Vibration Assessment Report

159 – 161 Iverson Road, West Hampstead

April 2015

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DOCUMENT CONTROL SHEET:

Rev.	Issue Purpose	Author	Signature	Checked	Signature	Date
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Executive Summary

This document presents the assessment criteria of vibration related Planning Conditions given in the permission for application 2013/7505/P dated 21 February 2014.

The assessment for Planning Condition 14 shows vibration from passing trains will be perceptible at times and overall vibration exposure will not give rise to complaint. Suitable building bedding on pile heads has been proposed to reduce possibility of ground borne noise intrusion. Predicted vibration levels with mitigation have been assessed as lower than a Low probability of complaint, in accordance with BS6472 methodology.

Introduction

This report has been produced to assess the Consented Development at 159-161 Iverson Road in accordance with the requirements of Planning Conditions 14 of decision for application 2013/7505/P dated 21 February 2014. The development is two buildings ranging between one and six stories, comprising of 19 residential units (Class C3), and 164sqm of employment floor space (Class B1c).

Within this document is a reproduction of the Planning Condition 14 wording, summary of environmental noise data used and details of relevant construction proposals. Reference is made to previous noise and vibration reports cited in the decision notice. The results of a vibration survey are presented, along with the methodology and instrumentation used.

Assessment Criteria

Planning Condition 14

The exact wording of Planning Condition 14 has been reproduced below for ease of reference.

a) Before building works commence on the site, a scheme shall be submitted to and approved in writing by the Local Planning Authority providing for adequate insulation of the proposed dwellings to prevent the transmission of vibration from road and railway traffic causing any discomfort to its occupants as measured and interpreted by BS.6472:1992 "Evaluation of human exposure to vibration in buildings [1 Hz to 80 Hz]."

b) The survey, as cited in acoustic report ref: 13P282 JT R1 260 - 188AA shall be carried out.

It is interpreted that "Before building works commence on the site" does not include demolition of existing buildings and enabling ground works. The vibration survey methodology in acoustic report ref: 13P282 JT R1 260 - 188AA is cited:

1. Measurement of ground-borne vibration in accordance with BS6472 at commencement of enabling groundwork's on site at two monitoring locations
2. Analysis and assessment of ground-borne vibration in accordance with BS6472 and LB Camden criteria to determine if perceptible vibration is acceptable in residential units at all floors.
3. Where assessment shows control of ground-borne vibration is required to comply with requirements of BS6472 and LB Camden criteria, develop a control scheme to include building isolation and separation of structure, fabric and services from ground. Submit report of vibration control scheme to LB Camden for review and approval.
4. Implement control scheme in full as agreed during construction.

Item 1 would need to take place on implementation or at least when enabling works on site allow the digging of test pits or setting of test piles.

Item 2 and 3 would need to occur at the earliest stage possible due to the cost and design implications of such control measures on structural and architectural requirements.

Item 4 would need to be an integral element of the construction process and not seen as an adjunct to it.

It is not economically feasible to bore "test" piles, all piling operations have to be completed when the piling rig is on site in one phase. A pit to the same depth of piles would not be safe or economic to construct.

Therefore it has been agreed with London Borough of Camden Planning Case Officer for this development that the vibration survey will be conducted on the actual piles that will support the building. The report*13P282 JT R1 260 - 188AA*[i] is available on the Camden planning portal.

BS 6472 -1: 2008 Assessment Methodology

The document BS 6472-1:2008[ii] contains a methodology for assessing the human response to vibration in terms of the vibration dose value (VDV).

When the vibration is intermittent, such as with trains, the vibration dose value may be used to assess the potential for effects. Intermittent vibration is vibration which is perceived in separately identifiable repeated bursts. Its onset can be sudden, or there might be a gradual onset and termination bounding a more sustained event. Bursts may happen several-to-many times in a day or night period.

For continuous vibration that is not time-varying in magnitude and has a crest factor which is between about three and six, an approximation to the vibration dose value may be determined from the estimated vibration dose value (eVDV). Use of the estimated dose value is not recommended for vibration with time-varying characteristics or shocks.

An assessment of train induced vibration can be undertaken by determining the VDV over a 16 hour day and 8 hour night period (taken to be 0700 to 2300 hours and 2300 to 0700 hours). This takes account of the level of vibration generated by each event, the duration of each event and the total number of events during the day and night periods. In homes, adverse comment about building vibrations is likely when the vibration levels to which occupants are exposed are only slightly above thresholds of perception. The Standard provides the following criteria for the assessment of vibration effect.

Table 1: Criteria for assessing adverse comment from vibration levels

Vibration dose value ranges which might result in various probabilities of adverse comment within residential buildings			
Place and time	Low probability of adverse comment m. s -1.75	Adverse comment possible m. s -1.75	Adverse comment probable m. s -1.75
Residential buildings 16 hr day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential buildings 8 hr night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8
Office buildings 16 hr day	0.4 to 0.8	0.8 to 1.6	1.6 to 3.2

The above values can be used for both vertical and horizontal vibration, provided that they are calculated according to the appropriate frequency weightings.

The weighted vibration levels can be aggregated to derive the VDVs. The VDV is a single figure descriptor that represents the cumulative dose of transient vibrations, taking into account the frequency spectrum and duration of each event. Probability of adverse comment to vibration is proportional to the speed, weight, length and number of trains passing the assessment location. There is likely to be little variation in these dimensions of passenger trains. The frequency of passage and laden weight of freight trains may vary with industrial market demands.

Additional guidance in BS 6472-1:2008 is given on the thresholds of perception of continuous whole-body vibration. Although it is recognised that thresholds vary widely among individuals the standard defines broad categories of thresholds of perception; as stated below: Approximately half the people in a typical population,

when standing or seated, can perceive a vertical W_b weighted peak acceleration of 0.015 m/s^2. A quarter of the people would perceive a vibration of 0.01 m/s^2 peak, but the least sensitive quarter would only be able to detect a vibration of 0.02 m/s^2 peak or more. Perception thresholds are slightly higher for vibration duration of less than about 1 s.

The weightings W_b (for vertical motion) and W_d (for horizontal motion) are defined in BS 6841 and reproduced in BS 6472.

