Cundy Street Quarter

Noise & Vibration Report

Prepared by Cundall

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GROSVENOR

Cundy Street Quarter

Noise & vibration assessment for planning

Grosvenor Estates Belgravia

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Principal author: Matthew Hyden

Signed by: m.hyden@cundall.com

19/05/2020

X

Checked by: Jason Gallimore

Signed by: Gallimore, Jason

19/05/2020

X pp

Verified by : Momo Hoshijima

Signed by: m.hyden@cundall.com

Executive Summary

An environmental noise survey and assessment has been undertaken for the Cundy Street Quarter development.

This assessment has only focused on the impact of the existing and future noise and vibration climate in the area on the Proposed Development. The impacts of the proposed scheme on existing noise and vibration sensitive receptors are included in the Noise and Vibration chapter of the Environmental Statement for the project (although the findings are summarised in this report).

The results of the noise survey have been assessed against Local Authority requirements and guidance in BS 8233:2014. The assessment has also considered guidance provided in the 'Professional Practice Guidance on Planning and Noise' (ProPG) document.

When assessed against the initial risk assessment criteria of the ProPG, it has been found that the proposed development site, without any mitigation measures, is at 'medium' to 'high' risk of adverse effects from noise across a significant portion of the site (although in more sheltered areas of the site a low risk of adverse effects has been identified). As such, an Acoustic Design Statement (ADS) relating mainly to the good acoustic design process undertaken for this project, internal noise levels and noise levels in external amenity areas has been completed. Where appropriate, this ADS contains details of design and mitigation measures to reduce the impact of noise on residents of the proposed development.

The key mitigation measures outlined in the ADS include:

- Appropriate façade treatments (glazing etc.) to control internal noise levels and meet Westminster City Council (WCC) planning requirements; and
- A mechanical ventilation system so that façade openings are not required to provide whole dwelling ventilation.

The assessment has found that through the use of appropriate glazing, façade construction and ventilation systems, the internal noise criteria of BS 8233:2014 can be met whilst whole dwelling ventilation is provided.

Based on the assessment carried out in light of the guidance in the ProPG, our recommendations in relation to noise are that:

'*Planning consent may be granted subject to the inclusion of suitable noise conditions'*

A vibration survey has been undertaken to estimate potential groundborne noise and vibration (GBN&V) impacts on the proposed development as a result of the existing District and Circle lines. It has been found that significant adverse vibration impacts are unlikely to occur but in areas of the Proposed Development close to the London Underground Lines some GBN impact may occur (without mitigation).

The proposed site lies within the Crossrail 2 (CR2) safeguarding zone. Potential GBN&V impacts on the proposed development, as a result of the proposed Crossrail 2 (CR2) rail scheme, have been predicted in line with CR2 guidance. It has been found that without mitigation the CR2 GBN criteria may be exceeded and this could result in adverse impacts.

Therefore, the proposed scheme design includes for GBN&V mitigation in the form of building foundation isolation. This mitigation will be designed to reduce GBN impacts to within CR2 guideline values and therefore significant adverse impacts as a result of GBN&V are unlikely. In addition, this mitigation will also reduce any GBN in the Proposed Development from the existing London Underground lines so that adverse impacts are unlikely.

In summary, a noise and vibration impact assessment has been undertaken and the proposed scheme has allowed for noise and vibration mitigation so that:

- WCC noise criteria are complied with;
- Crossrail 2 GBN&V criteria are met;
- Significant adverse noise and vibration impacts are unlikely to occur; and
- Adverse noise and vibration impacts are minimised.

Contents

1.0 Introduction

Cundall has been commissioned by Grosvenor Estates Belgravia to undertake a noise and vibration assessment for the proposed Cundy Street Quarter development, London, SW1. This report is intended to be submitted as part of a planning application for the Proposed Development.

The Proposed Development would provide a residential led scheme, which delivers new homes for a range of people, with a mix of uses, high quality architecture, public realm and landscaping.

The purpose of this report is to;

- review appropriate national and local planning policy and legislation;
- assess the impact of the existing noise environment on the Proposed Development;
- undertake an acoustic assessment of the external building fabric requirements and where appropriate outline mitigation advice;
- assess potential vibration (and groundborne noise) impacts on the proposed development from existing (District and Circle Line) and proposed new (Crossrail 2) underground rail lines; and
- where appropriate, propose vibration mitigation measures.

It should be noted that consideration of likely noise and vibration effects of the Proposed Development on nearby receptors is not in the scope of this report. For full details regarding potential noise and vibration effects of the development on existing nearby receptors, please see Noise and Vibration Chapter 12 of the Environmental Statement (ES) for the proposed development. However, the findings of the assessment are also summarised in this report.

2.0 Proposed Development

Proposals are for the demolition of the existing Cundy Street and Walden House residential buildings for the development of a mix of residential, commercial, community and external amenity spaces. The residential elements of the scheme are to include provision for a mix of private, affordable and senior living type dwellings.

The site is bounded by Pimlico Road (A3214) to the south, Ebury Street to the north-east, Cundy Street / Ebury Square to the north-east and Avery Farm Row to the east.

Figure 1 shows the extent of the red line boundary in the context of the current as built environment and Figure 2 shows the proposed site plan.

Figure 1 - Indicative plan of the extent of the site

Figure 2 - Proposed site plan

3.0 Assessment criteria

This section of the report outlines the key legislation and guidance relevant to the assessment of noise and vibration for a development of this type.

The site falls within the City of Westminster. The assessment methodology adopted has been based on national and regional policy, British Standards and the standard planning requirements of Westminster City Council (WCC).

3.1 Noise Policy Statement for England

The Noise Policy Statement for England (NPSE) was published by Defra in March 2010. The NPSE sets out the long-term vision of Government noise policy:

"Promote good health and a good quality of life through the effective management of noise within the context of Government policy on sustainable development."

The NPSE long term vision is supported by the following aims:

"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."*

3.2 National Planning Policy Framework

The revised National Planning Policy Framework was updated on 19 February 2019 and sets out the Government's planning policies for England and how these are expected to be applied.

The NPPF states:

130. Permission should be refused for development of poor design that fails to take the opportunities available for improving the character and quality of an area and the way it functions, taking into account any local design standards or style guides in plans or supplementary planning documents. Conversely, where the design of a development accords with clear expectations in plan policies, design should not be used by the decision-maker as a valid reason to object to development. Local planning authorities should also seek to ensure that the quality of approved development is not materially diminished between permission and completion, as a result of changes being made to the permitted scheme (for example through changes to approved details such as the materials used).

170. Planning policies and decisions should contribute to and enhance the natural and local environment by;

[…]

e) preventing new and existing development from contributing to, being put at unacceptable risk from, or being adversely affected by, unacceptable levels of soil, air, water or noise pollution or land instability. Development should, wherever possible, help to improve local environmental conditions such as air and water quality, taking into account relevant information such as river basin management plans;

180. Planning policies and decisions should also ensure that new development is appropriate for its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development. In doing so they should:

a) mitigate and reduce to a minimum potential adverse impacts resulting from noise from new development – and avoid noise giving rise to significant adverse impacts on health and the quality of life;

b) identify and protect tranquil areas which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason; […]

182. *Planning policies and decisions should ensure that new development can be integrated effectively with existing businesses and community facilities (such as places of worship, pubs, music venues and sports clubs). Existing businesses and facilities should not have unreasonable restrictions placed on them as a result of development permitted after they were established. Where the operation of an existing business or community facility could have a significant adverse effect on new development (including changes of use) in its vicinity, the applicant (or 'agent of change') should be required to provide suitable mitigation before the development has been completed.*

3.3 London Plan

Policy 7.15 of the London Plan states the following regarding planning decisions:

Development proposals should seek to manage noise by:

- *Avoiding significant adverse noise impacts on health and quality of life as a result of new development;*
- *Mitigating and minimising the existing and potential adverse impacts of noise on, from, within as a result of or in the vicinity of new development without placing unreasonable restrictions on development or adding unduly to the costs and administrative burdens on existing businesses;*
- *Improving and enhancing the acoustic environment and promoting appropriate soundscapes (including Quiet Areas and spaces of relative tranquillity);*
- *Separating new noise sensitive development from major noise sources, (such as road, rail, air transport and some types of industrial development) through the use of distance, screening or internal layout – in reference to sole reliance on sound insulation;*
- *Where it is not possible to achieve separation of noise sensitive development objectives, then any potential adverse effects should be controlled and mitigated through the application of good acoustic design principles;*
- *Having particular regard to the impact of aviation noise on noise sensitive development*
- *Promoting new technologies and improved practices to reduce noise at source, and on the transmission path from source to receiver.*

In addition, in the 'intend to publish' version of the upcoming new London Plan adds the following to the above requirements for development proposals:

- *Reflecting the Agent of Change principle as set out in Policy D13 Agent of Change*

3.4 Westminster City Council planning requirements

Westminster City Council's (WCC's) City Plan (November 2016) states the following in Policy S32 relation to noise:

The council will work to reduce noise pollution and its impacts and protect Noise Sensitive Receptors from noise by:

- *Requiring development to minimise and contain noise and vibration;*
- *Ensuring development provides an acceptable noise and vibration climate for occupants and is designed to minimise exposure to vibration and external noise sources; and*
- *Securing improvements to Westminster's sound environment, including protecting open spaces of particular value for their relative tranquillity.*

The WCC Unitary Development Plan also contains guidance and information on Noise Pollution in Chapter 9, in particular this includes Policies ENV 6 'Noise Pollution' and ENV 7 'Controlling noise from plant, machinery and internal activity'.

WCC have a set of standard noise-related planning conditions (outlined in the WCC 'Conditions and Reasons' document, updated 2013) intended to protect sensitive properties from excessive noise and vibration levels.

With particular relevance to protecting new residential development from adverse noise impacts of the existing noise environment is Condition C49AA and C49BA, reproduced below:

Condition C49: *Where proposed or existing residential would suffer noise from outside, or from within the same or adjoining building*

C49AA: *Noise from mixed sources – where proposed residential development would be subject to noise exposure from existing external sources exceeding:*

a) 55dB ($L_{Aeq,16hour\ day}$) (07:00-23:00hrs)

b) 45dB ($L_{Aeq,8\ hour\ night}$) (23:00-07:00hrs)

The design and structure of the development shall be of such a standard that it will protect residents within it from existing external noise so that they are not exposed to levels indoors of more than 35 dB $L_{Aeq,\ 16\ hrs}$ daytime and of more than 30 dB $L_{Aeq\ 8\ hrs}$ in bedrooms at night.

C49BA: *Noise from mixed sources – where existing or proposed residential development would be subject to noise exposure from within the same building or an adjoining building.*

The design and structure of the development shall be of such a standard that it will protect residents within the same building or in adjoining buildings from noise and vibration from the development, so that they are not exposed to noise levels indoors of more than 35 dB $L_{Aeq\ 16\ hrs}$ daytime and of more than 30 dB $L_{Aeq\ 8\ hrs}$ in bedrooms at night.

There are also a number of additional noise and vibration conditions included in the document that may be relevant to the development.

3.5 BS 8233: 2014 'Guidance on sound insulation and noise reduction for buildings' (BS 8233)

Table 4 of British Standard 8233: 2014 provides guidance on internal ambient noise levels in residential spaces from steady external sources, such as traffic. The guidance in BS 8233 is aligned with WCC's planning requirements. These values are generally considered to represent the 'lowest observed adverse effect level' and the table is reproduced below:

Location	Daytime (07:00 to 23:00 hours)	Night-time (23:00 to 07:00 hours)
Living room	≤ 35 dBA $L_{eq,16hour}$	N/A
Dining room	≤ 40 dBA $L_{eq,16hour}$	N/A
Bedroom	≤ 35 dBA $L_{eq,16hour}$	≤ 30 dBA $L_{eq,8hour}$

Table 1 - BS 8233:2014 'indoor ambient noise levels for dwellings'

The following notes should be considered when following the guidance above:

If relying on closed windows to meet the guide values, there needs to be an appropriate alternative ventilation that does not compromise the façade insulation or the resulting noise level;

In relation to the noise guidelines reproduced in Table 1 above, BS 8233 states:

"Where development is considered necessary or desirable, despite external noise levels above WHO guidelines, the internal target levels may be relaxed by up to 5 dB and reasonable internal conditions still achieved'

BS 8233: 2014 provides the following consideration for façade attenuation when partially open windows are used for ventilation:

"If partially open windows were relied upon for background ventilation, the insulation [of the building façade] *would be reduced to approximately 15 dB*

The 2014 version of BS 8233 does not include any specific requirement for maximum instantaneous noise levels within dwellings. However, BS 8233: 1999 (superseded) stated that "*For a reasonable standard in bedrooms at night, individual noise events (measured with F time-weighting) should not normally exceed 45 dB L_{AFMax}.*"

3.6 ProPG – Professional Practice Guidance on Planning and Noise

The 'Professional Practice Guidance on Planning & Noise – New Residential Development' (ProPG) was produced to provide practitioners with guidance and a recommended approach for the assessment of noise impact on residential developments during the planning stage.

