A C O U S T I C S   A N D   A I R

NUNDAH BANK

NOISE & VIBRATION COMPLIANCE MONITORING

REPORT NO. 10073-N2
VERSION D

JUNE 2018

PREPARED FOR

AUSTRALIAN RAIL TRACK CORPORATION
20 NEWTON STREET
BROADMEADOW NSW 2292

WILKINSON MURRAY

DOCUMENT CONTROL

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A	Final	16 February 2018	Katie Weekes	Ben Lawrence
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C	Final	14 March 2018	Ben Lawrence	-
D	Final	26 June 2018	Ben Lawrence	-

Note

Quality Assurance

Wilkinson Murray operates a Quality Management System which complies with the requirements of AS/NZS ISO 9001:2015. This management system has been externally certified and Licence No. QEC 13457 has been issued.

AAAC

This firm is a member firm of the Association of Australasian Acoustical Consultants and the work here reported has been carried out in accordance with the terms of that membership.

Celebrating 50 Years in 2012

Wilkinson Murray is an independent firm established in 1962, originally as Carr & Wilkinson. In 1976 Barry Murray joined founding partner Roger Wilkinson and the firm adopted the name which remains today. From a successful operation in Australia, Wilkinson Murray expanded its reach into Asia by opening a Hong Kong office early in 2006. Today, with offices in Sydney, Newcastle, Wollongong, Orange, Queensland and Hong Kong, Wilkinson Murray services the entire Asia-Pacific region.

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GLOSSARY OF ACOUSTIC TERMS

Most environments are affected by environmental noise which continuously varies, largely as a result of road traffic. To describe the overall noise environment, a number of noise descriptors have been developed and these involve statistical and other analysis of the varying noise over sampling periods, typically taken as 15 minutes. These descriptors, which are demonstrated in the graph below, are here defined.

Maximum Noise Level (L_{Amax}) – The maximum noise level over a sample period is the maximum level, measured on fast response, during the sample period.

L_{A1} – The L_{A1} level is the noise level which is exceeded for 1% of the sample period. During the sample period, the noise level is below the L_{A1} level for 99% of the time.

L_{A10} – The L_{A10} level is the noise level which is exceeded for 10% of the sample period. During the sample period, the noise level is below the L_{A10} level for 90% of the time. The L_{A10} is a common noise descriptor for environmental noise and road traffic noise.

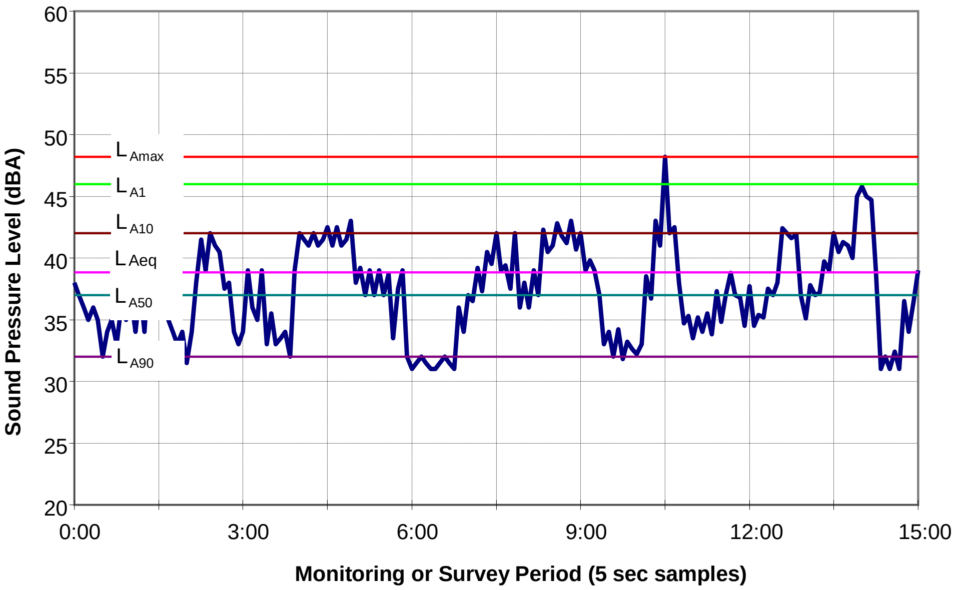
L_{A90} – The L_{A90} level is the noise level which is exceeded for 90% of the sample period. During the sample period, the noise level is below the L_{A90} level for 10% of the time. This measure is commonly referred to as the background noise level.

L_{Aeq} – The equivalent continuous sound level (L_{Aeq}) is the energy average of the varying noise over the sample period and is equivalent to the level of a constant noise which contains the same energy as the varying noise environment. This measure is also a common measure of environmental noise and road traffic noise.

ABL – The Assessment Background Level is the single figure background level representing each assessment period (daytime, evening and night time) for each day. It is determined by calculating the 10th percentile (lowest 10th percent) background level (L_{A90}) for each period.

RBL – The Rating Background Level for each period is the median value of the ABL values for the period over all of the days measured. There is therefore an RBL value for each period – daytime, evening and night time.

Typical Graph of Sound Pressure Level vs Time



VDV – The Vibration Dose Value is the accumulation of energy measured over a given time period. This is usually measured in each of the three axes of motion. In most cases, vibration tends to be higher in the Z (vertical) axis. This is measured with units of $m/s^{1.75}$.

PPV – Peak Particle Velocity is the instantaneous peak of the resultant vector sum of all three axes of motion. Results are expressed in terms of velocity, m/s or mm/s.

Peak Acceleration – This is the peak acceleration level measured in each of the three axes of motion. In some cases, this can also be combined in a vector sum. This is measured in m/s^2.

1 INTRODUCTION

Wilkinson Murray has undertaken operational noise and vibration monitoring of the Nundah Bank Third Track Project (the Project) to address the Ministers Condition of Approval (MCoA) (Conditions D2, D3 and D4).

Condition D2 of the MCoA requires compliance with the following criteria.

The Proponent shall design and operate the project with the objective of not exceeding the airborne and ground-borne noise trigger levels associated with the project at sensitive receivers as presented in the Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects (DECC and DoP, 2007).

Condition D3 of the MCoA requires the following.

The Proponent shall design and operate the project with the objective of not exceeding, at receivers, the vibration goals for human exposure as presented in Assessing Vibration: A Technical Guideline (DECC, 2006) and German Standard DIN 4150 for structural vibration impacts.

Condition D4 of the MCoA requires the following.

"The Proponent shall undertake noise and vibration compliance monitoring and assessment to confirm compliance with the goals and limits identified in condition D2 and D3. The monitoring and assessment shall be undertaken in consultation with the OEH and the Department and will:

a) identify sensitive receivers within the immediate proximity of the project,

b) identify noise and vibration goals at sensitive receivers consistent with the requirements of condition D2 and D3;

c) identify a monitoring and assessment methodology, including representative monitoring locations; and

d) consider complaints received relating to operational noise and vibration impacts.

The noise and vibration monitoring and assessment shall be undertaken prior to the commencement of operations, 1 and 5 years from the commencement of operations."

The process of compliance monitoring involves the comparison of "with Project" and "without Project" rail noise levels at sensitive receivers. Effectively comparisons will be made at two intervals, consistent with the MCoA stated above: at one year post-commencement of operations and at five years post-commencement of operations.

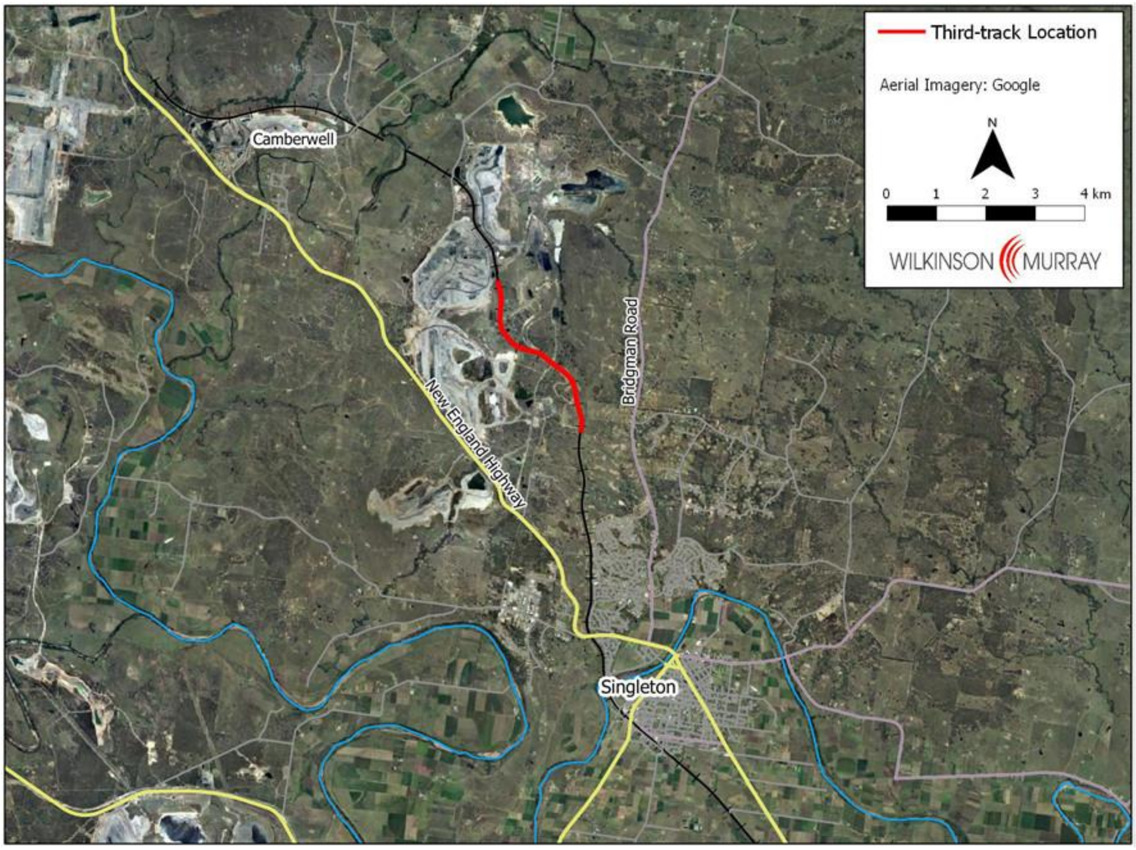
This report details operational noise monitoring at five years post-commencement of operations.

2 SITE DESCRIPTION

2.1 Project Description

The Project is located north of Singleton as detailed in Figure 2-1. The site surrounds are generally rural in nature with few residential receivers surrounding the rail corridor. The area surrounding the Project also includes the Rix's Creek Coal Mine to the west and its associated infrastructure.

Figure 2-1 Project Location



The nearest two receivers as identified in the pre-construction monitoring have been considered in this assessment, these are:

- 427 Bridgman Road; and
- Dulwich House, Falbrook.

Access to 427 Bridgman Road was not available, so the noise logger was installed at the rear of the adjacent property 411 Bridgman Road at the request of the owner. Corrections for the difference in location have been accounted for as discussed in Section 4.4 below. The logger at Dulwich House was installed in the same location as previous surveys.

In addition to the above receiver locations, noise monitoring was also undertaken at a control location, Location A – approximately 175m setback from the rail line. This location is consistent with the control location at which monitoring was undertaken as part of the Project's EA.

2.2 Rail Traffic

Table 2-1 shows the average actual number of train movements on the line during the course of this and the last compliance surveys. These are supplied for reference only and are not used for further calculations.

Table 2-1 Train Numbers
[Source: 2013 PHOENIX data supplied by ARTC for the 2013 'post-completion' logging period/ 2018 data supplied by ARTC]

Train Type	Train pass-bys per 24 hours					
	2013 Actual			2018 Actual		
	Day 7am-10pm	Night 10pm-7am	Total 24-hour	Day 7am-10pm	Night 10pm-7am	Total 24-hour
Freight (All types)	63	44	107	47	26	73
Passenger	8	2	10	6	2	8
Total	**71**	**46**	**117**	**53**	**28**	**81**

Note: Fractional averages have been rounded up to the nearest whole train.

It should be noted that lower than expected train numbers were observed during our survey. During December 2013, an average of 456kt/day of coal was delivered to the terminals, whereas in January 2018 an average of only 365kt/day of Coal was delivered. This trend is typical, with spikes in demand observed in June and December to meet operational targets, with volumes typically lower in January as mines look to rebuild site stockpiles.

2.3 Complaints Received

No complaints have been received by ARTC relating to operation of the project.

3 NOISE & VIBRATION CRITERIA

3.1 Operational Noise Criteria

The EA determined applicable criteria in accordance with the NSW Environment Protection Authority (EPA, formerly known as the Office of Environment and Heritage) *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* [*IGANRIP*] (2007). These criteria are summarised in Table 3-1.

