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Noise & Vibration Planning Report Sandy Brown

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5 – 17 Haverstock Hill, London

Noise and vibration planning report

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A	29 Mar 16		Jake Howarth	Andrew Long
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Summary

Sandy Brown Associates LLP (SBA) has been commissioned by Chapman BDSP Ltd to provide acoustic advice in relation to the proposed mixed use development at 5 - 17 Haverstock Hill.

An environmental noise and vibration survey has been carried out at the site. The noise survey was performed between 25 February 2016 and 29 February 2016. The vibration survey was performed on 29 February 2016.

The representative background sound levels measured during the survey were $L_{A90,15min}$ 56 dB during the daytime and $L_{A90,15min}$ 47 dB at night.

Based on the requirements of Camden Council and on the results of the noise survey, all plant must be designed such that the cumulative noise level at 1 m from the worst affected windows of the nearby noise sensitive premises does not exceed L_{Aeq} 51 dB during the daytime and L_{Aeq} 42 dB during the night.

The average ambient noise levels measured during the survey were $L_{Aeq,16h}$ 66 dB during the daytime and $L_{Aeq,8h}$ 64 dB at night.

Typical maximum noise levels of up to L_{AFmax} 84 dB were recorded during the night.

An initial facade sound insulation assessment has been carried out to determine the required acoustic performance of the facade and provide guidance on the ventilation strategy.

The vibration survey indicated that tactile vibration is not expected to be an issue within the proposed development. Re-radiated noise from underground trains is expected to result in noise intrusion criteria to be exceeded on some residential floors. Mitigation measures will be required.

Contents

1 Introduction

Sandy Brown Associates LLP (SBA) has been commissioned by Chapman BDSP Ltd to provide acoustic advice in relation to the proposed mixed use development at 5 - 17 Haverstock Hill, London.

An environmental noise survey has been carried out, the purpose of which was to establish the existing ambient and background sound levels in the vicinity of the site and nearby noise sensitive premises.

The background sound levels measured during the survey are used as the basis for setting limits for noise emission from proposed building services plant. These limits are set in accordance with the requirements of Camden Council.

The environmental noise survey results are also used to inform facade sound insulation, which will be assessed in order to determine the necessary performance required to achieve appropriate internal noise levels for residences set in accordance with BS 8233:2014 *Sound insulation and noise reduction for buildings*, World Health Organisation guidance and the requirements of the London Borough of Camden (LBC).

A vibration survey was performed with the objective of assessing the degree to which the proposed development will be affected by tactile vibration and also re-radiated structure-borne noise resulting from train movements along the London Underground Northern line, which passes below the site.

This report presents:

- the noise and vibration survey methods
- the survey results
- a discussion of acceptable limits for noise emission from building services plant
- minimum sound insulation requirements for the building envelope
- an assessment of tactile and ground-borne vibration levels.

2 Site description

2.1 The site and its surroundings

The site location in relation to its surroundings is shown in Figure 1. A six-storey building currently occupies the site and it is understood this was formerly a multi-storey carpark used by the Metropolitan Police. It is proposed that the existing building will be demolished to make way for the buildings forming the proposed 5-17 Haverstock Hill development.

Haverstock Hill (A502) runs along the north side of the site with Adelaide Road running along the south. A London Underground station, Chalk Farm Station is located to the east on the corner of Haverstock Hill and Adelaide Road.

The site is located in a mixed-use area. There are residences directly to the east, south and west. The Haverstock School is located directly north of the site and retail premises are located along Adelaide Road and Haverstock Hill. The Chalk Farm London Underground station adjoins the building to the south.

Figure 1 Site map (courtesy of Google Earth Pro)

2.2 Adjacent premises

The nearest noise sensitive premises to the site are highlighted in Figure 1 are as follows:

- Eton Place located approximately 20 metres to the north west of the site (outlined in red)
- Haverstock School approximately 25 metres to the north (highlighted in green)
- Residential flats approximately 33 metres to the east (highlighted in blue)
- Bridge House approximately 36 metres to the south (highlighted in yellow)

3 Method

Details of the equipment used, the noise indices and the weather conditions during the survey are provided in Appendix A. Further information on the specific survey method is provided in this section.

3.1 Noise survey method

3.1.1 Unattended measurements

Two unattended noise monitoring positions were used and measurements were taken at the site over a four day period to determine the existing background sound levels in the vicinity of nearby noise sensitive premises both on Haverstock Hill and Adelaide Road.

The unattended measurements were performed over 15 minute periods between 11:35 on 25 February 2015 and 14:05 on 29 February 2016. The equipment was installed by and collected by Richard Deane and Steven Wheeler.

The measurement positions used during the survey are indicated in Figure 1 as ‘L1’ and ‘L2’ on Haverstock Hill and Adelaide Road respectively. Photographs showing the measurement locations are provided in Figure 2. At location L1 the microphone was placed above the second floor flat roof, overlooking the road. At location L2 the microphone was placed approximately 1 m outside of a fourth floor window. Background noise levels at these locations were considered to be reasonably representative of those experienced at the nearest noise sensitive premises and the ambient and maximum noise levels experienced at the facades of the proposed new buildings.

Figure 2 Photographs showing unattended measurement locations L1 (left) and L2 (right)

3.1.2 Attended measurements

Attended sample measurements, synchronised with the unattended measurements, were performed by Richard Deane and Steven Wheeler at three ground level locations around the existing building. These are indicated in Figure 1 as positions 1 to 3. The attended measurements were carried out on 29 February 2016, over 15 minute periods, with the purpose of determining the existing noise levels from road traffic, pedestrians and other significant noise sources in the area. The measurements taken underneath the logging locations (1 & 2) are also useful for gauging the difference in noise level with height.

In each case the microphone was mounted on a tripod approximately 1.5 m above the ground level and at least 1 m from any other reflective surface.

3.2 Vibration survey method

Vibration measurements were performed at three locations within the existing building in order to determine the maximum vibration levels from the passage of trains on the underground tracks beneath the site. The vibration measurement locations are indicated in Figure 3 and Figure 4 as positions V1, V2 and V3. Simultaneous noise measurements were also taken at position V1 (see section 3.2.1).

These measurements were performed on 29 February 2016.

For the vibration measurements, three accelerometers were set up at each location in order to record acceleration time histories in three axes (X, Y & Z). Train pass-bys were recorded over 10 second measurement periods. The acceleration time-histories were post processed in order to obtain Vibration Dose Values (VDVs) and the 1/3 octave band slow weighted RMS acceleration values. The latter were used to predict the re-radiated L_{ASmax} levels in the proposed building.

At each position, the accelerometers were magnetically fixed to a metal washer, which was glued to the concrete floor slab away from the boundaries of the room.

The VDV measurements were conducted in three axes as follows:

- X axis - Horizontal vibration;
- Y axis - Horizontal vibration, perpendicular to X axis;
- Z axis - Vertical vibration.

Figure 3 Vibration measurements locations – Existing ground floor

Figure 4 Vibration measurements locations – Existing first floor

3.2.1 Simultaneous noise measurement

Simultaneous noise and vibration measurements were performed at location 1. The measurements were carried out in order to compare predictions of re-radiated noise (based on measured vibration) with directly measured re-radiated noise (with a microphone).

For each measurement the microphone was mounted on a tripod approximately 1.5 m above the floor level.

4 Measurement results

4.1 Observations

The dominant noise sources observed at the site during the survey consisted of vehicles (including busses and HGVs passing on Haverstock Hill and Adelaide Road), aircraft flyovers and children playing in Haverstock School yard.

Less significant noise sources included pedestrians passing and occasional sirens.

Re-radiated structure-borne noise from underground train movements was clearly audible throughout the existing building.

4.2 Unattended measurement results

The results of the unattended noise measurements are summarised in the following sections. Graphs showing the results of the unattended measurements are provided in Appendix B.

Period-averaged ambient sound levels ($L_{\mathrm{Aeq,T}}$) have been derived for each position along with representative background sound levels. Representative background sound levels have been derived in line with guidance set out within BS 4142:2014. These have been quantified using a statistical analysis of the continuous logging measurements as presented in Appendix C.

4.2.1 Position L1

The results of the unattended noise measurements taken at location 'L1' are summarised in the following tables. A graph showing the results of the unattended measurements is provided in Appendix B.

The day and night time ambient noise levels measured during the unattended survey are presented in Table 1.

Measurements at position L1 were free field measurements, and as such a 3 dB correction would need to be applied to derive facade noise levels.

