Are cumulative noise criteria relevant for the assessment of mining noise?

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ABSTRACT

The NSW Department of Planning and Environment undertakes a significant amount of research into the noise generated by open cut coal mines in order to build the knowledge base and to assist industry and regulators better manage these impacts, both individually and cumulatively. The present paper considers a range of simplified theoretical scenarios as well as examining two empirical studies that were undertaken by the Department to investigate cumulative noise impacts of coal mining activities. Together, these works have been used to test a hypothesis as to whether absolute criteria, or relative criteria (as determined by the NSW *Industrial Noise Policy*) is the controlling criterion in regulating noise from these premises. Empirical data were collected under a range of meteorological conditions designed to align with 'worst case' scenarios for the propagation of noise and also allowed estimations of individual mine contributions to the overall noise catchments to be made. The conclusion of the present paper is that due to the geographical size of mines, the relative criteria will be the controlling criterion, and attempts to apply the absolute criteria are unnecessary where the relative criterion of surrounding mines is 40 dB(A) or less.

1. INTRODUCTION

NSW is home to 56 coal mines (NSW Minerals Council, 2016) including some of the largest open-cut coal mines in the world with production from these mines varying from around 2 Mtpa up to more than 30 Mtpa. Because of the way coal seams often outcrop, it is common for multiple mines to operate in the same geographical area to one another, sometimes within a single mine lease. Noise generated on such industrial sites can be regulated in a number of ways including:

- Hours of operation (i.e. 7am – 6pm);
- Prescriptive control of equipment (type, quantity, quality, method of operation, etc.);
- Permissibility of activity (i.e. no pile driving or blasting on site); and / or
- Performance based noise criteria (i.e. noise levels to be met at nearest receiver).

Pragmatically, the control of noise impacts from a mine site will incorporate some, if not all of these options. In recognition that regulators are often not best placed to advise industry on innovative or cost effective methods of noise control, it is common practice for the regulator to set performance based noise goals. If these noise goals can be met, then no further requirements are necessary. If however, these noise goals cannot be feasibly and reasonably met, then there are usually a number of steps that must be followed to justify why the regulator should consider approval of higher limits rather than rejection of the project, or the prescription of other regulatory measures.

2. NOISE GOALS

In NSW the *Industrial Noise Policy* (INP) (EPA, 2000) is the relevant reference for the control of noise generated on industrial premises such as mine sites. Whilst a draft revised document has been released for public comment (*draft Industrial Noise Guideline*, EPA, 2015) it maintains the 'two criteria' approach of the current policy. In setting noise goals, there are two ways in which this may be achieved.

2.1 Relative Criteria

Relative criteria are established when noise limits are set with regard to the existing background noise level (usually measured in absence of the source being assessed) such as 'background + 5 dB'. The objective of limiting excursions of one noise above another is based on the premise that a change in noise level (i.e. a new noise source) can result in increased annoyance if it occurs above a certain base level. In the INP this is known as the Intrusive noise criterion and applies only to the noise generated by individual industrial facilities.

Intrusive noise limits are generally based on the predicted $Leq_{(15\ minute)}$ value that will occur as a result of the industrial source, under typical adverse meteorology. A minimum background of 30 dB(A) is assumed for all areas which corresponds to a minimum limit of 35 dB(A) once 5 dB is added.

2.2 Absolute Criteria

It is more common to set noise objectives based on 'dose/response' relationships. Such noise goals are based on studies of the total acceptable level of industrial noise for the land use of an area. In the INP, this objective is known as the Amenity noise criterion and applies to cumulative noise from all industries impacting on a receiver.

Mines are almost exclusively located in rural land use zones and from Table 2.1 of the INP are assigned a recommended Amenity level of 50 dB(A) $Leq_{(day)}$ (11 hour), 45 dB(A) $Leq_{(evening)}$ (4 hour), and 40 dB(A) $Leq_{(night)}$ (9 hour). It is generally accepted that the relationship between $Leq_{(15\ minute)}$ and a $Leq_{(period)}$ is that numerically the $Leq_{(period)}$ + 3dB = $Leq_{(15\ minute)}$ where period = either the day, evening or night. For the purposes of comparison throughout this present paper, Amenity noise objectives will be converted to the $Leq_{(15\ minute)}$ indice using the 3 dB adjustment factor to give a proxy level of 43 dB(A) for the night time period.

