

Report VA3049.191209.NIA

The Burrows, West Street, Bedhampton

Noise and Vibration Assessment

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1. Introduction

It is proposed to develop the land at The Burrows, West Street, Bedhampton for residential use.

Venta Acoustics has been commissioned by PDP Architecture to undertake an assessment of the current environmental noise impact on the site in support of an application for planning permission.

An environmental noise survey has been undertaken to determine the noise and vibration levels incident on the site. These levels are then used to undertake an assessment of the likely impact in accordance with the National Planning Policy Framework with reference to relevant standards, guidance and the planning requirements of Havant Borough Council. Vibration will be assessed in accordance with BS 6472: Part 1: 2008 *Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting*.

Outline mitigation measures are considered and an appraisal of the requirements of external building fabric elements are provided where appropriate.

2. Guidance and Legislation

2.1 The National Planning Policy Framework (2019)

The revised *National Planning Policy Framework* (NPPF), adopted in 2019, sets out the Government's planning policies for England, superseding all previous planning policy statements and guidance.

In respect of noise, the NPPF states that the planning system should contribute to and enhance the natural and local environment by preventing both new and existing developments from contributing to or being put at unacceptable risk from, or being adversely affected by unacceptable levels of noise pollution.

Hence, Paragraph 180 states that *planning policies and decisions should also ensure 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*

In regards to the term adverse impact, reference is made to the Noise Policy for England:

2.2 Noise Policy Statement for England (2010)

The Noise Policy Statement for England (NPSE) sets out the long term vision of Government noise policy: to promote good health and a good quality of life through the effective management of noise within the context of Government policy on sustainable development.

This vision is supported by the following aims:

- *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.*

The terms “significant adverse” and “adverse” are related to the following concepts:

- No Observed Effect Level (NOEL) - the level below which no effect on health and quality of life can be detected.
- Lowest Observed Adverse Effect Level (LOAEL) - the level above which adverse effects on health and quality of life can be detected.
- Significant Observed Adverse Effect Level (SOAEL) - the level above which significant adverse effects on health and quality of life occur.

The guidance acknowledges that it is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise in all situations, but will be different for different noise sources, receptors and times.

In order to enable assessment of impacts in line with these requirements, reference should be made to other currently available guidance.

2.3 WHO Guidelines for Community Noise (1999)

The guidance in this document details suitable noise levels for various activities within residential and commercial buildings.

The relevant sections of this document are shown in Table 2.2.

Criterion	Environment	Design range $L_{Aeq,T}$ dB
Maintain speech intelligibility and avoid moderate annoyance, daytime and evening	Living Room	35 dB
Prevent sleep disturbance, night time	Bedrooms	30 dB

Table 2.1 – Excerpt from WHO

[dB ref. 20µPa]

This guidance also states:

For a good sleep, it is believed that indoor sound pressure levels should not exceed approximately 45dB L_{Amax} more than 10-15 times a night (Vallet & Vernet 1991).

For outdoor living areas, it is stated that:

To protect the majority of people from being seriously annoyed during the daytime, the outdoor sound level from steady, continuous noise should not exceed 55dB LAeq on balconies, terraces and in outdoor living areas. To protect the majority of people from being moderately annoyed during the daytime, the outdoor sound level should not exceed 50dB LAeq. Where it is practical and feasible, the lower outdoor sound level should be considered the maximum desirable sound level for new development.

For sleep disturbance, i.e. in bedrooms at night, the NOEL can, therefore, be taken as anything below 30dB(A), whilst the onset of the LOAEL occurs at 30dB(A) and above. The SOAEL cannot be inferred from this information.

During daytime periods, for avoidance of annoyance, the NOEL relates to anything up to 50dB(A) (typically applied to external areas, such as gardens), whilst the onset of the LOAEL occurs at 50dB(A) and above.

2.4 BS8233:2014

BS8233 *Guidance on sound insulation and noise reduction for buildings* provides guidance as to desirable internal ambient noise levels for different areas within residential buildings.

The relevant section of the standard is shown below in Table 2.2.

Activity	Location	07:00 to 23:00	23:00 to 07:00
Resting	Living Room	35 dB LAeq, 16 hour	-
Dining	Dining Room	40 dB LAeq, 16 hour	-
Sleeping (daytime resting)	Bedroom	35 dB LAeq, 16 hour	30 dB LAeq, 8 hour

Table 2.2 – Excerpt from BS8233:2014 - Indoor ambient noise levels for dwellings

[dB ref. 20μPa]

For external areas the standard states the following:

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 LAeq,T, with an upper guideline value of 55 dB LAeq,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.

2.5 BS6472-1:2008

BS6472 specifies building vibration with respect to human response to be measured and assessed in the form of a vibration dose value (VDV). The VDV defines a relationship that yields a consistent assessment of continuous, intermittent, occasional and impulsive vibration and correlates well with subjective response. The vibration is to be evaluated for the axis in which the magnitude of weighted acceleration is greatest, against the values in Table 2.3.

Place and Time	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
16h day (07:00 – 23:00)	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
8h night (23:00 – 07:00)	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

Table 2.3 – VDV ranges with regard to risk of probable comment

[values ref. $\text{m/s}^{-1.75}$]

2.6 BS4142:2014

British Standard BS4142:2014 *Methods for rating and assessing industrial and commercial sound* describes a method for rating and assessing sound of an industrial and/or commercial nature, which includes sound from fixed installations comprising mechanical and/or electrical plant and equipment;

The assessment methodology considers the Specific Sound Level, as measured or calculated at a potential noise sensitive receptor, due to the source under investigation. A correction factor is added to this level to account for the acoustic character of the sound as follows:

Tonality – A correction of up to 6dB depending on the prominence of tones;

Impulsivity - A correction of up to 9dB depending on the prominence of impulsivity;

Other sound characteristics - A 3dB correction may be applied where a distinctive acoustic character is present that is neither tonal nor impulsive;

Intermittency - A 3dB correction may be applied where the specific sound has identifiable on/off conditions.