Table 1 Ambient noise levels measured during the survey at location L1 (free-field noise levels)

Date	Daytime (07:00 – 19:00) $L_{Aeq,12h}$ (dB)	Evening (19:00-23:00) $L_{Aeq,4h}$	Night (23:00 – 07:00) $L_{Aeq,8h}$ (dB)
25 February 2016	65[1]	64	62
26 February 2016	66	65	64
27 February 2016	64	67	63
28 February 2016	66	64	61
29 February 2016	66[2]	-	-
Weekday average	66	65	63
Weekend average	65	66	62

[1] Measurement made over 7 hour period
[2] Measurement made over 7 hour period

The representative background sound levels measured during the unattended survey are given in Table 2

Table 2 Representative background noise levels measured at location L1

	Daytime (07:00 – 19:00) $L_{A90,15min}$ (dB)	Evening (19:00-23:00) $L_{A90, 15min}$ (dB)	Night (23:00 – 07:00) $L_{A90, 15min}$ (dB)
Weekday	55	54	52
Weekend	55	53	48

4.2.2 Position L2

The results of the unattended noise measurements taken at location 'L2' are summarised in the following tables. A graph showing the results of the unattended measurements is provided in Appendix B.

The day and night time ambient noise levels measured during the unattended survey are presented in Table 3.

Measurements at position L2 were facade measurements, and as such a 3 dB correction would need to be applied in order to derive free-field noise levels.

Table 3 Ambient noise levels measured during the survey at location L2 (facade noise levels)

Date	Daytime (07:00 – 19:00) $L_{Aeq,12h}$ (dB)	Evening (19:00-23:00) $L_{Aeq,4h}$	Night (23:00 – 07:00) $L_{Aeq,8h}$ (dB)
25 February 2016	65[1]	65	63
26 February 2016	66	67	65
27 February 2016	66	67	64
28 February 2016	65	66	63
29 February 2016	68[2]	-	-
Weekday average	66	66	64
Weekend average	66	67	64

[1] Measurement made over 7 hour period
[2]Measurement made over 7 hour period

The representative background sound levels measured during the unattended survey are given in Table 4.

Table 4 Representative background noise levels measured at location L2

	Daytime (07:00 – 19:00) $L_{A90,15min}$ (dB)	Evening (19:00-23:00) $L_{A90,\ 15min}$ (dB)	Night (23:00 – 07:00) $L_{A90,\ 15min}$ (dB)
Weekday	56	55	49
Weekend	55	56	49

4.3 Attended measurement results

The sound pressure levels recorded during the attended measurements are summarised in Table 5. The dominant noise sources noted during the measurements are also described in the table. All the attended measurements were performed over 15 minute periods.

Measurement positions 1 and 2 are considered to be facade measurements and measurement position 3 is considered to be a free field measurement.

Table 5 Sound pressure levels from attended measurements

Position	Start time	Sound pressure levels (dB)			Noise sources
		$L_{Aeq,15min}$	$L_{AFmax,15min}$	$L_{A90,15min}$	
1	11:50	70	93	59	Road traffic from Haverstock Hill, siren passing at 11:52, Helicopter pass at 11:55
2	12:05	66	83	54	Road traffic from Adelaide Road including bus passes, school children, siren at 12:06
1	12:20	69	86	54	Road traffic, including HVGs, from Haverstock Hill, pedestrians passing
2	12:50	67	81	55	Road traffic from Adelaide Road including busses, school children, lorry unloading
3	13:12	58	76	49	Road traffic from Haverstock Hill and Adelaide Road, school children playing in yard
3	13:27	57	72	50	

4.4 Vibration measurement results

4.4.1 Tactile vibration measurements

The following table presents the VDVs measured at locations V1, V2 and V3. These measurements were performed on 29 February 2016,

Table 6 Vibration dose values measured at location V1, V2 and V3

Position	Time	Event/source	VDV ($m/s^{1.75}$)		
			X	Y	Z
V1	14:47	Train	0.000328	0.000226	0.003224
V1	14:51	Train	0.000326	0.000205	0.003009
V1	14:52	Background	0.000162	0.000116	0.000438
V1	14:53	Train	0.000232	0.000195	0.002201
V1	14:54	Background	0.000212	0.000162	0.001551
V1	15:56	Train	0.000176	0.000138	0.000432
V1	15:57	Train	0.000271	0.000231	0.002467
V1	15:59	Train	0.000191	0.000182	0.001476
V1	15:03	Train	0.000267	0.000235	0.001787
V1	15:04	Train	0.000316	0.000250	0.002768
V2	15:18	Train	0.001203	0.001872	0.009848
V2	15:19	Train	0.001009	0.001046	0.000964
V2	15:19	Background	0.000435	0.000535	0.001876
V2	15:20	Train	0.000774	0.000413	0.008286
V2	15:24	Train	0.000604	0.000335	0.008272
V3	15:27	Train	0.000591	0.000346	0.003058
V3	15:27	Background	0.000926	0.000409	0.000535
V3	15:29	Train	0.000209	0.000209	0.001549
V3	15:30	Background	0.000289	0.000222	0.000604
V3	15:32	Background	0.000351	0.000299	0.000436
V3	15:33	Train	0.000376	0.000275	0.001718
V3	15:33	Train	0.000611	0.000418	0.002770
V3	15:35	Train	0.00037	0.000535	0.001856

4.4.2 Re-radiated noise measurements

Ground-borne noise within the proposed development was predicted using an empirical formula described in '*Guidelines for the Measurement & Assessment of Groundborne Noise and Vibration (2nd Edition)*' published by the Association of Noise Consultants in 2012.

The predicted re-radiated noise level, from the vibration measurements at locations V1, V2 and V3 are presented in the following tables in terms of L_{ASmax}. The corresponding noise level measurements have also been provided for comparative purposes where available.

Table 7 Predicted re-radiated noise levels from vibration measurements at location V1

	Vibration location V1		
Start time	Duration (s)	Predicted L_{ASmax} (dB)	Measured L_{ASmax} (dB)
14:47	10	37	40
14:51	10	30	36
14:53	10	38	39
15:56	10	37	40
15:57	10	41	40
15:59	10	27	-
15:03	10	29	-
15:04	10	37	-

Table 8 Predicted re-radiated noise levels from vibration measurements at location V2

	Vibration location V2	
Start time	Duration (s)	Predicted L_{ASmax} (dB)
15:18	10	41
15:19	10	29
15:20	10	42
15:24	10	42

Table 9 Predicted re-radiated noise levels from vibration measurements at location V3

	Vibration location V3	
Start time	Duration (s)	Predicted L_{ASmax} (dB)
15:27	10	35
15:29	10	31
15:33	10	31
15:33	10	28
15:35	10	32

5 Assessment criteria

5.1 NPPF and NPSE

The National Planning Policy Framework (NPPF) sets out the government planning requirements, and supersedes previous guidance notes such as PPG24. No specific noise criteria are set out in the NPPF, or in the Noise Policy Statement for England (NPSE) to which it refers.

The NPPF states:

'Planning policies and decisions should aim to:

- *Avoid noise from giving rise to significant adverse impacts on health and quality of life as a result of new development;*
- *Mitigate and reduce to a minimum other adverse impacts on health and quality of life arising from noise from new development, including through the use of conditions;*
- *Recognise that development will often create some noise and existing businesses wanting to develop in continuance of their business should not have unreasonable restrictions put on them because of changes in nearby land uses since they were established; and*
- *Identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason.'*

The NPSE states that its aims are as follows:

'Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

- *Avoid significant adverse impacts on health and quality of life;*
- *Mitigate and minimise adverse impacts on health and quality of life; and*
- *Where possible, contribute to the improvement of health and quality of life.'*

As such, although neither of these documents sets out specific acoustic criteria for new residential development, the requirement to control both the effect of existing noise on the new development and the effect of noise from the development on the surroundings needs to be considered.

5.2 External noise levels – noise egress

5.2.1 Standard guidance

Guidance for noise emission from proposed new items of building services plant is given in BS 4142: 2014 '*Methods for rating and assessing industrial and commercial sound*'.

BS 4142 provides a method for assessing noise from items such as building services plant against the existing background sound levels at the nearest noise sensitive.

BS 4142 suggests that if the noise level is 10 dB or more higher than the existing background sound level, it is likely to be an indication of a significant adverse impact. If the level is 5 dB above the existing background sound level, it is likely to be an indication of an adverse impact. If the level does not exceed the background level, it is an indication of having a low impact.

If the noise contains 'attention catching features' such as tones, bangs etc, a penalty, based on the type and impact of those features, is applied.

5.2.2 Local Authority criteria

From email correspondence with Carlos Martin, Planning Officer, it is understood that LBC stipulates the noise egress criteria set out in Development Policy DP28, as reproduced in Table 10.

