LOW FREQUENCY NOISE AND ENVIRONMENTAL ASSESSMENT

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Abstract

This paper reviews the NSW Environment Protection Authority (EPA), Department for Environment, Food and Rural Affairs (DEFRA) (UK) and other approaches to the assessment of low frequency noise (LFN) and the relative success or otherwise of these in environmental noise impact assessment. The EPA through its policy provides guidelines for applying 'modifying factor' adjustments to account for LFN impacts. Where there is a difference of 15 decibels or more between the measured 'C' weighted and measured 'A' weighted levels, the policy applies a penalty of 5 dB to the measured noise at the assessment location. The policy also provides similar correction factors to account for tonal and intermittent sources of noise.The EPA's policy has been tested for 15 years and has had serious challenges in practice at large distances from sources. For example, sources that do not emit low frequency dominant spectra would pass the INP test in the near field, but by virtue of increased atmospheric absorption over distance at higher frequencies, would fail (e.g. greater than 3 km) and therefore attract the 5 dB penalty. This can lead to perverse outcomes where properties further from the source with lower noise are defined as more impacted than those that are closer to the source.

The DEFRA process involves measuring the noise in third octave bands between 10 Hz and 160 Hz within an unoccupied room where the alleged LFN source has been observed. If the measured Leq exceeds the predefined levels in any one-third octave band, then this indicates the potential for the low frequency noise to be subjectively classed as a nuisance. The DEFRA process also provides some consideration of the threshold of acceptability for pure and 'beating' tones by the application of a 5 dB penalty. Some European countries adopt similar approaches to DEFRA and others apply an absolute overall difference criterion similar to the INP. Other alternate methods include recommended overall dBC values where annoyance can be expected.

A case study is used in the paper and includes measurement data for locations at varying distances (kilometres) from major industrial facilities to show where LFN impacts are expected according to the application of various guidelines. The focus of the case study is on rural environments with relatively low ambient noise and sparsely populated land. In providing this comparison of approaches, an alternate criteria is developed and is compared to others with regard to practical application and effectiveness of identifying nuisance low frequency noise. The alternate criteria is aimed at providing a direct and practical compliance approach to the assessment of LFN impacts.

1. Introduction

In the context of this topic, low frequency noise (LFN) is noise energy within the range of 10 Hz to 250 Hz, and more specifically the cause of reactions is typically in response to major components or energy below 100 Hz. Human hearing sensitivity gradually decreases with decreasing frequency and so to perceive LFN the energy at such frequencies must be relatively high as compared to mid and high frequency noise, e.g. above 500Hz. Importantly this differs from infrasound which is energy that is necessarily below 20 Hz, that is the 'normal' limit of human hearing. Sound at frequencies below 20Hz can be perceived and are often described as being 'felt' rather than heard.

Previous studies and our experience demonstrate that principally LFN manifests in an annoyance based response and cannot be assessed using the traditional overall 'A-weighted' level [1, 2, 3-5]. Furthermore, people seem to adapt to the loudness relatively quicker than they adapt to the annoyance, and therefore exacerbating the affect due to annoyance. This is specifically so for sound with prominent frequencies below 50 Hz, particularly if the sound exhibits 'beating' [6].

LFN has been raised as an issue by residences near major industrial operations in rural communities for many years. Complaints and submissions on such have been gathered through consultation undertaken as part of typical noise management activities, compliance monitoring and also as a part of social impact assessment consultation typically completed as part of Environmental Impact Statements (EIS) for new or changes to major industrial operations (e.g. mining sites).

2. NSW EPA Industrial Noise Policy (INP)

Where a noise source contains certain characteristics, such as tonality, impulsiveness, intermittency, irregularity or dominant low-frequency content, there is evidence to suggest that it can cause greater annoyance than other noise at the same noise level. To account for this, the INP [7] provides modification factors to be added to the measured or predicted noise levels at the receiver before comparison with impact assessment criteria.

The INP defines low frequency noise (LFN) as that which contains major components within the range 20 Hz to 250 Hz of the frequency spectrum. Section 4 of the INP provides guidelines for applying ‘modifying factor’ adjustments to account for LFN emissions. The INP requires that where there is a difference of 15 decibels or more between the site's measured ‘C’ weighted (dBC) and measured ‘A’ weighted (dBA) levels, then a correction factor of 5 dB is applicable to the measured noise at the assessment location. The INP notes that "C-weighting is designed to be more responsive to low-frequency noise" [7].

The INP's approach to the assessment of LFN policy has been tested now for 15 years and has had serious challenges in practice at large distances from sources. For example, sources that do not emit low frequency dominant spectra would pass the INP test in the near field, but by virtue of increased atmospheric absorption over distance at higher frequencies, would fail (e.g. greater than 3 km), and could perversely attract the INP LFN penalty. The INP LFN criteria were originally intended for testing sources at relatively close range.

