Our ref: NIA/8466/19/8389/v3/Kingsmark Way

13th March 2020

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NOISE IMPACT ASSESSMENT FOR PROPOSED RESIDENTIAL DEVELOPMENT AT LAND AT KINGSMARK WAY, GOLDTHORPE, ROTHERHAM

BARNSLEY METROPOLITAN BOROUGH COUNCIL PLANNING PERMISSION REF: 2018/0103

1.00 INTRODUCTION

1.01 Environmental Noise Solutions Limited (ENS) has been commissioned by Countryside Plc and the Ogden Group of Companies to carry out a noise impact assessment for a proposed residential development at land at Kingsmark Way, Goldthorpe, Rotherham (hereafter referred to as the subject site).

1.02 Planning Permission (ref: 2018/0103) for the development was granted by Barnsley Metropolitan Borough Council in April 2018, subject to conditions. Condition 12 relates to the control of noise as follows:

> *12. A detailed noise impact assessment report shall accompany the reserved matters application assessing noise and vibration associated with the commercial/industrial premises located adjacent to the west/north west boundary and specifying suitable mitigation, in line with BS8233:2014, for any part of the proposed development that would be affected. The development shall be carried out in strict accordance with the approved mitigation.*

1.03 The objectives of the noise impact assessment were to:

- Determine the ambient noise climate at the subject site.
- Assess the potential impact of the ambient noise climate on the proposed residential development with reference to BS 8233:2014.
- Provide recommendations for a scheme of sound attenuation works, as necessary, to ensure that the future occupants of the proposed residential development do not experience any unacceptable loss of amenity due to noise.

1.04 This report details the methodology and results of the assessment and provides recommendations for the building envelope (fenestration and ventilation) and boundary treatments. It has been prepared to aid in the discharge of Condition 12 of Planning Permission 2018/0103.

1.05 This report has been prepared for Countryside Plc and the Ogden Group of Companies for the sole purpose described above and no extended duty of care to any third party is implied or offered. Third parties making reference to the report should consult Countryside Plc, the Ogden Group of Companies and ENS as to the extent to which the findings may be appropriate for their use.

1.06 A glossary of acoustic terms used in the main body of the text is contained in Appendix 1.

2.00 SUBJECT SITE SETTING AND PROPOSED RESIDENTIAL DEVELOPMENT

2.01 The subject site is located in a mixed-use setting on the eastern fringe of Goldthorpe. Roughly rectangular in shape, the subject site is bound by (see site location plan in Appendix 2):

- Beever Street (a very lightly-trafficked estate road), a fabricators (G. M. Asquith Fabricators Ltd.) and existing residential dwellings on Beever Street to the west.
- Allotments to the north and south.
- Kingsmark Way (a very lightly-trafficked estate road) to the east, with existing residential dwellings beyond.

2.02 The proposed residential development consists of the construction of 138 no. residential dwellings with associated landscaping and estate roads (a site layout is contained in Appendix 2 for reference). Site plans indicate that the residential development 'backs onto' the adjacent fabricators. It is understood that parts of the application site are elevated by a retaining wall between the site and the fabricators to the west.

2.03 For reference, the adjacent fabricators supply and manufacture fencing supplies, and operate 0800–1700 hours Monday to Friday (with no night time working).

2.04 The ambient noise climate at the subject site is formed by local and distant road traffic, with localised contributions from the adjacent fabricators along the western boundary of the subject site during the daytime.

3.00 BASELINE NOISE SURVEY

3.01 In order to establish the ambient noise levels at the subject site, a baseline noise survey was carried out during the daytime and night time on Monday 15th April and Tuesday 16th April 2019.

3.02 For the purpose of the assessment, the following noise monitoring positions were adopted (the approximate location of the noise monitoring positions is contained in Appendix 2 for reference):

- MP1 was located along the western boundary of the subject site at circa 4 metres from the site boundary and at 4 metres above ground level (AGL).
- MP1A was located along the western boundary of the subject site at circa 20 metres from site boundary and at 4 metres AGL.
- MP2 was located towards the eastern boundary of the subject site at circa 4 metres from the nearside kerb of Kingsmark Way at 1.5 metres AGL.
- MP3 was located towards the south-western corner of the subject site at 4 metres AGL.
- MP4 was located at the northern boundary of the subject site at 1.5 metres AGL.
- MP5 was located at the southern boundary of the application at 4 metres AGL.

3.03 Noise measurements were undertaken using a Bruel & Kjaer 2250 Type 1 integrating sound level meter. The measurement system calibration was verified immediately before the commencement of the measurement sessions and again at the end, using a Bruel & Kjaer Type 4231 calibrator. No drift in calibration level was noted. Weather conditions throughout the survey were appropriate for monitoring.