Table 3-1 Airborne Rail Traffic Noise Trigger Levels for Residential Land Uses [Source: Extract of Table 1 of the DECCW's *IGANRIP*]

Type of Development	Day (7am-10pm)	Night (10pm-7am)	Comment
Redevelopment of existing rail line	Development increases existing rail noise levels **and** resulting rail noise levels exceed:		These numbers represent external levels of noise that trigger the need for an assessment of the potential noise impacts from a rail infrastructure project.
	65 $L_{Aeq(15hr)}$ 85 L_{Amax}	60 $L_{Aeq(9hr)}$ 85 L_{Amax}	An 'increase' in existing rail noise levels is taken to be an increase of 2 dBA or more in L_{Aeq} in any hour or an increase of 3 dBA or more in L_{Amax}.

The definition of an 'increase' of existing rail levels in Table 3-1 is not completely clear in *IGANRIP*, particularly in the case where the number of movements is likely to increase due to developments not associated with the proposal. In undertaking this assessment, guidance has been taken from the *NSW Rail Infrastructure Noise Guideline (RING)* which succeeds *IGANRIP*.

RING confirms that the determination of the 'increase' due to the development is to be made by comparing noise levels of like times both with and without the development.

IGANRIP states that the trigger levels apply to the time immediately after opening and also at a time up to 10 years in the future.

As the trains are distributed evenly throughout the 24 hour period, the $L_{Aeq,period}$ increase has been assumed to be synonymous with the $L_{Aeq,1hr}$ increase and as such the $L_{Aeq,1hr}$ is not considered separately. This directive was given by ARTC and is consistent with the *RING*.

Note that this interpretation differs from that adopted in the Project's EA. We consider that this interpretation supersedes that which was adopted in the EA and subsequently this will be adopted in this and future compliance monitoring/assessments associated with the Project. We note also that the Project's conditions of approval are not explicit in this regard, nor do they condition the criteria detailed in the EA. Therefore, it is considered that the decision to apply the most recent (and believed correct) interpretation of *IGANRIP* is not in opposition to the MCoA.

3.2 Operational Vibration Criteria

When assessing vibration there are two components that require consideration:

- human exposure to vibration; and
- the potential for building damage from vibration.

3.2.1 Human Exposure to Vibration

The EPA's *Assessing Vibration: A Technical Guideline* provides guidance for assessing human exposure to vibration. The publication is based on British Standard BS 6472:1992. Vibration from train passbys is intermittent vibration and is best assessed by the Vibration Dose Value (VDV) which is based on the *weighted* root mean quartic (rmq) acceleration. Research has shown that the VDV can be adequately approximated by the estimated vibration dose value (eVDV) for vibration exhibiting a crest factor (the ratio between peak and rms acceleration) below 6. Typically, train vibration has a crest factor well below 6 and thus the eVDV is a suitable assessment parameter.

BS 6472:1992 provides the following advice on the probability of adverse comment resulting from various values of eVDV.

Table 3-2 Probability of Adverse Comment Resulting from VDV in Residences [Source: Table 7, Appendix A, BS 6472:1992]

Period	Low Probability of Adverse Comment ($m/s^{1.75}$)	Adverse Comment Possible ($m/s^{1.75}$)	Adverse Comment Probable ($m/s^{1.75}$)
Day (7am-10pm)	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Night (10pm-7am)	0.13	0.26	0.51

For operational vibration, the EA adopted values expected to have a low probability of adverse comment as vibration goals.

For reference the OEH *Assessing Vibration: A Technical Guideline* specifies 0.56mm/s PPV, for exposure to continuous vibration, as a criterion for the assessment of human comfort from vibration. This can be used as a simple conservative assessment tool, as compliance with this level demonstrates that vibration impacts will result in a 'low probability of adverse comment', though it should be noted that PPV vibration levels resulting from construction and exceeding 0.56mm/s may be acceptable.

3.2.2 Building Damage from Vibration

The EA adopted vibration criteria described by DIN 4150 for the evaluation of the potential for building damage from vibration. Table 3-3 summarises the goal levels specified in DIN 4150.

With regard to these levels DIN 4150 states:

"Experience has shown that if these values are complied with, damage that reduces the serviceability of the building will not occur. If damage nevertheless occurs, it is to be assumed that other causes are responsible. Exceeding [these] *values does not necessarily lead to damage; should they be significantly exceeded; however, further investigations are necessary."*

Table 3-3 Guideline Values for Vibration Velocity to be used when Evaluating the Effects of Short-Term Vibration on Structures
[Source: Table 1, DIN 4150-3:1999]

Type of Structure	Guideline Values for Velocity – PPV (mm/s)		
	1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz
Buildings used for commercial purposes, industrial buildings, and buildings of similar design	20	20 to 40	40 to 50
Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20
Structures that, because of their particular sensitivity to vibration, cannot be classified under either of the other classifications and of great intrinsic value	3	3 to 8	8 to 10

For train passbys the vibration is typically in the frequency range of 31.5 – 100 Hz and is dependent on speed, wheel condition and rail condition. Because the dominant frequency of vibration cannot be determined with certainty, the EA adopted a goal level 5 mm/s for the nearest residences.

4 MEASURED NOISE & VIBRATION LEVELS

Unattended noise and vibration measurements were undertaken between Friday, 12 January 2018 and Monday, 23 January 2018. Weather conditions were favourable for environmental noise logging throughout the measurement period with nil rain recorded and low to moderate wind speeds observed at Singleton and Cessnock airport.

4.1 Measurement Locations

Noise and vibration monitoring was undertaken at three locations:

- R1 – 411 Bridgman Road (adjacent to 427 Bridgman Road at similar setback to rail line);
- R2 – Dulwich House, Falbrook; and
- Location A, a calibration position set back approximately 175m from the centreline of the rail line (Coordinates: Easting 326734.57 m E, Northing 6401185.02 m S). Noise and vibration loggers chained to the western (Rail) side of the eucalypt tree at this location.

Measurement Locations are shown in Figure 4-1.

4.2 General Measurement Procedure

The following describes the general measurement procedure undertaken:

1) Unattended noise monitoring utilised an environmental noise logger with audio recording capability. The noise logger recorded one-tenth of a second A-weighted and C-weighted SPLs with "FAST" time weighting, and a digital recording of real-time audio saved in (lossless) wav file format for the duration of the monitoring.
2) Microphones were positioned in free-field locations at a height of approximately 1.5 metres.
3) Unattended vibration monitoring utilised equipment that stored the PPV vibration level every 1 to 6 seconds.
4) Detailed analysis of the unattended monitoring data was undertaken following collection of the equipment and using a semi-automated processing methodology developed by Wilkinson Murray. The analysis involved:
   (a) the automatic identification of possible train events based on the characteristic noise level history of rail events. Wav files corresponding to identified events were also extracted during this stage;
   (b) visual inspection of 30-minute SPL-history plots to confirm that all apparent rail events had been identified;
   (c) aural verification that each of the identified events were from rail operations. Those events that were identified as being extraneous were eliminated from further analysis;
   (d) aural analysis of rail events to identify relative contributions from rail sources (e.g. rolling noise, gearbox whine, locomotive engine/exhaust, wheel squeal etc.).
   (e) reanalysis of events identified as containing extraneous noise such as horns, traffic or birds. For analysis, periods containing extraneous noise were excluded;

(f) calculation of noise parameters relevant to rail operations – being L_{AFmax} from the one-tenth second SPL-history;

(g) calculation of rail noise summary descriptors $L_{Aeq,day}$, $L_{Aeq,night}$ and the 95th Percentile L_{AFmax};

(h) analysis of vibration data by an automated routine, with identified events confirmed against those aurally identified in the noise analysis; and

(i) calculation of rail vibration summary descriptors.

A key feature of the above system is that sound pressure levels and wav file audio are recorded for the duration of the measurement period, and not only when events are triggered by a predetermined sound pressure level. This process results in far greater quality of data, especially in elevated ambient noise environments, because trigger levels are not required to be determined during installation, thus negating the loss of data due to incorrectly set triggers and/or a variable ambient noise environment.

4.3 Measurement Equipment

The noise monitoring equipment used for these measurements consisted of three ARL Ngara environmental noise loggers set to A-weighted, fast response, continuously monitoring over 15-minute sampling periods. This equipment is capable of remotely monitoring and storing one-tenth second noise levels for later detailed analysis. The equipment calibration was checked before and after the survey and no significant drift occurred.

The noise loggers also recorded the sound level every one-tenth of a second as well as recording audio files at high quality. This time-history of sound pressure level allows individual rail events to be identified.

A Texcel ETM vibration monitor was set to record maximum peak particle velocity (PPV) in each of the three orthogonal axes (x, y and z) every minute and was located at Location A, installed adjacent to the noise logger.

Figure 4-1 Measurement Locations

4.4 Results

A summary of the measured rail noise descriptors is presented in Table 4-1 through Table 4-4. Results are presented exclusively for the residential receivers.

Up to 700 trains were measured during the eight-day study, averaging 87 per 24-hour period. This data was used to calculate the levels below.

Train movements at 411 Bridgman Road (indicative logging location of 427 Bridgman Road) were audible at times, but difficult to measure above ambient noise levels (given the large distances involved) with the exception of L_{Amax} levels from some locomotives. This is consistent with previous pre- and post-construction noise measurements at this location.

As the measurements were undertaken in free-field locations, a facade correction of +2.5dB has been applied.

Table 4-1 Summary of Measured Train Events Day $L_{Aeq,15hr}$ – dBA

Location ID	5-year Post completion (Jan 2018) Measured Level[1]	1-year Post-completion (Dec 2013) Measured Level[1]	Pre-operation (Feb 2013) Measured Level[1]	*IGANRIP* Trigger Level	*IGANRIP* Trigger
R1	48.3	N/M[2]	N/M[2]	>65dBA and ≥2 dB 'increase'	-
R2	46.1	49.8	41.6		NO

Notes: 1. L_{Aeq} level over the measurement period;
2. L_{Aeq} from rail events could not be determined at R1 due to higher ambient noise; and
3. N/M = not measurable.

Table 4-2 Summary of Measured Train Events Night $L_{Aeq,9hr}$ – dBA

Location ID	5-year Post completion (Jan 2018) Measured Level[1]	1-year Post-completion (Dec 2013) Measured Level[1]	Pre-operation (Feb 2013) Measured Level[1]	*IGANRIP* Trigger Level	*IGANRIP* Trigger
R1	51.8	N/M[2]	N/M[2]	>60dBA and ≥2 dB 'increase'	NO
R2	49.5	52.3	46.0		NO

Notes: 1. L_{Aeq} level over the measurement period; and
2. L_{Aeq} from rail events could not be determined at R1 due to higher ambient noise.

Table 4-3 Summary of Measured Train Events L_{AMax} – dBA

Location ID	5-year Post completion (Jan 2018) Measured Level[1]	1-year Post-completion (Dec 2013) Measured Level[1]	Pre-operation (Feb 2013) Measured Level[1]	*IGANRIP* Trigger Level	*IGANRIP* Trigger
R1	76.2	63.7	64.6	>85dBA and ≥3 dB 'increase'	NO
R2	81.4	79.9	81.0		NO

Notes: 1. L95% L_{Amax} over the measurement period.

Table 4-4 Summary of Measured Train Events L_{AE}[1] – dBA

Location ID	5-year Post completion (Jan 2018) Measured Level	1-year Post-completion (Dec 2013) Measured Level	Pre-operation (Feb 2013) Measured Level	Pre-construction (2010) Measured Level
R1	83.5	N/M[2]	N/M[2]	N/M[2]
R2	81.1	80.8	79.9	N/M[2]
Loc. A[3]	81.5	85.0	88.8	89.3

Notes: 1. Energy Average L_{AE} level over the measurement period;
2. N/M = not measurable; L_{AE} from rail events could not be determined at R1 due to ambient noise; and
3. Free-field L_{AE} is presented at Location A.

The measured $L_{Aeq,day}$, $L_{Aeq,night}$, and L_{Amax} noise levels were all below 'base' *IGANRIP* triggers. Compliance was demonstrated at both receivers.

4.5 Measured Vibration Levels

The vibration monitor recorded the peak particle velocity (PPV) in each of the three orthogonal axes. To simplify the analysis the maximum component (i.e. the greatest magnitude PPV on any of the three axes) was calculated and is reported. This is considered to be representative of the maximum resultant PPV.

Based on results of vibration monitoring during previous studies, which showed that rail vibration was undetectable at the R1 and R2, vibration monitoring was undertaken at Location A only.

Measured vibration levels at Location A from rail movements were generally below 0.1mm/s indicating that they were well within both structural damage and human comfort levels. On three separate occasions, results ranged between 1.2 and 1.9mm/s. These results were likely to be extraneous given the large distances involved, but even these levels would be well below both the structural damage and human comfort criteria given the short durations involved.

5 CONCLUSION

Wilkinson Murray has undertaken operational noise and vibration monitoring adjacent to the Nundah Bank Rail Project to satisfy the 5-year compliance monitoring requirements of the MCoA.

This report details this monitoring and provides results. Measured noise levels were significantly below the *IGANRIP* base trigger levels that were determined in the EA, and therefore compliance with this criterion has been achieved.