The primary goal of the ProPG is to:

"Assist the delivery of sustainable development by promoting good health and wellbeing through the effective management of noise."

The document seeks to do this by:

"Encouraging a good acoustic design in and around proposed new residential development having regard to national policy on planning and noise"

The ProPG advocates a 2-stage approach to facilitate *"…straightforward accelerated decision making for lower risk sites and assists proper consideration of noise issues where the acoustic environment is challenging".*

The recommended approach is summarised below:

- Stage 1 – an initial noise risk assessment of the proposed development site; and
- Stage 2 – a systematic consideration of four key elements.
  - Element 1 – Demonstrating a "Good Acoustic Design Process";
  - Element 2 – Observing internal "Noise Level Guidelines";
  - Element 3 – Undertaking an "External Amenity Area Noise Assessment"; and
  - Element 4 – consideration of "Other relevant Issues".

In addition to the above, the ProPG states:

"The approach is underpinned by the preparation and delivery of an 'Acoustic Design Statement' (ADS). An ADS for a site assessed as high risk should be more detailed than for a site assessed as low risk. An ADS should not be necessary for a site assessed as low risk."

Having followed the recommended approach, the ProPG suggests that the noise practitioner should be able to make one of four recommendations to the relevant planning decision maker:

A) Planning consent may be granted without any need for noise conditions;

B) Planning consent may be granted subject to the inclusion of suitable noise conditions;

C) Planning consent should be refused on noise grounds in order to avoid significant adverse effects ("avoid"); or

D) Planning consent should be refused on noise grounds in order to prevent unacceptable adverse effects ("prevent").

3.7 BS 6472-1:1992 'Evaluation of human exposure to vibration in buildings' (BS 6472-1)

BS 6472-1 provides general guidance on the evaluation of human exposure to vibration in buildings in the frequency range 1 Hz to 80 Hz.

Table 2 presents vibration dose value ranges which could result in various probabilities of adverse comment within residnetial type buildings.

Place & time	Low probability of adverse comment ($m.s^{-1.75}$)*	Adverse comment possible ($m.s^{-1.75}$)	Adverse comment probable ($m.s^{-1.75}$)**
Residential buildings 16h day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential buildings 8h day*	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8
* Below these ranges adverse comment is not expected.			

** Above these ranges adverse comment is very likely For offices a multiplying factor of 2 should be applied to the above VDVs for a 16h day

Table 2 - Vibration dose value ranges which might result in various probabilities of adverse comment within residential buildings

3.8 Groundborne noise - Crossrail 2 Information for developers

Sections of the proposed development site fall within the Crossrail 2 (CR2) safeguarding area. For developments proposed within the safeguarding area, the *Crossrail 2 Tunnel Section: Information for Developers* document provides guidance on groundborne noise and vibration (GBN&V). This includes GBN&V design aims and criteria for such developments when CR2 is operational.

These GBN&V criteria will also be used to assess potential impacts on the proposed development as a result of the existing GBN&V climate in the area.

The GBN design aims most relevant to the Proposed Development from the CR2 '*Tunnel Section: Information for Developers* ' document are reproduced in Table 3 below:

Building	Level / Measure $L_{Amax,F}$ (dB)
Residential buildings	≤ 35
Offices	≤ 40
Theatres	≤ 25
Hotels	≤ 40
Small Auditoria / Halls	≤ 35
Libraries	≤ 40

Table 3 - Operational Groundborne Noise Design Aims

Table 4 below reproduces the operational vibration criteria contained in the CR2 document:

In the absence of appreciable existing levels of vibration		Appreciable existing levels of vibration (% increase in VDV)
VDV ($m.s^{-1.75}$) Daytime	VDV ($m.s^{-1.75}$) Night-time	
0.31	0.18	4
*Highest impact category used, daytime or night-time. There is an appreciable existing level of vibration where daytime and night-time vibration dose values (VDVs) exceed 0.22 $m.s^{-1.75}$ and 0.13 $m.s^{-1.75}$ respectively.		

Table 4 - Operational vibration criteria

4.0 Noise and vibration baseline surveys

4.1 Environmental noise survey

An environmental noise survey has been completed to feed into the design of the Proposed Development and inform this planning noise impact assessment.

The environmental noise survey comprised attended measurements and unattended monitoring in and around the Site.

Unattended monitoring took place on the roof of the Stack House building, Cundy Street, between 31 October and 12 November 2018. The noise levels collected by this meter have been used to evaluate longer-term trends in the noise climate and, where necessary, corrected against the noise levels measured at the attended positions.

Attended measurements were also taken around the site in a range of locations. Noise measurement locations are detailed in Figure 3.

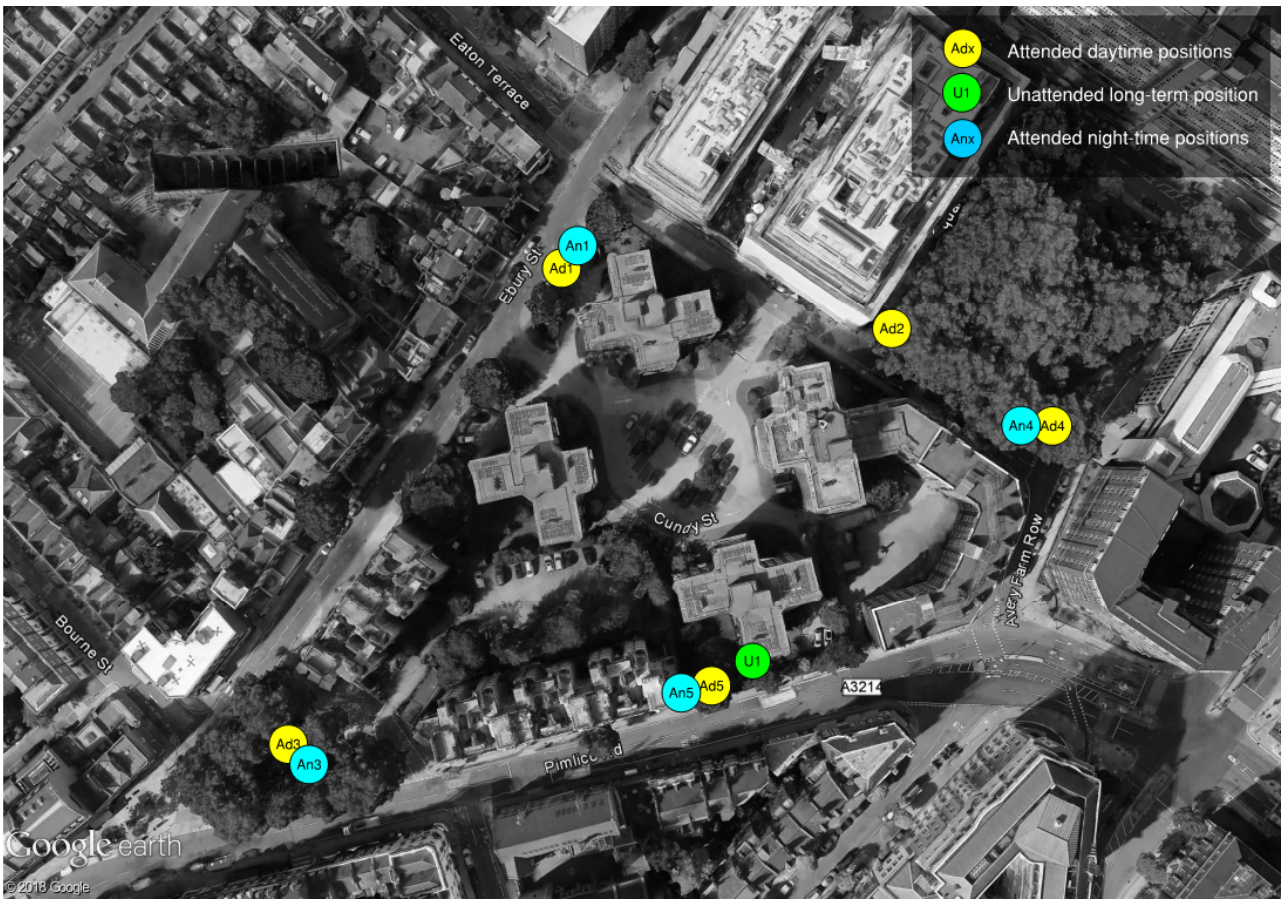


Figure 3 - Noise monitoring locations

4.1.1 Ambient noise climate

During daytime (07:00–23:00) and night-time (23:00–07:00) periods, the noise climate was dominated by road traffic noise from the surrounding roads in all locations, in particular from vehicles using Pimlico Road and Ebury Street. Table 5 summarises the start time and durations of the noise measurements.

Location Ref.	Dominant noise source	Daytime – start time and duration (T)	Night-time – start time and duration (T)
A1 - Ebury Road	Intermittent traffic noise on Ebury Street.	10:30 (2 hours)	01:50 (30 mins)
*A2 - West corner of Ebury Square	Traffic noise on Ebury Street and Cundy Street.	10:30 (2 hours)	-
A3 - Orange Square, between Ebury Street and Pimlico Road	Traffic noise from Pimlico Road and Ebury Street	13:50 (2 hours)	01:10 (30 mins)
A4 - South Corner of Ebury Square	Traffic noise from Pimlico road	13:50 (2 hours)	02:25 (30 mins)
A5 - Pimlico Road, adjacent to Stack House	Traffic noise from Pimlico road	17:30 (30 mins)	03:05 (30 mins)
U1 - Roof of Stack House	Traffic noise from Pimlico Road	17:00 31/10/2018 to 14:00 12/11/2018 (approx. 285 hours)	
* No night-time measurements were completed at location A2			

Table 5 - Noise measurement locations, timings and environments

Noise climate conditions are not anticipated to have changed significantly between the time of the survey and the time of writing this report.

4.1.2 Measurement equipment

Table 6 provides relevant details of the equipment used during the environmental noise survey. The sound level meter used, conforms to BS EN 60650 type 1 accuracy and was field calibrated before and after use.

Equipment	Manufacturer & model	Serial number
Sound level meter	01dB Fusion	11766
Calibrator	01dB Cal31	84908
Sound level meter	Norsonic Nor140	1405754
Calibrator	Casella CEL Type 120/1	2652023

Table 6 - Survey equipment

Copies of external calibration certificates are available upon request.

4.1.3 Weather conditions

Weather conditions during attended measurements were conducive with noise monitoring, with low wind speeds and no rain.

Weather conditions during the entirety of the survey were measured by a weather station set up on site. Adverse weather conditions, including rain and windspeeds above 5 m/s were noted for short periods during the unattended monitoring survey. Data for periods where noise measurements have been deemed to have been adversely affected by such conditions have been discounted from the assessment (these periods are shown in Appendix A).

4.1.4 Noise survey results

The results of the environmental noise survey are summarised in tables Table 7, Table 8 and Table 9:

Ambient noise levels

Measurement Position	Indicative façade location	Ambient noise levels dB	
		Daytime $L_{Aeq,T}$	Night-time $L_{Aeq,T}$
A1	Ebury Street	65	58
A2	Ebury Square	60	-
A3	Orange Square	62	58
A4	Avery Farm Row	64	53
A5	Pimlico Road	71	66
U1	Pimlico Road	62 to 65 (T = 16hr)	56 to 60 (T = 8hr)

Table 7 - Day and night-time ambient ($L_{Aeq,T}$) noise levels at the Site

Background noise levels

Measurement Position	Indicative façade location	Lowest background noise levels dB	
		Daytime $L_{A90,15min}$	Night-time $L_{A90,15min}$
A1	Ebury Street	50	39
A2*	Ebury Square	50	-
A3	Orange Square	57	46
A4	Avery Farm Row	53	50
A5	Pimlico Road	59	41
U1	Pimlico Road	49	43
* No night-time measurements were completed at location A2			

Table 8 - Day and night-time background ($L_{A90,T}$) noise levels at the Site

Noise events (maximum levels)

Measurement Position	Indicative façade location	Typical* maximum noise levels dB $L_{AFmax,5min}$
A1	Ebury Street	78
A3	Orange Square	73
A4	Avery Farm Row	64
A5	Pimlico Road	83
U1	Pimlico Road	72 to 75
*Typical maximum noise levels for the unattended measurement position have been selected as the level that is exceeded 15 times a night. For the shorter, attended measurements the highest measured L_{AFmax} value has been reported.		