3.04 Measurements consisted of A–weighted broadband parameters, together with linear 1/3rd octave band L_{eq} levels.

3.05 Table 3.1 contains a summary of the measurement data for each measurement session, at each measurement position, rounded to the nearest decibel.

Table 3.1 – Summary of Noise Measurement Data

Position	Date	Time	L_{Aeq} (dB)	L_{A90} (dB)	L_{A10} (dB)	L_{A1} (dB)	Comment
MP1	15/04/19	1335–1405	63	47	69	71	Concrete mixer / vibrating table and low-level impacts from fabricators
		1405–1435	52	46	55	61	Low-level impacts from fabricators (concrete mixer off)
		2308–2338	42	35	46	49	Distant road traffic noise
MP1 daytime ambient noise level circa 63 dB $L_{Aeq,T}$ (during use of the concrete mixer at adjacent fabricators) MP1 daytime ambient noise level circa 52 dB $L_{Aeq,T}$ (during typical operations at adjacent fabricators) MP1 night time ambient noise level circa 42 dB $L_{Aeq,T}$ (maximum noise levels up to 55 dB L_{AFMax})							
MP1A	15/04/19	1437–1508	57	46	61	64	Concrete mixer / vibrating table and low-level impacts from fabricators
MP1A daytime ambient noise level circa 57 dB $L_{Aeq,T}$ (during use of the concrete mixer / vibrating table at adjacent fabricators) Note: Ambient noise level decreasing with increasing distance from fabricators							
MP2	16/04/19	1304–1349	53	40	58	65	Occasional vehicle passes on Kingsmark Way, distant road traffic
MP2	15/04/19	0013–0033	42	29	38	55	1 no. car pass on Kingsmark Way, distant road traffic
MP2 daytime and night time ambient noise level circa 53 dB $L_{Aeq,T}$ and 42 dB $L_{Aeq,T}$ respectively Maximum noise levels up to 65 dB L_{AFMax} during the night time.							
MP3	16/04/19	1203–1223	46	41	49	54	Local and distant road traffic (no significant noise from fabricators)
MP4	16/04/19	1228–1259	49	45	51	55	Local and distant road traffic
MP4	15/04/19	2348–0003	44	35	47	53	
MP5	16/04/19	1122–1137	45	41	48	52	Local and distant road traffic
MP5	15/04/19	2340–2345	38	32	41	45	
MP3 daytime ambient noise level circa 46 dB $L_{Aeq,T}$ MP4 daytime and night time ambient noise level circa 49 dB $L_{Aeq,T}$ and 44 dB $L_{Aeq,T}$ respectively MP5 daytime and night time ambient noise level circa 45 dB $L_{Aeq,T}$ and 38 dB $L_{Aeq,T}$ respectively Maximum noise levels ≤ 60 dB L_{AFMax} during the night time							

3.06 The ambient noise levels at the subject site were predominantly due to local and distant road traffic, with localised contributions from the adjacent fabricators at the western site boundary during the daytime.

3.07 Worst case ambient noise levels associated with the fabricators were measured at up to **63 dB $L_{Aeq,T}$** (during use of a concrete mixer / vibrating table) at MP1, with noise levels dropping off with increased distance to the fabricators. This level is robustly adopted for habitable rooms which overlook the fabricators.

4.00 NOISE IMPACT ASSESSMENT CRITERIA

4.01 British Standard 8233:2014 'Guidance on Sound Insulation and Noise Reduction for Buildings' (BS 8233) sets indoor ambient noise levels from residential dwellings (see table below).

Table 4.1 – Indoor Ambient Noise Levels in Dwellings (BS 8233)

Activity	Location	Good Indoor Ambient Noise Levels	
Resting	Living Room	35 dB $L_{Aeq\ (0700–2300)}$	-
Sleeping (daytime resting)	Bedroom	35 dB $L_{Aeq\ (0700–2300)}$	30 dB $L_{Aeq\ (2300–0700)}$

4.02 Note 4 to the above table states '*Regular individual noise events (for example, scheduled aircraft or passing trains) can cause sleep disturbance. A guideline value may be set in terms of SEL or L_{AFMax} depending on the character and number of events per night. Sporadic noise events could require separate values'.*

4.03 It is evident that BS 8233 considers that night time maxima guideline values relate to discrete, individual noise events (such as aircraft or trains, etc) rather than general road traffic noise. In the case of the subject site, however, consideration of the night time maximum noise levels will not have a material impact upon the glazing and ventilation specification (i.e. in order to meet the indoor noise level criterion, a similar reduction is required to L_{Aeq} as would be to L_{AFMax}).

4.04 Note 5 to the above table states '*If relying on closed windows to meet the guide values, there needs to be appropriate alternative ventilation that does not compromise the façade insulation or the resulting noise level. If applicable, any room should have adequate ventilation (e.g. trickle ventilators should be open) during assessment*'.

