United Kingdom Holocaust Memorial and Learning Centre

Environmental Statement (Volume 5)

Appendix D Noise Surveys and Assessments

December 2018

The Secretary of State for Housing Communities and Local Government

DCLG

NATIONAL HOLOCAUST MUSEUM

Acoustic Application Report

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WSP
4th Floor
6 Devonshire Square
London
EC2M 4YE
Phone: +44 20 7337 1700
Fax: +44 20 7337 1701
WSP.com

CONTENTS

1. INTRODUCTION

1.1.1. WSP has been commissioned by the Ministry of Housing, Communities and Local Government to produce a suite of Application Reports to support the planning application for the proposed UK Holocaust Memorial and Learning Centre in Victoria Tower Gardens, adjacent to Parliament in Westminster ('The Site').

1.1.2. This Report is intended for the sole benefit of the parties named above and shall not be capable of assignment. WSP shall not be liable for any use of the Report for any reasons other than that for which the Report was originally prepared and provided.

1.1.3. A glossary of technical terms used in this report is given in Appendix A.

1.1.4. The limitations to this report are presented in Appendix B.

1.2. PURPOSE OF REPORT

1.2.1. This Report summarises the results of an Environmental Noise Survey, which was conducted between Tuesday 6 and Friday 9 March 2018, and provides noise emission limits to be imposed on the noise control of the building services plant associated with the memorial.

2. SOURCES AND RECEPTORS

2.1. NOISE SOURCES

2.1.1. The Site of the proposed UK Holocaust Memorial and Learning Centre is in Victoria Tower Gardens, Westminster, in the centre of London. As such, it is subject to relatively high levels of ambient noise during the day and night, due to road traffic, occasional air and river traffic, and building services noise from surrounding buildings. The main source of noise affecting The Site is road traffic on Millbank, which is directly to the west. During the survey, the sound of emergency sirens from Guy's and St Thomas' Hospital on the east side of the River Thames were occasionally audible.

2.2. NEAREST NOISE SENSITIVE PROPERTIES

2.2.1. The use type of the surrounding buildings is shown in Figure 1and Figure 2 overleaf. 9 Millbank is immediately to the east of The Site, and since it is currently being developed to accommodate residential apartments, it is both the closest building and the closest Noise Sensitive Receptor (according to the City of Westminster City Plan).

2.2.2. The buildings along the other side of Millbank appear to be predominantly office use. It is not clear whether these buildings include residential or hotel areas; however, by designing to protect the closet building, 9 Millbank, any noise sensitive elements of other such buildings would be protected as a matter of course.

2.2.3. Hospital buildings are also identified as Noise Sensitive Receptors by the City of Westminster City Plan. On this basis, Guy's and St Thomas' Hospital located to the east, on the other side of the River Thames, will also be considered in the design of noise emission control. In summary, the two, key noise sensitive receptors on which the design will be based are:

- 9 Millbank
- Guy's and St Thomas' Hospital

2.2.4. By controlling noise emissions potentially affecting these two addresses, all other nearby properties will also be protected.

Figure 1 – Nearest buildings and noise monitoring positions (west)

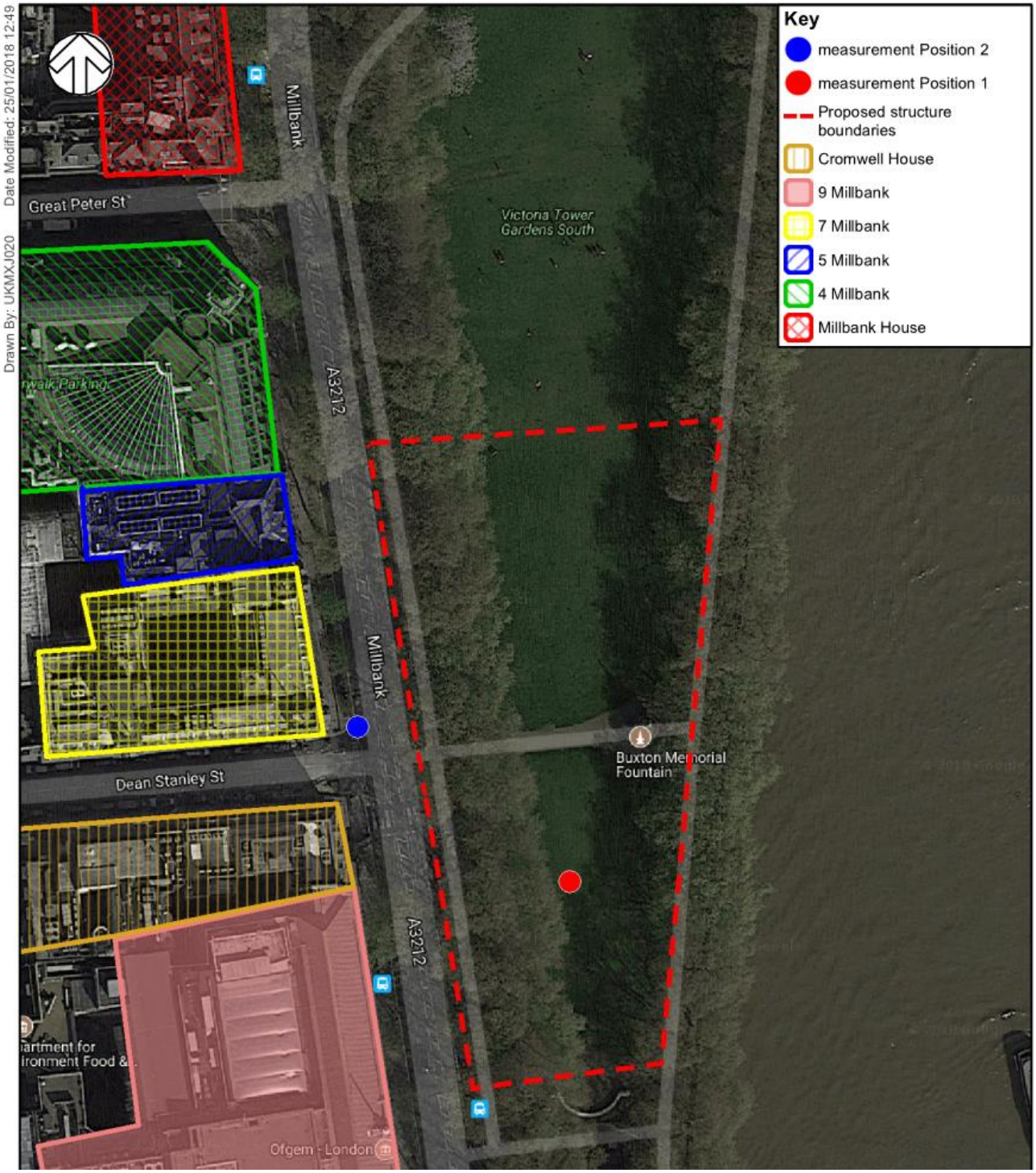
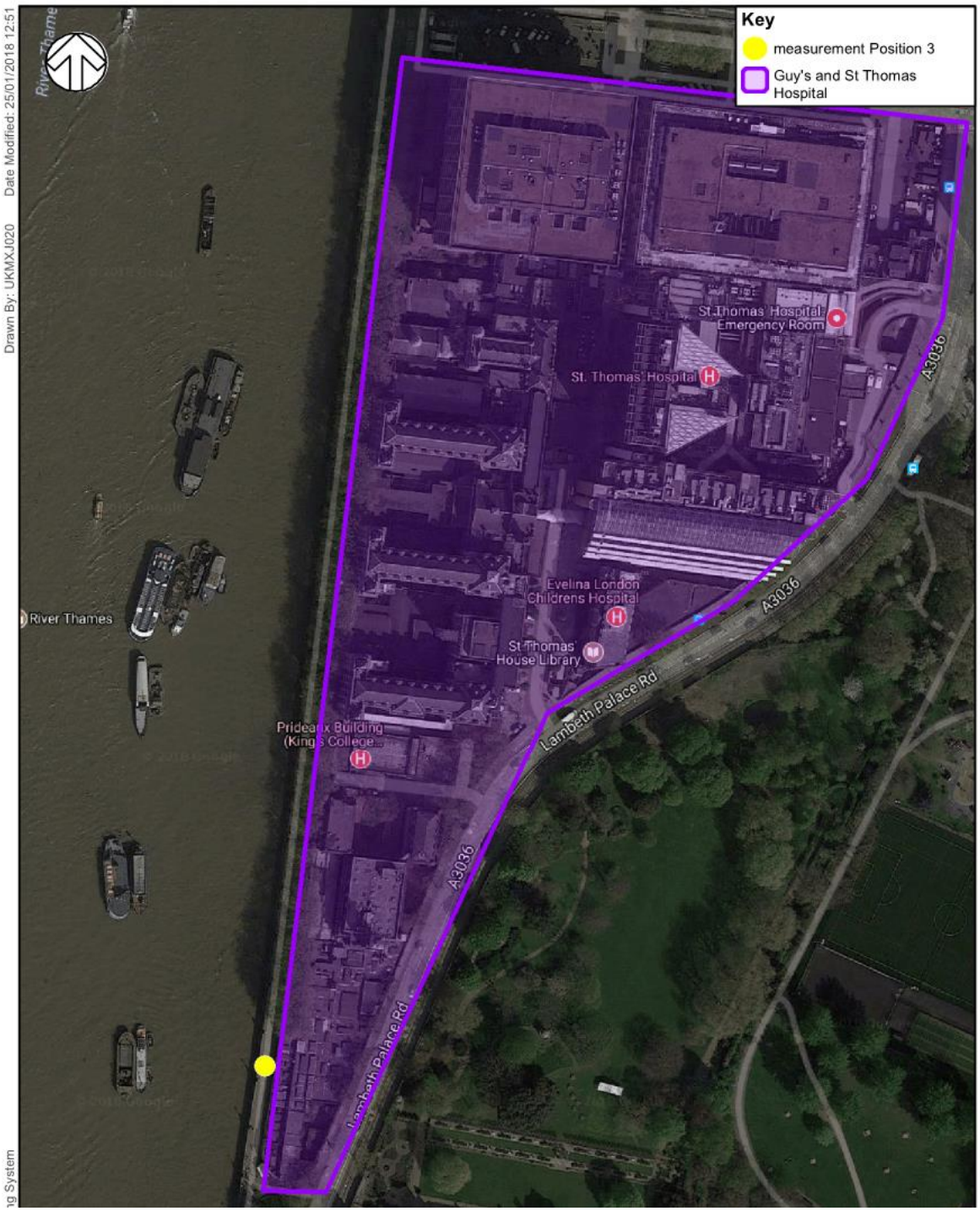