In cases where it is not possible to measure within buildings, either because of denial of access or for a building yet to be constructed, it will be necessary to estimate the vibration environment to be expected within the building. The presence of a building tends to compress the ground locally by virtue of its weight, which therefore affects the vibration propagation in its vicinity. Calculation of building vibration response is performed by considering the mass, stiffness and damping properties of the structure, and by applying the pre-defined excitation function. Simplified methods exist to calculate the building vibration response under both internal and external excitation and should be applied conservatively.

Noise arising from the vibration of building structures (whether caused by ground-borne vibration, acoustic excitation from external sources, or from internal sources) is sometimes heard within buildings. It is typically characterized by low-frequency noise in the spectral region below about 100 Hz. BS6472 – 1: 2008 does not define acceptable levels for re-radiated noise levels within buildings. London authority Supplementary Planning Documents indicate that 35 dB $L_{Amax,slow}$ should not be exceeded in residential buildings. The design aims for major railway projects in the UK have been set at 40 dB $L_{Amax,slow}$ within residential buildings. Projects that have adopted such criteria are the Channel Tunnel Rail Link, Docklands Light Railway, Bank Line Extension, Woolwich Line Extension, Jubilee Line Extension, and Thames link 2000. For the purposes of this assessment 35 to 40 dB $L_{Amax,slow}$ is the design target in the proposed residential buildings.

Survey Measurements

Vibration level measurements were made on Sunday 22nd March 2015. Measurements of LAeq, 1s dB noise levels were made simultaneously to vibration level measurements. The purpose of the survey was to qualitatively and quantitatively characterise the level of ground borne vibration at the development site. The measured vibration levels should be representative of excitation due to typical train movements on the nearby West Hampstead Thameslink railway line. Due to piling operations taking place Monday to Saturday, the survey was conducted on a Sunday.

All acoustic measurements were undertaken by a consultant certified as competent in environmental noise and vibration monitoring and in accordance with the principles of BS 7445: 2003 and BS 6412: 2008. Noise measurement instrumentation used conforms to the specifications of Type 1 as defined by BS EN 61672 and an inventory is given in Table 2 below.

Table 2: Inventory of Measurement Equipment

System	*Item*	*Make & model*	*Serial Number*
1	PC based data logger	Asus EeePC901	89OAAQ016532
1	Type 1 DAQ	Roga PlugnDAQ	119
1	Accelerometer	PCB 333B42	38562
1	Accelerometer	PCB 333B42	39882
1	Accelerometer	PCB 333B42	39881

1	Preamplifier	PCB 426E01	30009
1	Microphone	PCB 377B02	140762
2	Sound Level Meter	Sinus Tango	0001113
2	Preamplifier	Sinus 907144.5	20005
2	Microphone	BSWA Tech MP201	4502376
3	Sound Level Meter	NTi XL2 TA	A2A-08541-E0
3	Microphone & Preamplifier	M2230	3424
1, 2, 3	Anemometer, Barometer, thermometer	Skywatch Xplorer 4	YKF20481-1
1, 2, 3	Acoustic Calibrator	Graigar ND9	N524726
1	Hand held Shaker	Total SRC706	N50013

Each acoustic measurement system was field calibrated before and after the survey. No drift in calibration was found to occur on any of the acoustic measurement systems.

The microphones of systems 2 was fitted with an open cell foam windshield. Metrological conditions were measured during the attended survey with the Skywatch Xplorer 4. Wind speeds were measured between 0 and 1 m/s during the survey, with a typical speed of 0 m/s. Gusts above 5 m/s were not observed at the development site. Day time temperatures were measured up to 18 C at the measurement positions (in the sun). The sky was 50% overcast throughout the survey period. The atmospheric pressure was measured at 1017 hPa with no variation.

The ground was observed to be infill at the surface, with pile spoils largely stiff London clay.
Measurements were made on pile heads P7 and P5 and identified in Figure 1 below. These are the nearest to the West Hampstead Thameslink railway line. The pile concrete had been allowed to cure for 1 week prior to measurement and appeared light in colour and dry.

Figure 1: Site Layout and Measurement Positions

Measurements of acceleration were made in 3 orthogonal axis, horizontal toward the track (x), horizontal along the boundary (y), vertical (z). The orientation of the accelerometer was the same for all train movement events and for all positions. The measurements were made between 11:00 and 17:00, with each movement noted. Some train movements coincided with high noise levels due to aircraft passing overhead or buses on Iverson Road. The accelerometers can be affected by airborne noise, therefore these events have been excluded. The measurement purpose was to characterise the vibration signature of typical train movements so that the vibration exposure during a busier Monday to Friday period can be calculated.

The axis directions are illustrated at the measurement on pile 7 in Figure 2 below.

Figure 2: Illustration of measurement axis

The integrated 1 second acceleration level (m/s2) for axis x,y,z has been used to calculated the VDV for each event. The highest Root Mean Square (RMS) acceleration for each event and the VDV calculated over the duration is shown in Table 3 below. The 1 second measurements for each of these movements are presented in Appendix A.

Table 3: Measured acceleration and calculated VDV levels

Time	Event	Duration	a.z.wd	a.x.wb	a.y.wb	VDVz	VDVx	VDVy
11:26	train pulling away	00:00:19	0.001045	0.0017	0.017878	0.020786	0.017875	0.020783
11:27	train pulling in	00:00:17	0.000995	0.001649	0.01732	0.022564	0.017321	0.022566
11:29	train pulling in	00:00:29	0.001258	0.002016	0.02909	0.041978	0.029097	0.041979
11:32	train pulling away	00:00:16	0.000917	0.001603	0.006411	0.007773	0.006414	0.007776
11:34	2 trains straight thru	00:00:29	0.001258	0.002016	0.02909	0.041978	0.029097	0.041979
11:34	train straight thru	00:00:05	0.001021	0.001368	0.024908	0.029928	0.02491	0.02993

11:41	train pulling away	00:00:19	0.003539	0.003655	0.014477	0.016604	0.014469	0.016597
11:43	train pulling in	00:00:16	0.003056	0.00451	0.003719	0.004333	0.003714	0.004328
11:45	train pulling away	00:00:17	0.000876	0.001481	0.006517	0.008182	0.006523	0.008186
11:56	train pulling away	00:00:19	0.001091	0.001783	0.019597	0.022766	0.019587	0.02276
12:09	train pulling in	00:00:15	0.003251	0.003549	0.008679	0.01064	0.008672	0.010633
12:13	train pulling in	00:00:22	0.000998	0.002559	0.002557	0.001807	0.003929	0.003927
12:14	train straight thru	00:00:16	0.00087	0.001563	0.024795	0.030797	0.024791	0.03079

The train movements in Table 3 have been used to determine the average vibration exposure for a train pulling in to West Hampstead Thameslink, a train pulling away, and a train travelling straight through without stopping. Analysis has shown no difference in exposure between pile 5 and pile 7. The summarised results are presented in Table 4 below.