4.05 It is evident that BS 8233 considers that adequate ventilation is provided by trickle ventilators in an open position. This is consistent with Building Regulations and the National Planning Policy Framework Planning Practice Guidance on Noise.

4.06 Note 7 to the above table 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 decibels and reasonable internal conditions still achieved.*'

4.07 On the basis of the above, the following criteria (with windows closed and trickle vents open) are considered appropriate for the proposed residential development:

- ≤ 35 dB $L_{Aeq\ (0700\text{-}2300)}$ in living rooms and bedrooms during the daytime
- ≤ 30 dB $L_{Aeq\ (2300\text{-}0700)}$ in bedrooms during the night time

4.08 These internal ambient noise levels represent good resting and sleeping conditions.

4.09 With respect to garden amenity, BS 8233 states:

For traditional external areas that are used for amenity space, such as gardens and patios, it is desirable that the external noise level does not exceed 50 dB $L_{Aeq,T}$, with an upper guideline value of 55 dB $L_{Aeq,T}$ which would be acceptable in noisier environments. However, it is also recognized that these guideline values are not achievable in all circumstances where development might be desirable. In higher noise areas, such as city centres or urban areas adjoining the strategic transport network, a compromise between elevated noise levels and other factors, such as the convenience of living in these locations or making efficient use of land resources to ensure development needs can be met, might be warranted. In such a situation, development should be designed to achieve the lowest practicable levels in these external amenity spaces, but should not be prohibited.'

BS 4142:2014 'Methods for Rating and Assessing Industrial and Commercial Sound'

4.10 The NPPF PPG requires that the character of the noise is taken into account. With cognisance to this, further useful contextual guidance is taken from British Standard BS 4142:2014 'Methods for Rating and Assessing Industrial and Commercial Sound' (BS 4142).

4.11 BS 4142 describes methods for determining, at the outside of a building, noise levels from factories or industrial premises and a method for assessing whether the noise is likely to give rise to adverse impacts, and states:

The significance of sound of an industrial and/or commercial nature depends upon both the margin by which the rating level of the specific sound source exceeds the background sound level and the context in which the sound occurs'.

4.12 The rating level is described as the specific sound level (the equivalent continuous A-weighted sound pressure level at the assessment (receptor) position produced by the specific sound source) plus any adjustment for the characteristic features of the sound. The character correction relates to whether and to what degree the specific sound is assessed to have an element of tonality, impulsivity and/or characteristics that are readily distinctive against the residual acoustic environment.

4.13 In terms of particular acoustic features, noise from the fabricators was noted to be subjectively impulsive and therefore a +6 dB penalty for impulsivity is considered appropriate.

4.14 It is considered that applying this correction to worst case noise levels measured at MP1 whilst assessing the development to BS 8233 criteria, represents a robust assessment methodology.

5.00 SOUND ATTENUATION SCHEME PROPOSALS

5.01 Based on external and internal noise measurements undertaken by ENS at other sites, it is considered that a standard double glazed window with standard trickle vents in a building façade will provide of the order of 27 dB(A) sound insulation (from external to internal) to road traffic noise.

5.02 It is therefore considered that standard double glazed windows and standard trickle vents are appropriate throughout the majority of the subject site, with the exception of habitable rooms overlooking the adjacent fabricators.

5.03 In order to calculate the sound insulation requirements of the building envelope for habitable rooms overlooking the adjacent fabricators, the Building Research Establishment (BRE) building envelope insulation calculation spreadsheet was used. This spreadsheet is based on the calculation methodology advocated in BS 8233. The spreadsheet allows input of external noise levels, room dimensions and reverberation time together with parameters for the various elements of the building envelope and calculates the internal noise level in terms of the external noise level metric (L_{Aeq} in this case).

5.04 Worst case ambient noise levels in the vicinity of the adjacent fabricators (MP1) were measured at up to **63 dB $L_{Aeq,T}$** during use of the concrete mixer / vibrating table. Adopting a +6 dB penalty for impulsivity, this equates to a design noise level of **69 dB $L_{Aeq,T}$** for habitable rooms fronting towards the fabricators.

5.05 In order to achieve good internal noise levels in habitable rooms fronting towards the fabricators, these rooms should be provided with enhanced glazing rated at least **40 dB $R_{w+}C_{tr}$**, such as 10 mm glass / 16mm argon / 9.1 mm Optiphon.

5.06 In order to compliment the glazing specification, habitable rooms overlooking the fabricators should be fitted with:

- Acoustic trickle vents rated at least **40 dB $D_{n,e,w}+C_{tr}$** (vent open) per 5000 mm² equivalent area, such as Invisivent EVO AK Ultra (0.7 metres per habitable room); or

- Acoustic wall vents rated at least **40 dB $D_{n,e,w}+C_{tr}$** (vent open) per 5000 mm² equivalent area, such as the Ryton AAC125HP (1 no. unit per habitable room).

