ARUP

Technical Note

Project title	13 Fitzroy Street, London
Job number	284217-80
File reference	Report 2 - Addendum A – Rev A
cc	
Prepared by	Lee Kirby
Date	11 July 2022
Subject	Update to the noise impact assessment

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1. Introduction

Following a revision to the 2020 scheme, London Borough of Camden has requested in its pre-application feedback that the previously approved Noise Impact Assessment is updated to accompany the Minor Material Amendment (MMA) application to planning permission reference 2019/2198/P at No. 13-17 Fitzroy Street, London, W1T 4BQ. The proposed changes to the scheme are summarised in the submitted Design Statement, but from a noise perspective relate to the creation of a new roof terrace on Block B and amendments to the approved plant/enclosures.

The pre-application feedback from LB Camden advised the following in relation to rooftop plant:

"…the noise assessment would need to be re-done to see if the noise impact would not be increased. The noise impact assessment must demonstrate that the new plant would comply with Camden's noise standards (policy A4) which state that the external noise level emitted from plant, machinery or equipment shall be lower than the lowest existing background noise level by at least 10dBA, or by 15dBA where the source is
tonal, as assessed according to BS4142:2014 at the nearest and/or most affected noise sensitive premises (with all machinery operating together at maximum capacity).
If this is not achievable, then the Council would expect suitable noise attenuation measures to reduce the noise levels of the proposed plant. Details of any necessary mitigation measures should also be supplied with the full planning application. "

In relation to Amenity:

"The replacement plant equipment would require the submission of a Noise Impact Assessment as detailed above to ensure that it would not result in disturbances to local residents/occupiers."

To address this, Arup carried out a survey in April 2022 to validate the original noise survey data from 2019 to support the planning assessment.

Revised noise emission limits and required mitigation is set out in this addendum.

There have also been some design changes following a project review. The plant enclosures originally proposed in the MMA application covered all plant at roof level. However, the external noise levels from the larger plant equipment (ie AHUs), located further north on the roof, are below the noise limits set by LB Camden. Therefore, this section of plant does not need any additional acoustic protection. Removing one of the aluminium plant enclosures will help to reduce embodied carbon during the redevelopment which is a key overarching driver for the scheme. By omitting the plant screen, it is expected that c. 7-10 tonnes of CO_2e will be saved.

Due to the above, it is now proposed that this section of plant equipment (the AHUs) will be exposed. The exposed plant is set within the roofline and will not be visible from the street level. The proposed changes will not impact on the verified views supporting the MMA application. Exposing part of the plant equipment at roof level is in keeping with other schemes in the vicinity of the site (as shown in the revised Design Statement).

2. Survey methodology

Measurement locations from the previous survey are shown in Figure 1. A logger was temporarily installed on the roof of 13 Fitzroy, shown as location 1B in Figure 1. This measurement location is near location 1 from the previous survey and therefore it is considered reasonable to compare the survey results from these two locations to determine whether or not the prevailing noise climate had changed in the intervening time.

Unattended measurements were taken over a five-day period. The proposed plant on 13 Fitzroy Street is expected to operate up to design duties during typical office hours, that is 08:00 to 20:00. Outside of working hours, the ventilation plant is expected to run at lower duties on certain evenings, otherwise it will be switched off. The heating and cooling plant will also run at lower duties outside of working hours.

It should be noted that although internal strip-out works were ongoing in 13 Fitzroy Street, during installation and collation of the noise monitoring kit, no site related activities could be heard on the roof. Additionally, there were no planned site works on the roof. The measured noise levels are therefore representative of the existing noise climate.

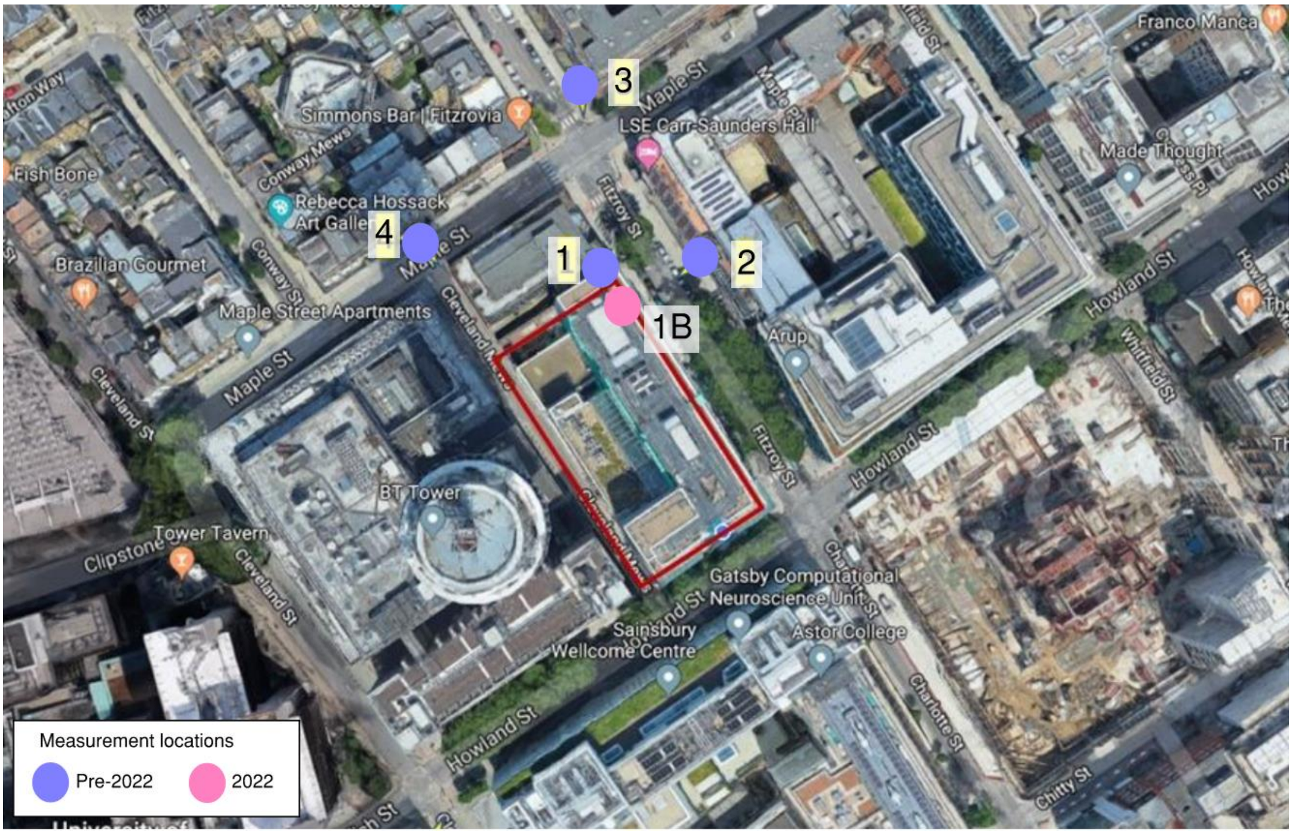

Figure 1: Measurement locations for previous and latest noise survey.

3. Survey results and revised noise emission limits

Table 1 outlines the typical and minimum measured background noise level during office hours for location 1 and 1B.

Location	Typical measured background noise level, dBL_{A90}	Lowest measured background noise level, dBL_{A90}
Location 1 (2019)	57	55
Location 1B (2022)	55	53

Table 1: Typical and minimum background noise levels at location 1 and 1B during office hours

The background levels measured in 2022 are slightly lower than those measured in 2019. This could be due to operations not fully resuming following the Covid-19 pandemic. Additionally, the measured background level at location 1B was in the absence of noise emissions from existing rooftop plant at 13 Fitzroy Street, whereas the measurements at location 1 were in the presence of existing rooftop plant running at design duty.

However, as a conservative approach, the 2022 background noise levels are used as a basis for determining the noise emission limits for the re-development of 13 Fitzroy. These have been derived by adding the difference between the 2022 and 2019 measured background level to the previous noise emission limits at all receptors.

Therefore, the revised noise emission limits shown in Table 2 and are used for the purposes of this planning assessment.

Receptor	Daytime noise limit, dBL_{Aeq}
1	43
2	39
3	41
4	40

Table 2: Proposed noise emission limits

4. Proposed roof terraces

The proposed scheme includes a new roof terrace for Block B for office and tenant amenity.