Table 9 - Night-time Maximum (L_{AFmax}) noise levels at the Site

Detailed measurement time history graphs, which include details of periods affected by adverse weather conditions which have been removed from the assessment are included in Appendix A to this report.

4.2 Baseline vibration survey

Measurements of vibration generated by rail movements on the Circle and District Lines were undertaken on 6 September 2019 at a number of locations in and around the site.

Vibration measurements of train pass-by events were undertaken on the tiled floor of the ground-floor lobby in Lochmore House. Measurements were also undertaken externally in the carpark adjacent to Lochmore House, on the pavement of the corner of Ebury Street and Cundy Street and on the pavement on the corner of Ebury Street and Eaton Terrace (See Figure 4).

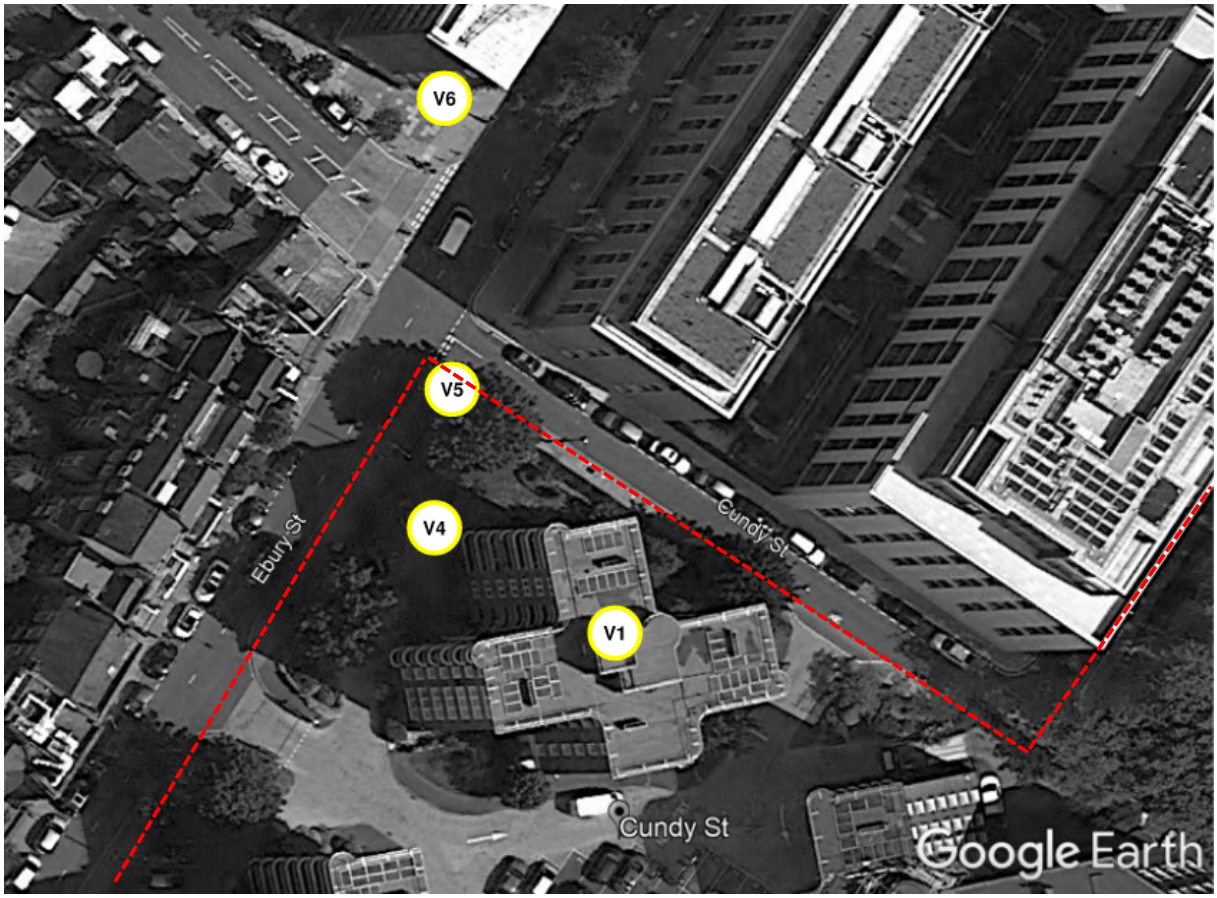


Figure 4 - Vibration measurement positions

Vibration measurement durations were between 10–15 minutes. This allowed for a several train pass-by events at each location, with a pass-by occurring approximately every 2–3 minutes.

Location Ref.	Start time
V1 – Ground Floor of Lochmore House	10:48
V4 - Carpark of Cundy Street flats	11:31
V5 – Corner of Cundy Street and Ebury Street	11:45
V6 – Pavement in front of Kilmuir House	12:02

Table 10 - Vibration measurement locations and times

Table 11 provides relevant details of the equipment used for the vibration survey. The accelerometer was mounted on a 'DIN' plate and was mounted securely on a hard surface for all measurements.

Equipment	Manufacturer & model	Serial number
Vibration level meter	01dB Fusion	11766
Calibrator	01dB Cal31	84908
Accelerometer	Acoem CAC1005000	10668
DIN Plate	Acoem	N/A

Table 11 - Vibration survey equipment

Copies of calibration certificates are available upon request.

4.2.1 Vibration survey results

4.2.1.1 Vibration Dose Values (VDV)

Measured vibration data was used to predict vibration dose values (VDVs ref. BS 6472). In addition, measured acceleration data was post-processed to obtain vibration velocity data. This was then used to estimate groundborne noise (GBN) levels in the proposed development based on guidance in the Association of Noise Consultants (ANC) '*Measurement and assessment of groundborne noise and vibration*' (known as the 'Red Book').

The following table summarises the 16-hour daytime and 8-hour night-time VDVs calculated from the VDV measurements made on site.

Measurement position	Daytime - VDV_{16h} ($mm.s^{-1.75}$)	Night-time - VDV_{8h} ($mm.s^{-1.75}$)	Criteria*
V1	0.05	0.04	Residential day: 0.2 to 0.4 Residential night: 0.1 to 0.2
V4	0.05	0.04	
V5	0.05	0.04	
V6**	0.09	0.08	

* These criteria correspond to the "low probability of adverse comment" presented in BS 6472-1.

**It is important to note that this measurement position was very close to the LU lines and was outside of the site boundary. Therefore, this data is for reference only.

Table 12 - Calculated vibration dose values (VDV)

4.2.1.2 Groundborne noise

The following table summarises the results of the indicative GBN level predictions[1] at ground floor in the proposed building based on the free-field vibration measurements:

Floor (reference measurement)	Predicted GBN dB L_{ASmax}
Ground floor (V1)	< 30
Ground floor (V4)	< 30
Ground floor (V5)	34 - 39

Table 13 - Predicted ground-borne noise levels

[1] Additional information in relation to the prediction methodology is provided in Section 6.1.2.

5.0 Noise assessment

This assessment has been carried out in light of the guidance in the ProPG document. Therefore, an initial site risk assessment has been undertaken and is followed by an 'acoustic design statement' (ADS). However, this assessment does not constitute a full assessment in accordance with the ProPG.

5.1 Stage 1 - Initial risk assessment

This section presents a "Stage 1" initial noise risk assessment for the site based on the guidance in the ProPG.

The Stage 1 assessment of the ProPG process aims to provide an indication of the likely risk of adverse effects on future residential development as a result of the existing noise climate around the proposed development site. The ProPG states that this risk assessment should not include any subsequent mitigation to be included as part of the development proposal and is therefore an initial estimate of noise impact risk.

5.1.1 Analysis of measured noise levels

A computer modelling exercise using the commercially available SoundPLAN 8.0 software has been undertaken to predict noise levels across the 'empty' site. The measured noise levels from the survey have been used to 'calibrate' noise sources in the model and predict the spread of noise across the site in the absence of any buildings.

The results of the noise survey and modelling exercise show that measured levels across the site range from 55 - 70 dB $L_{Aeq,T}$ during the daytime (see Figure 5) and 50 - 65 dB $L_{Aeq,T}$ during the night-time.

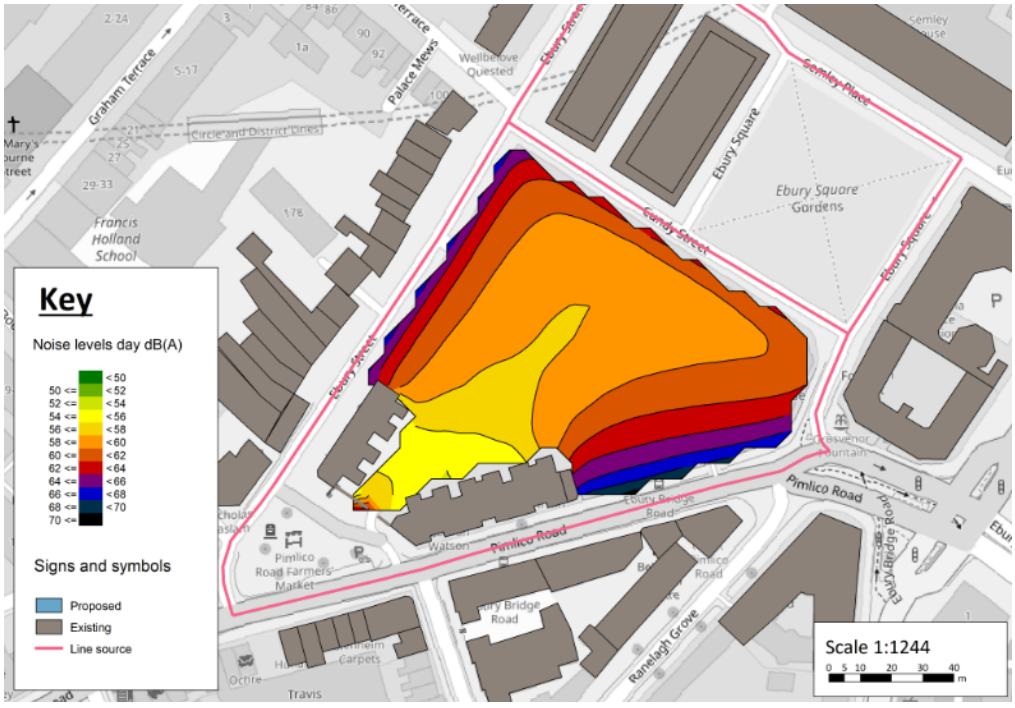


Figure 5 - Modelled existing daytime noise levels ($L_{Aeq,T}$) across the site

This prediction exercise, undertaken as part of the ProPG initial noise risk assessment does not include for any shielding provided by the Proposed Development or any noise mitigation measures included as part of the scheme.

The site is dominated by road traffic noise on surrounding roads, in particular from vehicles using Pimlico Road and, to a lesser extent, Ebury Street. The range of noise levels across the site means that areas of the site most exposed to road

traffic noise are likely to be considered ‘medium’ to ‘high’ risk, with some areas most sheltered from the roads only being at ‘low’ risk from noise when assessed in accordance with the ProPG Stage 1 assessment (Figure 6).

The proposed scheme does include a significant number of inward facing facades sheltered from road traffic noise that may be exposed to lower levels of noise than those identified above due to screening from the development itself.