5.07 Appendix 3 contains locations of enhanced glazing and ventilation, and Appendix 4 contains BRE Calculation Spreadsheets for the worst-case habitable room.

External Amenity (Gardens)

5.08 Worst-case daytime garden levels have been calculated up to **69 dB $L_{Aeq,\,T}$** (including +6 dB penalty for impulsivity) at the western boundary of the subject site (MP1). Daytime ambient noise levels throughout the remainder of the subject site were measured at ≤ 53 dB $L_{Aeq,\,T}$.

5.09 In order to screen the nearest gardens from operations at the adjacent fabricators, it is recommended that a solid timber fences are installed along the western boundary, returning along the southern boundary of the adjacent fabricators.

5.10 The height of the retaining wall and the finished floor levels (FFLs) of plots in the vicinity of the fabricators varies, and it is understood that the height of the solid timber fences should vary accordingly in order to minimise the visual impact, with cognisance to the requirements of BS 8233 / ProPG.

5.11 Screening attenuation to gardens in the vicinity of the fabricators has been calculated using the Maekawa barrier calculation with the above design noise level of **69 dB $L_{Aeq,T}$**. The octave data and the following barrier model inputs have been used to calculate the screening attenuation for garden amenity.

- Ground level at the adjacent fabricators is taken as a zero datum
- Source height (vibrating table/concrete mixer) is taken as 1 metre above datum
- Barrier height is the retaining wall height (varies) plus the height of the timber barrier (varies)
- Receiver height is taken as 1.2 metres (resident seated in garden) plus the FFL

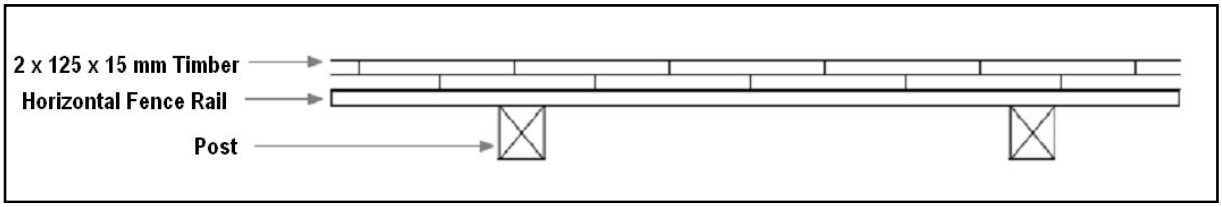
5.12 Table 5.1 below summarises the barrier attenuation calculations for gardens in the vicinity of the fabricators (see Appendix 3 for locations of barriers). Full Maekawa barrier calculation spreadsheets are contained in Appendix 5.

Table 5.1 – Maekawa Barrier Calculation Summary

Plot No.	Finished Floor Level	Receiver Height	Retaining Wall	Fence Height	Total Barrier	Barrier Attenuation	Daytime Garden Level
43	Datum + 2.15m	3.35m	0.60m	2.4m	3.0m	14 dB	55 dB
44-45	Datum + 1.75m	2.95m	1.20m	2.1m	3.3m	15 dB	54 dB
46	Datum + 1.55m	2.75m	1.50m	1.5m	3.0m	14 dB	55 dB
48	Datum + 0.35m	1.55m	1.35m	1.5m	2.85m	16 dB	53 dB
49	Datum + 0.35m	1.55m	0.45m	2.0m	2.45m	14 dB	55 dB
50-51	Datum - 0.10m	1.10m	0.45m	2.0m	2.45m	15 dB	54 dB

5.13 With the provision of the acoustic barrier, the resultant noise levels within gardens during use of the vibrating table are calculated at ≤ 55 dB L_{Aeq}. This satisfies the upper guideline value for external amenity areas, as recommended by BS8233 / ProPG.

5.14 The acoustic fence should be built in double-thickness (2 x 15 mm) solid timber construction as illustrated below. The fence should have no gaps or holes and should be fully sealed at the ground (i.e. include a gravel board).



6.00 CONCLUSIONS

6.01 A noise impact assessment has been undertaken for the proposed residential development at land at Kingsmark Way, Goldthorpe, Rotherham.

6.02 The ambient noise climate at the subject site is formed by local and distant road traffic, with localised contributions from the adjacent fabricators along the western boundary of the subject site during the daytime.

6.03 A scheme of sound insulation has been developed to protect residential amenity from the ambient noise climate. As a consequence, the ambient noise climate is not considered to represent a constraint to the proposed residential development.

I trust the foregoing is sufficient for your needs. Should you have any queries regarding the above, please do not hesitate to contact me.