Table 4: Summary of train movement event vibration levels

Event	Duration	a.z.wb	a.x.wd	a.y.wd	VDVz	VDVx	VDVy
train pulling in	00:00:18	0.002075	0.003067	0.008069	0.009836	0.008409	0.010363
train pulling away	00:00:18	0.001494	0.002044	0.012976	0.015222	0.012974	0.015221
train straight thru	00:00:17	0.00105	0.001649	0.026264	0.034234	0.026266	0.034233

The VDVs calculated for each type of train movement are used to predict the vibration exposure during a scheduled Monday to Friday in the following section.

Planning Condition 14 Assessment

The measured spectral RMS acceleration has been assessed to determine the impact of train movements on the development. Ground borne vibration at the site boundary with Iverson Road was not perceptible. The road surface has low depth surface texture typical of urban roads in residential areas, there are no aggressive speed control measures that would cause high levels of vibration. The adjacent section of Iverson Road is not a known haul route for Heavy Goods Vehicles or mobile plant. Further assessment of vibration due to road traffic is considered unnecessary.

The proposed residential dwelling is within 10m of the railway boundary and 17m to the nearest rail head. Measurements of vibration level were taken at 10m from the railway boundary.

The Thameslink Train Times[iii], has been used to determine the total number of scheduled passenger movements during typical Monday to Friday operation. The number of freight movements typical for this line has been determined from the slots available, as published on the Freight Master timetable[iv]. It has been determined that freight uses the West Hampstead railway line and not the West Hampstead Thameslink railway line.

The number of events of each type of train movement has been used with the measurements of acceleration in mm/s^2 (Table 11). The calculated VDV from measured values for each type of train movement is presented in Table 5 below.

Table 5: Measured VDV's for each type of train movement

Movement	VDV m/s$^{1.75}$	Number of events day	Number of events nights	Duration of event
Passenger Train non-stop	0.03	75	5	12
Passenger train stopping	0.01	118	23	15

The daily exposure eVDV$_N$ has been calculated and is compared to the BS6472 ranges for probability of adverse comment in Table 6 below.

Table 6: Calculated eVDV$_N$ compared with BS6472 adverse comment ranges, residential

Period	Calculated eVDV$_N$ m/s$^{1.75}$	BS 6472 adverse comment probability ranges of VDV m/s$^{1.75}$		
		Low	*Possible*	*Probable*
16h day	0.11	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
8h night	0.05	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

The VDV analysis has shown that there is a less than Low probability of adverse comment during the daytime and a less than Low probably of adverse comment during the night time, according the assessment methodology of BS 6472 -1: 2008. However the human response and sensitivity to vibration is varied, the laden weight and speed of freight trains can also vary, although the adjacent section of track is speed limited. It is likely that some train movements will be felt by some people in dwellings along the northern boundary of the site. It is stated in BS6472 that "In homes, adverse comment about building vibrations is likely when the vibration levels to which occupants are exposed are only slightly above thresholds of perception. A 10 dB reduction in vibration level would reduce the possibility of vibration perception.

Table 7: Calculated eVDV$_N$ compared with BS6472 adverse comment ranges, office

Period	Calculated eVDV$_N$ m/s$^{1.75}$	BS 6472 adverse comment probability ranges of VDV m/s$^{1.75}$		
		Low	*Possible*	*Probable*
16h day	0.11	0.4 to 0.8	0.8 to 1.6	1.6 to 3.2

There is a less than Low probability of adverse comment in offices, according to BS6472.

To accurately predict structure borne noise, mathematical modelling such as finite element analysis should be undertaken on a variety of possible foundation and structure configurations. A simplified method has been used, assuming the piles provide no loss due to foundation coupling with the ground and amplification due to a raised ground floor slab. It is predicted that structure borne noise from rail movements within plots 25m of the railhead may be between L_{AFmax} 38 dB and 42 dB (+/- 5 dB) if no specific vibration mitigation is employed in the design. This is slightly than the design target of 35 to 40 L_{AFmax} dB and likely to cause some disturbance. There is variation in the source data and variation in the results produced by the empirical re-radiated noise calculation methodology, resulting in an uncertainty of +/- 5 dB.

Vibration induced noise levels normally decay 1 to 3 dB (A) per floor in a steel frame building. It is therefore assumed that vibration induced L_{AFmax} dB noise levels will be acceptable on upper floors if acceptable in the ground floor. To reduce the vibration induced noise levels it is recommended that piles within 20m of the northern boundary (47m to the railhead) will need to be isolated from the building by the use of a resilient bedding material. The natural frequency of the isolating material should be 25Hz or less. Suitable products are made by Regupol, Sylomer or Mason Industries. Formwork or bedding is preferable to spring damper systems and should provide a vibration transmission reduction of 10 dB or more.

The vibration exposure and re-radiated noise have been calculated with a reduction of 10 dB in vibration level. Table 7 below shows comparison of the predicted VDV with mitigation against the BS6472-1:2008 complaint probability.

Table 7: Predicted $eVDV_N$ levels with Vibration Isolation Building Bedding

Period	eVDV $m/s^{1.75}$	Probability adverse comment
16 hour Day	0.01	***less than Low***
8 hour Night	0.007	***less than Low***

The horizontal vibration levels were the highest of the three directions measured and is the data where empirical correlations are suited. As vibration is measured at pile caps the worst case assumption is that there is no foundation coupling loss into the building. However a modest coupling loss has been included.

It is unlikely that the vibration exposure where pile heads are treated with a vibration isolation material of natural frequency less than 25 Hz would result in complaints due to vibration from passing trains.
It is predicted that re-radiated noise from vibration would result in internal noise levels between 33 to 37 L_{AFmax} dB with this mitigation in place. These maxima levels are below the design target of 35 to 40 L_{AFmax} dB and unlikely to give rise to complaints.

