency (Hz)	Dev. (%)	Frequency (Hz)	Dev. (%)
10	1.1	300	-0.9
15	0.9	500	-1.4
30	0.5	1000	-1.6
50	0.1	3000	2.0
REF. FREQ.	0.0		

Mounting Surface: Beryllium Fastener: Adhesive Fixture Orientation: Inverted Vertical
Acceleration Level (pk)¹: 1.00 g (9.81 m/s²)
¹The acceleration level may be limited by shaker displacement at low frequencies. If the listed level cannot be obtained, the calibration system uses the following formula to set the vibration amplitude: Acceleration Level (g) = 0.008 x (freq)²
²The gravitational constant used for calculations by the calibration system is: 1 g = 9.80665 m/s²

Condition of Unit

As Found: n/a

As Left: New Unit, In Tolerance

Notes

1. Calibration is NIST Traceable thru Project 681/280472 and PTB Traceable thru Project 10065.
2. This certificate shall not be reproduced, except in full, without written approval from PCB Piezotronics, Inc.
3. Calibration is performed in compliance with ISO 9001, ISO 10012-1, ANSI Z540.3 and ISO 17025.
4. See Manufacturer's Specification Sheet for a detailed listing of performance specifications.
5. Measurement uncertainty (95% confidence level with coverage factor of 2) for frequency ranges tested during calibration are as follows: 5-9 Hz; +/- 2.0%, 10-99 Hz; +/- 1.5%, 100-1999 Hz; +/- 1.0%, 2-10 kHz; +/- 2.5%.

Technician: Gary Oatis Date: 6/25/2012

ACCREDITED
CALIBRATION CERT #1862.02

PCB PIEZOTRONICS
VIBRATION DIVISION
Headquarters: 3425 Walden Avenue, Depew, NY 14043
Calibration Performed at: 10869 Highway 903, Halifax, NC 27839
TEL: 888-684-0013 · FAX: 716-685-3886 · www.pcb.com

PAGE 1 of 1

CERTIFICATE OF CALIBRATION

ISSUED BY	Gracey & Associates	BSI CERTIFICATE	FS 25913
DATE OF ISSUE	23 September 2013	CERTIFICATE NUMBER	2013-0329
DATE OF CALIBRATION	23 September 2013		
CALIBRATION INTERVAL	12 months		PAGE 1 OF 1

Gracey & Associates
Barn Court Shelton Road
Upper Dean PE28 0NQ
Tel: 01234 708835
Fax: 01234 252332
www.gracey.com

TEST ENGINEER
Greg Rice

APPROVING SIGNATORY
Greg Rice

Equipment **B&K 4507 002, s/n: 10412**
Description Accelerometer - IEPE - 100mV/ms2, Bruel & Kjaer UK Limited
Customer Gracey & Associates
High Street, Chelveston, Northamptonshire, NN9 6AS

Standards
Manufacturer's Original Specifications

Conditions
Atmospheric Pressure 101.9 kPa
Temperature 21.4 °C
Relative Humidity 48.8 %

Calibration Data

At Frequency (Hz) :	159.15
Voltage Sensitivity (mV/ms^{-2}) :	97.5130
Voltage Sensitivity (mV/g) :	956.2759
Charge Sensitivity (pC/ms^{-2}) :	n/a
Charge Sensitivity (pC/g) :	n/a

A value of g = 9.80665 ms^{-2} has been used in relevant caclulations.

Calibration Reference Sources

Equipment	S/N	Last Cal	Equipment	S/N	Last Cal
B&K 4294-002	1608724	25-Mar-13	B&K 8305	1483344	25-Mar-13
Druck DPI 141	479	27-Jul-11	HP 34401	3146A16728	18-Oct-12
Stanford DS36	33213	14-Jul-11			

Notes

We certify that the above product was duly tested and found to be within the specification at the points measured (except where indicated). Measurements are traceable to UKAS reference sources from the UK National Physical Laboratory. Where no national or international standards exist, traceability is to standards maintained by the manufacturer. Our Quality Management System has been assessed to comply with BS EN ISO 9001:2008 - BSI Certificate number FS 25913. Tests were carried out in environmental conditions controlled to the extent appropriate to the instrument's specification. All relevant test certificates are available for inspection.
The uncertainties are for a confidence probability of not less than 95%.

Gracey & Associates is the trading name of W T Gracey Ltd. Registered in Upper Dean England No 1176412
BSI approved for the hire and calibration of noise and vibration instruments. Established 1972

CERTIFICATE OF CALIBRATION

ISSUED BY	Gracey & Associates	BSI CERTIFICATE	FS 25913
DATE OF ISSUE	23 September 2013	CERTIFICATE NUMBER	2013-0330
DATE OF CALIBRATION	23 September 2013		
CALIBRATION INTERVAL	12 months		PAGE 1 OF 1

Gracey & Associates
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Fax: 01234 252332
www.gracey.com

TEST ENGINEER	APPROVING SIGNATORY
Greg Rice	Greg Rice

Equipment	**B&K 4507 002, s/n: 10413**
Description	Accelerometer - IEPE - 100mV/ms2, Bruel & Kjaer UK Limited
Customer	Gracey & Associates High Street, Chelveston, Northamptonshire, NN9 6AS

Standards

Manufacturer's Original Specifications

Conditions

Atmospheric Pressure	101.9 kPa
Temperature	21.4 °C
Relative Humidity	48.8 %

Calibration Data

At Frequency (Hz) :	159.15
Voltage Sensitivity (mV/ms^{-2}) :	99.0690
Voltage Sensitivity (mV/g) :	971.5350
Charge Sensitivity (pC/ms^{-2}) :	n/a
Charge Sensitivity (pC/g) :	n/a

A value of g = 9.80665 ms^{-2} has been used in relevant caclulations.

Calibration Reference Sources

Equipment	S/N	Last Cal	Equipment	S/N	Last Cal
B&K 4294-002	1608724	25-Mar-13	B&K 8305	1483344	25-Mar-13
Druck DPI 141	479	27-Jul-11	HP 34401	3146A16728	18-Oct-12
Stanford DS36	33213	14-Jul-11			

Notes

We certify that the above product was duly tested and found to be within the specification at the points measured (except where indicated). Measurements are traceable to UKAS reference sources from the UK National Physical Laboratory. Where no national or international standards exist, traceability is to standards maintained by the manufacturer. Our Quality Management System has been assessed to comply with BS EN ISO 9001:2008 - BSI Certificate number FS 25913. Tests were carried out in environmental conditions controlled to the extent appropriate to the instrument's specification. All relevant test certificates are available for inspection.

The uncertainties are for a confidence probability of not less than 95%.

Gracey & Associates is the trading name of W T Gracey Ltd. Registered in Upper Dean England No 1176412
BSI approved for the hire and calibration of noise and vibration instruments. Established 1972

CERTIFICATE OF CALIBRATION

ISSUED BY	Gracey & Associates	BSI CERTIFICATE	FS 25913
DATE OF ISSUE	23 September 2013	CERTIFICATE NUMBER	2013-0331
DATE OF CALIBRATION	23 September 2013		
CALIBRATION INTERVAL	12 months		PAGE 1 OF 1

TEST ENGINEER: Greg Rice

APPROVING SIGNATORY: Greg Rice

Gracey & Associates
Barn Court Shelton Road
Upper Dean PE28 0NQ
Tel: 01234 708835
Fax: 01234 252332
www.gracey.com

Equipment **B&K 4507 002, s/n: 10414**

Description Accelerometer - IEPE - 100mV/ms2, Bruel & Kjaer UK Limited

Customer Gracey & Associates
High Street, Chelveston, Northamptonshire, NN9 6AS

Standards

Manufacturer's Original Specifications

Conditions

Atmospheric Pressure	101.9 kPa
Temperature	21.4 °C
Relative Humidity	48.8 %

Calibration Data

At Frequency (Hz) :	159.15
Voltage Sensitivity (mV/ms^{-2}) :	98.5710
Voltage Sensitivity (mV/g) :	966.6513
Charge Sensitivity (pC/ms^{-2}) :	n/a
Charge Sensitivity (pC/g) :	n/a

A value of g = 9.80665 ms^{-2} has been used in relevant caclulations.

Calibration Reference Sources

Equipment	S/N	Last Cal	Equipment	S/N	Last Cal
B&K 4294-002	1608724	25-Mar-13	B&K 8305	1483344	25-Mar-13
Druck DPI 141	479	27-Jul-11	HP 34401	3146A16728	18-Oct-12
Stanford DS36	33213	14-Jul-11			

Notes

We certify that the above product was duly tested and found to be within the specification at the points measured (except where indicated). Measurements are traceable to UKAS reference sources from the UK National Physical Laboratory. Where no national or international standards exist, traceability is to standards maintained by the manufacturer. Our Quality Management System has been assessed to comply with BS EN ISO 9001:2008 - BSI Certificate number FS 25913. Tests were carried out in environmental conditions controlled to the extent appropriate to the instrument's specification. All relevant test certificates are available for inspection.

The uncertainties are for a confidence probability of not less than 95%.

Calibration Chart for Accelerometers

MMF

Type KS 823B
Serial number 10074

Reference Sensitivity at and 20 Hz 22 °C

Voltage Sensitivity **

X-axis	53,14 mV/m/s² /	521,1 mV/g *
Y-axis	53,23 mV/m/s² /	522 mV/g *
Z-axis	53,28 mV/m/s² /	522,5 mV/g *

Output bias voltage (at 4 mA)

X: 12,7 V Y: 12,4 V Z: 12,3 V

date 08.04.2013 signature B. L[illegible]

* 1 g = 9,807 m/s²
** The calibration is traceable to the PTB

Operating temperature Tmin/Tmax	-30/90 °C
Maximum acceleration â+, â-	120 m/s²
Temperature coefficient TK(Bua)	-0,05 %/K

Polarity

Polarity is positive on the output pin of the connector for an acceleration directed from the mounting surface into the body of the accelerometer.

Environmental characteristics

Temperature transients baT	0,0005 m/s²/ K
Base strain baS	--
Magnetic field baB	--
Acoustic noise baP	--
Electric noise (20 .. 50000 Hz)	< 20 µV

Physical parameter

Material	Stainless steel / AlMg
Weight (without cable)	365 g
Electrical Connector	Binder 718
Mounting	M8 thread in base

Piezo design Shear design

Current source

The current for the internal charge converter amount 2 .. 20 mA at a supply voltage of 24 - 30V.

Additional data IP 67

COPY

Appendix E. Track Inspections

Project:	East-West Rail Phase 1	**To:**	Inan Ekici/David terry
From:	Julien Green (CEM)	**Cc:**	Mike Ashton, Peter Hampshire, Alan Yeung, Chris Brooks, Stephen Wilson, Ken Lam
Subject:	Permanent Way Inspections at Vibration Monitoring Sites		
Date:	10 October 2011		
Reference:	Document No. 5114534-ATK-GEN-TN-00044 P01		

East-West Rail Phase 1

Permanent Way Condition Inspections at Vibration Monitoring Sites

1. Introduction and Scope

As part of the EWRP1 project, vibration monitoring is being undertaken at sites on the existing Bicester to Oxford line (ELR – OXD) and the Oxford to Anyho Junction line (ELR – DCL). As part of the vibration monitoring, the existing permanent way, was inspected to determine the following:

a. Component type;

b. Component condition;

c. Overall condition of the permanent way;

d. Identify factors that would unduly impact on the vibration results.

The inspection of both lines was undertaken by Julien Green the project CEM, and a former Permanent Way Maintenance Engineer, on 9 October 2013. The weather was overcast, slight wind and 160C.

Due to restrictions of access, the inspection was undertaken from the lineside cess and reviewing of the high speed track recording train quality reports.

It should be noted that the dimensions quoted are miles and chains, (however, the dimensions provided in () are those of the project chainage that has been set up for the project on the OXD line. For the DCL line the project chainage is not required and therefore is not provided.

2. Oxford to Bicester Line – OXD

This is a line that runs from Bicester to Oxford and is currently a single line, with a line speed of 30mph and the ELR of the line is OXD, see Figure 1. The area chosen for the vibration monitoring was the Down (southern – left hand side facing Oxford) cess at 29m 27.5chains. This is 4.5chains East (Islip side) of Underbridge OXD50 which crosses the canal. Figure 2, provides a hand drawn sketch of the layout at this location.

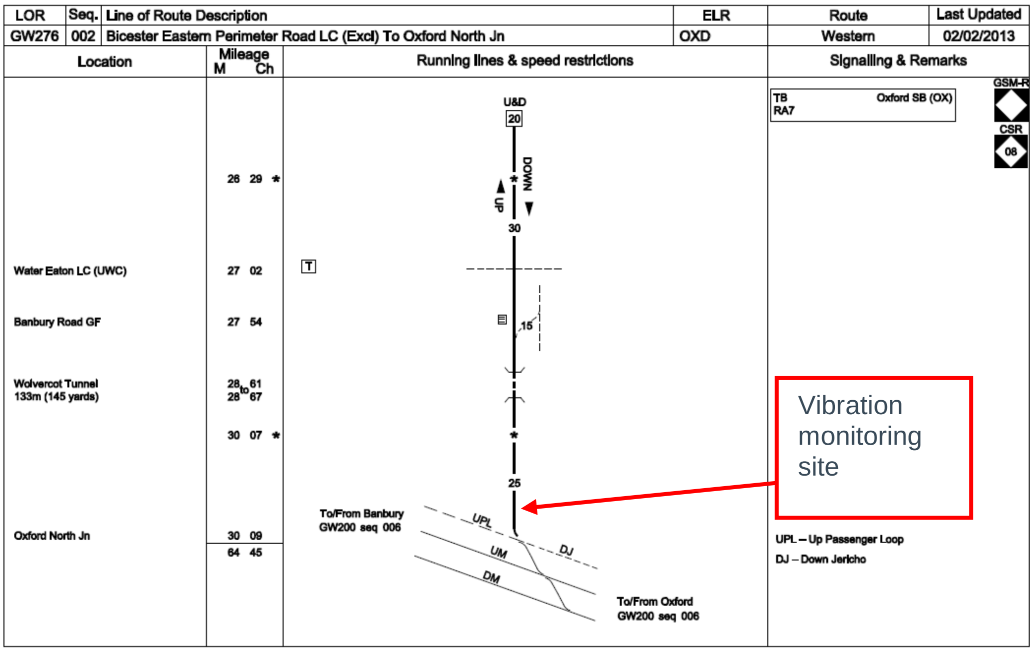


Figure 1: Extract of Sectional Appendix for the OXD Line

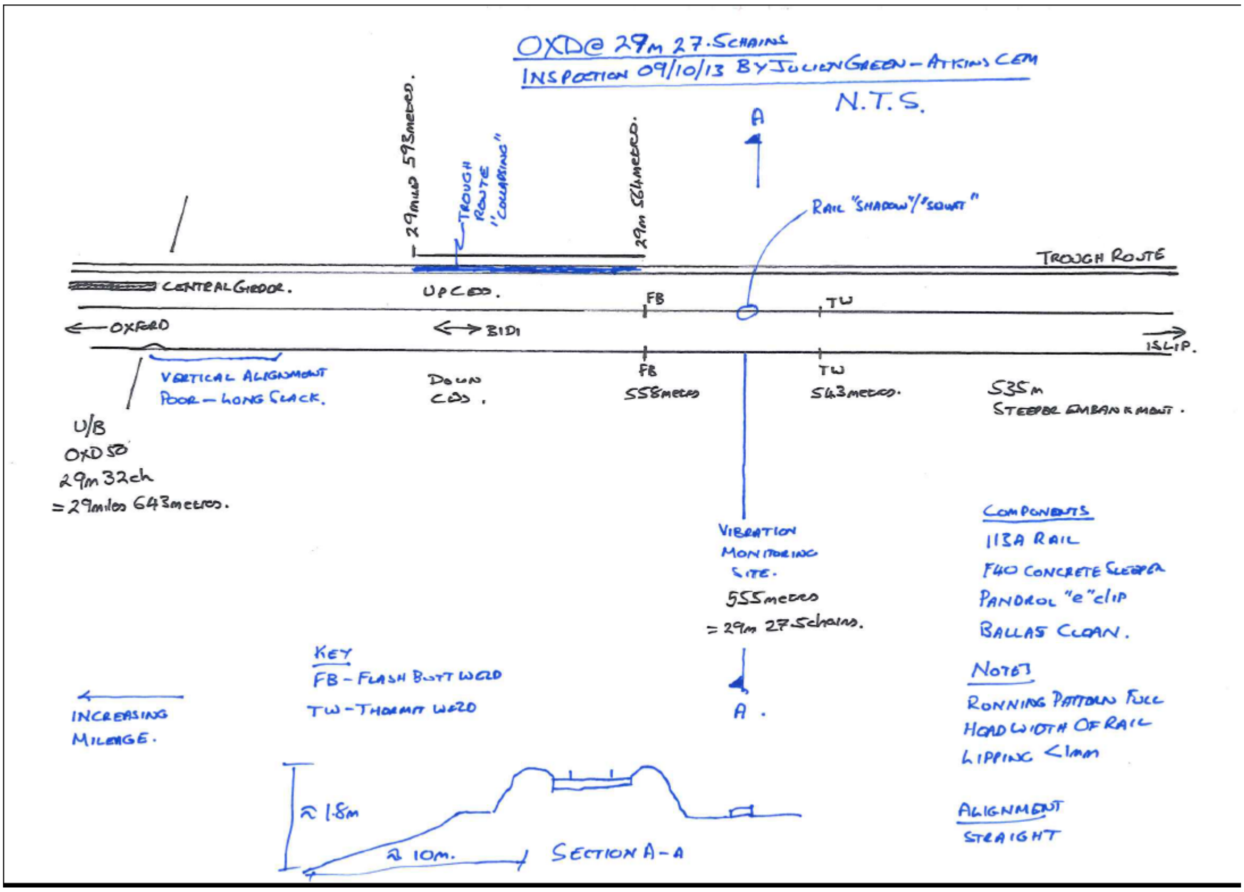


Figure 2: OXD 29m 27.5ch - Site Sketch

2.1 Components

2.1.1 Alignment

At this location, the track is situated on a straight alignment. The horizontal alignment looks satisfactory for the line speed. The vertical alignment at the vibration location is of a satisfactory condition, however at the Islip side of U/B OXD 50, between 29m 30ch and 32chain (the bridge end), there is a long vertical "slack", see Photograph 2. This is 85m from the vibration monitoring site, however under visual inspection during dynamic loading, no excessive forces were heard or felt over this location.

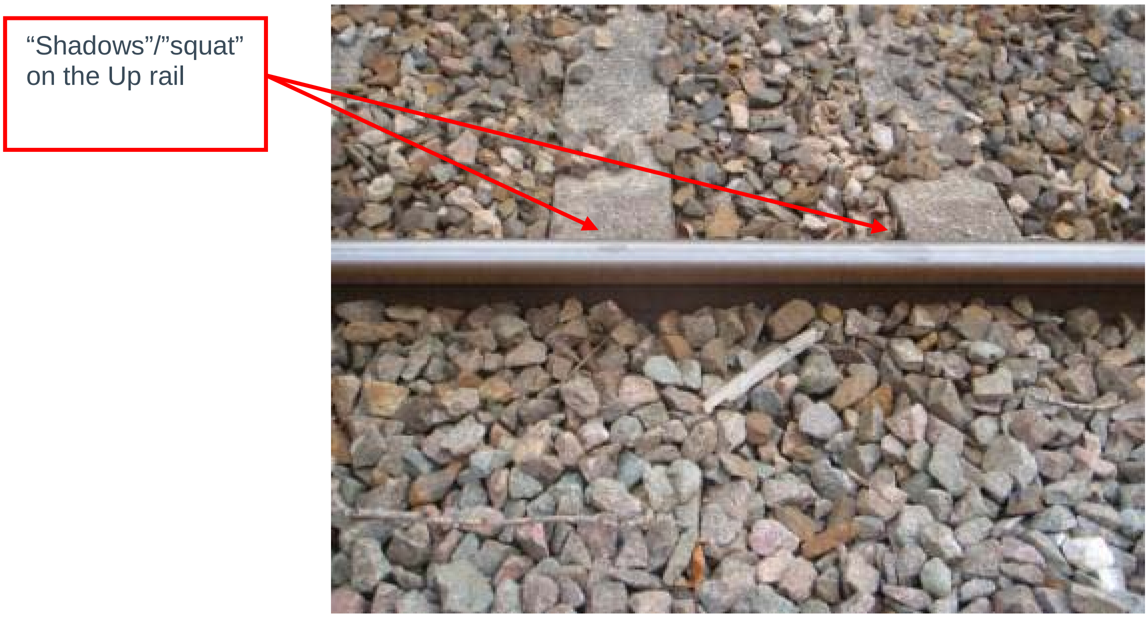
Photograph 1: OXD Line looking towards Islip (Up direction)

Photograph 2: OXD Line looking towards Oxford (Down Direction)

2.1.2 Rail

The rail is 113A Flat Bottom Workington 1976 rail, on concrete F27 sleepers with pandrol "e" clip" fastenings and rubber pads. Flash butt and thermit welds are located approximately 10m either side of the vibration monitoring site (see figure 2). All the welds looked to be in good condition and no irregularities could be identified, and therefore are assumed to conform to standards.

The Up rail (right hand rail looking towards Oxford) at the vibration monitoring location, showed signs of "shadowing" or a local "squat" developing, see photograph 3. However, no surface "breaking out" had started to occur and when the site was witnessed under dynamic loading, no noticeable change in noise was noted.



Photograph 3: Shadowing on right hand rail facing Oxford

The running pattern on top of the rail, was for the full width of the rail, but appeared smooth in appearance. Minor (<1mm) of lipping was noted on the cess (left hand rail facing Oxford) rail.

2.1.3 Sleepers

The sleepers are concrete F27 sleepers with pandrol "e" clip fastening. All fastenings, pads, insulators were in position and there were none missing.

2.1.4 Ballast

The ballast seems clean, well graded, and free of fines. The cess on both sides is lower than the formation (see photographs 4-7), and as a consequence the ballast shoulder is suitable to resist thermal forces. There is no evidence of any "wet spots" and the track was witnessed under dynamic loading (freight train) and there were no excessive vertical movements.

Photograph 4 and 5: Up Cess (right hand side facing Oxford) looking towards Islip (left) and Oxford (right) ballast shoulder and cess

Photograph 6 and 7: Down Cess (left hand side facing Oxford) looking towards Islip (left) and Oxford (right) ballast shoulder and cess

2.1.5 Topography

The vibration site is on a small shallow embankment (approx 2m height). Between 29miles 564metres to 593metres, the up cess (northern right hand side facing Oxford), a new local ballast retention wall has been installed to stabilise the cable trough route, see photograph 5. The cess in this area, seems to indicate a localised movement in this area. However, the track alignment through here is still consistent at the time of the inspection.

The slopes are heavily vegetated with shrubs and trees.

2.1.6 Track Quality

The latest available track quality data available from the track recording train can be seen in figure 3 below.

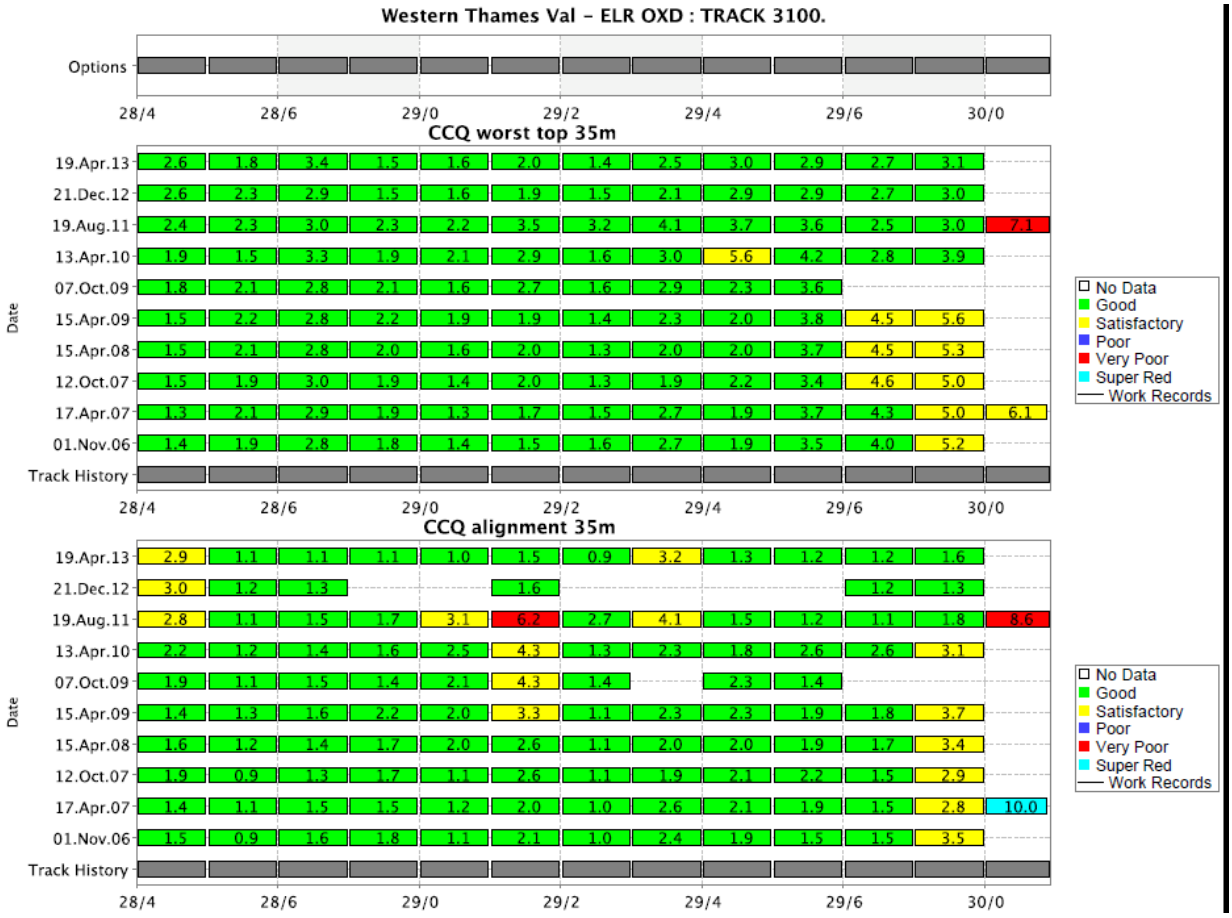


Figure 3: Track Recording vehicle Track Quality Data

The data clearly shows that for April 2013, that between the 29/2 (29m ¼ milepost = 20chains) and 29/4 (29m ½ milepost = 40chains) that the horizontal alignment is in the good quality band. It can be seen that on the vertical alignment that the 1/8th mile band prior to 29/4 is in the satisfactory band. This is no doubt due to the vertical alignment at the underbridge OXD50 bridge ends. As highlighted in photograph 2 and section 2.1.1.

2.2 Conclusion

The track is in a good condition, with no evidence of "track pumping" or other issues that are likely to provide excessive vibration or noise characteristics at this location, and that would be outside of the normal parameters for a well maintained line for the track category currently in service.

3 Oxford to Anyho Junction – DCL

See Appendix B for inspection records.

This is a line that runs from Oxford to Anyho junction and is currently 3 lines, the Up Passenger Loop, Up and Down Main. It should be noted that at the time of the inspection, construction work was underway in the Down cess to reinstate the Down Passenger loop.

The line speed for the Up Passenger Loop is 25mph and for the Up and Down Main it is 90mph and the ELR of the line is DCL, see Figure 4. The area chosen for the vibration monitoring was the Up cess (eastern – left hand side facing Oxford) cess at 65m 23chains. Figure 5, provides a hand drawn sketch of the lay out at this location.