3. Department of Environment, Food and Rural Affairs (DEFRA) – Internal Criteria

DEFRA (UK) commissioned the University of Salford to prepare a detailed study on LFN in the community with the intent of formulating a practical LFN criterion to be used in the field by environmental health officers. The *Procedure for the assessment of low frequency noise complaints* (the Procedure) [9], recommends a frequency based reference criterion.

The process involves measuring the L_{eq}, L_{10} and L_{90} averaged over 5 minute periods in one-third octave band centre frequency between 10 Hz and 160 Hz within an unoccupied room where the alleged LFN source has been observed. If the measured L_{eq} levels exceed those in Table 1 in any one-third octave band, then this indicates the presence of LFN that could be responsible for annoyance. The data in the first row of Table 1 are relevant to time-varying noise sources. As provided in the table note, these levels can be relaxed if it can be demonstrated that the source is present during the daytime hours only or if the source is steady (refer second row of Table 1). The procedure states the following with regard to the recommended criterion:

The criterion curve below 31.5 Hz is based on average threshold of audibility for steady sounds. However, individual thresholds vary considerably. Also, unsteady sounds with an L_{eq} lower than the threshold curve may be audible. Therefore, if a sound is recorded as up to say 5dB below the criterion curve this does not necessarily mean it is inaudible to the complainant.

This means that internal noise levels up to 5 dB lower than those presented in Table 1 may be audible to some people if the low frequency noise is varying.

Table 1. DEFRA – low frequency reference curves (internal)

Hz	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Time-varying dB, $L_{eq(5\text{-}min)}$	92	87	83	74	64	56	49	43	42	40	38	36	34
Steady dB, $L_{eq(5\text{-}min)}$	97	92	88	79	89	61	54	48	47	45	43	41	39

Note: The levels can be relaxed by 5 dB if: the source is present during the day only; or if the source is steady as demonstrated by: L_{10} minus L_{90} is less than 5 dB or the rate of change of sound pressure level (Fast time weighting) is less than 10 dB per second, where these parameters are evaluated in the third octave band which exceeds the reference curve values by the greatest margin.

4. Broner Method – External Criteria

Broner [8] provides absolute level criteria for low frequency noise. Broner recommends the following external targets for sensitive receivers:

- Residential
  - night time or plant operates 24/7:
    - desirable 60 dBC L_{eq}; and
    - maximum 65 dBC L_{eq}.
  - daytime or intermittent (1-2 hours)
    - desirable 65 dBC L_{eq}; and
    - maximum 70 dBC L_{eq}

- Commercial/office/industrial
  - night time or plant operates 24/7:
    - desirable 70 dBC L_{eq}; and
    - maximum 75 dBC L_{eq}.
  - daytime or intermittent (1-2 hours)
    - desirable 75 dBC L_{eq}; and
    - maximum 80 dBC L_{eq}

Broner also recommends that if the measured LFN level is fluctuating by at least ±5 dBC then a "penalty" of 5 dBC to the proposed criterion (i.e. a reduction in the proposed limit) should apply. Broner states:

> "When measuring the noise, all energy down to 10 Hz should be considered (the weightings are not defined for frequencies less than the 10 Hz one-third-octave-band and, in addition, do not generally contribute significantly to the overall SPL). Further, a minimum sampling duration of 3-5 minutes should be used so as not to average out the LFN fluctuations which are characteristic of many LFN problems.
>
> The noise levels to be recorded are the maximum and minimum C-weighted SPLs using the Fast time weighting, the LC10 and LC90 levels (the C weighted SPL's exceeded for 10% and 90% of the recording time) for the purpose of providing an indication of the level fluctuation of the LFN. The same metrics are to be recorded using the A-weighting instead of the C-weighting."

5. Case Study

The following case study relates to noise from a relatively isolated industrial site located in a rural setting and its contributions to LFN at a property over 5km away, having very low ambient and background noise typical of isolated rural properties. The suspected primary cause of LFN from the site is a coal preparation plant (CPP). Screens and centrifuges within the CPP are typically known for exhibiting relatively high energy at lower frequencies.

5.1 Monitoring methodology

Four unattended noise monitors were time synchronised and installed at the locations provided in Table 2 and shown in Figure 1. Noise monitoring equipment collected data over 16 contiguous days in June/July 2015. A series of operator-attended noise surveys were also conducted at NM2, NM3 and NM4 at various times during the unattended monitoring period. Operator-attended noise surveys were undertaken using Brüel & Kjær 2250 Type 1 sound analysers, with microphones fitted with seven inch wind shields. All acoustic instrumentation employed throughout the monitoring programme had current National Association of Testing Authorities (NATA) or manufacturer calibration certificates. Instrument calibration was checked before and after each measurement survey, with the variation in calibrated levels being nil or negligible (i.e. not exceeding ±0.5 dB). The operational status of significant sources at the subject site was provided by operators and has been utilised, in conjunction with the noise data obtained from near to the source, in correlating measured data with plant (CPP) operations.