Conclusion

NRG Consulting has carried out an assessment of the Consented Development at 159 – 161 Iverson Road, in accordance with the criteria of Condition 14 of permission dated 21 February 2014 of Planning Application 2013/7505/P. This Planning Condition requires a survey and assessment of vibration affecting the site to be carried out in accordance with the methodology in report *13P282* 13P282 JT R1 260 - 188AA.

A survey of vibration has been carried out at two monitoring locations on the site. Analysis of the measured data has shown that without mitigation vibration levels due to passing trains will be perceptible at times. The overall daily vibration exposure has been assessed in accordance with BS6472 probability of complaints. It was found that without mitigation vibration exposure carries a Possible likelihood of complaints.

It has been proposed that vibration isolating building bedding maybe applied to the pile heads. The building bedding pads are to have a natural frequency of 25Hz or less and provide a vibration reduction of 10 dB. Piles within 20m of the northern boundary (47m to the railhead) are required to be treated with this vibration isolation.

In view of all the above, the information presented with regard to the imposed Planning Conditions 14 is considered acceptable, in our opinion.

Appendix A

Event	Time	a.rms.z.wb	a.rms.x.wd	a.rms.y.wd	VDVz	VDVx	VDVy	VDVzxy
train pulling away	11:26:35	0.000787	0.000787	0.000529	0.000529	0.000528	0.000528	0.001085
train pulling away	11:26:36	0.000636	0.00086	0.000828	0.000861	0.000827	0.00086	0.00149
train pulling away	11:26:37	0.000764	0.000971	0.00144	0.001484	0.001438	0.001482	0.002311
train pulling away	11:26:38	0.000666	0.001021	0.003007	0.003051	0.003006	0.003049	0.004432
train pulling away	11:26:39	0.000788	0.001101	0.008538	0.008573	0.008539	0.008574	0.012174
train pulling away	11:26:40	0.000773	0.001163	0.015228	0.015596	0.015225	0.015594	0.022086
train pulling away	11:26:41	0.000713	0.001202	0.017878	0.020042	0.017875	0.020038	0.028366
train pulling away	11:26:42	0.001045	0.001346	0.012489	0.020758	0.01249	0.020755	0.029385
train pulling away	11:26:43	0.000726	0.001373	0.005288	0.02078	0.005288	0.020777	0.029417
train pulling away	11:26:44	0.000726	0.0014	0.002681	0.020781	0.002683	0.020778	0.02942
train pulling away	11:26:45	0.00081	0.001437	0.002208	0.020782	0.002209	0.020779	0.029423
train pulling away	11:26:46	0.000868	0.001483	0.002062	0.020782	0.002064	0.020779	0.029426
train pulling away	11:26:47	0.000842	0.00152	0.002196	0.020783	0.002193	0.02078	0.029429
train pulling away	11:26:48	0.000832	0.001553	0.002556	0.020784	0.002556	0.020781	0.029432
train pulling away	11:26:49	0.000931	0.001601	0.002659	0.020786	0.002662	0.020782	0.029437
train pulling away	11:26:50	0.000749	0.00162	0.002055	0.020786	0.002055	0.020783	0.029438
train pulling away	11:26:51	0.000894	0.001656	0.001341	0.020786	0.001339	0.020783	0.02944
train pulling away	11:26:52	0.000734	0.001672	0.001187	0.020786	0.001182	0.020783	0.029441
train pulling away	11:26:53	0.000567	0.001678	0.001099	0.020786	0.001095	0.020783	0.029442
train pulling away	**11:26:54**	0.00081	0.0017	0.000925	0.020786	0.000926	0.020783	**0.029443**
train pulling in	11:27:42	0.000837	0.000837	0.000908	0.000908	0.000909	0.000909	0.001534
train pulling in	11:27:43	0.000769	0.000958	0.001409	0.001466	0.001409	0.001466	0.002284
train pulling in	11:27:44	0.000676	0.001013	0.003517	0.003543	0.003517	0.003543	0.005112
train pulling in	11:27:45	0.00078	0.001092	0.005765	0.00596	0.005766	0.005961	0.0085
train pulling in	11:27:46	0.000735	0.001144	0.006103	0.007174	0.006103	0.007175	0.01021
train pulling in	11:27:47	0.000782	0.001202	0.0044	0.007415	0.004398	0.007415	0.010556
train pulling in	11:27:48	0.000869	0.001277	0.002582	0.007443	0.002579	0.007442	0.010602
train pulling in	11:27:49	0.000668	0.0013	0.002041	0.007453	0.002038	0.007453	0.01062
train pulling in	11:27:50	0.000641	0.001319	0.002498	0.007476	0.002496	0.007476	0.010655
train pulling in	11:27:51	0.000995	0.001415	0.006044	0.008172	0.006044	0.008171	0.011643
train pulling in	11:27:52	0.000752	0.001442	0.011069	0.011813	0.011069	0.011813	0.016768
train pulling in	11:27:53	0.000732	0.001466	0.014759	0.016084	0.014759	0.016084	0.022793
train pulling in	11:27:54	0.000809	0.001499	0.01732	0.019903	0.017321	0.019903	0.028187
train pulling in	11:27:55	0.000813	0.00153	0.016322	0.021849	0.016326	0.021851	0.030938
train pulling in	11:27:56	0.000763	0.001553	0.01292	0.022488	0.012921	0.02249	0.031842
train pulling in	11:27:57	0.000753	0.001574	0.006935	0.022539	0.006938	0.022541	0.031915
train pulling in	11:27:58	0.000918	0.001618	0.004532	0.022548	0.004534	0.02255	0.03193
train pulling in	**11:27:59**	0.000861	0.001649	0.00517	0.022564	0.005168	0.022566	**0.031954**
train pulling in	11:29:32	0.000847	0.000847	0.000328	0.000328	0.000327	0.000327	0.000965
train pulling in	11:29:33	0.000771	0.000966	0.000491	0.000514	0.000493	0.000515	0.001209
train pulling in	11:29:34	0.000694	0.001024	0.000702	0.000747	0.000709	0.000754	0.001475