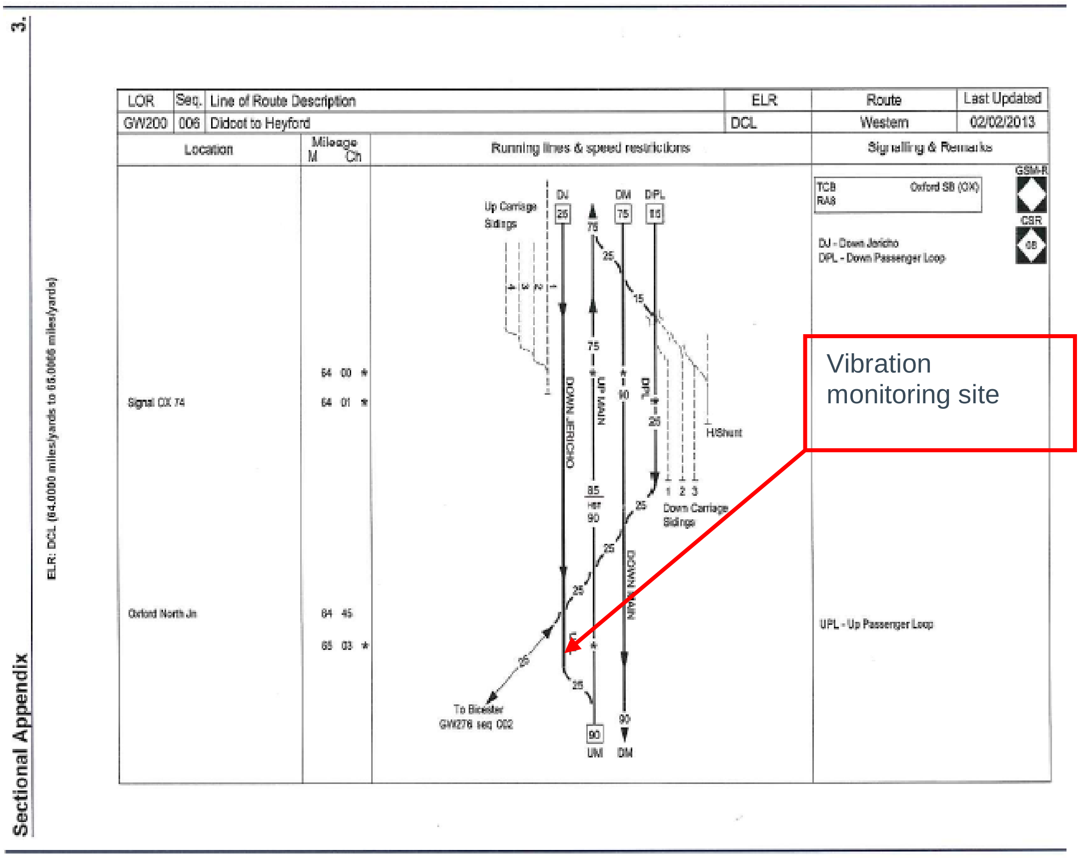


Figure 4: Extract of Sectional Appendix for the OXD Line

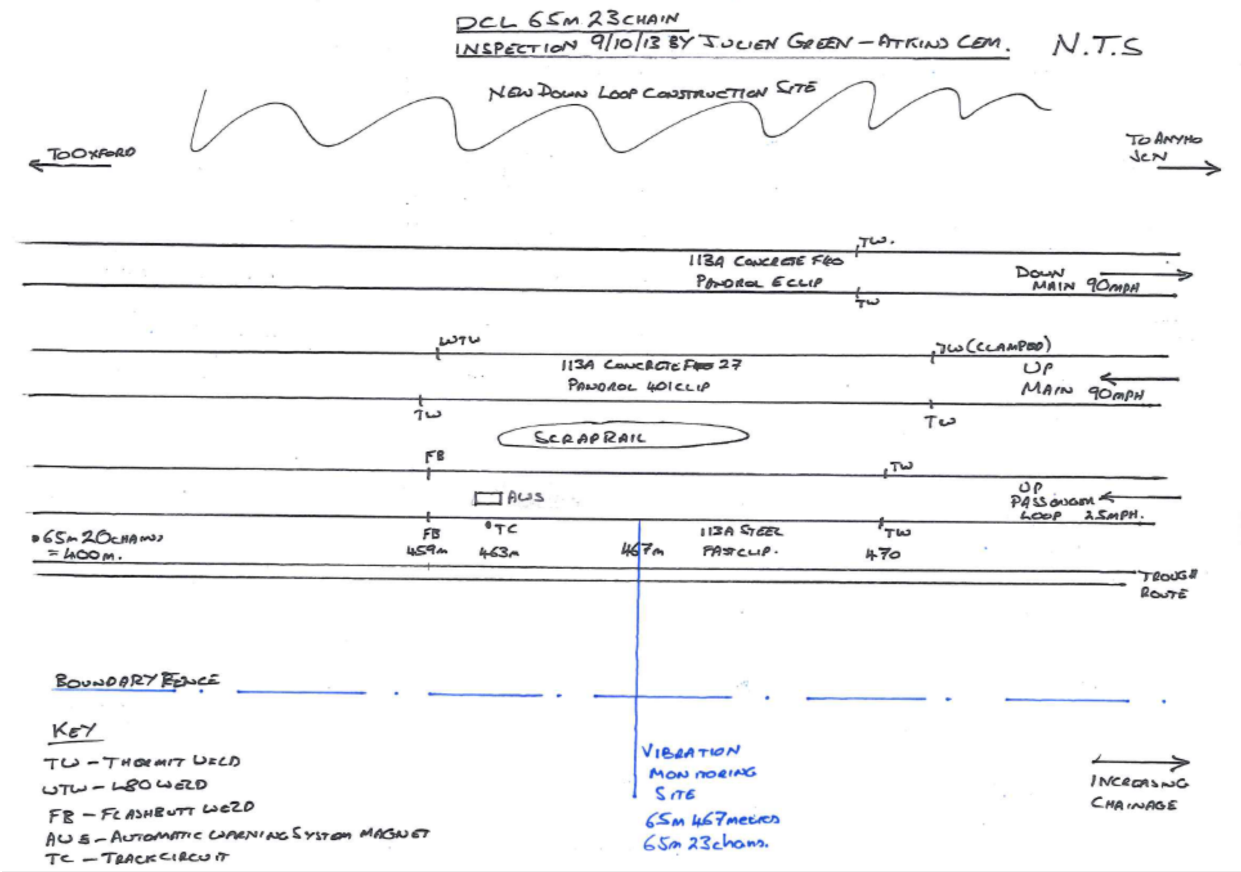


Figure 5: DCL 65m 23chains Site Sketch

3.1 Components

3.1.1 Alignment

At this location, the track is situated on a straight alignment with the alignment going into a transition and right hand curve travelling in the up direction towards Oxford. The horizontal alignment looks satisfactory for the line speed. The vertical alignment at the vibration location is of a good condition. All the lines were witnessed under dynamic loading of freight and passenger trains, and all demonstrated good characteristics with no excessive movement under load.

Photograph 8: DCL Line looking towards Anyho Junction

Photograph 9: DCL Line Looking towards Oxford

3.1.2 Rail

The rail is 113A Flat Bottom rail on all the lines. Table 1 below lists the details for each line. Note that the inspection is only what could be undertaken from lineside.

Table 1: Rail, Sleeper, Fastening types for the DCL lines

Line	Rail	Sleepers	Fastenings	Welds/Joints	Comments
Up Passenger Loop	113A Colivilles 1965 Running pattern, is approximately 50mm and is from the middle to the outside edge of the rail head	Steel	Pandrol fastclips	Thermit welds within 3m of monitoring site to the north and flashbutt welds within 8m to the south	AWS in the 4' within 4m of the monitoring site. (photograph 9)
Up Main	113A The rail head shows evidence of recent rail grinding. The running pattern is approximately 40mm wide in the centre of the rail head.	Concrete F27	Pandrol 401	Thermit welds within 4m to the north. The 6' rail was emergency clamped. (photograph 10) Thermit welds within 8m to the south of the monitoring site. The 6' rail was an "L80" wide gap weld. (photograph 11)	Scrap rail situated in the 10' between the Up Main and Up Passenger Loop. Photograph 9.
Down Main	113A The rail head shows evidence of recent rail grinding. The running pattern is approximately 40mm wide in the centre of the rail head.	Concrete F40	Pandrol "e" clips	Thermit welds within 2m of the monitoring site to the north.	

It was noted that on the Up Main, a thermit weld has been emergency clamped and that there was an L80 wide gap weld installed. There was no evidence of these causing any issues at present and under dynamic loading no excessive track movement or "banging" was noted.

Photograph 10: DCL Line Up Main 6' rail 65m 515yards. Thermit Weld Emergency clamped

Photograph 11: DCL Line Up Main 6' rail 65m 501yards. L80 wide gap weld

3.1.3 Sleepers

The sleepers are as per table 1, all sleepers were in good condition, with all fastenings present and correct.

3.1.4 Ballast

The ballast seems clean, well graded, and free of fines. No evidence of wet beds or "pumping" was identified or witnessed during dynamic loading.

There was some weed growth noted in the 4' and on cess ballast shoulder of the Up Passenger loop however this was well clear of the vibration monitoring site, and no pumping of the track was noted.

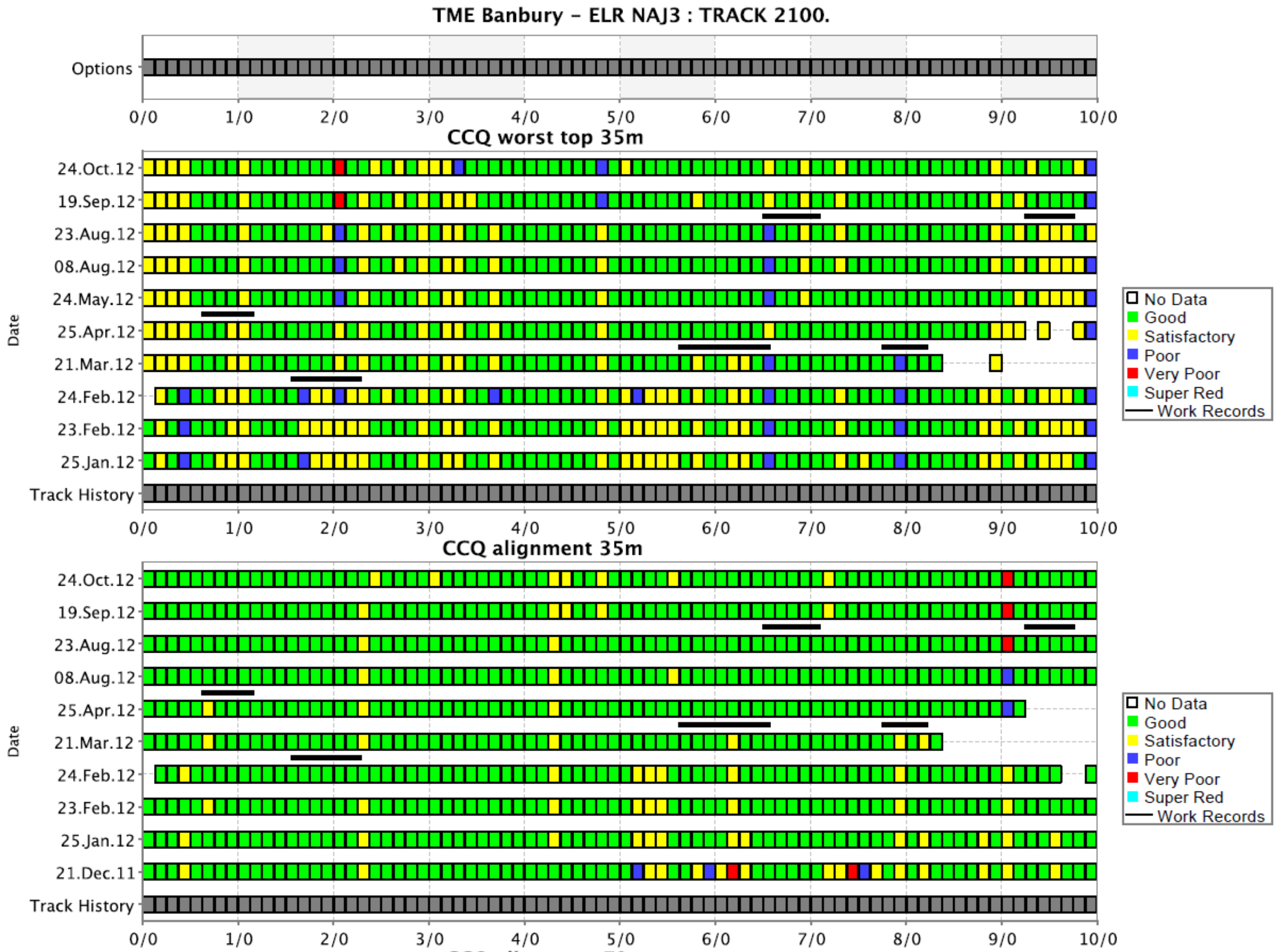
3.1.5 Topography

The vibration site is on a steep embankment (approx 3-4m height) on the Up side and at grade on the Down cess side.. There is minimal cess on the Up side.

The slopes are heavily vegetated with shrubs and trees.

3.1.6 Track Quality

The latest available track quality data available from the track recording train can be seen in figures 6-7 below.



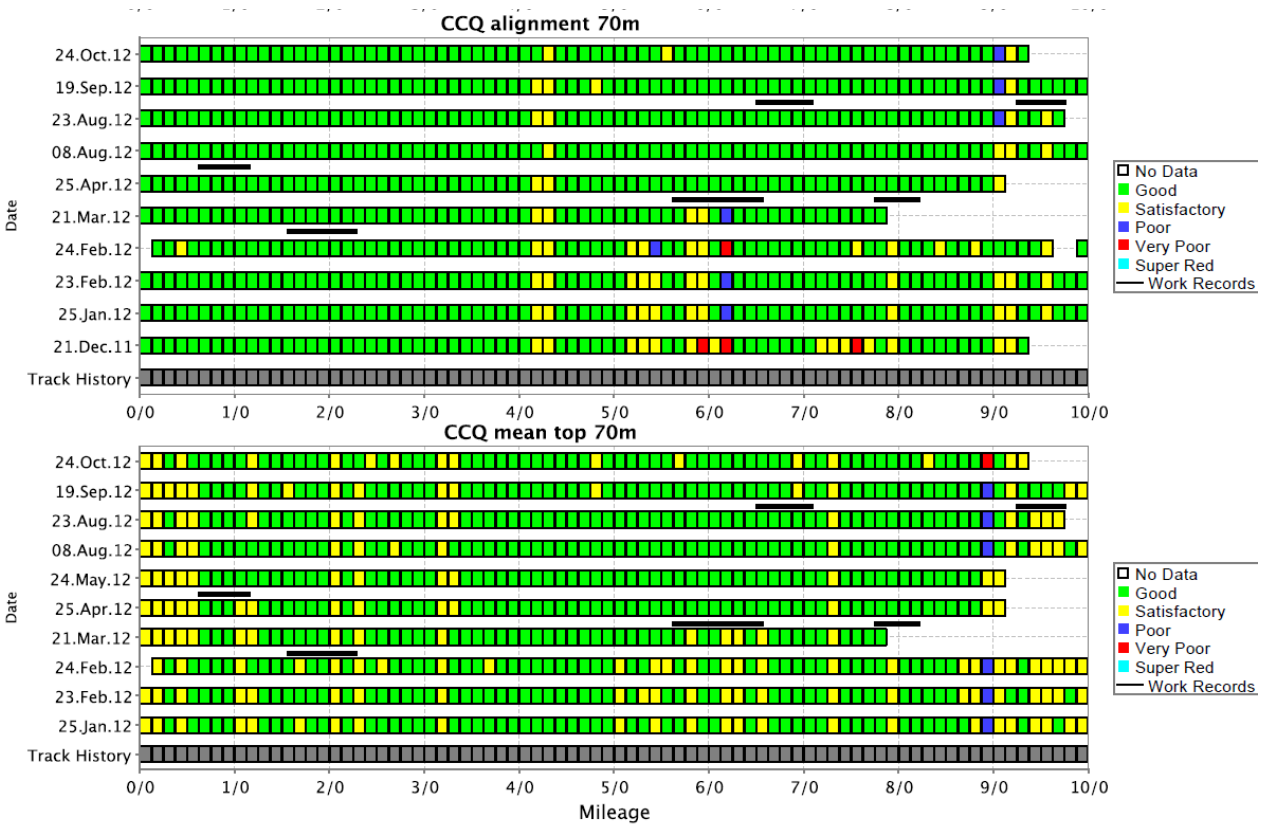
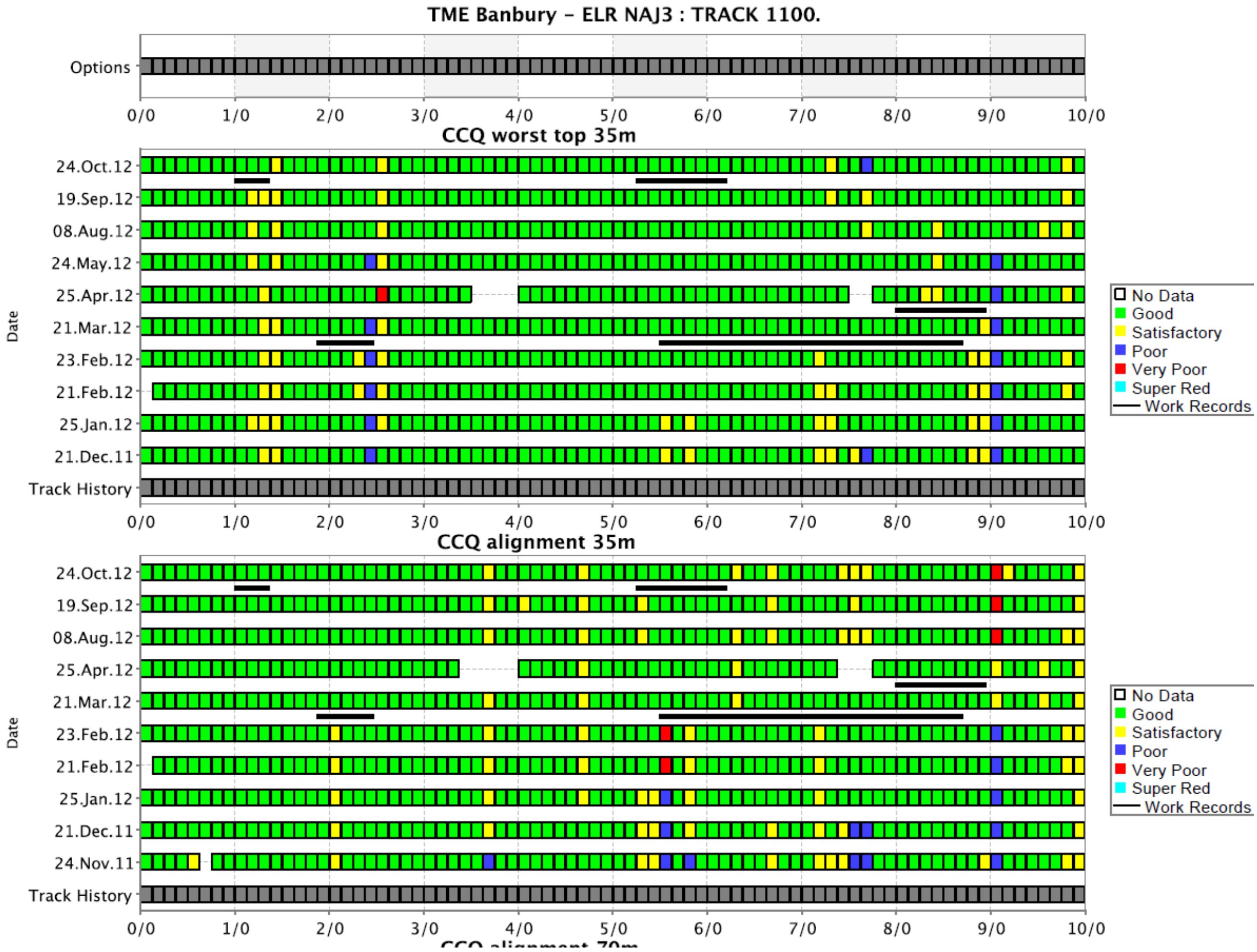


Figure 6: Track Recording vehicle Track Quality Data (DOWN LINE)



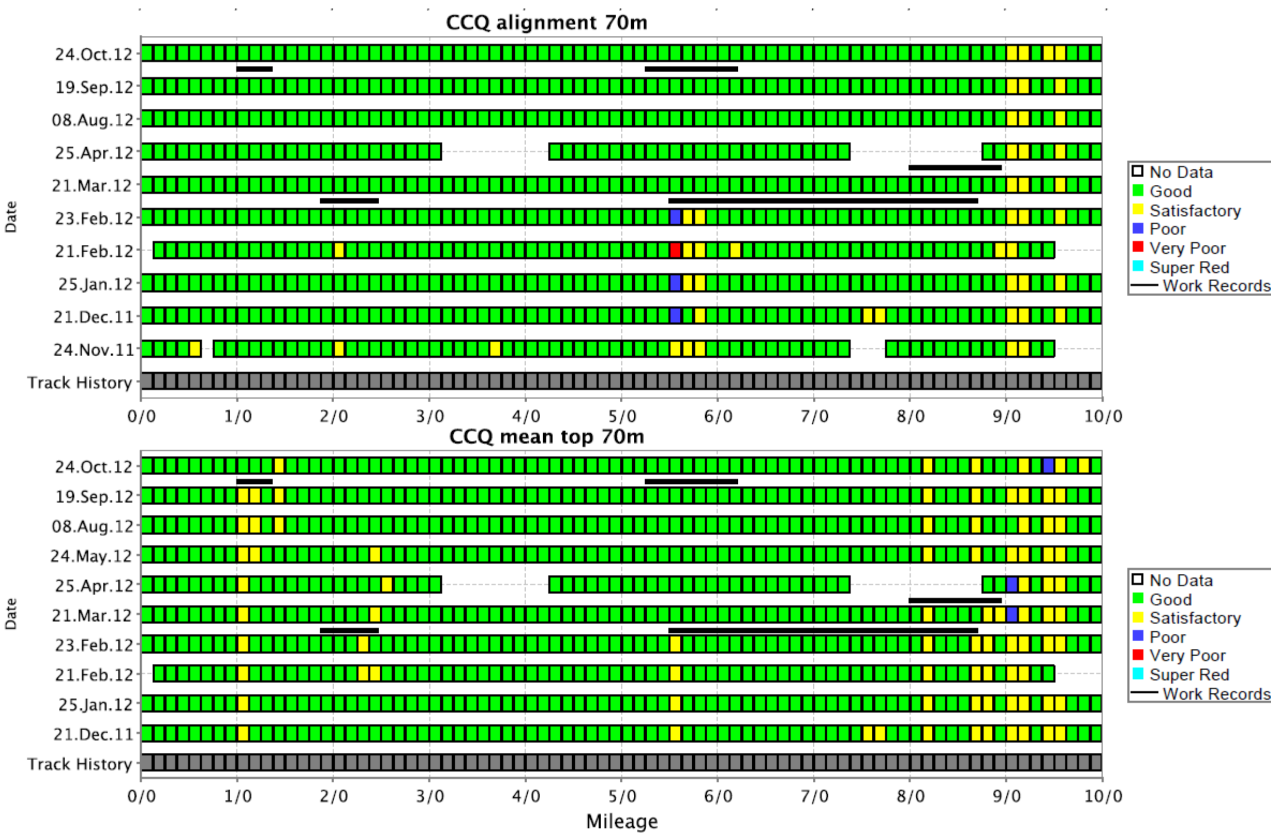


Figure 7: Track Recording vehicle Track Quality Data (UP LINE)

3.2 Conclusion

The track is in a good condition, with no evidence of “track pumping” or other issues that are likely to provide excessive vibration or noise characteristics at this location, and that would be outside of the normal parameters for a well maintained line for the track category currently in service.

Figure 6: Track Quality Inspection Form

Appendix F. Detailed Description of Pass-by Events

Table 36. Pass-by Event Data – March/April

For 'Event Reference', the number in brackets corresponds to the period of testing. (1) indicates that the event was recorded during the March to April period in 2013, (2) indicates that the event was recorded during the second period of measurement in October 2013.

Event Reference	Line	Specific Track	Type of Train (number of cars)	Train Details	Speed Estimate (mph)	Pass-by duration (seconds)
1(1)	DCL	Loop	Freight (>23)	Two types of flat bed wagon, FWA Shortliner / Ecofret intermodal spines, and the longer FSA Arbel Fauvet 'outer' intermodal flats.	22	25
2(1)	DCL	Up	Cross Country Voyager (4)	Class 220	67	1.5
3(1)	DCL	Down	Cross Country Voyager (4)	Class 220	60	2
4(1)	DCL	Down	First Great Western (2)	Class 166 (centre car removed)	55	2.5
5(1)	DCL	Down	Freight EWS 66167 (30)	Flatbed wagons.	38	33
6(1)	DCL	Up	First Great Western (5)	Class 180	60	2
7(1)	DCL	Down	Cross Country Voyager (4)	Class 220	67	4
8(1)	DCL	Up	Cross Country Voyager (4)	Class 220	75	3
9(1)	DCL	Down	Cross Country Voyager (4)	Class 220	60	4
10(1)	DCL	Down	Freight EWS 66079 (33)	Class 66 pulling IPA-B-STVA 4-unit covered single level flat.	24	44
11(1)	DCL	Up	Freightliner 66517 (27)	Long flatbed - FSA Arbel Fauvet 'outer' intermodal flats.	60	19
12(1)	DCL	Up	Cross Country (5)	Class 221	75	3.5
13(1)	DCL	Down	Cross Country (4)	Class 220	60	3.8
14(1)	DCL	Down	Freight (est.12)	Additional details not recorded.	30	25

Event Reference	Line	Specific Track	Type of Train (number of cars)	Train Details	Speed Estimate (mph)	Pass-by duration (seconds)
15(1)	DCL	Down	Passenger (4)	Additional details not recorded.	60	4.5
1B(1)	OXD	Single Track	Passenger (2)	Class 165/0 two car DMU. Operated by Chiltern Trains.	35	5
2B(1)	OXD	Single Track	Passenger (2)	Class 165/0 two car DMU. Operated by Chiltern Trains.	35	3.5
3B(1)	OXD	Single Track	Freight (Stone Train)	Class 59 Diesel Locomotive (59206) pulling JNA-39XX wagons (leased by NACO Ltd France). Box open top gondola wagon for aggregates.	35	21
4B(1)	OXD	Single Track	Passenger (2)	Class 165/0 two car DMU. Operated by Chiltern Trains.	35	5

Table 37. Pass-by Event Data – October

Event Reference	Line	Specific Track	Type of Train (number of cars)	Train Details	Speed Estimate (mph)	Pass-by duration (seconds)
1(2)	DCL	Up	First Great Western (3)	Class 166	73	2.10
2(2)	DCL	Down	Cross Country Voyager (4)	Class 220/221	82	2.53
3(2)	DCL	Up	Cross Country Voyager (5)	Class 220/221	86	3.03
4(2)	DCL	Up	First Great Western (5)	Class 180	69	3.77
5(2)	DCL	Down	First Great Western (5)	Class 180	69	3.80
6(2)	DCL	N/A	Dump Truck Measurement	N/A	N/A	N/A
7(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	88	2.37
8(2)	DCL	Down	Cross Country Voyager (5)	Class 220/221	74	3.50
9(2)	DCL	Down	Freight (36)	Loco 66125. The wagons are owned by STVA. They appear to be Car carrying wagons,	36	30.60

Event Reference	Line	Specific Track	Type of Train (number of cars)	Train Details	Speed Estimate (mph)	Pass-by duration (seconds)
				connected in pairs. There appears to be two versions. Operated by DB Schenker (EWS).		
10(2)	DCL	Loop	Freight (30)	EWS 66174. The wagons are container flats. 9 pairs are "Megafret Flats" Code FKA and the remainder are "Intermodal Flats" Code FYA. Operated by DB Schenker (EWS).	28	73.83
11(2)	DCL	Up	Freight (>20)	The start of the train cannot be seen so it is not possible to determine the overall length. As the train is moving fast it is also difficult to establish what the wagons are. The speed is estimated by the length of 3x20 foot containers (18.2m) passing a certain point.	68	0.60
12(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	108	2.40
13(2)	DCL	Down	Cross Country Voyager (3)	Class 220/221	59	2.60
14(2)	DCL	Down	First Great Western (3)	Class 166	53	0.97
15(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	88	2.37
16(2)	DCL	Down	Cross Country Voyager (4)	Class 220/221	82	2.53
17(2)	DCL	Down	Freight (33)	No video file available.	N/A	N/A
18(2)	DCL	Up	First Great Western (4)	No video file available.	N/A	N/A
19(2)	DCL	Up	First Great Western (10)	HST	62	7.90
20(2)	DCL	N/A	Background Measurement	N/A	N/A	N/A
21(2)	DCL	Down	First Great Western (5)	Class 180	50	5.17

Event Reference	Line	Specific Track	Type of Train (number of cars)	Train Details	Speed Estimate (mph)	Pass-by duration (seconds)
22(2)	DCL	Up	First Great Western (3)	Class 166	79	1.93
23(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	77	2.70
24(2)	DCL	Down	Cross Country Voyager (5)	Class 220/221	75	3.47
25(2)	DCL	Up	Freight (24)	Class 70. Operated by Freightliner	64	0.63
26(2)	DCL	Up	First Great Western (5)	Class 180	39	6.70
27(2)	DCL	Down	Freight (30)	Class 66. The wagons are in sets of 5 and there are 6 sets. They are likely to be covered car carrying wagons (Code WIA) manufactured by Arbel Fauvet France.Operated by DB Schenker (EWS)	69	13.50
28A(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	82	2.53
28B(2)	DCL	Down	Passenger (4)	No video file available.	N/A	N/A
29(2)	DCL	Up	First Great Western (3)	Class 166	60	2.57
30(2)	DCL	Down	First Great Western (3)	Class 166	55	2.77
31(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	87	2.40
32(2)	DCL	Down	Cross Country Voyager (5)	Class 220/221	82	3.17
33(2)	DCL	Down	Freight (30)	Class 66. Container wagons. Operated by Freightliner.	68	0.60
34A(2)	DCL	Up	Passenger (4)	No video file available.	N/A	N/A
34B(2)	DCL	Down	Passenger (4)	No video file available.	N/A!	N/A
35(2)	DCL	N/A	Background Measurement	N/A	N/A	N/A
36(2)	DCL	Down	Cross Country Voyager (4)	Class 220/221	79	2.63
37(2)	DCL	Up	Cross Country Voyager (5)	Class 220/221	N/A	N/A

Event Reference	Line	Specific Track	Type of Train (number of cars)	Train Details	Speed Estimate (mph)	Pass-by duration (seconds)
38(2)	DCL	Down	First Great Western (10)	HST	46	10.77
39(2)	OXD	N/A	Background Measurement	N/A	N/A	N/A
40(2)	OXD	Single Track	Chiltern Railways (2)	Class 165/0. "Networker Turbo" Diesel Multiple Unit - each vehicle is powered, with one powered and one unpowered bogie per vehicle. Unit No. 165022 consisting of two vehicles. Not possible to estimate speed as camera is not stationary.	N/A	N/A
41(2)	OXD	Single Track	Freight (12)	Class 59. Loco 59206. Bogie Wagons - Appear to be open topped heavy wagons. Probably JNA Type Used by Mendip Rail. Operated by DB Schenker (EWS)	28	1.70
42(2)	DCL	Loop	Freight (31)	No video file available.	N/A	N/A
43(2)	DCL	Up	Passenger (4)	No video file available.	N/A	N/A
44(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	86	2.43
45(2)	DCL	Up	First Great Western (5)	Class 180	67	3.87
46(2)	DCL	Up	First Great Western (3)	Class 166	77	2.00
47(2)	DCL	Up	Freight (30)	Container wagons. Operated by freightliner.	68	0.60
48(2)	DCL	Down	Cross Country Voyager (4)	Class 220/221	75	2.80
49(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	86	2.43
50(2)	DCL	Up	First Great Western	Class 166	62	2.47

Event Reference	Line	Specific Track	Type of Train (number of cars)	Train Details	Speed Estimate (mph)	Pass-by duration (seconds)
			(3)			
51(2)	DCL	Down	First Great Western (5)	Class 180	77	3.37
52(2)	DCL	Up	Cross Country Voyager (4)	Class 220/221	82	2.53
53(2)	DCL	Down	Cross Country Voyager (4)	Class 220/221	82	2.53
54(2)	DCL	Up	Freight (26)	Container wagons. Operated by freightliner.	68	0.60
55(2)	DCL	Up	First Great Western (3)	Class 166	58	2.63
56(2)	DCL	Down	Freight (25)	Class 66. Mixture of wagons some with low platforms and some normal. Some are twin wagons capable of carrying 18m and some are individual wagons which carry 12m containers. Operated by freightliner.	68	0.60
57(2)	OXD	Single Track	Freight (17)	Class 66. Mendip Rail Stone Carrying Wagons - Type JNA - 15.5m long. Operated by DB Schenker.	25	24.17