An estimate of the impact of the source is obtained by subtracting the typical background noise level from the corrected Specific Sound Level.

- Typically, the greater this difference, the greater the magnitude of the impact.
- A difference of around +10 dB or more is likely to be an indication of a significant adverse impact, depending on the context.
- A difference of around +5 dB could be an indication of an adverse impact, depending on the context.
- The lower the rating level is relative to the measured background sound level, the less likely it is that there will be an adverse impact. Where the rating level does not exceed the

background sound level, this is an indication of the specific sound having a low impact, depending on the context.

3. Site Description

As illustrated on attached site plan VA3049/SP1, the site is a currently undeveloped parcel of land between Hermitage Stream, a railway line and established residential dwellings.

To the north is a railway line with existing housing beyond. Further terraced housing is located immediately to the east and south of the site. To the west is an area of hardstand, currently used from car sales and the stream, beyond which is a car dealership and service workshop. The access to the service workshop is from the east of the building and well screened from the site.

The site is accessed from the south via West Street.

Bedhampton Station is located some 200m to the west with a level crossing on West Street, with associated claxon, in front of the station.

The dominant noise sources expected to affect the site are trains on the railway line.

4. Environmental Noise Survey

4.1 Survey Procedure & Equipment

In order to establish the existing background noise levels at the site, a noise survey was carried out between Wednesday 4th and Friday 6th December 2019 at the locations shown in site plan VA3049/SP1. These locations were chosen to be representative of the noise levels across the site.

Continuous 5-minute samples of the L_{Aeq} , L_{Amax} , L_{A10} and L_{A90} sound pressure levels were undertaken at each of the measurement locations.

The weather during the survey period was generally dry with light winds. The background noise data is not considered to have been compromised by these conditions.

Measurements were made generally in accordance with ISO 1996 2:2017 *Acoustics - Description, measurement and assessment of environmental noise – Part 2: Determination of sound pressure levels*.

The following equipment was used in the course of the survey:

Manufacturer	Model Type	Serial No	Calibration	
			Certificate No.	Date
NTi Class 1 Integrating SLM	XL2	A2A-11586-E0	UCRT18/1582	7/6/18
Svantek Class 1 Integrating SLM	958A	59177	Sound: UCRT19/1108 Vibration: TCRT19/1061	23/1/19 21/1/19
Larson Davis calibrator	CAL200	13049	UCRT19/1501	18/4/19

Table 4.1 – Equipment used for the survey

The calibration of the sound level meters was verified before and after use with no significant calibration drift observed.

4.2 Results

The measured sound levels are shown as time-history plots on the attached charts VA3049/TH1-3 for position 1 and VA3049/TH4-6 for position 2.

The site is primarily affected by rails on railway with a lessor influence from the local roads.

The average noise levels for the Daytime and Night-time periods, as measured at the automated monitoring position were:

Monitoring Period	Typical $L_{Aeq,T}$	
	Position 1	Position 2
07:00 – 23:00 hours	59 dB	57 dB
23:00 – 07:00 hours	54 dB	53 dB

Table 4.2 – Typical ambient noise levels at measurement locations [dB ref. 20µPa]

The typical night time L_{Amax} events, generated by train pass-by events, were recorded to be in the order of 74dB $L_{Amax,fast}$ at location 1.

The background noise level measured during the day was L_{A90} 46dB.

Measurements were made of the level crossing claxon as follows:

Measurements	Level
Claxon Measured at 45m	62dB – Tone at 2.5kHz.

Table 4.3 – Measurement of level crossing claxon

This corresponds to a level of around L_{Aeq} 45dB at the application site when allowances for distance and screening are made. This is below the ambient noise level at the site and no tonal elements are observed in the monitoring data. Observations on site indicated that while the claxon was faintly audible, it was not considered to be loud or intrusive.

5. Vibration Survey

An automated vibration monitor was installed at the position shown on the attached Site Plan VA3049/SP1 to record vibration levels due to train movements.

The transducer was set to record vibration levels as acceleration in three perpendicular axes, from which Vibration Dose Values were determined for day and night-time periods following the procedures described in BS 6472: Part 1: 2008 *Guide to evaluation of human exposure to vibration in buildings: Vibration sources other than blasting*.

The measurement location was at the nearest position available (with a structure with good adhesion with the surrounding geology) to the nearest proposed residential façade to the railway line. On this basis, worst case results, with regard to levels across the site, would be obtained. All measurements were made generally in accordance with BS6472 and ANC guidelines for vibration measurement.

Vibration levels were monitored at site over consecutive 5-minute periods in three axes Wednesday 4th and Friday 6th December 2019.

5.1 Results

Axis	Period	VDV	Probability of Comment
X	16h day (07:00 – 23:00)	0.008	Less than a low probability of adverse comment
Y		0.014	Less than a low probability of adverse comment
Z		0.045	Less than a low probability of adverse comment
X	8h night (23:00 – 07:00)	0.005	Less than a low probability of adverse comment
Y		0.005	Less than a low probability of adverse comment
Z		0.005	Less than a low probability of adverse comment

Table 5.1 – VDV ranges with regard to risk of probable comment [values ref. $m/s^{-1.75}$]

The vibration levels measured on site are substantially lower than levels with a low probability of adverse comment. BS6472-1:2008 states that ‘below these ranges adverse comment is not expected’ and hence, conditions on site are within acceptable limits.