Table 10 LBC noise egress criteria

Noise description and location of measurement	Period	Noise level
Noise at 1 m external to a sensitive facade	Day, evening and night (00:00-24:00)	5 dB(A) < L_{A90}
Noise that has a distinguishable discrete continuous note (whine, hiss, screech, hum) at 1 m external to a sensitive facade	Day, evening and night (00:00-24:00)	10 dB(A) < L_{A90}
Noise that has distinct impulses (bangs, clicks, clatters, thumps) at 1 m external to a sensitive facade	Day, evening and night (00:00-24:00)	10 dB(A) < L_{A90}
Noise at 1 m external to sensitive façade where L_{A90} > 60 dB	Day, evening and night (00:00-24:00)	L_{Aeq} 55 dB

5.3 Internal noise level – noise ingress

5.3.1 Standard guidance

Guidance on acceptable internal noise levels in residential dwellings is given in BS 8233:2014 *Sound insulation and noise reduction for buildings*, and is also provided by the World Health Organisation. The guidance given by BS 8233 and WHO is shown in Table 11.

Table 11 Internal noise criteria for sleeping/resting

Internal space	Indoor ambient noise level L_{Aeq} (dB)		
	BS 8233 (07:00 to 23:00)	BS 8233 (23:00 to 07:00)	WHO
Living rooms	35	-	30/35[1]
Dining room	40	-	-
Bedrooms	35	30[2]	30[2]

[1] WHO does not differentiate between different types of living spaces, but recommends L_{Aeq} 30 dB in relation to sleep disturbance and L_{Aeq} 35 dB in relation to speech intelligibility. WHO provides a 16 hour time base when referring to speech intelligibility and an 8 hour time base when referring to sleep disturbance.

[2] BS 8233 notes that individual noise events can cause sleep disturbance, and that a guideline value may be set depending on the character and number of events per night, although no specific limit is provided. Section 3.4 of the WHO guidelines for community noise suggests that good sleep will not generally be affected if internal levels of L_{Amax} 45 dB are not exceeded more than 10-15 times per night.

BS8233:2014 suggests an indoor ambient noise limit of L_{Aeq} 55 dB within retail spaces.

5.3.2 Local Authority requirements

LBC does not have specific criteria relating to acceptable internal noise levels within apartments from environmental noise sources. As such, the guidance provided in BS 8233:2014 is assumed to be the most relevant.

5.4 Tactile vibration criteria

5.4.1 Standard guidance

Tactile vibration is that which is perceived as mechanical motion. BS 6472-1: 2008 *Guide to Evaluation of Human Exposure to Vibration in Buildings Part 1: Vibration Sources Other Than Blasting* provides procedures for assessing the potential human response to vibration.

Vibration is assessed in terms of the equivalent 'Vibration Dose Value'. This relates the level and duration of vibration.

For information, the BS 6472-1: 2008 assessment table is reproduced below:

Table 12 BS 6472-1: 2008 tactile vibration assessment criteria

Vibration dose values (m/s$^{1.75}$) above which might result in various degrees of adverse comment within residential buildings.			
Place	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Residential buildings 16 hr day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential building 8 hr night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

Note that offices and workshops, multiplying factors of 2 and 4 respectively should be applied to the above vibration dose value ranges for a 16 hr day.

It is important to note that people exhibit wide variations of vibration tolerance. Specific values are dependent upon social and cultural factors, psychological attitudes and expected degree of intrusion.

5.4.2 Local Authority requirements

LBC requirements relating to tactile vibration in buildings is provided in Table C of DP28, which is reproduced in Table 13.

Table 13 LBC tactile vibration limits in buildings taken from Table C of DP28

Vibration description and location of measurement	Period	Time	Vibration Dose Value (VDV)
Vibration inside dwellings	Day and evening	0700-2300	0.2-0.4 $ms^{-1.75}$
Vibration inside dwellings	Night	2300-0700	0.13 $ms^{-1.75}$
Vibration inside offices	Day, evening and night	0000-2400	0.4 $ms^{-1.75}$

5.5 Re-radiated noise criteria

5.5.1 Residential buildings – standard guidance

There is currently no international or British Standard which provides guidance on assessing the impact of ground-borne noise from railways on the occupants of a residential building. The Association of Noise Consultants (ANC) guidelines '*Measurement and assessment of ground-borne noise and vibration*', 2nd edition published in 2012, is generally used as the basis of assessments such as this.

This document also provides discussion on the relevant research that has been carried out, along with a summary of typically adopted criteria.

The most relevant items are set out below:

- The American Public Transit Association (APTA) guidelines recommend criteria of between 30 and 40 dB(A) depending on the density and type of residential properties. They do not define where within a building these apply, or the time response that should be used
- The Federal Transit Administration (FTA) of the US Department of Transportation, recommends limits for maximum pass-by levels of 35 dB(A) for frequent events (more than 70 events per day) and 43 dB(A) for infrequent events
- London Underground Limited has studied the relationship between ground-borne noise levels and complaint thresholds. This was used to define a complaint threshold of 40 dB L_{Amax}.
- The ANC guidelines also note that Local Authority guidelines for ground-borne noise were published in London and the South East, and state a limit of 35 dB L_{Amax}.

In all of the above examples, the time constant is not defined, with the exception of the Local Authority guidelines in London and the South East, which is defined as having a fast time weighting. BS ISO 14837-1:2005, however suggests that ground-borne noise should be quantified using the L_{Amax} parameter with the slow time constant.

It should be noted that most of this research relates to residential accommodation, and is aimed at providing good sleeping / resting conditions.

5.5.2 Residential buildings – local authority requirements

DP28 states that "*Where dwellings may be affected by ground borne regenerated noise internally from, for example, railways or underground trains within tunnels noise levels within the rooms should not be greater than 35 dB(A)max".*

The above criterion does not specify a time-weighting constant. A slow time-weighting is recommended based on BS ISO 14837-1:2005. Therefore, the proposed criterion for the residences within the proposed development is L_{ASmax} 35 dB.

5.5.3 Retail

Ground floor retail units with an open door policy are not as sensitive to structure-borne noise from trains as offices and residences. Also, spaces such as busy restaurants and retail spaces with music playing in the background are less susceptible to being affected by structure-borne noise from underground trains. As such, a re-radiated noise criterion of L_{ASmax} 40-45 dB is recommended.

5.5.4 Summary

The proposed re-radiated noise criteria are summarised in Table 14.

Table 14 Proposed re-radiated noise criteria

Space	Re-radiated noise limit (L_{ASmax}, dB)
Residences	35
Retail	40-45

6 Plant noise limits – noise egress

6.1 Basic limits

Based on the representative background noise levels given in Table 2 and Table 4 and the requirements of LBC the plant noise egress limits have been set achieve a level of 5 dB below the existing background levels at each noise sensitive receiver. These limits are presented in Table 15.

Table 15 Noise egress limits at 1 m from noise sensitive receivers

Noise sensitive receiver	Plant noise limit at 1 m from facade, L_{Aeq} (dB)					
	Weekday			Weekend		
	Day	Evening	Night	Day	Evening	Night
A) Haverstock Hill Flats	50	49	47	50	48	43
B) Eton Place (east side)	50	49	47	50	48	43
B) Eton Place (west side)	51	50	44	50	51	44
C) Bridge House	51	50	44	50	51	44
D) Haverstock School	50	N/A*	N/A*	N/A*	N/A*	N/A*

*Noise limit not considered to be applicable as the premises would not normally be occupied during this period.

6.2 Assessment

An assessment of the major building services plant items is currently being undertaken and the results of which will be issued in a separate document. All plant items are being designed to achieve the plant noise limits set out above, including any corrections for attention catching features.

7 Facade sound insulation – noise ingress

This section assesses the required facade sound insulation performance. In principle, the required facade specification depends on two factors – the external noise levels at the site, and the internal noise criteria.

The following assessment is based on achieving the internal noise levels recommended in BS 8233, which are set out in Section 5.3.

7.1 External noise levels

In order to allow an assessment of the worst case scenario, the highest ambient (L_{Aeq}) and maximum (L_{AFmax}) noise levels recorded during the attended and unattended noise surveys have been used. The results are given below in Table 16.