Table 2. Continuous noise monitoring locations and equipment

Ref	Location details	Equipment details[1]
NM1	Approx 190 m NW of source (CPP)	01dB Duo (type 1, 1/3Oct 1-sec logging)
NM2 Intermediate	Approx 2500 m west of source	01dB Duo (type 1, 1/3Oct 1-sec logging)
NM3 Residence (external)	Data not used due to technical issues	-
NM4 Residence (internal)	Front bedroom of residence	01dB Duo (type 1, 1/3Oct 1-sec logging)

5.2 Meteorology

The noise monitoring was conducted during winter which represents a worst-case season in terms of potentially noise-enhancing weather conditions due to colder temperatures and the presence of temperature inversions, as was the case during measurements. Mobile weather stations were installed immediately adjacent to the noise monitors at NM2 and NM3 for the purpose of noise data exclusion (e.g. rainfall and/or wind speeds above 5 m/s as per AS1055.1). The measured parameters include wind speed, wind direction, temperature, humidity and rainfall at microphone height. At site meteorological data at 10 m high was also available. This weather station is located approximately 1 km south-west of the source and approximately 4.8 km west of the subject residence at NM3.

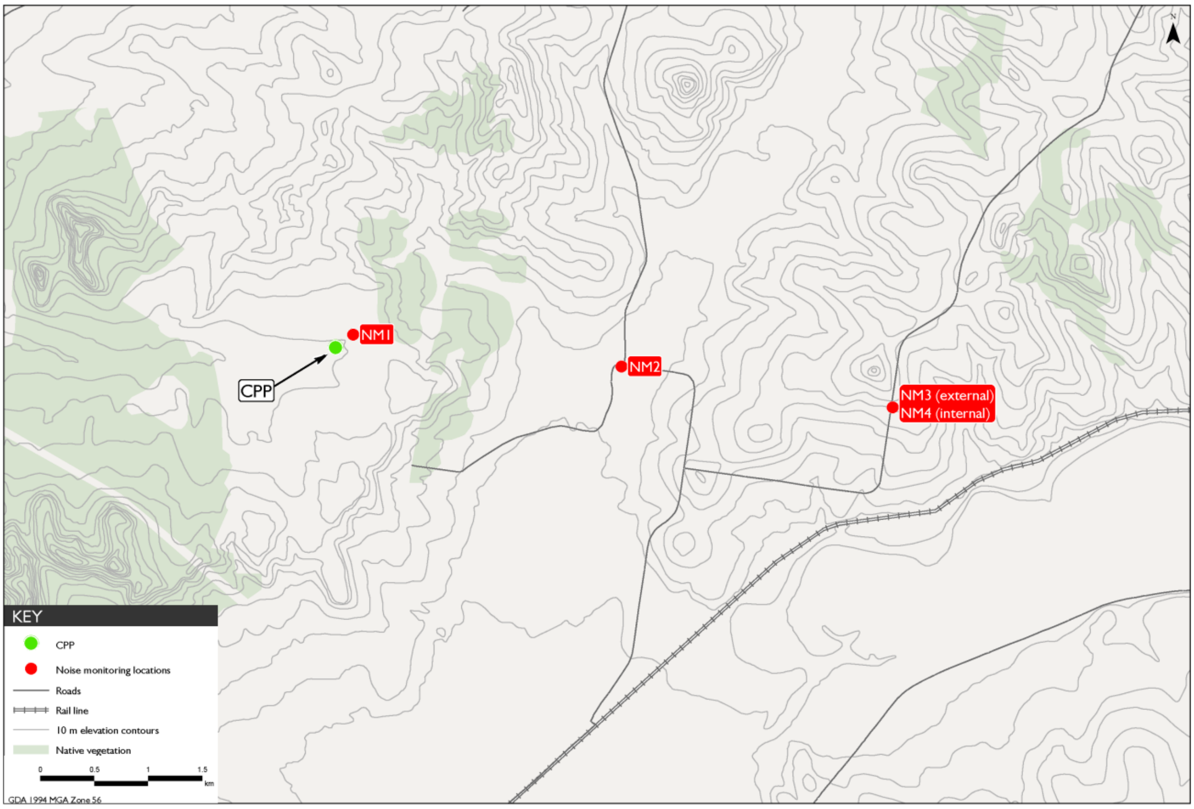

Figure 1. Continuous and attended noise monitoring locations

5.3 Noise monitoring results

5.3.1 Unattended noise levels

The results of unattended continuous noise monitoring can be summarised as follows:

- NM1 (near source): overall A-weighted and C-weighted noise levels are relatively constant at this location with C-weighted noise levels generally 80 dB to 85 dB and A-weighted noise levels generally 55 dB to 60 dB. It is shown that a notable reduction in noise levels (20 dBC and 10 dBA) at this location occurs during plant shutdown which occurred for several hours.