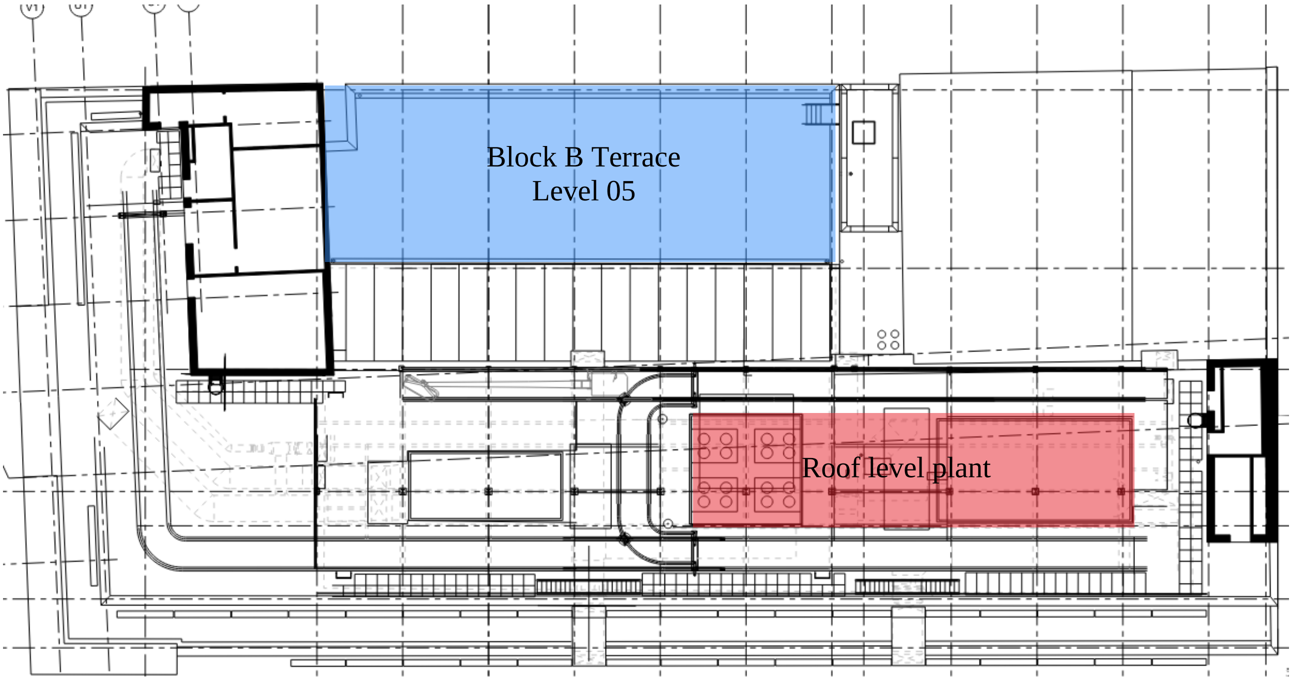

Figure 2: Location of proposed roof terrace and roof level plant

The proposed roof terrace on Block B will be exposed to background noise levels of around 55dBL_{Aeq}. This level of noise exposure is not expected to be a problem to the users of the terrace since being connected to the London soundscape is part of the appeal of the external roof terrace areas.

External noise emission and required mitigation

There are several items of plant on the roof of Block A. This is outlined in Table 3. Assumed sound power levels are shown in Table 4 and Table 5.

Equipment	Quantity
Air handling unit	1
Variable refrigerant flow (VRF)	16

Table 3: Proposed new plant and equipment on Block A

Item / Description		dB(A)	Octave band centre frequency, Hz							
			63	125	250	500	1k	2k	4k	8k
Roof AHU	Intake	77	72	86	81	76	66	60	52	48
	Exhaust	88	84	88	85	86	83	80	77	74
	Casing	69	76	82	64	63	61	57	51	37

Table 4: Sound power levels of the air handling unit on the rooftop

Item / Description	dB(A)	Octave band centre frequency, Hz							
		63	125	250	500	1k	2k	4k	8k
VRF	84	92	84	82	84	77	74	74	70

Table 5: Sound power levels of the VRF units on the rooftop – at full duty

At normal occupancy and mild external conditions, only one VRF unit running at 70% load is likely to serve each floorplate. When the building is at full capacity and peak external conditions, all VRF units will run at 70% load, this is considered worst case.

Worst case predicted external noise levels from the proposed plant at these receptors is shown in Table 6.

Without mitigation, the noise emission from proposed external plant exceeds criteria, therefore, to meet planning requirements, an acoustic louvre with a minimum thickness of 300mm surrounding the VRF units is required. Insertion loss for the acoustic louvre is given in Table 7.

Emergency/back-up plant is also located on the roof and at lower ground level. Noise emissions from all emergency/back-up plant will be controlled to not exceed the background level by more than 10dB.

Receptor	External noise levels, dBL_{Aeq}	
	Limit	Predicted – With 300mm acoustic louvre
R01	43	42
R02	39	39
R03	41	35
R04	40	35

Table 6: Noise emission levels at identified receptors during working hours when operating at worst case

	Octave band centre frequency, Hz					
	125	250	500	1k	2k	4k
Minimum insertion loss (dB)	7	10	12	18	14	13

Table 7: Minimum required insertion loss for the acoustic louvre.

The predicted noise emissions at the terrace from the proposed plant with the required mitigation is shown in Table 8.

Terrace	Predicted noise emission level, dBL_{Aeq}
Block A	54
Block B	50

Table 8: Noise emission levels at proposed roof terraces

5. Summary

An acoustic assessment has been undertaken based on an environmental noise survey (undertaken in April 2022) and noise emission data for the plant on Block A.

The assessment has shown that the plant noise levels at the nearest noise sensitive receivers will meet noise limits set by LB Camden, based on the inclusion of 300mm deep acoustic louvres within the remaining acoustic plant screen (as detailed in the revised Design Assessment).

This assessment has also shown that the proposed roof terrace on Block B will be exposed to background noise levels of around $55dBL_{Aeq}$. This level of noise exposure is not expected to be a problem to the users of the terrace since being connected to the London soundscape is part of the appeal of the external roof terrace areas and is within the recommended WHO noise limits.

The approved noise assessment from January 2020 has been appended for reference.

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Job number	284217-80
Date	12 May 2022

DOCUMENT CHECKING

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Signature			

Arup

13 Fitzroy Street, London

Revised Building Services Noise Impact Assessment for Planning Application

AAc/ 259991-53/R01-KS

0 | 17 January 2020

Job number 259991-53

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Document Verification

ARUP

Job title		13 Fitzroy Street, London			**Job number** 259991-53
Document title		Revised Building Services Noise Impact Assessment for Planning Application			**File reference**
Document ref		AAc/ 259991-53/R01-KS			
Revision	**Date**	**Filename**	Revised Building Services Noise Impact Assessment for Planning Application		
0	17 January 2020	**Description**	Issue		
			Prepared by	Checked by	Approved by
		Name	Kathryn Salter MPhys	Adrian Passmore BEng CEng MIOA	Kyriakos Anatolitis MEng CEng MIMechE MCIBSE
		Signatures			
01	17 February 2020	**Filename**			
		Description	Issue		
			Prepared by	Checked by	Approved by
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		Signature			

Issue Document Verification with Document ✓

Contents

Appendices

1 Summary

In response to Camden London Borough Council's proposed planning condition relating to building services noise emissions, Arup has carried-out an additional noise impact assessment.

Detailed, environmental noise surveys have been carried-out in the vicinity of the nearest noise sensitive receptors 13 Fitzroy Street to quantify the prevailing background noise levels.

The results of the surveys have been used to set cumulative noise emission limits outside the nearest noise sensitive receptors in accordance with the requirements of policies A1, A4 and Appendix 3 of the London Borough of Camden Local Plan 2017.

Cumulative building services noise emissions have been predicted using the suppliers' noise data for the preliminary selections of the principle plant items and the noise mitigations that have been developed.

The outcome of this assessment is that the predicted cumulative building services noise emissions are expected to be within the assessed noise emission limits outside the nearest noise sensitive receptors, and the requirements of policies A1 and A4 of the London Borough of Camden Local Plan 2017 are therefore expected to be satisfied.

2 Introduction

2.1 Background

Arup has been instructed by Workspace to assess the potential noise and vibration impacts as relates to the planned refurbishment of 13 Fitzroy Street, London, identified as being:- proposed replacement of building services plant; proposed new use of the future rooftop terrace; potential noise and vibration considerations associated with the construction processes.

During April 2019 Arup submitted a report (AAc/----/R01, 18 April 2019) to Camden London Borough Council (Camden LBC), which detailed the outcome of our original analysis and assessments.

In response to that original Arup report, Jaspreet Chana of Camden LBC emailed Sarah Fabes of Lichfields on 13th September 2019, and the relevant extract is provided below:-

“Noise officer –

No objection subject to the following conditions:

The external noise level emitted from plant, machinery or equipment at the development hereby approved shall be lower than the lowest existing background noise level by at least 10dBA, by 15dBA where the source is tonal, as assessed according to BS4142:2014 at the nearest and/or most affected noise sensitive premises, with all machinery operating together at maximum capacity.
Reason: *To safeguard the amenities of the adjoining premises and the area generally in accordance with the requirements of policies A1 and A4 of the London Borough of Camden Local Plan 2017.*

Prior to use, plant or equipment and ducting at the development shall be mounted with proprietary anti-vibration isolators and fan motors shall be vibration isolated from the casing and adequately silenced and maintained as such.
Reason: *To ensure that the amenity of occupiers of the development site and surrounding premises is not adversely affected by vibration.”*

So, whereas Camden LBC accepted the assessments we carried out with regards to the proposed use of rooftop terrace and construction noise and vibration, a further assessment was needed of the noise emissions from the proposed building services installation.

This report presents the findings of that new assessment. For brevity the previously submitted information as related to the proposed use of rooftop terrace and construction noise and vibration is not included.

3 Project Site Location, Its Environs and Building Plans

3.1 Project Site Location and Its Environs

The project site is located north of Howland Street, address 13 Fitzroy Street, London, W1T 4BQ. Its surrounds comprise office / commercial premises, institution premises, public houses / restaurants, residential dwellings and construction sites, including a large office building south of Howland Street. Figure 1 shows the project site location and its environs.