Table 16 Worst-case facade noise levels

Elevation	Daytime (07:00 – 19:00) $L_{Aeq,12h}$ (dB)	Evening (19:00-23:00) $L_{Aeq,4h}$	Night (23:00 – 07:00) $L_{Aeq,8h}$ (dB)	Night (23:00 – 07:00) L_{AFmax} (dB)*
Haverstock Hill	69	70	66	84
Adelaide Road	68	67	65	87

*Typical L_{AFmax} exceeded 10-15 times per night

7.2 Indicative facade sound insulation

To achieve the internal noise criteria given in Section 5.3 for bedrooms, living areas and retail minimum facade sound insulation requirements have been determined, based on the external noise levels at each facade stated above and an assessment of representative maximum noise level events.

The minimum sound insulation performances for the main facades are given in Table 17.

Please note that these values are only initial values and may be subject to change following the results of the three-dimensional acoustic modelling.

Table 17 Facade sound insulation performance requirements

Elevation	Minimum facade sound insulation performance $R_w + C_{tr}$ (dB)		
	Bedrooms	Living room/Kitchen	Retail
Haverstock Hill	41[1]	36	17
Adelaide Road	40[1]	35	16

[1]Perofromance driven by achieving L_{AFmax} 45 dB criterion at night.

7.3 Guidance on facade construction, glazing, and ventilation strategy

The following table sets out some examples of glazing build ups and ventilation strategies that could be employed to achieve the required sound insulation performance for the various elevations.

Table 18 Example glazing configurations and ventilation strategies

Sound insulation R_w+C_{tr} (dB)	Example glazing configuration	Ventilation Strategy
≤10	6 mm/12 mm/6 mm	Open windows
10-15	6 mm/12 mm/6 mm	Limited open area opening windows
15-29	6 mm/12 mm/6 mm	Attenuated passive ventilation (eg, trickle vents)
30-32	6.4 mm/12 mm/6 mm	Attenuated passive ventilation
33-35	6.4 mm/12 mm/10 mm	High performance acoustically attenuated passive ventilation
36-38	12.8 mm/12 mm/10 mm	Mechanical ventilation (eg, whole house ventilation)
39-41	12.8 mm/20 mm/10 mm	Mechanical ventilation (eg, whole house ventilation)
42-44	This represents a very high sound insulation performance. The highest performance typically achievable using double glazing is around R_w+C_{tr} 42 dB (16.8 mm/20 mm/16.8 mm). For higher performances, a substantial facade construction, limited glazing area, and mechanical ventilation is likely to be required.	

The attenuation of sound provided by an open window is typically in the region of 10 to 15 dB when located in a solid facade, depending on the open area. As such, where the required facade sound insulation performance is less than R_w+C_{tr} 10 dB, it is likely that opening windows can be used whilst achieving the necessary internal noise levels.

In areas where the necessary facade sound insulation is between R_w+C_{tr} 10 and 15 dB, partially open windows may be used for ventilation purposes depending on the open area.

The performance required by each element will depend on the construction of the solid elements, the glazing specification, the relative areas of the solid and glazed elements, and the ventilation strategy (including the acoustic performance of the trickle ventilators and the number of ventilators required to serve individual rooms, if applicable).

As the design progresses, a more detailed facade sound insulation assessment will need to be performed, taking into account the factors listed above, to ensure that the overall performance requirements will be met.

8 Vibration assessment

8.1 Tactile vibration

BS 6472 states that the assessment should be based on the axis along which the highest VDV is measured. At all measurement locations, the highest VDV was measured on the Z axis.

Published timetables indicate that approximately 40 trains pass by the site per hour. This will result in approximately 640 trains passing on the tracks between 07:00 – 23:00. At night, between 23:00 – 07:00, the number of trains operating along this line is expected to be approximately 320 trains assuming a 24 hour tube service which may be in place in the near future.

Based on the number of trains passing on the tracks between 07:00 – 23:00 and 23:00 – 07:00, the equivalent VDVs over a 16 hour day and an 8 hour night are given in Table 19.

Table 19 Equivalent vibration dose values

Location	Maximum VDV measured (m/s$^{1.75}$)	Equivalent VDV (m/s$^{1.75}$)	
		Daytime (07:00 – 23:00)	Night time (23:00 – 07:00)
V1	0.003224	0.0162	0.0136
V2	0.008286	0.0417	0.0350
V3	0.003058	0.0154	0.0129

By comparing the calculated day and night time vibration dose values above with the assessment table given in section 5.4 of this report, it can be seen that the predicted vibration dose values during the daytime and night periods are lower than the threshold of the ‘low probability of adverse comment’ category.

Levels experienced may vary depending on the type of train and position of the future buildings. However, it the measured vibration levels are below the lowest BS 6472 threshold, and it a significant increase in the number of trains would be required for the threshold to be exceeded. Tactile vibration due to trains is therefore not considered to be problematic at this site.

8.2 Re-radiated noise

During the vibration survey, approximately 23 individual train events were observed. The highest predicted L_{ASmax} level for all of these events was 42 dB at position V2.

The existing and proposed buildings are both concrete framed without basements. As such the predicted re-radiated noise levels from the acceleration measurements are arguable similar to the proposed situation. However, the type of foundations of the existing building is unknown. It is understood the proposed building is to have piled foundations. There is a possibility that this may increase vibration induction into the building.

Table 20 Summary of predicted and measured re-radiated noise levels

Position	Highest predicted noise level L_{ASmax} (dB)	Highest measured noise level L_{ASmax} (dB)	Dominant axis
V1 (ground floor)	41	40	Z
V2 (ground floor)	42	-	Z
V3 (first floor)	35	-	Z

It can be seen from the predicted L_{ASmax} levels given above that the criterion of L_{ASmax} 35 dB for residences is likely to be exceeded at ground floor level by up to 7 dB. The predicted re-radiated noise at first floor level meets the criterion but there is no safety margin and the level could very well increase at a different location on the floor plate. On this basis vibration isolation of residential dwelling is likely to be required on levels 0 – 4.

The recommended retail criterion of L_{ASmax} 40-45 dB should be met at the ground floor retail level. On this basis, vibration isolation is not recommended. However, it can be expected that re-radiated rail noise will be audible within the spaces. If this is not acceptable then isolation will be required.

As such, the vibration mitigation strategy for residences will need to be developed and it may be necessary to undertake a more extensive survey as the design progresses.

8.3 Potential mitigation measures

There are a number of potential vibration mitigation measures that could be adopted, examples of which include:

- A reduction in the transmission path
    - Vibration screen
    - Sleeved piles
- Additional building mass
- Building isolation
- Localised isolation of dwellings.

9 Conclusion

The representative measured background sound levels ranged from $L_{A90,15min}$ 49 dB during the night and $L_{A90,15min}$ 56 dB during the day. On the basis of the requirements of the Local Authority, the relevant plant noise limits at the worst affected existing noise sensitive premises should not exceed those given L_{Aeq} 51 dB during the daytime and L_{Aeq} 44 dB during the night. These limits are cumulative, and apply with all plant operating under normal conditions. If plant items contain tonal or attention catching features, the limits will be more stringent than those set out above.

An initial facade assessment has been carried out. The results of which indicate that the facades with direct line of site to the roads will require sealed facades and high performance glazing within bedrooms in order to control maximum levels during the night.

Tactile vibration is not considered to be an issue on this site. However, calculations and measurements suggest that vibration mitigation will be required in order to reduce structure borne noise from underground trains in line with LBC's standard criterion of L_{ASmax} 35 dB.

Appendix A

Survey details

Equipment

The unattended measurements were carried out using a Rion NL-52 and a Svan 957 sound level meter. The attended noise measurements were performed using a B&K 2250 sound level meter.

The vibration survey was carried out using a DA-20 vibration level meter. The re-radiated noise level measurements were carried out using a B&K 2250 sound level meter.

The calibration details for the equipment used during the survey are provided in Table A1.

Table A1 Equipment calibration data

Equipment description	Type/serial number	Manufacturer	Calibration expiry	Calibration certification number
Sound level meter	NL-52/00242702	Rion	4 Jun 17	1506331
Microphone	UC-59/06185	Rion	4 Jun 17	1506331
Pre-amp	NH-25/32730	Rion	4 Jun 17	1506331
Calibrator	CAL200/4499	Larson Davis	4 Jun 17	1506327
Sound level meter	SVAN957/12326	Svantek	03 Aug 17	1508454
Microphone	7052H/41518	Svantek	03 Aug 17	1508454
Pre-amp	SV12L/13571	Svantek	03 Aug 17	1508454
Calibrator	SV30A/10931	Svantek	03 Aug 17	1508440
Sound level meter	2250/2693829	Bruel & Kjaer	11 Feb 18	08930
Microphone	4189/2689268	Bruel & Kjaer	11 Feb 18	08930
Pre-amp	ZC0032/12061	Bruel & Kjaer	11 Feb 18	08930
Calibrator	4231/3001923	Bruel & Kjaer	11 Feb 18	08930
Data Recorder	DA-20/10870889	Rion	7 Sep 17	TCRT15/1252
Accelerometer	PV-87/33827	Rion	8 Sep 17	1509496
Accelerometer	PV-87/33828	Rion	8 Sep 17	1509497
Accelerometer	PV-87/33829	Rion	8 Sep 17	1509498
Vibration Calibrator	AT01/3015	AP Technology	8 Sep 17	1509495

Calibration of the meters used for the tests is traceable to national standards. The calibration certificates for the sound level meter(s) used in this survey are available upon request.