- NM2 (Intermediate): compared to NM1 there is a greater level of variation in noise levels at this location as would be expected. However, similar differences in A-weighted and C-weighted noise levels is exhibited (i.e. typically in the order of 25 dB), indicating the presence of low frequency noise energy. During plant shutdown, overall C-weighted levels at this location reduce by 10 dB to 15 dB. The difference in overall A-weighted and C-weighted levels during the shutdown period decreases but remains in the order of 15 dB to 20 dB. This indicates there is another source of low frequency noise contributing to ambient levels at this location.

- NM4 (Bedroom - internal): C-weighted noise levels typically range from 45 dB to 60 dB. The A-weighted levels are typically very low; often below 20 dB at night and typically in the range 20 dB to 30 dB. During the plant shutdown period there is a decrease in C-weighted levels in the order of 15 dB, indicating that operation of the plant was a contributor to ambient low frequency noise levels during this time. There is no corresponding reduction in the recorded A-weighted level inside the bedroom during the plant shutdown. This demonstrates the likely lack of audible plant noise generally inside the residence (i.e. plant related frequencies below human audibility thresholds at this distance). This finding is consistent with observations made by monitoring personnel.

5.3.2 Operator-attended noise surveys

Operator-attended noise surveys were used to quantify contribution from source using a combination of a low-pass filter (10Hz – 630Hz) on the sound level meter, observations made by the operator while on site as to the level and directionality of audible noise and post-analysis of audio and data files to exclude extraneous noises (e.g. transport related). All readings were conducted during the night period (e.g. 10pm to 7am).

A total of 73 operator-attended noise surveys of 15-minute duration each were conducted at the residence over seven nights during the two week period in June/July 2015 coinciding with unattended monitoring. Almost half the readings concluded site was inaudible. Those conducting the monitoring were experienced and trained acousticians with a number of years of experience. They noted the very low background noise levels at the residence (e.g. 20 dB and 22 dB L_{A90} on a number of occasions externally), particularly inside the dwelling where L_{Aeq} levels dropped below 20 dB. This low ambient level is considered to heighten the occupant's sensitivity to any amount of site related noise, including LFN.

The main contributors to ambient noise levels identified at the subject residence include (in no particular order) trains, farm animals (e.g. cattle, chickens), distant industrial operations (subject site and others), wildlife (e.g. frogs, insects) as well as local and distant traffic. Of relevance to this study are three attended and consecutive readings where site was audible and contributions were relatively elevated compared to others and occurred during 'valid' weather conditions. These were site contributions of 31dBA (62dBC total), 35dBA (67dBC total) and 32dBA (62dBC total). Further analysis of these three survey periods is provided below.

5.3.3 Additional analysis

5.3.3.1 Plant operational and meteorological conditions

Operational and meteorological conditions at the times when noise emissions from plant operations were audible and relatively elevated were examined. Site operations during this time were considered typical and consisted of normal activity.

Meteorological conditions during this time consisted of wind speeds less than 0.9 m/s and F-class atmospheric stability, if estimated using the sigma-theta method as provided in Part E4 of Appendix E to the INP [7], or G-class if estimated using Pasquill-Gifford scheme provided in Part E3.1 of Appendix E to the INP [7].

Five operator-attended noise surveys conducted just before the three subject readings showed site noise was inaudible or otherwise below 30dBA. Similarly, during subsequent nights with seemingly the same or similar meteorology (based on estimation techniques described above), site noise was inaudible or otherwise below 30dBA.

Given there was no significant change in operations during the subject period, the relatively elevated noise levels occurring at this time were considered to have been caused by noise-enhancing weather conditions. It is also worth noting that a second CPP exists a similar distance from the subject house but in an opposite direction to that of the subject CPP. However, given the frequencies in question and the levels measured, understandably operators were not able to ascertain a direction of possible LFN contributions.

5.3.3.2 Spectral comparison

A comparison of the spectral information recorded during each attended survey when noise emissions from plant operations were audible and relatively elevated was conducted. An indicative predicted spectrum of noise from site's CPP is also provided. This prediction is based on the typical spectrum measured at the CPP monitoring location (NM1) and considers attenuation due to distance and atmospheric absorption only. The predicted levels (site only) are well below measured values (all sources), as shown in Figure 2.