Appendix G. Measured Vibration Levels

Table 38. Derived VDV ($ms^{-1.75}$) – Passenger Trains

				VDV (ms-1.75)																									
				Distance / Line																									
Type	Date	Line	Event	Loop			Up			Down			Branch	Loop				Up				Down				Branch			
				4.3	6.3	8.3	8.5	10.5	11.9	12.5	13.9	15.9	4	3.3	6.7	8.7	11.2	7.8	11.2	13.2	15.7	11.2	14.6	16.6	19.1	2.5	4.5	6.6	8.5
Passenger	March	Up	Event 2				0.019	0.014		0.009																			
		Down	Event 3						0.009		0.012	0.005																	
		Down	Event 4						0.011		0.030	0.006																	
		Up	Event 6				0.040		0.025		0.020																		
		Down	Event 7						0.012		0.010	0.008																	
		Up	Event 8				0.028	0.023		0.016																			
		Down	Event 9						0.015		0.011	0.009																	
		Up	Event 12				0.02811	0.023		0.017																			
		Down	Event 13						0.014		0.009	0.007																	
		Down	Event 14						0.040		0.026	0.019																	
		Down	Event 15						0.013		0.009	0.006																	
	April	Bran	Event 1B										0.034																
		Bran	Event 2B										0.031																
		Bran	Event 4B										0.032																
	October	Up	Event 1															0.017	0.015	0.014	0.011								
		Down	Event 2																			0.010	0.009	0.009	0.010				
		Up	Event 3															0.028	0.026	0.045	0.021								
		Up	Event 4															0.019	0.014	0.012	0.012								
		Down	Event 5																			0.012	0.011	0.011	0.008				
		Up	Event 7															0.025	0.019	0.015	0.017								
		Down	Event 8																			0.019	0.017	0.015	0.011				
		Up	Event 12															0.022	0.016	0.013	0.015								
		Down	Event 13																			0.009	0.007	0.007	0.006				
		Down	Event 14																			0.008	0.007	0.006	0.007				
		Up	Event 15															0.023	0.017	0.013	0.016								
		Down	Event 16																			0.010	0.008	0.008	0.010				
		Up	Event 18															0.030	0.028	0.019	0.013								
		Up	Event 19															0.018	0.014	0.013	0.014								
		Down	Event 21																			0.007	0.006	0.006	0.007				
		Up	Event 22															0.017	0.017	0.015	0.012								
		Up	Event 23															0.018	0.013	0.012	0.013								
		Down	Event 24																			0.019	0.016	0.015	0.012				
		Up	Event 26															0.009	0.007	0.006	0.007								
		Up	Event 28A															0.018	0.013	0.011	0.014								
		Down	Event 28B																			0.010	0.009	0.009	0.009				
		Up	Event 29															0.013	0.011	0.010	0.008								
		Down	Event 30																			0.008	0.008	0.007	0.006				
		Up	Event 31															0.025	0.023	0.015	0.016								
		Down	Event 32																				0.016	0.015	0.012				
		Up	Event 34A															0.011	0.009	0.009	0.010								
		Down	Event 34B																			0.006	0.006	0.005	0.004				
		Down	Event 36																			0.010	0.009	0.009	0.009				
		Up	Event 37															0.026	0.022	0.019	0.020								
		Up	Event 38															0.020	0.023	0.014	0.016								
		Bran	Event 40																							0.042	0.022	0.014	0.009
		Up	Event 43															0.021	0.016	0.015	0.016								
		Up	Event 44															0.022	0.015	0.013	0.015								
		Up	Event 45															0.019	0.014	0.013	0.012								
		Up	Event 46															0.017	0.016	0.015	0.012								
		Down	Event 48																			0.012	0.011	0.010	0.008				
		Up	Event 49															0.032	0.035	0.027	0.017								
		Up	Event 50															0.014	0.014	0.012	0.010								
		Down	Event 51																			0.015	0.011	0.011	0.009				
		Up	Event 52															0.016	0.013	0.012	0.014								
		Down	Event 53																			0.012	0.015	0.013	0.010				
		Up	Event 55															0.008	0.010	0.007	0.006								

Table 39. Derived VDV ($ms^{-1.75}$) – Freight Trains

				VDV (ms-1.75)																									
				Distance / Line																									
Type	Date	Line	Event	Loop			Up			Down			Branch	Loop				Up				Down				Branch			
				4.3	6.3	8.3	8.5	10.5	11.9	12.5	13.9	15.9	4	3.3	6.7	8.7	11.2	7.8	11.2	13.2	15.7	11.2	14.6	16.6	19.1	2.5	4.5	6.6	8.5
Freight	March	Loop	Event 1	0.093	0.044	0.030																							
		Down	Event 5						0.040		0.025	0.020																	
		Down	Event 10						0.018		0.016	0.010																	
		Up	Event 11				0.046	0.038		0.025																			
	October	Down	Event 9																			0.016	0.014	0.013	0.010				
		Loop	Event 10											0.082	0.060	0.042	0.042												
		Up	Event 11															0.037	0.030	0.026	0.023								
		Down	Event 17																			0.017	0.016	0.016	0.015				
		Up	Event 25															0.032	0.029	0.026	0.023								
		Down	Event 27																			0.016	0.015	0.015	0.013				
		Down	Event 33																			0.023	0.021	0.019	0.016				
		Loop	Event 42											0.027	0.019	0.017	0.014												
		Up	Event 47															0.033	0.029	0.026	0.024								
		Up	Event 54															0.033	0.029	0.026	0.023								
		Down	Event 56																			0.023	0.022	0.020	0.015				

Table 40. Derived VDV ($ms^{-1.75}$) – Stone Trains

				VDV (ms-1.75)																									
				Distance / Line																									
Type	Date	Line	Event	Loop			Up			Down			Branch	Loop				Up				Down				Branch			
				4.3	6.3	8.3	8.5	10.5	11.9	12.5	13.9	15.9	4	3.3	6.7	8.7	11.2	7.8	11.2	13.2	15.7	11.2	14.6	16.6	19.1	2.5	4.5	6.6	8.5
Stone	April	Bran	Event 3B										0.124																
	October	Bran	Event 41																							0.107	0.061	0.045	0.039
		Bran	Event 57																							0.046	0.060	0.037	0.025

Table 41. Derived eVDV ($ms^{-1.75}$) – Passenger Trains

				eVDV (ms-1.75)																									
				Distance / Line																									
Type	Date	Line	Event	Loop			Up			Down			Branch	Loop				Up				Down				Branch			
				4.3	6.3	8.3	8.5	10.5	11.9	12.5	13.9	15.9	4	3.3	6.7	8.7	11.2	7.8	11.2	13.2	15.7	11.2	14.6	16.6	19.1	2.5	4.5	6.6	8.5
Passenger	March	Up	Event 2				0.013	0.012		0.007																			
		Down	Event 3						0.007		0.010	0.004																	
		Down	Event 4						0.008		0.020	0.005																	
		Up	Event 6				0.015	0.009		0.007																			
		Down	Event 7						0.010		0.008	0.006																	
		Up	Event 8				0.029	0.023		0.017																			
		Down	Event 9						0.012		0.010	0.008																	
		Up	Event 12				0.027	0.023		0.016																			
		Down	Event 13						0.011		0.008	0.007																	
		Down	Event 14						0.025		0.017	0.012																	
		Down	Event 15						0.010		0.007	0.005																	
		Bran	Event 1B										0.034																
		Bran	Event 2B										0.031																
		Bran	Event 4B										0.029																
	October	Up	Event 1															0.015	0.014	0.013	0.010								
		Down	Event 2																			0.010	0.009	0.009	0.010				
		Up	Event 3															0.027	0.026	0.022	0.020								
		Up	Event 4															0.004	0.003	0.006	0.002								
		Down	Event 5																			0.002	0.002	0.004	0.002				
		Up	Event 7															0.022	0.017	0.014	0.016								
		Down	Event 8																			0.019	0.018	0.015	0.012				
		Up	Event 12															0.020	0.015	0.013	0.014								
		Down	Event 13																			0.008	0.007	0.007	0.006				
		Down	Event 14																			0.008	0.007	0.006	0.007				
		Up	Event 15															0.021	0.016	0.012	0.015								
		Down	Event 16																			0.010	0.008	0.008	0.010				
		Up	Event 18															0.024	0.021	0.016	0.014								
		Up	Event 19															0.019	0.015	0.014	0.015								
		Down	Event 21																			0.007	0.006	0.006	0.007				
		Up	Event 22															0.015	0.015	0.013	0.011								
		Up	Event 23															0.016	0.013	0.012	0.013								
		Down	Event 24																			0.019	0.017	0.015	0.012				
		Up	Event 26															0.010	0.008	0.007	0.008								
		Up	Event 28A															0.017	0.013	0.011	0.013								
		Down	Event 28B																			0.009	0.009	0.008	0.009				
		Up	Event 29															0.013	0.011	0.010	0.008								
		Down	Event 30																			0.008	0.007	0.007	0.006				
		Up	Event 31															0.022	0.019	0.014	0.015								
		Down	Event 32																				0.016	0.015	0.012				
		Up	Event 34A															0.011	0.009	0.009	0.010								
		Down	Event 34B																			0.007	0.006	0.005	0.004				
		Down	Event 36																			0.010	0.009	0.009	0.009				
		Up	Event 37															0.025	0.023	0.019	0.021								
		Up	Event 38															0.017	0.017	0.013	0.016								
		Bran	Event 40																										
		Up	Event 43															0.019	0.015	0.014	0.015								
		Up	Event 44															0.019	0.014	0.013	0.014								
		Up	Event 45															0.018	0.015	0.013	0.012								
		Up	Event 46															0.015	0.015	0.014	0.012								
		Down	Event 48																			0.012	0.011	0.010	0.008				
		Up	Event 49															0.026	0.025	0.021	0.016								
		Up	Event 50															0.014	0.014	0.012	0.009								
		Down	Event 51																			0.015	0.012	0.011	0.010				
		Up	Event 52															0.016	0.013	0.012	0.014								
		Down	Event 53																			0.011	0.013	0.012	0.010				
		Up	Event 55															0.008	0.011	0.007	0.006								

Table 42. Derived eVDV ($ms^{-1.75}$) – Freight Trains

Type	Date	Line	Event	eVDV (ms-1.75)																									
				Distance / Line																									
				Loop			Up			Down			Branch	Loop				Up				Down				Branch			
				4.3	6.3	8.3	8.5	10.5	11.9	12.5	13.9	15.9	4	3.3	6.7	8.7	11.2	7.8	11.2	13.2	15.7	11.2	14.6	16.6	19.1	2.5	4.5	6.6	8.5
Freight	March	Loop	Event 1	0.071	0.038	0.024																							
		Down	Event 5						0.025		0.022	0.017																	
		Down	Event 10						0.015		0.013	0.009																	
		Up	Event 11				0.043	0.030		0.022																			
	October	Down	Event 9																			0.016	0.015	0.014	0.009				
		Loop	Event 10											0.046	0.034	0.026	0.020												
		Up	Event 11															0.035	0.030	0.027	0.024								
		Down	Event 17																			0.018	0.017	0.016	0.016				
		Up	Event 25															0.032	0.029	0.026	0.022								
		Down	Event 27																			0.017	0.016	0.015	0.013				
		Down	Event 33																			0.023	0.021	0.019	0.016				
		Loop	Event 42											0.023	0.020	0.017	0.014												
		Up	Event 47															0.033	0.029	0.027	0.024								
		Up	Event 54															0.034	0.030	0.026	0.023								
		Down	Event 56																			0.024	0.023	0.021	0.015				

Table 43. Derived eVDV ($ms^{-1.75}$) – Stone Trains

Type	Date	Line	Event	eVDV (ms-1.75)																									
				Distance / Line																									
				Loop			Up			Down			Branch	Loop				Up				Down				Branch			
				4.3	6.3	8.3	8.5	10.5	11.9	12.5	13.9	15.9	4	3.3	6.7	8.7	11.2	7.8	11.2	13.2	15.7	11.2	14.6	16.6	19.1	2.5	4.5	6.6	8.5
Stone	March	Bran	Event 3B										0.102																
	October	Bran	Event 41																							0.094	0.061	0.046	0.041
		Bran	Event 57																								0.058	0.037	0.025

Table 44. Selected 1/3 Octave Frequency Data - Weighted RMS Acceleration (ms^{-2})

Event	Channel	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
3B(1) (stone)	x1	0.0006	0.0007	0.0002	0.0004	0.0008	0.0009	0.0008	0.0008	0.0005	0.0009	0.0014	0.0053	0.0021	0.0022	0.0038	0.0019	0.0006	0.0009	0.0016	0.0012	0.0004
	y2	0.0001	0.0003	0.0001	0.0001	0.0006	0.0019	0.0011	0.0009	0.0004	0.0009	0.0008	0.0038	0.0023	0.0015	0.0019	0.0015	0.0005	0.0003	0.0006	0.0004	0.0001
	z3	0.0000	0.0000	0.0000	0.0001	0.0041	0.0061	0.0027	0.0018	0.0015	0.0026	0.0033	0.0197	0.0102	0.0066	0.0086	0.0111	0.0072	0.0102	0.0113	0.0062	0.0022
6(1)	z3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0017	0.0034	0.0043	0.0031	0.0017	0.0017	0.0004	0.0000
	z6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0019	0.0024	0.0020	0.0021	0.0011	0.0012	0.0001	0.0000
	z8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0012	0.0014	0.0017	0.0007	0.0003	0.0002	0.0001	0.0000
8(1)	z3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0057	0.0068	0.0036	0.0036	0.0024	0.0069	0.0056	0.0064	0.0057	0.0024	0.0005	0.0001
	z6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0046	0.0056	0.0033	0.0025	0.0017	0.0051	0.0061	0.0053	0.0031	0.0019	0.0003	0.0000

Event	Channel	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
	z8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0038	0.0022	0.0021	0.0018	0.0029	0.0035	0.0024	0.0008	0.0004	0.0001	0.0000
9(1)	z3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0028	0.0026	0.0011	0.0013	0.0015	0.0051	0.0021	0.0022	0.0012	0.0006	0.0002
	z6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0030	0.0016	0.0010	0.0014	0.0012	0.0025	0.0020	0.0018	0.0018	0.0004	0.0001
	z8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0030	0.0016	0.0009	0.0011	0.0005	0.0020	0.0012	0.0004	0.0003	0.0001	0.0001
11(1) (Freight)	x1	0.0000	0.0000	0.0000	0.0002	0.0003	0.0004	0.0003	0.0003	0.0003	0.0008	0.0015	0.0010	0.0015	0.0018	0.0019	0.0018	0.0005	0.0005	0.0002	0.0001	0.0000
	y2	0.0000	0.0000	0.0000	0.0002	0.0002	0.0003	0.0005	0.0004	0.0003	0.0005	0.0009	0.0010	0.0012	0.0013	0.0013	0.0010	0.0003	0.0004	0.0002	0.0001	0.0000
	z3	0.0000	0.0000	0.0000	0.0002	0.0026	0.0046	0.0040	0.0022	0.0016	0.0026	0.0034	0.0027	0.0029	0.0037	0.0061	0.0064	0.0038	0.0044	0.0033	0.0010	0.0001
	z6	0.0000	0.0000	0.0000	0.0002	0.0024	0.0044	0.0041	0.0022	0.0017	0.0028	0.0031	0.0021	0.0019	0.0032	0.0057	0.0037	0.0030	0.0026	0.0021	0.0004	0.0001
	z8	0.0000	0.0000	0.0000	0.0001	0.0013	0.0038	0.0037	0.0020	0.0016	0.0025	0.0027	0.0015	0.0014	0.0020	0.0030	0.0023	0.0010	0.0008	0.0006	0.0002	0.0001
12(1) (passenger - 75mph)	x1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0003	0.0009	0.0065	0.0075	0.0112	0.0191	0.0229	0.0355	0.0343	0.0251	0.0219	0.0129
	y2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004	0.0060	0.0044	0.0157	0.0083	0.0302	0.0211	0.0302	0.0251	0.0174	0.0174	0.0068
	z3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0005	0.0028	0.0059	0.0083	0.0052	0.0054	0.0048	0.0150	0.0150	0.0182	0.0237	0.0153
	z6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.0011	0.0033	0.0053	0.0054	0.0127	0.0140	0.0251	0.0143	0.0275	0.0376	0.0136
	z8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0004	0.0057	0.0042	0.0102	0.0046	0.0162	0.0195	0.0126	0.0078	0.0136	0.0269	0.0069
13(1)	z3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0027	0.0036	0.0012	0.0015	0.0017	0.0047	0.0010	0.0012	0.0005	0.0002	0.0000
	z6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0028	0.0024	0.0010	0.0013	0.0009	0.0020	0.0007	0.0008	0.0006	0.0001	0.0000
	z8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0026	0.0020	0.0010	0.0010	0.0006	0.0014	0.0005	0.0002	0.0001	0.0000	0.0000

Appendix H. Frequency Decay Curves

H.1. Freight Trains (Excluding Stone Train)