Figure 2 – Nearest buildings and noise monitoring position (east)



3. ENVIRONMENTAL NOISE SURVEY

3.1. SUMMARY

3.1.1. In order to inform the design, it is necessary to obtain both representative ambient noise levels prevailing on the proposed building façade (for the design of the external building fabric acoustic performance), and the background noise levels representative of the nearest noise sensitive properties (to set building services noise emission limits relative to the existing levels in accordance with both British Standard and City of London requirements).

3.1.2. The 24 hour period was split as follows, following standard guidance:

- Day 07:00 – 19:00 hrs;
- Evening 19:00 – 23:00 hrs; and
- Night 23:00 – 07:00 hrs

3.1.3. As locations to install noise measurements equipment to be left for a prolonged period were not available, short term attended measurements were carried out, during periods pertinent to the acoustic design. The following periods were selected, for the reasons shown:

07:00 – 10:00 hrs	Selected to capture the likely quietest period of the day (07:00 – 07:30), and the morning rush hour, which is likely to be one of the noisiest daytime periods.
17:00 – 23:00 hrs	Selected to capture the evening rush hour, which is likely to be one of the noisiest daytime periods, and the evening, which could potentially include one of the quietest periods during which the memorial is operational.
02:00 – 04:00 hrs	Selected to capture the quietest time of a 24 hour period.

3.1.7. To obtain representative measurements of these periods, four site visits were made:

- Site Visit 1: Tuesday 6 March 2018 02:00 – 04:00 hrs
- Site Visit 2: Wednesday 7 March 2018 17:00 – 20:00 hrs
- Site Visit 3: Thursday 8 March 2018 20:00 – 23:00 hrs
- Site Visit 4: Friday 9 March 2018 07:00 – 10:00 hrs

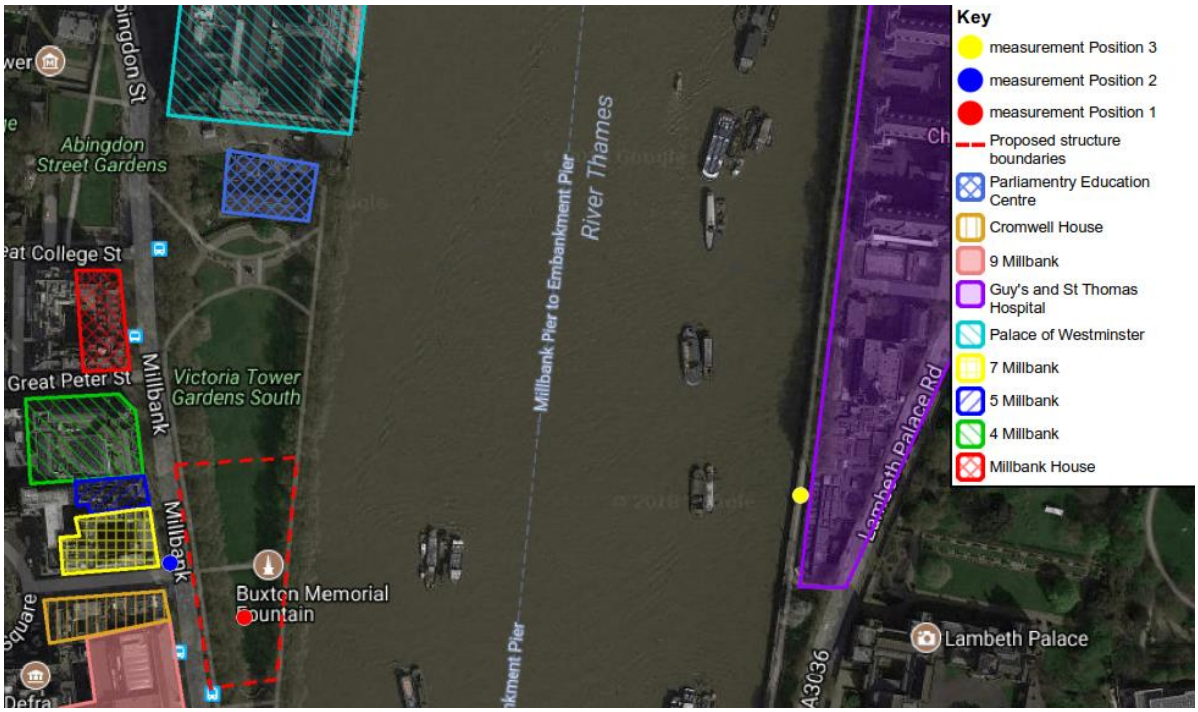
3.1.8. Attended measurements were carried out at the following locations to assess the ambient noise levels likely to affect the proposed development, and the existing background noise levels at the nearby noise sensitive receptors:

- Measurement Position 1 (MP1): located at the proposed memorial entrance.
- Measurement Position 2 (MP2): located on the side walk of Millbank near junction with Dean Stanley Street.
- Measurement Position 3 (MP3): located on the pedestrian pathway on the east bank of the river Thames next to Guy's and St Thomas' Hospital boundary.

3.1.9. The measurement locations are shown in Figure 3.

3.1.10. All sound level meters were set to record the L_{Aeq}, L_{AFmax} and L_{AF90} indices at a sufficiently fine resolution to enable further post processing if required. The microphones were fitted with windshields throughout the measurement survey.

Figure 3 – Survey measurement positions



3.1.11. The measurements were taken at street level, with the microphone positioned approximately 1.5 metres above the ground.

3.1.12. At MP1 and MP3 the microphone was more than 3.5 metres from any other reflective surfaces and, as such, these measurements can be regarded as being in free-field conditions.

3.1.13. At MP2 the microphone was 1 meter away from the façade of the building and, as such, can be regarded as a façade level measurement.

3.2. MEASUREMENT EQUIPMENT

3.2.1. Details of the equipment used to take the measurements are presented in Table 1.

Table 1 - Noise measurement equipment used for the survey

Equipment description		Manufacturer & Type No.	Serial No.
01dB Solo (Visit 1)	Sound Level Meter	01dB-Stell Solo Master	11810
	Pre-amplifier	01dB-Stell PRE 21 S	12495
	Microphone	Microtech Gefell GmbH MCE212	67311
	Calibrator	01dB-Stell Cal 21	34323996
01dB Solo (Visits 2, 3 and 4)	Sound Level Meter	01dB-Stell Solo Master	10705
	Pre-amplifier	01dB-Stell PRE 21 S	16860
	Microphone	Microtech Gefell GmbH MCE212	181885
	Calibrator	01dB-Stell Cal 21	35293350

3.2.2. Each meter had been calibrated by a UKAS accredited laboratory within the previous 24 months. The equipment was also field calibrated at the commencement and conclusion of each set of measurements using the above calibrators, which had themselves been calibrated by a UKAS accredited laboratory within the previous twelve months. No significant drift in the calibration signal was noted.