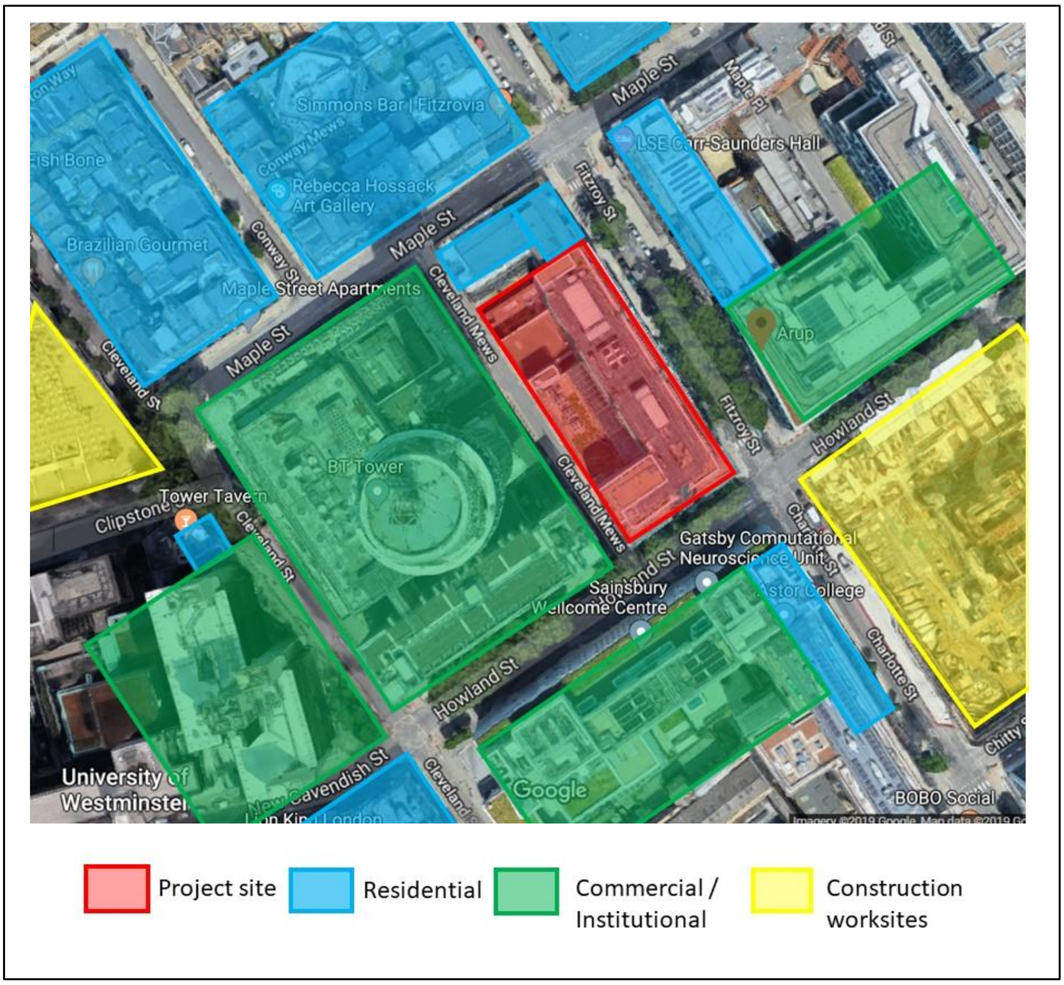

Figure 1 Project site and its environs (Google maps)

3.2 Building Plans

Figures 2 to 5 are relevant extracts from building plans showing the location of plant that will be replaced. As can be seen the replacement plant will comprise, on the Block A roof

- 1 air handling unit
- 2 toilet extract fans
- 1 array of VRF condensers (20 units)

and on the Block B roof

- 1 array of VRF condensers (6 units). This entails a small change from the original application, in order to ensure sufficient condenser capacity whilst minimising noise emissions to noise sensitive receptors.