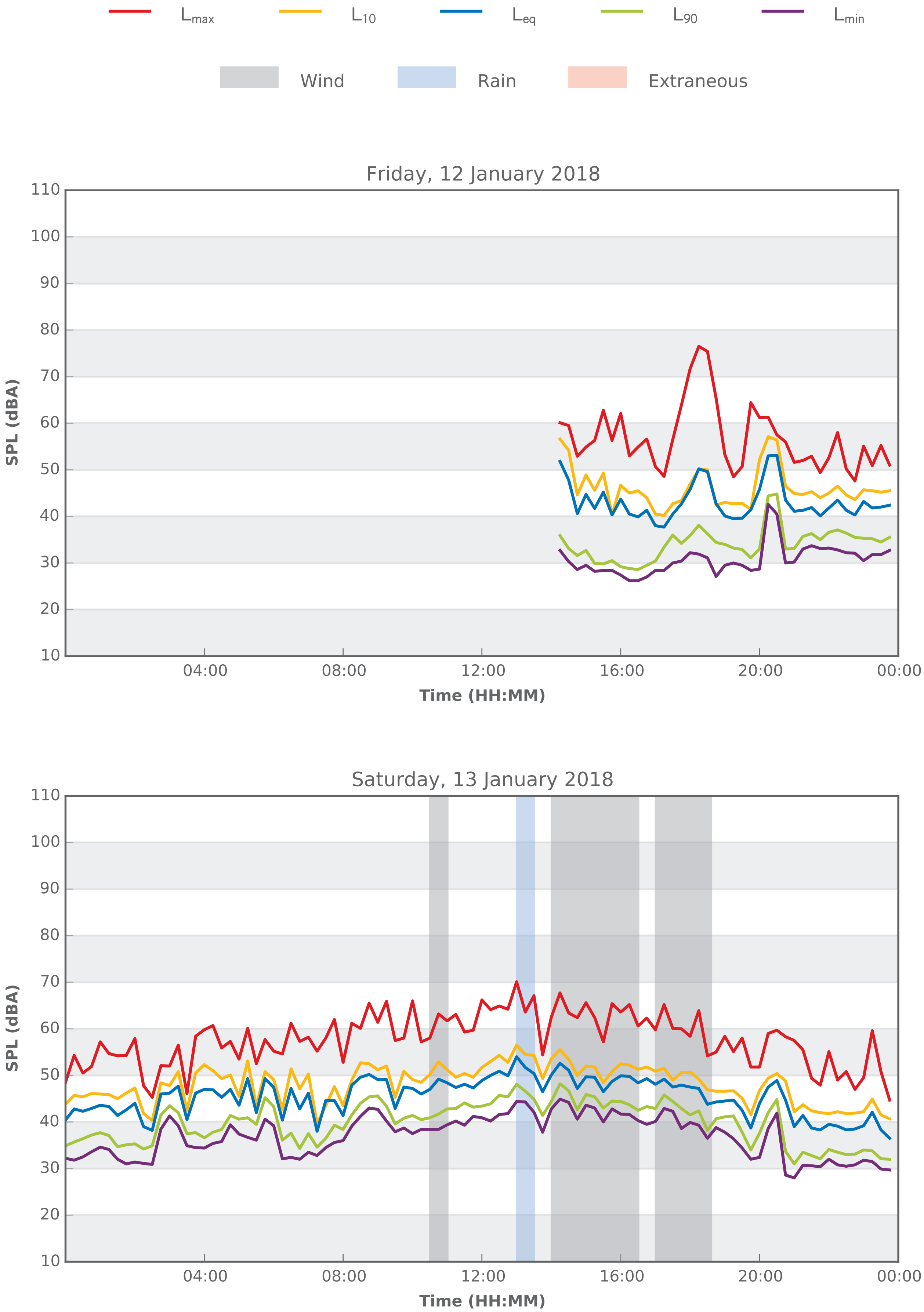
Measured vibration levels were consistent with previous measurements. As such, we have concluded that vibration levels are well within the 'Goal Levels' that were adopted for assessing potential building damage and protecting human comfort at the nearest residence.

Operational compliance with the noise and vibration criteria presented in the MCoA (Conditions D2, D3 and D4) has been demonstrated as a result of this monitoring.

APPENDIX A

NOISE MEASUREMENT RESULTS

Location A



L_{max}
L_{10}
L_{eq}
L_{90}
L_{min}
Wind
Rain
Extraneous
Friday, 12 January 2018
SPL (dBA)
110
100
90
80
70
60
50
40
30
20
10
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)
Saturday, 13 January 2018
SPL (dBA)
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80
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04:00
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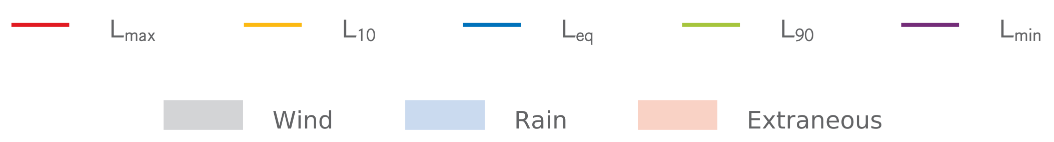
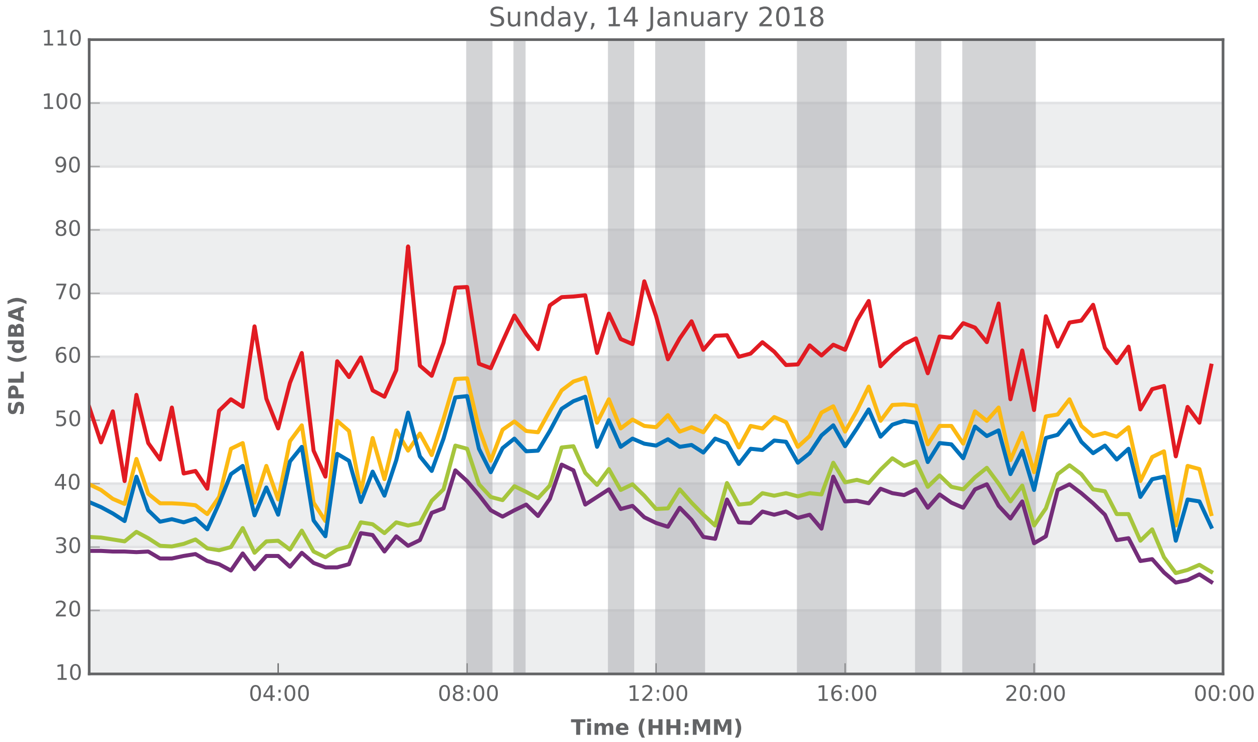
00:00
Time (HH:MM)

Location A



Lmax
L10
Leq
L90
Lmin
Wind
Rain
Extraneous



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SPL (dBA)
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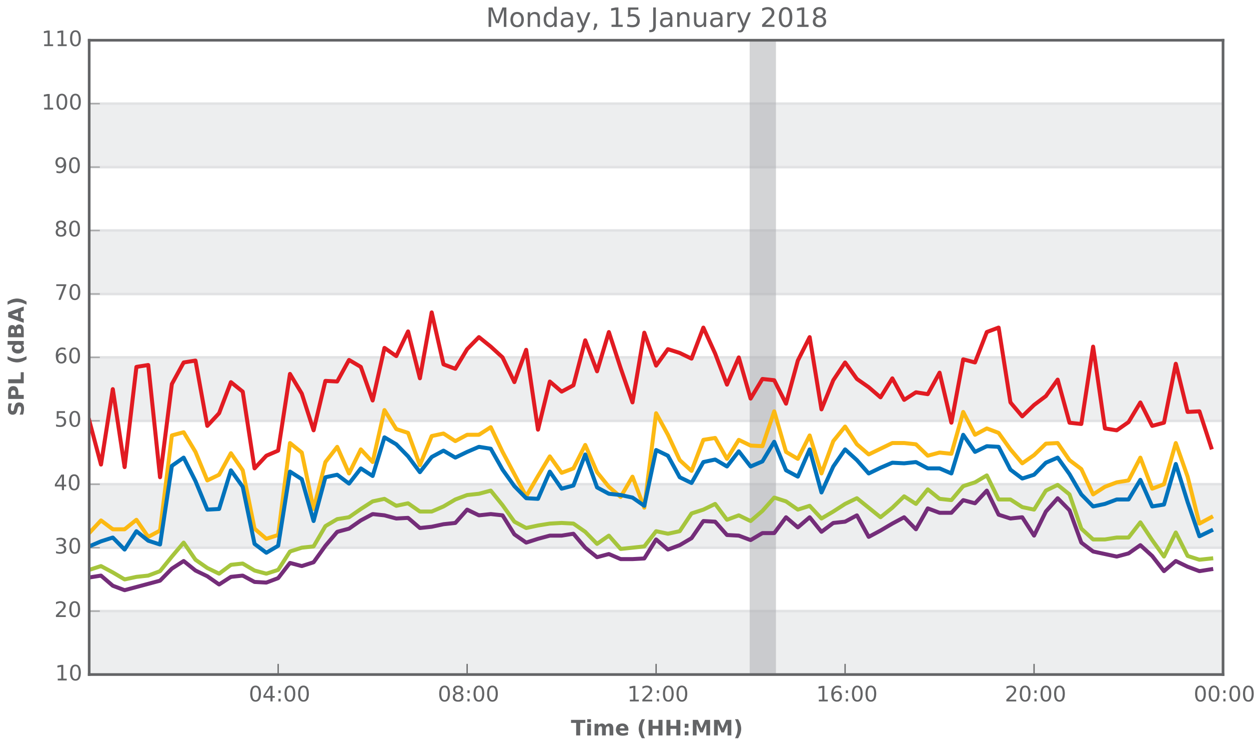
Time (HH:MM)



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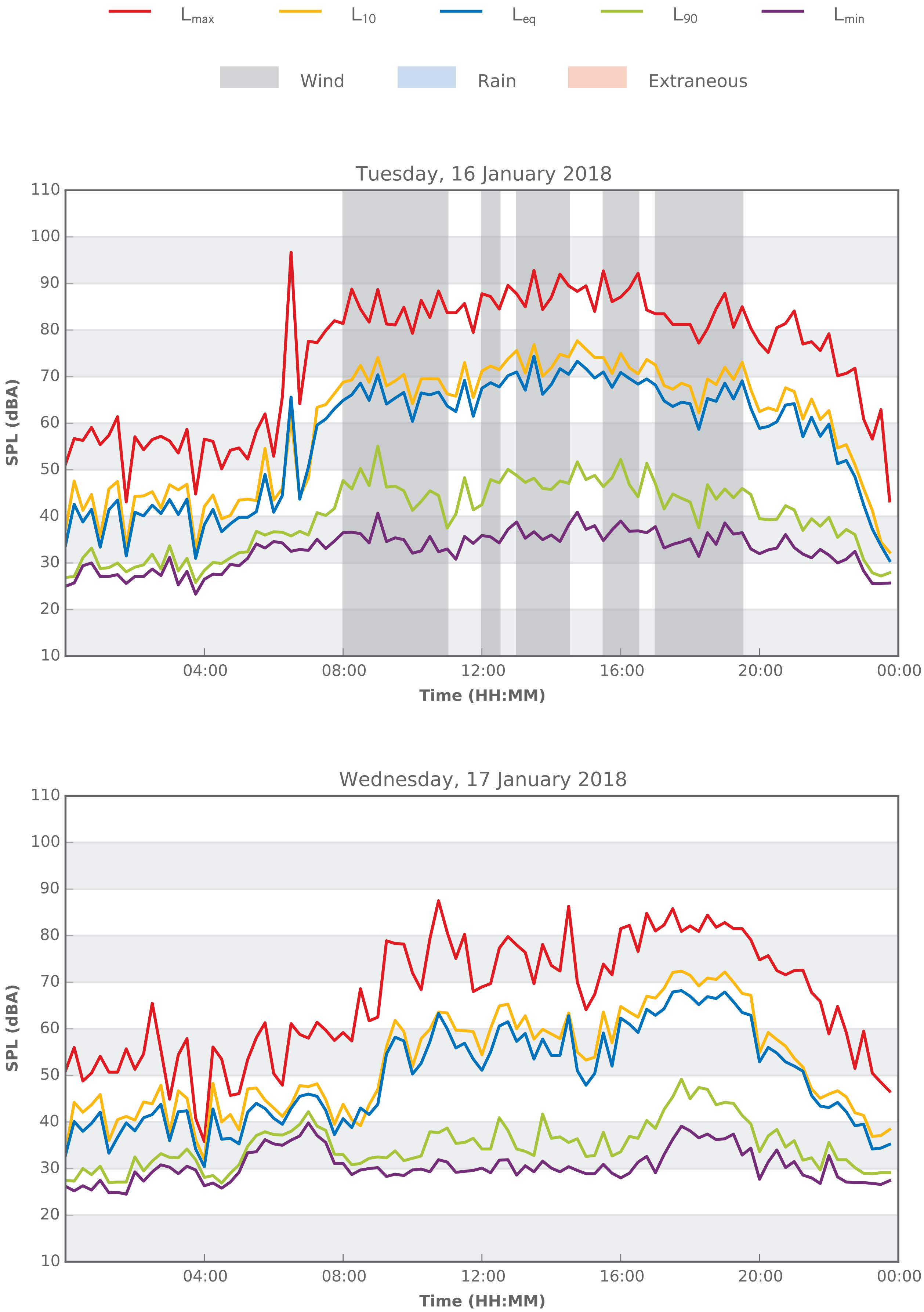
Time (HH:MM)