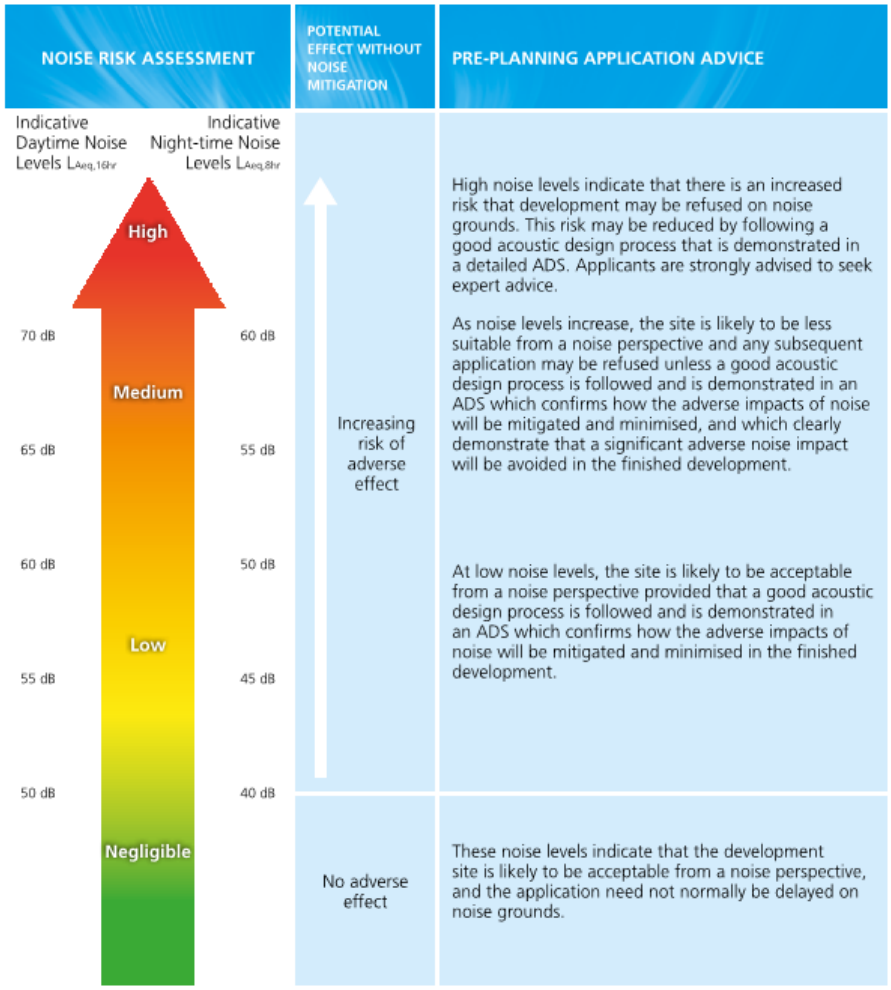


Figure 6 - ProPG Stage 1 risk assessment table (Fig.1 ref. ProPG)

5.2 Stage 2 - Acoustic Design Statement

The initial noise risk assessment undertaken in line with the ProPG, has found that the site is likely to be above the ‘negligible’ risk from a noise perspective. Therefore, as recommended by the ProPG, an Acoustic Design Statement (ADS) has been produced.

This section of the report provides an ADS based on the recommended approach outlined in the ProPG to assess the level of noise impact on the proposed development.

The ProPG suggests that an ADS should consider four key elements. Each of these four elements are discussed in the following sections.

5.2.1 Element 1 – Good acoustic design process

The potential effects of noise have been considered throughout the design of the Proposed Development .

The proposed site layout provides a number of benefits from an acoustic perspective.

One of the benefits of the proposed layout is that a significant number of residential facades are inward facing, set back away from the main noise sources and will be shielded by the proposed buildings.

In addition, external amenity areas, notably the internal shared garden areas and a number of rooftop terraces are shielded from, or located away from, the surrounding road traffic noise sources.

5.2.2 Element 2 – Internal Noise Level Guidelines

This element of the assessment seeks to identify if and how the 'internal noise level guidelines' (INLGs) defined in the ProPG can be achieved in noise sensitive rooms within the proposed development.

In relation to the INLG the ProPG states the following:

Most residents value the ability to open windows at will, for a variety of reasons, and LPAs [Local Planning Authorities] should therefore normally request that designers principally aim, through the use of good acoustic design, to achieve the internal noise level guidelines in noise-sensitive rooms with windows open. Where internal noise levels are assessed with windows closed the justification for this should be included in the ADS.

Where the LPA accepts that there is a justification that the internal target noise levels can only be practically achieved with windows closed, which may be the case in urban areas and at sites adjacent to transportation noise sources, special care must be taken to design the accommodation so that it provides good standards of acoustics, ventilation and thermal comfort without unduly compromising other aspects of the living environment. In such circumstances, internal noise levels can be assessed with windows closed but with any façade openings used to provide "whole dwelling ventilation" in accordance with Building Regulations Approved Document F (e.g. trickle ventilators) in the open position (see Supplementary Document 2). Furthermore, in this scenario the internal LAeq target noise levels should not generally be exceeded.

The proposed site is located in an urban area near a relatively busy road. This means that in some areas of the site it will not be possible to meet the ProPG INLGs whilst windows are open. Therefore, for this site, internal noise levels will be assessed with windows closed. The assessment will take account of measures required to provide 'whole dwelling ventilation', as recommended by the ProPG

The proposed ProPG INLGs are based on BS 8233, which contains guidance on suitable internal noise levels (described in Section 3.5). It is important to note that ProPG states that it is generally accepted that the internal noise criteria outlined in BS 8233 (and the 45 dB L_{AFmax} maximum noise criteria from ProPG) represent the lowest observable adverse effect level. Therefore, if these internal noise levels are met, it is unlikely that adverse noise effects on future residents will occur. If noise levels exceed these values, adverse effects may occur but they will not necessarily be significant and are therefore likely to be acceptable in some situations. By meeting these BS 8233 noise levels, the WCC planning requirements will also be met.

ProPG also references BS 8233 regarding the internal noise levels:

"Where development is considered necessary or desirable, despite external noise levels above WHO guidelines, the internal LAeq target levels may be relaxed by up to 5 dB and reasonable internal conditions still achieved.

The more often internal L_{Aeq} levels start to exceed the internal L_{Aeq} target levels by more than 5 dB, the more that most people are likely to regard them as "unreasonable". Where such exceedances are predicted, applicants should be required to show how the relevant number of rooms affected has been kept to a minimum. Once internal L_{Aeq} levels exceed the target levels by more than 10 dB, they are highly likely to be regarded as "unacceptable" by most people, particularly if such levels occur more than occasionally. Every effort should be made to avoid relevant rooms experiencing "unacceptable" noise levels at all and where such levels are likely to occur frequently, the development should be prevented in its proposed form."

The following sub-sections describe the proposed measures included as part of the design to control internal noise levels and help achieve the ProPG INLGs.

5.2.2.1 Façade break-in

Calculations have been undertaken to determine a suitable façade sound insulation strategy for the Proposed Development .

Based on the results of the survey, a detailed noise model (using SoundPlan 8.0 modelling software) has been used to predict noise levels incident on various parts of the building façade during the day and night time periods. Figure 7 and Figure 8 from the computer modelling exercise show daytime noise levels incident upon the different facades of the development.

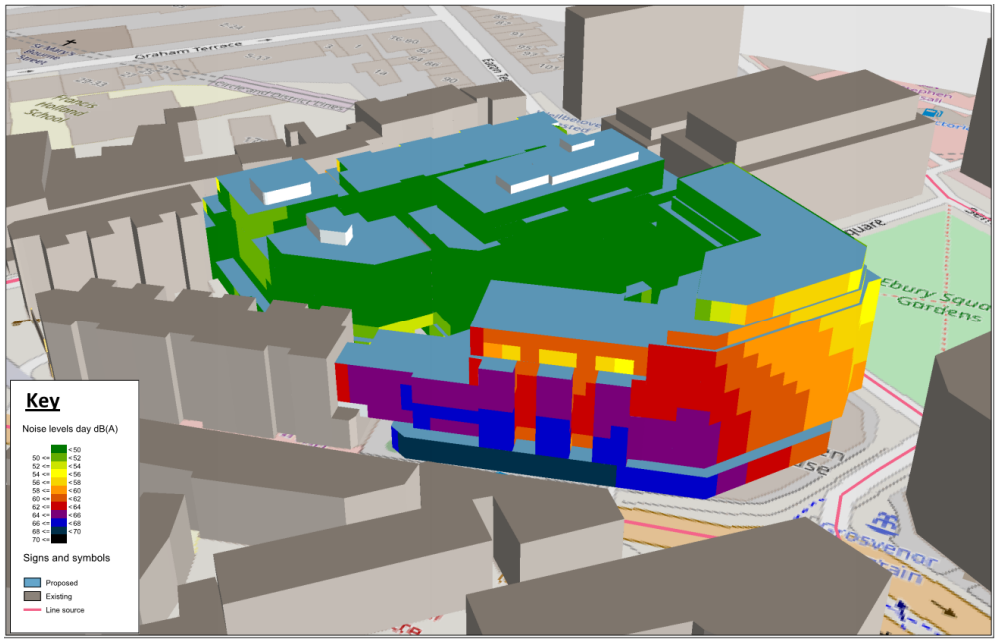


Figure 7 – Daytime façade noise levels – Pimlico Road

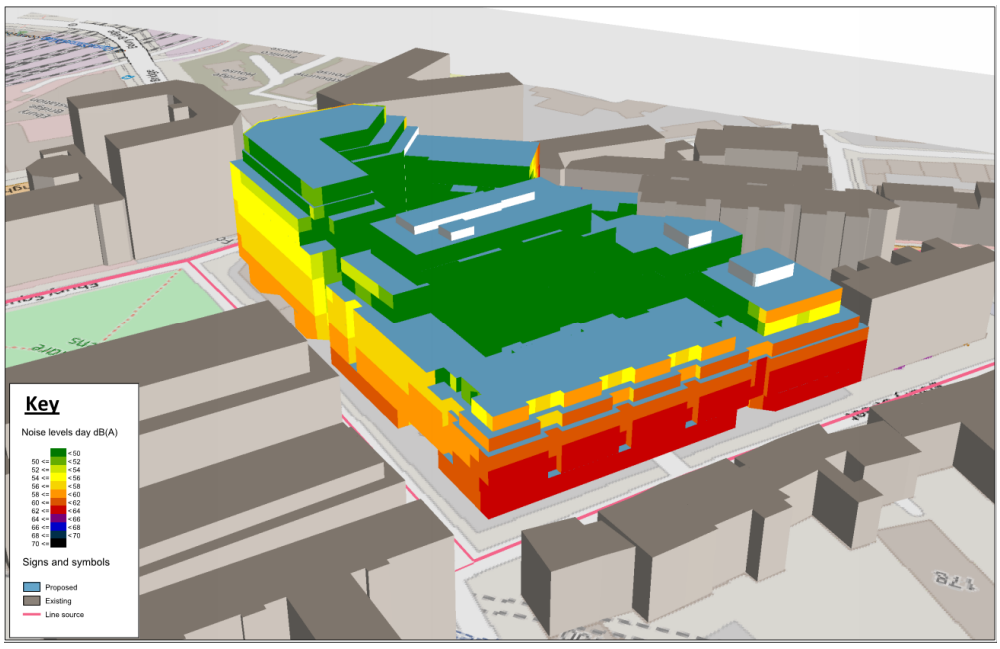


Figure 8 – Daytime façade noise levels – Ebury Street / Ebury Square

This information has been used to identify the required acoustic performance of façade elements to meet the ProPG INLGs. Calculations have been undertaken to predict internal ambient noise levels and appropriate façade sound

insulation requirements. These calculations have been undertaken in accordance with the 'rigorous method' outlined in Annexe G of BS8233: 2014. The following assumptions have been made during the calculations:

- Room and façade geometry from Architect's drawings
- Reverberation time of 0.5 Seconds in all rooms
- Calculations have been undertaken in terms of octave band noise data
- It has been assumed that non-glazed areas of the façade will be of masonry construction
- Internal noise levels to meet ProPG / BS8233 criteria

Based on the calculations, the most exposed facades, glazed elements will need to provide approximately 40-42 dB R_w + C_{tr} sound insulation to meet night-time noise level targets for bedrooms.

Façade	Description	Calculated façade noise level (dB)	Internal ambient noise level criteria (dB)	Worst case sound insulation requirement for glazing	Example construction to achieve the sound insulation requirement
Ebury St	Bedroom	Daytime: 67 $L_{Aeq,16hr}$ Night-time: 61 $L_{Aeq,8hr}$ * Night-time: 85 $L_{AFmax,5min}$	Daytime: 35 $L_{Aeq,16hr}$ Night-time: 30 $L_{Aeq,8hr}$ Night-time: 45 $L_{AFmax,5min}$	42 dB R_w + C_{tr}	▪ 10.8 mm acoustic laminated glass; ▪ 24mm argon cavity; ▪ 16.8 mm acoustic laminated glass OR Appropriately rated secondary glazing system.
Pimlico Road / Avery Farm Row		Daytime: 70 $L_{Aeq,16hr}$ Night-time: 67 $L_{Aeq,8hr}$ Night-time: 85 $L_{AFmax,5min}$			

* The L_{AFmax} noise levels measured during the attended measurements on Ebury Street were relatively low. However, due to the relatively short measurement period this may not represent a worst-case scenario. Therefore, for the purposes of this planning assessment and to assess a work case, the L_{AFmax} values from the long-term noise measurements undertaken on Pimlico have also been assumed for Ebury Road. This is judged to represent a worst-case scenario as Pimlico was more heavily trafficked (and subject to higher ambient noise levels) than Ebury Street.