6. Commercial Noise Assessment

Noise from the Suzuki dealership is assessed following the BS4142:2014 methodology. The workshop is located within the warehouse building with access via a roller shutter door on the west façade, facing away from the application site.

6.1 Noise Data

Noise from the dealership was not noted on site and so measurements could not be obtained.

Library data measured at other, similar sites have been included in the assessment, including the use of tools and car horns, which are tested as part of the MOT process.

All noise data are summarised in Table 6.1.

Noise Source	Measurement Distance	Measured L_{Aeq}	Notes
Pressure washer	2m	76 dB	Measurement taken with spray against metal panel for worst case. Pressure washer is using low noise nozzle and motor.
Vacuum	3m	63dB	Vacuum and nozzle outside car, quieter when working inside the car
Wheel Gun	40m	58dB	All works take place inside building, Library data
Car horn	40m	60dB	
Angle Grinder	10m	80dB	

Table 6.1 –Library data noise sources used for assessment

6.2 Sound Propagation

The entrance to the dealership is approximately 50m from the site.

A distance loss of $20\log(r/r_0)$ and a screening loss of 10dB are applied to the source noise levels. The following levels are predicted at the dwellings:

Sound Source	Sound Level, L_{Aeq} at the dwellings
Pressure washer	38 dB(A)
Vacuum	29 dB(A)
Wheel Gun	46 dB(A)
Car horn	48 dB(A)
Angle Grinder	56 dB(A)

Table 6.2 – Sound levels expected at the dwellings

6.3 Acoustic Character Correction

The penalties for the different noise sources at the receiver are shown below in Table 6.3.

Noise Source	Subjective Description	Allocated Corrections
Pressure Washer	Intermittent operation and slow start, although some impulsivity of noise from water hitting body panels. Non-tonal noise	Tonality: 0dB Impulsivity: +3dB Intermittency: +3dB
Vacuum	Intermittent operation with slightly impulsive startup, slight whine to motor, although not audible at receiver	Tonality: 0dB Impulsivity: +3dB Intermittency: +3dB
Wheel Gun	Clearly perceived impulsive character with intermittent characteristics. High pitched but not tonal at the dwellings.	Tonality: +3dB Impulsivity: +3dB Intermittency: +3dB
Car Horn	Clearly perceived tonal, impulsive and intermittent characteristics when checked as part of MOT test.	Tonality: +3dB Impulsivity: +3dB Intermittency: +3dB
Angle Grinder	Expected to be slightly perceptible above background and intermittent and impulsive in use.	Tonality: 0dB Impulsivity: +3dB Intermittency: +3dB

Table 6.3 – Acoustic character corrections

These penalties are applied to the specific noise level in section 6.4 to obtain the rating noise level.

6.4 Rating Noise Level and Assessment

The rating noise levels at the assessment locations are compared against the relevant background noise levels to assess the notional significance of the noise impact as follows. Operations are adjusted to the appropriate on times.

Character penalties have been applied to the noise sources.

Table 6.4 show the assessments on the most affected façade of the residential development. A screening loss has been allowed for the building structure.

Noise Source	Specific Sound Level	On time per hour (Correction)	Character penalties			Rating Level	Difference from Background (46dB)
			Tonality	Impulsivity	Intermittency		
Pressure Washer	38 dB	40 mins (-2)	0	3	3	42 dB	-4 dB
Vacuum	29 dB	40 mins (-2)	0	3	3	33 dB	-13 dB
Wheel Gun	46 dB	0.5 mins (-21)	3	3	3	34 dB	-12 dB
Car Horn	48 dB	0.5 mins (-21)	3	3	3	36 dB	-10 dB
Angle Grinder	56 dB	1 min (-18)	0	3	3	44 dB	-2 dB

Table 6.4 Specific and Rating Sound Levels for Workshop

The BS4142 rating of workshop noise would be a strong indication of low noise impact on the proposed dwellings.

6.5 Context

The site is located in an established residential area with housing immediately adjacent. Several houses are in closer proximity to the surrounding commercial noise sources than the proposed new dwellings.

The noise from the commercial uses are well below the local ambient noise levels and background noise levels and are not expected to represent a disturbance to occupants of the proposed dwellings.

The development would therefore be compatible with the “agent of change” principle as the existing commercial uses would not be unduly affected.

7. External Building Fabric and Internal Noise Levels

The external noise levels measured would require that windows remain closed to achieve appropriate internal noise levels.

Trains operate between 05:00 hours and midnight.

The required specification for the external building fabric elements have been specified against the measured and predicated external levels and appropriate internal levels.

7.1.1 Sound Reduction Performances of Building Elements

It has been assumed that all the non-glazed elements, i.e. walls and roof systems, will be capable of providing the following minimum sound insulation performance, when tested in accordance with BS EN ISO 10140-2:2010 *Acoustics - Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation*.

Building Element	Single figure weighted sound reduction index, dB
Masonry	R _w 51

Table 7.1 – Assumed sound reductions performances of non-glazed elements

7.1.2 Sound Reduction Performance of Windowsets and Vents

The monitoring data along with the architectural drawings have been used to calculate the required sound insulation performance for the windowsets (glazing and frame combination) and open ventilators for the building. These are summarised in Table 7.2 below.