Figure 35. Freight train decay characteristics at 3.15Hz

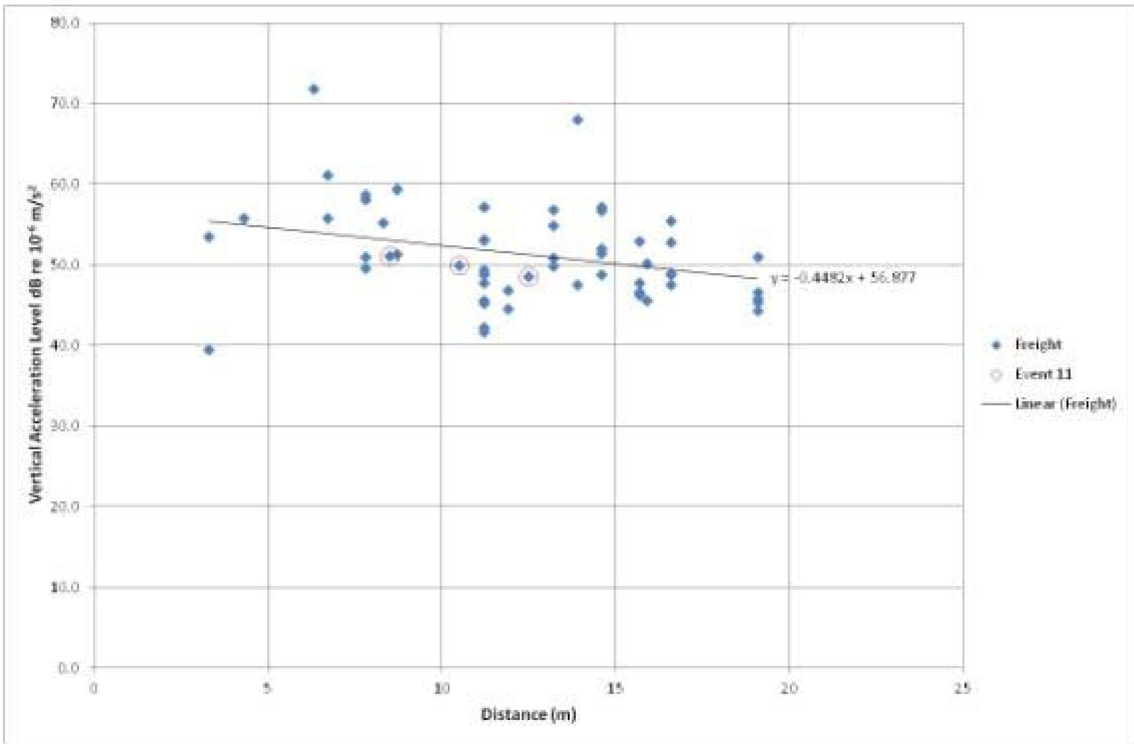


Figure 36. Freight train decay characteristics at 4Hz

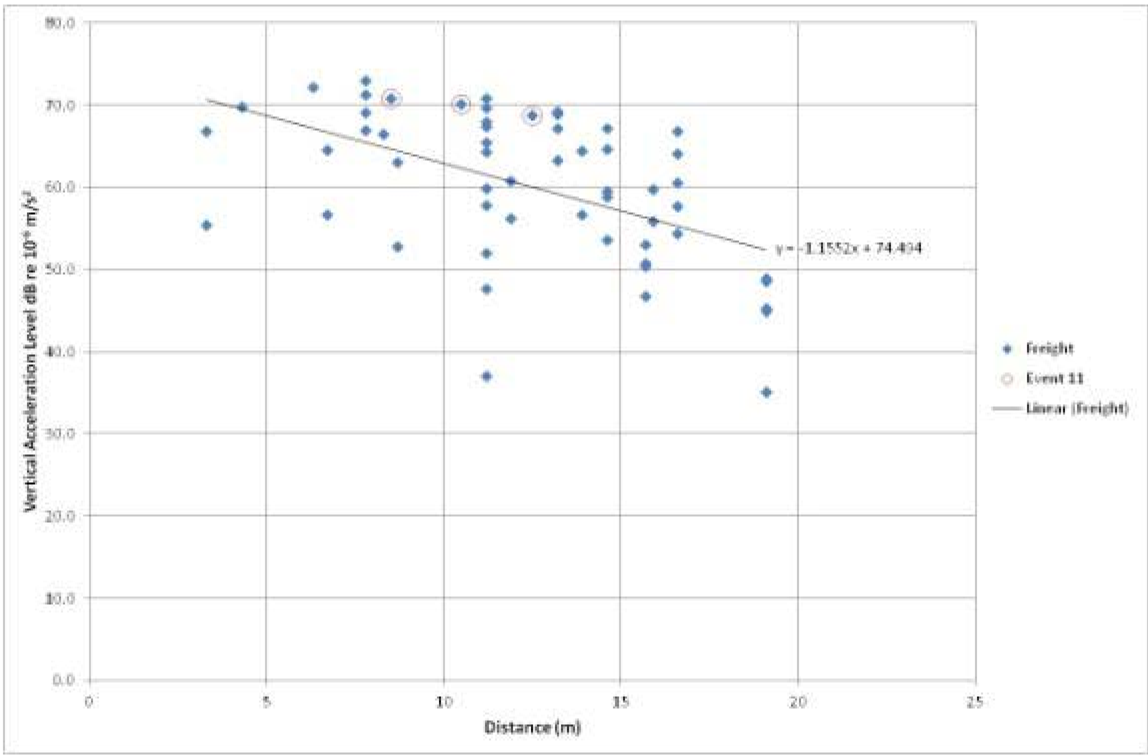


Figure 37. Freight train decay characteristics at 5Hz

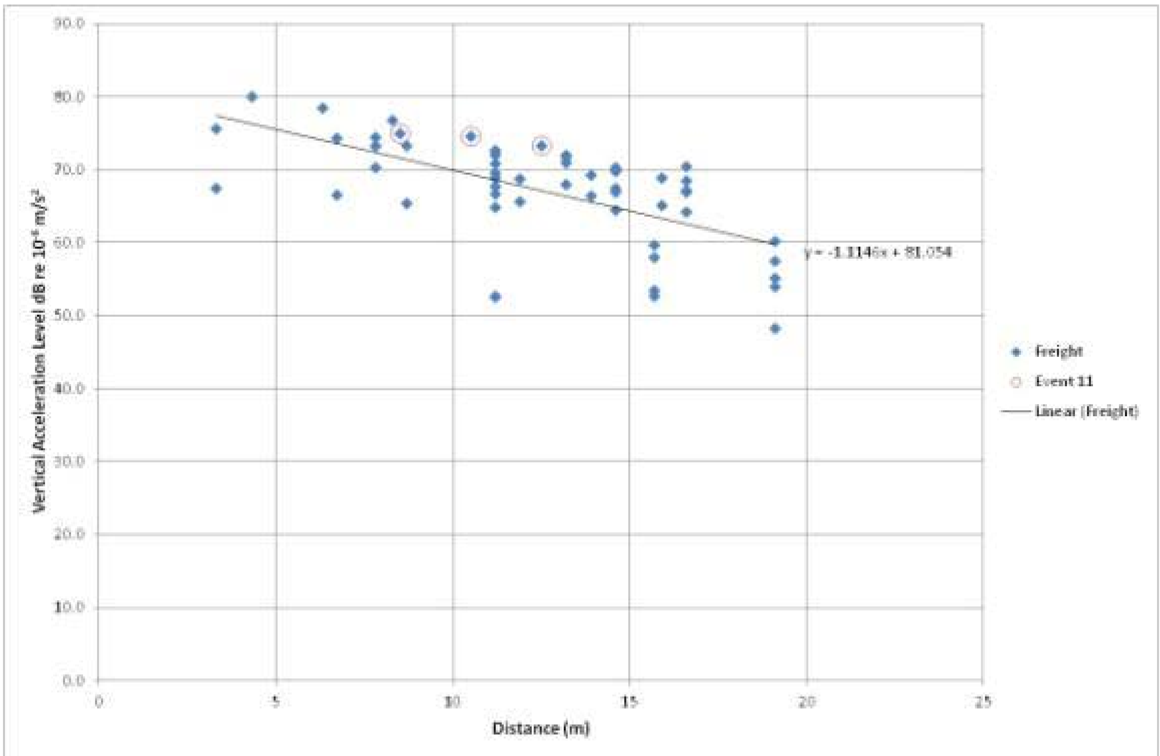


Figure 38. Freight train decay characteristics at 6.3Hz

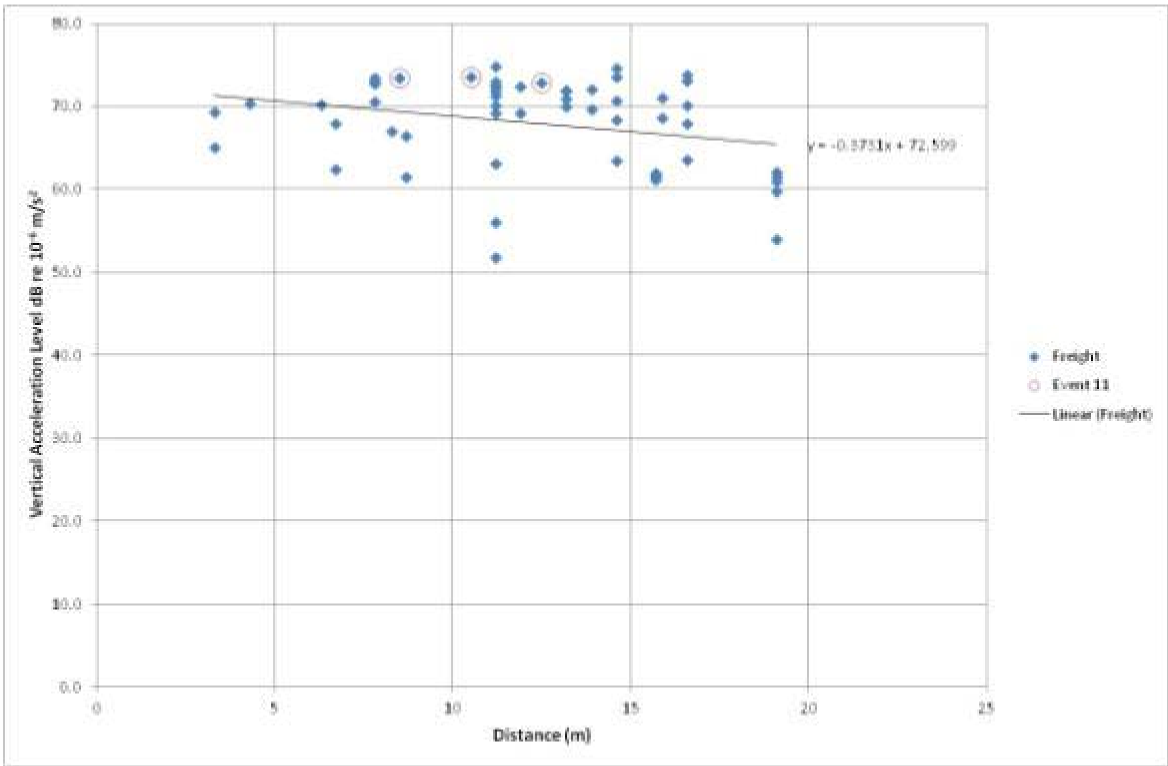


Figure 39. Freight train decay characteristics at 8Hz

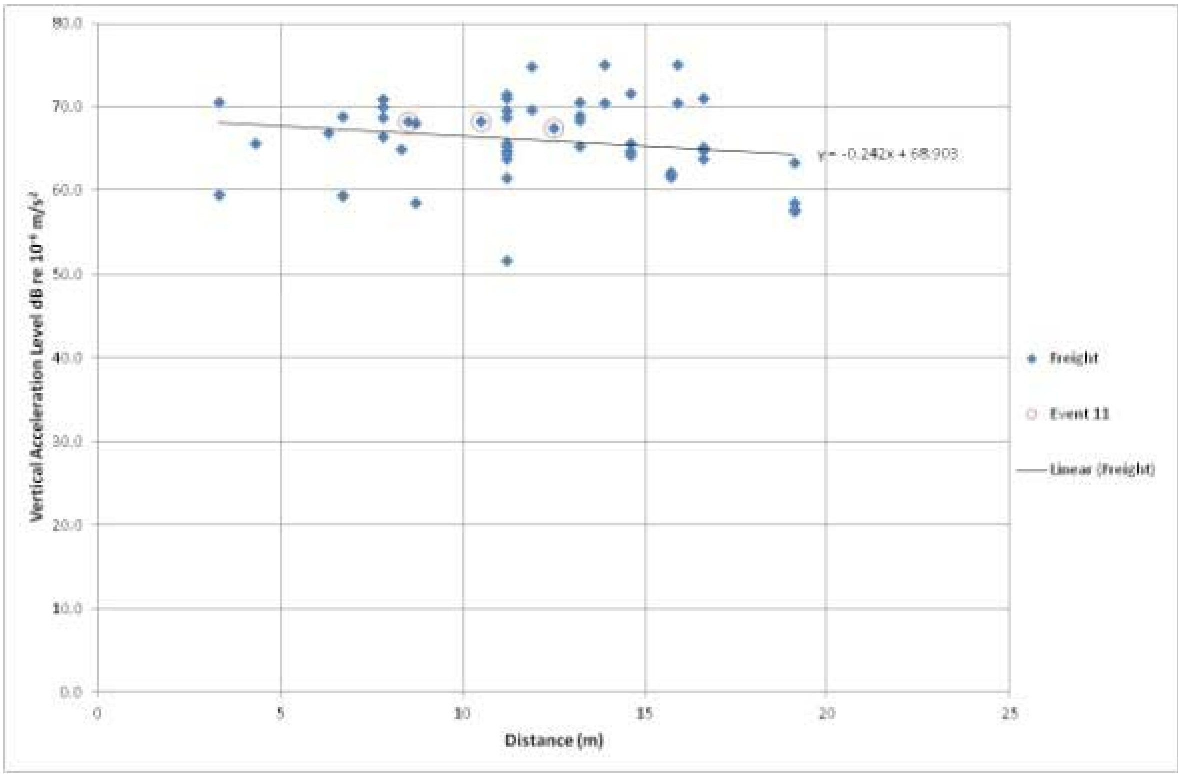


Figure 40. Freight train decay characteristics at 10Hz

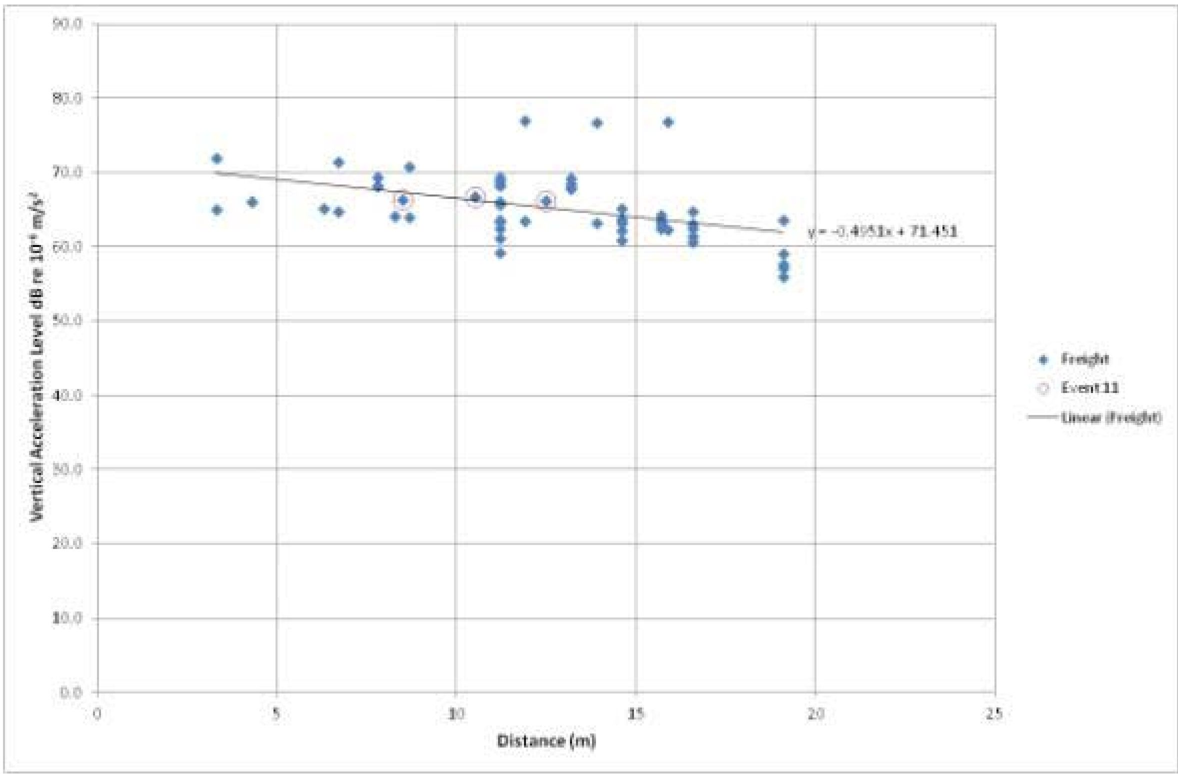


Figure 41. Freight train decay characteristics at 12.5Hz

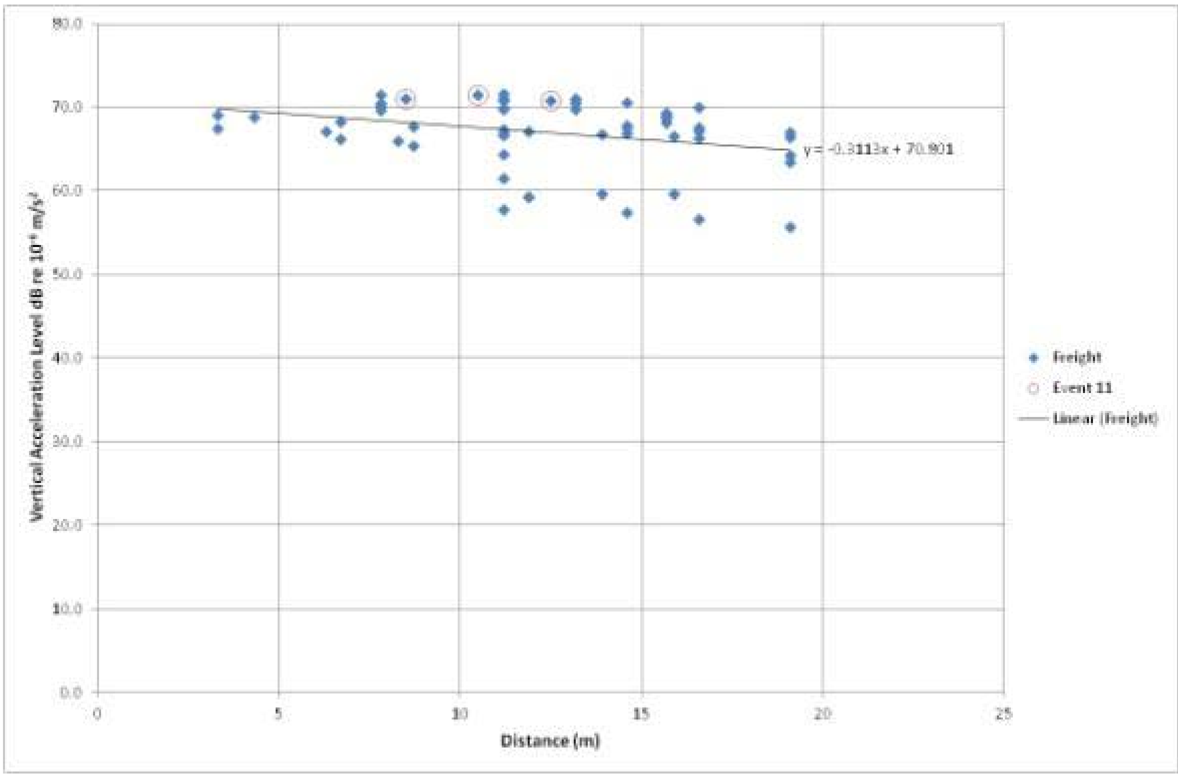


Figure 42. Freight train decay characteristics at 16Hz

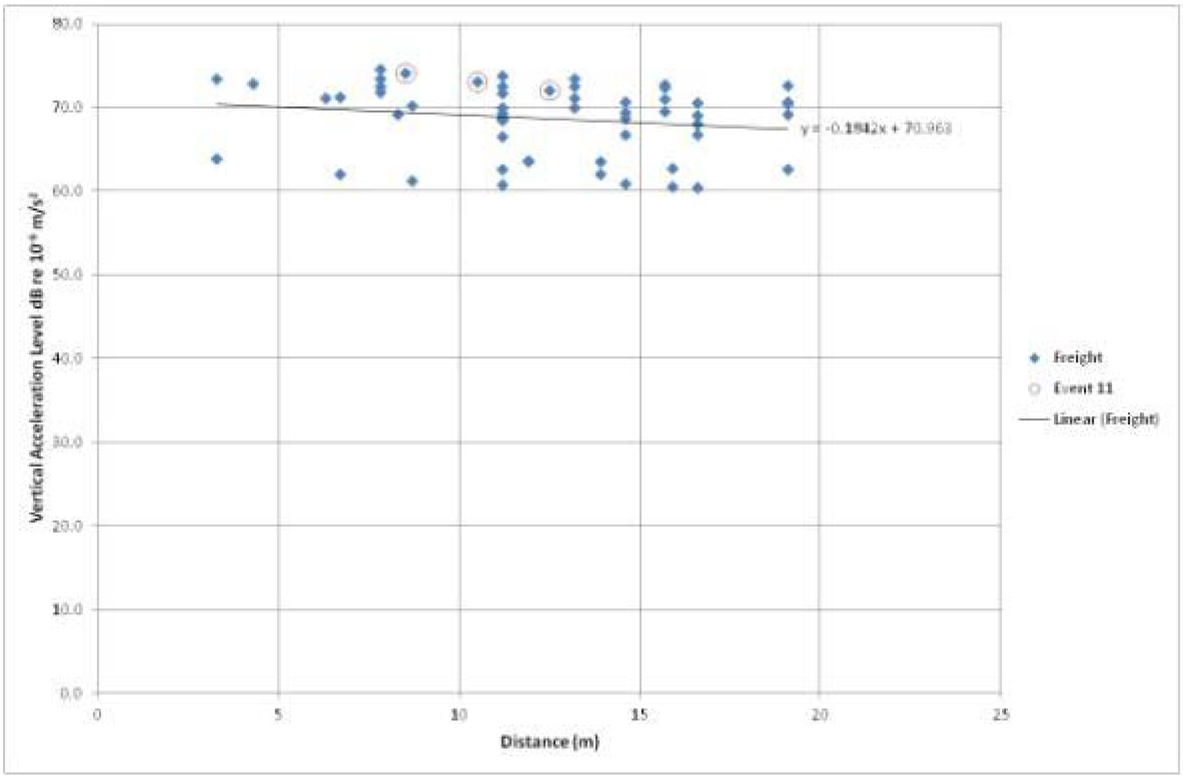


Figure 43. Freight train decay characteristics at 20Hz

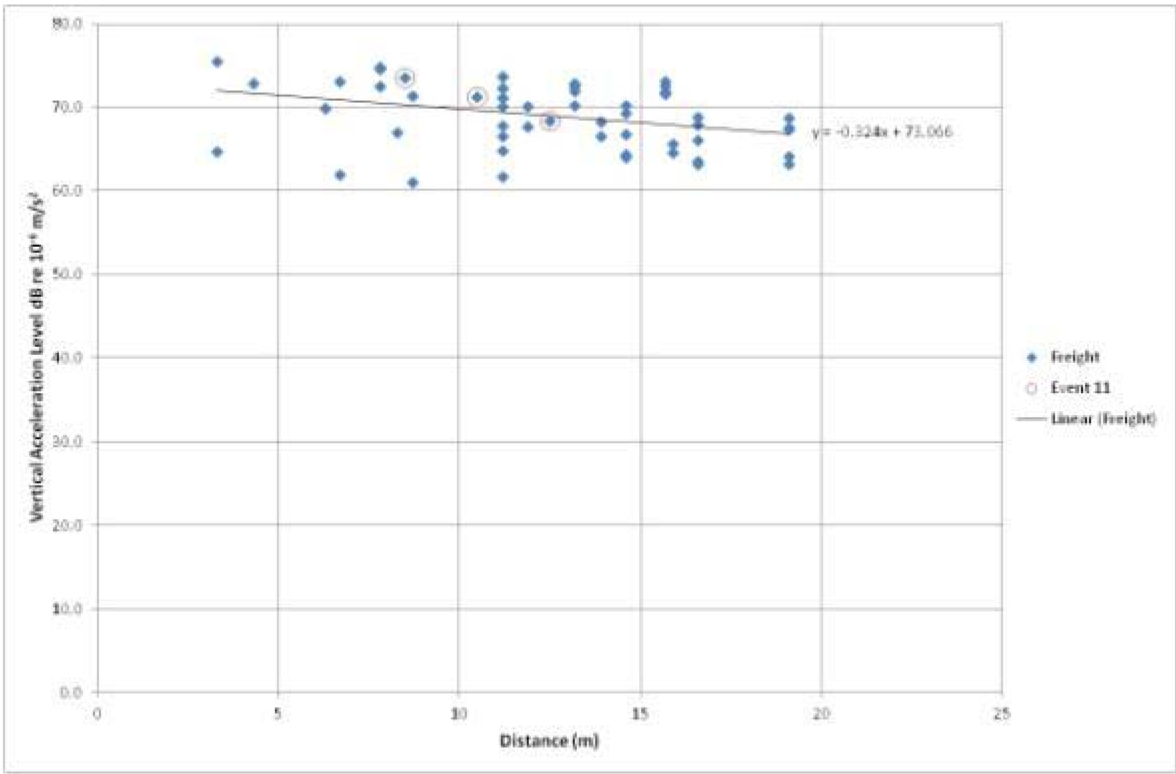


Figure 44. Freight train decay characteristics at 25Hz

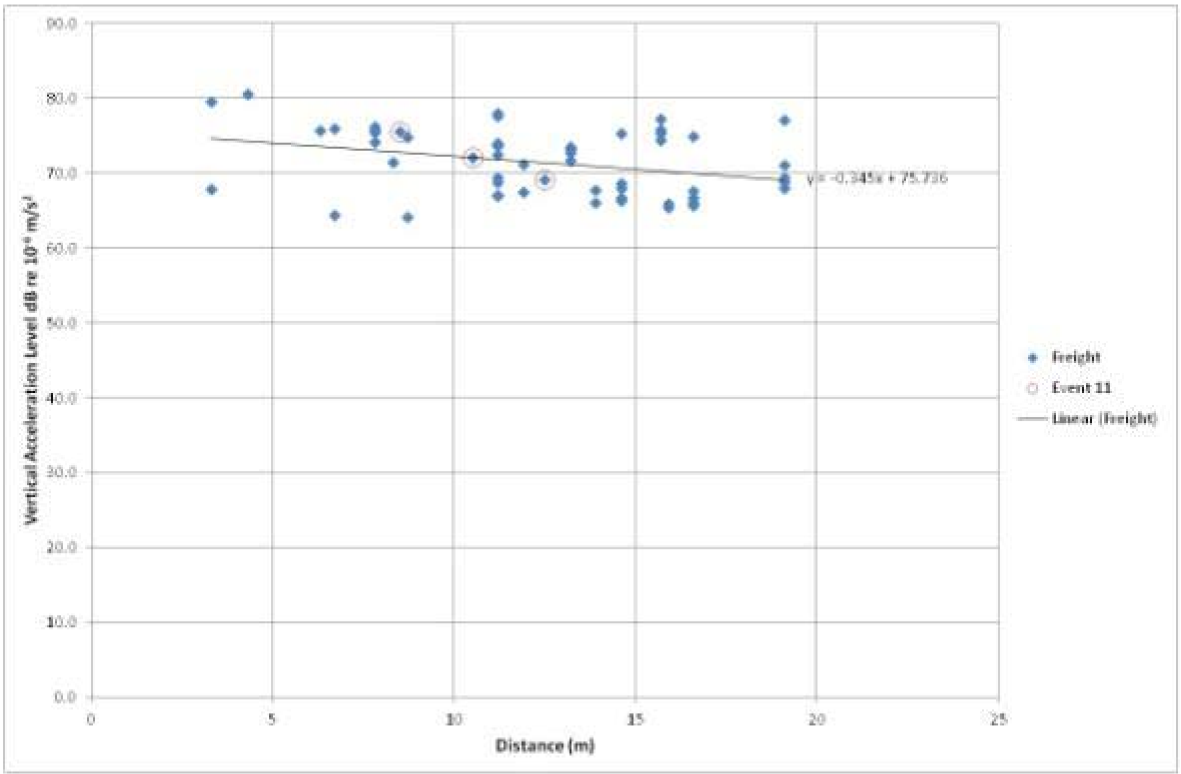


Figure 45. Freight train decay characteristics at 31.5Hz

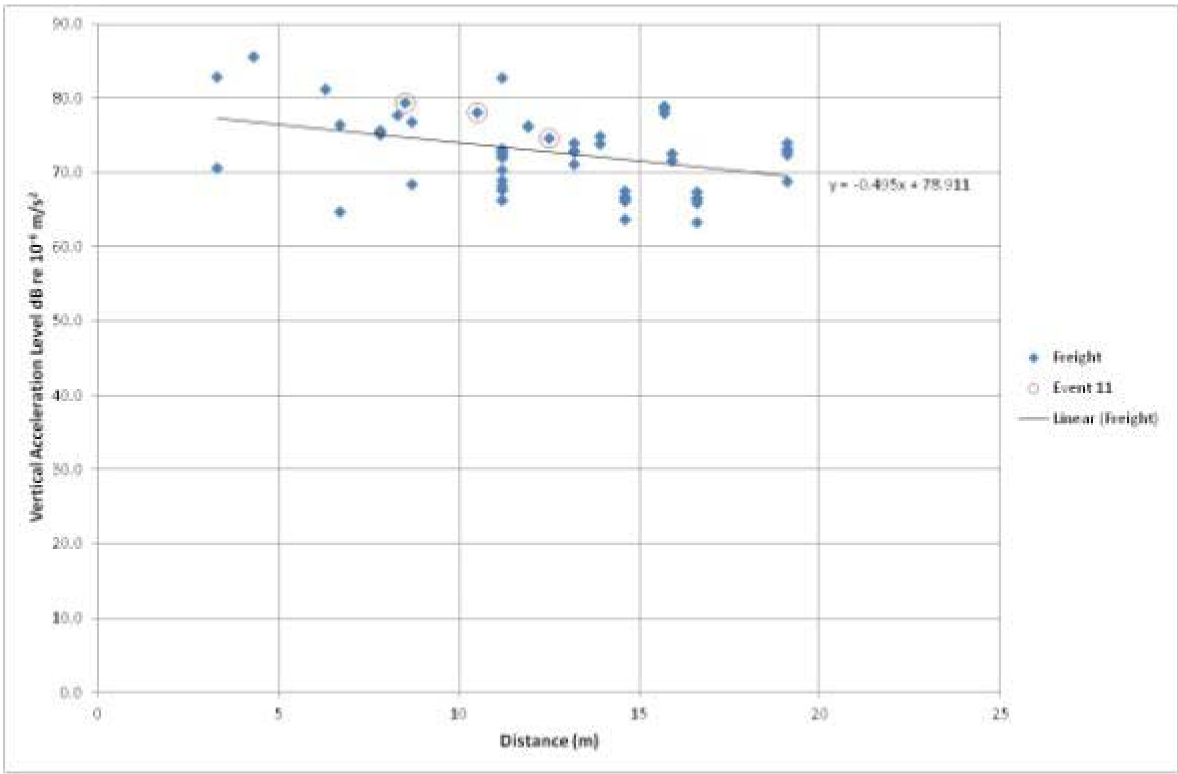


Figure 46. Freight train decay characteristics at 40Hz

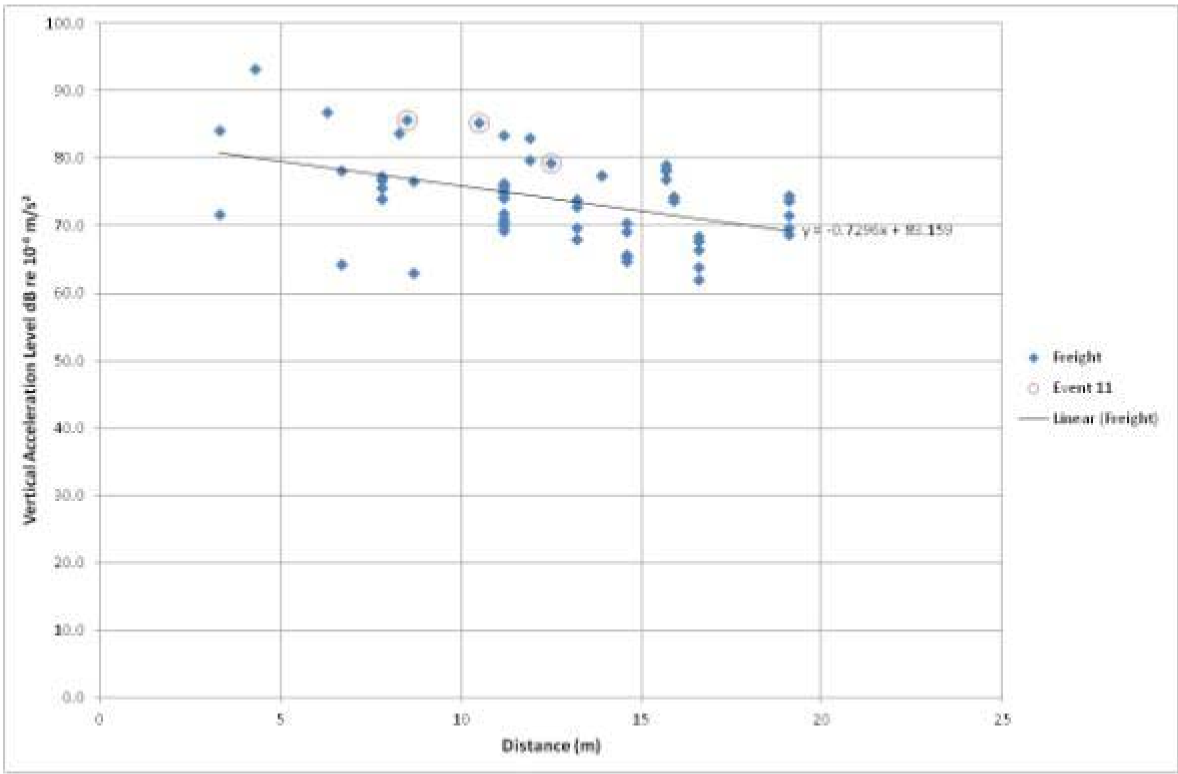


Figure 47. Freight train decay characteristics at 50Hz

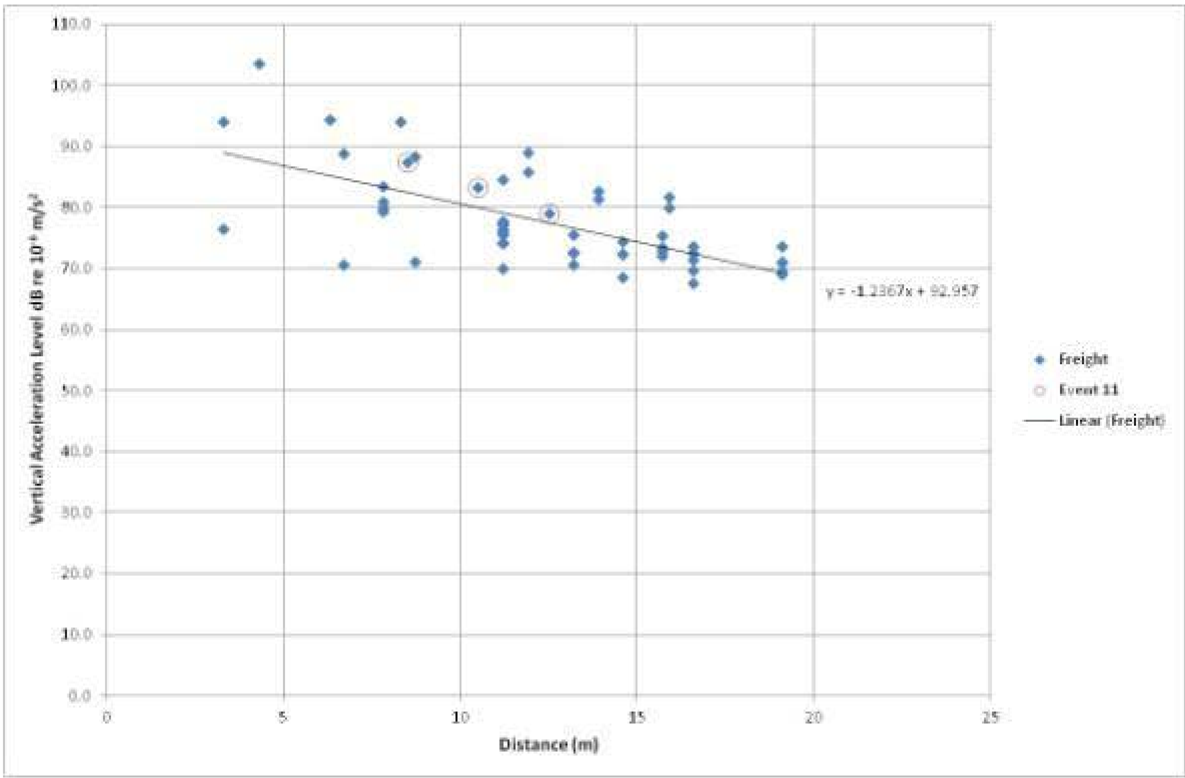


Figure 48. Freight train decay characteristics at 63Hz

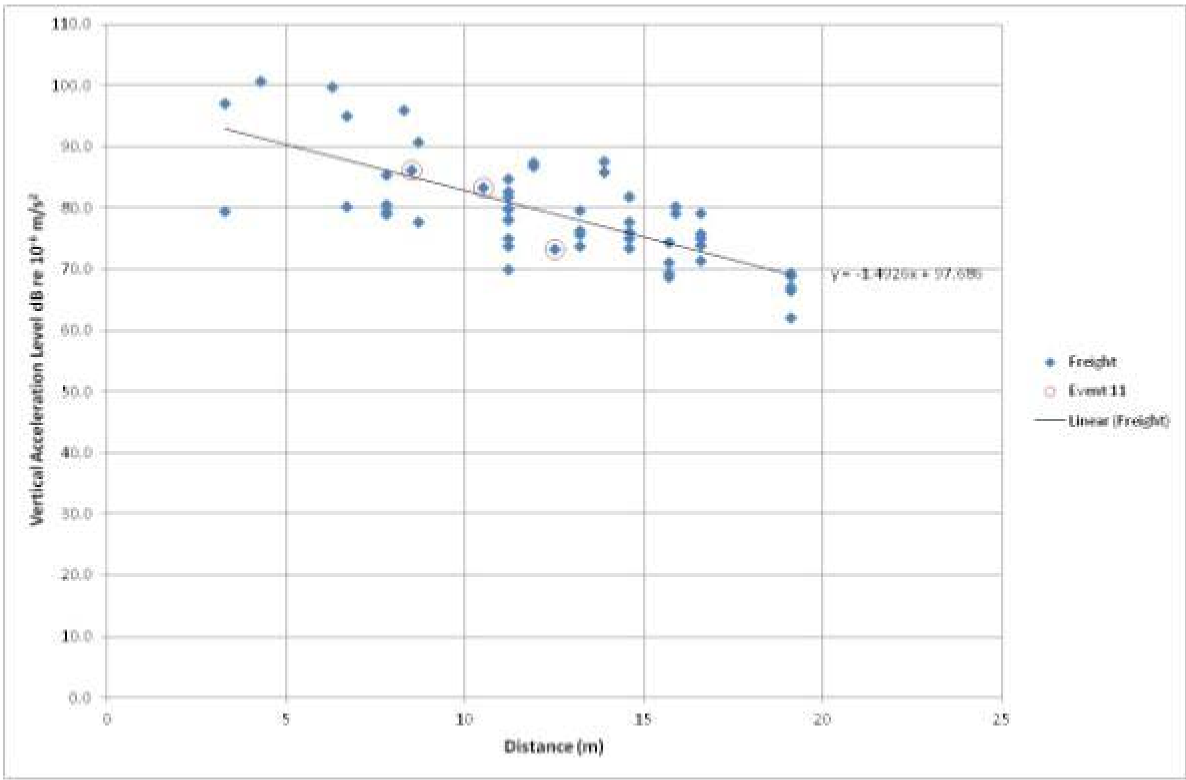


Figure 49. Freight train decay characteristics at 80Hz

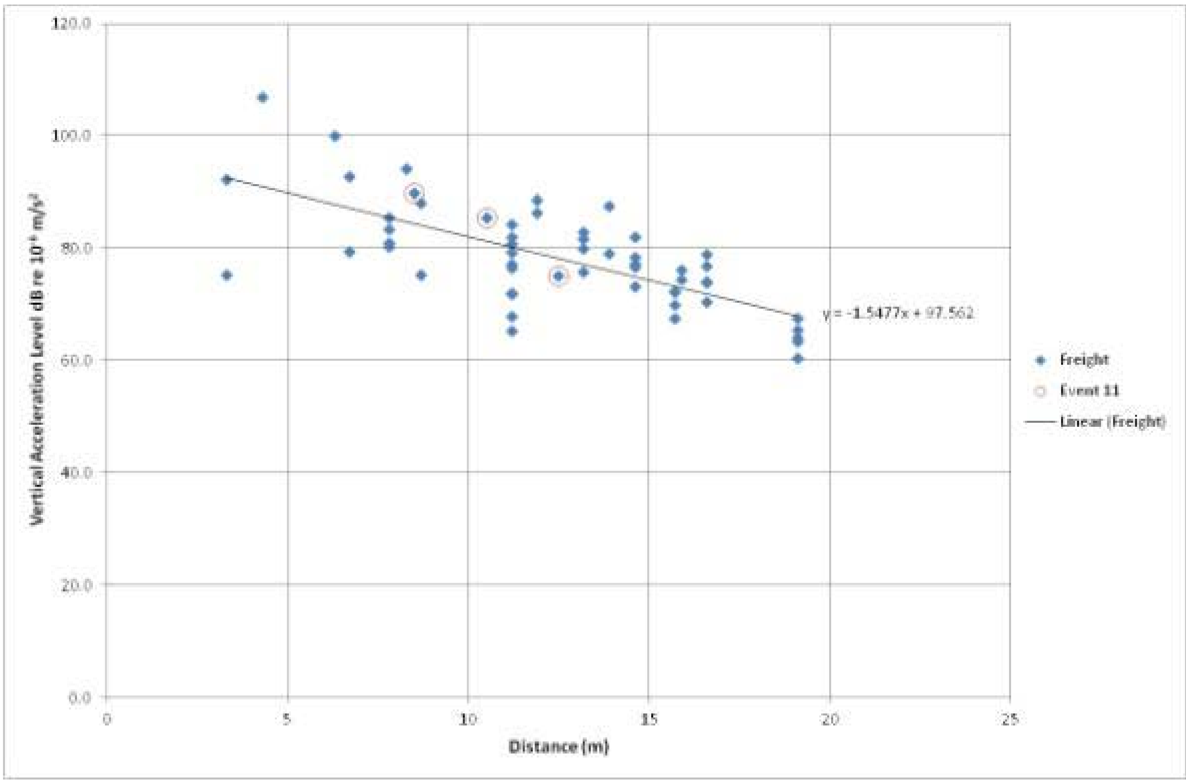


Figure 50. Freight train decay characteristics at 100Hz

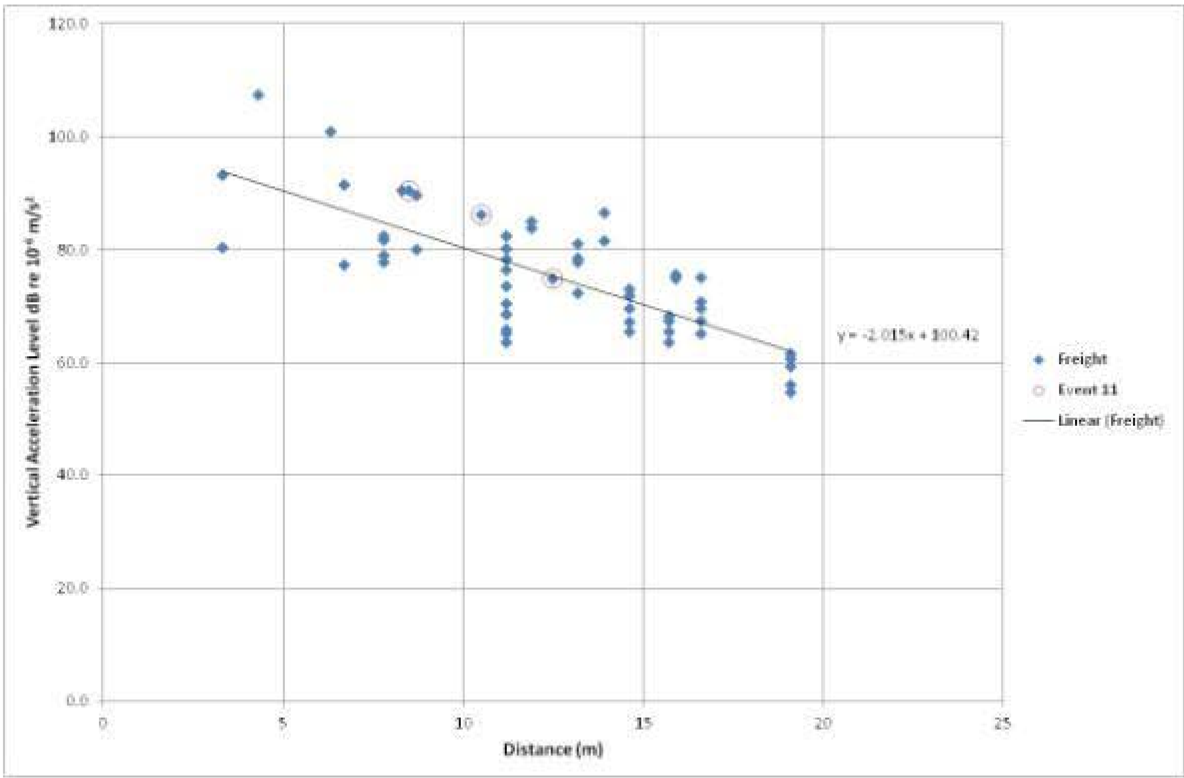


Figure 51. Freight train decay characteristics at 125Hz

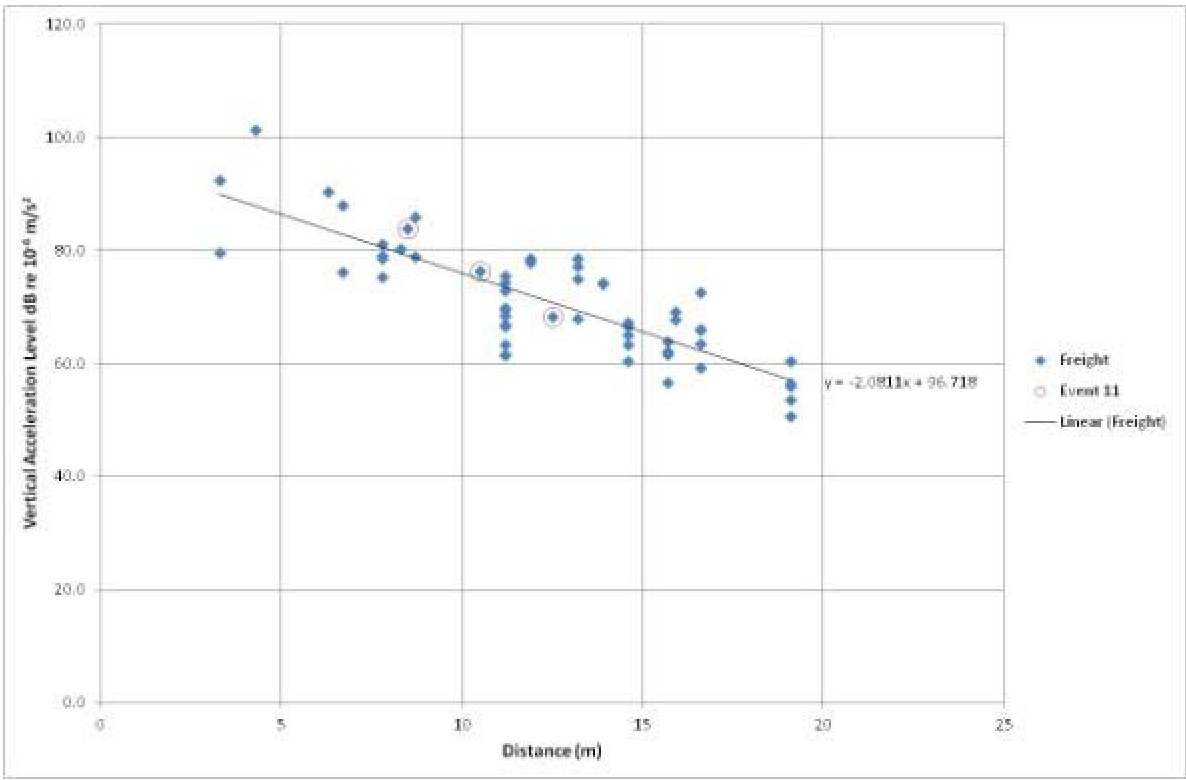
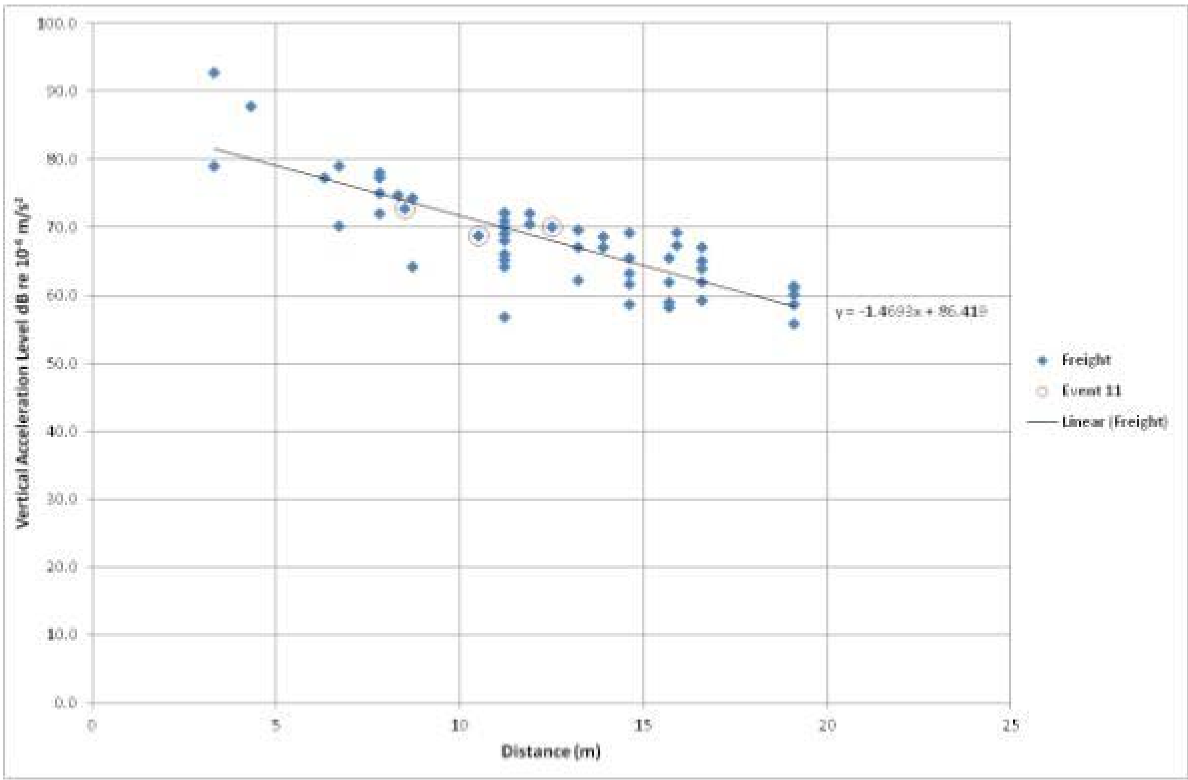