Yours sincerely

Richard Whitaker
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Environmental Noise Solutions Limited

Appendix 1
Glossary of Acoustic Terms

Sound Pressure Level (L_p)

The basic unit of sound measurement is the sound pressure level. As the pressures to which the human ear responds can range from 20 µPa to 200 Pa, a linear measurement of sound levels would involve many orders of magnitude. Consequently, the pressures are converted to a logarithmic scale and expressed in decibels (dB) as follows:

$$L_p = 20 \log_{10}(p/p_0)$$

Where L_p = sound pressure level in dB; p = rms sound pressure in Pa; and p_0 = reference sound pressure (20 µPa).

A-weighting Network

A frequency filtering system in a sound level meter, which approximates under defined conditions the frequency response of the human ear. The A-weighted sound pressure level, expressed in dB(A), has been shown to correlate well with subjective response to noise.

Equivalent continuous A-weighted sound pressure level, $L_{Aeq, T}$

The value of the A-weighted sound pressure level in decibels of continuous steady sound that within a specified time interval, T, has the same mean-square sound pressure as a sound that varies with time. $L_{Aeq, 16h}$ (07:00 to 23:00 hours) and $L_{Aeq, 8h}$ (23:00 to 07:00 hours) are used to qualify daytime and night time noise levels.

$L_{A10, T}$

The A-weighted sound pressure level in decibels exceeded for 10% of the measurement period, T. $L_{A10, 18h}$ is the arithmetic mean of the 18 hourly values from 06:00 to 24:00 hours.

$L_{A90, T}$

The A-weighted sound pressure level of the residual noise in decibels exceeded 90% of a given time interval, T. L_{A90} is typically taken as representative of background noise.

$L_{AF\ max}$

The maximum A-weighted noise level recorded during the measurement period. The subscript 'F' denotes fast time weighting, slow time weighting 'S' is also used.

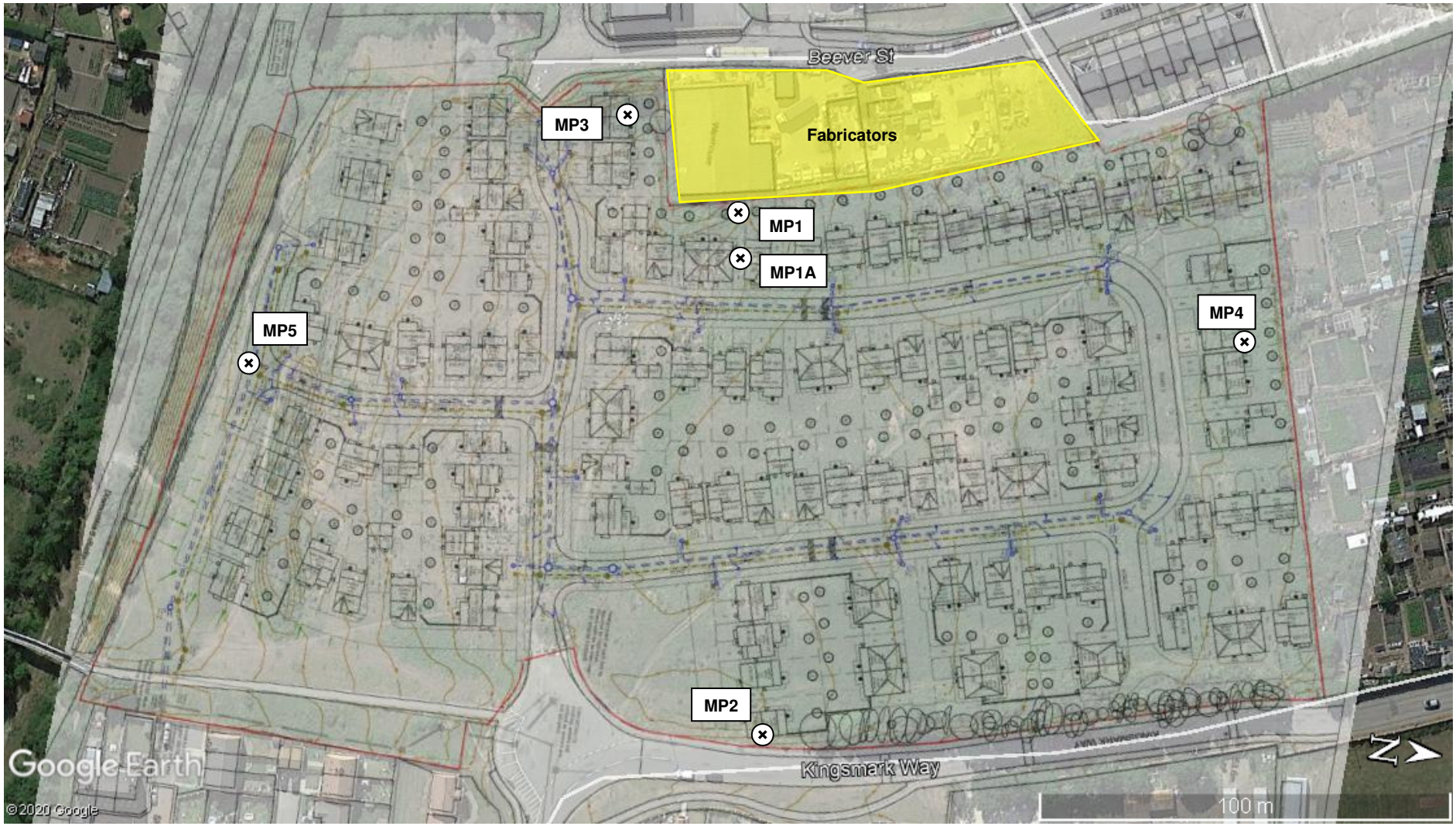
Sound Exposure Level (SEL or L_{AE})