Location A



Lmax
L10
Leq
L90
Lmin
Wind
Rain
Extraneous
Tuesday, 16 January 2018
SPL (dBA)
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08:00
12:00
16:00
20:00
00:00
Time (HH:MM)
Wednesday, 17 January 2018
SPL (dBA)
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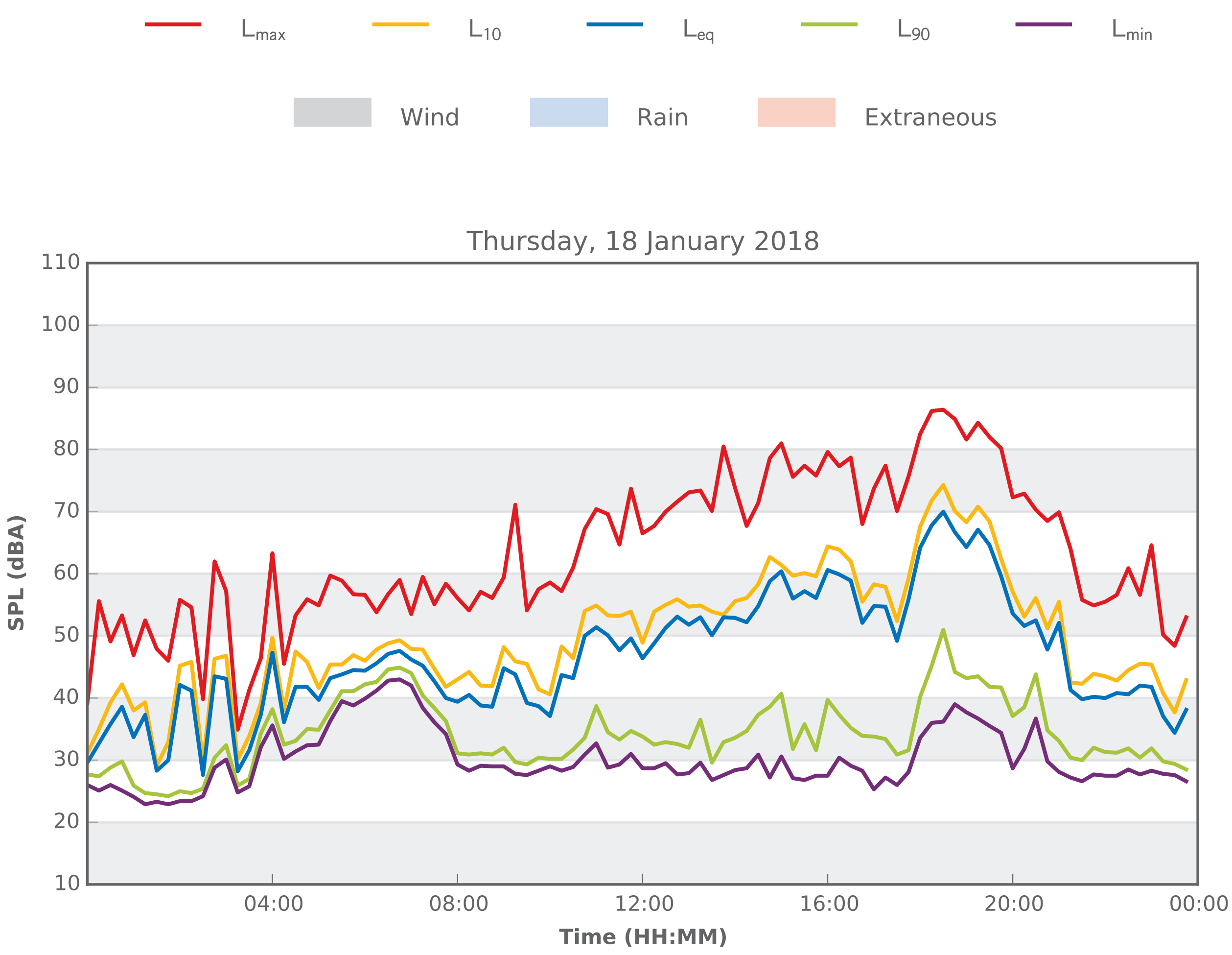
Time (HH:MM)

Location A



Lmax
L10
Leq
L90
Lmin
Wind
Rain
Extraneous
Thursday, 18 January 2018
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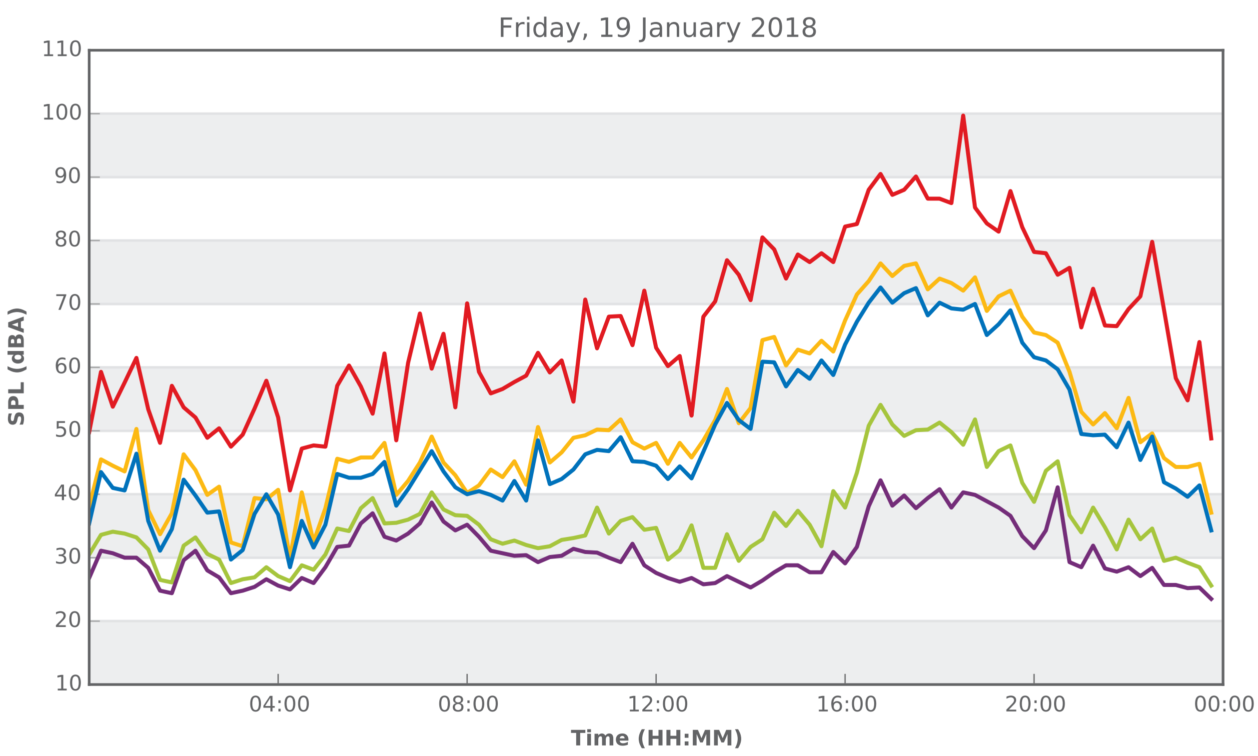
Time (HH:MM)



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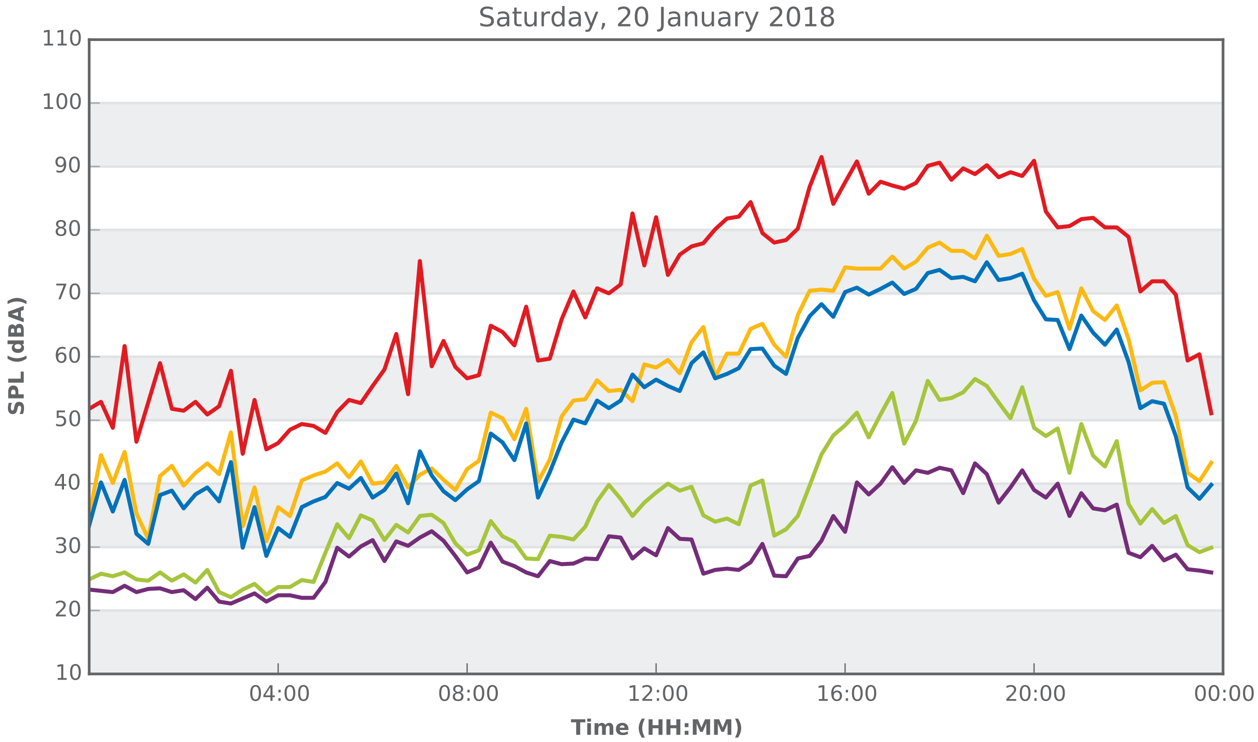
20:00
00:00
Time (HH:MM)