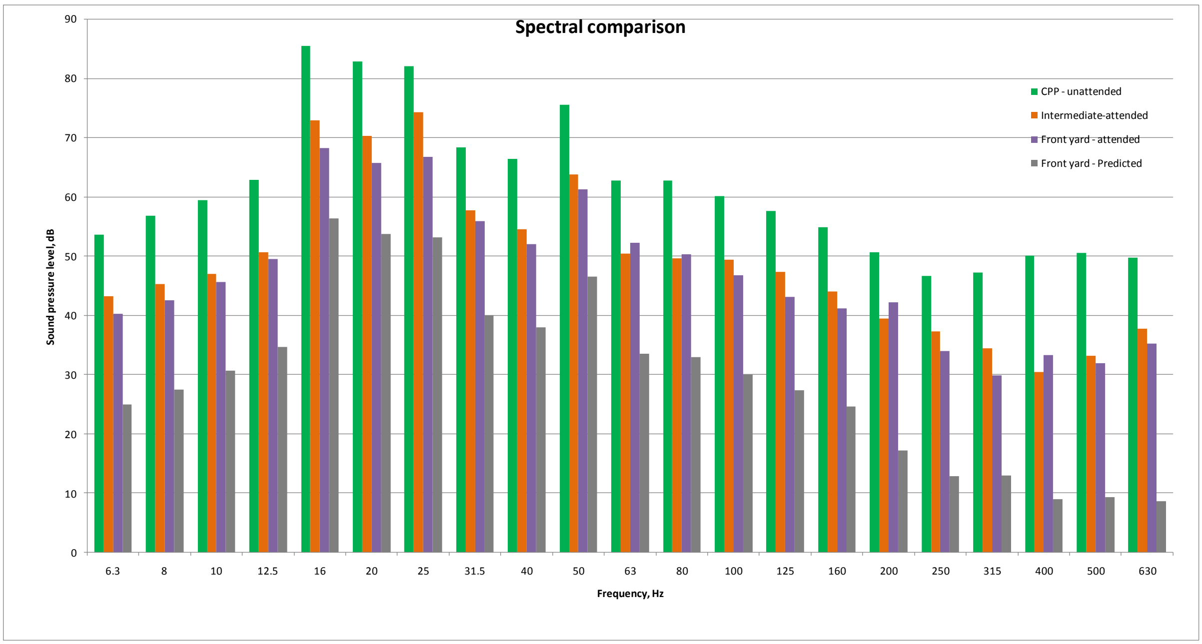

Figure 2. 1/3 Octave band centre frequency spectral comparison

Results of noise measurements using narrowband frequency analysis captured during this time indicate the prominent tones are 17.4 Hz and 24.7 Hz which are consistent with known operating speeds of equipment within the CPP. Noise data from NM1 (close to the CPP) confirms that noise emission from the CPP is dominant in the 16 Hz and 25 Hz one-third octave bands, and also with a peak in the 50 Hz band, likely due to electrical influences. Short-term operator-attended noise measurements were also undertaken inside the bedroom with household appliances (i.e. refrigerator, clocks, air-conditioning) on and off. The level measured in the 50 Hz band was 47 dB with appliances on; with all appliances off the measured level in the 50 Hz band was 28 dB indicating that local (likely electrical) sources are also contributing to the internal 50 Hz noise level.

5.4 NSW EPA INP assessment

An assessment against the NSW EPA INP's LFN approach is relatively straightforward since the site's 'C' minus site's 'A' weighted noise at relatively close range (NM1) and at the intermediate location (NM2) exceed the INP's 15 dB threshold. It therefore follows that this threshold will also be exceeded at further locations by virtue of atmospheric absorption due to additional distance attenuating higher frequencies relative to lower frequencies. The majority of the 39 attended 15minute measurements (that are considered unaffected by weather) at the residence generally exhibit exceedance of the INP's 15 dB threshold. Hence the INP would imply LFN influence and require a penalty of 5dB to be added to dBA contributions from site assessed at a sensitive receiver.

5.5 DEFRA assessment

Figure 3 shows a summary of the noise levels measured inside the residence (NM4) during the three periods where noise emissions from plant operations were determined to be relatively elevated and the CPP was known to be fully operational. This figure also provides a comparison to the DEFRA noise criteria curves; the time varying and steady noise curves are shown. Based on a five minute averaging of noise (as per the DEFRA guideline), the noise from site is characteristic of a time varying noise, as defined in DEFRA (i.e. L_{10}-L_{90}>5dB) for the prominent plant related frequencies of 16 Hz and 25 Hz. Results presented in Figure 3 (noting that this is all noise sources) show that noise levels in the 16 Hz and 25 Hz one-third octave bands (those most relevant to the CPP) are below the relevant DEFRA criteria. Furthermore, the highest 5-minute average noise level measured in each of these two frequency bands did not exceed the DEFRA criteria for the entire two week monitoring period. It is noted that the internal measured 50 Hz noise level was above the DEFRA criteria for most of the subject period. Given the preceding discussion, it is considered that the relatively elevated levels in the 50 Hz band are not site related (and possibly includes influences from house appliances as well as other extraneous sources). It is also noted there was one single 5-minute average noise level that was above the stricter DEFRA curve criteria in the 63 Hz band. This was at the time of a train pass-by event and considered not to be site related.