3.3. METEOROLOGICAL CONDITIONS

3.3.1. The weather conditions throughout the attended noise surveys are presented in Table 2.

Table 2 - Weather conditions

Site Visit	Weather Observations
Site Visit 1: 6 March 2018 02:00 – 04:00	Temperature around 9°C and no rain. Winds speeds were generally low and did not exceed 3 m/s. These conditions will not have influenced the measured noise levels on site.
Site Visit 2: 7 March 2018 17:00 – 20:00	Temperature around 10°C and no rain. Winds speeds were generally low and did not exceed 5 m/s. These conditions will not have influenced the measured noise levels on site.
Site Visit 3: 8 March 2018 20:00 – 23:00	Temperature around 9°C and no rain. Winds speeds were generally low and did not exceed 5 m/s. These conditions will not have influenced the measured noise levels on site.
Site Visit 4: 9 March 2018 07:00 – 10:00	Temperature around 4-7°C, cloudy, but no rain. Winds speeds were generally low and did not exceed 3 m/s. These conditions will not have influenced the measured noise levels on site.

3.4. NOISE MEASUREMENT RESULTS

NIGHT-TIME PERIOD

3.4.1. The night-time noise survey was carried out between 02:08 – 04:10 hrs on Tuesday 6 March 2018. The results are shown in Table 3.

Table 3 - Night attended noise measurements

Location	Period start	Equivalent Continuous Level (Energy Average) dB, $L_{Aeq,15mins}$	Background Noise Level dB, $L_{A90,15mins}$	Maximum Event Noise Level dB, $L_{Amax,15mins}$
MP1 (Free-field measurements	06/03/18 02:08	55	47	70
	06/03/18 03:16	55	50	66
MP2 (Façade measurements)	06/03/18 02:26	64	48	84
	06/03/18 03:33	63	49	78
MP3 (Free-field	06/03/18 02:53	49	46	57

measurements)	06/03/18 03:55	49	46	55

EVENING TIME PERIOD

3.4.2. The evening time noise survey was carried out between 17:00 – 20:06 hrs on Wednesday 7 March 2018 and on Thursday 8 March 2018 between 20:03-23:09 hrs. The levels measured at each measurement position are shown in Table 4 below.

Table 4 - Evening time attended noise measurements

Location	Period start	Equivalent Continuous Level (Energy Average) dB, $L_{Aeq,15mins}$	Background Noise Level dB, $L_{A90,15mins}$	Maximum Event Noise Level dB, $L_{Amax,15mins}$
MP1 (Free-field measurements	07/03/18 17:00	62	57	77
	07/03/18 18:05	63	57	83
	07/03/18 19:11	68	57	85
	08/03/18 20:03	59	56	68
	08/03/18 21:07	58	55	67
	08/03/18 22:13	58	55	67
MP2 (Façade measurements)	07/03/18 17:17	69	61	82
	07/03/18 18:23	69	61	84
	07/03/18 19:28	68	60	89
	08/03/18 20:21	66	59	85
	08/03/18 21:26	70	58	95
	08/03/18 22:31	66	59	79
MP3 (Free-field measurements)	07/03/18 17:41	63	57	80
	07/03/18 18:47	59	55	78
	07/03/18 19:51	58	54	75
	08/03/18 20:44	56	54	71
	08/03/18 21:49	55	53	66
	08/03/18 22:54	55	52	71

DAYTIME PERIOD

3.4.3. The daytime noise survey was carried out between 07:00 – 10:03 hrs on Friday 9 March 2018. The results of the measurements at each measurement position are shown below.

Table 5 - Daytime attended noise measurements

Location	Period start	Equivalent Continuous Level (Energy Average) dB, $L_{Aeq,15mins}$	Background Noise Level dB, $L_{A90,15mins}$	Maximum Event Noise Level dB, $L_{Amax,15mins}$
MP1 (Free-field measurements	09/03/18 07:00	62	56	81
	09/03/18 08:05	61	57	79
	09/03/18 09:08	61	57	72
MP2 (Façade level measurements)	09/03/18 07:18	69	59	85
	09/03/18 08:22	69	61	88
	09/03/18 09:25	69	60	87
MP3 (Free-field measurements)	09/03/18 07:41	59	53	80
	09/03/18 08:45	58	54	75
	09/03/18 09:48	57	53	74

SUMMARY

3.4.4. During the day, noise levels at the entrance to the proposed memorial are expected to be 61 dB $L_{Aeq,T}$. During the evening rush hour, the levels are expected to rise, as shown by one sample measurement that reached 68 dB $L_{Aeq,T}$. These levels will be used to determine the risk of noise break-in to the internal spaces of the memorial.

3.4.5. The lowest background noise levels, which will be referred to when establishing noise emission limits are shown in Table 6.

Table 6 - Lowest Background Noise Measurements

Location	Lowest Background Noise Level dB, $L_{A90,15mins}$		
	Day (07:00 – 19:00 hrs)	Evening (19:00 – 23:00 hrs)	Night (23:00 hrs – 07:00 hrs)
MP1 (Free-field measurements	56	55	47
MP2 (Façade measurements)	59	58	48
MP3 (Free-field measurements)	53	52	46

4. PLANNING POLICY AND GUIDANCE

4.1. PLANNING CONDITIONS

4.1.1. This Report addresses only noise emissions from building services plant associated with the memorial that would be operational once the memorial has been built and is occupied.

4.1.2. The following guidance is taken from the Westminster City Council (WCC) Unitary Development Plan. The policy ENV 7 is current and forms part of the Core Strategy, which was adopted by WCC on the 26 January 2011.

POLICY ENV 7: CONTROLLING NOISE FROM PLANT, MACHINERY AND INTERNAL ACTIVITY

(A) Where development is proposed, the City Council will require the applicant to demonstrate that this will be designed and operated so that any noise emitted by plant and machinery and from internal activities, including noise from amplified or unamplified music and human voices, will achieve the following standards in relation to the existing external noise level at the nearest noise sensitive properties, at the quietest time during which the plant operates or when there is internal activity at the development.

1) where the existing external noise level exceeds WHO Guideline levels of LAeq,12hrs 55 dB daytime (07.00 - 19.00); LAeq,4hrs 50 dB evening (19.00 - 23.00); LAeq,8hrs 45 dB night-time (23.00 - 07.00):

either

(a) and where noise from the proposed development will not contain tones or be intermittent sufficient to attract attention, the maximum emission level (LAeq,15min) should not exceed 10 dB below the minimum external background noise at the nearest noise sensitive properties. The background noise level should be expressed in terms of LA90,15min.

or

(b) and where noise emitted from the proposed development will contain tones, or will be intermittent sufficient to attract attention, the maximum emission level (LAeq,15min) should not exceed 15 dB below the minimum external background noise at the nearest noise sensitive properties. The background noise level should be expressed in terms of LA90,15min.

2) where the external background noise level does not exceed the above WHO Guideline levels, policy ENV 7(A)(1)(a) and (b) will apply except where the applicant is able to demonstrate to the City Council that the application of slightly reduced criteria of no more than 5 dB will provide sufficient protection to noise sensitive properties:

either

(a) where noise emitted from the proposed development will not contain tones or be intermittent sufficient to attract attention, the maximum emission level (LAeq,15min) should

not exceed 5 dB below the minimum external background noise level at the nearest noise sensitive properties. The background noise levels should be expressed in terms of LA90,15min.

or

(b) where noise emitted from the proposed development will contain tones or will be intermittent sufficient to attract attention, the maximum emission level (LAeq15min) should not exceed 10 dB below the minimum external background noise level at the nearest noise sensitive properties. The background noise levels should be expressed in terms of LA90,15min.

(B) Noise from emergency generators

Where emergency generation plant is installed and requires testing, the City Council will permit noise emitted from this plant to increase the minimum assessed background noise levels by no more than 10dB for the purpose of testing. This testing period is for up to one hour per month between 09.00 and 17.00 Monday to Friday only and not on public holidays.

4.1.3. The definition of Noise Sensitive Receptor is provided in Westminster's City Plan dated Jul 2016, which states that 'noise sensitive receptors comprise residential use, education establishments, hospitals, hotels, hostels, concert halls, theatres, law courts, and broadcasting and recording studios'.

4.1.4. A noise survey has been carried out to establish the prevailing background noise level at the nearest noise sensitive receptors. Maximum background noise levels have been established in accordance with Policy ENV 7.

4.1.5. The noise measurements show that, in all locations, the WHO Guideline levels of $L_{Aeq,12hrs}$ 55 dB daytime (07.00 - 19.00), $L_{Aeq,4hrs}$ 50 dB evening (19.00 - 23.00) and $L_{Aeq,8hrs}$ 45 dB night-time (23.00 - 07.00) are exceeded. On this basis, ENV 7(A)(1) applies.

5. BUILDING SERVICES ENVIRONMENTAL NOISE EMISSIONS

5.1. BUILDING SERVICES NOISE EMISSION CRITERIA

5.1.1. As the ambient noise levels at The Site and surrounding properties exceed the WHO Guideline levels, Westminster City Council Policy ENV 7(A)(1)(a) applies, as identified above, to noise emissions from normal plant operation, whilst Policy ENV(B) applies to emergency plant. In accordance with the Policy, these limits are relative to the minimum assessed background noise levels. The limits for each receptor are summarised below.