Figure 52. Freight train decay characteristics at 160Hz



H.2. Passenger Trains

Figure 53. Passenger train decay characteristics at 6.3Hz

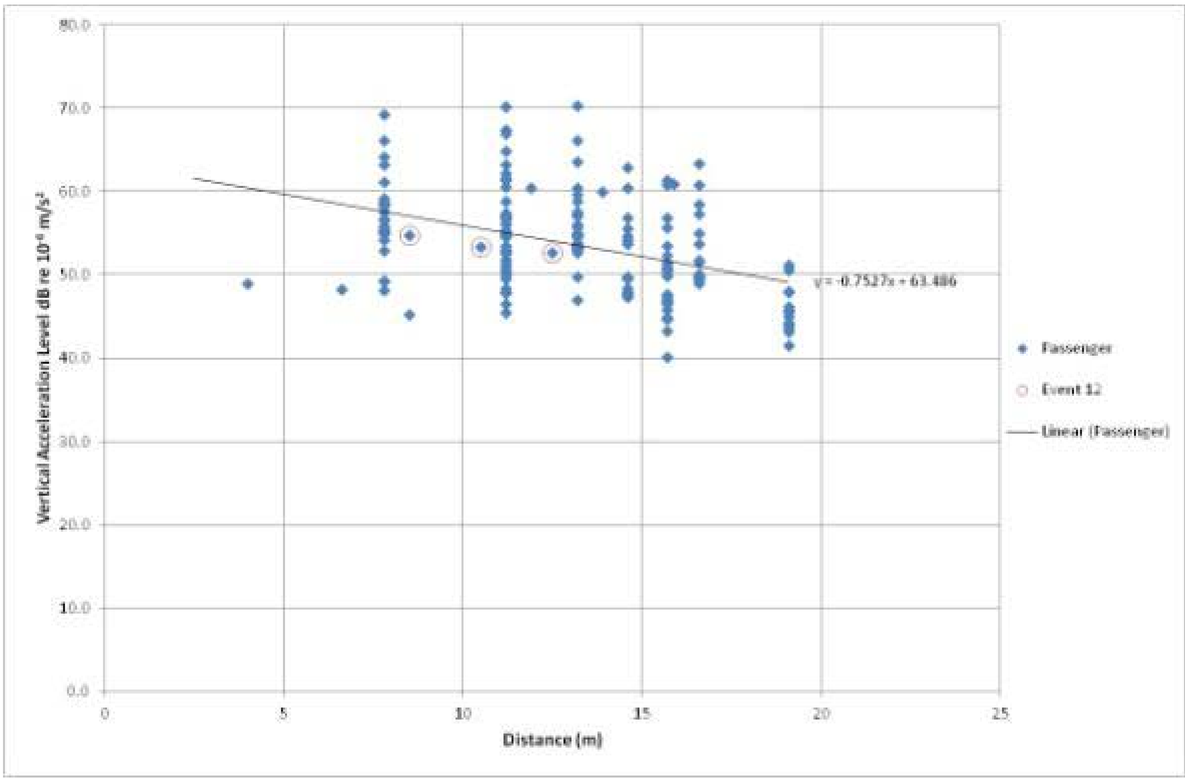


Figure 54. Passenger train decay characteristics at 8Hz

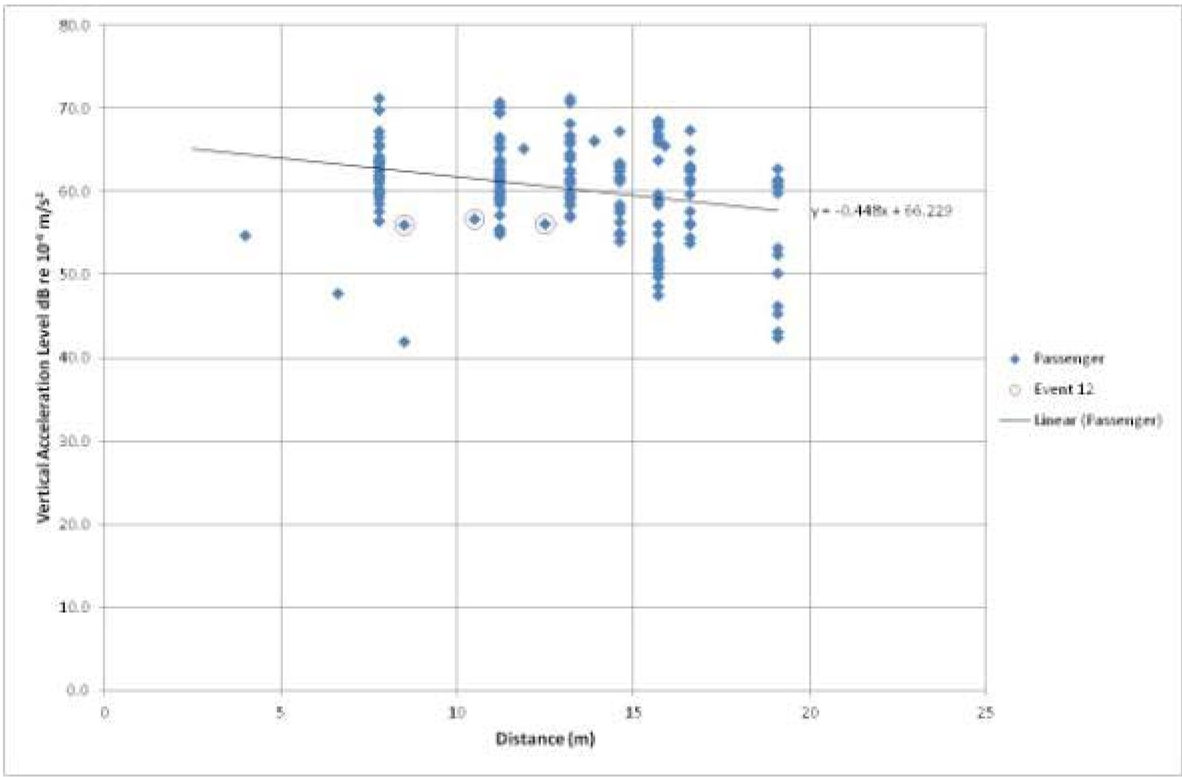


Figure 55. Passenger train decay characteristics at 10Hz

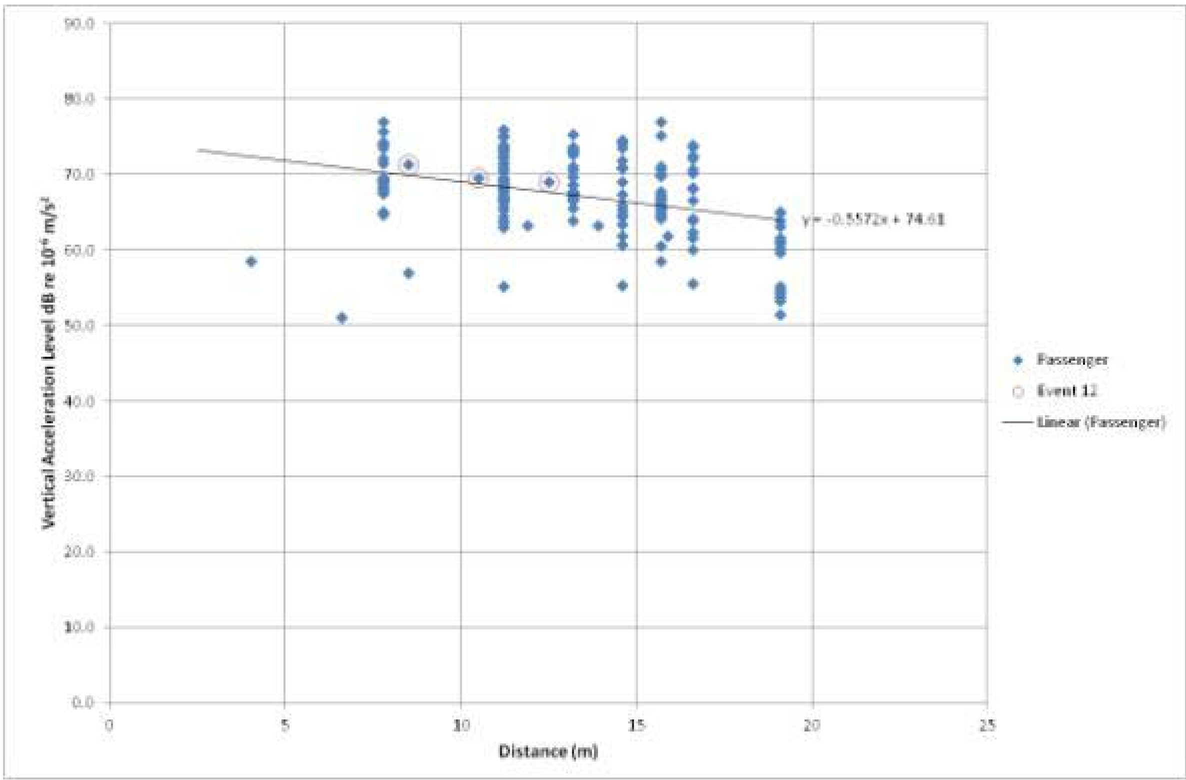


Figure 56. Passenger train decay characteristics at 12.5Hz

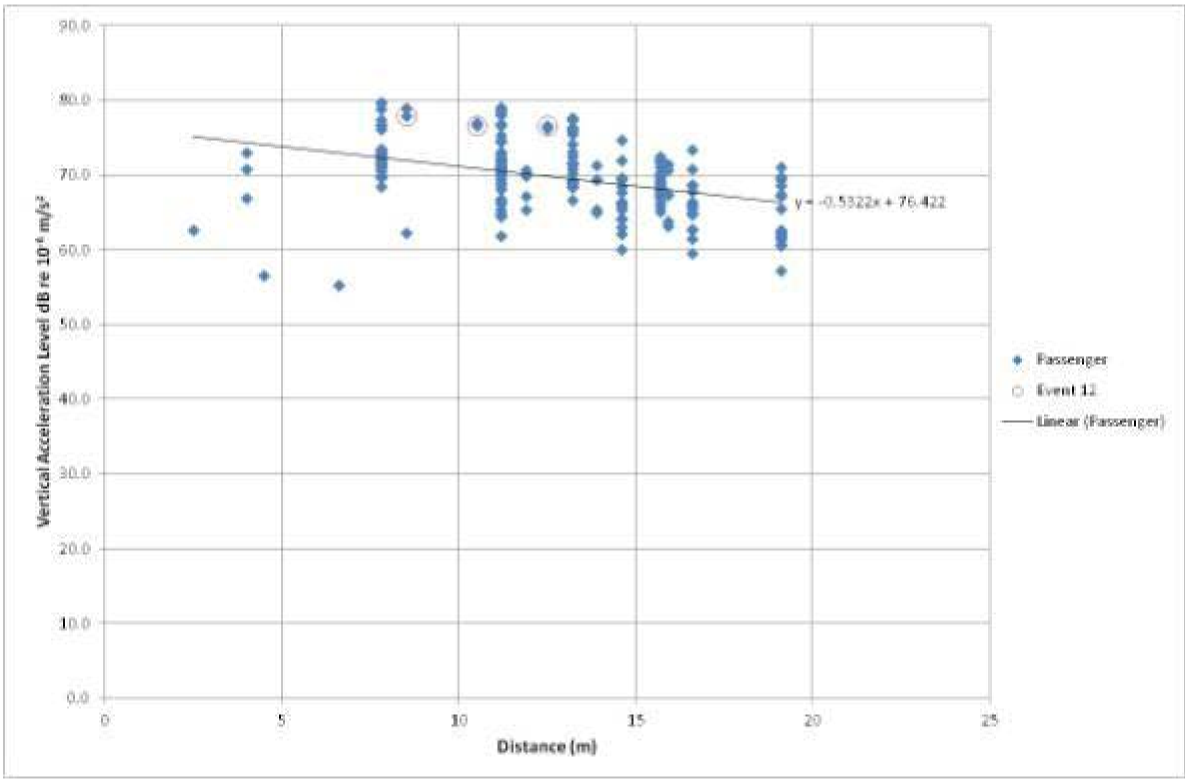


Figure 57. Passenger train decay characteristics at 16Hz

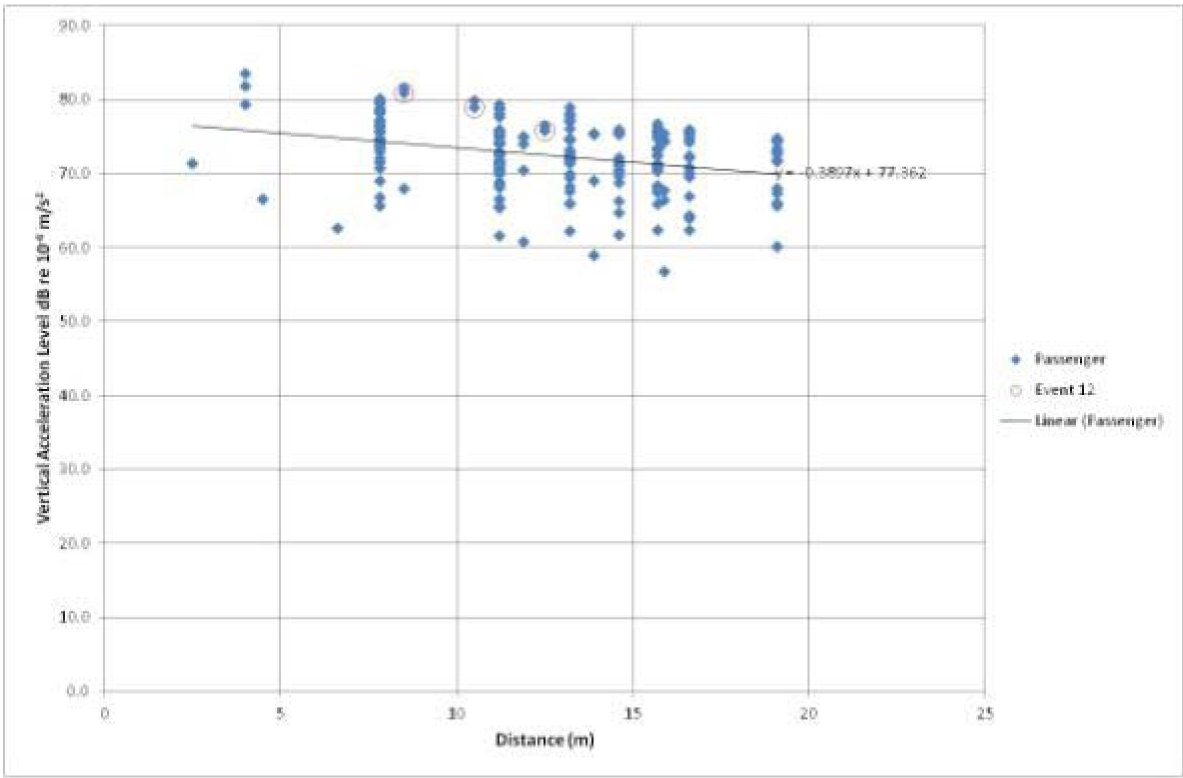


Figure 58. Passenger train decay characteristics at 20Hz

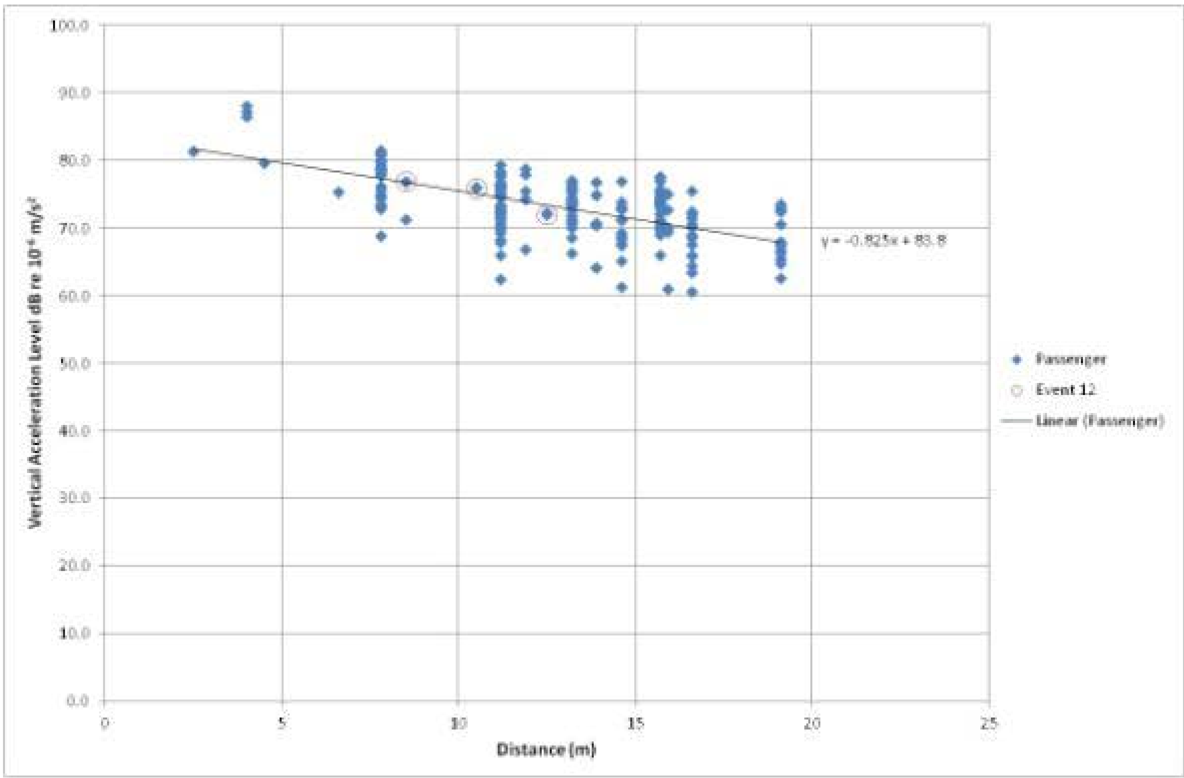


Figure 59. Passenger train decay characteristics at 25Hz

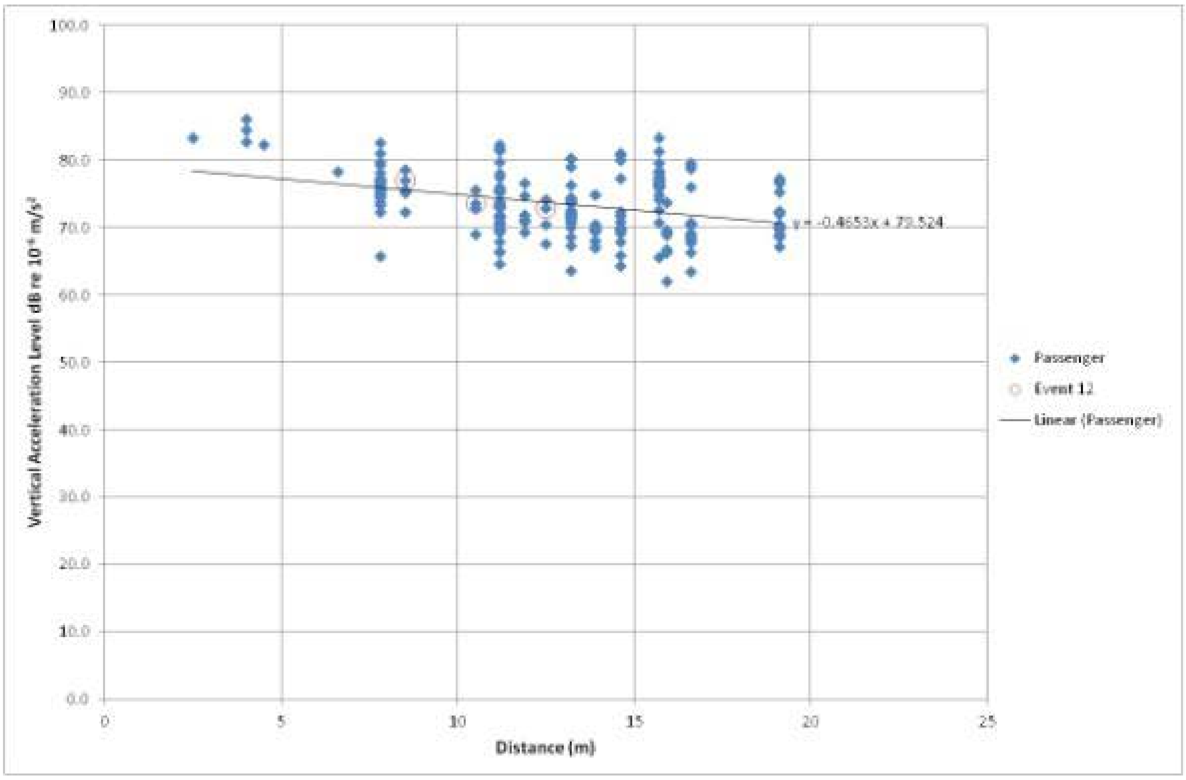


Figure 60. Passenger train decay characteristics at 31.5Hz

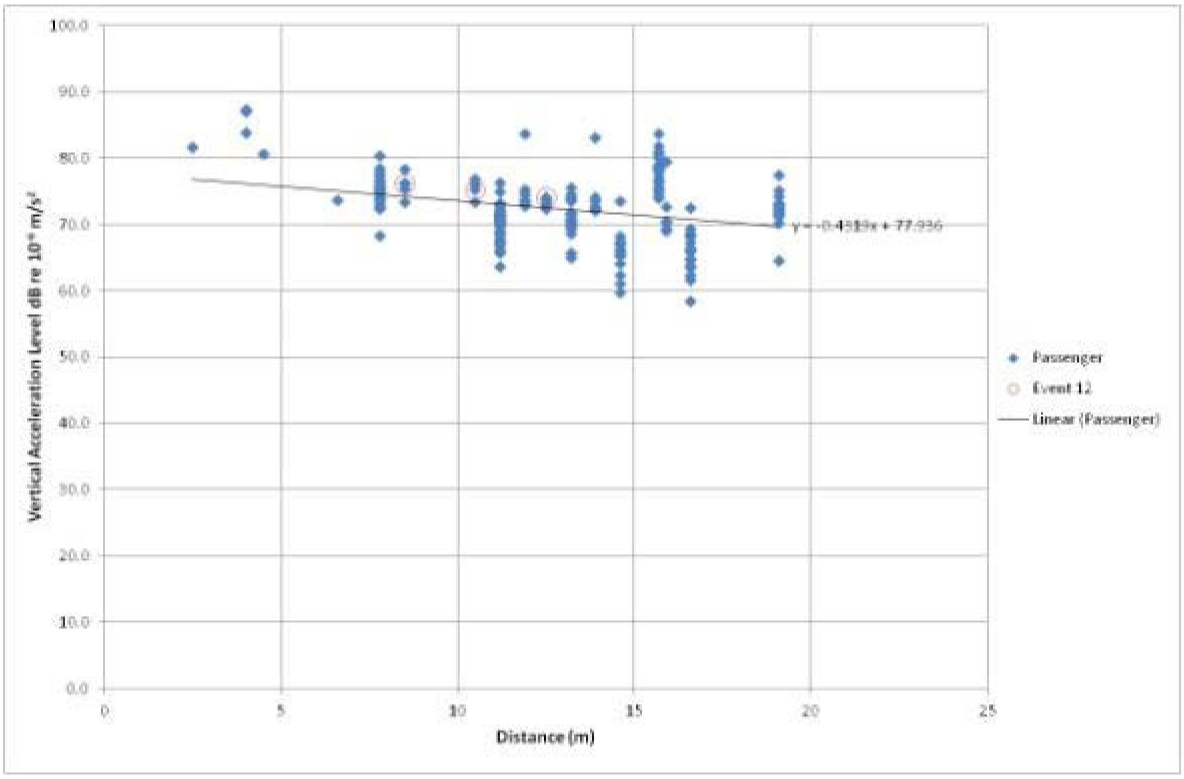


Figure 61. Passenger train decay characteristics at 40Hz

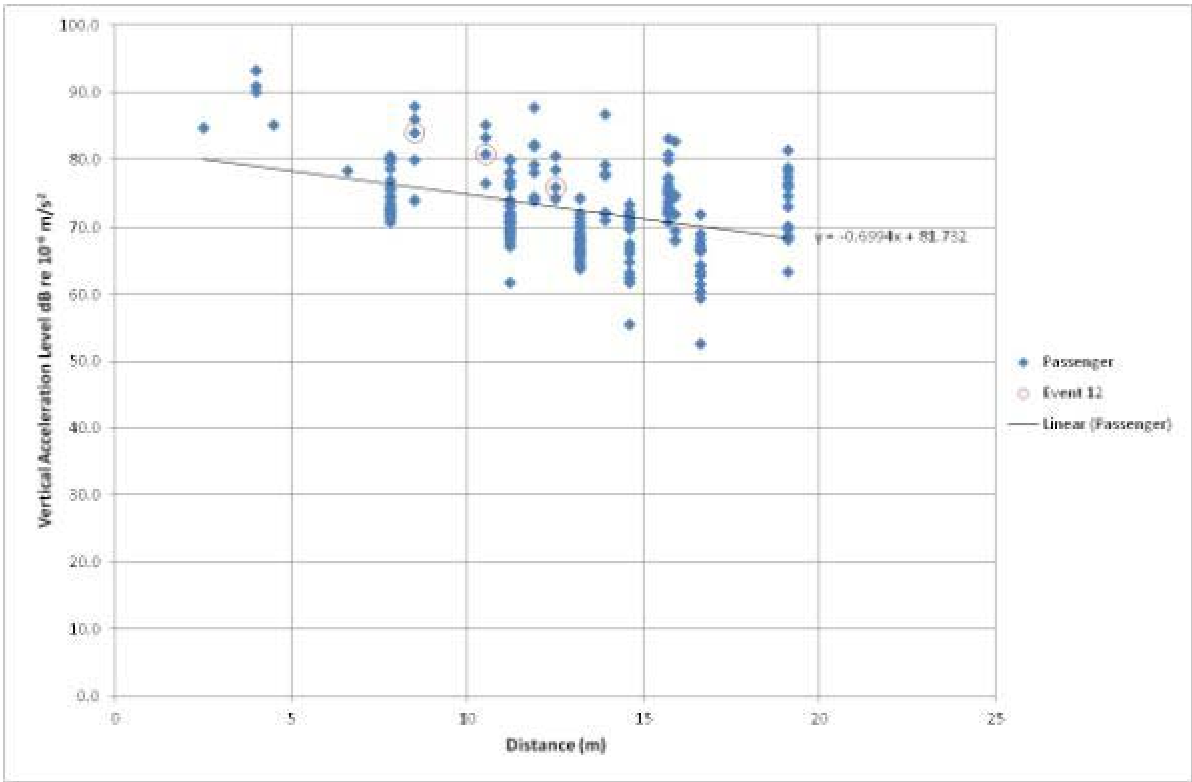


Figure 62. Passenger train decay characteristics at 50Hz

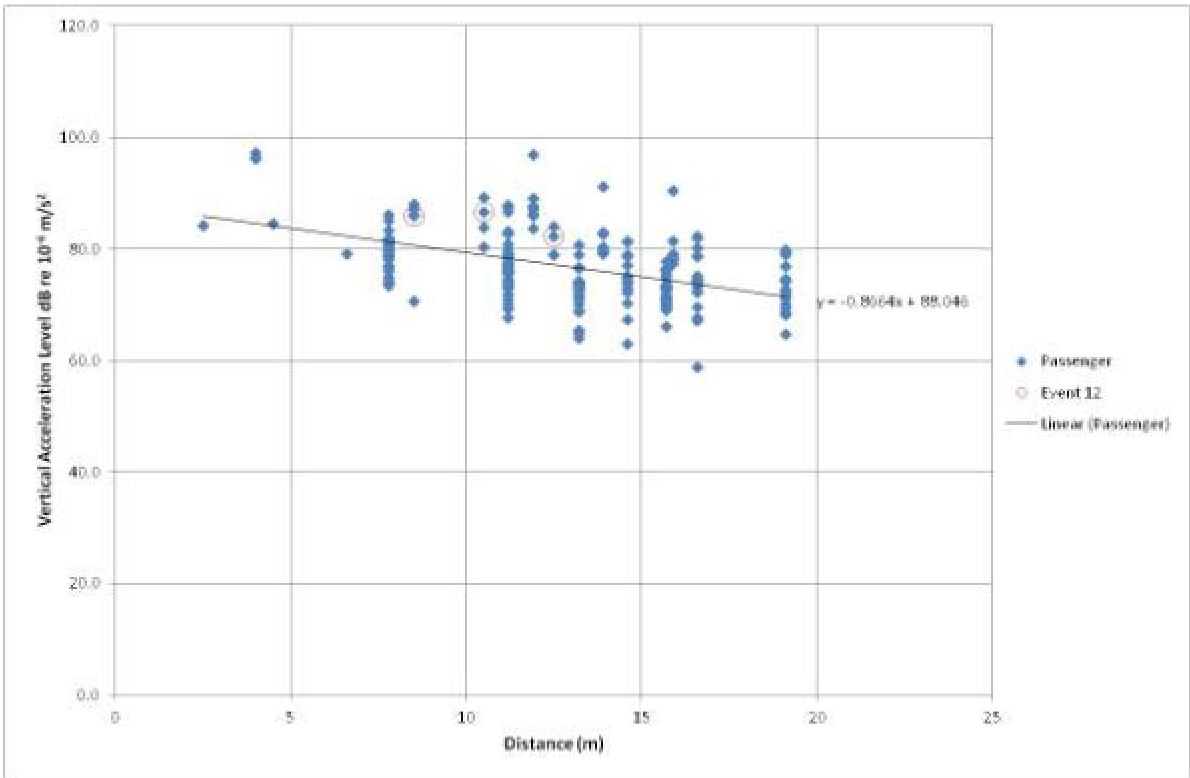


Figure 63. Passenger train decay characteristics at 63Hz

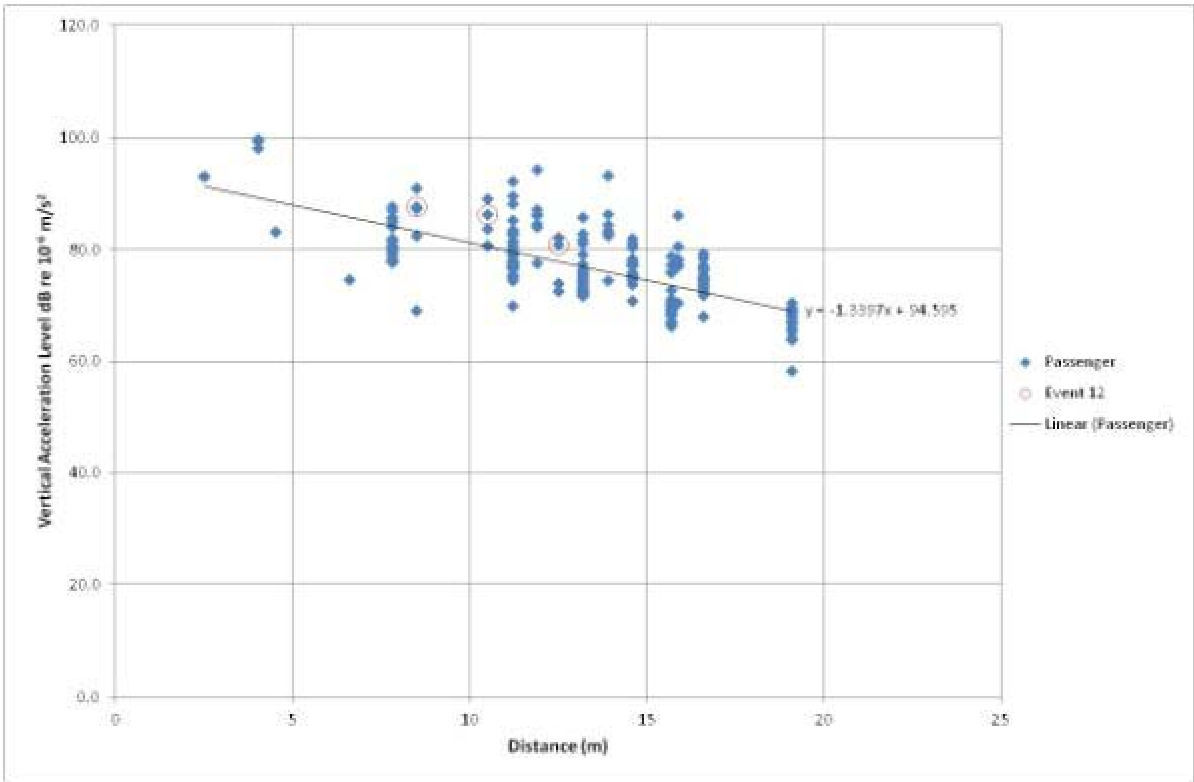


Figure 64. Passenger train decay characteristics at 80Hz

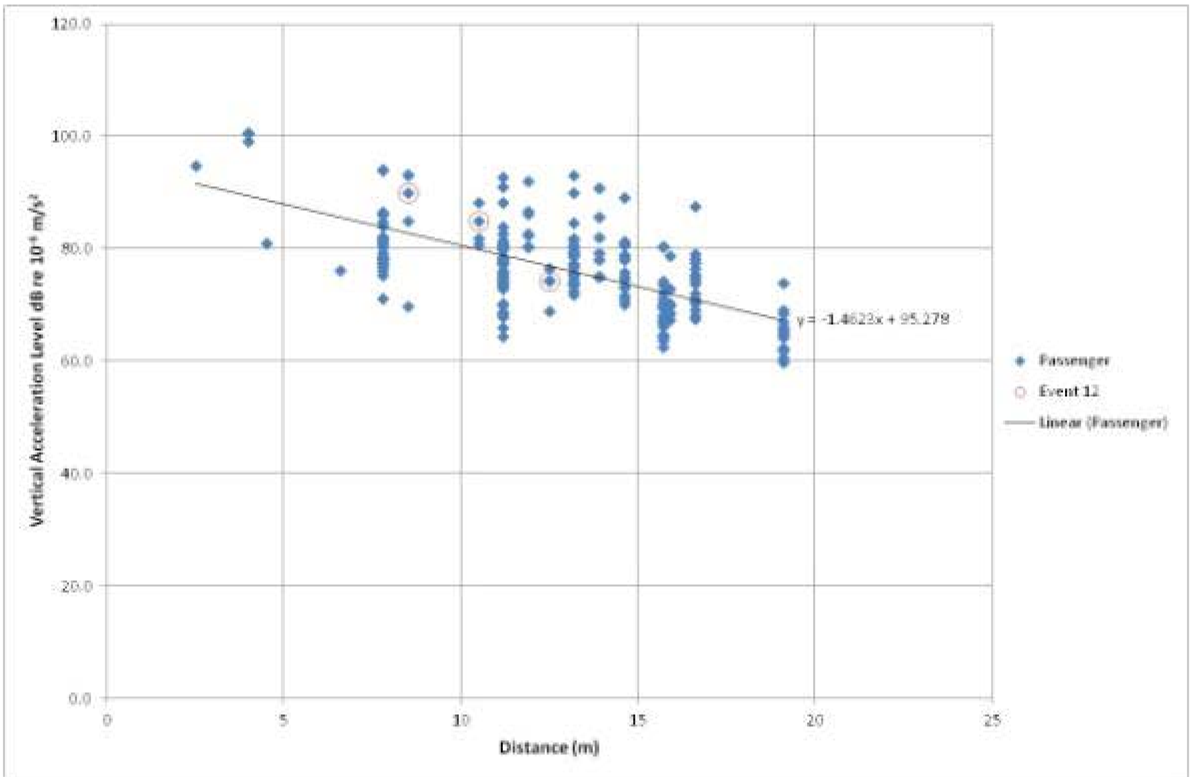


Figure 65. Passenger train decay characteristics at 100Hz

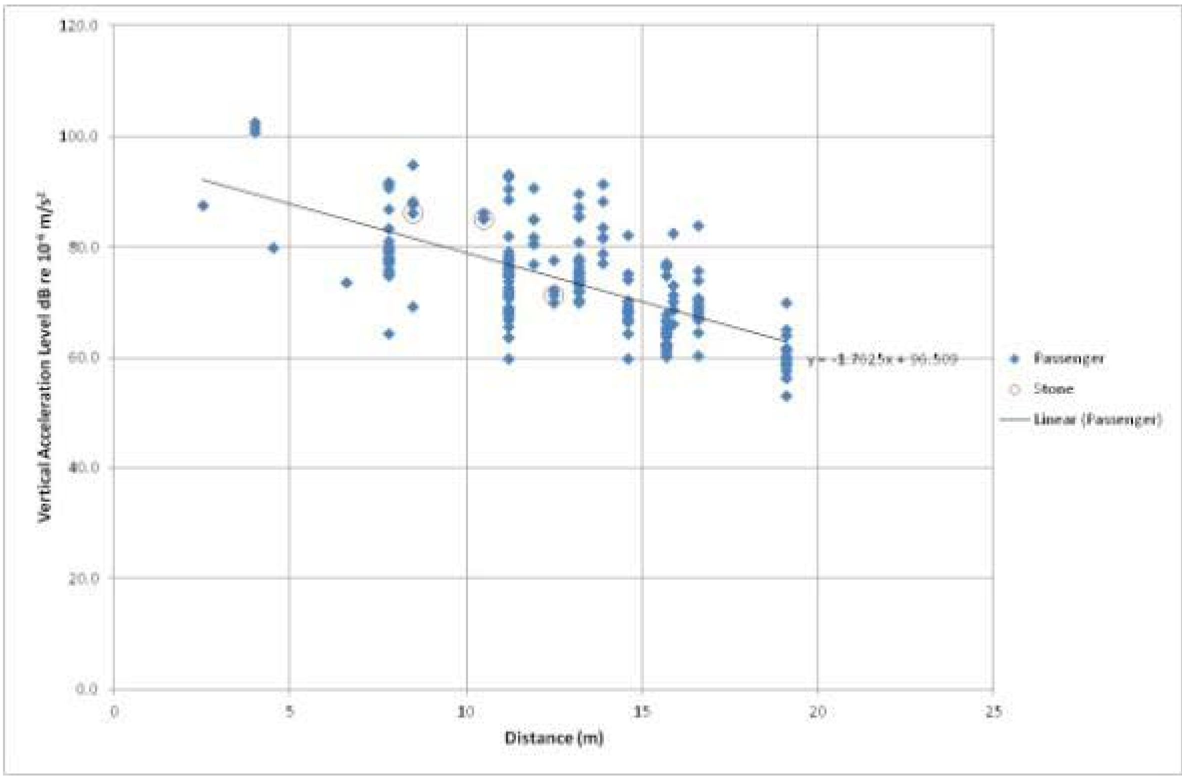


Figure 66. Passenger train decay characteristics at 125Hz

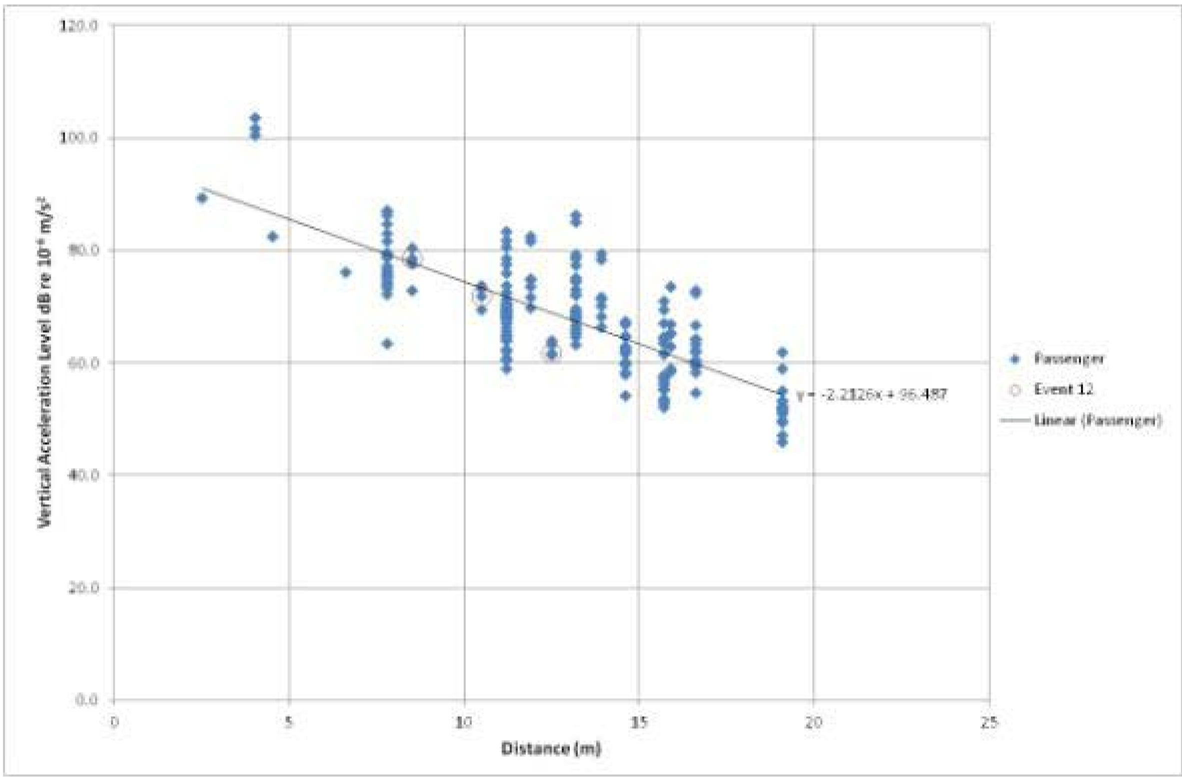
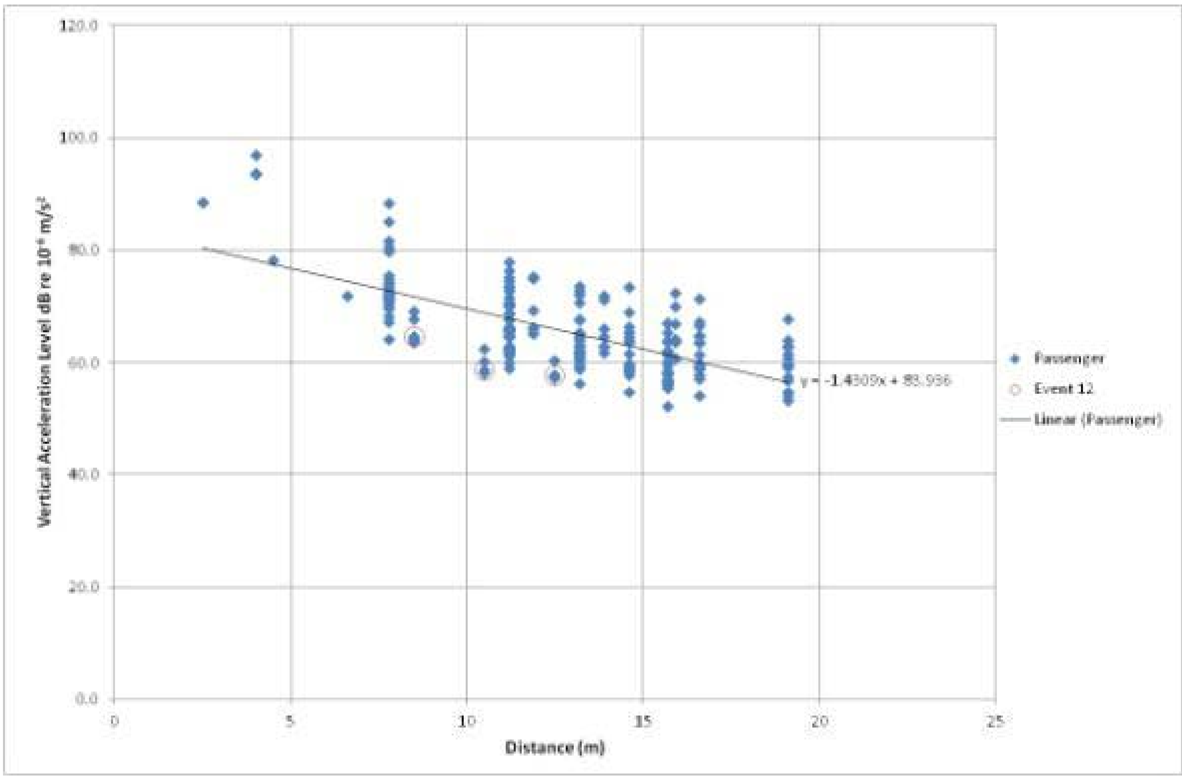


Figure 67. Passenger train decay characteristics at 160Hz



Appendix I. Speed dependence of Vibration Levels

Table 45. Application of 20Log speed relationship to r.m.s acceleration values

The main steps are explained with the aid of example calculation below;

	Event 1	Event 2	20*log (speed/ref)	Ratio
Speed, mph,	75	80	0.56dB	Speed = 1.067
Vibration level, rms acceleration, $m.s^{-2}$	0.0212	0.0226		RMS acceleration = 1.067
Reference level, $m.s^{-2}$	10^{-6}			
Vibration level, dB	86.5	87.1		

Example Calculation

Step 1 - The following simple relationship is used for estimating speed dependence on vibration levels in dB.
Change in dB vibration levels, d = 20 x log (speed/ speed ref)
This results in a 0.56dB difference between speeds of 75mph and 80mph.
Step 2 - The base r.ms. vibration levels X1 are expressed as vibration level D1 in dB using the relationship below;
D1 = 20 x log (X1 / Xo)
X1 – The base rms vibration level (0.0212 $m.s^{-2}$ in above example)
Xo – Reference value
In the example calculation, this results in 86.5 dB.
Step 3 – The vibration levels in Steps 1 and 2 are linearly added together to determine the new vibration level D2 in dB
D2 = D1 + d
This results in 87.1 dB.
Step 4 - The following relationship is used to convert new vibration level X2 in dB to r.m.s vibration level
X2 = Xo x 10^ (D2 / 20)
X2 – Predicted rms vibration level at the new speed
Xo – Reference value
The resulting new rms vibration level is 0.0226 $m.s^{-2}$

The analysis described above gives a relationship for rms vibration levels for small changes in train speeds. It is found that a speed increase of 5mph, for example from 75mph to 80mph (6.7% increase) would be expected to result in the same percentage increase in rms vibration levels.

Table 46. Deriving speed relationships for VDVs

The calculation steps are explained below;

Event No -→	**41**	**11**	**12**	**5**	**1B**	**Comment**
Parameter	Stone Train	Freight	Passenger	Freight	Passenger	
VDVz (1)	0.1074	0.046	0.028	0.040	0.03419	obtained directly from vibration signal
eVDVz (1)	0.0943	0.043	0.029	0.02458	0.03439	obtained directly from vibration signal
a(rms) (1)	0.0313	0.0146	0.0153	0.008	0.016	obtained directly from vibration signal
speed (1), mph	**28**	**60**	**75**	**38**	**35**	measured on site
VDVz / eVDVz	1.14	1.07	0.97	1.63	0.99	ratio of VDV and eVDV obtained from same signal
t (1)	21.4	19.6	3.4	23.2	5.6	calculate t(1) from eVDV and rms acceleration determined from same signal
speed (2)	**40**	**75**	**60**	**40**	**40**	enter new speeds
t (2)	15.0	15.7	4.2	22.0	4.9	calculate t(2) at the new speed (faster the train, smaller the t)
factor a(rms) for speed	1.43	1.25	0.80	1.05	1.14	use rms vibration ratios determined from 20Log relationship, described above
a(rms) (2)	0.0447	0.0183	0.0122	0.0084	0.0183	apply factor to rms acceleration (1) to obtain new value (2)
eVDV (2)	0.1232	0.0508	0.0245	0.0255	0.0380	calculate corresponding eVDV using t(2) and a(rms) (2)
VDVz (2)	0.1403	0.0544	0.0237	0.0416	0.0378	apply specific VDVz/eVDVz ratio derived from same signal to determine new VDV(2)
VDVz (2) / VDVz (1)	**1.31**	**1.18**	**0.85**	**1.04**	**1.11**	

Appendix J. Detailed Assessments

J.1. Assessment of vibration decay, dB, with 1/3 octave band frequencies

Table 47. 53 London Road - Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	6.84	40	20	84.1	0.0326	1.11	2.1	**0.076**	3E-05
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	6.84	40	1	85.1	0.0556	1.04	1.0	**0.058**	1E-05
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.08

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	54	54	69	75	77	73	70	68	76	74	75	74	69	58	37
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	1	1	1	47	70	75	73	67	65	69	71	69	70	72	77	78	74	75	74	63	42
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 48. 53 London Road – Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	6.84	100	140	84.1	0.0326	1.24	3.4	**0.139**	0.0004
2	P	10.28	100	79	81.4	0.0241	1.24	3.0	**0.089**	6E-05
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	6.84	75	9	85.1	0.0556	1.18	1.7	**0.114**	0.0002
2	F	10.28	75	9	81.9	0.0384	1.18	1.7	**0.078**	4E-05
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.16

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	54	54	69	75	77	73	70	68	76	74	75	74	69	58	37
Track 2 Passenger	0	0	0	0	0	0	51	52	67	73	75	70	69	66	74	71	70	69	63	50	32
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	1	1	1	47	70	75	73	67	65	69	71	69	70	72	77	78	74	75	74	63	42
Track 2 Freight	-1	-1	-1	45	66	71	71	66	63	68	70	68	69	70	74	74	69	70	67	56	37
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 49. 53 London Road - Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	6.84	40	2	84.1	0.0326	1.11	1.2	**0.043**	3E-06