Figure 4 shows a summary of the noise levels measured inside the front bedroom during the period when the CPP was known to be shutdown. This figure also provides a comparison of measured internal levels to the DEFRA noise criteria curves and shows that the criteria is exceeded in the 50 Hz one-third octave frequency band without the influence of the CPP.

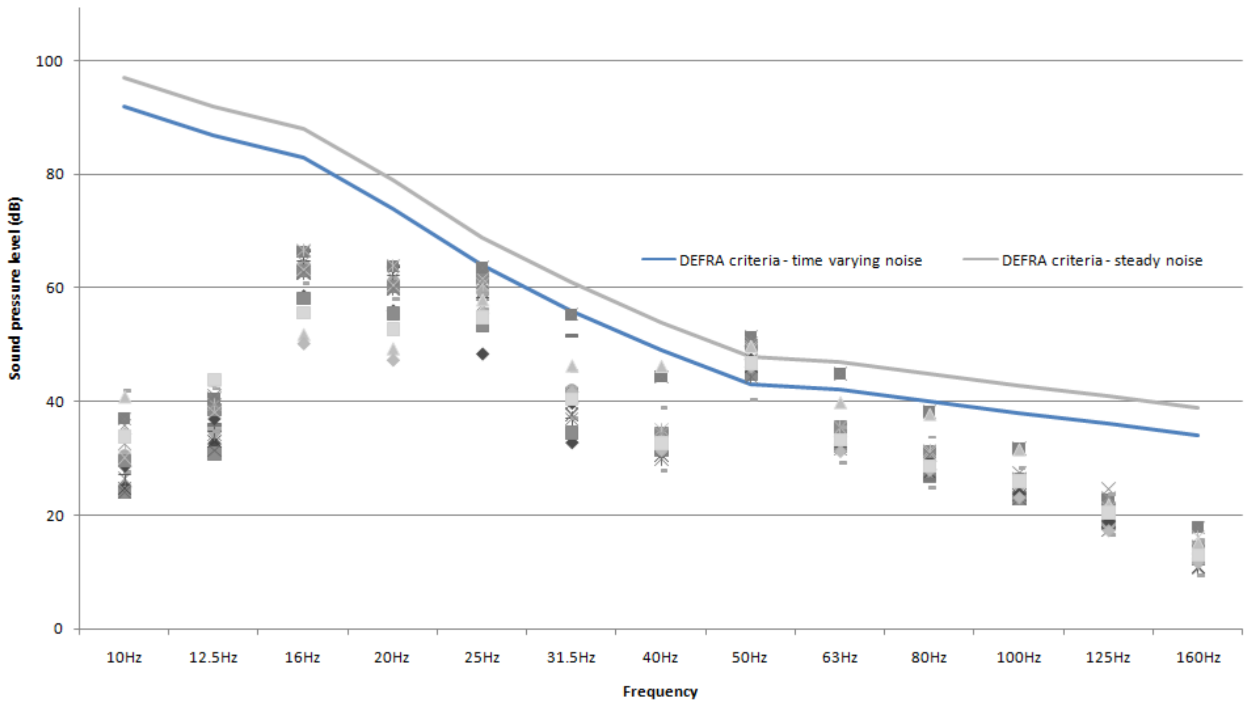

Figure 3. DEFRA assessment with CPP operating (20 indoor 5-min samples)