Table 14 - Example bedroom glazing requirements

The above assessment looks at the most exposed sections of the development. The level of sound insulation required from glazing will be reduced on less 'noisy' facades and in less sensitive areas of the development.

Glazing for the most sheltered facades of the development are likely to be able to meet INLGs using standard double glazing rated at 25 dB R_w + C_{tr}.

Detailed façade sound insulation requirements for glazing and façade elements will be reviewed during the more detailed design of the developments. If required, a report can be submitted to WCC to demonstrate the relevant internal ambient noise levels are achieved inside dwellings.

Notwithstanding the above, it has been demonstrated that even on the most affected building facades, internal ambient noise levels in line with ProPG guidance and WCC requirements can be achieved through the use of appropriate glazing and facade systems.

5.2.2.2 Noise from commercial elements of the development

In addition, to the existing transport noise sources in the area, the Proposed Development includes for a number of commercial uses at ground floor level including potential A1, A3 and A4 uses and a commercial cinema.

These use types have the potential to generate noise that could impact on the more sensitive residential parts of the Proposed Development. There are two ways that this could occur:

- Noise transfer through the building structure (i.e. through floor to residential areas above); or
- External commercial noise impacting 'breaking-in' to residential areas.

The development will include for enhanced sound insulation between commercial and residential areas as required to reduce noise to appropriate levels in sensitive areas. This can be ensured, if required, through the use of an appropriately worded planning condition (should planning permission be granted).

With regard to external noise from the commercial activities, this can be controlled through the use of appropriate façade and glazing materials. On 'external' facing facades (i.e overlooking Pimlico Road and Ebury Street), the level of attenuation required to control the existing transportation noise is also likely to control any commercial noise sources to appropriate levels. However, on internal facing facades of the development, where transportation noise levels will be significantly reduced, it may be that noise from commercial activities may be the dominant source in some locations or during certain periods.

At this stage of the development it is not possible to quantitatively assess these noise impacts as the details of these uses are not known. However, through the correct use of façade materials (and in particular, glazing) any external commercial noise can be appropriately controlled. This will be considered in detail as the design of the Proposed development progresses and, if required, appropriate internal ambient noise levels can be secured through the use of an appropriately worded planning condition (should planning permission be granted).

5.2.2.3 Ventilation systems

It is a requirement of the Building Regulations that 'whole dwelling ventilation' (previously known as background ventilation) is provided continuously in dwellings. The ProPG also recommends that the INLGs are not exceeded whilst this ventilation is provided. This ventilation is normally provided by either:

- Natural / passive ventilation openings (e.g. trickle vents, ventilation stacks);
- Mechanical ventilation (e.g. mechanical ventilation and heat recovery [MVHR]).

In the Proposed Development, whole dwelling ventilation is to be provided by MVHR in all dwellings. Therefore, there will be no need for any ventilation openings in the building façade that could reduce the sound insulation of the building envelope.

MVHR systems require ducted intakes and exhausts which inherently provide a good level of noise attenuation. However, this should be reviewed and, where necessary, attenuation should be included in the design of any ventilation inlets / outlets where required to meet the INLGs.

Any mechanical ventilation system used will need to be appropriately designed so that noise generated by the system itself does not result in significant adverse effects. This should be examined in more detail during the design stage of the project, but the following initial internal mechanical services noise level limits are proposed in dwellings:

- Living rooms (daytime and night-time): .. NR30
- Bedrooms (daytime): NR30
- Bedrooms (night-time): NR25

5.2.2.4 Purge ventilation

The only time windows will be required to be open for the purpose of ventilation will be for occasional 'purge' ventilation. With respect to noise levels during purge ventilation, the ProPG states the following:

'*It should also be noted that the internal noise level guidelines are generally not applicable under 'purge ventilation' conditions as defined by Building Control Approved Document F, as this should only occur occasionally (e.g. to remove odour from painting and decorating or from burnt food).'*
It is therefore not considered necessary to further consider noise levels during purge ventilation conditions and using windows for this purpose is unlikely to result in any significant adverse effects.

Based on the above statement, it is considered that any increase in noise level when windows are open to provide purge ventilation are unlikely to result in significant adverse effects.

5.2.2.5 Thermal comfort (overheating)

There is no Building Regulation or statutory requirement relating to noise inside dwellings when windows are open. However, if windows are to be used to provide relief from overheating internal noise levels will increase when this occurs. The impact this will have on residents will depend on the internal noise levels when windows are open and how often this occurs.

This is less likely to be an issue on internal facing facades of the development where road traffic noise levels are reduced due to shielding. However, on external facades, where noise levels are higher there is an increased risk of adverse noise impacts.

The design of the development has allowed for comfort cooling to the most exposed residential facades so that windows do not need to be opened to provide relief from overheating.

Cumulative noise contributions from MVHR systems and comfort cooling systems will need to satisfy internal noise criteria identified in Section 5.2.2.3.

5.2.3 Element 3 - External amenity areas

This element of the assessment seeks to assess noise levels in external amenity areas as part of the proposed development.

5.2.3.1 External amenity areas

The principal external amenity area of the development is an internal courtyard area on the first-floor podium level. As this area is sheltered from road noise by the Proposed Development, noise levels are predicted to be below 50 dB $L_{Aeq,T}$ in this area. This is below the 50-55 dB $L_{Aeq,16hr}$ ProPG/BS 8233 guideline values.

Although not strictly considered to be external living areas, roof terraces are predicted to have noise levels of around 55 - 65 dB $L_{Aeq,T}$ without any mitigation. The use of carefully designed solid barriers should reduce noise levels in the majority of these areas to below the 55 dB $L_{Aeq,16hr}$ ProPG/BS 8233 guideline values.

5.2.3.2 Balconies

The development includes private balconies. Noise levels on balconies which face onto the interior of the development are predicted to be below ProPG/BS 8233 guideline values. Balconies situated on elevations which face onto roads are likely to exceed ProPG/BS 8233 guidelines. However, in relation to noise on balconies, BS 8233 states that:

"Other locations, such as balconies, roof gardens and terraces, are also important in residential buildings where normal external amenity space might be limited or not available, i.e. in flats, apartment blocks, etc. In these locations, specification of noise limits is not necessarily appropriate. Small balconies may be included for uses such as drying washing or growing pot plants, and noise limits should not be necessary for these uses…"

Therefore, on small private balconies, although higher than desirable noise levels are likely to occur, it is not considered that the increased noise levels will result in significant adverse noise effects on future residents.

5.2.4 Element 4 – Other relevant issues

As one section of the development is for senior living, it is possible that some residents may be more sensitive to noise. However, it has been shown that internal noise levels can be reduced to meet ProPG/BS 8233 guidance levels. These levels are generally regarded as the 'lowest observed adverse effect level' and should therefore provide a good level of protection from noise for the residents.

No other significant acoustic issues have been identified.

5.3 Acoustic design statement conclusions (recommendations to the decision maker)

An assessment has been undertaken in line with the guidance in the new ProPG document.

The Stage 1 risk assessment found that the risk of adverse effects associated with the majority of the site is between ‘medium’ to ‘high’ risk, with some more shielded areas in the ‘low’ risk category.

A ProPG Stage 2 assessment has been undertaken and an ADS has been produced for the site. It is believed that the ADS demonstrates that a good acoustic design process has been followed and appropriate design and mitigation measures are included in the scheme to avoid significant adverse effects and, where possible, mitigate adverse effects.

Therefore, it is recommended that from an acoustics perspective, planning consent be granted subject to the inclusion of suitable noise conditions.

6.0 Vibration and groundborne noise assessment

6.1 Existing groundborne noise and vibration

6.1.1 Vibration dose values (VDVs)

VDVs derived from measurements on site of the existing District and Circle Line are summarised in Table 12. The VDVs have been found to be at a level where 'adverse comment is not expected' as per BS 6472-1.

This correlates with the subjective impressions formed on site that vibration from passing underground trains was not perceptible on the Site.

Measured VDVs also fall below "appreciable existing vibration levels" set out in the *Crossrail 2 – Information for developers* document (see below).

6.1.2 Groundborne noise

6.1.2.1 Baseline conditions – District and Circle Line

Groundborne noise levels have been estimated in the Proposed Development based on the guidance in the Association of Noise Consultants (ANC) Red Book. This method involves applying a correction to measured one-third octave band vibration velocity levels to predict A-weighted sound levels inside buildings at ground floor level.

Predicted ground borne noise levels at ground floor level, summarised in Table 13, are likely to be below the target criteria at locations away from the District and Circle Line. However, at locations to the far north of the site (i.e. closest to the line), the predicted values are close to or just exceed the residential GBN criteria.

GBN levels are likely to decrease at higher levels of the building, however, it is also possible that levels could increase in some locations due to amplification by the building structure.

Notwithstanding the above, the initial impact assessment has identified that there is the possibility of adverse effects in the Proposed Development as a result of GBN from existing underground rail movements in locations close to the existing LUL rail lines.

This is discussed further in Section 6.3.

6.2 Groundborne noise and vibration from Crossrail 2

6.2.1 Prediction methodology

A prediction of GBN and vibration affecting the Proposed Development has been undertaken based on the guidance in the *Crossrail 2 Tunnel Section: Information for Developers* document. Full details of this assessment are provided in Appendix B. Two design options have been examined as follows:

- Building on 'raft' slab without stabilisation piles (raft foundation approx. 9.4 m vertically from CR2 tunnel)
- Building on 'raft slab' with stabilisation piles (closest pile approx. 3.5m horizontally from CR2 tunnel)

6.2.2 Crossrail 2 groundborne noise and vibration prediction results

The prediction exercise has found the vibration dose values are likely to comply with the CR2 criteria (see Appendix B).

However, the predicted GBN levels are likely to exceed the criteria in some sensitive areas of the building.

The results of the prediction exercise are summarised in the tables below:

Floor	Most noise sensitive receptors	CR2 design aim, dB L_{AFmax}	Predicted GBN level, dB L_{AFmax}
Basement	Treatment Rooms	40	40
Ground floor	Retail / restaurants	40	45
First floor	Residential	35	41

Table 15 – Summary of GBN prediction results – No stabilisation piles

Floor	Most noise sensitive receptors	CR2 design aim, dB L_{AFmax}	Predicted GBN level, dB L_{AFmax}
Basement	Treatment Rooms	40	48
Ground floor	Retail / restaurants	40	53
First floor	Residential	35	50

Table 16 – Summary of GBN prediction results – Stabilisation piles @ 3.5m

Since this original assessment outlined in Appendix B, the structural design of the proposed development has changed.

The currently proposed structural design now includes for stabilisation piles at a minimum distance of 6.7 metres from the proposed CR2 tunnel. Based on calculation method in the CR2 *'Tunnel Section: Information for Developers'* document, the predicted GBN levels with stabilisation piles at 6.7 metres are outlined in the following table:

Floor	Most noise sensitive receptors	CR2 design aim, dB L_{AFmax}	Predicted GBN level, dB L_{AFmax}
Basement	Treatment Rooms	40	46
round floor	Retail / restaurants[2]	40	51
First floor	Residential	35	48

Table 17 – Summary of GBN prediction results – Stabilisation piles @ 6.7m

Based on the proposed structural design of a raft slab with stabilisation piles at a minimum of 6.7m from the proposed CR2 tunnel location, the CR2 design aim values are exceeded by a maximum of 13 dB (ref. Table 17).

If stabilisation piles were not required the CR2 design aims would be exceeded by a maximum of 6 dB (ref. Table 15).

To reduce GBN levels to within the CR2 design aims, and avoid significant adverse impacts, mitigation will therefore be required, even if stabilisation piles are not required.

6.2.2.1 Commercial cinema

Since this initial assessment (Appendix B) was completed, a small commercial cinema has been added to the basement of the building. This will be more sensitive to GBN than the Treatment Rooms currently assessed at basement level (CR2 design aim of 35 dB $L_{Amax,F}$ for a small auditoria / hall). However, it is important to note that this cinema is located at a significant distance away from the CR2 tunnel (approximately 45 metres shortest horizontal separation between cinema element of the scheme and CR2 tunnel) and therefore GBN levels are likely to be significantly reduced at this distance from the source.