Location A

Lmax
L10
Leq
L90
Lmin
Wind
Rain
Extraneous



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08:00
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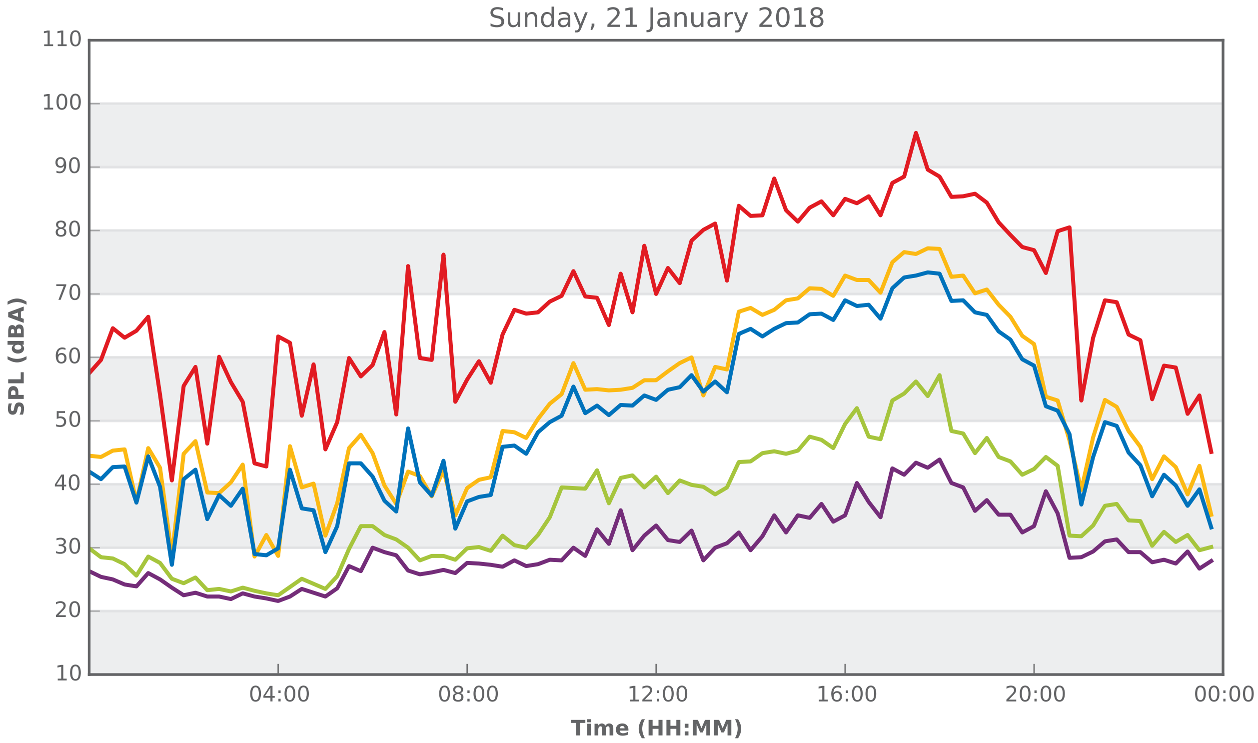
00:00
Time (HH:MM)



Sunday, 21 January 2018
SPL (dBA)
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100
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20
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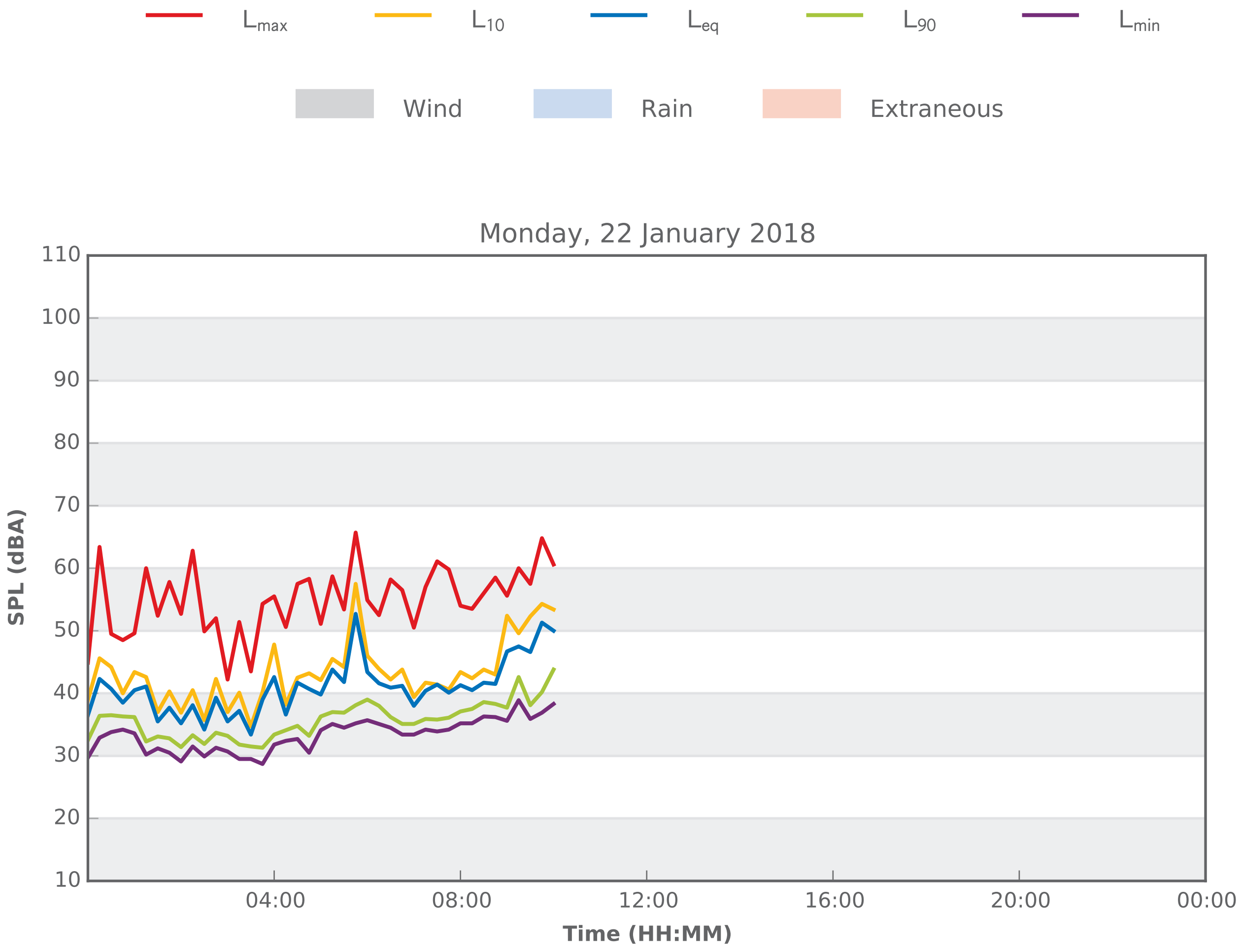
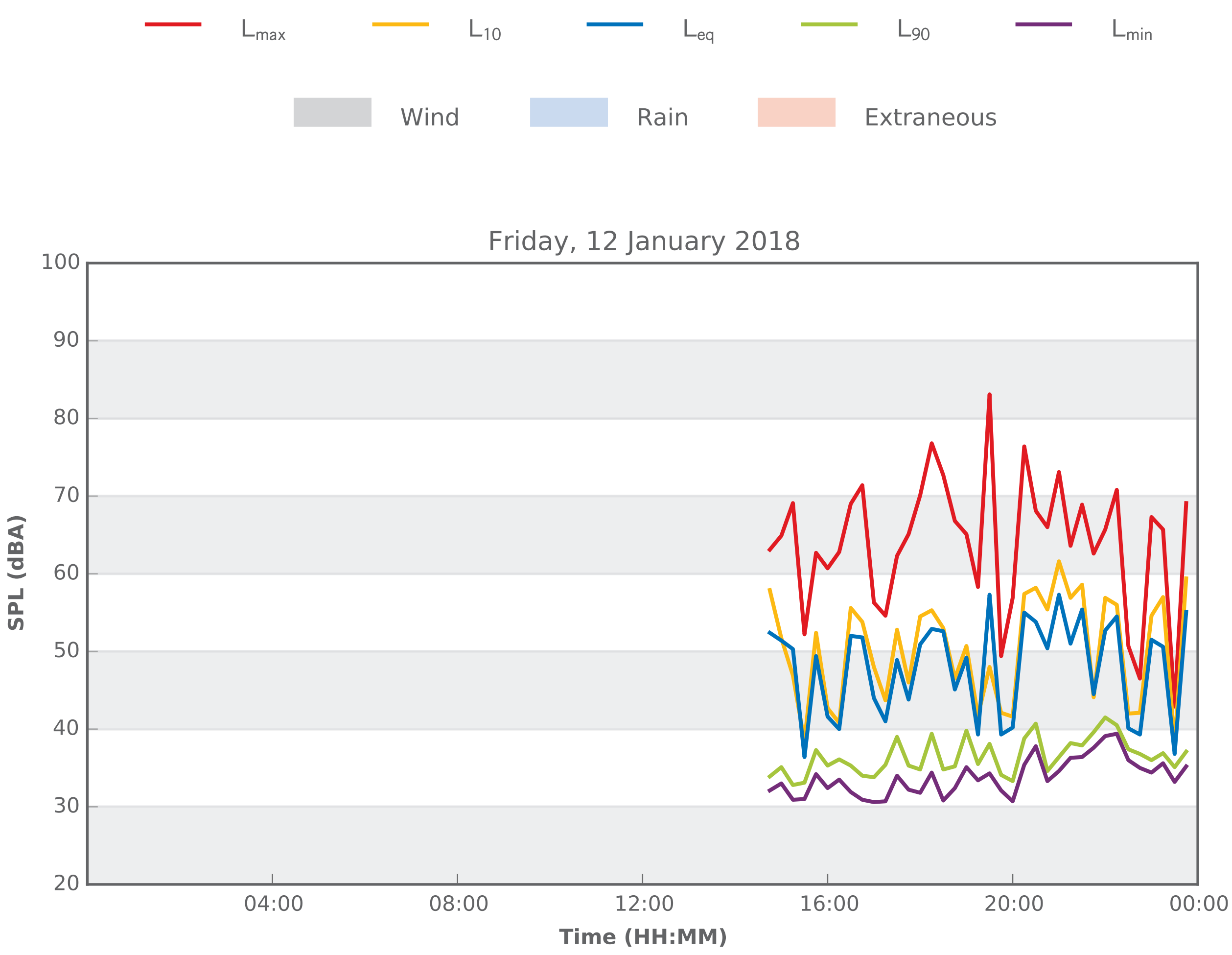
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)