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	6.84	40	1	85.1	0.0556	1.04	1.0	**0.058**	1E-05
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.06

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	54	54	69	75	77	73	70	68	76	74	75	74	69	58	37
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	1	1	1	47	70	75	73	67	65	69	71	69	70	72	77	78	74	75	74	63	42
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 50. 53 London Road – Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	6.84	100	21	84.1	0.0326	1.24	2.1	**0.086**	6E-05
2	P	10.28	100	14	81.4	0.0241	1.24	1.9	**0.058**	1E-05
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	6.84	75	4	85.1	0.0556	1.18	1.4	**0.093**	7E-05
2	F	10.28	75	4	81.9	0.0384	1.18	1.4	**0.064**	2E-05
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.11

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	54	54	69	75	77	73	70	68	76	74	75	74	69	58	37
Track 2 Passenger	0	0	0	0	0	0	51	52	67	73	75	70	69	66	74	71	70	69	63	50	32
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	1	1	1	47	70	75	73	67	65	69	71	69	70	72	77	78	74	75	74	63	42
Track 2 Freight	-1	-1	-1	45	66	71	71	66	63	68	70	68	69	70	74	74	69	70	67	56	37
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 51. Islip Crossing - Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	2.87	40	20	87.6	0.0491	1.11	2.1	**0.115**	0.0002
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	2.87	40	3	89.7	0.0944	1.04	1.3	**0.129**	0.0003
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.15

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	57	56	71	77	78	76	72	70	79	78	80	80	76	66	43
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	3	3	3	49	75	80	74	68	67	70	72	70	71	74	80	83	80	82	82	72	48
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 52. Islip Crossing – Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	3.51	100	79	87.0	0.0457	1.24	3.0	**0.169**	0.0008
2	P	6.74	100	79	84.1	0.0329	1.24	3.0	**0.122**	0.0002
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	3.51	75	9	88.9	0.0860	1.18	1.7	**0.176**	0.001
2	F	6.74	75	9	85.2	0.0562	1.18	1.7	**0.115**	0.0002
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.22

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	56	55	71	77	78	75	72	69	78	77	79	79	74	65	42
Track 2 Passenger	0	0	0	0	0	0	54	54	69	75	77	73	70	68	76	74	75	74	69	58	38
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	2	2	2	48	74	79	74	68	67	70	72	70	71	74	79	82	79	81	80	70	47
Track 2 Freight	1	1	1	47	70	75	73	67	65	69	71	69	70	72	77	78	74	76	74	64	43
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 53. Islip Crossing - Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	2.87	40	2	87.6	0.0491	1.11	1.2	**0.065**	2E-05
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	2.87	40	1	89.7	0.0944	1.04	1.0	**0.098**	9E-05
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.10

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	57	56	71	77	78	76	72	70	79	78	80	80	76	66	43
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	3	3	3	49	75	80	74	68	67	70	72	70	71	74	80	83	80	82	82	72	48
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 54. Islip Crossing – Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	3.51	100	14	87.0	0.0457	1.24	1.9	**0.110**	0.0001
2	P	6.74	100	14	84.1	0.0329	1.24	1.9	**0.079**	4E-05
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	3.51	75	4	88.9	0.0860	1.18	1.4	**0.144**	0.0004
2	F	6.74	75	4	85.2	0.0562	1.18	1.4	**0.094**	8E-05
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.16

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	56	55	71	77	78	75	72	69	78	77	79	79	74	65	42
Track 2 Passenger	0	0	0	0	0	0	54	54	69	75	77	73	70	68	76	74	75	74	69	58	38
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	2	2	2	48	74	79	74	68	67	70	72	70	71	74	79	82	79	81	80	70	47
Track 2 Freight	1	1	1	47	70	75	73	67	65	69	71	69	70	72	77	78	74	76	74	64	43
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 55. Oddington Crossing – Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	5.09	40	20	85.5	0.0387	1.11	2.1	**0.091**	7E-05
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	5.09	40	3	87.0	0.0692	1.04	1.3	**0.095**	8E-05
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.11

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	55	55	70	76	77	74	71	69	77	76	77	77	72	62	40
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	2	2	2	48	72	77	73	68	66	69	71	70	70	73	78	80	77	78	77	67	45
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 56. Oddington Crossing – Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	5.09	100	79	85.5	0.0387	1.24	3.0	**0.143**	0.0004
2	P	8.62	100	79	82.7	0.0277	1.24	3.0	**0.102**	0.0001
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	5.09	75	9	87.0	0.0692	1.18	1.7	**0.142**	0.0004
2	F	8.62	75	9	83.4	0.0454	1.18	1.7	**0.093**	7E-05
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.18

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	55	55	70	76	77	74	71	69	77	76	77	77	72	62	40
Track 2 Passenger	0	0	0	0	0	0	52	53	68	74	76	71	70	67	75	73	73	72	65	54	35
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	2	2	2	48	72	77	73	68	66	69	71	70	70	73	78	80	77	78	77	67	45
Track 2 Freight	0	0	0	46	68	73	72	67	64	68	71	69	69	71	76	76	71	73	70	60	40
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 57. Oddington Crossing – Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	5.09	40	2	85.5	0.0387	1.11	1.2	**0.051**	7E-06
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	5.09	40	1	87.0	0.0692	1.04	1.0	**0.072**	3E-05
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.08

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	55	55	70	76	77	74	71	69	77	76	77	77	72	62	40
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	2	2	2	48	72	77	73	68	66	69	71	70	70	73	78	80	77	78	77	67	45
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 58. Oddington Crossing – Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	5.09	100	14	85.5	0.0387	1.24	1.9	**0.093**	7E-05
2	P	8.62	100	14	82.7	0.0277	1.24	1.9	**0.066**	2E-05
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	5.09	75	4	87.0	0.0692	1.18	1.4	**0.116**	0.0002
2	F	8.62	75	4	83.4	0.0454	1.18	1.4	**0.076**	3E-05
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.13