train pulling in	11:29:35	0.000716	0.001081	0.001035	0.001099	0.001041	0.001106	0.001897
train pulling in	11:29:36	0.000703	0.001126	0.001488	0.001588	0.001488	0.00159	0.002514
train pulling in	11:29:37	0.000837	0.001203	0.001731	0.001979	0.00173	0.001979	0.003047
train pulling in	11:29:38	0.000853	0.001273	0.001703	0.002208	0.001703	0.002208	0.003372
train pulling in	11:29:39	0.000849	0.001332	0.001365	0.002284	0.001362	0.002284	0.003494
train pulling in	11:29:40	0.000629	0.001348	0.001102	0.002314	0.001102	0.002314	0.00354
train pulling in	11:29:41	0.000627	0.001364	0.001099	0.002343	0.001102	0.002343	0.003583
train pulling in	11:29:42	0.000791	0.001401	0.001032	0.002365	0.001034	0.002365	0.003626
train pulling in	11:29:43	0.000684	0.00142	0.00089	0.002377	0.00089	0.002377	0.003649
train pulling in	11:29:44	0.000852	0.001464	0.000928	0.002391	0.000928	0.002391	0.003684
train pulling in	11:29:45	0.000796	0.001495	0.001236	0.002432	0.001239	0.002433	0.003751
train pulling in	11:29:46	0.000849	0.001533	0.001308	0.002482	0.001312	0.002482	0.00383
train pulling in	11:29:47	0.001035	0.001607	0.001257	0.002521	0.001259	0.002522	0.003912
train pulling in	11:29:48	0.000818	0.001633	0.001288	0.002563	0.001284	0.002564	0.003976
train pulling in	11:29:49	0.000804	0.001656	0.001468	0.00263	0.00147	0.00263	0.004071
train pulling in	11:29:50	0.000906	0.001692	0.001583	0.002712	0.001581	0.002712	0.004192
train pulling in	11:29:51	0.000566	0.001698	0.001497	0.002773	0.0015	0.002773	0.004273
train pulling in	11:29:52	0.000859	0.001725	0.001365	0.002813	0.001364	0.002813	0.004336
train pulling in	11:29:53	0.000739	0.001739	0.00136	0.00285	0.001358	0.002851	0.00439
train pulling in	11:29:54	0.000715	0.001751	0.001589	0.002917	0.001585	0.002917	0.004481
train pulling in	11:29:55	0.00088	0.001779	0.001565	0.002975	0.001568	0.002976	0.004568
train pulling in	11:29:56	0.000759	0.001793	0.001261	0.002999	0.001263	0.003	0.004605
train pulling in	**11:29:57**	0.00076	0.001807	0.000932	0.003006	0.000933	0.003007	**0.00462**
train pulling away	11:32:05	0.000745	0.000745	0.000704	0.000704	0.000703	0.000703	0.001243
train pulling away	11:32:06	0.000896	0.000988	0.000999	0.001055	0.000997	0.001053	0.001789
train pulling away	11:32:07	0.000846	0.0011	0.002048	0.002083	0.00205	0.002085	0.003146
train pulling away	11:32:08	0.0008	0.00117	0.002904	0.00308	0.002904	0.00308	0.00451
train pulling away	11:32:09	0.000577	0.001187	0.002684	0.003451	0.002685	0.003452	0.005024
train pulling away	11:32:10	0.000712	0.001224	0.002228	0.003592	0.002226	0.003593	0.005226
train pulling away	11:32:11	0.000745	0.001264	0.002416	0.003763	0.002415	0.003763	0.00547
train pulling away	11:32:12	0.000851	0.001324	0.003057	0.004119	0.003055	0.004118	0.005974
train pulling away	11:32:13	0.000733	0.001354	0.002471	0.004247	0.00247	0.004246	0.006156
train pulling away	11:32:14	0.000712	0.001379	0.001386	0.004259	0.001386	0.004258	0.006178
train pulling away	11:32:15	0.000782	0.001414	0.001813	0.004293	0.001815	0.004292	0.006233
train pulling away	11:32:16	0.00071	0.001436	0.004242	0.005076	0.004244	0.005076	0.007321
train pulling away	11:32:17	0.000694	0.001455	0.006411	0.006965	0.006414	0.006967	0.009958
train pulling away	11:32:18	0.00074	0.001479	0.005906	0.00773	0.005908	0.007732	0.011033
train pulling away	11:32:19	0.000827	0.001514	0.002994	0.007773	0.002994	0.007775	0.011098
train pulling away	11:32:20	0.000896	0.001558	0.000932	0.007773	0.000933	0.007776	0.011104
train pulling away	**11:32:21**	0.000917	0.001603	0.000723	0.007773	0.000725	0.007776	**0.011111**
2 trains straight thru	11:34:08	0.000786	0.000786	0.001656	0.001656	0.001655	0.001655	0.00247
2 trains straight thru	11:34:09	0.000752	0.000916	0.00247	0.002586	0.002469	0.002586	0.00377
2 trains straight thru	11:34:10	0.000643	0.000967	0.004541	0.004656	0.00454	0.004655	0.006654
2 trains straight thru	11:34:11	0.000706	0.001029	0.005565	0.006148	0.005565	0.006148	0.008756
2 trains straight thru	11:34:12	0.000759	0.001098	0.005857	0.007145	0.005862	0.007147	0.010165