5.1.2. Please note, for consistency, the limits are stated as equivalent free-field levels at MP2. To determine the equivalent free-field noise level at MP2, 3 dB is subtracted from the measured façade level.

Table 7 - Building Services Noise Emission Limits MP2 (9 Millbank and adjacent properties)

Period	Day (07 – 19 hrs)	Evening (19 – 23 hrs)	Night (23 – 07 hrs)
Lowest Background Noise Level (façade measurements) (dB, $L_{A90,15mins}$)	59	58	48
Free-field maximum emission level where noise from the proposed development will not contain tones or be intermittent sufficient to attract attention (dB, $L_{Aeq,15mins}$)	46	45	35
Free-field maximum emission level where noise emitted from the proposed development will contain tones, or will be intermittent sufficient to attract attention (dB, $L_{Aeq,15mins}$)	41	40	30
Free-field noise limit for emergency generators (dB, $L_{Aeq,15mins}$)	66		

Table 8 - Building Services Noise Emission Limits MP3 (Guy's and St Thomas' Hospital)

Period	Day (07 – 19 hrs)	Evening (19 – 23 hrs)	Night (23 – 07 hrs)
Lowest Background Noise Level (free-field measurements) (dB, $L_{A90,15mins}$)	53	52	46
Free-field maximum emission level where noise from the proposed development will not contain tones or be intermittent sufficient to attract attention (dB, $L_{Aeq,15mins}$)	43	42	36
Free field maximum emission level where noise emitted from the proposed development will contain tones, or will be intermittent sufficient to attract attention (dB, $L_{Aeq,15mins}$)	38	37	31
Free-field noise limit for emergency generators ($L_{Aeq,15mins}$)	63		

5.1.3. A testing schedule for the generators must be imposed that follows Westminster City Council's guidance.

5.1.4. Provided the above limits are not exceeded, the requirements of Westminster City Council would be achieved.

6. CONCLUSIONS

6.1.1. WSP has been commissioned by the Ministry of Housing, Communities and Local Government to provide acoustic consultancy services associated with the proposed UK Holocaust Memorial and Learning Centre in Victoria Tower Gardens, adjacent to Parliament in Westminster.

6.1.2. A baseline Environmental Noise Survey has been undertaken to establish the existing noise levels affecting The Site and surrounding area. Using these measured noise levels and noise criteria taken from WCC's Unitary Development Plan, noise emission criteria have been set for all nearby noise sensitive receptors for any fixed building services plant associated with the development.

6.1.3. The proposed configuration and layout of plant will not be fixed until later in the design. A further assessment of the plant noise emissions will be required when details of the plant are known. The plant items selected should be assessed in accordance WCC policy.

Appendix A

TECHNICAL GLOSSARY

Noise is defined as unwanted sound. Human ears are able to respond to sound in the frequency range 20 Hz (deep bass) to 20,000 Hz (high treble) and over the audible range of 0 dB (the threshold of perception) to 140 dB (the threshold of pain). The ear does not respond equally to different frequencies of the same magnitude, but is more responsive to mid-frequencies than to lower or higher frequencies. To quantify noise in a manner that approximates the response of the human ear, a weighting mechanism is used. This reduces the importance of lower and higher frequencies, in a similar manner to the human ear.

Furthermore, the perception of noise may be determined by a number of other factors, which may not necessarily be acoustic. In general, the impact of noise depends upon its level, the margin by which it exceeds the background level, its character and its variation over a given period of time. In some cases, the time of day and other acoustic features such as tonality or impulsiveness may be important, as may the disposition of the affected individual. Any assessment of noise should give due consideration to all of these factors when assessing the significance of a noise source.

The most widely used weighting mechanism that best corresponds to the response of the human ear is the 'A'-weighting scale. This is widely used for environmental noise measurement, and the levels are denoted as dB(A) or L_{Aeq}, L_{A90} etc, according to the parameter being measured.

The decibel scale is logarithmic rather than linear, and hence a 3 dB increase in sound level represents a doubling of the sound energy present. Judgement of sound is subjective, but as a general guide a 10 dB(A) increase can be taken to represent a doubling of loudness, whilst an increase in the order of 3 dB(A) is generally regarded as the minimum difference needed to perceive a change under normal listening conditions.

An indication of the range of sound levels commonly found in the environment is given in the following table:

Typical sound levels found in the environment

Sound Level	Location
0 dB(A)	Threshold of hearing
20 to 30 dB(A)	Quiet bedroom at night
30 to 40 dB(A)	Living room during the day
40 to 50 dB(A)	Typical office
50 to 60 dB(A)	Inside a car
60 to 70 dB(A)	Typical high street
70 to 90 dB(A)	Inside factory
100 to 110 dB(A)	Burglar alarm at 1m away
110 to 130 dB(A)	Jet aircraft on take off
140 dB(A)	Threshold of Pain

Term	Definition
Sound Pressure	Sound, or sound pressure, is a fluctuation in air pressure over the static ambient pressure.
Sound Pressure Level (Sound Level)	The sound level is the sound pressure relative to a standard reference pressure of 20μPa ($20x10^{-6}$ Pascals) on a decibel scale.
Decibel (dB)	A scale for comparing the ratios of two quantities, including sound pressure and sound power. The difference in level between two sounds s1 and s2 is given by 20 $\log_{10}$ (s1 / s2). The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20μPa.
A-weighting, dB(A)	The unit of sound level, weighted according to the A-scale, which takes into account the increased sensitivity of the human ear at some frequencies.
Noise Level Indices	Noise levels usually fluctuate over time, so it is often necessary to consider an average or statistical noise level. This can be done in several ways, so a number of different noise indices have been defined, according to how the averaging or statistics are carried out.
$L_{Aeq,T}$	A noise level index called the equivalent continuous noise level over the time period T. This is the level of a notional steady sound that would contain the same amount of sound energy as the actual, possibly fluctuating, sound that was recorded.
$L_{max,T}$	A noise level index defined as the maximum noise level during the period T. L_{max} is sometimes used for the assessment of occasional loud noises, which may have little effect on the overall L_{eq} noise level but will still affect the noise environment. Unless described otherwise, it is measured using the 'fast' sound level meter response.
$L_{90,T}$	A noise level index. The noise level exceeded for 90% of the time over the period T.L_{90} can be considered to be the "average minimum" noise level and is often used to describe the background noise.
Free-field	Far from the presence of sound reflecting objects (except the ground), usually taken to mean at least 3.5 metres.
Façade	At a distance of 1 metre in front of a large sound reflecting object such as a building façade.

Appendix B

LIMITATIONS OF THIS REPORT

LIMITATIONS OF THIS REPORT

This report has been prepared for the titled project or named part thereof and should not be used in whole or in part and relied upon for any other project without the written authorisation of WSP UK Limited. WSP UK Limited accepts no responsibility or liability for the consequences of this document if it is used for a purpose other than that for which it was commissioned. Persons wishing to use or rely upon this report for other purposes must seek written authority to do so from the owner of this report and/ or WSP UK Limited and agree to indemnify WSP UK Limited for any and all loss or damage resulting therefrom. WSP UK Limited accepts no responsibility or liability for this document to any other part other than the person by whom it was commissioned.

The findings and opinions expressed are relevant to the dates of The Site works and should not be relied upon to represent conditions at substantially later dates. Opinions included therein are based on information gathered during the study and our experience. If additional information becomes available which may affect our comments, conclusions or recommendations WSP UK Limited reserve the right to review the information, reassess any new potential concerns and modify our opinions accordingly.

4th Floor
6 Devonshire Square
London
EC2M 4YE

wsp.com

DCLG

NATIONAL HOLOCAUST MEMORIAL

Preliminary Construction Noise and Vibration Assessment

TYPE OF DOCUMENT: PUBLIC

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DATE: NOVEMBER 2018

WSP
WSP House
70 Chancery Lane
London
WC2A 1AF
Phone: +44 20 7314 5000
Fax: +44 20 7314 5111
WSP.com

CONTENTS

1. EXECUTIVE SUMMARY

An assessment of noise and vibration generated by the construction of the proposed United Kingdom Holocaust Memorial and Learning Centre in Victoria Tower Gardens, London, has been undertaken. The assessment is outline in nature in keeping with the level of information available at this stage.

The primary receptors have been identified as:

- Buildings on Millbank, opposite the site;
- The Parliamentary Education Centre and Westminster Palace; and
- Guy's and St. Thomas' hospital, across the Thames.

The key construction activities have been identified as the piling associated with the foundations and basement walls (including pile breakdown works), the excavation of the basement, and the concreting to the basement and upper slabs.

The corresponding noise and vibration levels have been predicted and assessed using relevant technical guidance (namely BS 5228:2009+A1:2014 Part 1 Noise and Part 2 Vibration, as referenced in Westminster City Council's Code of Construction Practice (CoCP)).