Glazing Location	Required Glazing SRI, dB	Ventilator Performance, dB
North, East, West Facade	R _w 25dB	D _{n,e,w} 31
South Facade	R _w 24dB	D _{n,e,w} 31

Table 7.2 – Required minimum sound reduction indices for glazing and ventilators

BS8233 indicates that standard thermal double glazing would provide a sound reduction index of R_w 27dB. Standard glazing and trickle ventilation systems are expected to achieve the above requirements.

7.2 Ventilation

In order that windows may remain closed to maintain the internal noise levels, it is expected that attenuated means of background ventilation will be required. The system should have full consideration for the requirements of summer overheating and rapid ventilation as outlined in Part F of the building regulations without reliance on open windows, which should be assessed by a suitably qualified thermal engineer.

If trickle vents are used the performance shown in Table 7.2 will be required. The figures stated are for a single vent per room. If multiple vents are required, then the performance requirement shown in Table 7.2 will increase by a value equal to $+10\log(N)$, with N being the total number of vents serving the room.

It should be noted that there is no reason why windows could not be opened as a matter of personal preference or for purge ventilation.

The ventilator performances provided would need to be achieved with the vents open. Should this performance not be achievable, a mechanical ventilation solution may be required.

7.3 Internal Noise Assessment

With the above recommendations implemented, the noise levels within the proposed dwellings would be expected to be in line with recommendations given in the WHO 1999 and BS8233:2014 guidance. Internal noise levels can therefore be considered to be between the NOEL the LOAEL levels.

7.4 Areas of External Amenity

External noise levels on the north side of the site are currently marginally above the World Health Organisation guideline value for external amenity of $L_{Aeq,16hour}$ 55dB.

It is recommended that a 2m high imperforate timber fence with be constructed along the north boundary of the site. This would provide a degree of acoustic screening from the railway line and would be expected to bring noise levels in the external amenity areas to below $L_{Aeq,16hour}$ 55dB.

The outdoor noise levels across the site can therefore be considered to fall between the LOAEL and SOAEL levels, generally being below the level that is expected to cause significant annoyance.

8. Conclusion

A baseline noise survey has been undertaken by Venta Acoustics to establish the prevailing noise climate in the locality of The Burrows, West Street, Bedhampton in support of a planning application for the proposed development of new residential dwellings.

The measured levels have been assessed against the National Planning Policy Framework and currently available standards and guidance documents including World Health Organisation *Guidelines for Community Noise* (1999), BS4142: 2014 *Methods for rating and assessing industrial and commercial sound* and BS8233:2014 *Guidance on sound Insulation and noise*.

Commercial noise is not considered to be significant at this site.

Appropriate external and internal noise criteria have been considered to minimise adverse impacts on health and quality of life as a result of the new development. Appropriate mitigation measures have been outlined which should be developed during detailed design, including thermal double-glazing and trickle vents and a timber fence along the north boundary.

The proposed scheme is not expected to experience an adverse noise impact and the site is considered acceptable for the proposed residential use.