The energy produced by a discrete noise event averaged over one second, no matter how long the event actually took. This allows for comparison between different noise events which occur over different lengths of time.

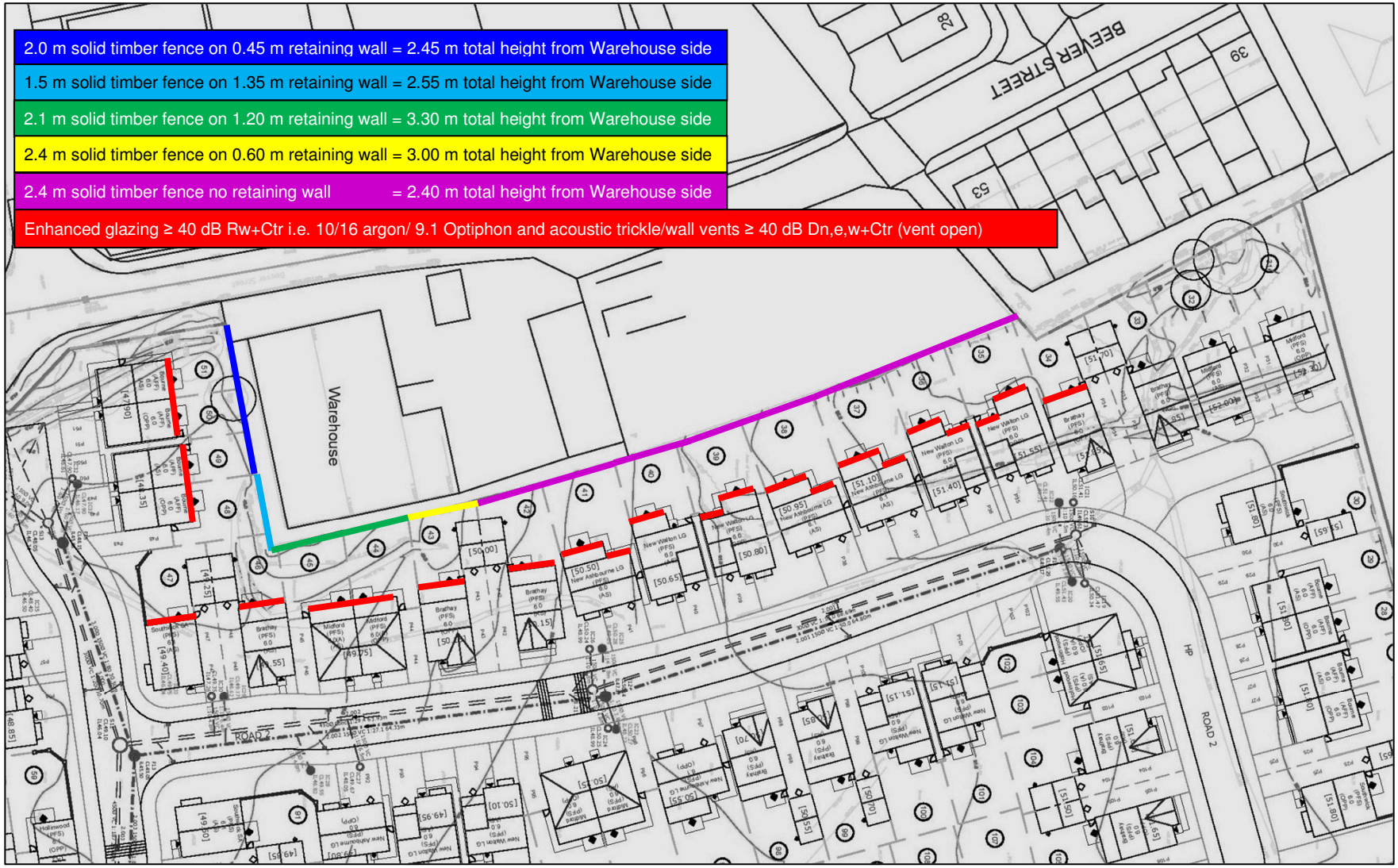
Weighted Sound Reduction Index (R_W)

Single number quantity which characterises the airborne sound insulation properties of a material or building element over a defined range of frequencies (R_W is used to characterise the insulation of a material or product that has been measured in a laboratory).