2 trains straight thru	11:34:13	0.000656	0.001131	0.008057	0.009088	0.008058	0.009089	0.012903
2 trains straight thru	11:34:14	0.000682	0.001167	0.009209	0.01088	0.00921	0.010881	0.015432
2 trains straight thru	11:34:15	0.001062	0.00133	0.010189	0.012548	0.010184	0.012546	0.017794
2 trains straight thru	11:34:16	0.000698	0.001354	0.014157	0.015964	0.014158	0.015965	0.022618
2 trains straight thru	11:34:17	0.0006	0.001367	0.021322	0.02283	0.021324	0.022831	0.032316
2 trains straight thru	11:34:18	0.00087	0.00142	0.023961	0.027846	0.023953	0.027842	0.039403
2 trains straight thru	11:34:19	0.000994	0.001498	0.019349	0.029344	0.019345	0.029339	0.041522
2 trains straight thru	11:34:20	0.000744	0.001521	0.011525	0.029517	0.011525	0.029512	0.041768
2 trains straight thru	11:34:21	0.000833	0.001554	0.011635	0.029694	0.011637	0.029689	0.042019
2 trains straight thru	11:34:22	0.000806	0.001581	0.018063	0.030662	0.018064	0.030658	0.043388
2 trains straight thru	11:34:23	0.000868	0.001616	0.022923	0.032818	0.022921	0.032814	0.046437
2 trains straight thru	11:34:24	0.000758	0.001635	0.020714	0.034049	0.020712	0.034045	0.048178
2 trains straight thru	11:34:25	0.000801	0.001658	0.015369	0.034397	0.015366	0.034393	0.04867
2 trains straight thru	11:34:26	0.000868	0.001689	0.014014	0.034632	0.014015	0.034628	0.049003
2 trains straight thru	11:34:27	0.000743	0.001704	0.022568	0.036097	0.022566	0.036093	0.051075
2 trains straight thru	11:34:28	0.00092	0.001739	0.02909	0.039417	0.029097	0.039417	0.055771
2 trains straight thru	11:34:29	0.00079	0.001758	0.023044	0.040521	0.023043	0.04052	0.057332
2 trains straight thru	11:34:30	0.000778	0.001774	0.014484	0.040685	0.014485	0.040685	0.057564
2 trains straight thru	11:34:31	0.000702	0.001785	0.014375	0.040843	0.014378	0.040842	0.057788
2 trains straight thru	11:34:32	0.001258	0.001886	0.019117	0.041324	0.019113	0.041324	0.058471
2 trains straight thru	11:34:33	0.001013	0.001924	0.018578	0.04174	0.018586	0.04174	0.059061
2 trains straight thru	11:34:34	0.001049	0.001965	0.015465	0.041935	0.015468	0.041935	0.059338
2 trains straight thru	11:34:35	0.00103	0.002001	0.010361	0.041974	0.010363	0.041975	0.059394
2 trains straight thru	11:34:36	0.00073	0.00201	0.005607	0.041977	0.005604	0.041978	0.059399
2 trains straight thru	**11:34:37**	0.00067	0.002016	0.003878	0.041978	0.003875	0.041979	**0.059401**
train straight thru	11:34:40	0.001004	0.001004	0.004723	0.004723	0.00472	0.00472	0.006752
train straight thru	11:34:41	0.001021	0.001204	0.012954	0.01301	0.012952	0.013009	0.018438
train straight thru	11:34:42	0.000724	0.001242	0.024908	0.02536	0.02491	0.025361	0.035887
train straight thru	11:34:43	0.000628	0.001262	0.024493	0.029656	0.024494	0.029658	0.04196
train straight thru	11:34:44	0.000839	0.001319	0.012831	0.029912	0.012832	0.029914	0.042324
train straight thru	**11:34:45**	0.00083	0.001368	0.006415	0.029928	0.006415	0.02993	**0.042348**
train pulling away	11:41:39	0.000939	0.000939	0.000346	0.000346	0.000342	0.000342	0.001058
train pulling away	11:41:40	0.000607	0.000977	0.000719	0.000728	0.000722	0.000731	0.001422
train pulling away	11:41:41	0.000694	0.001034	0.002081	0.002089	0.002087	0.002095	0.003134
train pulling away	11:41:42	0.000663	0.001075	0.00592	0.005942	0.005918	0.005941	0.008472
train pulling away	11:41:43	0.000696	0.00112	0.012116	0.012287	0.012114	0.012285	0.017412
train pulling away	11:41:44	0.000594	0.001141	0.014477	0.016072	0.014469	0.016065	0.022753
train pulling away	11:41:45	0.00068	0.001176	0.009351	0.016513	0.009346	0.016507	0.023378
train pulling away	11:41:46	0.000745	0.00122	0.00598	0.016584	0.005984	0.016577	0.02348
train pulling away	11:41:47	0.000666	0.001247	0.002613	0.016587	0.002609	0.01658	0.023485
train pulling away	11:41:48	0.000807	0.001298	0.002322	0.016588	0.002316	0.016582	0.02349
train pulling away	11:41:49	0.000694	0.001324	0.002308	0.01659	0.002297	0.016583	0.023494
train pulling away	11:41:50	0.000956	0.001406	0.00236	0.016591	0.00236	0.016585	0.023501
train pulling away	11:41:51	0.001134	0.001536	0.002768	0.016595	0.002761	0.016588	0.023514
train pulling away	11:41:52	0.001038	0.00161	0.002653	0.016597	0.002656	0.016591	0.023523