Steven Liddell MIOA

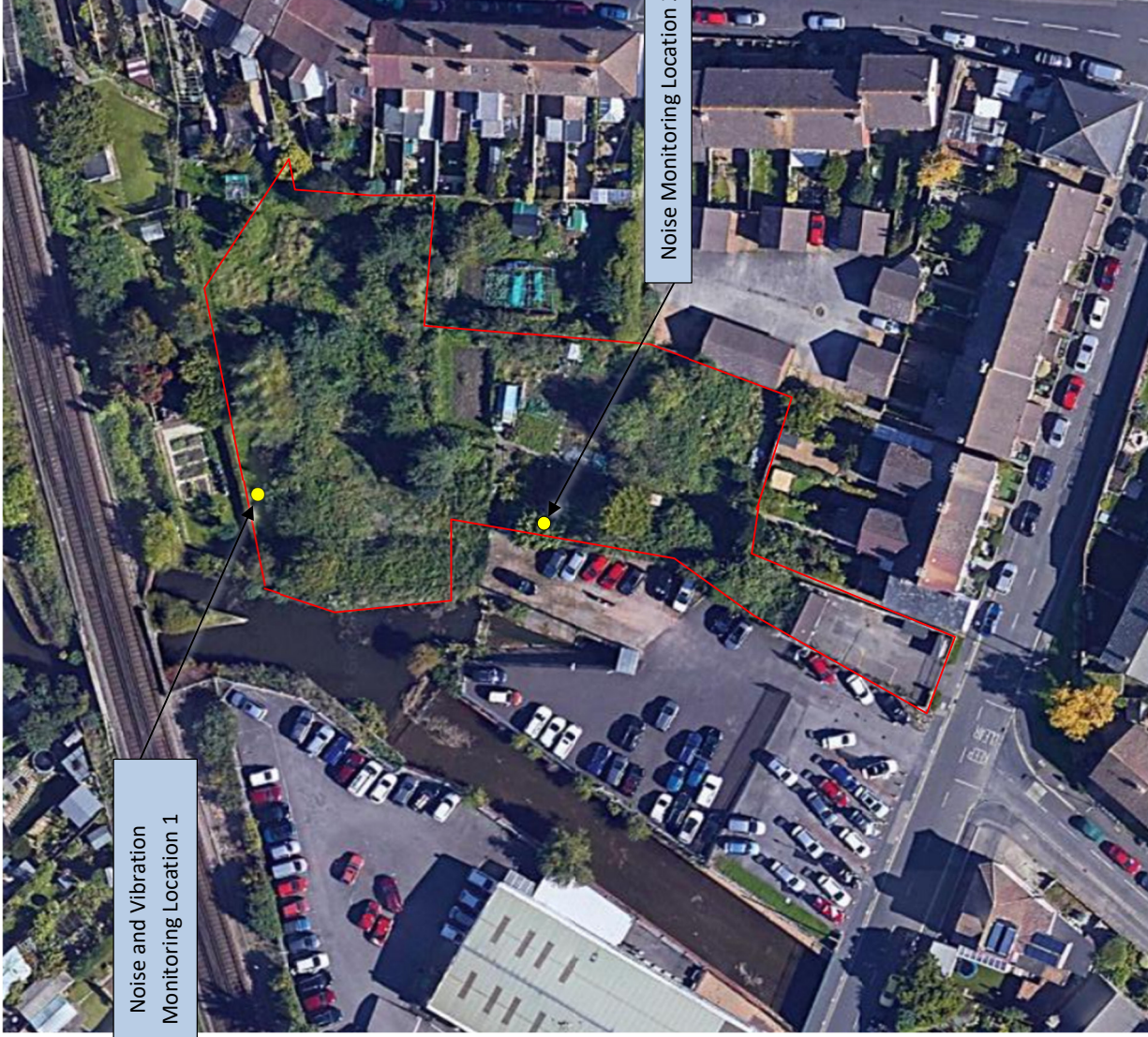
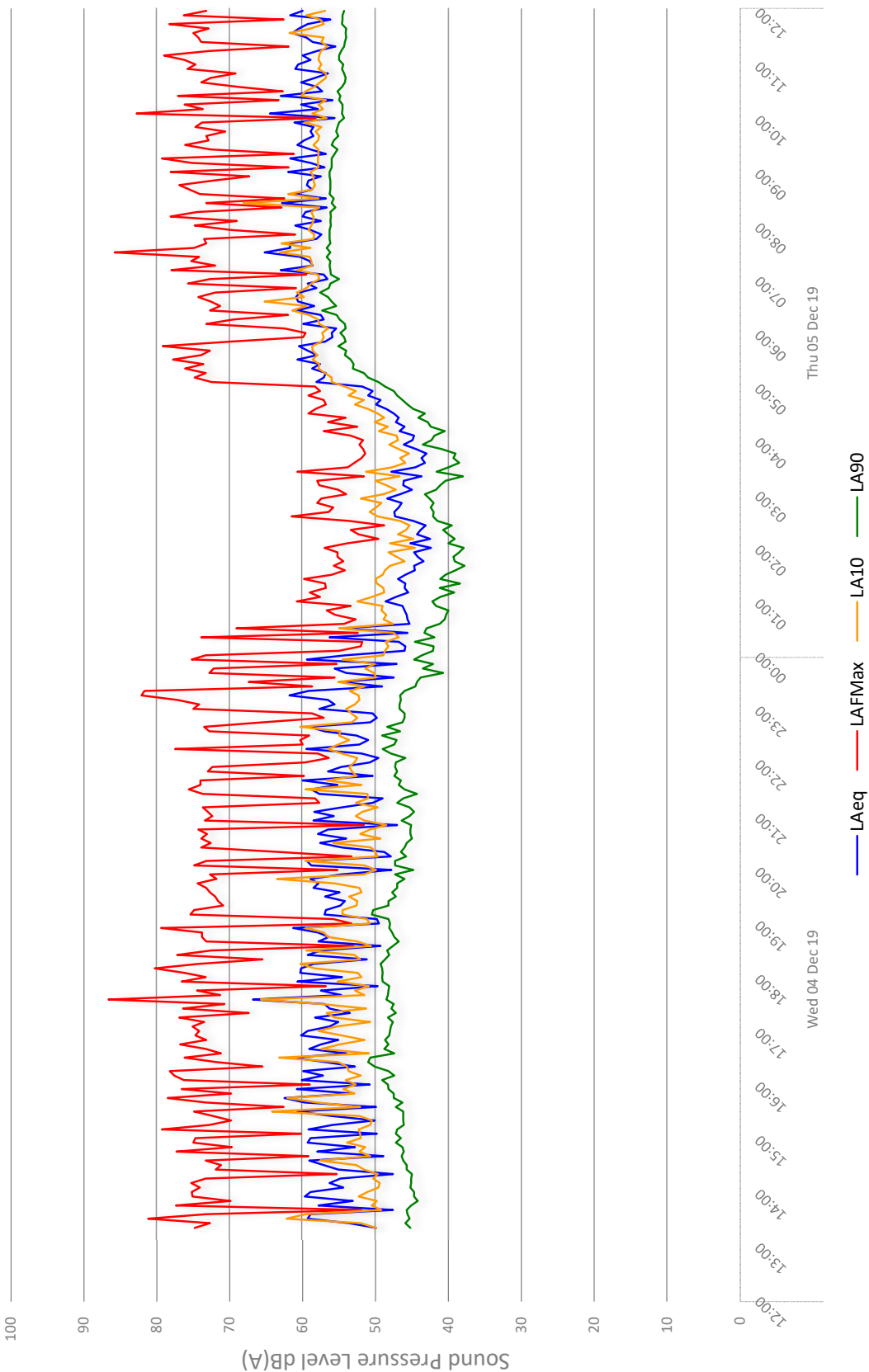