In keeping with the requirements of the CoCP and standard practice, it has been assumed that best practicable means would be employed, and that the construction works would be limited as follows (unless otherwise agreed):

- Weekdays: 08:00 – 18:00 hrs
- Weekends: 08:00 – 13:00 hrs
- Noisy works (e.g. demolition, piling or earthworks) should be limited to weekday hours in residential areas

At all the assessed receptors, the predicted noise and vibration levels do not exceed the thresholds at which there is deemed to be potential for significant effect. Accordingly, on the basis of the assumptions made in the preparation of this assessment, no significant noise or vibration effects are anticipated, with no requirement for particular mitigation measures beyond the adoption of best practicable means and compliance with the Council's CoCP.

2. INTRODUCTION

2.1.1. WSP has been appointed by the Ministry of Housing, Communities and Local Government to undertake a preliminary assessment of the effects of noise and vibration arising from the construction of the proposed United Kingdom Holocaust Memorial and Learning Centre at Victoria Tower Gardens, London.

2.1.2. The assessment has been undertaken based on outline information on the construction works and programme available at this time and using relevant technical standards.

2.1.3. The prevailing noise levels at the site and the nearest noise-sensitive receptors have been established by an environmental noise survey. The results of the survey have been used, together with the relevant guidance, to determine the likelihood of significant noise and vibration effects at the nearest receptors. Full detail of the environmental noise survey is presented in WSP's *Acoustic Application Report. Report No. 70040431-600, October 2018*.

2.1.4. This report is necessarily technical in nature. A glossary of acoustic terminology is included in Appendix A.

3. SITE AND DEVELOPMENT DESCRIPTION

3.1. EXISTING SITE

3.1.1. The site of the proposed United Kingdom Holocaust Memorial and Learning Centre is located in Victoria Tower Gardens, Westminster, in the centre of London.

3.1.2. The surrounding area is predominantly commercial. The site is bounded: to the north by Victoria Tower Gardens and, further north, the Palace of Westminster; to the east by the River Thames; to the south by Millbank and Lambeth Bridge; and to the east by Millbank, with a mix of commercial and residential units overlooking the site on the opposite side of the road.

NOISE-SENSITIVE RECEPTORS

3.1.3. The nearest receptors, identified as possibly being affected by noise and/or vibration from the proposed development, are identified as follows and as in Figure 1 and Figure 2 overleaf:

- Future residential receptors on 9 Millbank, to the west;
- Guy's and St. Thomas' hospital, to the east of the River Thames; and
- The Parliamentary Education Centre and Westminster Palace, to the north.

3.1.4. While many of the buildings along Millbank are predominantly office use (as opposed to residential), it is considered prudent to control noise and vibration exposure to these buildings also.

3.2. PROPOSED DEVELOPMENT

3.2.1. The proposed development is a memorial building and learning centre located at the south of Victoria Tower Gardens.

3.2.2. Part of the design intent is for the gardens to remain usable space and, therefore, the development is primarily subterranean.

3.2.3. There are two levels of basement, which, it is understood, will be set out using a secant pile retaining wall and will contain a number of different use areas, including a number of exhibition spaces, café and retail units and meeting space.

3.2.4. Above ground there will be a visible entrance pavilion, and concrete/paved public space.

Figure 1: Site plan showing the receptors and noise monitoring positions (west of the River Thames)

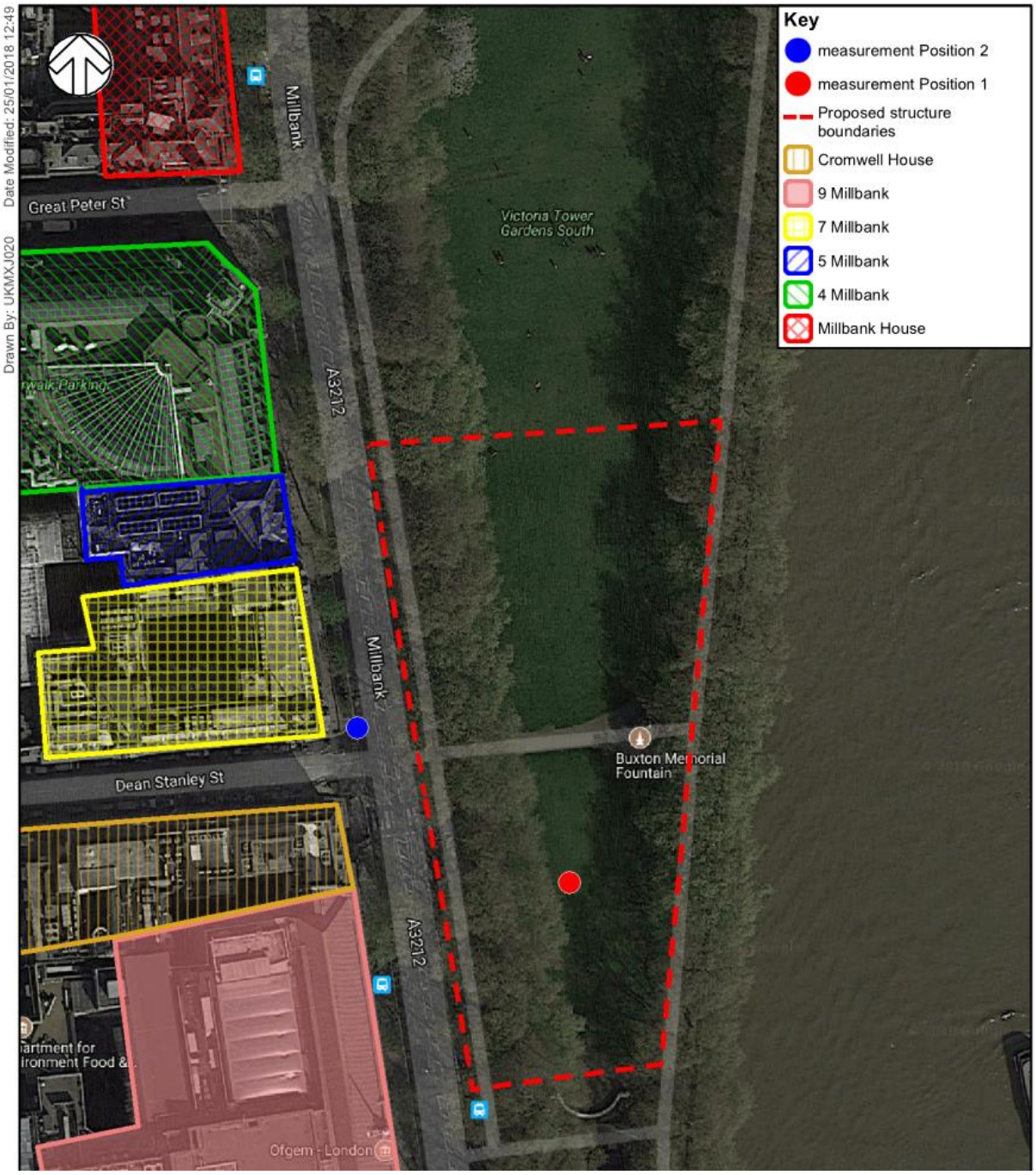
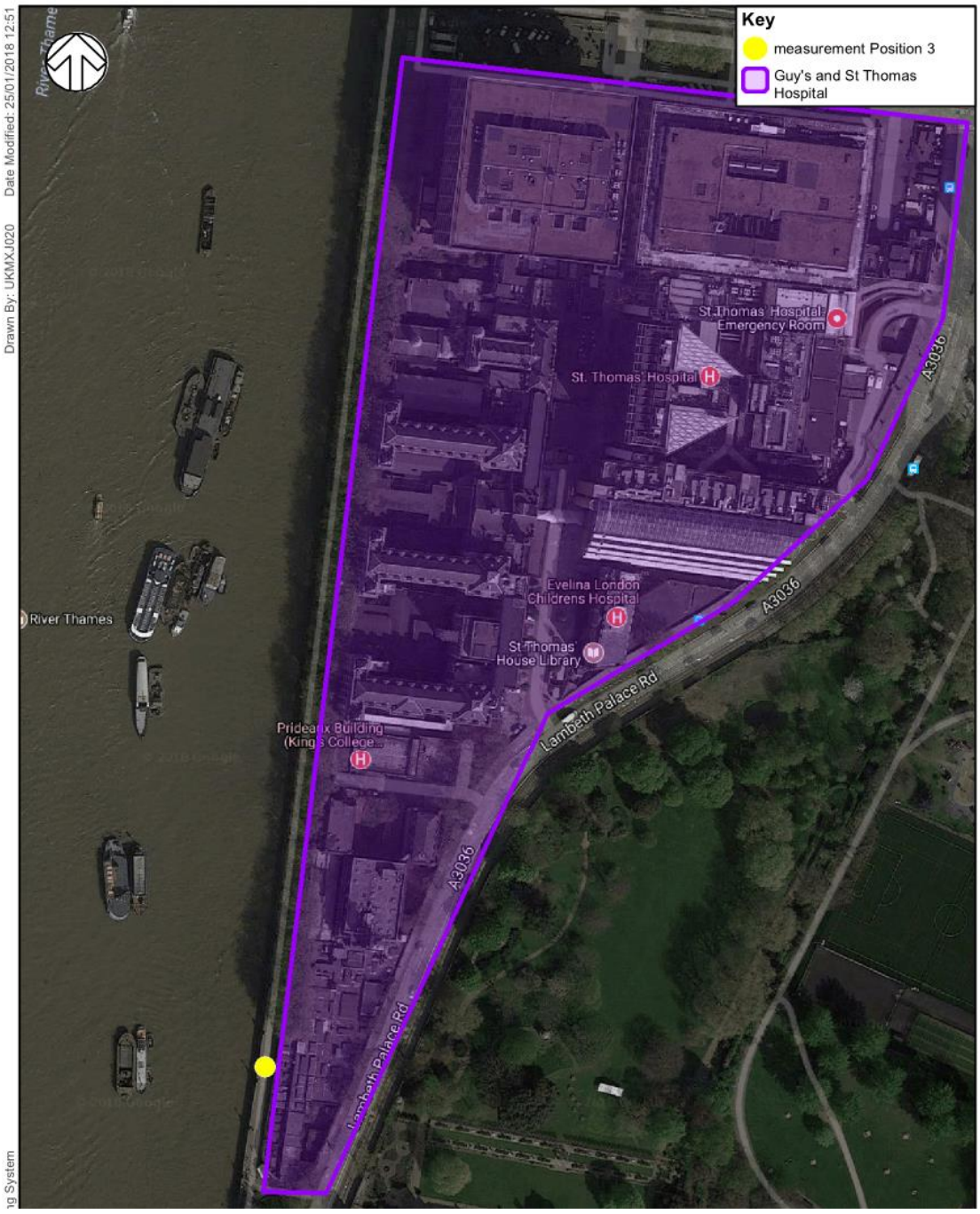