train pulling away	11:41:53	0.001118	0.001697	0.002208	0.016599	0.002209	0.016592	0.023531
train pulling away	11:41:54	0.000966	0.00174	0.001845	0.016599	0.001846	0.016593	0.023535
train pulling away	11:41:55	0.001113	0.001808	0.001647	0.0166	0.001651	0.016593	0.02354
train pulling away	11:41:56	0.001593	0.002035	0.001815	0.0166	0.001813	0.016594	0.02356
train pulling away	11:41:57	0.001461	0.002158	0.002296	0.016602	0.0023	0.016595	0.023573
train pulling away	**11:41:58**	0.003539	0.003655	0.002557	0.016604	0.002561	0.016597	**0.02376**
train pulling in	11:43:00	0.002123	0.002123	0.001011	0.001011	0.001014	0.001014	0.002561
train pulling in	11:43:01	0.002456	0.002744	0.002977	0.002987	0.002972	0.002982	0.005034
train pulling in	11:43:02	0.002412	0.003085	0.003719	0.004057	0.003714	0.004051	0.00651
train pulling in	11:43:03	0.003056	0.003651	0.002655	0.004232	0.002655	0.004226	0.007007
train pulling in	11:43:04	0.00278	0.003926	0.000792	0.004233	0.00079	0.004227	0.007155
train pulling in	11:43:05	0.002793	0.004156	0.000492	0.004233	0.000497	0.004228	0.007285
train pulling in	11:43:06	0.003029	0.004422	0.000707	0.004234	0.000701	0.004228	0.007441
train pulling in	11:43:07	0.001615	0.004442	0.000744	0.004235	0.00074	0.004229	0.007453
train pulling in	11:43:08	0.001998	0.004487	0.000838	0.004237	0.000844	0.004231	0.007482
train pulling in	11:43:09	0.001178	0.004492	0.001532	0.004255	0.001532	0.004249	0.007506
train pulling in	11:43:10	0.001134	0.004497	0.001977	0.004303	0.001977	0.004298	0.007564
train pulling in	11:43:11	0.000825	0.004498	0.001699	0.004329	0.001699	0.004324	0.007594
train pulling in	11:43:12	0.000992	0.004501	0.000988	0.004332	0.00099	0.004327	0.007599
train pulling in	11:43:13	0.001105	0.004505	0.000601	0.004333	0.000598	0.004327	0.007602
train pulling in	11:43:14	0.000829	0.004506	0.000563	0.004333	0.000557	0.004328	0.007603
train pulling in	11:43:15	0.000926	0.004508	0.000497	0.004333	0.00049	0.004328	0.007604
train pulling in	**11:43:16**	0.000974	0.00451	0.000453	0.004333	0.000449	0.004328	**0.007606**
train pulling away	11:45:18	0.000807	0.000807	0.000872	0.000872	0.000876	0.000876	0.001476
train pulling away	11:45:19	0.000778	0.000943	0.001548	0.001585	0.001549	0.001587	0.002433
train pulling away	11:45:20	0.000597	0.000979	0.003	0.003056	0.002999	0.003056	0.004432
train pulling away	11:45:21	0.000577	0.001007	0.005184	0.005334	0.00519	0.00534	0.007615
train pulling away	11:45:22	0.00065	0.001048	0.006517	0.00715	0.006523	0.007157	0.010171
train pulling away	11:45:23	0.000665	0.001088	0.004518	0.00742	0.004524	0.007427	0.010554
train pulling away	11:45:24	0.000779	0.001154	0.002604	0.007448	0.002603	0.007455	0.0106
train pulling away	11:45:25	0.000584	0.001172	0.002348	0.007466	0.002347	0.007473	0.010628
train pulling away	11:45:26	0.000712	0.00121	0.003171	0.007526	0.003173	0.007533	0.010717
train pulling away	11:45:27	0.000803	0.001265	0.003947	0.007664	0.00394	0.00767	0.010917
train pulling away	11:45:28	0.000638	0.001285	0.004145	0.007823	0.004146	0.007829	0.011142
train pulling away	11:45:29	0.000625	0.001302	0.004334	0.008001	0.004328	0.008005	0.011393
train pulling away	11:45:30	0.000849	0.001358	0.004229	0.008153	0.004232	0.008157	0.011613
train pulling away	11:45:31	0.000646	0.001375	0.002737	0.008179	0.002738	0.008183	0.011651
train pulling away	11:45:32	0.00053	0.001382	0.001394	0.008181	0.001396	0.008185	0.011655
train pulling away	11:45:33	0.000582	0.001393	0.001	0.008181	0.000997	0.008185	0.011656
train pulling away	11:45:34	0.000876	0.001445	0.001051	0.008182	0.001056	0.008186	0.011663
train pulling away	**11:45:35**	0.000821	0.001481	0.000893	0.008182	0.000894	0.008186	**0.011668**
train pulling away	11:56:24	0.000771	0.000771	0.001012	0.001012	0.001014	0.001014	0.001627
train pulling away	11:56:25	0.000957	0.001045	0.0025	0.002516	0.002502	0.002519	0.00371
train pulling away	11:56:26	0.000834	0.001138	0.008843	0.008858	0.008845	0.008859	0.012579
train pulling away	11:56:27	0.000837	0.001213	0.019597	0.019798	0.019587	0.019789	0.028019

train pulling away	11:56:28	0.000871	0.001287	0.01768	0.022391	0.017676	0.022383	0.031686
train pulling away	11:56:29	0.00088	0.001352	0.01127	0.022742	0.011281	0.022735	0.032186
train pulling away	11:56:30	0.000683	0.001374	0.003833	0.022746	0.003832	0.02274	0.032193
train pulling away	11:56:31	0.000808	0.001413	0.002454	0.022747	0.002451	0.022741	0.032196
train pulling away	11:56:32	0.000837	0.001455	0.00268	0.022748	0.002677	0.022742	0.032199
train pulling away	11:56:33	0.000775	0.001483	0.00312	0.02275	0.003121	0.022744	0.032203
train pulling away	11:56:34	0.000771	0.001509	0.003925	0.022755	0.003925	0.022749	0.032212
train pulling away	11:56:35	0.001091	0.001603	0.00394	0.02276	0.003947	0.022754	0.032223
train pulling away	11:56:36	0.000816	0.00163	0.003443	0.022763	0.003448	0.022757	0.032229
train pulling away	11:56:37	0.000755	0.001648	0.003017	0.022765	0.003024	0.022759	0.032232
train pulling away	11:56:38	0.000666	0.001659	0.002441	0.022766	0.002433	0.02276	0.032234
train pulling away	11:56:39	0.000658	0.001669	0.001643	0.022766	0.001638	0.02276	0.032235
train pulling away	11:56:40	0.000772	0.001688	0.001398	0.022766	0.001394	0.02276	0.032236
train pulling away	11:56:41	0.000854	0.001715	0.001259	0.022766	0.001256	0.02276	0.032237
train pulling away	11:56:42	0.00099	0.001761	0.001147	0.022766	0.001143	0.02276	0.03224
train pulling away	**11:56:43**	0.000839	0.001783	0.001256	0.022766	0.001258	0.02276	**0.032241**
train pulling in	12:09:40	0.001077	0.001077	0.001302	0.001302	0.001306	0.001306	0.002135
train pulling in	12:09:41	0.000805	0.001153	0.002563	0.002605	0.002565	0.002607	0.003862
train pulling in	12:09:42	0.001274	0.001448	0.004766	0.004869	0.004768	0.004871	0.007038
train pulling in	12:09:43	0.001279	0.001631	0.008019	0.008278	0.008012	0.008273	0.011817
train pulling in	12:09:44	0.001098	0.001709	0.008679	0.010091	0.008672	0.010084	0.014368
train pulling in	12:09:45	0.001335	0.001849	0.00662	0.010529	0.006618	0.010522	0.015
train pulling in	12:09:46	0.001056	0.001897	0.004081	0.010588	0.004086	0.010581	0.015089
train pulling in	12:09:47	0.001523	0.002069	0.002476	0.010596	0.002479	0.010589	0.015122
train pulling in	12:09:48	0.001368	0.002161	0.002386	0.010603	0.002383	0.010596	0.015145
train pulling in	12:09:49	0.001127	0.0022	0.002398	0.01061	0.002392	0.010603	0.01516
train pulling in	12:09:50	0.003251	0.003409	0.002456	0.010617	0.00245	0.01061	0.015393
train pulling in	12:09:51	0.001822	0.003477	0.002473	0.010625	0.002471	0.010618	0.015418
train pulling in	12:09:52	0.001621	0.003517	0.002397	0.010632	0.002391	0.010625	0.015437
train pulling in	12:09:53	0.001168	0.003528	0.00219	0.010637	0.002193	0.01063	0.015446
train pulling in	12:09:54	0.001085	0.003536	0.001791	0.010639	0.001791	0.010632	0.015451
train pulling in	**12:09:55**	0.001247	0.003549	0.001284	0.01064	0.001287	0.010633	**0.015455**
train stopping	12:13:28	0.000884	0.000425	0.000427	0.000884	0.000425	0.000427	0.00107
train stopping	12:13:29	0.000726	0.001095	0.001092	0.000971	0.001102	0.001098	0.001834
train stopping	12:13:30	0.000631	0.001831	0.001833	0.001011	0.001888	0.00189	0.002856
train stopping	12:13:31	0.000803	0.002026	0.002021	0.0011	0.002332	0.00233	0.003475
train stopping	12:13:32	0.000665	0.002425	0.002429	0.001135	0.00283	0.002832	0.004161
train stopping	12:13:33	0.000998	0.002086	0.002082	0.001276	0.003019	0.003019	0.004456
train stopping	12:13:34	0.000769	0.001951	0.001947	0.001316	0.003143	0.003142	0.004635
train stopping	12:13:35	0.000576	0.001468	0.001464	0.001328	0.00318	0.003178	0.004688
train stopping	12:13:36	0.000843	0.001477	0.001476	0.001379	0.003216	0.003215	0.004752
train stopping	12:13:37	0.000894	0.001671	0.00167	0.001436	0.003273	0.003272	0.004846
train stopping	12:13:38	0.00094	0.001907	0.001908	0.001498	0.003364	0.003362	0.004986
train stopping	12:13:39	0.000793	0.001875	0.001883	0.001526	0.003442	0.003442	0.005102
train stopping	12:13:40	0.000723	0.001738	0.001734	0.001545	0.003497	0.003496	0.005181