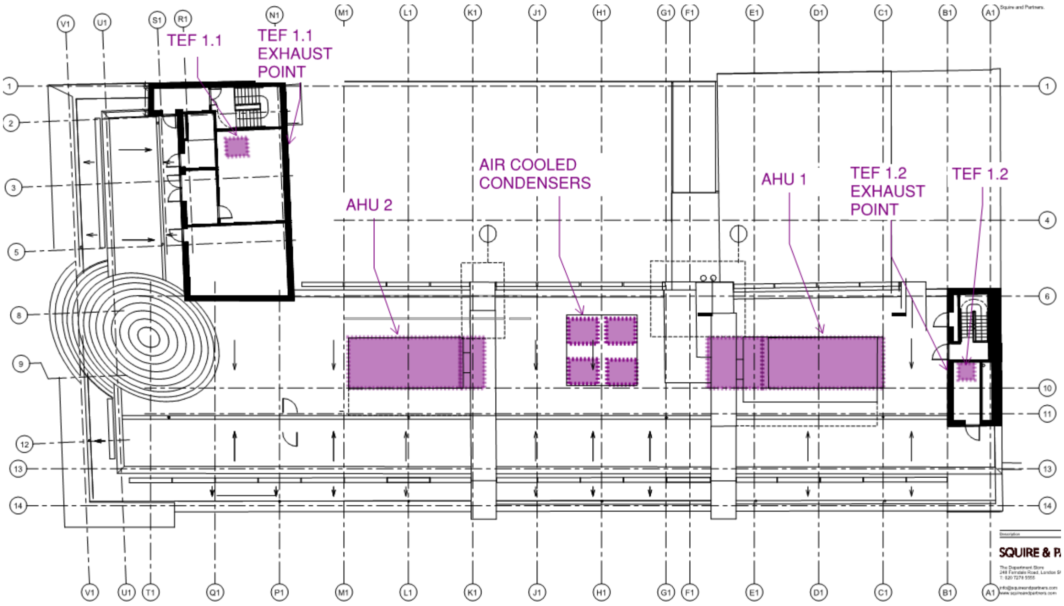

Figure 2 Block A Roof - Existing Plant

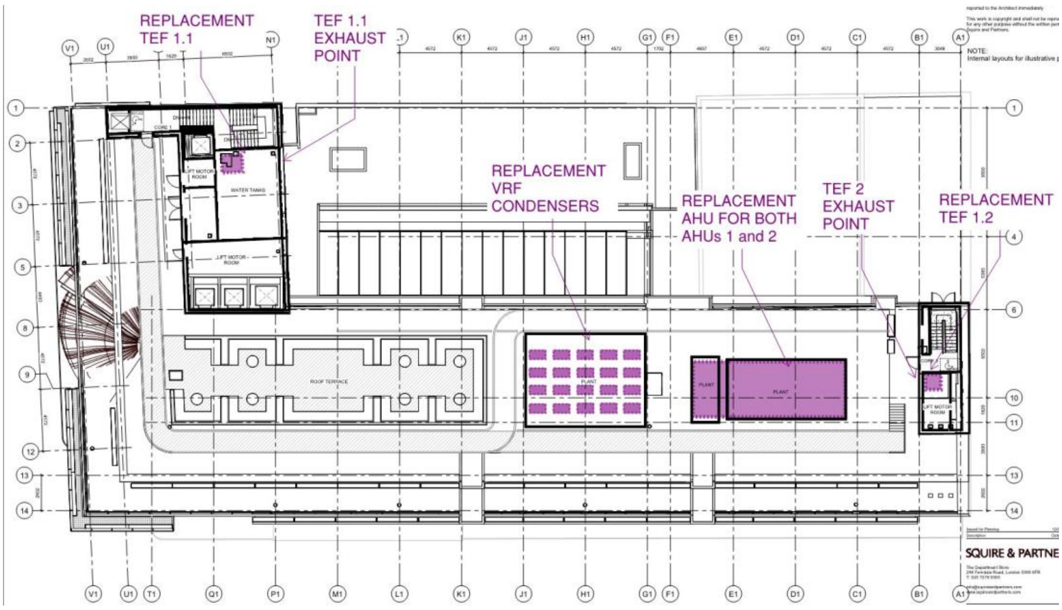

Figure 3 Block A Roof - Replacement Plant

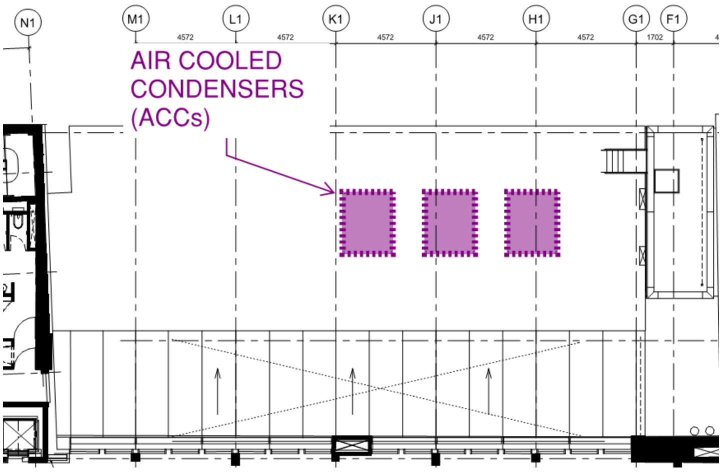

Figure 4 Block B Roof (Level 3) - Existing Plant

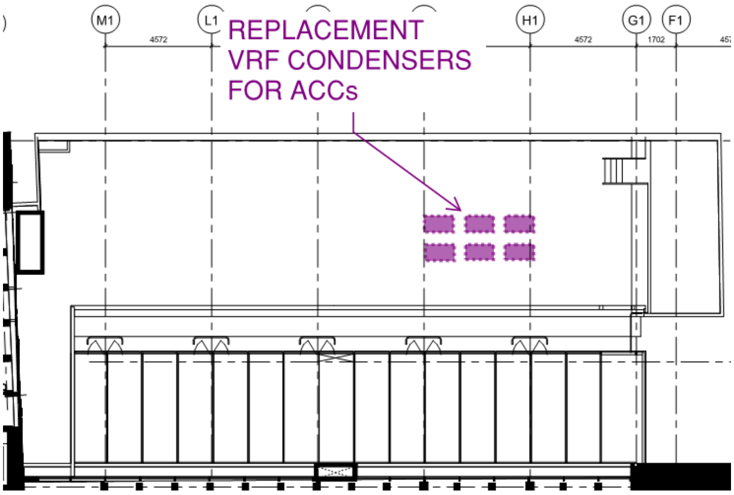

Figure 5 Block B Roof (Level 5) - Replacement Plant

Figures 6, 7 and 8 below show the location of the proposed roof terrace and cross-sectional views.

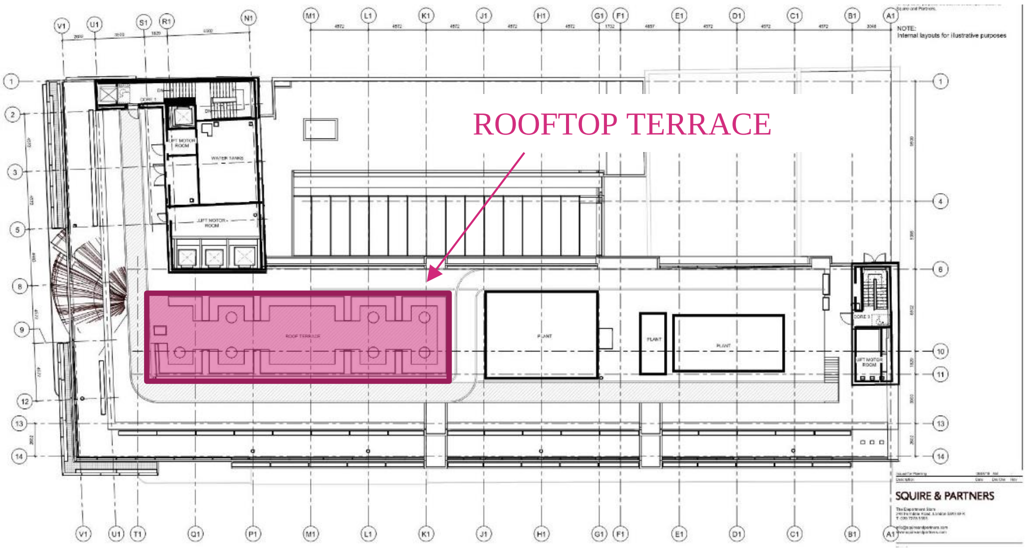

Figure 6 Block A Rooftop Terrace

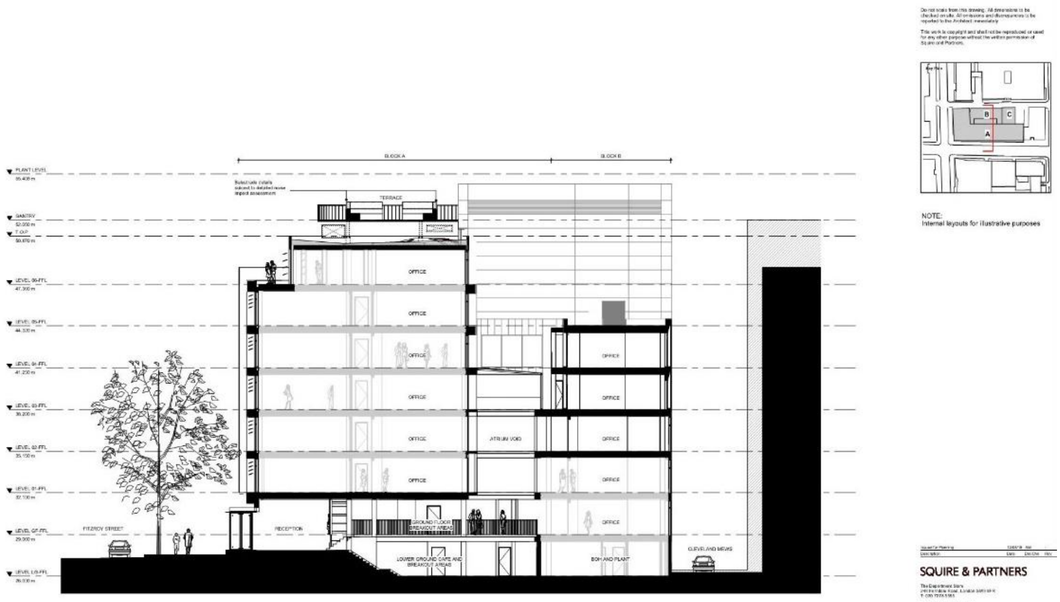

Figure 7 Cross-sectional View of Block A and Block B

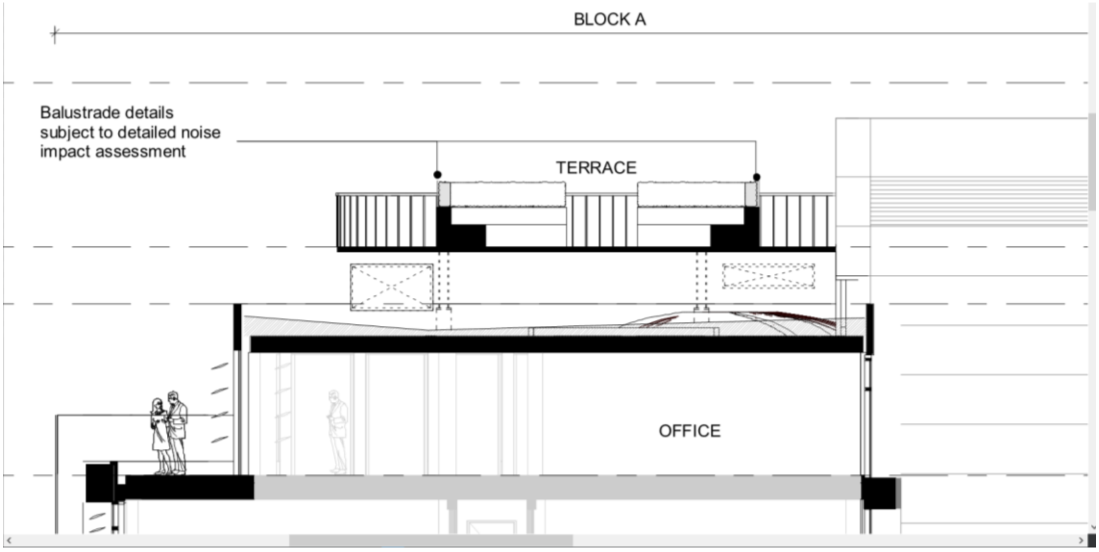

Figure 8 Cross-sectional View of Rooftop Terrace

4 Baseline environmental noise survey

Environmental noise surveys have been undertaken to determine the existing background noise levels at the nearest sensitive receptors. The full survey details can be found in Appendix B. A glossary of acoustic terminology can be found in Appendix A.

4.1 Measurement locations and times

Four nearest noise sensitive receptors were identified. These receptors are all residential. Measurements were taken at representative locations for each of the identified receptors, as displayed in Figure 9. At location 1, measurements were taken from a seventh-floor terrace facing outwards onto Fitzroy Street. At locations 2 to 4 measurements were taken at street level a representative distance from the façade, directed towards 13 Fitzroy Street.