Figure 2: Noise showing the receptors and monitoring position (east of the River Thames)



4. GUIDANCE AND METHODOLOGY

4.1. INTRODUCTION

4.1.1. This section presents the legislation and guidance used to inform the assessment approach, and outlines the assessment methodology.

4.2. LEGISLATIVE FRAMEWORK

CONTROL OF POLLUTION ACT 1973, PART III

4.2.1. Sections 60 and 61 of the Control of Pollution Act 1974 provide the local authority special powers for controlling noise arising from construction and demolition works, regardless of whether a statutory nuisance has been caused or is likely to be caused. These powers may be exercised either before works start or after they have started.

4.2.2. Section 72 of the Act defines “best practicable means” (BPM) to be adopted during construction activities. “Practicable” means reasonably practicable having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to the financial implications. The means to be employed include the design, installation, maintenance and manner and periods of operation of plant and machinery, and the design, construction and maintenance of buildings and acoustic structures.

4.3. LOCAL POLICY

WESTMINSTER CODE OF CONSTRUCTION PRACTICE

4.3.1. Westminster’s Code of Construction Practice (CoCP) sets out the standards and procedures to which developers and contractors must adhere when undertaking construction of major projects in Westminster. This will assist with managing the environmental impacts and will identify the main responsibilities and requirements of developers and contractors in constructing their projects.

4.3.2. The document sets out procedures for the planning and undertaking of construction related projects, including requirements for monitoring and reporting to the City Council.

4.3.3. The CoCP refers to BPM, as described in the section above, and also recommends measures that may be employed to mitigate against adverse noise impacts arising from construction activity – such as the enclosing of plant items and use of vibratory, rather than percussive, methods of piling or breaking.

4.3.4. It establishes the core working hours, to which construction sites should abide, as follows:

- Weekdays: 08:00 – 18:00 hrs
- Weekends: 08:00 – 13:00 hrs
- Noisy works (e.g. demolition, piling or earthworks) should be limited to weekday hours in residential areas

4.3.5. With respect to the prediction and assessment of noise and vibration arising from demolition and construction activity, the CoCP references British Standard (BS) 5228:2014. This document is summarised in the following section.

4.4. GUIDANCE DOCS

BRITISH STANDARD 5228:2009+A1:2014

4.4.1. BS 5228 *Code of practice for noise and vibration control on construction and open sites* parts 1 and 2 (noise and vibration, respectively) provide guidance on the measurement and prediction of noise and vibration generated by construction activity.

NOISE (BS 5228-1)

4.4.2. Annex F to BS 5228-1 describes procedures which may be used to quantify the likely noise levels from specific construction activities.

4.4.3. The noise level generated by construction activities depends on a number of factors. The prediction procedures described in BS 5228-1 take into account the more significant factors, these being:

- The sound power output of the plant or machine;
- the periods of operation;
- the distance between source and receiver;
- the presence of screening by barriers;
- absorbent ground cover attenuation; and
- the reflection of noise.

4.4.4. BS 5228-1 also notes (in Annex F, section F.1) that:

"…other factors such as meteorological conditions (particularly wind speed and direction) and atmospheric absorption may also influence the level of noise received. The estimation of the effects of these factors is complicated… In general, at short distances (say less than 50 m), the size of any effects arising from these factors will be small, whereas at longer distances there will be a tendency towards an increase in sound attenuation."

4.4.5. Annex D of BS 5228-1 contains historic source sound level data on site equipment and activities. In 2005 the findings of a relevant study, commissioned by Defra, were reported. The purpose of the study was to obtain, in a rigorous manner, field measurements of noise from plant and equipment currently in use on construction and open sites in the UK and provide a database of noise emissions to update the existing construction plant noise database contained in BS 5228-1. These data appear in Annex C of BS 5228-1.

4.4.6. The construction noise levels predicted in this report have been calculated using the methods contained within Annex F of BS 5228-1 and using source data, primarily, contained within Annex C and Annex D of BS 5228-1.

The ABC Method

4.4.7. An example method for establishing whether significant effects occur from construction noise is presented in para E.3.2, the 'ABC method'. This method is applicable to assessing the potential effects on dwellings.

4.4.8. Using the ABC method, thresholds above which potentially significant effects could occur are established based on the pre-construction ambient noise level measured at positions representing the nearest dwellings. The threshold is determined using the approach laid out in Table 1.

Table 1: Example thresholds of potential significant effects due to construction noise at dwellings

Period	Threshold of Potential Significant Effect [dB $L_{Aeq,T}$]		
	Category A	Category B	Category C
Day-time (07:00 – 19:00); Saturdays (07:00 – 13:00)	65	70	75
Evenings and weekends[1]	55	60	65
Night-time (23:00 – 07:00)	45	50	55
Guidance:	Thresholds to be used when ambient noise levels are less than these values (to nearest 5 dB)	Thresholds to be used when ambient noise levels are the same as the Category A values (to nearest 5 dB)	Thresholds to be used when ambient noise levels are greater than the Category A values (to nearest 5 dB)

[1] Defined as 19:00-23:00 weekdays, 13:00-23:00 Saturdays and 07:00-23:00 Sundays

4.4.9. Where the thresholds in Table 1 are exceeded, it is an indication that potentially significant effects could occur from the site due to construction noise. The standard also notes that where the ambient noise levels exceed the Category C threshold values, a potential significant effect is indicated if the total $L_{Aeq,T}$ noise level for the period increases by more than 3 dB due to site noise.

4.4.10. It should be noted that, in the determination of overall significance, other factors need to be considered, including the number of residential properties affected, the duration and character of the impact and the exceedance of the threshold value (in dB $L_{Aeq,T}$).

VIBRATION (BS 5228-2)

4.4.11. Unlike its predecessors, the current version of BS 5228-2 now includes (in Annex E) formulae that enable predictions to be made of resultant PPV for a variety of processes, including percussive and vibratory piling, which by their very nature generate vibration.

4.4.12. With respect to human exposure to vibration, Table B1 of Annex B to BS 5228-2 provides guidance on the effects of vibration levels on human beings which is reproduced in Table 2.

Table 2: Guidance on effects of vibration levels

Vibration Level	Effect
0.14 mm/s	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3 mm/s	Vibration might be just perceptible in residential environments.
1.0 mm/s	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents.

Vibration Level	Effect
10 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level in most building environments.

[1] The magnitudes of the values presented apply to a measurement position that is representative of the point of entry into the recipient.

[2] A transfer function (which relates an external level to an internal level) needs to be applied if only external measurements are available.

[3] Single or infrequent occurrences of these levels do not necessarily correspond to the stated effect in every case. The values are provided to give an initial indication of potential effects, and where these values are routinely measured or expected then an assessment in accordance with BS 6472-1 or -2, and/or other available guidance, might be appropriate to determine whether the time varying exposure is likely to give rise to any degree of adverse comment.