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	55	55	70	76	77	74	71	69	77	76	77	77	72	62	40
Track 2 Passenger	0	0	0	0	0	0	52	53	68	74	76	71	70	67	75	73	73	72	65	54	35
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	2	2	2	48	72	77	73	68	66	69	71	70	70	73	78	80	77	78	77	67	45
Track 2 Freight	0	0	0	46	68	73	72	67	64	68	71	69	69	71	76	76	71	73	70	60	40
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 59. Quadrangle – Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	8.97	40	20	82.4	0.0269	1.11	2.1	**0.063**	2E-05
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	8.97	40	4	83.0	0.0438	1.04	1.4	**0.064**	2E-05
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	8.97	40	1	85.3	0.0631	1.11	1.0	**0.070**	2E-05
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.09

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	52	53	68	74	76	71	69	67	75	72	72	71	65	53	34
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	0	0	0	46	68	73	72	67	64	68	71	68	69	71	75	76	71	72	69	59	39
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	36	44	35	42	67	72	62	53	55	58	70	78	78	79	79	70	67	66	64	63	61
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 60. Quadrangle – Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	7.49	70	79	83.5	0.0307	0.95	3.0	**0.087**	6E-05
2	P	10.89	70	79	81.0	0.0229	0.95	3.0	**0.065**	2E-05
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	7.49	70	8	84.5	0.0515	1.12	1.7	**0.097**	9E-05
2	F	10.89	70	8	81.4	0.0362	1.12	1.7	**0.068**	2E-05
1	S	7.49	60	1	86.2	0.0701	1.77	1.0	**0.124**	0.0002
2	S	10.89	60	1	84.2	0.0557	1.77	1.0	**0.099**	9E-05
										0.15

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	53	54	69	75	76	72	70	68	76	74	74	73	67	56	36
Track 2 Passenger	0	0	0	0	0	0	51	52	67	73	75	69	68	66	73	71	70	68	61	49	32
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	0	0	0	46	69	74	72	67	65	69	71	69	70	72	76	77	73	74	72	62	41
Track 2 Freight	-1	-1	-1	45	66	71	71	66	63	68	70	68	68	70	74	73	68	69	66	55	36
Track 1 Stone Train	37	45	36	43	69	74	62	53	55	58	70	78	78	80	80	71	69	68	67	66	63
Track 2 Stone Train	35	43	34	41	65	70	61	52	54	57	69	77	77	78	77	67	64	63	60	59	58

Table 61. Quadrangle – Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	8.97	40	2	82.4	0.0269	1.11	1.2	**0.035**	2E-06
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	8.97	40	1	83.0	0.0438	1.04	1.0	**0.046**	4E-06
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.05

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	52	53	68	74	76	71	69	67	75	72	72	71	65	53	34
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	0	0	0	46	68	73	72	67	64	68	71	68	69	71	75	76	71	72	69	59	39
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 62. Quadrangle – Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	7.49	70	14	83.5	0.0307	0.95	1.9	**0.056**	1E-05
2	P	10.89	70	14	81.0	0.0229	0.95	1.9	**0.042**	3E-06
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	7.49	70	4	84.5	0.0515	1.12	1.4	**0.082**	4E-05
2	F	10.89	70	4	81.4	0.0362	1.12	1.4	**0.057**	1E-05
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.09

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	53	54	69	75	76	72	70	68	76	74	74	73	67	56	36
Track 2 Passenger	0	0	0	0	0	0	51	52	67	73	75	69	68	66	73	71	70	68	61	49	32
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	0	0	0	46	69	74	72	67	65	69	71	69	70	72	76	77	73	74	72	62	41
Track 2 Freight	-1	-1	-1	45	66	71	71	66	63	68	70	68	68	70	74	73	68	69	66	55	36
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 63. 3 Bladon Close – Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	14.34	40	20	78.8	0.0177	1.11	2.1	**0.042**	3E-06
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	14.34	40	4	78.9	0.0272	1.04	1.4	**0.040**	3E-06
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	14.34	40	1	82.4	0.0454	1.31	1.0	**0.059**	1E-05
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.07

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	48	51	65	71	74	66	67	65	71	68	65	63	55	41	27
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-3	-3	-3	43	62	67	70	65	61	66	70	67	67	68	71	69	63	64	59	48	31
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	34	42	33	39	61	67	60	52	52	56	69	76	76	77	75	63	59	58	53	52	53
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 64. 3 Bladon Close – Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	12.9	70	79	79.7	0.0197	0.95	3.0	**0.056**	1E-05
2	P	13.6	60	79	79.2	0.0187	0.85	3.0	**0.047**	5E-06
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	12.9	70	8	79.9	0.0304	1.12	1.7	**0.057**	1E-05
2	F	13.6	60	8	79.4	0.0288	1.00	1.7	**0.048**	5E-06
1	S	12.9	60	1	83.1	0.0493	1.77	1.0	**0.087**	6E-05
2	S	13.6	60	1	82.8	0.0473	1.77	1.0	**0.084**	5E-05
										0.11

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	49	51	66	72	74	68	68	65	72	69	67	65	58	44	29
Track 2 Passenger	0	0	0	0	0	0	48	51	65	71	74	67	67	65	71	68	66	64	57	43	28
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-2	-2	-2	44	63	68	70	66	62	67	70	67	68	69	72	71	65	66	62	51	34
Track 2 Freight	-2	-2	-2	44	62	68	70	66	62	67	70	67	67	69	72	70	64	65	60	49	33
Track 1 Stone Train	34	43	33	40	63	68	60	52	53	57	69	77	76	77	76	65	61	60	56	55	55
Track 2 Stone Train	34	42	33	40	62	67	60	52	52	56	69	77	76	77	75	64	60	59	55	53	54

Table 65. 3 Bladon Close – Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	14.34	40	2	78.8	0.0177	1.11	1.2	**0.023**	3E-07
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	14.34	40	1	78.9	0.0272	1.04	1.0	**0.028**	6E-07
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.03

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	48	51	65	71	74	66	67	65	71	68	65	63	55	41	27
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-3	-3	-3	43	62	67	70	65	61	66	70	67	67	68	71	69	63	64	59	48	31
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 66. 3 Bladon Close – Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	12.9	70	14	79.7	0.0197	0.95	1.9	**0.036**	2E-06
2	P	13.6	60	14	79.2	0.0187	0.85	1.9	**0.031**	9E-07
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	12.9	70	4	79.9	0.0304	1.12	1.4	**0.048**	5E-06
2	F	13.6	60	4	79.4	0.0288	1.00	1.4	**0.041**	3E-06
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.06

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	49	51	66	72	74	68	68	65	72	69	67	65	58	44	29
Track 2 Passenger	0	0	0	0	0	0	48	51	65	71	74	67	67	65	71	68	66	64	57	43	28
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-2	-2	-2	44	63	68	70	66	62	67	70	67	68	69	72	71	65	66	62	51	34
Track 2 Freight	-2	-2	-2	44	62	68	70	66	62	67	70	67	67	69	72	70	64	65	60	49	33
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 67. 12 Whimbrel Close - Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	12.24	40	20	80.1	0.0207	1.11	2.1	**0.048**	6E-06
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	12.24	40	1	80.4	0.0321	1.04	1.0	**0.033**	1E-06
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.05

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	49	52	66	72	75	68	68	66	72	70	68	66	59	46	30
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-2	-2	-2	44	64	69	71	66	62	67	70	67	68	70	73	72	66	67	63	52	35
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 68. 12 Whimbrel Close – Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	9.8	100	109	81.8	0.0251	1.24	3.2	**0.100**	0.0001
2	P	13.32	100	79	79.4	0.0191	1.24	3.0	**0.070**	2E-05
3	P	5.18	40	31	85.5	0.0383	1.11	2.4	**0.100**	0.0001
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	9.8	75	9	82.3	0.0402	1.18	1.7	**0.082**	5E-05
2	F	13.32	75	9	79.6	0.0294	1.18	1.7	**0.060**	1E-05
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.13

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	51	53	67	73	75	70	69	67	74	72	71	70	63	51	33
Track 2 Passenger	0	0	0	0	0	0	49	51	66	72	74	67	67	65	72	69	66	65	57	43	28
Chord 1 Passenger	0	0	0	0	0	0	55	55	70	76	77	74	71	69	77	76	77	77	71	61	40
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-1	-1	-1	45	67	72	72	67	63	68	70	68	69	71	75	75	70	71	68	57	38
Track 2 Freight	-2	-2	-2	44	63	68	70	66	62	67	70	67	68	69	72	70	64	65	61	50	33
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 69. 12 Whimbrel Close - Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	12.24	40	2	80.1	0.0207	1.11	1.2	**0.027**	6E-07
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	12.24	40	1	80.4	0.0321	1.04	1.0	**0.033**	1E-06
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.04

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	49	52	66	72	75	68	68	66	72	70	68	66	59	46	30
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-2	-2	-2	44	64	69	71	66	62	67	70	67	68	70	73	72	66	67	63	52	35
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 70. 12 Whimbrel Close – Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	9.8	100	18	81.8	0.0251	1.24	2.1	**0.064**	2E-05
2	P	13.32	100	14	79.4	0.0191	1.24	1.9	**0.046**	4E-06
3	P	5.18	40	4	85.5	0.0383	1.11	1.4	**0.060**	1E-05
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	9.8	75	4	82.3	0.0402	1.18	1.4	**0.067**	2E-05
2	F	13.32	75	4	79.6	0.0294	1.18	1.4	**0.049**	6E-06
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.09

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	51	53	67	73	75	70	69	67	74	72	71	70	63	51	33
Track 2 Passenger	0	0	0	0	0	0	49	51	66	72	74	67	67	65	72	69	66	65	57	43	28
Chord 1 Passenger	0	0	0	0	0	0	55	55	70	76	77	74	71	69	77	76	77	77	71	61	40
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-1	-1	-1	45	67	72	72	67	63	68	70	68	69	71	75	75	70	71	68	57	38
Track 2 Freight	-2	-2	-2	44	63	68	70	66	62	67	70	67	68	69	72	70	64	65	61	50	33
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 71. 21 Nuthatch Way– Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	17.52	40	20	76.9	0.0143	1.11	2.1	**0.033**	1E-06
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	17.52	40	1	77.1	0.0220	1.04	1.0	**0.023**	3E-07
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.04

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	46	49	63	69	72	64	65	63	69	65	61	59	50	34	22
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-4	-4	-4	42	58	63	69	65	60	65	69	66	66	67	69	65	58	59	52	41	27
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 72. 21 Nuthatch Way– Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	14.03	100	140	79.0	0.0181	1.24	3.4	**0.077**	4E-05
2	P	17.52	100	79	76.9	0.0143	1.24	3.0	**0.053**	8E-06
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	14.03	75	9	79.1	0.0279	1.18	1.7	**0.057**	1E-05
2	F	17.52	75	9	77.1	0.0220	1.18	1.7	**0.045**	4E-06
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.09

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	48	51	65	71	74	67	67	65	71	68	65	64	56	42	27
Track 2 Passenger	0	0	0	0	0	0	46	49	63	69	72	64	65	63	69	65	61	59	50	34	22
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-2	-2	-2	44	62	67	70	66	61	67	70	67	67	69	72	69	63	64	59	48	32
Track 2 Freight	-4	-4	-4	42	58	63	69	65	60	65	69	66	66	67	69	65	58	59	52	41	27
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 73. 21 Nuthatch Way– Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	17.52	40	2	76.9	0.0143	1.11	1.2	**0.019**	1E-07
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	17.52	40	1	77.1	0.0220	1.04	1.0	**0.023**	3E-07
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.03

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	46	49	63	69	72	64	65	63	69	65	61	59	50	34	22
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-4	-4	-4	42	58	63	69	65	60	65	69	66	66	67	69	65	58	59	52	41	27
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 74. 21 Nuthatch Way– Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	14.03	100	21	79.0	0.0181	1.24	2.1	**0.048**	5E-06
2	P	17.52	100	14	76.9	0.0143	1.24	1.9	**0.034**	1E-06
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	14.03	75	4	79.1	0.0279	1.18	1.4	**0.046**	5E-06
2	F	17.52	75	4	77.1	0.0220	1.18	1.4	**0.037**	2E-06
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.06

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	48	51	65	71	74	67	67	65	71	68	65	64	56	42	27
Track 2 Passenger	0	0	0	0	0	0	46	49	63	69	72	64	65	63	69	65	61	59	50	34	22
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-2	-2	-2	44	62	67	70	66	61	67	70	67	67	69	72	69	63	64	59	48	32
Track 2 Freight	-4	-4	-4	42	58	63	69	65	60	65	69	66	66	67	69	65	58	59	52	41	27
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 75. Alchaster House– Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	16	40	20	77.8	0.0158	1.11	2.1	**0.037**	2E-06
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	16	40	3	77.9	0.0242	1.04	1.3	**0.033**	1E-06
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.04

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	47	50	64	70	73	65	66	64	70	66	63	61	52	37	24
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-3	-3	-3	43	60	65	69	65	60	66	69	66	67	68	70	67	60	61	55	44	29
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 76. Alchaster House– Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	12.25	100	79	80.1	0.0206	1.24	3.0	**0.076**	3E-05
2	P	16	100	79	77.8	0.0158	1.24	3.0	**0.058**	1E-05
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	12.25	75	9	80.4	0.0321	1.18	1.7	**0.066**	2E-05
2	F	16	75	9	77.9	0.0242	1.18	1.7	**0.050**	6E-06
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.09

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	49	52	66	72	74	68	68	66	72	70	68	66	59	46	30
Track 2 Passenger	0	0	0	0	0	0	47	50	64	70	73	65	66	64	70	66	63	61	52	37	24
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-2	-2	-2	44	64	69	71	66	62	67	70	67	68	70	73	71	66	67	63	52	34
Track 2 Freight	-3	-3	-3	43	60	65	69	65	60	66	69	66	67	68	70	67	60	61	55	44	29
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 77. Alchaster House– Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	16	40	2	77.8	0.0158	1.11	1.2	**0.021**	2E-07
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	16	40	1	77.9	0.0242	1.04	1.0	**0.025**	4E-07
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.03

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	47	50	64	70	73	65	66	64	70	66	63	61	52	37	24
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-3	-3	-3	43	60	65	69	65	60	66	69	66	67	68	70	67	60	61	55	44	29
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 78. Alchaster House– Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	12.25	100	14	80.1	0.0206	1.24	1.9	**0.050**	6E-06
2	P	16	100	14	77.8	0.0158	1.24	1.9	**0.038**	2E-06
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	12.25	75	4	80.4	0.0321	1.18	1.4	**0.054**	8E-06
2	F	16	75	4	77.9	0.0242	1.18	1.4	**0.040**	3E-06
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.07

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	49	52	66	72	74	68	68	66	72	70	68	66	59	46	30
Track 2 Passenger	0	0	0	0	0	0	47	50	64	70	73	65	66	64	70	66	63	61	52	37	24
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-2	-2	-2	44	64	69	71	66	62	67	70	67	68	70	73	71	66	67	63	52	34
Track 2 Freight	-3	-3	-3	43	60	65	69	65	60	66	69	66	67	68	70	67	60	61	55	44	29
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 79. 5 Westholme Court – Current Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	9.63	40	20	81.9	0.0254	1.11	2.1	**0.060**	1E-05
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	9.63	40	1	82.5	0.0409	1.04	1.0	**0.043**	3E-06
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.06

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	51	53	68	74	76	70	69	67	74	72	71	70	64	52	33
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-1	-1	-1	46	67	72	72	67	64	68	70	68	69	71	75	75	70	71	68	58	38
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 80. 5 Westholme Court – Proposed Scheme Day-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	9.8	100	140	81.8	0.0251	1.24	3.4	**0.107**	0.0001
2	P	13.17	100	79	79.5	0.0193	1.24	3.0	**0.071**	3E-05
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	9.8	75	9	82.3	0.0402	1.18	1.7	**0.082**	5E-05
2	F	13.17	75	9	79.7	0.0298	1.18	1.7	**0.061**	1E-05
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.12

Frequency weighted vibration level dB (distance corrected)	**1.6 Hz**	**2 Hz**	**2.5 Hz**	**3.15 Hz**	**4 Hz**	**5 Hz**	**6.3 Hz**	**8 Hz**	**10 Hz**	**12.5 Hz**	**16 Hz**	**20 Hz**	**25 Hz**	**31.5 Hz**	**40 Hz**	**50 Hz**	**63 Hz**	**80 Hz**	**100 Hz**	**125 Hz**	**160 Hz**
Track 1 Passenger	0	0	0	0	0	0	51	53	67	73	75	70	69	67	74	72	71	70	63	51	33
Track 2 Passenger	0	0	0	0	0	0	49	51	66	72	74	67	67	65	72	69	66	65	57	44	28
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-1	-1	-1	45	67	72	72	67	63	68	70	68	69	71	75	75	70	71	68	57	38
Track 2 Freight	-2	-2	-2	44	63	68	70	66	62	67	70	67	68	69	72	70	65	66	61	50	33
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 81. 5 Westholme Court – Current Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	9.63	40	2	81.9	0.0254	1.11	1.2	**0.034**	1E-06
2	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	9.63	40	1	82.5	0.0409	1.04	1.0	**0.043**	3E-06
2	F	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.05

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	51	53	68	74	76	70	69	67	74	72	71	70	64	52	33
Track 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-1	-1	-1	46	67	72	72	67	64	68	70	68	69	71	75	75	70	71	68	58	38
Track 2 Freight	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 82. 5 Westholme Court – Proposed Scheme Night-Time Situation

Track	Vehicle Category	Distance (m) from track	Speed, mph	No of trains	Frequency weighted vibration level dB (distance corrected)	VDV, ms-1.75 (distance corrected)	VDV correction factor for speed	VDV correction factor for no. of trains	PER TRACK Calculated VDV, ms-1.75	TOTAL Calculated VDV, ms-1.75
1	P	9.8	100	21	81.8	0.0251	1.24	2.1	**0.067**	2E-05
2	P	13.17	100	14	79.5	0.0193	1.24	1.9	**0.046**	5E-06
3	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
4	P	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
1	F	9.8	75	4	82.3	0.0402	1.18	1.4	**0.067**	2E-05
2	F	13.17	75	4	79.7	0.0298	1.18	1.4	**0.050**	6E-06
1	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
2	S	0	0	0	13.2	0.0000	0.00	0.0	**0.000**	0
										0.08

Frequency weighted vibration level dB (distance corrected)	1.6 Hz	2 Hz	2.5 Hz	3.15 Hz	4 Hz	5 Hz	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz
Track 1 Passenger	0	0	0	0	0	0	51	53	67	73	75	70	69	67	74	72	71	70	63	51	33
Track 2 Passenger	0	0	0	0	0	0	49	51	66	72	74	67	67	65	72	69	66	65	57	44	28
Chord 1 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chord 2 Passenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 1 Freight	-1	-1	-1	45	67	72	72	67	63	68	70	68	69	71	75	75	70	71	68	57	38
Track 2 Freight	-2	-2	-2	44	63	68	70	66	62	67	70	67	68	69	72	70	65	66	61	50	33
Track 1 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Track 2 Stone Train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

J.2. Assessment of vibration decay, in VDV, m.s$^{-1.75}$

Table 83. 53 London Road – Current Situation

	PASSENGER			FREIGHT - CONVENTIONAL			FREIGHT - STONE TRAIN		
EVENT MEASUREMENT	Track 1 - near			Track 1 - near			Track 1 - near		
Distance (m) from track	4			11.9					
Actual speed, mph	35			38					
No of trains	1	C	k	1	C	k		C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105			
eVDV	0.03439			0.0246					
Event duration (seconds)	5			31					
frequency weighted acceleration, event (measured) ms-2	0.016			0.008					

53 London Road

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	6.84				6.84								
Line Speed, mph	40				40								
Actual speed, mph (over-ride)	40				40								
No of trains	20				1								
VDV scale factor for no of trains	2.1				1								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.81				1.70								
VDV, period (calculated) rel. to selected event mesaurement	0.065				0.070								0.08

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	6.84				6.84								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.81				1.70								
VDV, period (calculated) rel. to selected event mesaurement	0.036				0.070								0.07

Table 84. 53 London Road – Proposed Scheme

EVENT MEASUREMENT	PASSENGER Track 1 - near			FREIGHT - CONVENTIONAL Track 1 - near			FREIGHT - STONE TRAIN Track 1 - near
Distance (m) from track	8.5			8.5			
Actual speed, mph	75			60			
No of trains	1	C	k	1	C	k	
VDV, event (measured) ms-1.75	0.028		0.075	0.046		0.105	
eVDV	0.029			0.043			
Event duration (seconds)	3.5			19			
frequency weighted acceleration, event (measured) ms-2	0.0153			0.0146			

53 London Road

AFTER SCHEME - DESIGN SCENARIO	DAY PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY TOTAL
Distance (m) from dwelling	6.84	10.28			6.84	10.28							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	140	79			9	9							
VDV scale factor for no of trains	3.4	3.0			1.7	1.7							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	1.13	0.88			1.19	0.83							
VDV, period (calculated) rel. to selected event mesaurement	0.135	0.090			0.110	0.077							0.16

AFTER SCHEME - DESIGN SCENARIO	NIGHT PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT TOTAL
Distance (m) from dwelling	6.84	10.28			6.84	10.28							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	21	14			4	4							
VDV scale factor for no of trains	2.1	1.9			1.4	1.4							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	1.13	0.88			1.19	0.83							
VDV, period (calculated) rel. to selected event mesaurement	0.084	0.059			0.091	0.064							0.11

Table 85. Islip Crossing – Current Situation

	PASSENGER			FREIGHT - CONVENTIONAL			FREIGHT - STONE TRAIN		
EVENT MEASUREMENT	Track 1 - near			Track 1 - near			Track 1 - near		
Distance (m) from track	4			11.9					
Actual speed, mph	35			38					
No of trains	1	C	k	1	C	k		C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105			
eVDV	0.03439			0.0246					
Event duration (seconds)	5			31					
frequency weighted acceleration, event (measured) ms-2	0.016			0.008					

Islip

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	2.87				2.87								
Line Speed, mph	40				40								
Actual speed, mph (over-ride)	40				40								
No of trains	20				3								
VDV scale factor for no of trains	2.1				1.3								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	1.09				2.58								
VDV, period (calculated) rel. to selected event mesaurement	0.087				0.141								0.15

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	2.87				2.87								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	1.09				2.58								
VDV, period (calculated) rel. to selected event mesaurement	0.049				0.107								0.11

Table 86. Islip Crossing – Proposed Scheme

	PASSENGER			FREIGHT - CONVENTIONAL			FREIGHT - STONE TRAIN
EVENT MEASUREMENT	Track 1 - near			Track 1 - near			Track 1 - near
Distance (m) from track	8.5			8.5			
Actual speed, mph	75			60			
No of trains	1	C	k	1	C	k	
VDV, event (measured) ms-1.75	0.028		0.075	0.046		0.105	
eVDV	0.029			0.043			
Event duration (seconds)	3.5			19			
frequency weighted acceleration, event (measured) ms-2	0.0153			0.0146			

Islip

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	3.51	6.74			3.51	6.74							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	79	79			9	9							
VDV scale factor for no of trains	3.0	3.0			1.7	1.7							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	1.45	1.14			1.69	1.20							
VDV, period (calculated) rel. to selected event mesaurement	0.150	0.118			0.157	0.111							0.20

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	3.51	6.74			3.51	6.74							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	14	14			4	4							
VDV scale factor for no of trains	1.9	1.9			1.4	1.4							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	1.45	1.14			1.69	1.20							
VDV, period (calculated) rel. to selected event mesaurement	0.098	0.077			0.130	0.092							0.15

Table 87. Oddington Crossing – Current Situation

EVENT MEASUREMENT	PASSENGER Track 1 - near			FREIGHT - CONVENTIONAL Track 1 - near			FREIGHT - STONE TRAIN Track 1 - near		
Distance (m) from track	4			11.9					
Actual speed, mph	35			38					
No of trains	1	C	k	1	C	k		C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105			
eVDV	0.03439			0.0246					
Event duration (seconds)	5			31					
frequency weighted acceleration, event (measured) ms-2	0.016			0.008					

Oddington

CURRENT SITUATION	DAY PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY TOTAL
Distance (m) from dwelling	5.09				5.09								
Line Speed, mph	40				40								
Actual speed, mph (over-ride)	40				40								
No of trains	20				3								
VDV scale factor for no of trains	2.1				1.3								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.92				2.04								
VDV, period (calculated) rel. to selected event mesaurement	0.074				0.111								0.12

CURRENT SITUATION	NIGHT PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT TOTAL
Distance (m) from dwelling	5.09				5.09								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.92				2.04								
VDV, period (calculated) rel. to selected event mesaurement	0.042				0.085								0.09

Table 88. Oddington Crossing – Proposed Scheme

EVENT MEASUREMENT	PASSENGER Track 1 - near			FREIGHT - CONVENTIONAL Track 1 - near			FREIGHT - STONE TRAIN Track 1 - near		
Distance (m) from track	8.5			8.5					
Actual speed, mph	75			60					
No of trains	1	C	k	1	C	k			
VDV, event (measured) ms-1.75	0.028		0.075	0.046		0.105			
eVDV	0.029			0.043					
Event duration (seconds)	3.5			19					
frequency weighted acceleration, event (measured) ms-2	0.0153			0.0146					

Oddington

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	5.09	8.62			5.09	8.62							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	79	79			9	9							
VDV scale factor for no of trains	3.0	3.0			1.7	1.7							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	1.29	0.99			1.43	0.99							
VDV, period (calculated) rel. to selected event mesaurement	0.133	0.102			0.133	0.092							0.17

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	5.09	8.62			5.09	8.62							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	14	14			4	4							
VDV scale factor for no of trains	1.9	1.9			1.4	1.4							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	1.29	0.99			1.43	0.99							
VDV, period (calculated) from selected event mesaurement	0.087	0.067			0.110	0.076							0.13

Table 89. Quadrangle – Current Situation

EVENT MEASUREMENT	PASSENGER Track 1 - near			FREIGHT - CONVENTIONAL Track 1 - near			FREIGHT - STONE TRAIN Track 1 - near		
Distance (m) from track	4			11.9			2.5		
Actual speed, mph	35			38			28		
No of trains	1	C	k	1	C	k	1	C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105	0.1074		0.194
eVDV	0.03439			0.0246			0.0943		
Event duration (seconds)	5			31			22		
frequency weighted acceleration, event (measured) ms-2	0.016			0.008			0.0313		

Quadrangle

CURRENT SITUATION	DAY PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY TOTAL
Distance (m) from dwelling	8.97				8.97				8.97				
Line Speed, mph	40				40				40				
Actual speed, mph (over-ride)	40				40				40				
No of trains	20				4				1				
VDV scale factor for no of trains	2.1				1.4				1.0				
VDV scale factor for speed	1.11				1.04				1.31				
VDV scale factor for distance	0.69				1.36				0.29				
VDV, period (calculated) rel. to selected event mesaurement	0.055				0.080				0.040				0.08

CURRENT SITUATION	NIGHT PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT TOTAL
Distance (m) from dwelling	8.97				8.97								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.69				1.36								
VDV, period (calculated) rel. to selected event mesaurement	0.031				0.056								0.06

Table 90. Quadrangle – Proposed Scheme

	PASSENGER			FREIGHT - CONVENTIONAL			FREIGHT - STONE TRAIN		
EVENT MEASUREMENT	Track 1 - near			Track 1 - near			Track 1 - near		
Distance (m) from track	8.5			8.5			2.5		
Actual speed, mph	75			60			28		
No of trains	1	C	k	1	C	k	1	C	k
VDV, event (measured) ms-1.75	0.028		0.075	0.046		0.105	0.1074		0.194
eVDV	0.029			0.043			0.0943		
Event duration (seconds)	3.5			19			22		
frequency weighted acceleration, event (measured) ms-2	0.0153			0.0146			0.0313		

Quadrangle

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	7.49	10.89			7.49	10.89			7.49	10.89			
Line Speed, mph	70	70			70	70			70	70			
Actual speed, mph	70	70			70	70			60	60			
No of trains	79	79			8	8			1	1			
VDV scale factor for no of trains	3.0	3.0			1.7	1.7			1.0	1.0			
VDV scale factor for speed	0.95	0.95			1.12	1.12			1.77	1.77			
VDV scale factor for distance	1.08	0.84			1.11	0.78			0.38	0.20			
VDV, period (calculated) rel. to selected event mesaurement	0.085	0.066			0.096	0.067			0.072	0.037			0.12

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	7.49	10.89			7.49	10.89							
Line Speed, mph	70	70			70	70							
Actual speed, mph	70	70			70	70							
No of trains	14	14			4	4							
VDV scale factor for no of trains	1.9	1.9			1.4	1.4							
VDV scale factor for speed	0.95	0.95			1.12	1.12							
VDV scale factor for distance	1.08	0.84			1.11	0.78							
VDV, period (calculated) rel. to selected event mesaurement	0.056	0.043			0.081	0.057							0.09

Table 91. 3 Bladon Close – Current Situation

EVENT MEASUREMENT	PASSENGER Track 1 - near	C	k	FREIGHT - CONVENTIONAL Track 1 - near	C	k	FREIGHT - STONE TRAIN Track 1 - near	C	k
Distance (m) from track	4			11.9			2.5		
Actual speed, mph	35			38			28		
No of trains	1	C	k	1	C	k	1	C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105	0.1074		0.194
eVDV	0.03439			0.0246			0.0943		
Event duration (seconds)	5			31			22		
frequency weighted acceleration, event (measured) ms-2	0.016			0.008			0.0313		

3 Bladon Close

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	14.34				14.34				14.34				
Line Speed, mph	40				40				40				
Actual speed, mph (over-ride)	40				40				40				
No of trains	20				4				1				
VDV scale factor for no of trains	2.1				1				1				
VDV scale factor for speed	1.11				1.04				1.31				
VDV scale factor for distance	0.46				0.77				0.10				
VDV, period (calculated) rel. to selected event mesaurement	0.037				0.045				0.014				0.05

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	14.34				14.34								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.46				0.77								
VDV, period (calculated) rel. to selected event mesaurement	0.021				0.032								0.03

Table 92. 3 Bladon Close – Proposed Scheme

	PASSENGER			FREIGHT - CONVENTIONAL			FREIGHT - STONE TRAIN		
EVENT MEASUREMENT	Track 1 - near			Track 1 - near			Track 1 - near		
Distance (m) from track	8.5			8.5			2.5		
Actual speed, mph	75			60			28		
No of trains	1	C	k	1	C	k	1	C	k
VDV, event (measured) ms-1.75	0.028		0.075	0.046		0.105	0.1074		0.194
eVDV	0.029			0.043			0.0943		
Event duration (seconds)	3.5			19			22		
frequency weighted acceleration, event (measured) ms-2	0.0153			0.0146			0.0313		