[2] Entrance areas for residential apartments are also located at ground floor level but these areas only consist of lobbies, entrance halls and shared ancillary spaces (including a library and entertainment suite) and do not include habitable rooms (habitable areas are at first floor and above). Therefore, it is considered that the criteria of 40 dB L_{AFmax} is appropriate at ground floor level spaces. Should the developer require an additional level of protection in any of these spaces they will need to consider additional mitigation measures.

It is therefore assumed that largest predicted exceedance of the CR2 Design Aims is likely to occur in residential dwellings on the first floor of the building close to the tunnel.

6.3 Proposed groundborne noise mitigation measures

It may be that the final CR2 scheme includes some form of track isolation to reduce GBN&V impacts at existing sensitive receptors in the area. This would reduce GBN&V impacts on the Proposed Development.

However, at this stage of the CR2 project it is not possible to confirm if this will be included in the scheme design or not. Therefore, it will therefore be necessary to include some form of GBN&V mitigation as part of the proposed CSQ scheme.

The exact form (and required attenuation performance) of this mitigation will partly depend on the foundation and structural design of the building which may evolve as the project design progresses. However, the current design includes raft foundation and stabilisation piles and has allowed for the following mitigation measures to be included:

- Raft foundation isolation mat system
- Isolation to stabilisation piles (full details of solution to be defined but likely to be some form of isolation bearing)

Based on the GBN predictions outlined in the previous sections of this report, it is likely the above solutions will need to provide the following approximate levels of GBN attenuation:

- Raft foundation isolation mat : 6 dB
- Stabilisation piles : 13 dB

These attenuation requirements are likely to be reduced in areas of the building further from the CR2 tunnel location. For example, for stabilisation piles at greater distances a reduced level of attenuation may required and it may not be necessary to use the pile mat across the whole footprint of the development. However, this will need further assessment to be confirmed.

The dominant frequencies of GBN contributing to the predicted A-weighted GBN levels are between approximately 80 and 160 Hz. It will therefore be necessary to select isolation solutions with an appropriate resonant frequency such that the required level of isolation is achievable.

Due to the frequency of the predicted GBN in the Proposed Development (main contributing frequencies > 80 Hz) the proposed attenuation requirements are likely to be achievable using appropriately designed building isolation solutions.

As the predicted levels of GBN from the existing LUL District and Circle lines are lower than those from CR2, the proposed GBN&V mitigation measures should also provide protection against GBN from the existing LUL District and Circle lines (and reduce GBN to below the values for residential buildings identified in Table 3).

The detailed design of the mitigation measures will be developed as the design progresses. CR2 will be consulted and invited to review the proposed GBN&V mitigation design proposals. The aim of the final design solution will be to comply with the CR2 design aims. If required, this could be ensured through the use of a suitably worded planning permission (should permission be granted).

The above information refers to building isolation mitigation measures that reduce the amount of GBN&V entering the building structure. However, should additional mitigation be required to specific locations in the building, it may also be possible to use ‘floating floor’ and ‘box-in-box’ type construction solutions to ‘locally’ reduce GBN&V in those areas.

7.0 Summary of noise impacts on existing noise sensitive receptors

The impact of the development on surrounding receptors is assessed in detail in the noise and vibration chapter of the Environmental Statement.

However, the key findings of this assessment are summarised below:

- Noise emissions from plant and equipment associated with the development will be designed and controlled to meet the requirements of WCC and therefore noise adverse impacts are expected
- Changes in road traffic as a result of the development, during construction and operation, have been found not to result in any significant increase in noise levels at sensitive receptors
- With appropriate mitigation measures in place (including compliance with the WCC Code of Construction Practice and entering in to a Control of Pollution Act 'Section 61' agreement with WCC) it is believed that noise and vibration impacts during the construction and demolition works can be controlled to an appropriate level.

8.0 Conclusion

Baseline noise and vibration surveys have been undertaken at the site of the proposed Cundy Street Quarter development, London.

Based on the results of the noise survey, a noise assessment in light of guidance from the ProPG has been carried out and has concluded that significant adverse effects due to noise are unlikely to occur if appropriate mitigation measures are implemented.

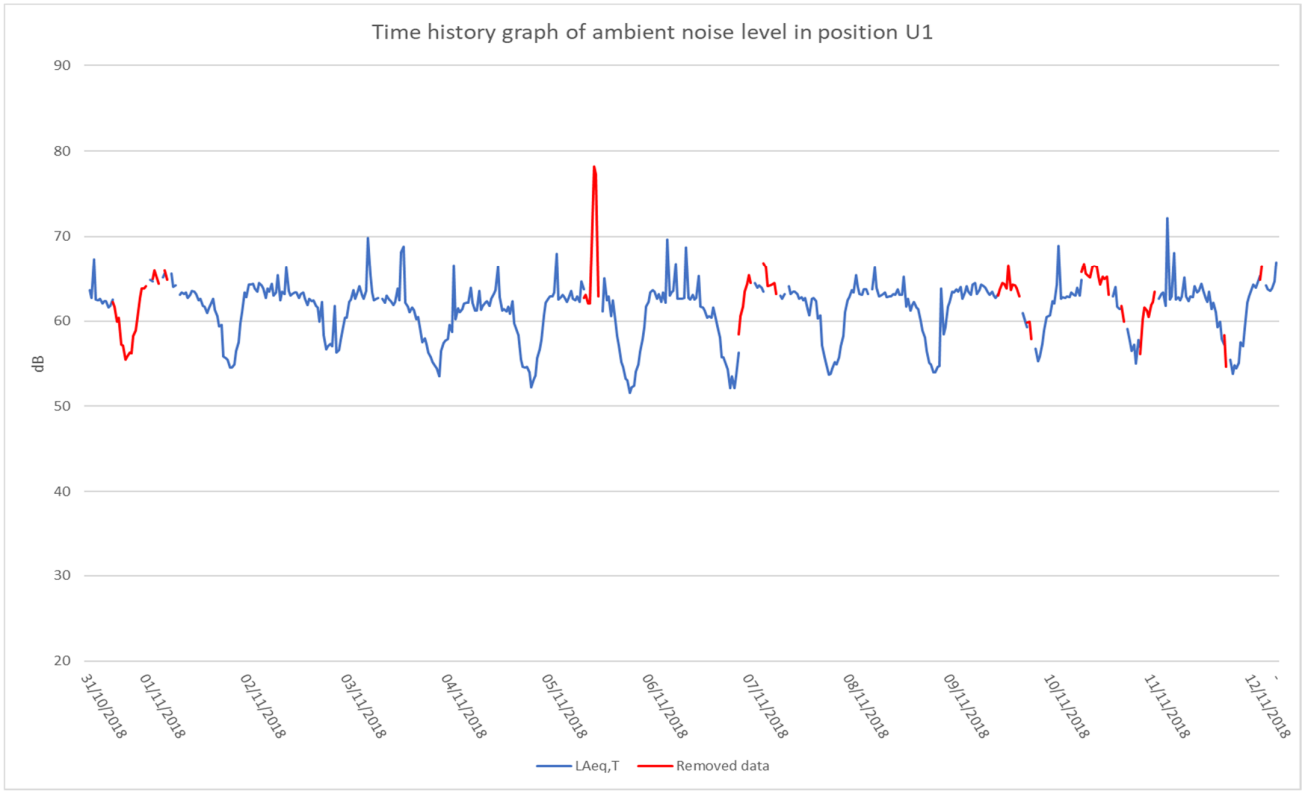
In addition, through the use of appropriate glazing and ventilation systems it has been shown the internal ambient noise level requirements of Westminster City Council can be met in the proposed new dwellings.

This assessment has found that significant vibration impacts are unlikely to occur on occupants of the proposed scheme as a result of existing rail lines of the proposed Crossrail 2 (CR2) line. However, it has been found that without mitigation the CR2 groundborne noise (GBN) design aims will be exceeded and occupants of the scheme could be subject to adverse GBN impacts.

The design of the buildings at the Proposed Development has included for GBN&V mitigation measures in the form of building isolation. With appropriately designed building isolation systems implemented, GBN levels in the development should meet the CR2 design aims and significant GBN adverse effects from CR2 and existing rail lines are unlikely to occur.

Therefore, it is considered that the site is suitable for a residential development, assuming appropriate acoustic design and mitigation measures are implemented.

9.0 Appendix A



Appendix A: Detailed time history graph

10.0 Appendix B

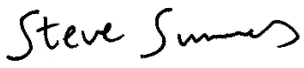
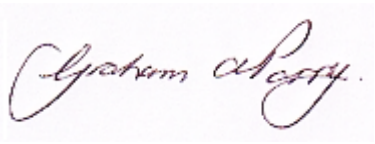
Report for:

Cundall

Cundy Street Quarter, London SW1

Groundborne Noise and Vibration from Crossrail 2

Status: Final **Date: 24.10.2019**

Author	 Steve Summers MSc MIOA AMICE CEng Associate Director
Approved By	 Graham Parry FIOA Managing Director
Report For	Cundall One Carter Lane London EC4V 5ER
Date	24.10.2019
Version Number	A3752/N/001
Status	Final

Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

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Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

LIST OF APPENDICES

Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
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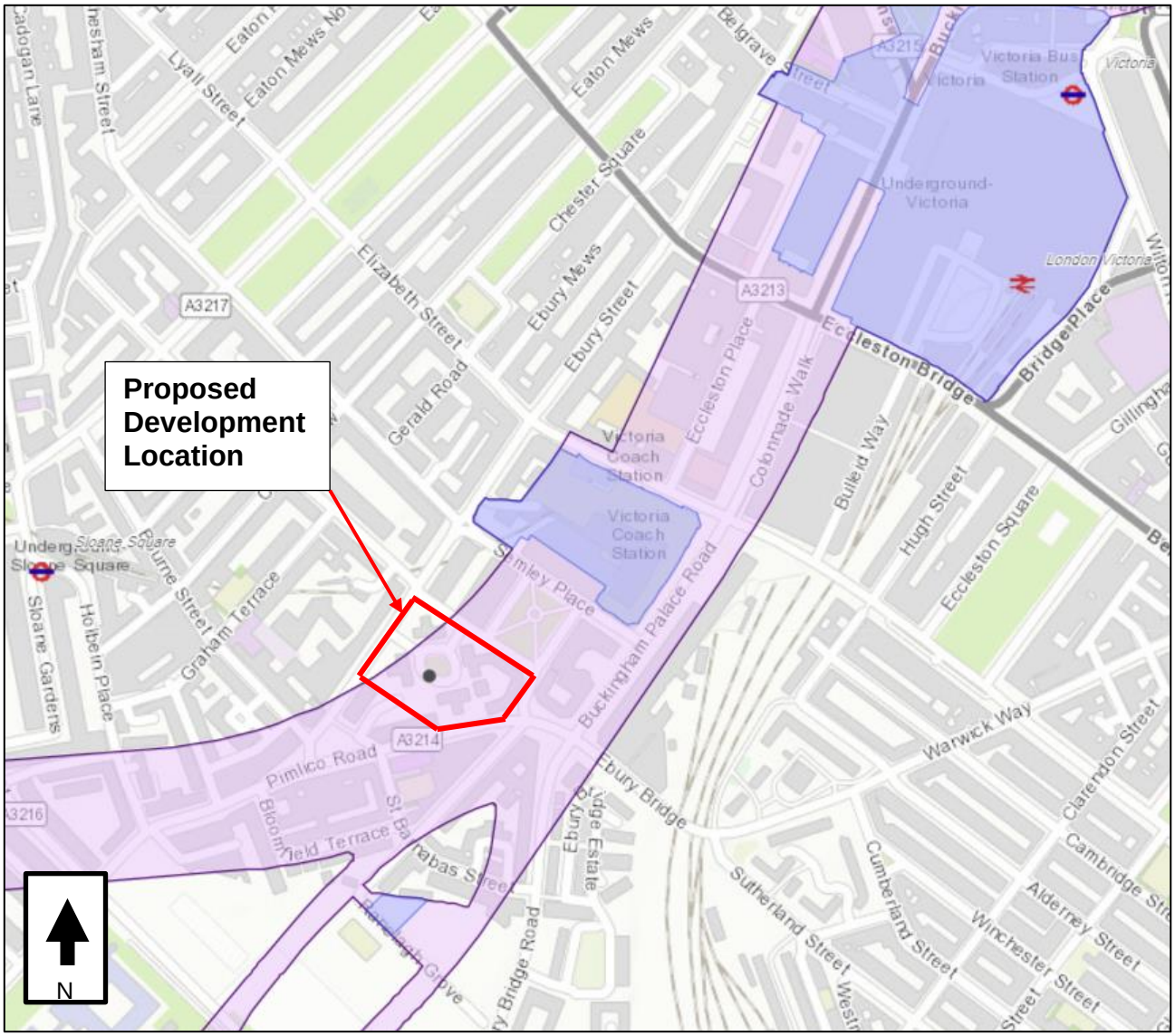
1. INTRODUCTION

ACCON UK Limited (ACCON) has been commissioned by Cundall to carry out an assessment of groundborne noise and vibration in respect of the potential effects of Crossrail 2 on the proposed development known as Cundy Street Quarter, London SW1.