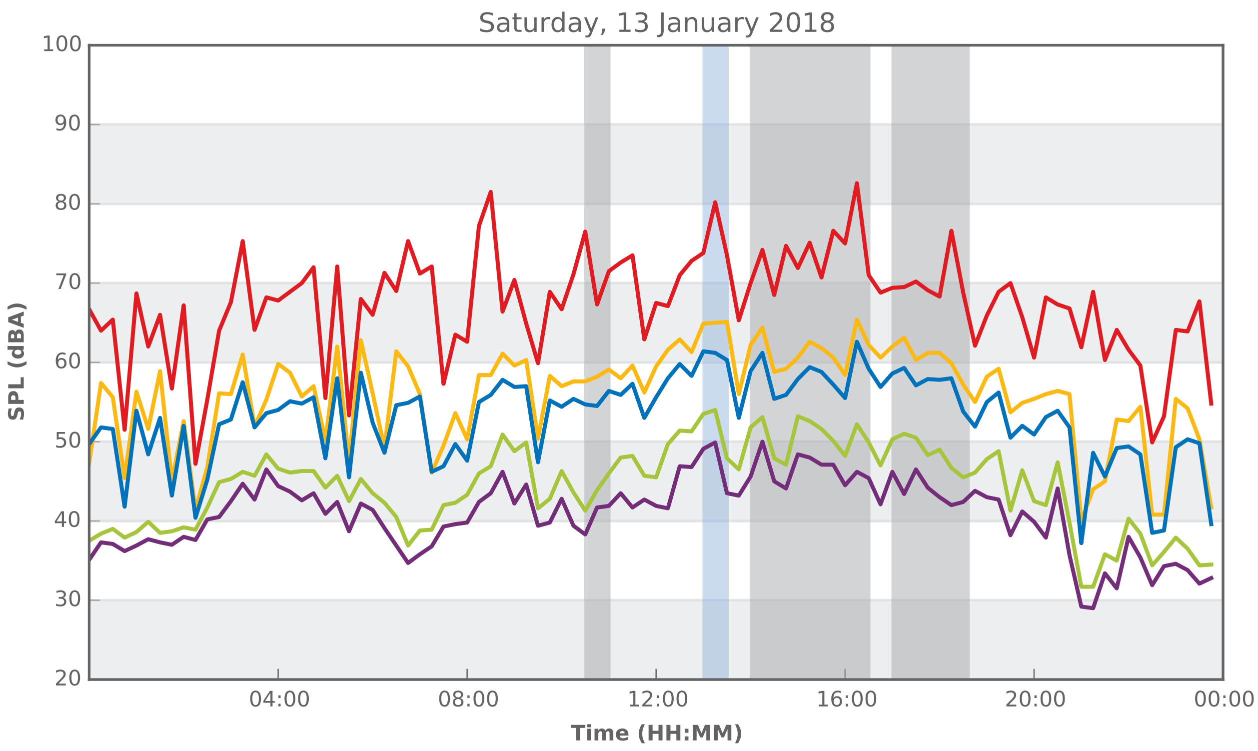
Location A



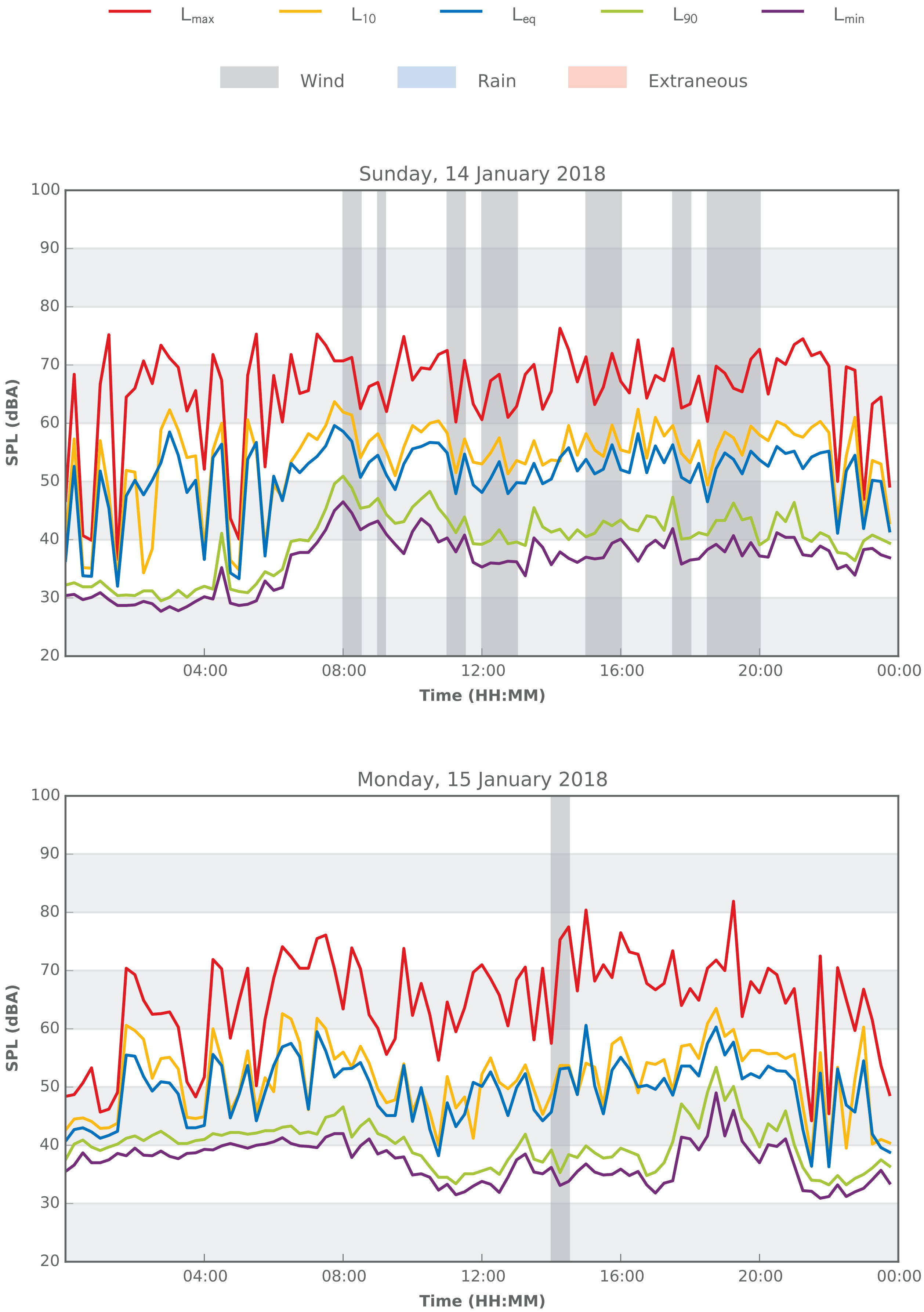
Lmax
L10
Leq
L90
Lmin
Wind
Rain
Extraneous
Monday, 22 January 2018
110
100
90
80
70
60
50
40
30
20
10
SPL (dBA)
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)