4.4.13. Accordingly, a limit of 1 mm/s is typically adopted outside the nearest dwellings in order to limit the amount of nuisance caused to a reasonable degree. It is assumed that prior warning and explanation would be given to the occupants. A higher limit of 3 mm/s can usually be applied to commercial premises, including offices, but where residential accommodation is similarly located, this will be the determining factor. For this outline assessment, therefore, the single limit of 1 mm/s has been adopted.

5. ASSESSMENT CRITERIA

5.1. NOISE

BASELINE NOISE SURVEY

5.1.1. A survey of the baseline noise climate was conducted between Tuesday 6 and Friday 9 March 2018 at the locations illustrated in Figure 1 and Figure 2. Full details of this survey can be found in WSP's *Acoustic Application Report. Report No. 70040431-600, October 2018*.

5.1.2. The measurements locations are described as follows:

- **Measurement Position 1 (MP1):** At the proposed entrance to the memorial
- **Measurement Position 2 (MP2):** On the pavement of Millbank near the junction with Dean Stanley Street.
- **Measurement Position 3 (MP3):** On the pedestrian pathway on the east bank of the River Thames next to Guy's and St Thomas' Hospital.

5.1.3. While no weekend measurements were undertaken, the noise sources affecting the measurement locations (predominantly vehicular traffic on nearby roads) do not vary significantly between weekends and weekdays. On this basis, the weekday measurements are considered representative of the noise climate during the weekend.

CRITERIA

5.1.4. Table 3 presents the assessment criteria relating to noise effects based on the results of the baseline noise survey and using the ABC method described in Section 4.

5.1.5. In accordance with Westminster's CoCP, thresholds have only been established for weekday daytime and Saturday morning periods.

5.1.6. As, at the time of the survey, a noise monitor could not be left unattended for a prolonged period, a selection of 15-minute sample measurements were undertaken at key periods of the day at each noise-sensitive receptor. The arithmetic average of the levels measured within the periods of interest here have been determined, which are considered sufficiently representative of the levels as if measured over the full period. It is these levels that are presented in Table 3 and used to determine the noise assessment criteria.

Table 3: Thresholds of potential significance for noise (façade levels, in accordance with the assessment methodology in BS 5228)

Noise Sensitive Receptor	Representative Measurement Position	Weekday Daytime[1] Noise Level ($L_{Aeq,T}$)[2]	Saturday Morning[1] Noise Level ($L_{Aeq,T}$)[2]	BS 5228 Category	Threshold of Significance ($L_{Aeq,10}$ / $L_{Aeq,5h}$)
Receptors on Millbank	MP2	69	69	C	75
Parliamentary Education Centre & Palace of Westminster	MP2	69	69	C	75

Guy's and St Thomas' Hospital	MP3	62	61	A	65

[1] Daytime is taken to be between 08:00 and 18:00 hrs, while Saturday morning is taken to be between 08:00 and 13:00 hrs, in accordance with Westminster's CoCP.

[2] The logarithmic average of the 15-minute sample measurements undertaken during the period of interest.

5.2. VIBRATION

5.2.1. The threshold for potential significant effects on human receptors from vibration generated by construction activities is summarised in Table 4.

Table 4: Threshold of potential significant effect for construction generated vibration

Receptor	Peak Particle Velocity (PPV mm/s)
All Receptors (immediately outside)	1.0

6. OUTLINE CONSTRUCTION NOISE ASSESSMENT

6.1. CONSTRUCTION PROGRAMME

6.1.1. Preliminary construction programme information has been provided by one of the bidding contractors, and outlines three broad phases of works: Site establishment, lasting 5 weeks; Substructure works, lasting 59 weeks; and Superstructure works, lasting 25 weeks.

6.1.2. Of these phases, the works undertaken during the creation of the substructure are considered to generate the highest levels of noise. This phase has been split into 3 discrete sub-phases for this assessment as follows:

- Foundations
- Excavation
- Concreting

6.1.3. Construction activities assumed within each of these sub-phases are discussed in the following section.

6.2. ACTIVITIES

6.2.1. As details of specific proposed plant items are not known, predictions of the effects of noise have been made assuming plant based on our experience.

Table 5: Assumed plant details for construction works

Phase of Work	Plant Item	NO.	Sound Pressure Level, L_p at 10 m (dB(A))	Data Source
Foundations	Diesel generator	1	61	BS 5228 C4/76
	Wheeled mobile crane	2	70	BS 5228 C4/43
	Lorries	2*	70	BS 5228 Annex D
	Poker vibrator	2	69	BS 5228 C4/34
	CFA piling rig – crawler mounted	2	80	BS 5228 C3/21
	Concrete pump	2	78	BS 5228 C3/25
	Breaker	1	92	BS 5228 C1/1
Excavation	Diesel generator	1	61	BS 5228 C4/76
	Lorries	3*	70	BS 5228 Annex D
	Tracked excavator	1	77	BS 5228 C2/2
	Tracked excavator (idling)	1	63	BS 5228 C2/6
	Wheeled loader	1	68	BS 5228 C2/8
	Wheeled loader (idling)	1	55	BS 5228 C2/9
	Dumper	1	56	BS 5228 C4/8

Phase of Work	Plant Item	NO.	Sound Pressure Level, L_p at 10 m (dB(A))	Data Source
Concreting	Diesel generator	1	61	BS 5228 C4/76
	Wheeled mobile crane	2	70	BS 5228 C4/43
	Lorries	1*	70	BS 5228 Annex D
	Truck mounted concrete pump	1	78	BS 5228 C4/32
	Concrete mixer truck	1*	80	BS 5228 C4/20
	Poker vibrator	2	78	BS 5228 C4/33

* In this instance, the number of plant represents the number of items anticipated to be present on site at any one time. More items are anticipated over the course of the day, which is reflected in the percentage on-time (not presented above).

6.3. PREDICTED NOISE LEVELS

6.3.1. Calculations have been made to determine noise levels likely to be generated by each of the above stages at the key existing receptors. Effects may also be experienced at existing receptors adjacent to and beyond those considered. However, the effects at these receptors will be the same as or less than those presented in this report; with increasing distance, noise effects will reduce.

6.3.2. The predictions presented follow the methodology in BS 5228-1 and are in terms of the $L_{Aeq,T}$ over the periods assessed (i.e. 08:00 – 18:00 hrs during weekdays and 08:00 – 13:00 hrs on Saturdays).

6.3.3. For the purpose of this assessment, it is assumed, as worst case, that the intervening ground between the construction activities and the receptors is hard ground.

6.3.4. While Westminster's CoCP requires that sites are bound by an imperforate hoarding of minimum height and density, for noise control reasons. Some areas of the primary receptors will likely overlook such hoarding, and, therefore, no losses for screening have been assumed as worst case in the majority of instances. The exception to this is in terms of the use of a breaker to breakdown piles when closest to Milbank, where at least partial screening has been assumed providing a reduction of 5 dB.

6.3.5. Table 6 presents the predicted noise levels at the façades of the assessed receptors. In line with the assessment procedures in BS 5228, all the predictions include a +3 dB correction from free-field to façade levels.

6.3.6. Noise level predictions are presented for both average-case conditions – where construction plant are located at an average distance from the receptors, and worst-case conditions – where construction plant are located at their nearest to the receptors. All values are rounded to the nearest 1 dB.

Table 6: Predicted noise levels at the assessment locations

Phase	Receptor	Predicted Noise Level (dB, $L_{Aeq,10h/5h}$)		Threshold of Potential Significant Effect (dB, $L_{Aeq,10h/5h}$)	Difference (Threshold minus Predicted Noise Level) (dB)	
		Average	Worst		Average	Worst
Foundations	Millbank	74	75[1]	75	- 1	0
	PEC & Westminster Pal.	56	63	75	- 13	- 12
	Guy's and St Thomas' Hospital	58	59	65	- 7	- 6
Excavation	Millbank	69	72	75	- 6	- 4
	PEC & Westminster Pal.	56	59	75	- 19	- 16
	Guy's and St Thomas' Hospital	53	47	65	- 12	- 18
Concreting	Millbank	69	72	75	- 6	- 3
	PEC & Westminster Pal.	58	59	75	- 17	- 16
	Guy's and St Thomas' Hospital	53	54	65	- 12	- 11

[1] As indicated in paragraph 5.3.4, a reduction of 5 dB is accounted for due to the assumption of at least partial screening from either site hoarding or localised screens, where necessary. The average-case does not include this screening, hence, despite the additional distances associated with this case, the predicted levels are similar.

6.3.7. In all instances it can be seen that the predicted noise levels are below the relevant thresholds. This provides a strong indication that there will be no significant noise effects during the works. In which case, there is considered to no need for any other factors (such as the duration and character of impact) to be taken into account.