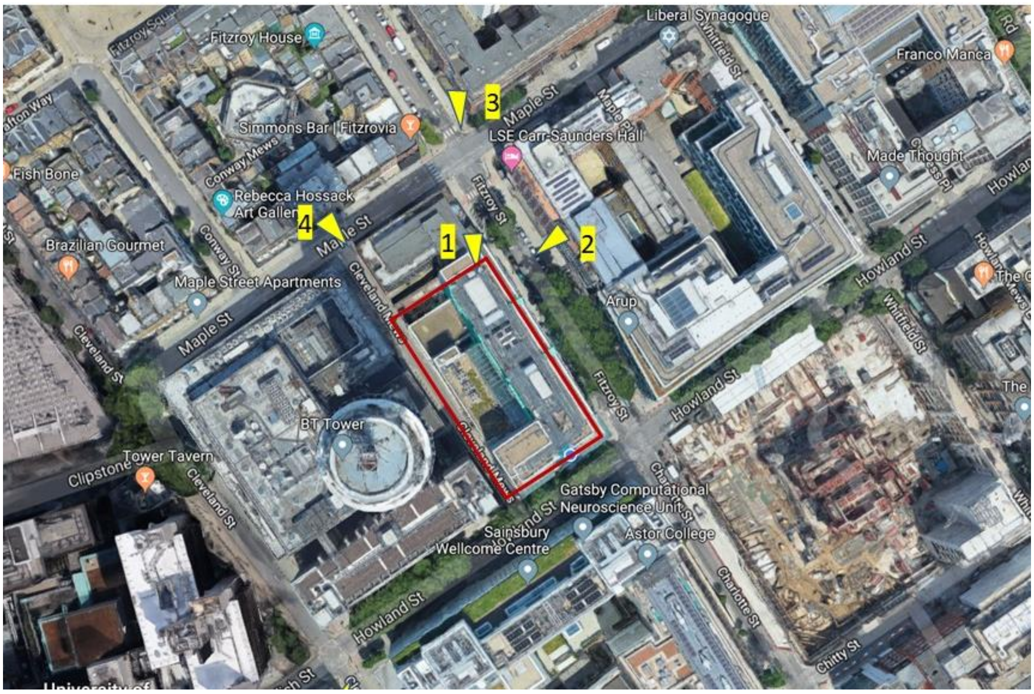

Figure 9 Measurement locations (1 to 4) representative of the identified nearest sensitive receptors. Red border: 13 Fitzroy Street.

Unattended measurements were taken over a five-day period at location 1. The unattended measurement results, presented in full in Appendix B, were used to select appropriate times for attended measurements. It is anticipated that the proposed plant on 13 Fitzroy Street could operate up to design duties during typical office hours, that is 08.00 to 20.00. The lowest background noise levels (L_{A90}) during typical office hours were observed in the morning, around 08.00, with levels later in the day being generally higher. Therefore, unattended measurements were taken between 7.00 and 08.45, when the background noise levels were expected to be at their lowest.

Outside office working hours, when the building is largely unoccupied, it is expected that building load conditions will be such that the majority of services will be either inoperative or operating at minimal load, such that noise emissions will be significantly lower than during the daytime.

4.2 Results summary

The typical daytime background noise level measured at location 1 during the unattended survey is presented in Table 1.

Table 1: Lowest background noise level ($L_{A90,\ 5min}$) measrued at location 1 during office hours (weekdays, betweene 08:00 and 20:00)

Location	**Lowest background noise level, dBL$_{A90}$**
1	55

The background noise levels measured at each location during the attended survey are summarised in Table 2.

Table 2: Background noise levels (L_{A90}, 15min) measured at each measurement location

Location	**Start time**	**Background noise level, dBL$_{A90}$**	**Lowest background noise level, dBL$_{A90}$**
2	07:08	51	51
	07:59	55	
3	07:25	53	53
	08:16	55	
4	07:42	52	52
	08:33	58	

5 Noise Assessment

In accordance with Camden Local Plan (2017), Camden LBC requires that noise from building services plant be designed to a level of 10dB below the existing background noise level. Based on the baseline survey results as summarised above, the following noise limits are required (Table 3). These limits apply cumulatively with all plant operating simultaneously.

Table 3: Daytime noise limits at nearest sensitive receptors

Receptor	Daytime noise limit, dBL_{Aeq}
1	45
2	41
3	43
4	42

5.1 Plant noise emissions

Based on the preliminary plant selections, Table 4 to Table 7 present the sound power levels at design load for the principle plant items, as provided by the suppliers.

Table 4: AHU1 sound power levels

	L_W @ octave band centre frequency (dB re 10^{-12}W)							
	63	125	250	500	1k	2k	4k	8k
Fresh air connection	84	89	88	83	70	71	66	59
Exhaust connection	81	90	89	89	85	83	79	74
To surroundings	80	82	78	67	56	58	53	38

Table 5: TEF 1 & 2 sound power levels (per unit). As the TEFs will be enclosed with the building, with only the outlet exposed, the 'Breakout' component will not contribute to the noise level at the receptors.

	L_W @ octave band centre frequency (dB re 10^{-12}W)							
	63	125	250	500	1k	2k	4k	8k
Induct outlet	88	98	78	76	81	82	78	72
Breakout	85	91	74	70	67	68	62	48

Table 6: VRF sound power levels running in 'Quiet Mode'

	L_W @ octave band centre frequency (dB re 10^{-12}W)							
	63	125	250	500	1k	2k	4k	8k
Type 1	75	69	63	62	62	60	57	49
Type 2	63	68	68	64	55	57	53	51
Type 3	73	65	65	68	62	58	55	51

Table 7: VRF sound power levels in 'normal' operation (i.e. full operating capacity and not in 'Quiet Mode')

	Lw @ octave band centre frequency (dB re 10^{-12}W)							
	63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Type 1	88	81	79	77	71	68	64	59
Type 2	94	90	86	86	78	75	73	71
Type 3	97	87	87	88	81	76	74	70

The arrays of condensers on Blocks A and B will consist of 20 and 6 units respectively. This assessment is based on a make-up of eight units of type 1, and six units each of types 2 and 3 on Block A, with two units of each type on Block B.

5.2 Noise mitigation

The condenser array on the Block A roof will be enclosed with a 2m high acoustic barrier with minimum surface weight 10 kg m^{-2}. This is shown in Figure 10.

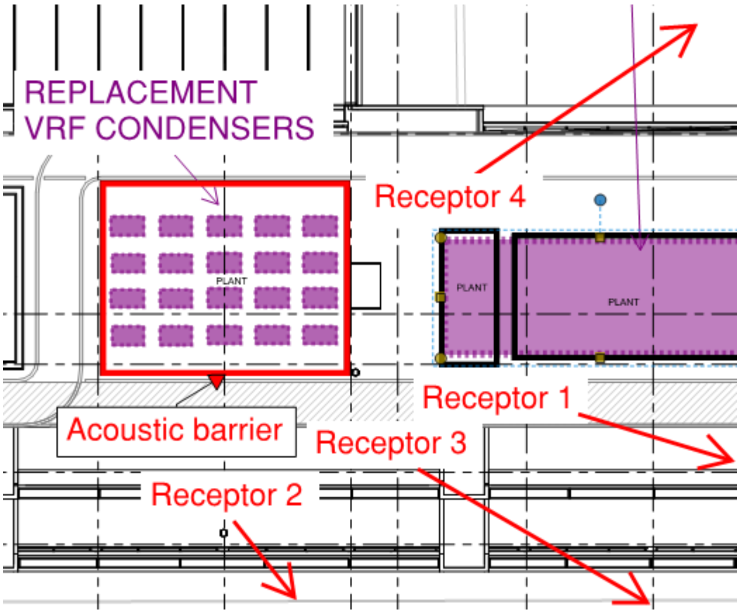

Figure 10 Plan showing location of acoustic barrier enclosing the condenser array on Block A. Arrows indicate the relative positions of the identified noise sensitive receptors.

The current selection of VRF on the Block A roof would operate in 'Quiet Mode'.

The AHU and TEFs will be fitted with atmosphere-side attenuators providing the following minimum noise reduction:

Table 8: Minimum attenuator insertion losses

Plant item	**Sample product**	**Dimensions (w x h x l, mm)**	**Minimum insertion loss @ octave band centre frequency (dB)**							
			63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
AHU1 Fresh air inlet	MSA100-43-14-PF	2000x1500x500	4	10	11	12	21	27	23	17
TEF 1.1	MSA100-75-4-PF	700x400x3000	8	19	38	44	50	50	42	34
TEF 1.2	MSA100-75-4-PF	700x400x1250	5	10	16	20	28	30	23	18

5.3 Predicted plant noise emissions

Based on the suppliers' data and noise mitigation measures, the cumulative noise emission to each of the four identified noise sensitive receptors has been calculated. Details of these calculations are presented in Appendix C. This calculation assumes a worst-case scenario, with all plant items running simultaneously at design load. The resultant sound pressure levels at each receptor are presented in Table 9, next to the daytime noise limits from above.

Table 9: Cumulative sound pressure level at the identified noise sensitive receptors.

Receptor	**Resultant sound pressure level (dB L_{Aeq})**	**Daytime noise limit, (dB L_{Aeq})**
1	40	45
2	40	41
3	38	43
4	38	42

6 Conclusion

An acoustic noise assessment has been undertaken based on an environmental noise survey and noise supplier-provided noise emission data for the planned replacement plant items on the roof of 13 Fitzroy Street. This assessment has demonstrated that by use of the recommended mitigation measures, the cumulative noise levels at the nearest noise sensitive receptors will not exceed the limits required by Camden LBC.

Appendix A

Acoustic Terminology

Decibel

The ratio of sound pressures which we can hear is a ratio of 10^6:1 (one million: one). For convenience, therefore, a logarithmic measurement scale is used. The resulting parameter is called the 'sound pressure level' (L_p) and the associated measurement unit is the decibel (dB). As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply.

dB(A)

The unit used to define a weighted sound pressure level, which correlates well with the subjective response to sound. The 'A' weighting follows the frequency response of the human ear, which is less sensitive to low and very high frequencies than it is to those in the range 500Hz to 4kHz.

In some statistical descriptors the 'A' weighting forms part of a subscript, such as L_{A10}, L_{A90}, and L_{Aeq} for the 'A' weighted equivalent continuous noise level.