3 Bladon Close

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	12.92	13.62			12.92	13.62			12.92	13.62			
Line Speed, mph	70	60			70	60			70	70			
Actual speed, mph	70	60			70	60			60	60			
No of trains	79	79			8	8			1	1			
VDV scale factor for no of trains	3.0	3.0			1.7	1.7			1.0	1.0			
VDV scale factor for speed	0.95	0.85			1.12	1			1.77	1.77			
VDV scale factor for distance	0.72	0.68			0.63	0.58			0.13	0.12			
VDV, period (calculated) rel. to selected event mesaurement	0.057	0.048			0.054	0.045			0.025	0.022			0.07

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	12.92	13.62			12.92	13.62							
Line Speed, mph	70	60			70	60							
Actual speed, mph	70	60			70	60							
No of trains	14	14			4	4							
VDV scale factor for no of trains	1.9	1.9			1.4	1.4							
VDV scale factor for speed	0.95	0.85			1.12	1							
VDV scale factor for distance	0.72	0.68			0.63	0.58							
VDV, period (calculated) rel. to selected event mesaurement	0.037	0.031			0.046	0.038							0.06

Table 93. 12 Whimbrel Close – Current Situation

	PASSENGER			FREIGHT - CONVENTIONAL			FREIGHT - STONE TRAIN		
EVENT MEASUREMENT	Track 1 - near			Track 1 - near			Track 1 - near		
Distance (m) from track	4			11.9					
Actual speed, mph	35			38					
No of trains	1	C	k	1	C	k		C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105			
eVDV	0.03439			0.0246					
Event duration (seconds)	5			31					
frequency weighted acceleration, event (measured) ms-2	0.016			0.008					

12 Whimbrel Close

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	12.24				12.24								
Line Speed, mph	40				40								
Actual speed, mph (over-ride)	40				40								
No of trains	20				1								
VDV scale factor for no of trains	2.1				1								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.54				0.96								
VDV, period (calculated) rel. to selected event mesaurement	0.043				0.040								0.05

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	12.24				12.24								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.54				0.96								
VDV, period (calculated) rel. to selected event mesaurement	0.024				0.040								0.04

Table 94. 12 Whimbrel Close – Proposed Scheme

EVENT MEASUREMENT	PASSENGER Track 1 - near (main)			Track 1 - near (chord)	FREIGHT - CONVENTIONAL Track 1 - near			FREIGHT - STONE TRAIN Track 1 - near
Distance (m) from track	8.5			4	8.5			
Actual speed, mph	75			35	60			
No of trains	1	C	k	1	1	C	k	
VDV, event (measured) ms-1.75	0.028		0.075	0.03419	0.046		0.105	
eVDV	0.029	C	k	0.03439	0.043			
Event duration (seconds)	3.5		0.076	5	19			
frequency weighted acceleration, event (measured) ms-2	0.0153			0.016	0.0146			

12 Whimbrel Close

AFTER SCHEME - DESIGN SCENARIO	DAY PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY TOTAL
Distance (m) from dwelling	9.8	13.32	5.18		9.8	13.32							
Line Speed, mph	100	100	40		75	75							
Actual speed, mph	100	100	40		75	75							
No of trains	109	79	31		9	9							
VDV scale factor for no of trains	3.2	3.0	2.4		1.7	1.7							
VDV scale factor for speed	1.24	1.24	1.11		1.18	1.18							
VDV scale factor for distance	0.91	0.70	0.91		0.87	0.60							
VDV, period (calculated) rel. to selected event mesaurement	0.102	0.072	0.082		0.081	0.056							0.12

AFTER SCHEME - DESIGN SCENARIO	NIGHT PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT TOTAL
Distance (m) from dwelling	9.8	13.32	5.18		9.8	13.32							
Line Speed, mph	100	100	40		75	75							
Actual speed, mph	100	100	40		75	75							
No of trains	18	14	4		4	4							
VDV scale factor for no of trains	2.0	1.9	1.4		1.4	1.4							
VDV scale factor for speed	1.24	1.24	1.11		1.18	1.18							
VDV scale factor for distance	0.91	0.70	0.91		0.87	0.60							
VDV, period (calculated) rel. to selected event mesaurement	0.064	0.047	0.047		0.067	0.046							0.08

Table 95. 21 Nuthatch Way – Current Situation

	PASSENGER			FREIGHT - CONVENTIONAL			FREIGHT - STONE TRAIN		
EVENT MEASUREMENT	Track 1 - near			Track 1 - near			Track 1 - near		
Distance (m) from track	4			11.9					
Actual speed, mph	35			38					
No of trains	1	C	k	1	C	k		C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105			
eVDV	0.03439			0.0246					
Event duration (seconds)	5			31					
frequency weighted acceleration, event (measured) ms-2	0.016			0.008					

21 Nuthatch Way

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	17.52				17.52								
Line Speed, mph	40				40								
Actual speed, mph (over-ride)	40				40								
No of trains	20				1								
VDV scale factor for no of trains	2.1				1								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.36				0.55								
VDV, period (calculated) rel. to selected event mesaurement	0.029				0.023								0.03

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
CURRENT SITUATION	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	17.52				17.52								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.36				0.55								
VDV, period (calculated) rel. to selected event mesaurement	0.016				0.023								0.02

Table 96. 21 Nuthatch Way – Proposed Scheme

	PASSENGER			FREIGHT - CONVENTIONAL			FREIGHT - STONE TRAIN
EVENT MEASUREMENT	Track 1 - near			Track 1 - near			Track 1 - near
Distance (m) from track	8.5			8.5			
Actual speed, mph	75			60			
No of trains	1	C	k	1	C	k	
VDV, event (measured) ms-1.75	0.028		0.075	0.046		0.105	
eVDV	0.029			0.043			
Event duration (seconds)	3.5			19			
frequency weighted acceleration, event (measured) ms-2	0.0153			0.0146			

21 Nuthatch Way

	DAY PASSENGER				DAY FREIGHT - CONVENTIONAL				DAY FREIGHT - STONE TRAIN				DAY TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	14.03	17.52			14.03	17.52							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	140	79			9	9							
VDV scale factor for no of trains	3.4	3.0			1.7	1.7							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	0.66	0.51			0.56	0.39							
VDV, period (calculated) rel. to selected event mesaurement	0.079	0.053			0.052	0.036							0.09

	NIGHT PASSENGER				NIGHT FREIGHT - CONVENTIONAL				NIGHT FREIGHT - STONE TRAIN				NIGHT TOTAL
AFTER SCHEME - DESIGN SCENARIO	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	
Distance (m) from dwelling	14.03	17.52			14.03	17.52							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	21	14			4	4							
VDV scale factor for no of trains	2.1	1.9			1.4	1.4							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	0.66	0.51			0.56	0.39							
VDV, period (calculated) rel. to selected event mesaurement	0.049	0.034			0.043	0.030							0.06

Table 97. Alchaster House, Langford Lane – Current Situation

EVENT MEASUREMENT	PASSENGER Track 1 - near	C	k	FREIGHT - CONVENTIONAL Track 1 - near	C	k	FREIGHT - STONE TRAIN Track 1 - near	C	k
Distance (m) from track	4			11.9					
Actual speed, mph	35			38					
No of trains	1	C	k	1	C	k		C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105			
eVDV	0.03439			0.0246					
Event duration (seconds)	5			31					
frequency weighted acceleration, event (measured) ms-2	0.016			0.008					

Alchaster House, Langford Lane

CURRENT SITUATION	DAY PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY TOTAL
Distance (m) from dwelling	16				16								
Line Speed, mph	40				40								
Actual speed, mph (over-ride)	40				40								
No of trains	20				3								
VDV scale factor for no of trains	2.1				1								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.41				0.65								
VDV, period (calculated) rel. to selected event mesaurement	0.033				0.035								0.04

CURRENT SITUATION	NIGHT PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT TOTAL
Distance (m) from dwelling	16				16								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.41				0.65								
VDV, period (calculated) rel. to selected event mesaurement	0.018				0.027								0.03

Table 98. Alchaster House, Langford Lane – Proposed Scheme

EVENT MEASUREMENT	PASSENGER Track 1 - near			FREIGHT - CONVENTIONAL Track 1 - near			FREIGHT - STONE TRAIN Track 1 - near
Distance (m) from track	8.5			8.5			
Actual speed, mph	75			60			
No of trains	1	C	k	1	C	k	
VDV, event (measured) ms-1.75	0.028		0.075	0.046		0.105	
eVDV	0.029			0.043			
Event duration (seconds)	3.5			19			
frequency weighted acceleration, event (measured) ms-2	0.0153			0.0146			

Alchaster House, Langford Lane

AFTER SCHEME - DESIGN SCENARIO	DAY PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY TOTAL
Distance (m) from dwelling	12.25	16			12.25	16							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	79	79			9	9							
VDV scale factor for no of trains	3.0	3.0			1.7	1.7							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	0.75	0.57			0.67	0.45							
VDV, period (calculated) rel. to selected event mesaurement	0.078	0.059			0.063	0.042							0.09

AFTER SCHEME - DESIGN SCENARIO	NIGHT PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT TOTAL
Distance (m) from dwelling	12.25	16			12.25	16							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	14	14			4	4							
VDV scale factor for no of trains	1.9	1.9			1.4	1.4							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	0.75	0.57			0.67	0.45							
VDV, period (calculated) from selected event mesaurement	0.051	0.038			0.052	0.035							0.06

Table 99. 5 Westholme Court – Current Situation

EVENT MEASUREMENT	PASSENGER Track 1 - near	C	k	FREIGHT - CONVENTIONAL Track 1 - near	C	k	FREIGHT - STONE TRAIN Track 1 - near	C	k
Distance (m) from track	4			11.9					
Actual speed, mph	35			38					
No of trains	1	C	k	1	C	k		C	k
VDV, event (measured) ms-1.75	0.03419		0.075	0.0398		0.105			
eVDV	0.03439			0.0246					
Event duration (seconds)	5			31					
frequency weighted acceleration, event (measured) ms-2	0.016			0.008					

5 Westholme Court

CURRENT SITUATION	DAY PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY TOTAL
Distance (m) from dwelling	9.63				9.63								
Line Speed, mph	40				40								
Actual speed, mph (over-ride)	40				40								
No of trains	20				1								
VDV scale factor for no of trains	2.1				1								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.66				1.27								
VDV, period (calculated) rel. to selected event mesaurement	0.053				0.053								0.06

CURRENT SITUATION	NIGHT PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT TOTAL
Distance (m) from dwelling	9.63				9.63								
Line Speed, mph	40				40								
Actual speed, mph	40				40								
No of trains	2				1								
VDV scale factor for no of trains	1.2				1.0								
VDV scale factor for speed	1.11				1.04								
VDV scale factor for distance	0.66				1.27								
VDV, period (calculated) rel. to selected event mesaurement	0.030				0.053								0.05

Table 100. 5 Westholme Court – Proposed Scheme

EVENT MEASUREMENT	PASSENGER Track 1 - near	C	k	FREIGHT - CONVENTIONAL Track 1 - near	C	k	FREIGHT - STONE TRAIN Track 1 - near		
Distance (m) from track	8.5			8.5					
Actual speed, mph	75			60					
No of trains	1	C	k	1	C	k			
VDV, event (measured) ms-1.75	0.028		0.075	0.046		0.105			
eVDV	0.029			0.043					
Event duration (seconds)	3.5			19					
frequency weighted acceleration, event (measured) ms-2	0.0153			0.0146					

5 Westholme Court

AFTER SCHEME - DESIGN SCENARIO	DAY PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	DAY TOTAL
Distance (m) from dwelling	9.8	13.17			9.8	13.17							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	140	79			9	9							
VDV scale factor for no of trains	3.4	3.0			1.7	1.7							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	0.91	0.70			0.87	0.61							
VDV, period (calculated) rel. to selected event mesaurement	0.108	0.073			0.081	0.057							0.12

AFTER SCHEME - DESIGN SCENARIO	NIGHT PASSENGER Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - CONVENTIONAL Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT FREIGHT - STONE TRAIN Track 1 - Mainline near	Track 2 - Mainline far	Track 3 - New Chord near	Track 4 - New Chord far	NIGHT TOTAL
Distance (m) from dwelling	9.8	13.17			9.8	13.17							
Line Speed, mph	100	100			75	75							
Actual speed, mph	100	100			75	75							
No of trains	21	14			4	4							
VDV scale factor for no of trains	2.1	1.9			1.4	1.4							
VDV scale factor for speed	1.24	1.24			1.18	1.18							
VDV scale factor for distance	0.91	0.70			0.87	0.61							
VDV, period (calculated) rel. to selected event mesaurement	0.067	0.047			0.067	0.047							0.08

Appendix K. Edison Sedra Mitigation Prognosis

Memo

edilon)(sedra

Noise & Vibration Prognosis
for East West Rail

e)(s R&D project code: T2013-1008
date: 25 October 2013

1. Introduction

edilon)(sedra has been requested to provide Atkins with an insertion loss prognosis based on the questionnaires that have been filled in for Oxfordshire, Oddington and Islip Level Crossings.

Gavrey and Woodstock junctions, which were also part of the request, cannot be modelled with the TRACKELAST SBM Selector software due to the various elements that are generally included during the construction of these sections.

The vibration performance is based on a calculation method which incorporates a simplification of a real ballasted track structure, only taking the most important components into consideration. The track structure is reduced to a set of parameters which describe the essential characteristics of a rail vehicle on a ballasted track structure. The track contains a maximum of 4 layers of elasticity: under the rail, under the sleeper, under the ballast and the soil/supporting structure.

2. Methodology

The calculation method is based on a mechanical model of 4 lumped masses separated by maximum 4 elastic elements (under the rail, under the rail support, under the slab and the soil/supporting structure) representing a vertical slice of a ballasted track structure. The calculation method follows the guidelines of DIN V 45673-4 for the computational determination of insertion loss.

The 4 lumped masses are:
- the unsprung mass of the vehicle plus the rail (equivalent portion)
- the mass of the sleeper
- the mass of the ballast (equivalent portion)
- the mass of the foundation layer and the soil (both equivalent portion)

The elastic elements between these lumped masses are:
- the rail pad (stiffness to be determined acc. EN 13146-9)
- the under sleeper pad (equivalent area, bedding modulus to be determined acc. DIN 45673-6)
- the sub ballast mat (equivalent area, bedding modulus to be determined acc. DIN 45673-5)
- the soil (equivalent area, shear modulus to be determined acc. DIN 45672-1 and/or bedding modulus to be determined acc. DIN 18134)

The model ends at a rigid (infinitely stiff) boundary. Every elastic element is defined by means of 3 values: static and dynamic stiffness and a loss factor, or any of the two stiffnesses, a value for dynamic stiffening and a loss factor. The presented transfer functions apply for the entire model, thus rail level vs. rigid boundary.

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3. Track properties

The fields in the TRACKELAST SBM Selector software were filled in with the values provided by Atkins as well as with some assumption made by edilon)(sedra. For the modeling the **TRACKELAST SBM/RPU/Blue/20-2GF** sub ballast mat was used which is a commonly applied mat.

More specifically:

Rail	
Type	UIC60

Rail pad	
Static stifness [MN/m]	100
Dynamic stifness [MN/m]	200
Loss factor	0.05

Sleeper	
Mass [kg]	250
Length [m]	2.5
Width [m]	0.3
Spacing [m]	0.65
End length [m]	0.83
End width [m]	0.3

Ballast		
Dynamic stiffness	$5 \cdot 10^8$	
Dynamic stiffening	2.0	
Loss factor	0.35	
Load angle [deg]	60	
Density [kg/m^3]	1800	
Thickness [m]	0.25	0.50

Soil	
E_{v2} [MN/m^2]	< 80
Density [kg/m^3]	1600
Static G modulus [N/m^2]	$7 \cdot 10^6$
Dynamic stiffening	1.20
Loss factor	0.30
Poisson ratio	0.35

Sub ballast mat	
Thickness [m]	0.020
Static bedding modulus [N/mm^3]	0.010
Dynamic bed. modulus [N/mm^3]	0.032
Loss factor	0.30

The track will be provided with a capping layer under the ballast layer. Due to input restriction in the SBM Selector, the capping layer has been modelled as part of the ballast layer (thicker layer).
In fact, the actual performance of the track with 0.25m ballast layer and 0.25 capping layer lies between the cases of a 0.25 m and a 0.50 m thick ballast layer. Therefore, these two cases have been examined.

4. Vehicles

In order to examine the influence of the vehicles, the lightest and the heaviest vehicle have been taken into account, namely the Class 168 DMU and the Class 66 Loco and Freight Wagon respectively. This represents the upper and lower limit of the performance depending on the vehicles. All the other vehicles will perform within this range.

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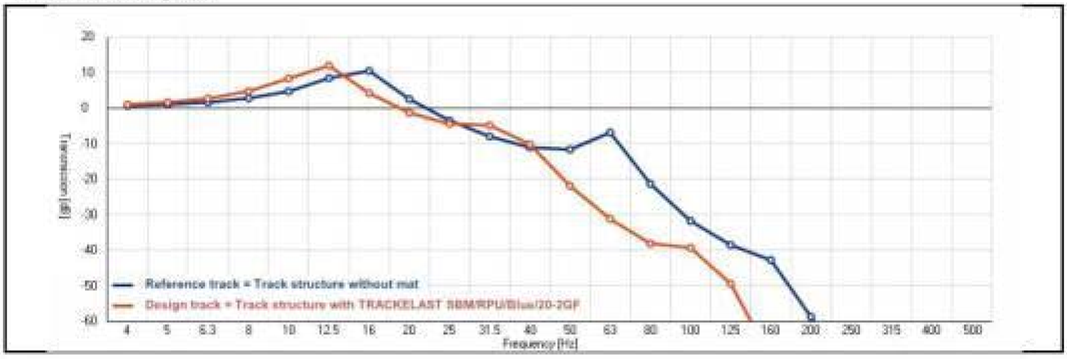
5. Cases

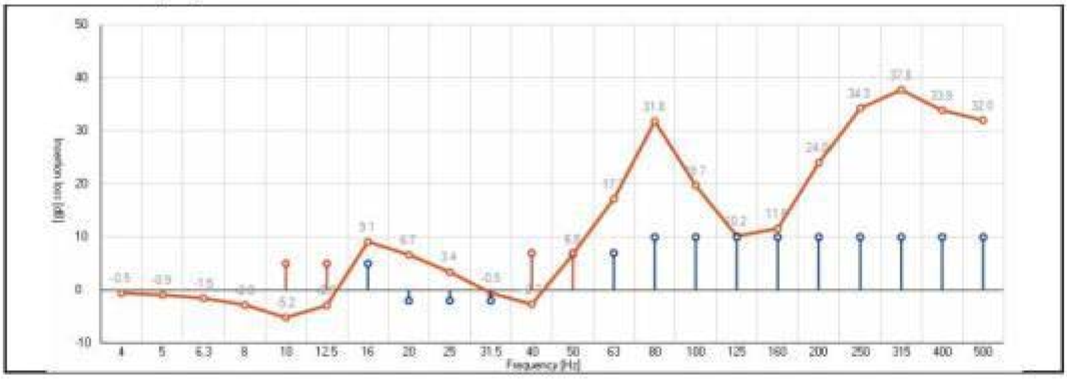
5.1. Case 1: Class 66 Loco + Freight Wagon, 0.25 m ballast layer

Transmission graph



Frequency [Hz]	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Design track [dB]	1.1	1.8	3.0	5.3	9.5	10.5	2.1	-3.2	-6.6	-7.7	-9.5	21.4	-31.9	-40.4	-46.5	-48.0	-58.7	-77.5	-91.9	-105.5	-118.8	-130.9
Reference track [dB]	0.6	0.9	1.5	2.6	4.3	7.7	11.2	3.4	-3.2	-8.2	-12.2	-14.6	-14.7	-8.6	-26.8	-37.8	-47.0	-53.5	-57.6	-67.7	-84.9	-96.9

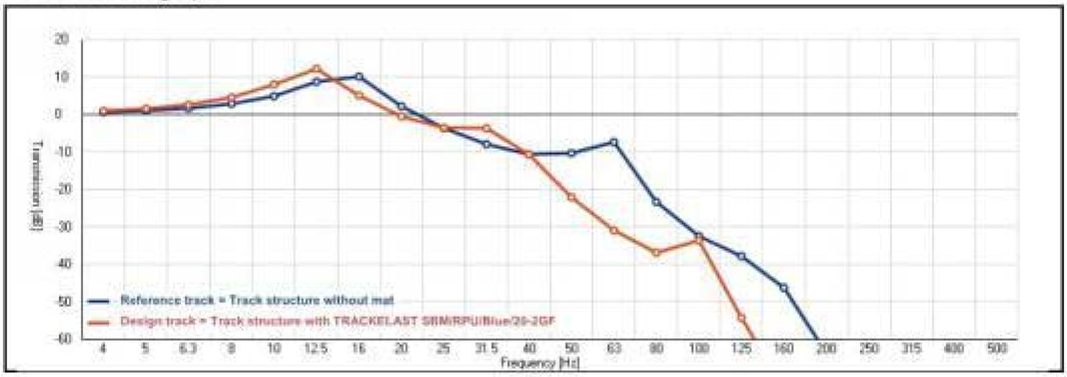
Insertion loss graph



Frequency [Hz]	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Insertion loss [dB]	-0.5	-0.9	-1.5	-2.0	-5.2	-2.9	9.1	6.7	3.4	-0.5	-2.7	6.8	17.2	31.8	19.7	10.2	11.6	24.0	34.3	37.8	33.9	32.0

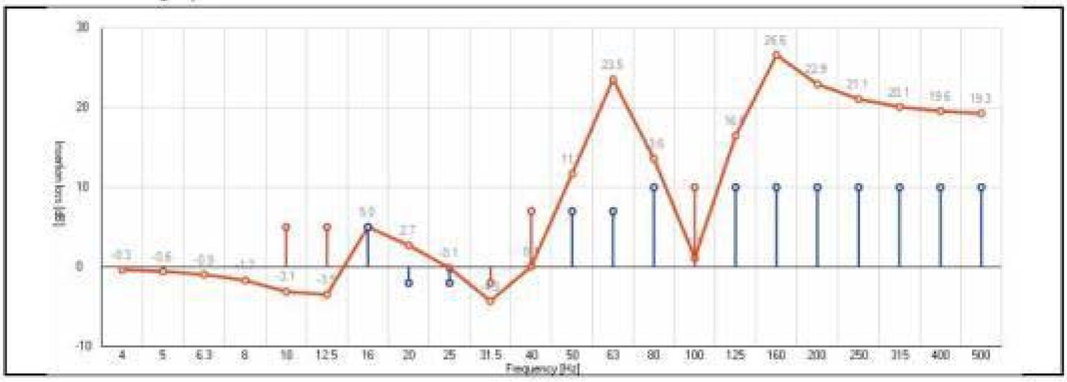
5.2. Case 2: Class 66 Loco + Freight Wagon, 0.50 m ballast layer

Transmission graph



Frequency [Hz]	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Design track [dB]	1.0	1.6	2.6	4.6	8.0	12.2	5.1	-0.5	-3.5	-3.6	-10.6	-22.0	-30.9	-36.8	-33.5	-54.2	-72.7	-86.5	-99.4	-112.1	-125.0	-136.9
Reference track [dB]	0.7	1.0	1.7	2.9	4.9	8.8	10.1	2.2	-3.6	-7.9	-10.6	-10.3	-7.3	-23.2	-32.4	-37.7	-46.1	-63.6	-78.3	-92.0	-105.5	-117.6

Insertion loss graph



Frequency [Hz]	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Insertion loss [dB]	-0.3	-0.6	-0.9	-1.7	-3.1	-3.5	5.0	2.7	-0.1	-4.3	0.1	11.7	23.5	13.6	1.1	16.5	26.6	22.9	21.1	20.1	19.6	19.3

Memo
Noise & Vibration Prognosis Report for East West Rail
Reference: **20131023 Memo Noise & Vibration Prognosis EWR**
Page: 4 of 6

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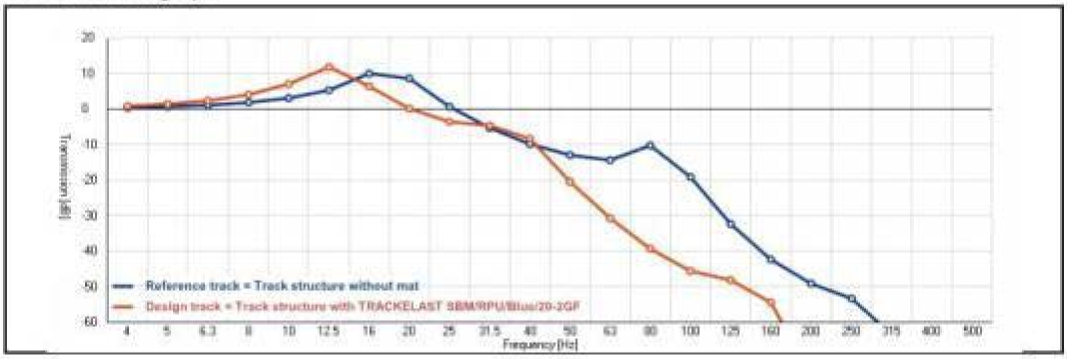
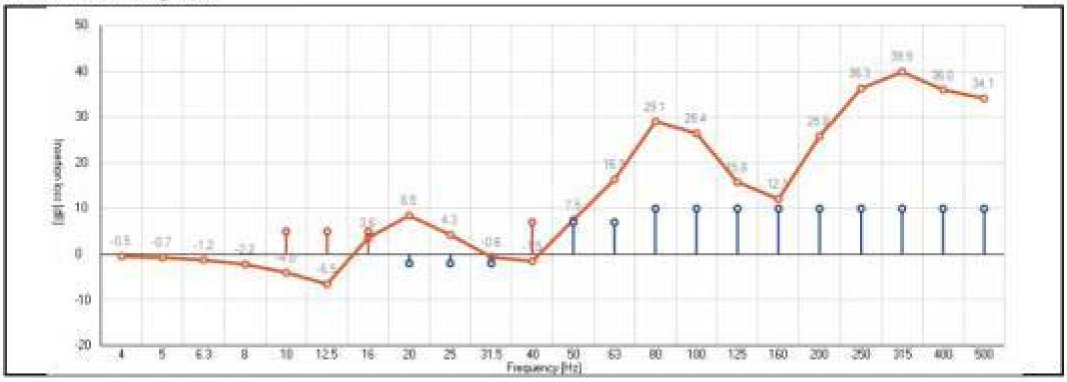
5.3. Case 3: Class 168 DMU, 0.25 m ballast layer

Transmission graph



Frequency [Hz]	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Design track [dB]	0.9	1.4	2.4	4.1	7.1	11.9	6.4	0.2	-3.5	-4.6	-8.3	-20.4	-30.7	-39.3	-45.5	-48.1	-54.3	-74.8	-89.6	-103.2	-116.6	-128.7
Reference track [dB]	0.4	0.7	1.1	1.9	3.1	5.3	10.0	8.6	0.7	-5.2	-9.8	-12.9	-14.3	-10.2	-19.1	-32.3	-42.3	-49.0	-53.3	-63.3	-80.6	-94.6

Insertion loss graph



Frequency [Hz]	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Insertion loss [dB]	-0.5	-0.7	-1.2	-2.2	-4.0	-6.5	3.6	8.5	4.3	-0.6	-1.5	7.5	16.3	29.1	26.4	15.8	12.1	25.8	36.3	39.9	36.0	34.1

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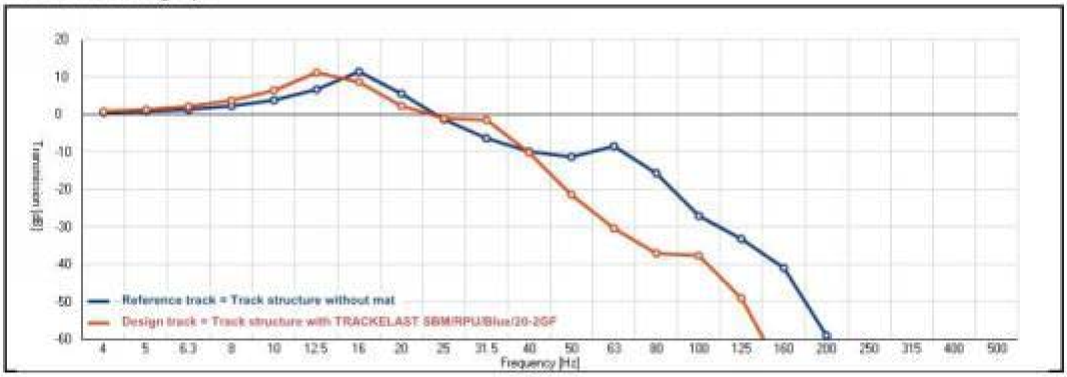
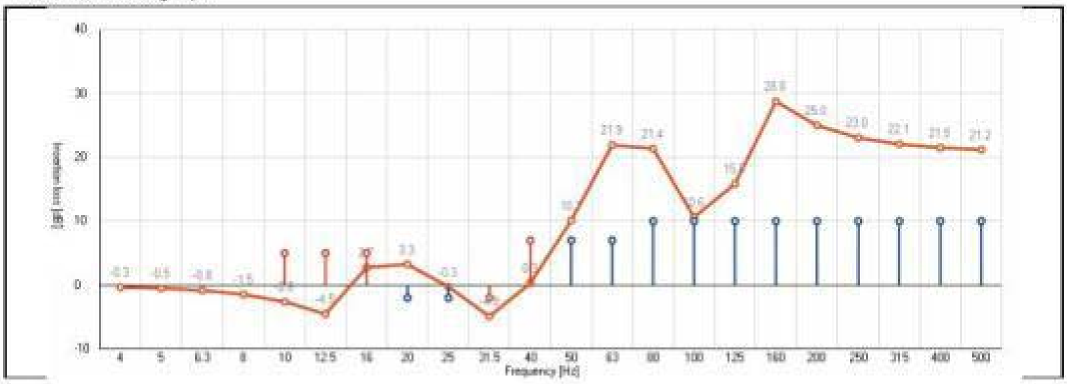
5.1. Case 4: Class 168 DMU, 0.50 m ballast layer

Transmission graph



Frequency [Hz]	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Design track [dB]	0.8	1.4	2.2	3.8	6.5	11.2	8.7	2.3	-1.0	-1.4	-10.1	-21.4	-30.3	-37.0	-37.6	-49.0	-69.6	-83.9	-96.9	-109.8	-122.7	-134.6
Reference track [dB]	0.5	0.8	1.4	2.3	3.9	6.7	11.5	5.6	-1.3	-6.3	-9.8	-11.3	-8.4	-15.6	-27.0	-33.1	-40.9	-58.9	-73.8	-87.7	-101.2	-113.4

Insertion loss graph



Frequency [Hz]	4	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500
Insertion loss [dB]	-0.3	-0.5	-0.8	-1.5	-2.6	-4.5	2.7	3.3	-0.3	-4.9	0.3	10.1	21.9	21.4	10.6	15.8	28.8	25.0	23.0	22.1	21.5	21.2

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