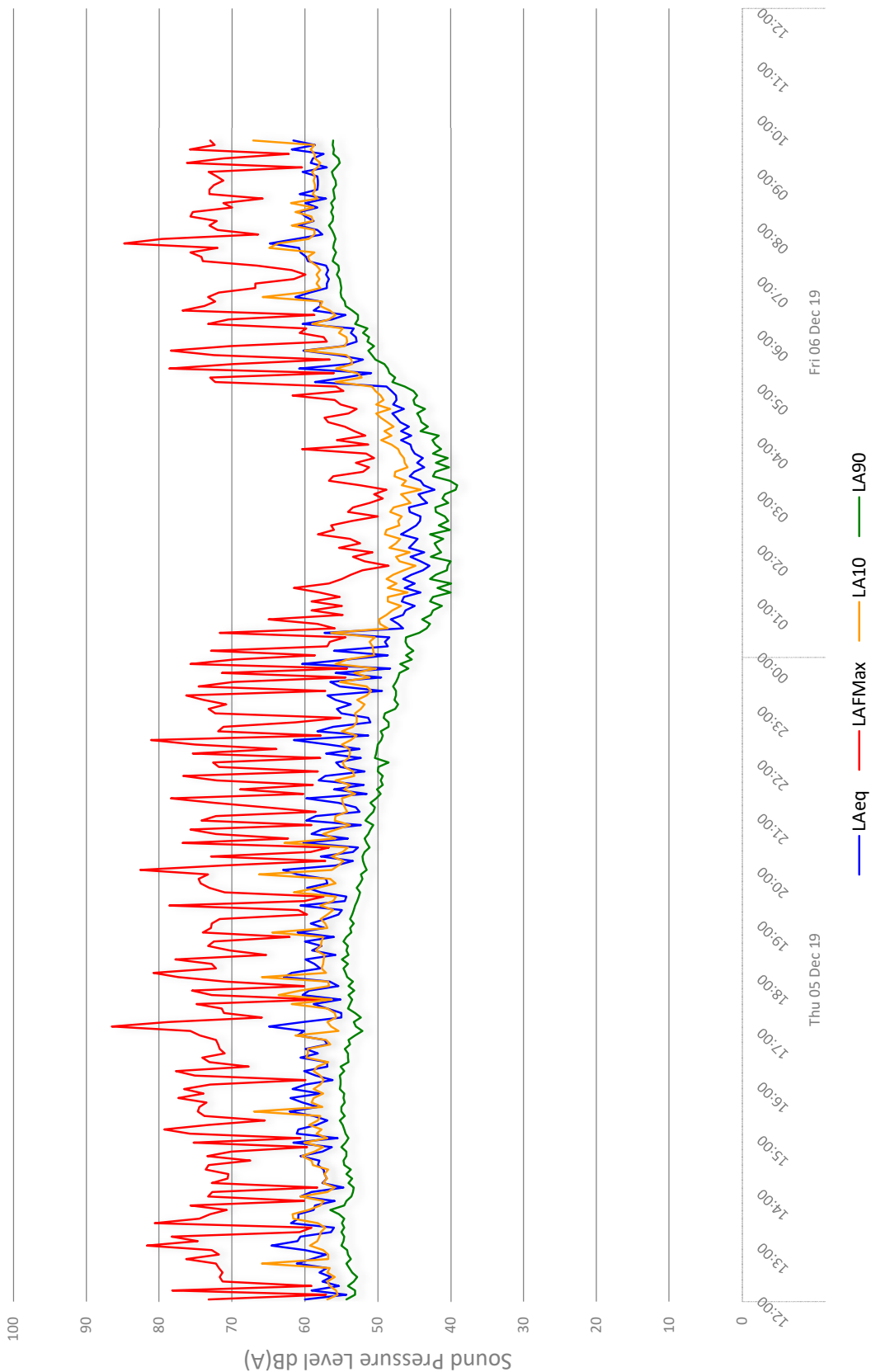
Figure VA3049/TH1

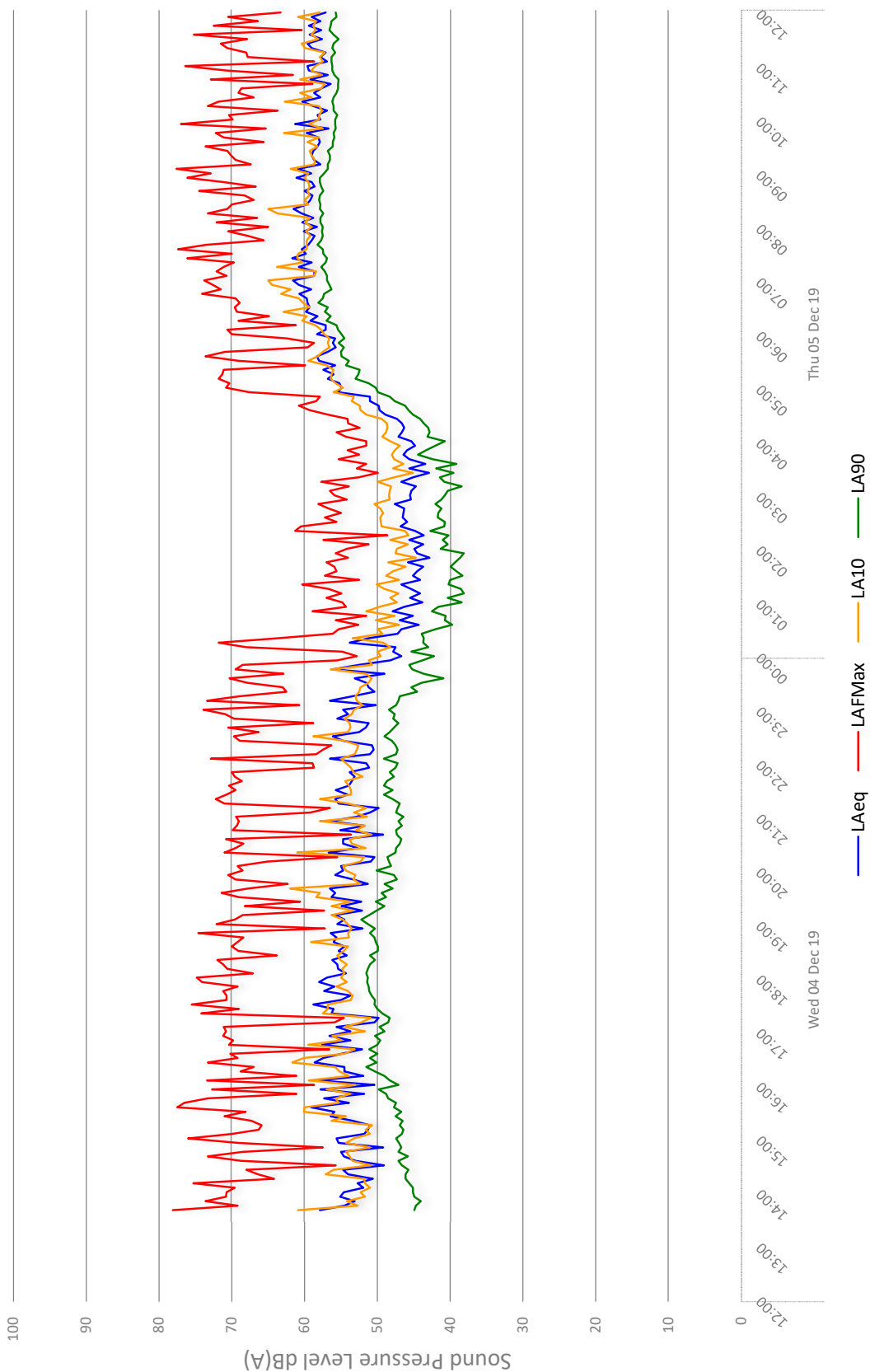


The Burrows, West Street, Bedhampton
Environmental Noise Time History: 2