Sound power level

The sound power level (L_w) of a source is a measure of the total acoustic power radiated by a source. The sound power level is an intrinsic characteristic of a source (analogous to its volume or mass), which is not affected by the environment within which the source is located.

Sound pressure level

The sound power emitted by a source results in pressure fluctuations in the air, which are heard as sound.

The sound pressure level (L_p) is ten times the logarithm of the ratio of the measured sound pressure (detected by a microphone) to the reference level of 2 x 10^{-5}Pa (the threshold of hearing).

Thus L_p (dB) = 10 log $(P_1/P_{ref})^2$ where P_{ref}, the lowest pressure detectable by the ear, is 0.00002 Pascals (i.e. $2x10^{-5}$ Pa).

The threshold of hearing is 0 dB, while the threshold of pain is approximately 120 dB. Normal speech is approximately 60 dBL_A and a change of 3 dB is only just detectable. A change of 10 dB is subjectively twice, or half, as loud.

$L_{A90,T}$

$L_{A90,T}$ is a statistical measure, and is the A-weighted sound pressure level exceeded for 90% of the measurement period, T. It has generally been adopted to represent the background noise level.

Appendix B

Baseline Noise Survey

B1 Introduction

An environmental noise survey has been undertaken to determine the existing noise climate in and around 13 Fitzroy Street. This appendix details the baseline noise survey and results.

B1.1 Site Description

13 Fitzroy Street is an eight-storey office building located to the north of Howland Street. Four sensitive receptors were identified in the immediate vicinity; these are displayed in Figure 11.

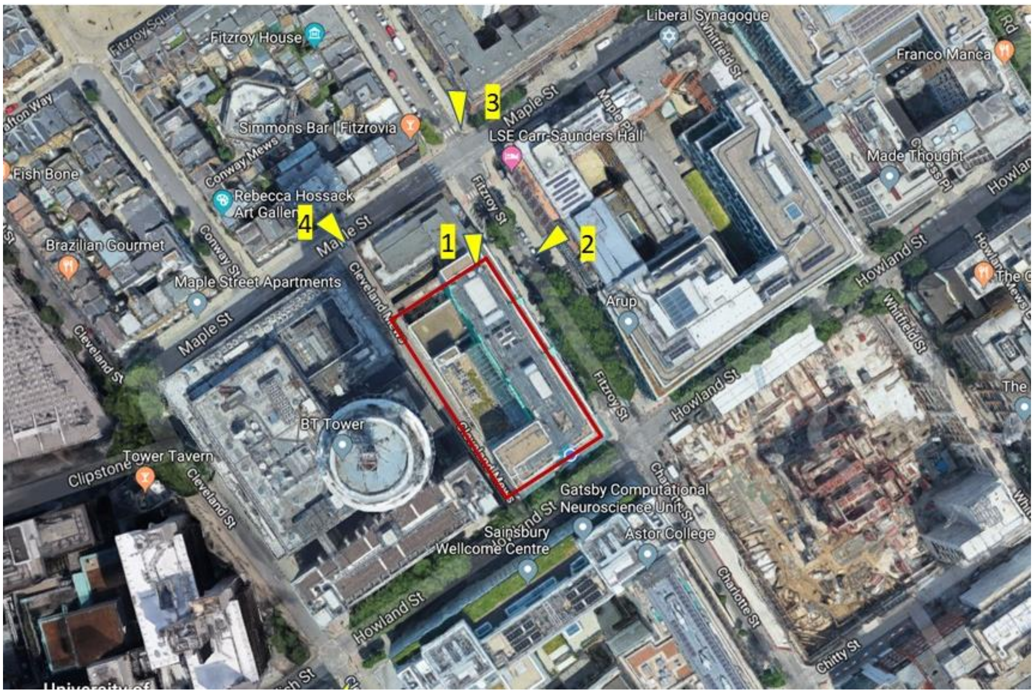

Figure 11 Site location and measurement locations.

B1.2 Instrumentation

The sound level meters and microphones are Class 1 conforming to BS EN 61672-1:2013. All equipment is calibrated annually according to international standards, together with traceable records. Calibration certificates can be provided upon request. Onsite calibration checks were conducted and no significant drift recorded. The monitoring equipment used is described in Table 10and Table 11.

Table 10: Measurement instrumentation for attended measurements

Description	Serial Number	Item Type
B&K 4189 Microphone	3180873	Microphone
B&K 4231 Calibrator	3014817	Sound level meter
B&K ZC-0032 Preamp	17013	Microphone

Table 11: Measurement instrumentation for unattended measurements

Description	Serial Number	Item Type
Nor-140 Microphone	1403425	Microphone
Nor-1251 Calibrator	33849	Sound level meter
Nor-1209 Preamp	12578	Microphone
Nor-140	1403425	Sound level meter

B1.3 Measurement Methodology

At each location L_{Aeq}, L_{A10}, L_{A90}, L_{Amax} metric values were measured. All broadband measurements were A-weighted and used a fast time constant (0.125s).

The sound level meter was mounted on a tripod with the microphone set approximately at 1.2m-1.5m above local ground level. All measurements were taken under acoustically free-field conditions, except where otherwise stated. A windshield was fitted to the microphone.

B2 Measurement Results

B2.1 Attended Measurements

B2.1.1 Location 2

Measurement Duration:
Wed 18/12/2019 07:08
to
Wed 18/12/2019 08:14

Environment and Observations:
The dominant noise sources were road traffic on Fitzroy Street and early morning deliveries.

Weather Conditions:
Wind Speed: < 5m/s
Wind Direction:
Summary:

Personnel:
Harry Bartley

Table 12: Summary of averaged sound pressure levels at 2

Period	Sound Pressure Level, dB(A) (re 20 µPa)			
	L_{A90}	L_{Aeq}	L_{A10}	$L_{A,max}$
Day (07:00-23:00)	53	61	64	69 - 81

Table 13: Measured sound pressure levels at 2

Date	Time		Sound Pressure Level, dB(A) (re 20 µPa)			
	Start [hh:mm]	Duration [hh:mm:ss]	L_{A90}	L_{Aeq}	L_{A10}	$L_{A,max}$
18/12/2019	07:08	00:05:00	51	60	64	76
18/12/2019	07:13	00:05:00	53	58	62	68
18/12/2019	07:18	00:05:00	51	57	60	71
18/12/2019	07:59	00:05:00	56	64	66	81
18/12/2019	08:04	00:05:00	56	63	66	80
18/12/2019	08:09	00:05:00	54	61	64	78

B2.1.2 Location 3

Measurement Duration:
Wed 18/12/2019 07:25
to
Wed 18/12/2019 08:31

Weather Conditions:
Wind Speed: < 5m/s
Wind Direction:
Summary:

Personnel:
Harry Bartley

Environment and Observations:
The dominant noise source was road traffic on Fitzroy Street.

Table 14: Summary of averaged sound pressure levels at 3

Period	Sound Pressure Level, dB(A) (re 20 µPa)			
	L_{A90}	L_{Aeq}	L_{A10}	$L_{A,max}$
Day (07:00-23:00)	54	64	67	73 - 85

Table 15: Measured sound pressure levels at 3

Date	Time		Sound Pressure Level, dB(A) (re 20 µPa)			
	Start [hh:mm]	Duration [hh:mm:ss]	L_{A90}	L_{Aeq}	L_{A10}	$L_{A,max}$
18/12/2019	07:25	00:05:00	53	60	63	73
18/12/2019	07:30	00:05:00	56	63	67	78
18/12/2019	07:35	00:05:00	53	63	68	74
18/12/2019	08:16	00:05:00	57	66	70	79
18/12/2019	08:21	00:05:00	54	65	68	80
18/12/2019	08:26	00:05:00	56	64	67	85

B2.1.3 Location 4

Measurement Duration:
Wed 18/12/2019 07:42
to
Wed 18/12/2019 08:45

Weather Conditions:
Wind Speed: < 5m/s
Wind Direction:
Summary:

Personnel:
Harry Bartley

Environment and Observations:

The dominant noise sources were road traffic on Fitzroy Street and deliveries.

Table 16: Summary of averaged sound pressure levels at 4

Period	**Sound Pressure Level, dB(A) (re 20 µPa)**			
	L_{A90}	L_{Aeq}	L_{A10}	$L_{A,max}$
Day (07:00-23:00)	55	66	69	77 - 90

Table 17: Measured sound pressure levels at 4

Date	**Time**		**Sound Pressure Level, dB(A) (re 20 µPa)**			
	Start [hh:mm]	Duration [hh:mm:ss]	L_{A90}	L_{Aeq}	L_{A10}	$L_{A,max}$
18/12/2019	07:42	00:04:40	52	63	66	79
18/12/2019	07:47	00:05:00	54	65	70	78
18/12/2019	07:52	00:05:00	52	66	70	83
18/12/2019	08:33	00:05:00	58	68	70	90
18/12/2019	08:38	00:05:00	57	66	70	81
18/12/2019	08:43	00:01:02	61	67	70	77

B2.2 Unattended Measurements

Figure 12 presents the full unattended results.