Appendix 2
Drawings (Annotated Site Location Plan / Approximate Noise Monitoring Positions)



Appendix 3
Drawings (Scheme of Sound Attenuation)



Appendix 4 – BRE Calculation Spreadsheet

Habitable Rooms fronting towards Fabricators – Daytime Ambient Noise Level (trickle vent)

BRE

Building Envelope Insulation

Switch to Reverberation Time Calculation

2) Select elements of facade structure, and enter corresponding internal surface area in m² OR enter number of vents.

HELP

		Surface area OR number of vents	
Wall 1	Brick/block cavity	7.8	m²
Wall 2	None		m²
Window 1	10 / 16 argon / 9.1 Optiphon	1.8	m²
Window 2	None		m²
Door	None		m²
Roof/Ceiling	None		m²
Vent 1	Invisivent®EVO AK Ultra	0.7	
Vent 2	None		

View/Edit Data

Number of vents must be a positive integer

1) Enter room dimensions or volume

Use dimensions

x m

y m

z m

Volume - m³

OR

Use volume 29 m³

3) Enter reverberation time of the room. 0.5 seconds

4) Select exterior sound level type

Option (A) User defined spectrum

69 dB LAeq (MP1)

View/Edit Data

Option (B) Spectrum shape

Select spectrum shape and enter free field exterior sound level, L_{Aeq} (considering only the octave bands between 125Hz and 2kHz)

L_{Aeq} 69 dB

ISO 717 - 1 (Ctr)

View Data

Internal sound level L_{Aeq} 33.7 dB

Habitable Rooms fronting towards Fabricators – Daytime Ambient Noise Level (wall vent)

BRE

Building Envelope Insulation

Switch to Reverberation Time Calculation

2) Select elements of facade structure, and enter corresponding internal surface area in m² OR enter number of vents.

HELP

		Surface area OR number of vents	
Wall 1	Brick/block cavity	7.8	m²
Wall 2	None		m²
Window 1	10 / 16 argon / 9.1 Optiphon	1.8	m²
Window 2	None		m²
Door	None		m²
Roof/Ceiling	None		m²
Vent 1	Ryton AAC125HPCWL	1	
Vent 2	None		

View/Edit Data

1) Enter room dimensions or volume

Use dimensions

x m

y m

z m

Volume - m³

OR

Use volume 29 m³

3) Enter reverberation time of the room. 0.5 seconds

4) Select exterior sound level type

Option (A) User defined spectrum

69 dB LAeq (MP1)

View/Edit Data

Option (B) Spectrum shape

Select spectrum shape and enter free field exterior sound level, L_{Aeq} (considering only the octave bands between 125Hz and 2kHz)

L_{Aeq} 69 dB

ISO 717 - 1 (Ctr)

View Data

Internal sound level L_{Aeq} 34.3 dB

Appendix 5 – Maekawa Barrier Calculation Spreadsheets

Plot 43

Calculation of Approximate Attenuation of a Thin Rigid Barrier												
Octave band centre frequencies (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**LAeq**		
Source octave analysis (dB)	78.0	69.9	70.6	71.3	64.9	65.5	59.8	52.4	45.6	-		
A-weighting (dB)	-39.4	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1			
Unscreened level at receptor (dB LAeq)	38.6	43.7	54.5	62.7	61.7	65.5	61.0	53.4	44.5	**69.4**		
Wavelength (m)	10.8	5.4	2.7	1.4	0.7	0.3	0.2	0.1	0.0			
Path difference (m)	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38			
Fresnel No. (40.δ/λ)	1.42	2.85	5.65	11.31	22.61	45.23	90.45	180.90	361.80			
Attenuation (dB) (Maekawa*)	6.5	7.7	9.4	11.6	14.1	16.8	19.7	22.6	25.6			
Screened level at receptor position (dB LAeq)	32.1	36.0	45.1	51.1	47.6	48.7	41.3	30.8	18.9	**55.0**	**14.4**	**Barrier Attenuation**

Plot 44 to 45

Calculation of Approximate Attenuation of a Thin Rigid Barrier												
Octave band centre frequencies (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**LAeq**		
Source octave analysis (dB)	78.0	69.9	70.6	71.3	64.9	65.5	59.8	52.4	45.6	-		
A-weighting (dB)	-39.4	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1			
Unscreened level at receptor (dB LAeq)	38.6	43.7	54.5	62.7	61.7	65.5	61.0	53.4	44.5	**69.4**		
Wavelength (m)	10.8	5.4	2.7	1.4	0.7	0.3	0.2	0.1	0.0			
Path difference (m)	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46			
Fresnel No. (40.δ/λ)	1.72	3.44	6.83	13.66	27.32	54.63	109.26	218.52	437.04			
Attenuation (dB) (Maekawa*)	6.7	8.1	9.9	12.2	14.8	17.6	20.5	23.5	26.4			
Screened level at receptor position (dB LAeq)	31.9	35.6	44.6	50.5	46.9	47.9	40.5	29.9	18.1	**54.3**	**15.1**	**Barrier Attenuation**