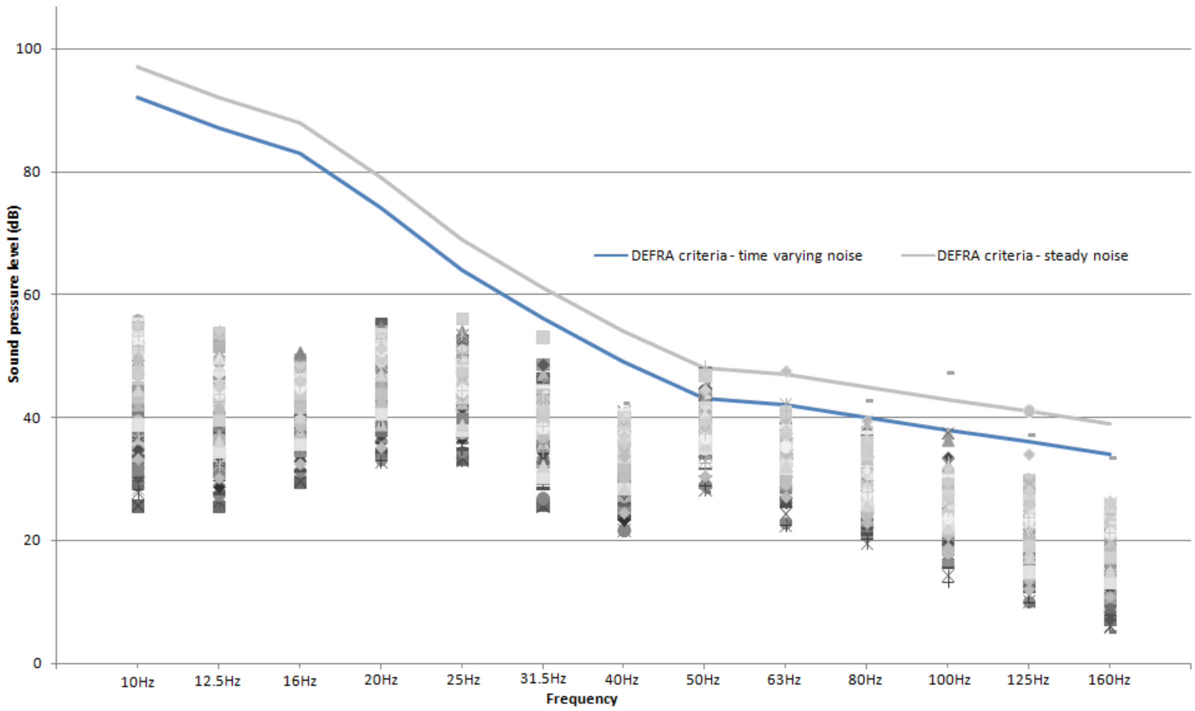

Figure 4. DEFRA assessment - CPP shutdown (172 indoor 5-min samples)

The five minute data measured inside the bedroom for 16 Hz, 25 Hz and 50 Hz one-third octave bands from just prior to the plant shutdown until just after the CPP becomes operational again (approximately 14 hours later) shows a clear reduction in all subject frequencies after the shutdown. As expected, noise levels in all three frequency bands increase and become more variable during the day period noting that noise levels in the 16 Hz and 25 Hz bands are never above the relevant time-varying DEFRA criteria but levels in the 50 Hz band are, on occasion, above the relevant criteria of 43 dB.

Data for the night period following the resumption of CPP operations shows that levels in the 50 Hz band are regularly below 43 dB (DEFRA criteria). It also shows significant variation in the 50 Hz noise level which is not consistent with the relatively constant nature of the noise emission from plant. It is also noted that there was not a strong correlation between the measured overall A-weighted level in the bedroom and the variation in the 16 Hz or 25 Hz levels. This provides further evidence that CPP contributions are at or below hearing threshold levels.

5.6 Broner assessment

Results of operator-attended noise surveys at the residence (externally) show that the overall C-weighted level (for all noise sources) was typically between 55 dB and 62 dB when the subject plant was known to be operating. When the CPP was shutdown, overall C-weighted levels dropped to between 45 dB and 53 dB, although it was noted that operational noise from other site sources was audible occasionally during the CPP shutdown.

The Broner assessment methodology recommends a sampling duration of approximately five minutes. As such, each of the three 15-minute operator-attended surveys where noise emissions from site were relatively elevated and weather conditions were 'valid' were analysed in five minute intervals. The results of this analysis show that, of the nine 5-minute samples, two were below 60 dB (at 59 dB), four were 60 dB to 64 dB and three were above 65 dB (66 dB, 67 dB and 68 dB). The measurements above 65 dB were affected by train noise and distant traffic.

Analysis was also conducted regarding the degree of variation in site-contributed C-weighted noise levels. This was done by examining the operator-attended results during the three 15-minute survey periods at the residence as well as the longer-term results from the unattended monitor at close proximity to the CPP (i.e. NM1). Results indicate that the variation in C-weighted noise levels, both overall ambient and site-contributed levels, was always less than ±5 dBC. Hence, no adjustment is required to the recommended Broner criteria.

The above indicates that site, and in particular the CPP, is a contributor to low frequency noise at the subject residence. Notwithstanding this, total ambient C-weighted noise levels were typically not above the recommended maximum of 65 dB (as recommended by Broner) during any operator-attended noise survey at the subject residence. Allowing for some contribution from non-site related sources, it is expected that site contributions are within the Broner criteria.

5.7 Discussion of results

The monitoring captured a variety of operational conditions, representative of normal operations, including all possible CPP operating modes and train loading activities. Results of operator-attended noise surveys indicated there were three surveys out of a total of 73 lots of 15-minute samples that were relatively elevated and occurred during periods of 'valid' meteorological conditions based on the INP’s sigma-theta method. Although the “low frequency” noise levels from site at the subject residence are below the theoretical threshold of audibility (in the 16 Hz and 25 Hz bands), results of measurements near to operations indicate that the source does have a concentration of energy in the low frequency range and, as such, the low frequency modifying factor would be applicable in accordance with the definition provided in the INP.

Additional analysis included comparison of measured noise levels during these times to other contemporary standards including internal criteria (DEFRA) and external criteria (Broner). Results of the additional analysis can be summarised as follows:

- Site operations, particularly the CPP, are contributors to low frequency noise levels at the subject residence.