The purpose of this assessment is to predict levels of groundborne noise and vibration within the proposed development to determine whether such levels will be acceptable or whether modifications to the foundation design or mitigation measures will be required.

A site location plan overlaid on the Crossrail 2 route is presented in **Figure 1.1** and a site layout plan showing the basement of the new units is presented in **Figure 1.2**.

Figure 1.1: Site Location Plan



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Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
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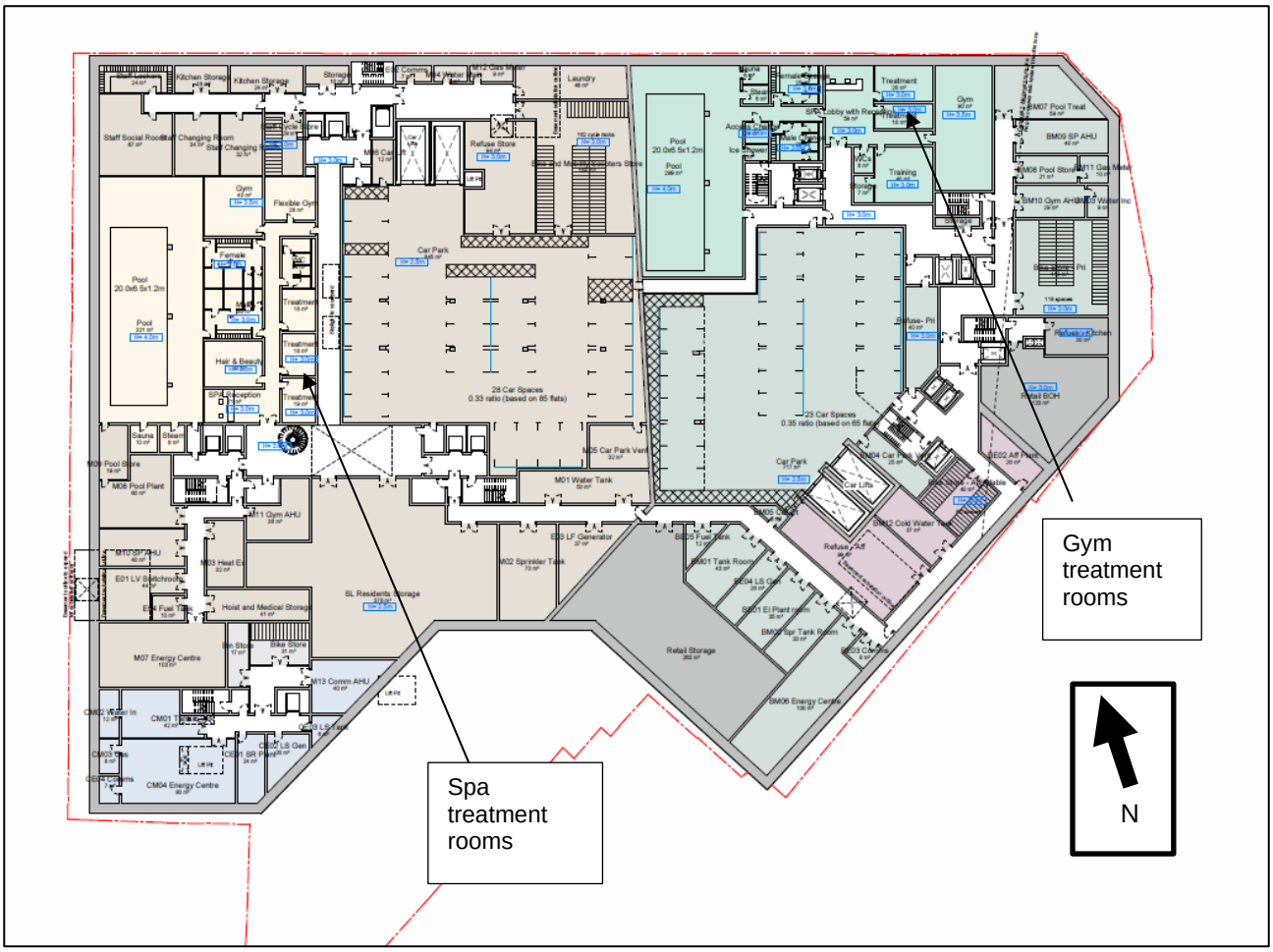
Figure 1.2: Site Layout Plan



A Glossary of Acoustic Terminology is provided in **Appendix 1**.

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Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

2. NOISE ASSESSMENT CRITERIA

2.1. Noise

Noise is often defined as sound that is undesired by the recipient. Whilst it is impossible to measure nuisance caused by noise directly, it is possible to characterise the loudness of that noise. '*Loudness*' is related to both sound pressure and frequency, both of which can be measured. The human ear is sensitive to a wide range of sound levels. The sound pressure level of the threshold of pain is over a million times that of the quietest audible sound. In order to reduce the relative magnitudes of the numbers involved, a logarithmic scale of decibels (dB) is normally used, based on a reference level of the lowest audible sound.

The response of the human ear is not constant over all frequencies. It is therefore usual to weight the measured frequencies to approximate the human response. The resulting 'A' weighted decibel, dB(A), has been shown to correlate closely to the subjective human response.

When related to changes in noise, a change of ten decibels, for example from 60 dB(A) to 70 dB(A), would represent a doubling in 'loudness'. Similarly, a 10 dB(A) decrease in noise, for example from 70 dB(A) to 60 dB(A), would represent a halving in 'loudness'. A change of 3 dB(A) is generally considered to be just perceptible[1]. **Table 2.1** provides typical noise levels of common sources.

Table 2.1: Typical Noise Levels

Approximate Noise Level (dB(A))	Example
0	Limit of hearing
30	Rural area at night
40	Library
50	Quiet office
60	Normal conversation at 1 m
70	In car noise without radio
80	Household vacuum cleaner at 1 m
100	Pneumatic drill at 1 m
120	Threshold of pain

A glossary of acoustic terminology is provided in **Appendix 1**.

[1] Institute of Environmental Management and Assessment (2014). Guidelines for environmental noise impact assessment.

Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

2.2. Vibration

When two objects come into contact through movement (such as a train wheel acting on a rail), the mechanical energy from the movement causes vibrations in the vicinity of the two objects. Vibrations in the air causes sound, but some vibrations can be felt through the ground or through structures, especially when a large amount of energy is exerted, such as the passage of heavy goods vehicles over an uneven surface.

Groundborne vibration, especially within structures, has a number of effects both to people and to the structures themselves.

The effects of groundborne vibration on buildings are dependent upon a range of factors, not least the magnitude and duration of the vibration, the structure of the soil, the properties and quality of the building materials, the design of the structure, as well as the general condition and age of the structure. In extreme cases, vibration can cause severe structural damage, but most vibration damage manifests itself in minor cosmetic damage such as cracks in rendering and roof tiles slipping, which in turn can cause other problems such as damp. When considering building damage, groundborne vibration affecting buildings is typically measured using the Peak Particle Velocity (PPV) expressed in mm/s. This is the maximum instantaneous velocity of a particle at a point during a given time interval. Where more detailed studies of vibration affecting buildings or objects or equipment within buildings is required it is normal practice to measure vibration acceleration.

Human exposure to vibration can cause annoyance, but in some cases can also cause health problems, especially from the stress and anxiety of prolonged annoyance. Humans are known to be very sensitive to vibration, with a threshold of perception typically in the particle velocity range of 0.15 mm/s to 0.3 mm/s at frequencies between 1 Hz and 80 Hz. Human exposure to vibration is often measured using a Vibration Dose Value (VDV) expressed in $m/s^{1.75}$. This measures the overall exposure to vibration that a person might receive over a given time period within a building.

2.3. Groundborne Noise

When groundborne vibration enters the structure of a building the resulting structure-borne noise can be re-radiated into the building. This phenomenon is known as groundborne noise. Groundborne noise most commonly arises in basements or ground floor rooms of buildings where railways are located in tunnels in close proximity. Levels of groundborne noise are usually characterised using the A-weighted maximum instantaneous sound pressure level in dB either measured on Slow (S) response, denoted $L_{Amax,S}$ or on Fast (F) response, denoted as $L_{Amax,F}$. Where a more detailed study is required $L_{Amax,S}$ or $L_{Amax,F}$ can be measured in octave bands or 1/3 octave bands.

Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

3. NOISE AND VIBRATION CRITERIA

3.1. Crossrail 2 Criteria

'Crossrail 2 Tunnel Section, Information for Developers' (June 2019)' indicates that where a developer proposes a new development within the safeguarded area for Crossrail 2, "*they should ensure that the foundations are designed so that the levels of vibration and groundborne noise generated within the building from the operation of Crossrail 2 trains remain within the design aims...".* The design aims are defined as a set of groundborne noise criteria which are reproduced in **Table 3.1** and vibration criteria reproduced in **Table 3.2**.

Table 3.1: **Crossrail 2 Operational Groundborne Noise Design Aims**

Building	Level/Measure
Residential building	35 dB $L_{Amax,F}$
Offices	40 dB $L_{Amax,F}$
Theatres	25 dB $L_{Amax,F}$
Hotels	40 dB $L_{Amax,F}$
Large Auditoria/Concert Halls	25 dB $L_{Amax,F}$
Sound recording studios	30 dB $L_{Amax,F}$
Places of meeting for religious worship	35 dB $L_{Amax,F}$
Courts, lectures, theatres	35 dB $L_{Amax,F}$
Small auditoria/halls	35 dB $L_{Amax,F}$
Hospitals, laboratories	40 dB $L_{Amax,F}$
Libraries	40 dB $L_{Amax,F}$

Table 3.2: **Crossrail 2 Operational Vibration Criteria**

In the Absence of Appreciable Existing Levels of Vibration		Appreciable Existing Levels of Vibration
VDV $ms^{-1.75}$ Daytime (07:00-23:00)	VDV $ms^{-1.75}$ Night-time (23:00-07:00)	% Increase in VDV
0.31	0.18	40

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Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

3.2. British Standard BS 6472-1

The British Standard BS 6472-1:2008 "Guide to evaluation of human exposure to vibration in buildings" assesses the effect of building vibration on people within buildings using the vibration dose value (VDV):

Equation 1: $$VDV = \left(\int_0^T a^4(t)dt\right)^{0.25}$$

Where:

- VDV is the vibration dose value (in $ms^{-1.75}$) (for the day or night period);
- a(t) is the frequency weighted acceleration (in ms^{-2}) using the appropriate frequency weighting;
- T is the total period of the day or night (in seconds) during which vibration can occur.

The standard, at paragraph 3.4.2, defines the day and night time periods as 0700 hrs to 2300 hrs for the daytime period and 2300 hrs to 0700 hrs for the night-time period.

The VDV depends both on the vibration magnitude and the duration of the vibration events in the respective period (day or night). It must be noted however that, since the acceleration is taken to the power 4, the VDV is much more strongly influenced by the vibration magnitude than by the total duration of the events.

The evaluation for the standard should be carried out at the point of entry to the body. However, since it is seldom possible to identify such a position uniquely, the evaluation is normally carried out for the location where the highest vibration magnitude is expected, usually in the middle of the room.

Table 3.3 identifies VDV ranges which might result in various probabilities of adverse comment within different types of buildings.

Table 3.3: **VDV Ranges According to BS 647**2

Place and time	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
	VDV ($ms^{-1.75}$)		
Residential buildings 16h day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential buildings 8h night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8
Offices (16h day)	0.4 to 0.8	0.8 to 1.6	1.6 to 3.2

It can be seen that the Crossrail 2 criteria correspond to the "low probability of adverse comment" range for residential buildings from BS 6472.

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3.3. Westminster City Council

Westminster City Council have not published any specific criteria for groundborne noise or vibration affecting development above railway tunnels or otherwise affected by railways.