The sound and vibration level meters and the respective measurement chains were calibrated at the beginning and end of the measurements using their respective sound level calibrators. No significant calibration deviation occurred.

Noise indices

The equipment was set to record a continuous series of broadband sound pressure levels. Noise indices recorded included the following:

- $L_{\mathrm{Aeq},T}$ The A-weighted equivalent continuous sound pressure level over a period of time, T.
- $L_{\mathrm{AFmax},T}$ The A-weighted maximum sound pressure level that occurred during a given period, T, with a fast time weighting.
- $L_{\mathrm{ASmax},T}$ The A-weighted maximum sound pressure level that occurred during a given period, T, with a slow time weighting.
- $L_{\mathrm{A90},T}$ The A-weighted sound pressure level exceeded for 90% of the measurement period. Indicative of the background sound level.

The L_{A90} is considered most representative of the background sound level for the purposes of complying with any local authority requirements.

Sound pressure level measurements are normally taken with an A-weighting (denoted by a subscript 'A', eg L_{A90}) to approximate the frequency response of the human ear.

A more detailed explanation of these quantities can be found in BS7445: Part 1: 2003 *Description and measurement of environmental noise, Part 1. Guide to quantities and procedures.*

Vibration indices

For each measurement period a number of parameters were recorded. The most relevant of these are described below:

- The vibration dose value (VDV) in each of three axes with the appropriate frequency weightings (as defined in BS 6472-1:2008).
- The maximum RMS acceleration levels in each of three axes in one-third-octave bands, measured using the 'slow response' exponential time weighting.

Weather conditions

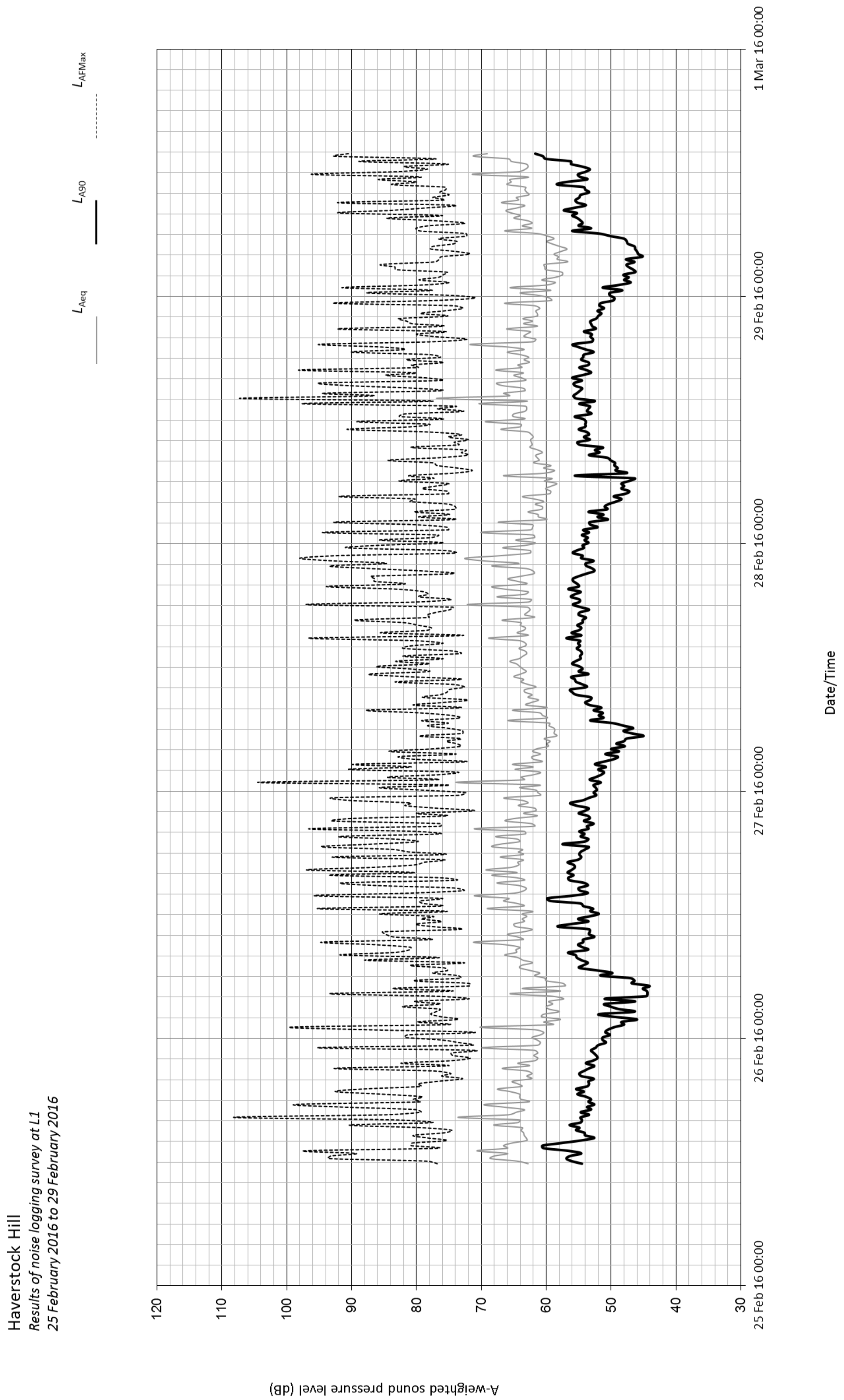
During the attended measurements carried out on 29 February 2016, the weather was generally clear and dry and no rain occurred. Wind speeds were generally low and did not affect the measurements.

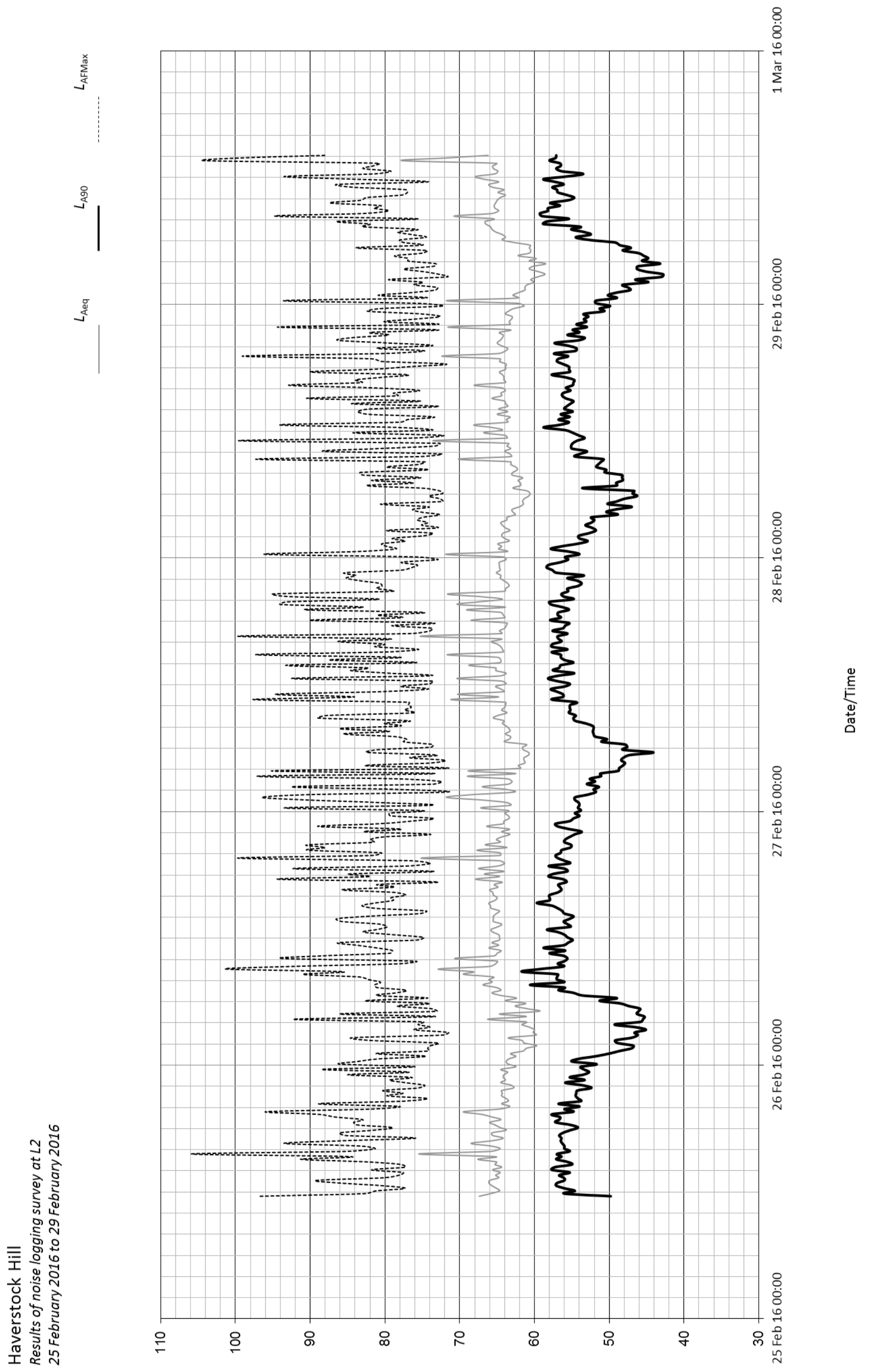
During the unattended noise measurements between 25 February 2016 and 29 February 2016, weather reports for the area indicated that temperatures varied between 6 °C at night and 15 °C during the day, and the wind speed was less than 11 m/s.