Plot 46

Calculation of Approximate Attenuation of a Thin Rigid Barrier												
Octave band centre frequencies (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**LAeq**		
Source octave analysis (dB)	78.0	69.9	70.6	71.3	64.9	65.5	59.8	52.4	45.6	-		
A-weighting (dB)	-39.4	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1			
Unscreened level at receptor (dB LAeq)	38.6	43.7	54.5	62.7	61.7	65.5	61.0	53.4	44.5	**69.4**		
Wavelength (m)	10.8	5.4	2.7	1.4	0.7	0.3	0.2	0.1	0.0			
Path difference (m)	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35			
Fresnel No. (40.δ/λ)	1.29	2.59	5.13	10.27	20.54	41.07	82.14	164.29	328.57			
Attenuation (dB) (Maekawa*)	6.3	7.5	9.1	11.2	13.7	16.4	19.3	22.2	25.2			
Screened level at receptor position (dB LAeq)	32.3	36.2	45.4	51.5	48.0	49.1	41.7	31.2	19.3	**55.3**	**14.1**	**Barrier Attenuation**

Plot 48

Calculation of Approximate Attenuation of a Thin Rigid Barrier												
Octave band centre frequencies (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**LAeq**		
Source octave analysis (dB)	78.0	69.9	70.6	71.3	64.9	65.5	59.8	52.4	45.6	-		
A-weighting (dB)	-39.4	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1			
Unscreened level at receptor (dB LAeq)	38.6	43.7	54.5	62.7	61.7	65.5	61.0	53.4	44.5	**69.4**		
Wavelength (m)	10.8	5.4	2.7	1.4	0.7	0.3	0.2	0.1	0.0			
Path difference (m)	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61			
Fresnel No. (40.δ/λ)	2.24	4.49	8.90	17.80	35.61	71.22	142.44	284.88	569.75			
Attenuation (dB) (Maekawa*)	7.2	8.7	10.8	13.2	15.9	18.7	21.6	24.6	27.6			
Screened level at receptor position (dB LAeq)	31.4	35.0	43.7	49.5	45.8	46.8	39.4	28.8	16.9	**53.3**	**16.1**	**Barrier Attenuation**

Appendix 5 – Maekawa Barrier Calculation Spreadsheets

Plot 49

Calculation of Approximate Attenuation of a Thin Rigid Barrier												
Octave band centre frequencies (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**LAeq**		
Source octave analysis (dB)	78.0	69.9	70.6	71.3	64.9	65.5	59.8	52.4	45.6	-		
A-weighting (dB)	-39.4	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1			
Unscreened level at receptor (dB LAeq)	38.6	43.7	54.5	62.7	61.7	65.5	61.0	53.4	44.5	**69.4**		
Wavelength (m)	10.8	5.4	2.7	1.4	0.7	0.3	0.2	0.1	0.0			
Path difference (m)	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36			
Fresnel No. (40.δ/λ)	1.35	2.70	5.36	10.72	21.43	42.86	85.73	171.45	342.90			
Attenuation (dB) (Maekawa*)	6.4	7.6	9.2	11.4	13.9	16.6	19.5	22.4	25.4			
Screened level at receptor position (dB LAeq)	32.2	36.1	45.3	51.3	47.8	48.9	41.5	31.0	19.1	**55.2**	**14.2**	**Barrier Attenuation**

Plot 50 to 51

Calculation of Approximate Attenuation of a Thin Rigid Barrier												
Octave band centre frequencies (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**LAeq**		
Source octave analysis (dB)	78.0	69.9	70.6	71.3	64.9	65.5	59.8	52.4	45.6	-		
A-weighting (dB)	-39.4	-26.2	-16.1	-8.6	-3.2	0.0	1.2	1.0	-1.1			
Unscreened level at receptor (dB LAeq)	38.6	43.7	54.5	62.7	61.7	65.5	61.0	53.4	44.5	**69.4**		
Wavelength (m)	10.8	5.4	2.7	1.4	0.7	0.3	0.2	0.1	0.0			
Path difference (m)	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43			
Fresnel No. (40.δ/λ)	1.60	3.20	6.36	12.72	25.43	50.86	101.72	203.44	406.88			
Attenuation (dB) (Maekawa*)	6.6	7.9	9.7	12.0	14.5	17.3	20.2	23.1	26.1			
Screened level at receptor position (dB LAeq)	32.0	35.8	44.8	50.7	47.2	48.2	40.8	30.3	18.4	**54.5**	**14.9**	**Barrier Attenuation**