- Given there was no significant change in operations during the noise surveys preceding and during the times of relatively elevated site noise levels, it is likely that the increase in noise levels at the residence from site operations were caused by noise-enhancing weather conditions (i.e. a strong temperature inversion).

- It is likely that another source(s) is contributing in the frequency bands of interest (16 Hz, 25 Hz and 50 Hz) at the subject residence.

- Ambient noise levels ($L_{eq(5\text{-}min)}$) measured inside the front bedroom of the subject residence (all sources) did not exceed the relevant DEFRA criteria in the 16 Hz or 25 Hz frequency bands (the dominant frequencies related to the CPP) for the duration of the noise monitoring program.

- Ambient noise levels ($L_{eq(5\text{-}min)}$) measured inside the front bedroom of the subject residence (all sources) were above the relevant DEFRA criteria in the 50 Hz band for most of the period that was the subject of further analysis. Results have indicated that other sources; including train pass-bys and internal electric appliances, are also contributing to internal noise levels in this frequency band.

- Ambient noise levels measured during operator-attended noise surveys outside the residence (all sources) were generally not above the Broner recommended maximum (C-weighted) external criteria of 65 dB. The exception to this was during a single operator-attended noise survey which was affected by a train pass-by and distant traffic. Allowing for some contribution from non-site related sources, it is expected that site contributions are within the Broner criteria.

6. Recommended Alternate LFN Criteria - External

One of the challenges facing regulators, operators and practitioners is monitoring of compliance when LFN is considered present. Hence, it is important to have a practical and simplistic means of doing so. Of the three LFN criteria discussed in this paper and the case study presented, it was evident that a spectral based criteria is best and for practical reasons needs to be assessable external to a sensitive receiver.

The recommended LFN reference curve is based on the UK DEFRA internal curve with a modest adjustment so as it can be applied externally. The adjustment is based on the case study data herein. Samples of attended external and unattended internal $L_{eq15min}$ data for 60 or 72 sample correlations (depending on the available 1/3 Octave band centre frequency) was used. The average differences between external and internal $L_{Aeq15min}$ noise levels is shown in Table 3. Note that samples were for a 'window closed' scenario for a relatively light weight dwelling (and therefore representative of standard or worst case construction).

Table 4 provides the recommended low frequency reference curve for assessment of impacts external to a residence. Two options are provided. Option 'A' where windows are likely to be kept closed (e.g. suburban or urban settings) or where closed windows are facilitated by supplementary mechanical ventilation in accordance with the Building Code of Australia (BCA) requirements. Option 'B' where windows are likely to be open (e.g. dwellings in rural settings unless alternate ventilation is provided).

Noting that the base DEFRA curve for time-varying sources is related to thresholds of audibility, it is recommended that if any 1/3 Octave band centre frequency is exceeded by 5 dB or less, then LFN is considered to be of marginal significance or impact. If the reference curve is exceeded by more than 5 dB in any band, then LFN is considered to be present in significant enough quantity.

If the LFN reference curve is exceeded by more than 5 dB in any band, then the case study indicates that the INP's C minus A 15 dB threshold would also be exceeded. Hence, where compliance with contemporary INP criteria is being assessed (for example), and site is confirmed as the source of that exceedance, the INP's 5 dB penalty should apply to a site's dBA night time (10pm to 7am) contribution before assessing against relevant contemporary dBA statutory noise limits (e.g. typically an $L_{Aeq,15minute}$ limit in NSW).

Table 3. External to internal $L_{Zeq\ 15min}$ average differences

Freq, Hz	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Difference, dB	3[1]	3[1]	3	3	4	7	12	12[2]	13	16	16	20[3]	20[3]
# Samples	60	60	72	72	72	72	72	72	72	72	72	72	72

1. Value based on the 16Hz result and measured values were higher at these frequencies.
2. Value based on the 40Hz result and actual average difference was 9 dB and likely influenced by electrical house appliances internally.
3. Value capped at 20 dB, although actual average differences exceeded 20 dB (being 22 and 23 dB for 125 Hz and 160 Hz respectively). The weakest path for noise in this and dwellings generally is the window. These differences are consistent with transmission loss test data for standard glass (e.g 4mm thick) at these frequencies.

Table 4. Recommended residential low frequency reference curves (external)

Freq, Hz	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
dB, $L_{Zeq(15\text{-}min)}$													
A. Window closed[1]	95	90	86	77	68	61	61	55	55	56	54	56	54
B. Window open[2]	92	87	86	77	68	61	55	49	49	48	46	46	44

1. For 'window closed' this is based on the average differences in Table 3.
2. For 'window open', lower frequencies 10 Hz and 12.5 Hz are considered uninfluenced (as compared to the DEFRA internal base curve - i.e. external and internal levels would not likely differ at these frequencies with open windows). The upper end frequencies 125 Hz and 160 Hz are capped at the typical and commonly accepted 10 dB (relative to the DEFRA internal curve) differential for partially open windows.

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