6.4. CONTROL MEASURES

6.4.1. Key mitigation measures applicable to this assessment are listed below:

- Best Practical Means (BPM), as defined under Section 72 of the Control of Pollution Act (CoPA) 1974, will be applied to all activities.
- Normal site working hours are:
  - Monday to Friday – 8am to 6pm
  - Saturday – 8am to 1pm
- Noisy operations shall not take place outside these hours without the prior approval from the Council.
- Any compressors brought on to site to be silenced or sound reduced models fitted with acoustic enclosures.
- All pneumatic tools to be fitted with silencers or mufflers.
- Care will be taken when erecting or striking scaffolds to avoid impact noise from banging steel. All operatives undertaking such activities to be instructed on the importance of handling the scaffolds to reduce noise to a minimum.
- Deliveries to be programmed to arrive during daytime hours only. Care will be taken when unloading vehicles to minimise noise. Delivery vehicles to be routed so as to minimise disturbance to local residents. Delivery vehicles to be prohibited from waiting within or in the vicinity of the Site with their engines running.
- All plant items to be properly maintained and operated according to manufacturers' recommendations in such a manner as to avoid causing excessive noise. All plant to be sited so that the noise impact at nearby noise sensitive properties is minimised.
- Local hoarding, screens or barriers to be erected as necessary to shield particularly noisy activities.
- A considerate and neighbourly approach will be taken to relations with the local occupants.

7. OUTLINE CONSTRUCTION VIBRATION ASSESSMENT

7.1. DESCRIPTION OF ACTIVITIES

7.1.1. While most construction activities can generate vibration to some extent, it is usually only a few that have the potential to generate sufficient vibration for any issues to occur in the vicinity.

7.1.2. In the absence of the need for any demolition as part of the works, the greatest source of vibration is likely to be the piling utilised in forming the foundations and secant wall structure.

7.1.3. It is assumed that the foundations and secant walls associated with the development will be constructed using either continuous flight auger (CFA) piling or rotary bored piling. The need for pile casings for the foundations has not yet been determined, but if they are required they should, where feasible, be inserted using rotary techniques, which should result in no more vibration than the main augering phase.

7.2. PREDICTED VIBRATION LEVELS

7.2.1. Predictions of vibration from a worst-case activity (bored piling) have been undertaken at both an average case location (where plant would be located at a typical distance from a receptor) and a worst-case location (where plant would be located at the nearest location to a receptor).

7.2.2. The predicted vibration levels experienced at the receptors are presented in Table 7.

Table 7: Predicted vibration levels at the assessment locations

Receptor	Predicted PPV (mm/s)		Threshold of Potential Significant Effect (PPV, mm/s)	Difference (mm/s)	
	Average	Worst		Average	Worst
Millbank	0.19	0.32	1	- 0.81	- 0.68
PEC & Westminster Palace	0.06	0.05	1	- 0.95	- 0.94
Guy's and St Thomas' Hospital	0.03	0.03	1	- 0.97	- 0.97

7.2.3. In all instances it can be seen that the predicted vibration levels are below the relevant threshold. This provides a strong indication that there will be no significant vibration effects during the works.

7.3. CONTROL MEASURES

7.3.1. The mitigation measures set out for noise will also keep vibration levels to a minimum. In particular, BPM will need to be adopted, whilst all plant items are to be properly maintained and operated according to manufacturers' recommendations in such a manner as to avoid causing excessive vibration.

Appendix A

GLOSSARY OF ACOUSTIC TERMINOLOGY

Noise

Noise is defined as unwanted sound. Human hearing is able to respond to sound in the frequency range 20Hz (deep bass) to 20,000Hz (high treble) and over the audible range of 0 dB (the threshold of perception) to 140 dB (the threshold of pain). The ear does not respond equally to different frequencies of the same magnitude, but is more responsive to mid-frequencies than to lower or higher frequencies. To quantify noise in a manner that approximates the response of the human ear, a weighting mechanism is used, which reduces the importance of lower and higher frequencies in a similar manner to human hearing.

The weighting mechanism that best corresponds to the response of the human ear is the 'A'-weighting scale. This is widely used for environmental noise measurement, and the levels are denoted as dB(A) or L_{Aeq}, L_{A90} etc, according to the parameter being measured. The glossary below explains the acoustic terminology that is used in this report.

The decibel scale is logarithmic rather than linear, and hence a 3 dB increase in sound level represents a doubling of the sound energy present. Judgement of sound is subjective, but as a general guide a 10 dB(A) increase can be taken to represent a doubling of loudness, whilst an increase in the order of 3 dB(A) is generally regarded as the minimum difference needed to perceive a change under normal listening conditions.

An indication of the range of sound levels found commonly in the environment is given in the table below.

Table A.1: Typical sound levels found in the environment

Sound Pressure Level, dB(A)	Location
0	Threshold of hearing
20 to 30	Quiet bedroom at night
30 to 40	Living room during the day
40 to 50	Typical office
50 to 60	Inside a car
60 to 70	Typical high street
70 to 90	Inside factory
100 to 110	Burglar alarm at 1m away
110 to 130	Jet aircraft on take off
140	Threshold of pain

The subjective response to a noise is dependent not only upon the sound pressure level and its frequency, but also its intermittency. Various indices have been developed to try and correlate annoyances with the noise level and its fluctuations.

- Sound Pressure: Sound, or sound pressure, is a fluctuation in air pressure over the static ambient pressure.
- Sound Pressure Level (Sound Level): The sound level is the sound pressure relative to a standard reference pressure of 20 Pa ($20x10^{-6}$ Pascals) on a decibel scale.
- Sound Power: The sound energy radiated per unit time by a sound source. Measured in Watts (W).
- Sound Power Level, L_W: Sound power measured on a decibel scale, relative to a reference value of 10^{-12} W.
- Decibel (dB): A scale for comparing the ratios of two quantities, including sound pressure and sound power. The difference in level between two sounds s1 and s2 is given by 20 log10 (s1/s2). The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20 Pa.
- A-weighting, dB(A): The unit of sound level, weighted according to the A-scale, which takes into account the increased sensitivity of the human ear at some frequencies.
- Noise Level Indices: Noise levels usually fluctuate over time, so it is often necessary to consider an average or statistical noise level. This can be done in several ways, so a number of different noise indices have been defined, according to how the averaging or statistics are carried out.
- $L_{eq,T}$: A noise level index called the equivalent continuous noise level over the time period T. This is the level of a notional steady sound that would contain the same amount of sound energy as the actual, possibly fluctuating, sound that was recorded.
- Free-Field: Far from the presence of sound reflecting objects (except the ground), usually taken to mean at least 3.5m away.
- Façade: At a distance of 1 m in front of a large sound reflecting object such as a building façade.

Vibration

Vibration is defined as a repetitive oscillatory motion. Groundborne vibration can be transmitted to the human body through the supporting surfaces; the feet of a standing person, the buttocks, back and feet of a seated person or the supporting area of a recumbent person. In most situations, entry into the human body will be through the supporting ground or through the supporting floors of a building. Vibration from road traffic can also be airborne. Such airborne vibration is transmitted as a low-frequency sound wave and is often perceived when the sound wave causes windows or other objects to rattle.

Vibration is often complex, containing many frequencies, occurring in many directions and changing over time. There are many factors that influence human response to vibration. Physical factors include vibration magnitude, vibration frequency, vibration axis, duration, point of entry into the human body and posture of the human body. Other factors include the exposed persons experience, expectation, arousal and activity.

Experience shows that disturbance or annoyance from vibration in residential situations is likely to arise when the magnitude of vibration is only slightly in excess of the threshold of perception.

The threshold of perception depends on the frequency of vibration. The human body is most sensitive to vibration in the frequency range 1 to 80 Hz and especially sensitive to vibration in the range 4 to 8 Hz. As with noise, a frequency weighting mechanism is used to quantify vibration in a way that best corresponds to the frequency response of the human body. For occupants within buildings, the frequency weighting curve is defined in BS 6472-1:2008 'Guide to evaluation of human exposure to vibration in buildings Part 1: Vibration sources other than blasting'. In general,

vibration is only perceptible in residential situations when the building is close to a railway, construction site or very close to a road that carries large and heavy vehicles.

- Displacement, Acceleration and Velocity; Root Mean Square (r.m.s.) and Peak Values; and Peak Particle Velocity (PPV): Vibration is an oscillatory motion. The magnitude of vibration can be defined in terms of displacement (how far from the equilibrium position that something moves), velocity (how fast something moves), or acceleration (the rate of change of velocity). When describing vibration, one must specify whether peak values are used (i.e. the maximum displacement or maximum velocity) or r.m.s. / r.m.q. values (effectively an average value) are used. Standards for the assessment of building damage are usually given in terms of peak velocity (usually referred to as Peak Particle Velocity, or PPV), whilst human response to vibration is often described in terms of r.m.s. or r.m.q. acceleration.

WSP House
70 Chancery Lane
London
WC2A 1AF

wsp.com