3.4. Criteria adopted for the Assessment

The Crossrail 2 design criteria set out in **Section 3.1** above provide appropriate criteria to assess predicted levels of groundborne noise and vibration.

The proposed development principally comprises residential uses at first floor and above and relevant Crossrail 2 criteria are clearly provided for this use. The ground floor mainly comprises retail and restaurant uses which are generally not considered particularly sensitive to noise and vibration. For the purposes of this assessment Office/Hotel criteria have been considered applicable to the ground floor. The basement comprises a car park, services and storage areas and also a gym and a spa. The gym and spa both include treatment rooms for which the criterion for hospitals has been applied. Other basement areas are not generally considered to be sensitive.

The adopted groundborne noise criteria are summarised in **Table 3.4** below.

Table 3.4: **Groundborne Noise Criteria adopted for the Assessment**

Building	Level/Measure
Residential building	35 dB $L_{Amax,F}$
Retail/Restaurants	40 dB $L_{Amax,F}$
Treatment Rooms	40 dB $L_{Amax,F}$

The Crossrail 2 vibration criteria identified in **Table 3.2** apply to all building uses.

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4. PREDICTION METHODOLOGY

A methodology for predicting vibration and groundborne noise from Crossrail 2 is provided as Appendix B to Crossrail 2 Tunnel Section, Information for Developers.

This document provides predicted vibration levels at the tunnel wall for two train speeds, 80 kph and 100 kph. An equation is provided to calculate the propagation losses through the soil from the tunnel wall to the nearest part of the foundation as follows:

$$L_r = L_t - 4.34\frac{\omega\eta r}{c_s} - 10\log_{10}\left[\frac{r_0 + r}{r_0}\right]$$

Where L_t is the tunnel wall radial velocity for a tunnel of radius r_0 and L_r is the soil radial velocity at distance r, both in dB re 1 nanometre/second, c_s is the phase speed of compression waves in soil with loss factor η and ω is the angular frequency of each 1/3 octave band in radians per second[2]. As the coupling loss factor and building response generally have opposite sign, as a reasonable approximation they can be assumed to cancel. For piled foundations, if r is taken to be the shortest distance between the tunnel and any part of the nearest pile, a worst-case estimate will be obtained. Any distance units may be used, provided they are consistent throughout.

For the purposes of the assessment the soil characteristics of London Clay have been assumed. Therefore the compression wave speed assumed was c_s=1610 m/s and a loss factor of η =0.1.

The outer tunnel diameter had been assumed to be 7.8 metres in accordance with the Crossrail 2 Information for Developers publication.

Floor to floor attenuation values have been used to estimate vibration on ground and first floors based on data published in the Transportation Noise Reference Book [Nelson P M, Butterworths, 1987]. Amplification of vibration due to floor resonances has also been taken into account based on data in the Transportation Noise Reference Book.

Groundborne noise levels have been calculated using the formula $L_p = L_v - 27$dB, where L_p is the 1/3 octave band sound pressure level: L_v is the 'rms' vibration velocity in dB re 1 nanometre per second.

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Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

5. ASSESSMENT RESULTS

5.1. Groundborne Noise

The predictions are based on the closest pile of the proposed development to the Crossrail 2 tunnel alignment which is shown in **Figure F.1** as 3.5m. The prediction results are set out in **Table 5.1** with an assessment against the adopted criteria.

Table 5.1: **Groundborne Noise Assessment**

Location	Predicted $L_{Amax,F}$ dB	Criteria $L_{Amax,F}$ dB	Meets Criteria
Basement - Treatment Rooms	48	40	No
Ground Floor - Retail/Restaurants	53	40	No
First Floor – Residential	50	35	No

A further set of predictions have been carried out assuming no piles are required. This is based on the vertical separation between the slab and the tunnel of 9.4 m. The results are provided in **Table 5.2**.

Table 5.2: **Groundborne Noise Assessment – Assuming No Piles**

Location	Predicted $L_{Amax,F}$ dB	Criteria $L_{Amax,F}$ dB	Meets Criteria
Basement - Treatment Rooms	40	40	Yes
Ground Floor - Retail/Restaurants	45	40	No
First Floor – Residential	41	35	No

It can be identified from **Table 5.1** that groundborne noise at first floor level requires mitigation by at least 15 dB and this is the limiting case.

Table 5.2 indicates that without piled foundations a 6 dB noise reduction would be required to meet the criteria for residential use at first floor.

5.2. Vibration

Worst case estimates of vibration in terms of eVDV have been calculated using the following assumptions for the total duration of Crossrail 2 train movements:

- Daytime duration 675 seconds
- Night-time duration 450 seconds.

The vibration predictions based on the closest pile to the Crossrail 2 tunnel alignment are set out in **Table 5.3** with an assessment against the adopted criteria.

Email: enquiry@accon-uk.com • www.accon-uk.com
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Table 5.3: **Vibration Assessment**

Location	VDV $ms^{-1.75}$ Daytime (07:00-23:00)	Meets Criteria	VDV $ms^{-1.75}$ Night-time (23:00-07:00)	Meets Criteria
Basement - Treatment Rooms	0.07	Yes	0.05	Yes
Ground Floor - Retail/Restaurants	0.21	Yes	0.16	Yes
First Floor – Residential	0.15	Yes	0.11	Yes

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6. CONCLUSION

The assessment of groundborne noise from Crossrail 2 affecting the Cundy Street Quarter has demonstrated that mitigation will need to be incorporated into the foundation design to meet the Crossrail 2 groundborne noise criteria. A common approach to mitigating train-induced vibration is to include elastomeric bearing pads within the foundation design to reduce the transfer of vibration into the building structure.

ACCON can provide further advice on such mitigation measures in order to progress the design of the proposed development.

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Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

ADDITIONAL FIGURES

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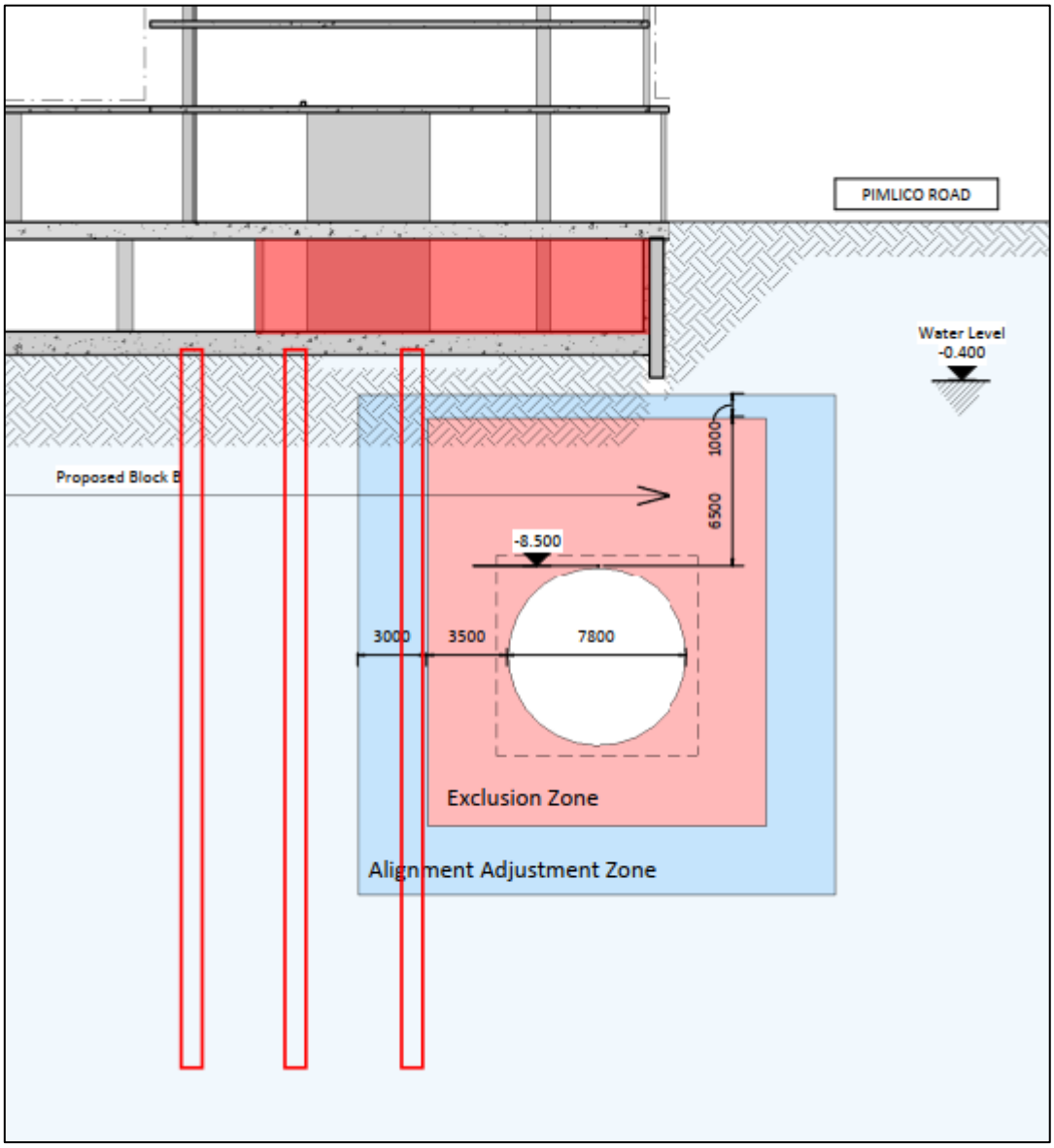
Figure F.1: Cross Section showing Preliminary Foundation Design



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Brighton Office: 01273 573 814

APPENDICES

Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

Appendix 1

Glossary of Acoustic & Vibration Terminology

Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
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Term	Description
'A'-Weighting	*This is a frequency weighting used to adjust measured sound pressure levels so that they correspond to the frequency response of human hearing.*
Decibel (dB)	*This is a tenth (deci) of a bel. Decibel can be a measure of the magnitude of sound, changes in sound level and a measure of sound insulation. Decibels are not an absolute unit of measurement but are an expression of ratio between two quantities expressed in logarithmic form.*
$L_{Aeq,T}$	*The equivalent steady sound level in dB containing the same acoustic energy as the actual fluctuating sound level over the given period, T. T may be as short as 1 second when used to describe a single event, or as long as 24 hours when used to describe the noise climate at a specified location. $L_{Aeq,T}$ can be measured directly with an integrating sound level meter.*
L_{Amax}	*The 'A'-weighted maximum sound pressure level measured over a measurement period.*
Frequency (Hz)	*The number of times that a vibration or other periodic motion occurs or repeats itself in a second - cycles per second. It is usually measured in Hertz (Hz).*
Octave	*Octave is a range of frequencies whose upper frequency limit is twice that of its lower frequency limit. In acoustical measurements, sound pressure level is often measured in octave bands, and the centre frequencies of these bands are defined by ISO - 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, 16 kHz to divide the audio spectrum into 10 equal parts.* *The sound pressure level of sound that has been passed through an octave band pass filter is termed the octave band sound pressure level.*
1/3 Octave Band	*Octave bands sub-divided into three parts, equal to 23% of the centre frequency. Used when octave analysis is not discrete enough. Divides the audio spectrum into 33 or more equal parts with Constant Percentage Bandwidth filter.*
Peak Particle Velocity (PPV)	*Ground vibration or vibration within a building or structure is typically evaluated using PPV. This is the maximum instantaneous velocity of a particle at a point during a given time interval and is normally expressed in mm/s.*
Groundborne Noise	*The vibration of walls, floors and other structural surfaces generated by the propagation of groundborne vibration into buildings such as to give rise to audible low frequency noise.*

Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

Email: enquiry@accon-uk.com • www.accon-uk.com
Unit B, Fronds Park, Frouds Lane, Aldermaston, Reading, RG7 4LH
Reading Office: 0118 971 0000
Brighton Office: 01273 573 814

ENVIRONMENTAL CONSULTANTS

Email: enquiry@accon-uk.com

Reading Office:
Unit B, Fronds Park,
Frouds Lane, Aldermaston,
Reading, RG7 4LH
Tel: 0118 971 0000 Fax: 0118 971 2272

Brighton Office:
Citibase, 95 Ditchling Road,
Brighton, East Sussex, BN1 4ST
Tel: 01273 573 814

www.accon-uk.com

Cundall Johnston & Partners LLP
One Carter Lane London EC4V 5ER
United Kingdom Tel:+44 (0)20 7438 1600
Asia Australia Europe MENA UK and Ireland
www.cundall.com