411 Bridgeman Road, Obanvale





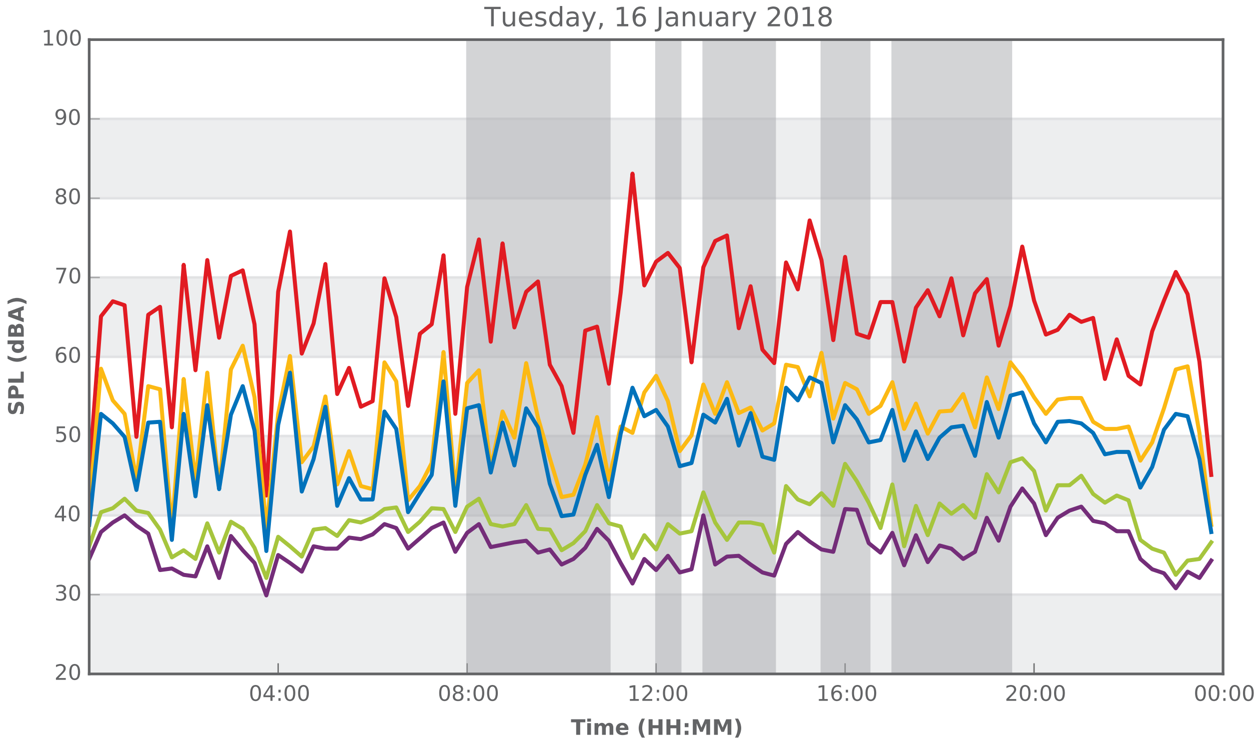
411 Bridgeman Road, Obanvale

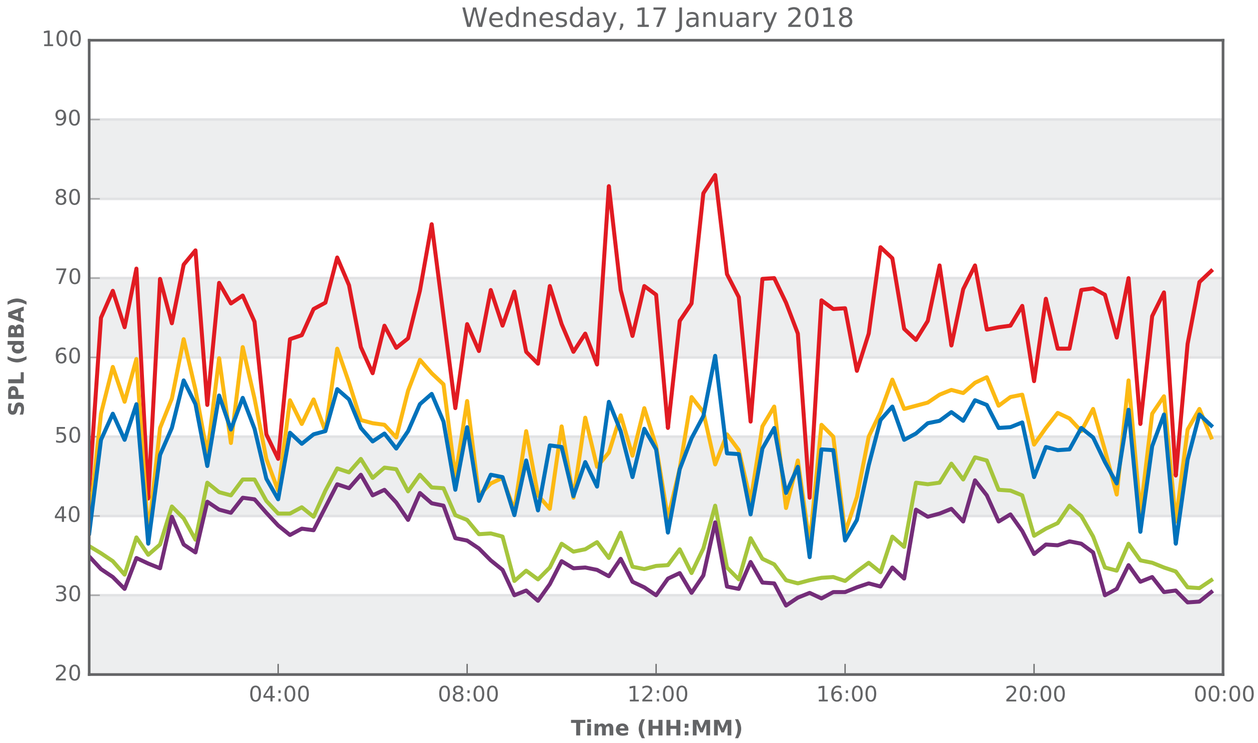


411 Bridgeman Road, Obanvale

Lmax — L10 — Leq — L90 — Lmin

Wind — Rain — Extraneous

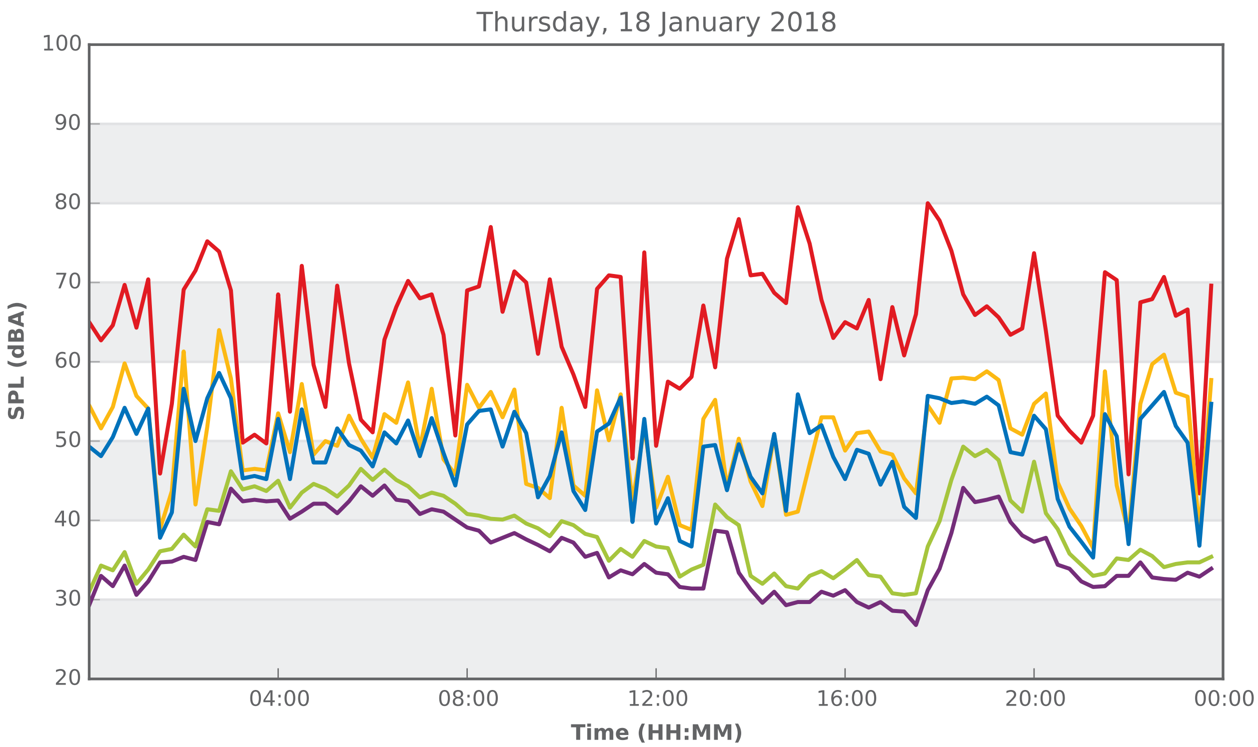


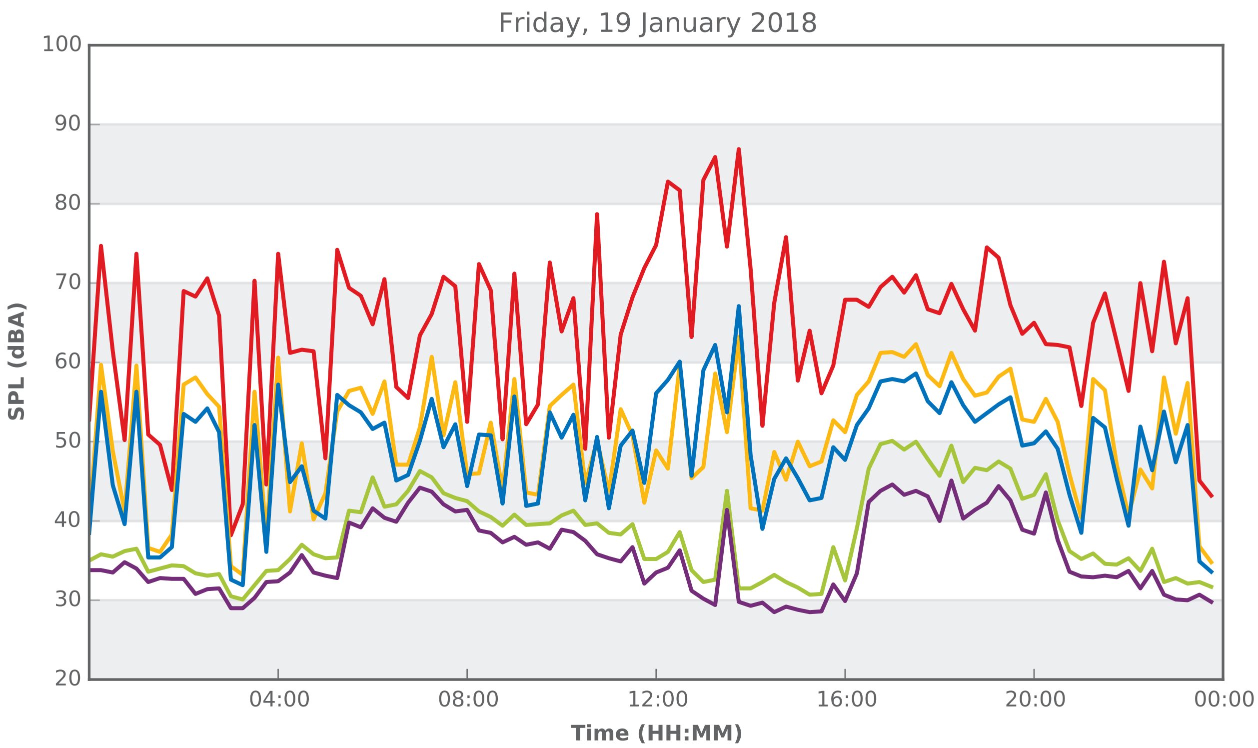


411 Bridgeman Road, Obanvale

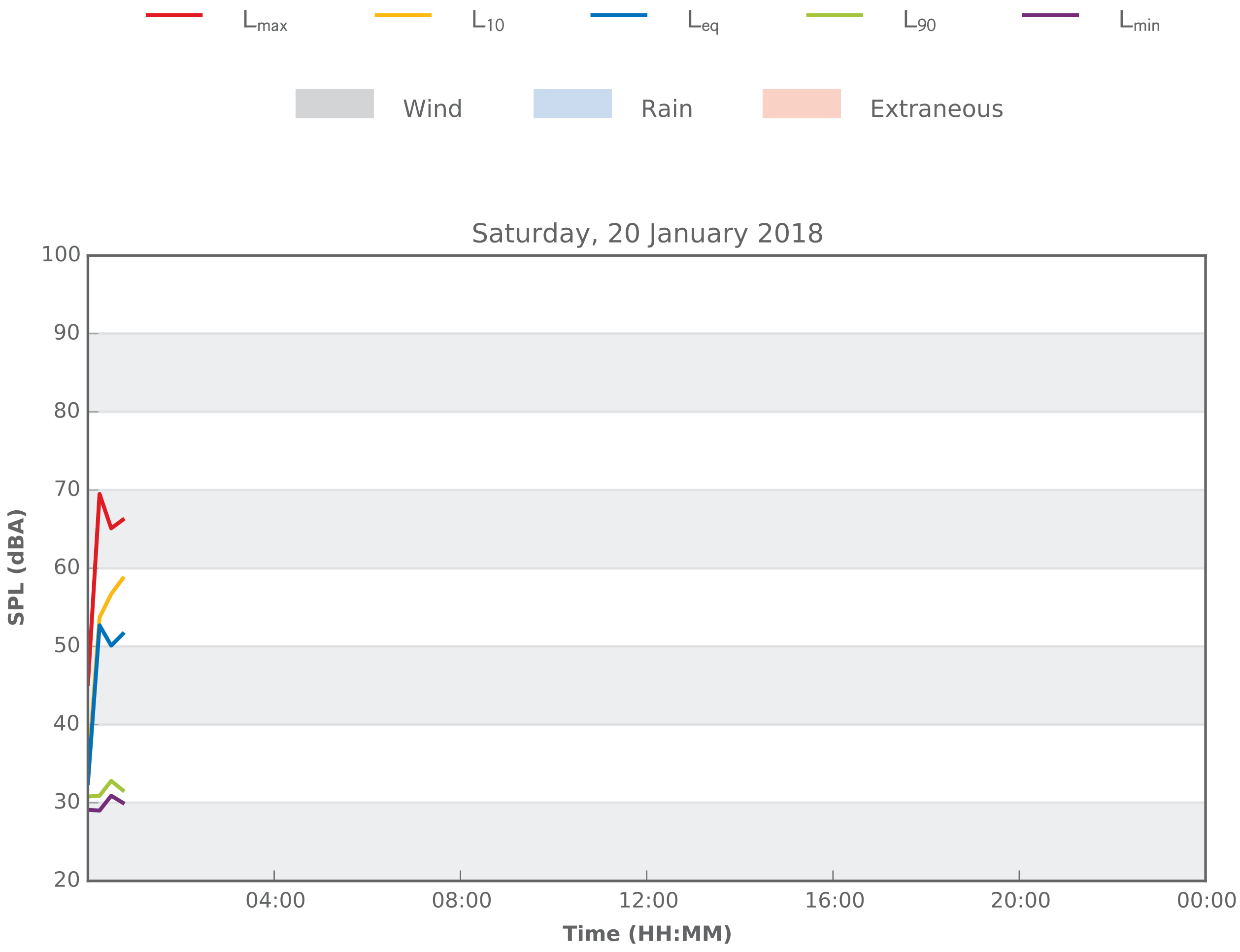
L_{max} L_{10} L_{eq} L_{90} L_{min}

Wind Rain Extraneous