Figure VA3049/TH2

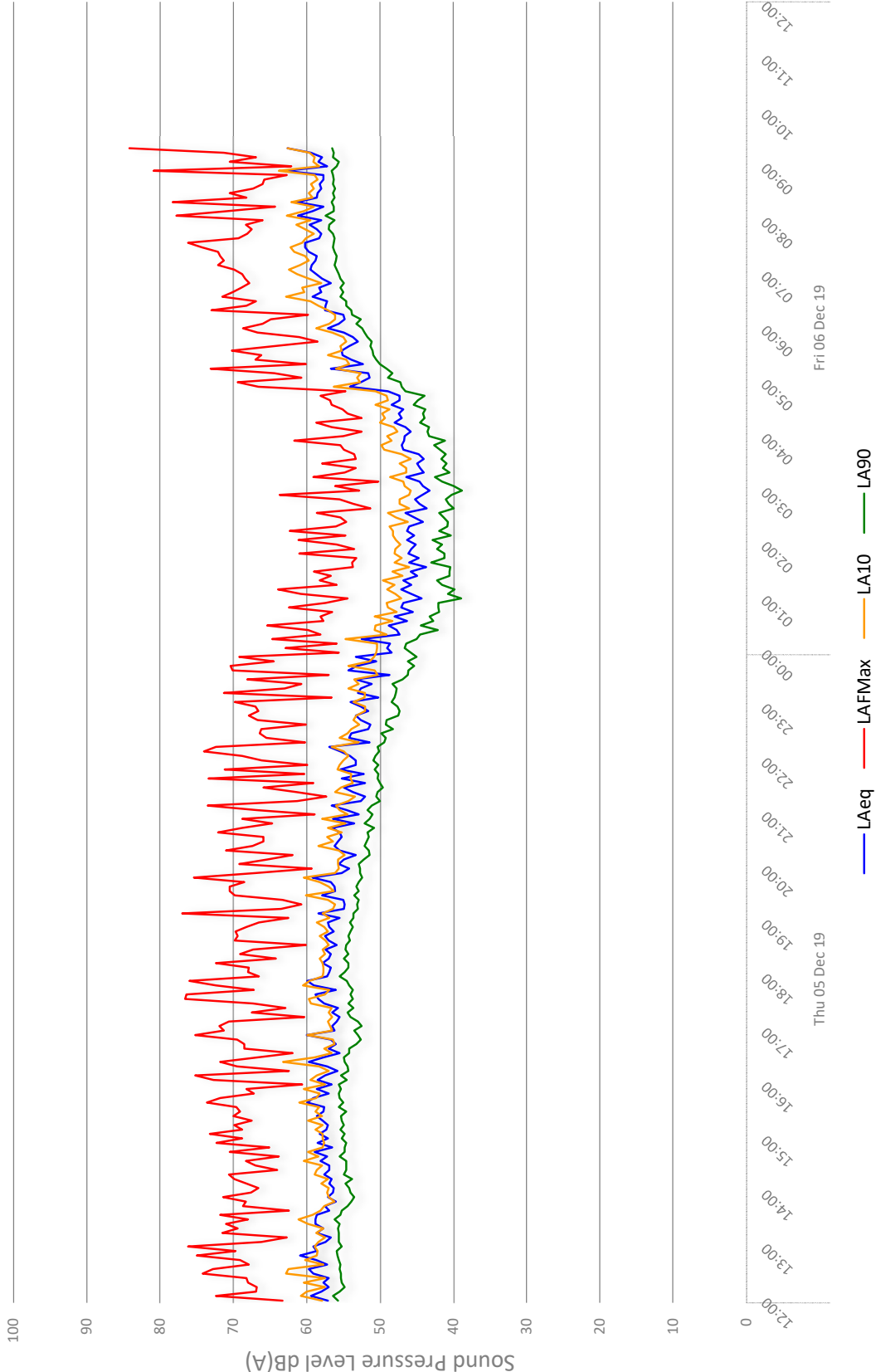




The Burrows, West Street, Bedhampton
Environmental Noise Time History: 4
Position 2