These weather conditions are considered suitable for obtaining representative measurements.

Appendix B

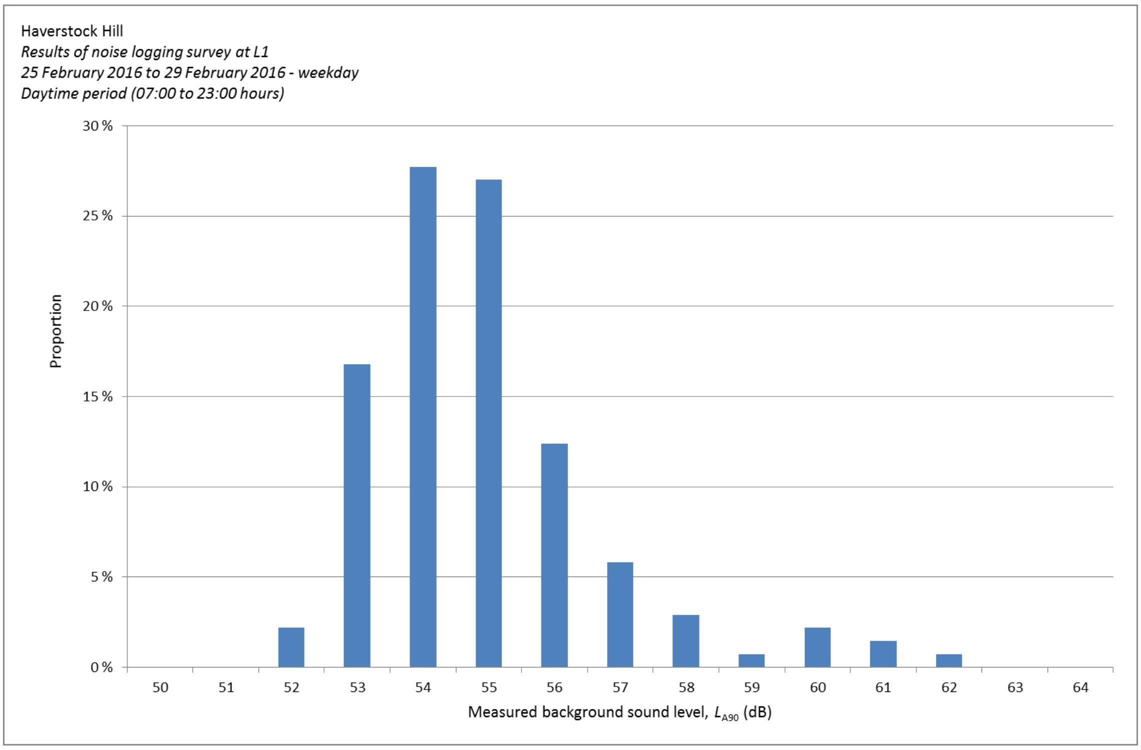
Results of unattended measurements at locations 1 & 2

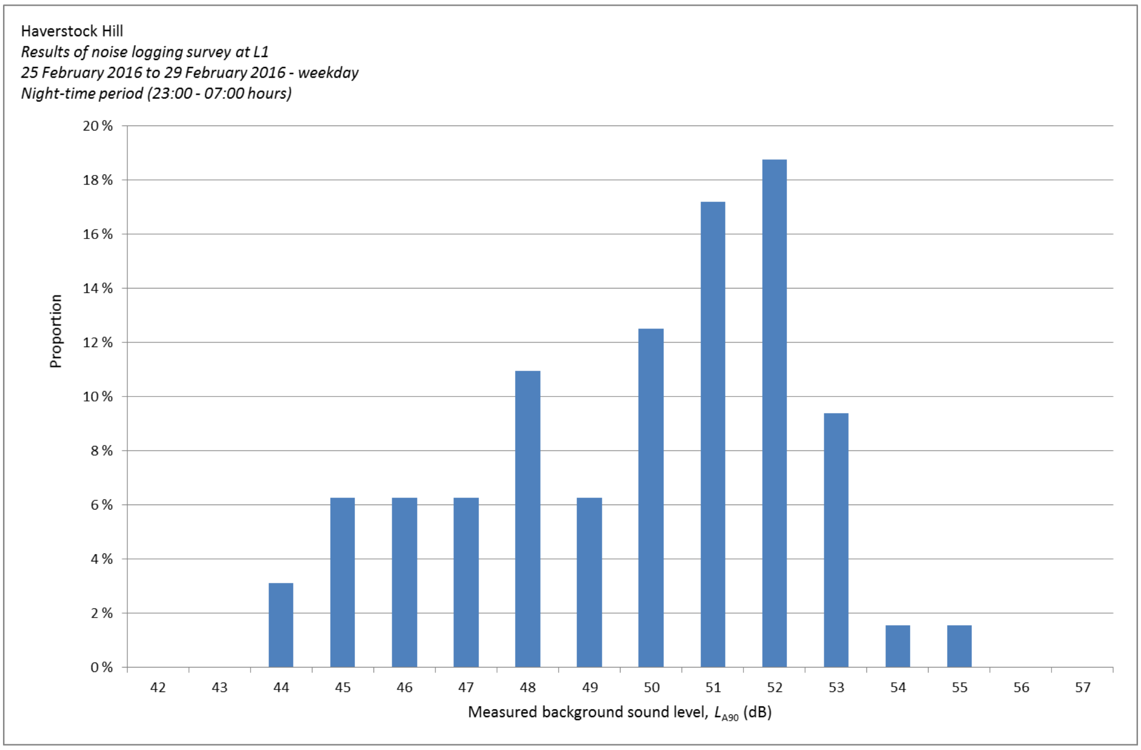

Haverstock Hill
Results of noise logging survey at L1
25 February 2016 to 29 February 2016
LAeq
LA90
LAFMax
A-weighted sound pressure level (dB)
120
110
100
90
80
70
60
50
40
30
25 Feb 16 00:00
26 Feb 16 00:00
27 Feb 16 00:00
28 Feb 16 00:00
29 Feb 16 00:00
1 Mar 16 00:00
Date/Time


Haverstock Hill
Results of noise logging survey at L2
25 February 2016 to 29 February 2016
L_{Aeq}
L_{A90}
L_{AFMax}
A-weighted sound pressure level (dB)
110
100
90
80
70
60
50
40
30
Date/Time
25 Feb 16 00:00
26 Feb 16 00:00
27 Feb 16 00:00
28 Feb 16 00:00
29 Feb 16 00:00
1 Mar 16 00:00