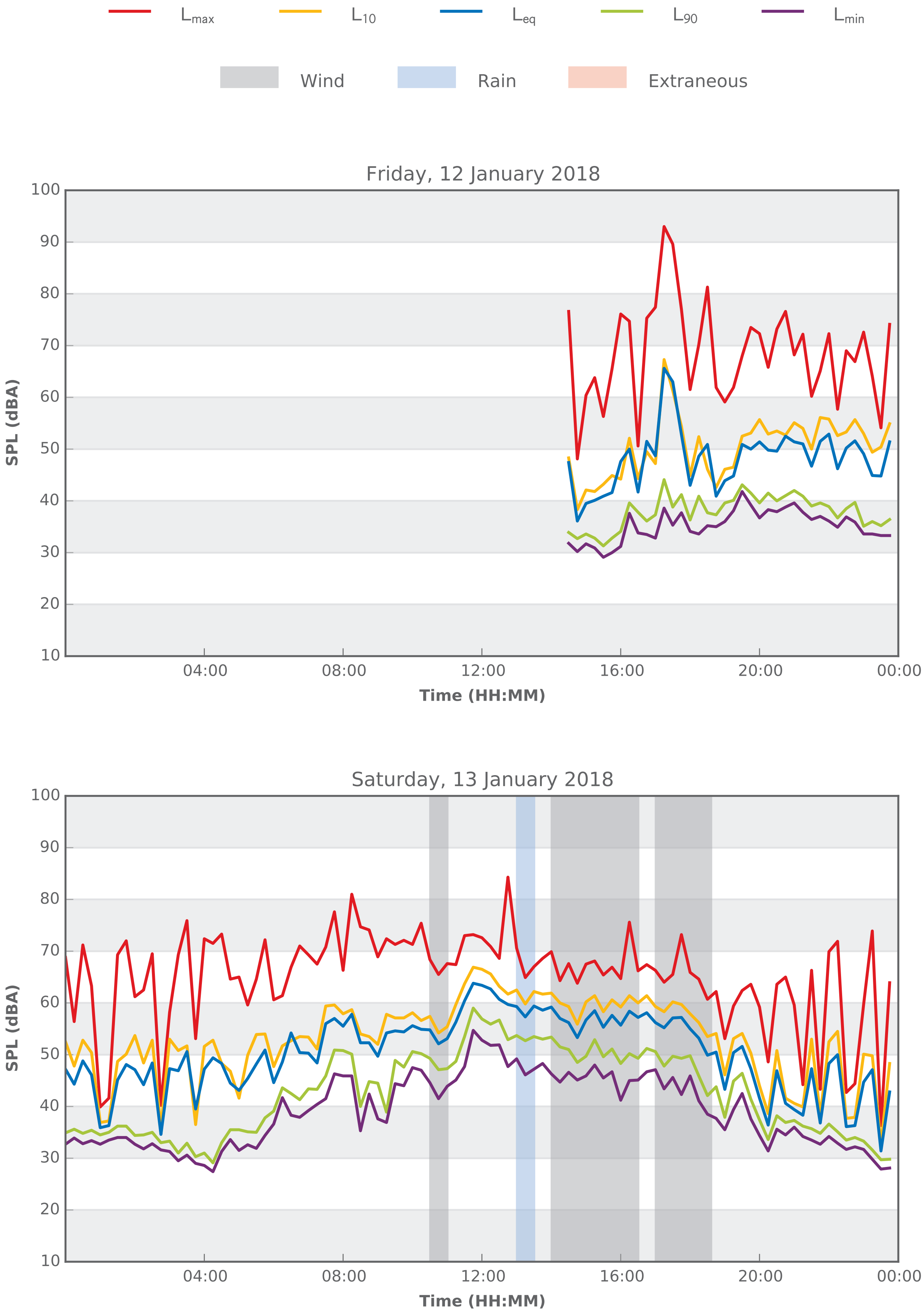




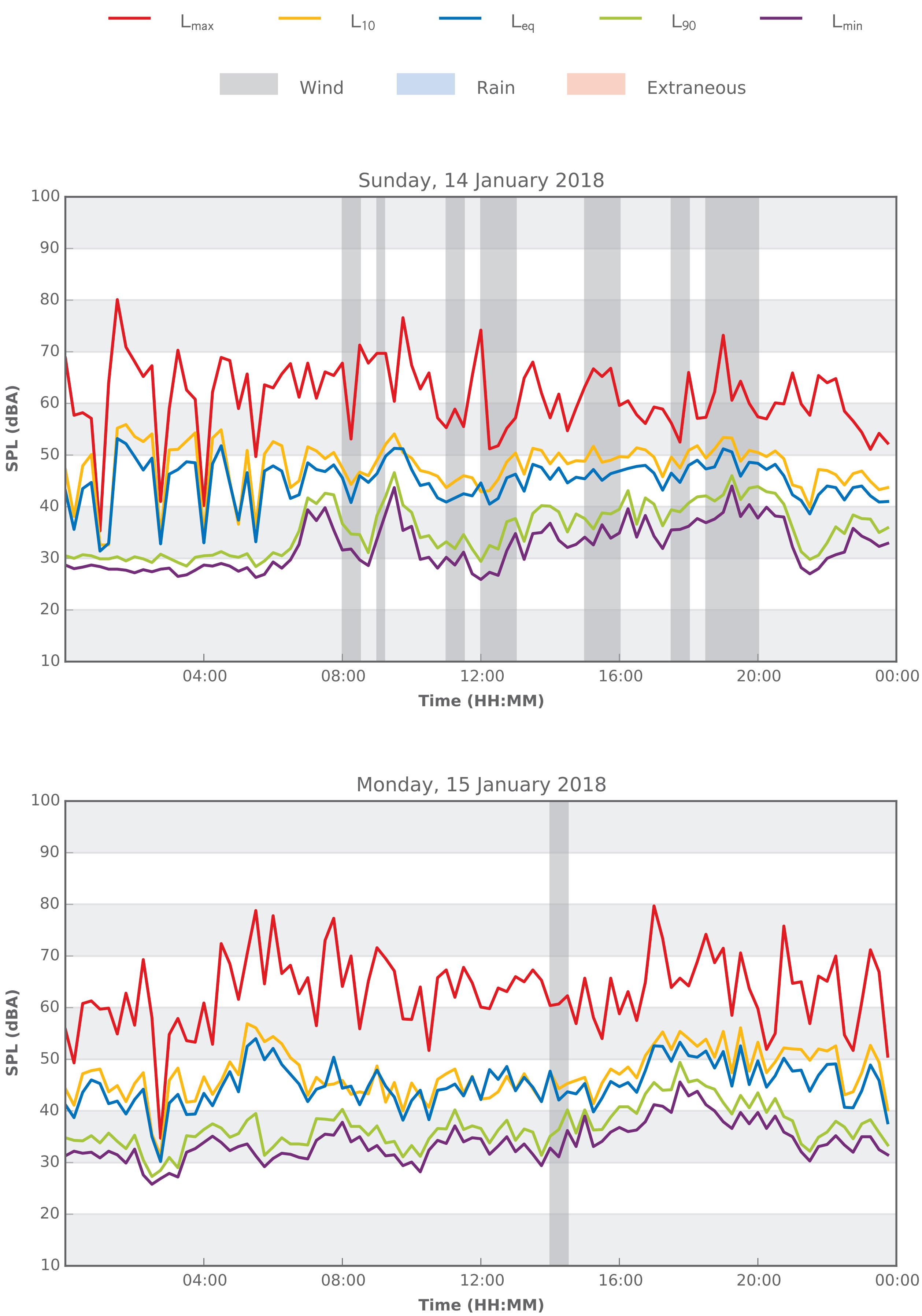
411 Bridgeman Road, Obanvale



Dulwich House, Fallbrook



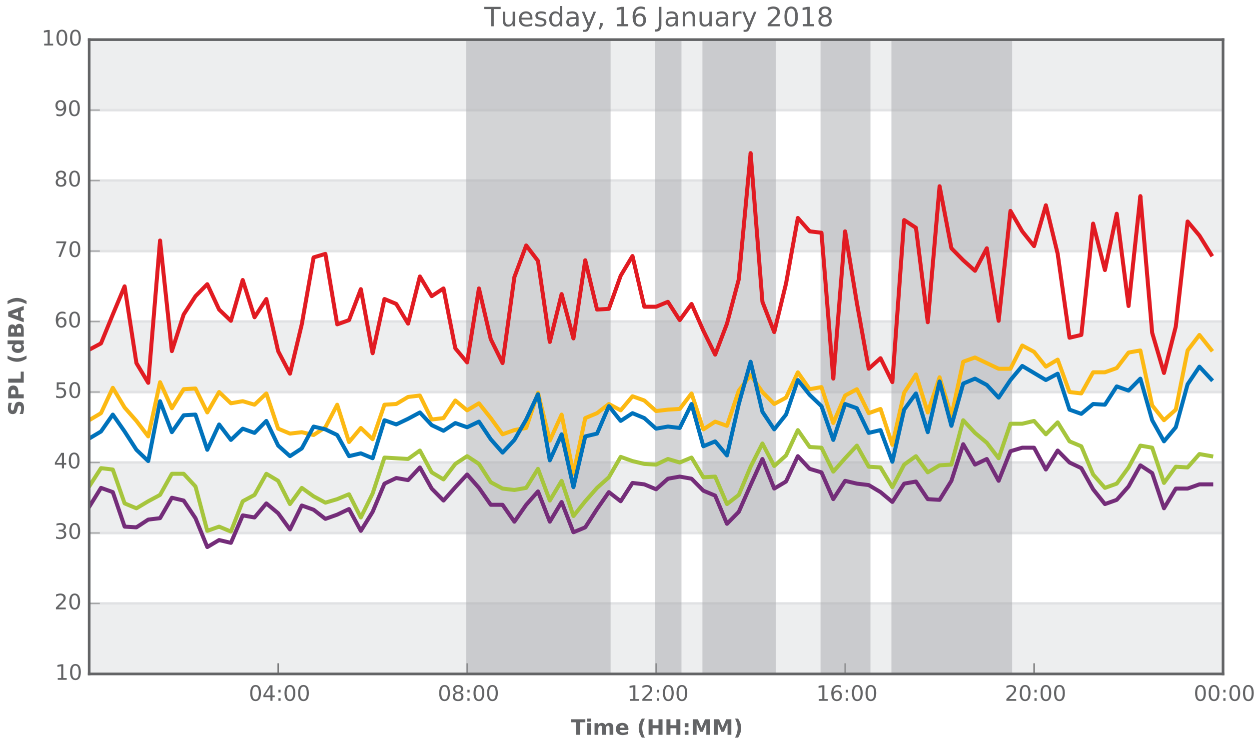
Dulwich House, Fallbrook

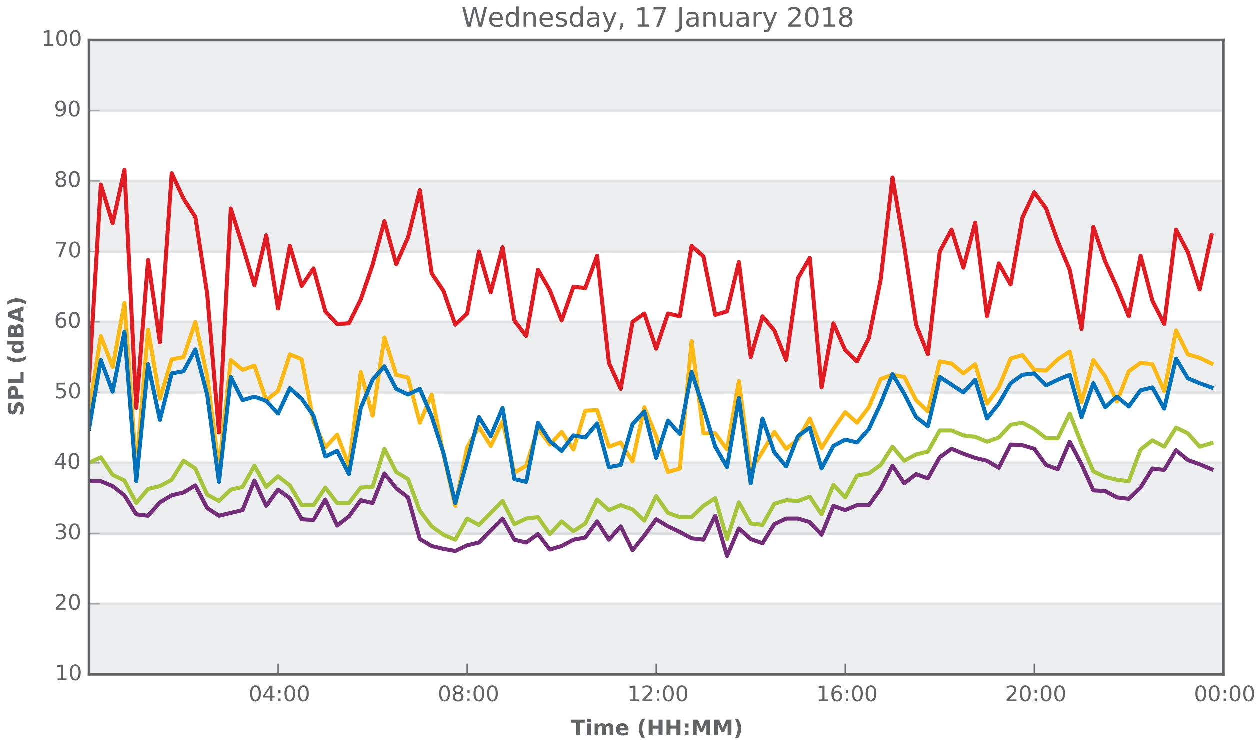


Dulwich House, Fallbrook

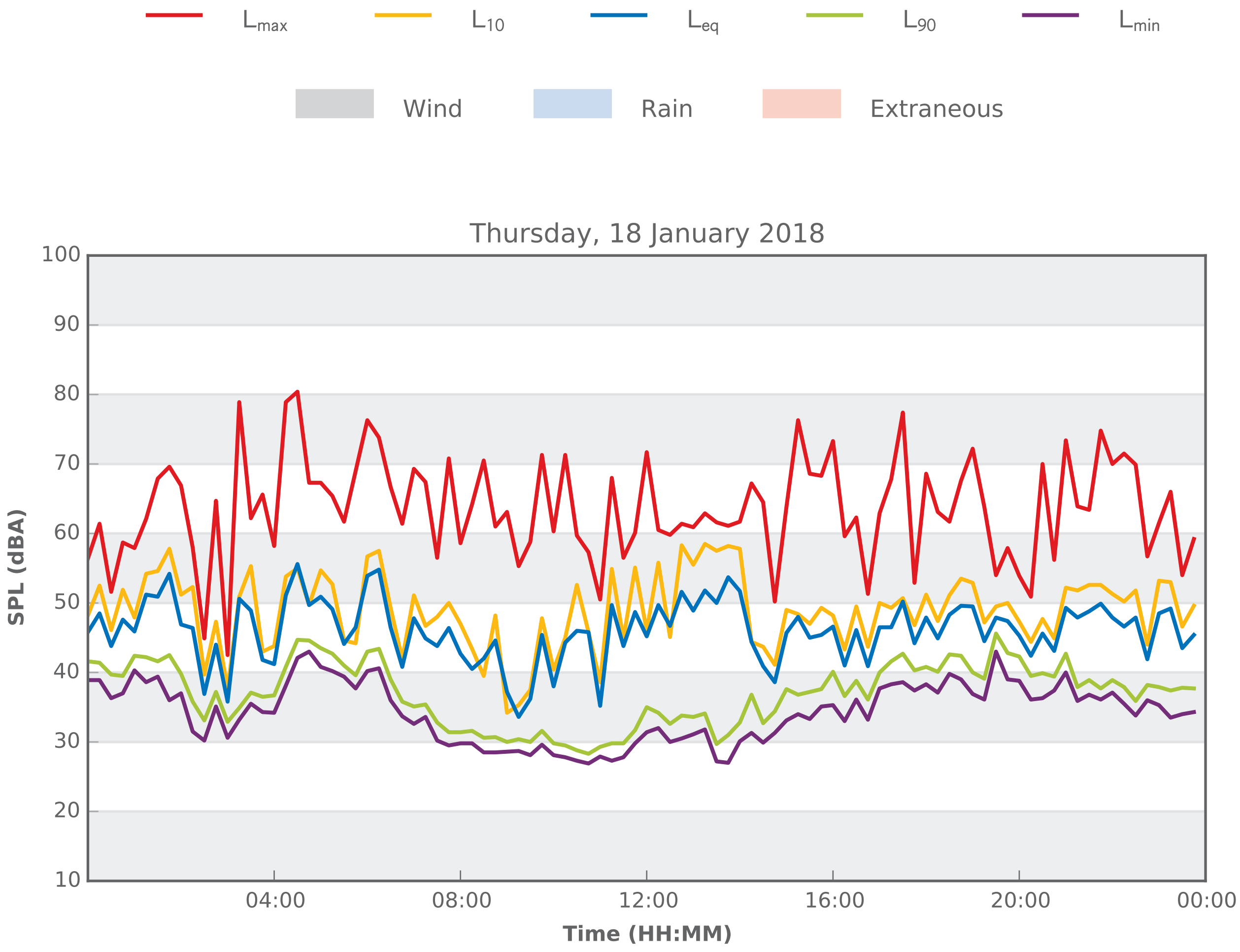
Lmax L10 Leq L90 Lmin

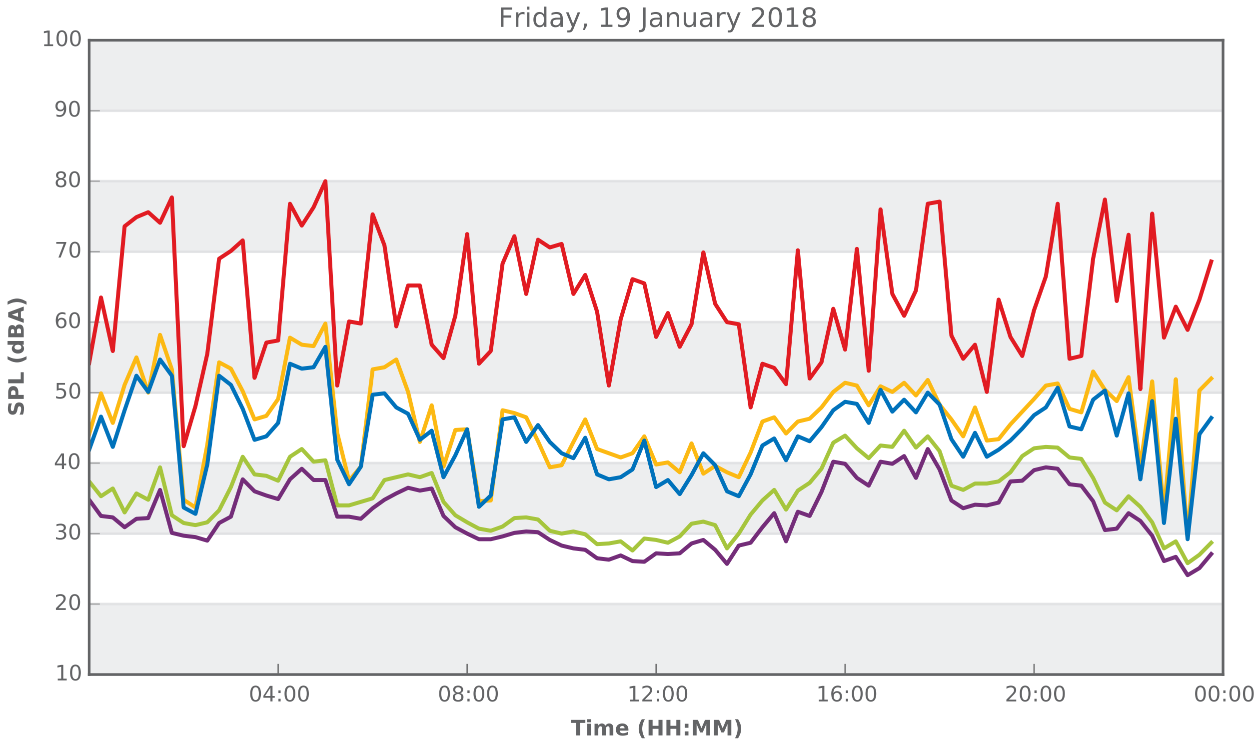
Wind Rain Extraneous





Dulwich House, Fallbrook





Dulwich House, Fallbrook