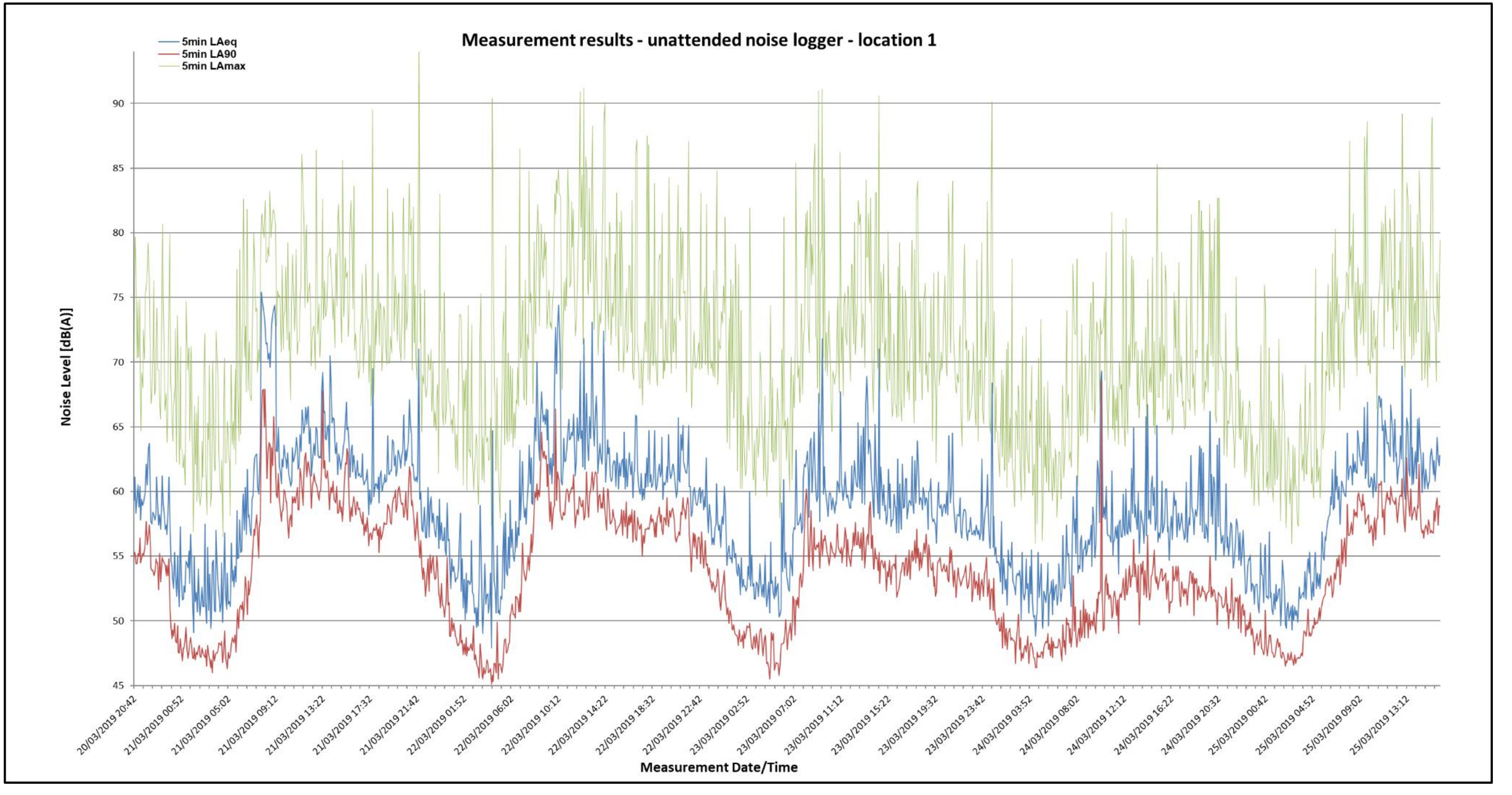

Figure 12 Full results of unattended measurements at location one. Note that 23 and 24 March fell on a weekend.

Appendix C

Details of Calculation of Cumulative Noise Levels

C1 Cumulative plant noise at receptors without mitigation

The cumulative sound pressure level at each identified noise sensitive receptor was initially calculated using the supplier-provided plant sound power levels (presented in 5.1, and also for convenience repeated below in Table 18) with no mitigation measures in place. The corrections applied to each source are presented in Table 19 to Table 22 and are as follows:

- Propagation loss is a reduction in sound pressure level due the inverse-square spreading of sound energy as it propagates away from the source.
- Where the source is directional, as is the case for duct outlets, the position of the receptor relative to the source will affect the amount of sound energy received (on-axis receptors will receive more sound energy, whereas receptors behind the source will receptor much less). This is accounted for in the directivity correction.
- Some receptors do not have a direct line of sight to all sources; in these cases a correction is included for the reduction in level due to intermediate barriers (generally Block A and 23 Fitzroy Street).

Table 18: Sound power levels of plant items without mitigation measures, i.e. with no attenuators fitted and not operating in Quiet Mode

Source		**L_W @ octave band centre frequency (dB re 10^{-12}W)**							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
AHU1	Fresh air connection	84	89	88	83	70	71	66	59
	Exhaust connection	81	90	89	89	85	83	79	74
	To surroundings	80	82	78	67	56	58	53	38
TEF1.1 & TEF1.2	Induct outlet	88	98	78	76	81	82	78	72
VRF Condensers	Type 1	88	81	79	77	71	68	64	59
	Type 2	94	90	86	86	78	75	73	71

Source		L_W @ octave band centre frequency (dB re 10^{-12}W)							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
(‘normal’ operation i.e. not ‘Quiet Mode’)	Type 3	97	87	87	88	81	76	74	70
	Total for Block A array	107	100	98	98	91	87	85	82
	Total for Block B array	102	95	93	93	86	82	80	77

Table 19: Calculation of cumulative sound pressure level without mitigation at Receptor 1

Source	Correction	L_P @ octave band centre frequency (dB re 20 μPa)							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
AHU1 fresh air connection	Plane source propagation loss	-31	-31	-31	-31	-31	-31	-31	-31
	Directivity	+5	+5	+6	+6	+6	+6	+6	+6
	Screening by Block A roof	-6	-6	-8	-9	-12	-14	-17	-20
	Resultant level at receptor	*53*	*57*	*56*	*49*	*34*	*33*	*25*	*15*
AHU1 exhaust connection	Plane source propagation loss	-36	-36	-36	-36	-36	-36	-36	-36
	Directivity	-8	-17	-16	-16	-16	-16	-16	-16
	Screening by Block A roof	-7	-8	-10	-12	-15	-18	-21	-24
	Resultant level at receptor	*30*	*29*	*27*	*25*	*18*	*13*	*7*	*-1*
AHU1 to surroundings	Parallelepiped source propagation loss	-37	-37	-37	-37	-37	-37	-37	-37
	Attenuation due to screening by Block A roof	-6	-7	-9	-11	-14	-16	-19	-22
	Resultant level at receptor	37	38	32	19	5	5	-3	-21
TEF1.1	Plane source propagation loss	-30	-30	-30	-30	-30	-30	-30	-30
	Directivity	+1	-1	-5	-12	-17	-16	-16	-16

Source	Correction	Lp @ octave band centre frequency (dB re 20 µPa)							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
	Screening by Block A roof	-8	-10	-12	-14	-17	-20	-23	-25
	Resultant level at receptor	*51*	*57*	*31*	*19*	*17*	*15*	*8*	*0*
VRF array Block A	Point source propagation loss	-38	-38	-38	-38	-38	-38	-38	-38
	Screening by Block A roof	-15	-17	-20	-23	-25	-25	-25	-25
	Resultant level at receptor	*55*	*45*	*40*	*37*	*28*	*24*	*22*	*19*
VRF array Block B	Point source propagation loss	-42	-42	-42	-42	-42	-42	-42	-42
	Screening by Block A roof	-15	-19	-23	-25	-25	-25	-25	-25
	Resultant level at receptor	*46*	*35*	*29*	*27*	*19*	*15*	*13*	*10*
Cumulative sound power level at Receptor 1		**58**	**60**	**56**	**49**	**35**	**33**	**27**	**21**

Table 20: Calculation of cumulative sound pressure level without mitigation at Receptor 2

Source	Correction	Lp @ octave band centre frequency (dB re 20 µPa)							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
AHU1 fresh air connection	Plane source propagation loss	-38	-38	-38	-38	-38	-38	-38	-38
	Directivity	+1	-3	-16	-16	-16	-16	-16	-16
	Resultant level at receptor	*47*	*48*	*34*	*29*	*16*	*17*	*12*	*5*
AHU1 exhaust connection	Plane source propagation loss	-39	-39	-39	-39	-39	-39	-39	-39
	Directivity	-12	-16	-16	-16	-16	-16	-16	-16
	Resultant level at receptor	*30*	*35*	*34*	*34*	*30*	*28*	*24*	*19*
AHU1 to surroundings	Parallelepiped source propagation loss	-42	-42	-42	-42	-42	-42	-42	-42