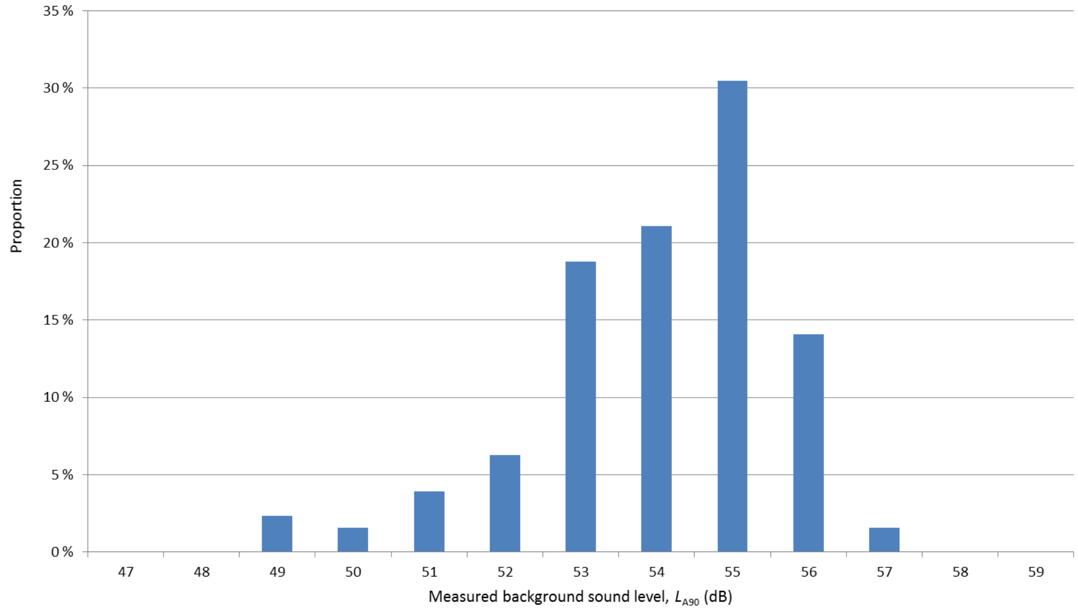
Appendix C

Statistical analyses of unattended measurements

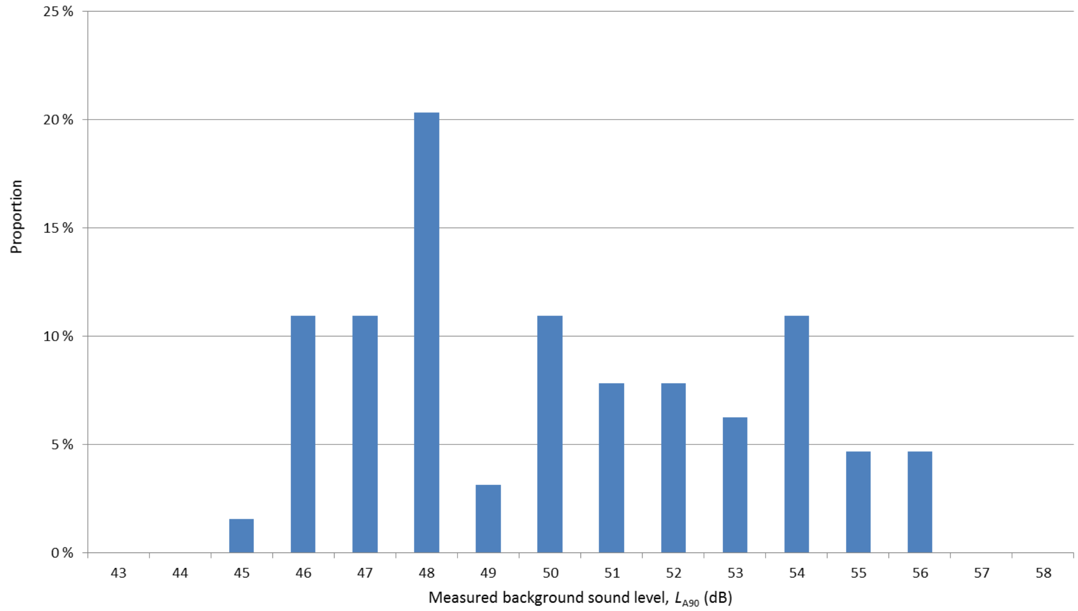

Haverstock Hill
Results of noise logging survey at L1
25 February 2016 to 29 February 2016 - weekday
Daytime period (07:00 to 23:00 hours)
Proportion
30 %
25 %
20 %
15 %
10 %
5 %
0 %
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
Measured background sound level, L_{A90} (dB)

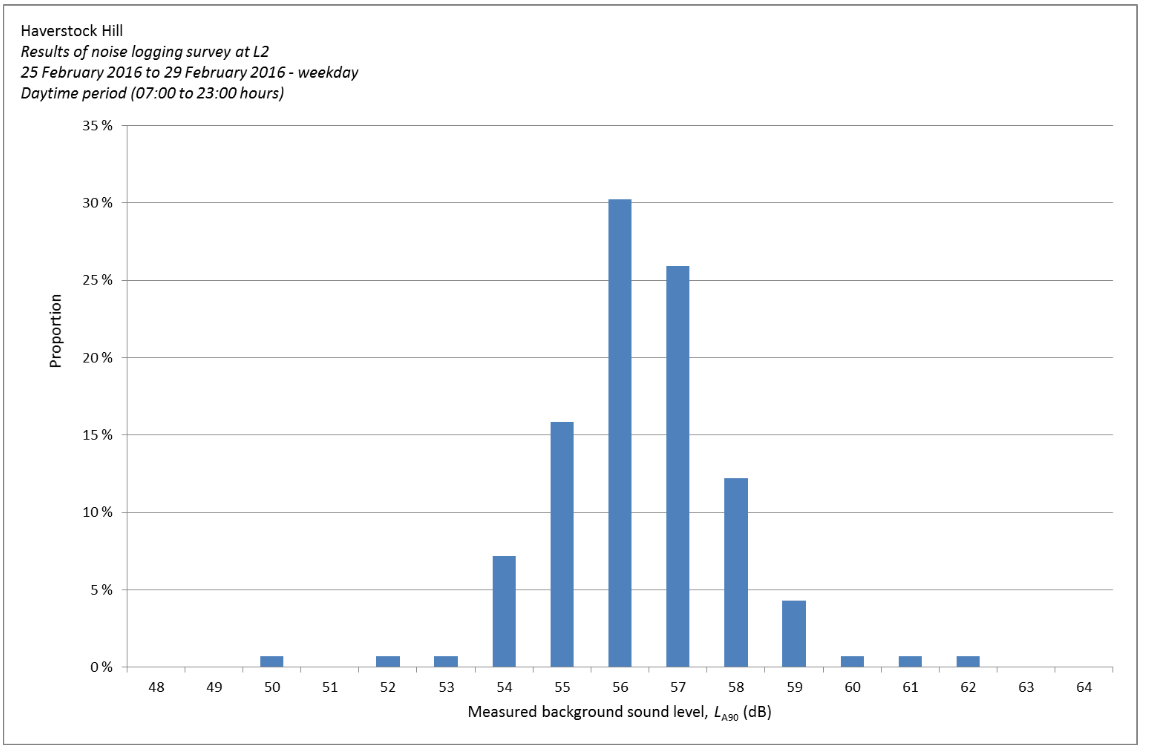

Haverstock Hill
Results of noise logging survey at L1
25 February 2016 to 29 February 2016 - weekday
Night-time period (23:00 - 07:00 hours)
Proportion
20 %
18 %
16 %
14 %
12 %
10 %
8 %
6 %
4 %
2 %
0 %
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
Measured background sound level, L_{A90} (dB)