Figure VA3049/TH4



APPENDIX A

Acoustic Terminology & Human Response to Broadband Sound

1.1 Acoustic Terminology

The human impact of sounds is dependent upon many complex interrelated factors such as 'loudness', its frequency (or pitch) and variation in level. In order to have some objective measure of the annoyance, scales have been derived to allow for these subjective factors.

Sound	Vibrations propagating through a medium (air, water, etc.) that are detectable by the auditory system.
Noise	Sound that is unwanted by or disturbing to the perceiver.
Frequency	The rate per second of vibration constituting a wave, measured in Hertz (Hz), where 1Hz = 1 vibration cycle per second. The human hearing can generally detect sound having frequencies in the range 20Hz to 20kHz. Frequency corresponds to the perception of 'pitch', with low frequencies producing low 'notes' and higher frequencies producing high 'notes'.
dB(A):	Human hearing is more susceptible to mid-frequency sounds than those at high and low frequencies. To take account of this in measurements and predictions, the 'A' weighting scale is used so that the level of sound corresponds roughly to the level as it is typically discerned by humans. The measured or calculated 'A' weighted sound level is designated as dB(A) or L_A . A notional steady sound level which, over a stated period of time, would contain the same amount of acoustical energy as the actual, fluctuating sound measured over that period (e.g. 8 hour, 1 hour, etc).
L_{eq} :	The concept of L_{eq} (equivalent continuous sound level) has primarily been used in assessing noise from industry, although its use is becoming more widespread in defining many other types of sounds, such as from amplified music and environmental sources such as aircraft and construction. Because L_{eq} is effectively a summation of a number of events, it does not in itself limit the magnitude of any individual event, and this is frequently used in conjunction with an absolute sound limit.
L_{10} & L_{90} :	Statistical L_n indices are used to describe the level and the degree of fluctuation of non-steady sound. The term refers to the level exceeded for n% of the time. Hence, L_{10} is the level exceeded for 10% of the time and as such can be regarded as a typical maximum level. Similarly, L_{90} is the typical minimum level and is often used to describe background noise. It is common practice to use the L_{10} index to describe noise from traffic as, being a high average, it takes into account the increased annoyance that results from the non-steady nature of traffic flow.
L_{max} :	The maximum sound pressure level recorded over a given period. L_{max} is sometimes used in assessing environmental noise, where occasional loud events occur which might not be adequately represented by a time-averaged L_{eq} value.

1.2 Octave Band Frequencies

In order to determine the way in which the energy of sound is distributed across the frequency range, the International Standards Organisation has agreed on "preferred" bands of frequency for sound measurement and analysis. The widest and most commonly used band for frequency measurement and analysis is the Octave Band. In these bands, the upper frequency limit is twice the lower frequency limit, with the band being described by its "centre frequency" which is the average (geometric mean) of the upper and lower limits, e.g. 250 Hz octave band extends from 176 Hz to 353 Hz. The most commonly used octave bands are:

Octave Band Centre Frequency Hz		63		125		250		500		1000		2000		4000		8000
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APPENDIX A

Acoustic Terminology & Human Response to Broadband Sound

1.3 Human Perception of Broadband Noise

Because of the logarithmic nature of the decibel scale, it should be borne in mind that sound levels in dB(A) do not have a simple linear relationship. For example, 100dB(A) sound level is not twice as loud as 50dB(A). It has been found experimentally that changes in the average level of fluctuating sound, such as from traffic, need to be of the order of 3dB before becoming definitely perceptible to the human ear. Data from other experiments have indicated that a change in sound level of 10dB is perceived by the average listener as a doubling or halving of loudness. Using this information, a guide to the subjective interpretation of changes in environmental sound level can be given.

Change in Sound Level dB	Subjective Impression	Human Response
0 to 2	Imperceptible change in loudness	Marginal
3 to 5	Perceptible change in loudness	Noticeable
6 to 10	Up to a doubling or halving of loudness	Significant
11 to 15	More than a doubling or halving of loudness	Substantial
16 to 20	Up to a quadrupling or quartering of loudness	Substantial
21 or more	More than a quadrupling or quartering of loudness	Very Substantial

1.4 Earth Bunds and Barriers - Effective Screen Height

When considering the reduction in sound level of a source provided by a barrier, it is necessary to establish the "effective screen height". For example if a tall barrier exists between a sound source and a listener, with the barrier close to the listener, the listener will perceive the sound as being louder if he climbs up a ladder (and is closer to the top of the barrier) than if he were standing at ground level. Equally if he sat on the ground the sound would seem quieter than if he were standing. This is explained by the fact that the "effective screen height" is changing with the three cases above. In general, the greater the effective screen height, the greater the perceived reduction in sound level.

Similarly, the attenuation provided by a barrier will be greater where it is aligned close to either the source or the listener than where the barrier is midway between the two.