Source	**Correction**	**L_P @ octave band centre frequency (dB re 20 µPa)**							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
	Resultant level at receptor	*38*	*40*	*36*	*25*	*14*	*16*	*11*	*-4*
TEF1.1	Plane source propagation loss	-39	-39	-39	-39	-39	-39	-39	-39
	Directivity	+3	+4	+4	+4	+3	+2	+2	+2
	Resultant level at receptor	*52*	*63*	*43*	*41*	*45*	*45*	*41*	*35*
TEF1.2	Plane source propagation loss	-43	-43	-43	-43	-43	-43	-43	-43
	Directivity	+4	+4	+4	+5	+4	+5	+5	+5
	Resultant level at receptor	*44*	*56*	*39*	*37*	*42*	*43*	*39*	*33*
VRF array Block A	Point source propagation loss	-39	-39	-39	-39	-39	-39	-39	-39
	Resultant level at receptor	68	61	59	59	52	48	46	43
VRF array Block B	Point source propagation loss	-43	-43	-43	-43	-43	-43	-43	-43
	Screening by Block A	-10	-12	-16	-20	-24	-25	-25	-25
	Resultant level at receptor	*49*	*40*	*34*	*31*	*19*	*14*	*12*	*9*
Cumulative sound power level at Receptor 2		**68**	**66**	**59**	**60**	**53**	**51**	**48**	**44**

Table 21: Calculation of cumulative sound pressure level without mitigation at Receptor 3

Source	**Correction**	**L_P @ octave band centre frequency (dB re 20 µPa)**							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
AHU1 fresh air connection	Plane source propagation loss	-43	-43	-43	-43	-43	-43	-43	-43
	Directivity	+6	+7	+8	+8	+8	+8	+8	+8
	Resultant level at receptor	*46*	*52*	*52*	*47*	*34*	*35*	*30*	*23*

Source	Correction	L_P @ octave band centre frequency (dB re 20 μPa)							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
AHU1 exhaust connection	Plane source propagation loss	-44	-44	-44	-44	-44	-44	-44	-44
	Directivity	-9	-16	-16	-16	-16	-16	-16	-16
	Resultant level at receptor	*80*	*82*	*78*	*67*	*56*	*58*	*53*	*38*
AHU1 to surroundings	Parallelepiped source propagation loss	-47	-47	-47	-47	-47	-47	-47	-47
	Resultant level at receptor	*33*	*35*	*31*	*20*	*9*	*11*	*6*	*-9*
TEF1.1	Plane source propagation loss	-43	-43	-43	-43	-43	-43	-43	-43
	Directivity	+2	+1	-2	-9	-16	-16	-16	-16
	Screening by Block A roof	-6	-8	-10	-14	-17	-20	-23	-25
	Resultant level at receptor	41	48	23	10	5	4	-3	-11
VRF array Block A	Point source propagation loss	-45	-45	-45	-45	-45	-45	-45	-45
	Resultant level at receptor	62	55	53	53	46	42	39	36
VRF array Block B	Point source propagation loss	-47	-47	-47	-47	-47	-47	-47	-47
	Screening by Block A	-8	-11	-14	-18	-21	-24	-25	-25
	Resultant level at receptor	*47*	*38*	*32*	*29*	*18*	*11*	*8*	*5*
Cumulative sound power level at Receptor 3		62	57	55	54	46	43	40	37

Table 22: Calculation of cumulative sound pressure level without mitigation at Receptor 4

Source	Correction	L_P @ octave band centre frequency (dB re 20 μPa)							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
AHU1 fresh air connection	Plane source propagation loss	-42	-42	-42	-42	-42	-42	-42	-42

Source	**Correction**	**L_P @ octave band centre frequency (dB re 20 µPa)**							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
	Directivity	+6	+7	+8	+8	+8	+8	+8	+8
	Resultant level at receptor	*48*	*54*	*54*	*49*	*36*	*37*	*32*	*25*
AHU1 exhaust connection	Plane source propagation loss	-43	-43	-43	-43	-43	-43	-43	-43
	Directivity	+2	-5	-4	-4	-4	-4	-4	-4
	Resultant level at receptor	*47*	*50*	*31*	*29*	*34*	*35*	*31*	*25*
AHU1 to surroundings	Parallelepiped source propagation loss	-46	-46	-46	-46	-46	-46	-46	-46
	Screening by 23 Fitzroy Street	-7	-8	-10	-14	-18	-21	-25	-25
	Resultant level at receptor	*28*	*28*	*22*	*8*	*-7*	*-9*	*-17*	*-33*
TEF1.1	Plane source propagation loss	-41	-41	-41	-41	-41	-41	-41	-41
	Directivity	+1	-1	-5	-12	-16	-16	-16	-16
	Screening by 23 Fitzroy Street	-1	0	0	0	0	0	0	0
	Resultant level at receptor	*47*	*56*	*32*	*23*	*24*	*25*	*21*	*15*
VRF array Block A	Point source propagation loss	-44	-44	-44	-44	-44	-44	-44	-44
	Screening by 23 Fitzroy Street	-10	-13	-17	-21	-24	-25	-25	-25
	Resultant level at receptor	53	43	37	33	22	17	15	12
VRF array Block B	Point source propagation loss	-45	-45	-45	-45	-45	-45	-45	-45
	Screening by 23 Fitzroy Street	-15	-19	-24	-25	-25	-25	-25	-25
	Resultant level at receptor	*42*	*31*	*24*	*23*	*16*	*12*	*10*	*7*
Cumulative sound power level at Receptor 4		**56**	**59**	**54**	**49**	**38**	**39**	**35**	**28**

C2 Cumulative plant noise at receptors with mitigation

The cumulative sound pressure levels at each identified noise sensitive receptor was then recalculated with the inclusion of the mitigation measures outline in 5.2, namely a 2m high acoustic barrier enclosing the Block A condenser array, the use of ‘Quiet Mode’ when running the Block A condensers and atmosphere-side attenuators fitted to the AHU1 fresh air inlet, TEF1.1 and TEF1.2. The VRF sound power level when operating in ‘Quiet Mode’ are presented in 5.1, but for convenience are repeated here.

Table 23: VRF sound power levels running in ‘Quiet Mode’

	L_W @ octave band centre frequency (dB 10^{-12}W)							
	63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Type 1	88	81	79	77	71	68	64	59
Type 2	94	90	86	86	78	75	73	71
Type 3	97	87	87	88	81	76	74	70
Total level for Block A array	86	81	78	78	74	72	68	63

C2.1 Reduction due to attenuators

The atmosphere-side attenuators fitted to AHU1, TEF1.1 and TEF1.2 introduce a reduction to the sound power level; this is the insertion loss. The attenuators also create additional noise, called regenerated noise. The resultant noise emission at the source is calculated using:

$$SWL + transmission\ loss + + regenerated\ noise \qquad (1)$$

where SWL is the sound power level of the source, + represents a geometric sum and + + represents a logarithmic sum. The corrections presented in C1 are then applied to the resultant noise emission at source to calculate the resultant noise level at each noise sensitive receptor.

Table 24: Reduction in noise emission from AHU1, TEF1.1 and TEF1.2 due to atmosphere-side attenuators of the type mentioned in 5.2.

Source	**Correction**	**L_W @ octave band centre frequency (dB 10^{-12}W)**							
		63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
AHU1 fresh air connection	Attenuator reduction	-4	-10	-11	-12	-21	-27	-23	-17
	Regenerated noise	63	59	54	50	46	42	38	35
	Resultant noise emission @ source	80	79	77	71	51	46	44	43
TEF1.1	Attenuator reduction	-8	-19	-38	-44	-50	-50	-42	-34
	Regenerated noise	57	53	48	44	40	36	32	29
	Resultant noise emission @ source	80	79	49	44	41	37	37	39
TEF1.2	Attenuator reduction	-5	-10	-16	-20	-28	-30	-23	-18
	Regenerated noise	57	53	48	44	40	36	33	29
	Resultant noise emission @ source	83	88	62	56	53	52	55	54

C2.2 Reduction due to acoustic barrier

The 2 m acoustics barrier, which will be placed around the VRF array on Block A, will provide additional screening. An additional barrier attenuation correction was applied to account for this barrier attenuation. The correction depends on the path distance of each receptor from the source and from the barrier. The correction was not applied for receptor 1, as significant screening was already provided by the edge of the Block A roof. Table 25 presents the additional barrier attenuation correction applied for the noise propagation to each receptor.

Table 25: Additional correction applied to calculation of noise level due to the acoustic barrier around the Block A VRF array at each receptor.

Receptor	L_P @ octave band centre frequency (dB re 20 µPa)							
	63	125	250	500	1k	2k	4k	8k
2	-8	-10	-12	-15	-17	-20	-23	-25
3	-8	-10	-12	-15	-17	-20	-23	-25
4	-10	-13	-17	-21	-24	-25	-25	-25

C2.3 Final results

The predicted cumulative noise levels at the identified noise sensitive receptors were calculated using the attenuated sound power levels for AHU1, TEF1.1 and TEF1.2 (Table 24), the ‘Quiet Mode’ sound power levels for the Block A condenser array (Table 23) and the ‘normal mode’ sound power levels for the Block B condenser array (Table 18). The corrections for propagation loss, directivity and screening by existing buildings (Table 19 to Table 22) and screening by the acoustic barrier (Table 25) were then applied to produce the following predictions of the cumulative sound pressure levels at each noise sensitive receptor:

Table 26: Cumulative sound pressure level at the identified noise senstive receptors.

Receptor	Resultant sound pressure level (dB L_{Aeq})	L_P @ octave band centre frequency (dB re 20 µPa)							
		63	125	250	500	1k	2k	4k	8k
1	40	51	48	45	38	23	19	15	11
2	40	52	50	40	36	31	29	25	21
3	38	49	44	42	37	26	24	20	15
4	38	48	45	43	37	20	15	13	11