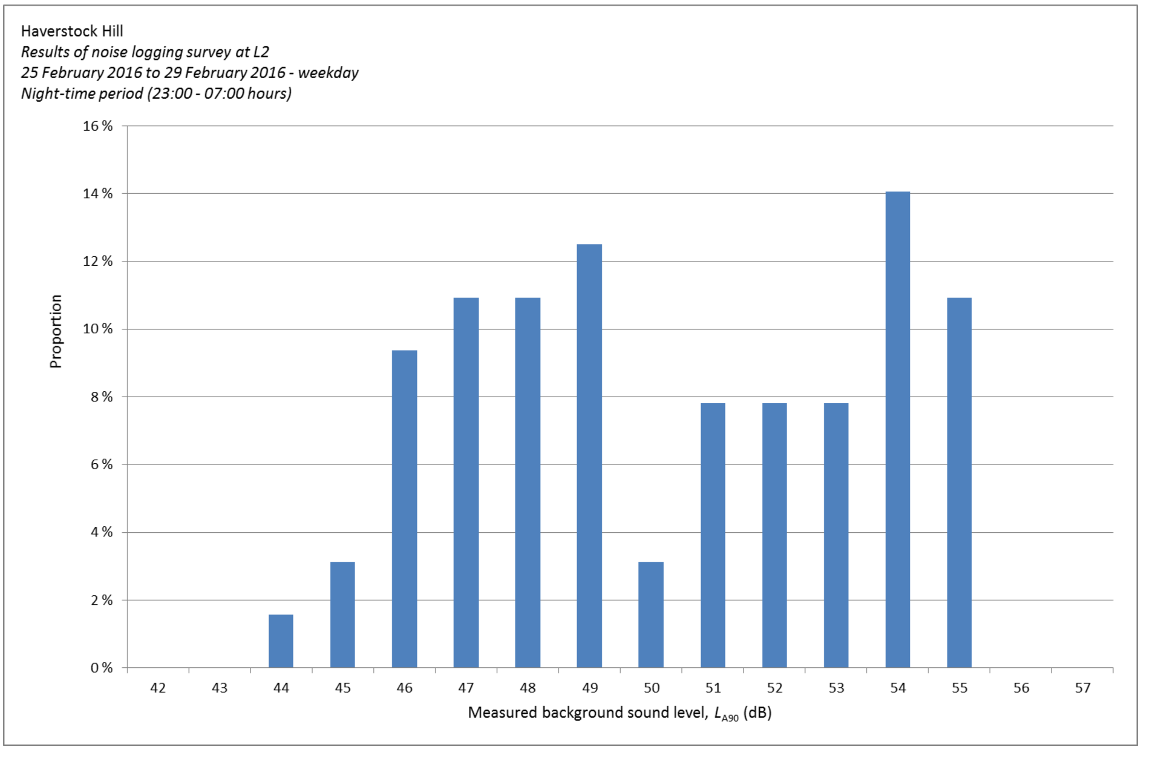
Haverstock Hill
Results of noise logging survey at L1
25 February 2016 to 29 February 2016 - weekend
Daytime period (07:00 to 23:00 hours)

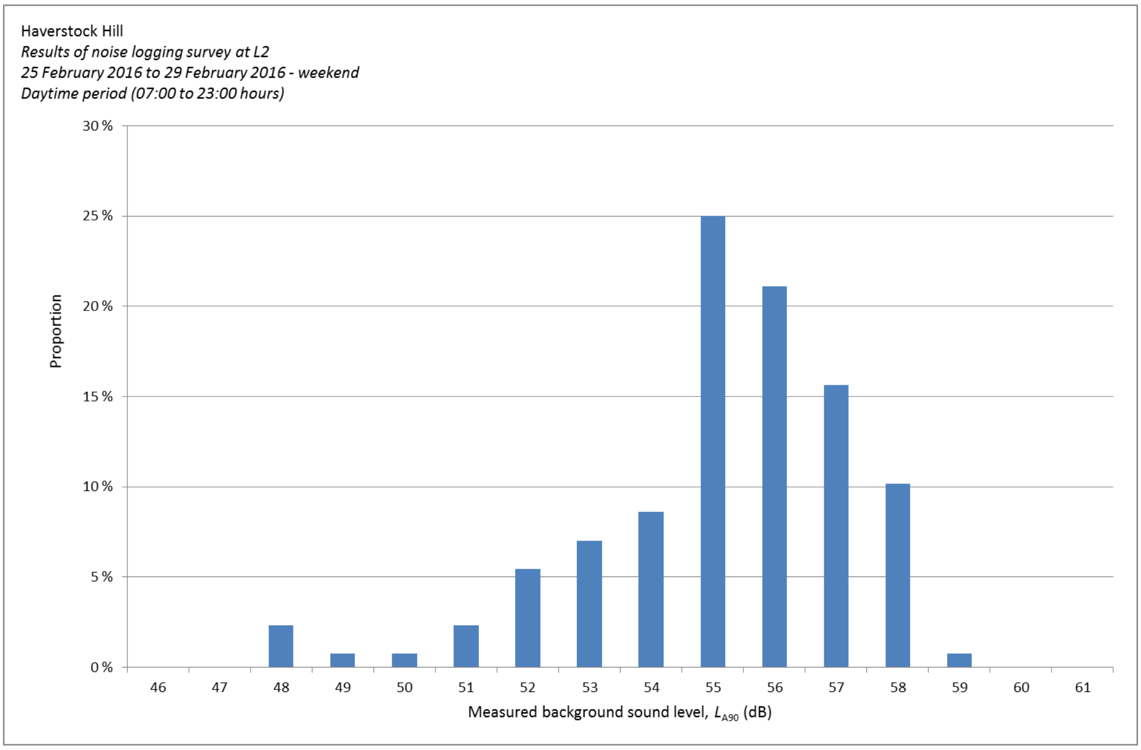


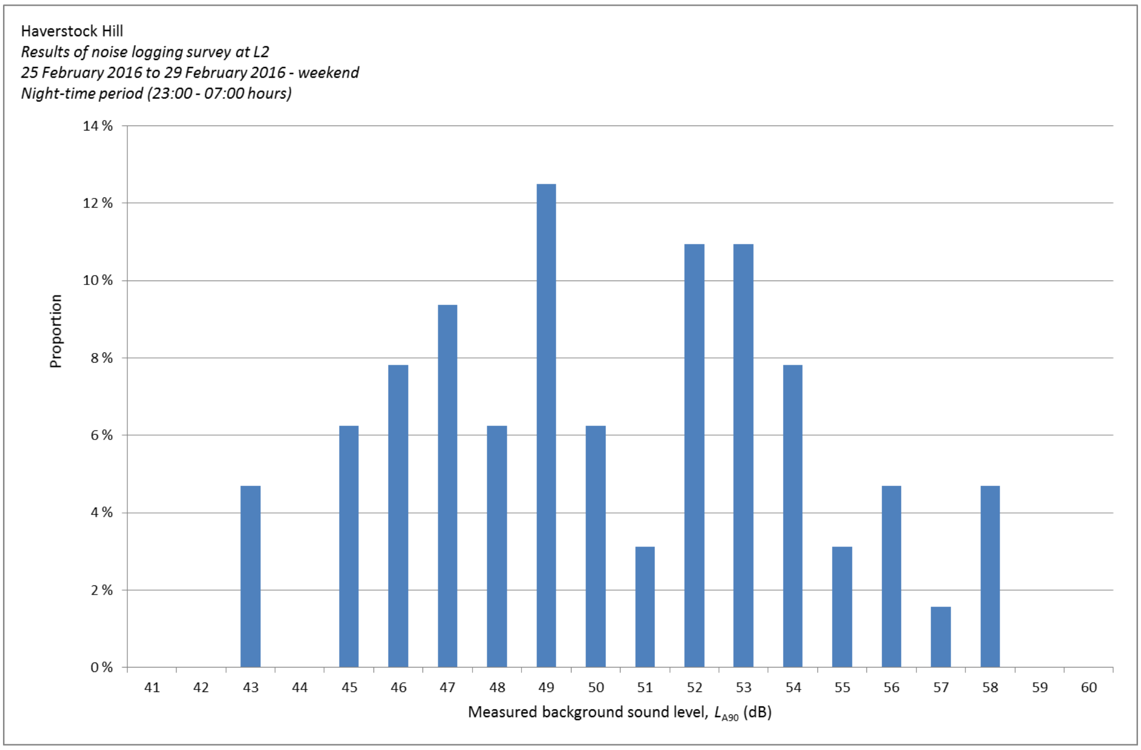
Haverstock Hill
Results of noise logging survey at L1
25 February 2016 to 29 February 2016 - weekend
Night-time period (23:00 - 07:00 hours)




Haverstock Hill
Results of noise logging survey at L2
25 February 2016 to 29 February 2016 - weekday
Daytime period (07:00 to 23:00 hours)
Proportion
35 %
30 %
25 %
20 %
15 %
10 %
5 %
0 %
48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
Measured background sound level, L_{A90} (dB)


Haverstock Hill
Results of noise logging survey at L2
25 February 2016 to 29 February 2016 - weekday
Night-time period (23:00 - 07:00 hours)
Proportion
16 %
14 %
12 %
10 %
8 %
6 %
4 %
2 %
0 %
42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57
Measured background sound level, L_{A90} (dB)


Haverstock Hill
Results of noise logging survey at L2
25 February 2016 to 29 February 2016 - weekend
Daytime period (07:00 to 23:00 hours)
Proportion
30 %
25 %
20 %
15 %
10 %
5 %
0 %
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
Measured background sound level, L_{A90} (dB)


Haverstock Hill
Results of noise logging survey at L2
25 February 2016 to 29 February 2016 - weekend
Night-time period (23:00 - 07:00 hours)
Proportion
14 %
12 %
10 %
8 %
6 %
4 %
2 %
0 %
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Measured background sound level, L_{A90} (dB)