train stopping	12:13:41	0.000834	0.001462	0.001455	0.001577	0.003523	0.003522	0.005225
train stopping	12:13:42	0.000819	0.001282	0.001281	0.001605	0.003538	0.003537	0.005254
train stopping	12:13:43	0.00087	0.00117	0.001169	0.001639	0.003549	0.003548	0.005279
train stopping	12:13:44	0.000826	0.001134	0.001146	0.001664	0.003558	0.003558	0.0053
train stopping	12:13:45	0.00072	0.001331	0.001333	0.001679	0.003575	0.003575	0.005328
train stopping	12:13:46	0.000933	0.001923	0.00192	0.001717	0.003648	0.003647	0.005437
train stopping	12:13:47	0.000889	0.002559	0.002557	0.001747	0.003851	0.00385	0.005719
train stopping	12:13:48	0.000858	0.002047	0.002041	0.001772	0.003926	0.003924	0.005826
train stopping	12:13:49	0.000841	0.000946	0.000942	0.001794	0.003929	0.003927	0.005838
train stopping	**12:13:50**	0.000735	0.000448	0.000454	0.001807	0.003929	0.003927	**0.005842**
train straight thru	12:14:48	0.0006	0.0006	0.000672	0.000672	0.000675	0.000675	0.001126
train straight thru	12:14:49	0.000676	0.000763	0.001284	0.001308	0.001281	0.001305	0.001998
train straight thru	12:14:50	0.000665	0.000855	0.002995	0.003022	0.002992	0.003018	0.004356
train straight thru	12:14:51	0.00059	0.0009	0.006534	0.006608	0.006542	0.006615	0.009393
train straight thru	12:14:52	0.00087	0.001053	0.012132	0.01239	0.012126	0.012386	0.017551
train straight thru	12:14:53	0.000847	0.001149	0.021152	0.021749	0.021144	0.021741	0.030773
train straight thru	12:14:54	0.000809	0.001214	0.024795	0.027851	0.024791	0.027844	0.039401
train straight thru	12:14:55	0.000865	0.001286	0.021062	0.029893	0.021055	0.029885	0.042289
train straight thru	12:14:56	0.00073	0.001318	0.015297	0.030392	0.015304	0.030386	0.042997
train straight thru	12:14:57	0.000836	0.001368	0.010277	0.030491	0.010273	0.030485	0.043138
train straight thru	12:14:58	0.000816	0.00141	0.011477	0.030643	0.011473	0.030636	0.043354
train straight thru	12:14:59	0.000829	0.00145	0.011246	0.030781	0.011243	0.030774	0.04355
train straight thru	12:15:00	0.000824	0.001486	0.006458	0.030796	0.006461	0.030789	0.043573
train straight thru	12:15:01	0.000717	0.001506	0.002672	0.030796	0.002682	0.03079	0.043574
train straight thru	12:15:02	0.000714	0.001525	0.001676	0.030796	0.00168	0.03079	0.043575
train straight thru	12:15:03	0.000776	0.00155	0.001279	0.030797	0.001275	0.03079	0.043576
train straight thru	**12:15:04**	0.000671	0.001563	0.001012	0.030797	0.001011	0.03079	**0.043576**

References

[i] *13P282 JT R1 260 - 188AA, "159- 161 Iverson Road, London, Environmental Noise Assessment Report", Aulos Acoustics, 20 November 2013, downloaded from Camden Planning Portal 29/07/2014*

[ii] BS 6472-1:2008 "Guide to evaluation of human exposure to vibration in buildings – Part 1 Vibration sources other than blasting", BSI, 2008

[iii] Train times, Thameslink, 14 December 2014 to 16 May 2015, downloaded from http://www.thameslinkrailway.com/your-journey/timetables/

[iv] www.freightmaster.co.uk accessed March 2015