2.3 Ruling Criterion

Whilst the INP requires the assessment of both the Intrusive and Amenity criteria, the most stringent of the two becomes the ruling criterion. In this sense, the Amenity criterion becomes a de facto cap for the Intrusive criterion by limiting the ability of background creep as a noise catchment becomes increasingly industrialised. The objective of the present paper is to examine which is the ruling criterion in areas of intensive mining, and to test the hypothesis that the Intrusive criteria will always be the ruling criterion.

3. METEOROLOGICAL ENHANCEMENT OF NOISE FROM MINE SITES

Typically, open cut mines are able to meet their noise objectives easily during non-enhancing meteorological conditions such as daytime when normal adiabatic lapse rates are the norm. It is generally only under adverse meteorological conditions that mine noise levels approach their approved limits. These adverse meteorological conditions tend to only occur at night, and even then do not last for the entire night. There are two meteorological conditions that can significantly enhance noise.

3.1 Temperature Inversions

As described in detail in Parnell (2015), temperature inversions can cause the homogeneous hemispherical spreading of noise from a source to be altered so that noise normally radiated skyward (and hence of no impact to terrestrial located receivers) is refracted towards the ground. In perfectly calm conditions, such enhancement would occur evenly in all directions, however in most cases, a slight wind or drainage flow (less than 2 m/s at 10 m above ground level (AGL)) will preferentially enhance the propagation of noise in one direction, at the expense of another direction. The INP considers F-Class stability with a 2 m/s AGL wind as representing the limits of typical adverse meteorological conditions. Beyond this, conditions are considered extreme and therefore generally invalid for the purposes of compliance. Once wind speed increases beyond about 2 m/s, then the atmosphere becomes less stable and the ability for a temperature inversion to be maintained is progressively degraded. Very strong G-Class inversions have been observed by the author to increase noise in the order of 15 dB. Anecdotally, enhancements of around 20 dB have been measured in NSW, particularly in the more arid areas.

3.2 Wind Gradient

Even when inversion conditions do not occur, wind can be a major (often the dominant) factor in enhancing the propagation of noise in a particular direction. The INP recommends that conditions where wind is above 3 m/s at 10 m AGL be excluded from compliance measurements as it represents extreme non-typical noise enhancement. However, as is often experienced in the measurement of wind turbine operation, beyond a wind speed of around 3 m/s AGL (approximately a Beaufort Wind Scale of 3) background noise levels will begin to rise due to wind turbulence and foliage noise which will often begin to mask any industrial noise. As a result, observations by the author of noise enhancement due to wind alone have tended to be no more than 6 – 8 dB.

4. CUMULATIVE IMPACTS

By definition, cumulative industrial noise levels result from the combined impact of all industrial sources on a particular receiver location. For developments such as ports or industrial estates, there may be a number of individual businesses or facilities that are located in close proximity to each other. In such a scenario, it is typical that receivers close to the industrial noise sources experience total noise levels that are a combination of 1 – 4 discrete sources depending on how dominant the major noise source is, and the direction in which noise is being preferentially propagated. Receivers located further afield may experience an indiscrete 'industrial hum' made up of all the noise sources in the area, however this will generally be well below any regulatory noise objective.

Open cut mines present a completely different scenario. These are very large industrial complexes in their own right, many spanning footprints of several km in each direction. Because of this, multiple mines cannot be both in the same direction and at similar distance from any particular receiver location. This inability for open cut coal mines to co-habit in very close proximity to each other due to size is significant, it being not possible for meteorological effects to strongly enhance noise from multiple directions at the same time.

5. THEORETICAL SCENARIOS

As discussed, meteorology plays a major role in the level of noise that may be experienced at a receiver location, particularly over the 2 – 4 km buffers that are often associated with open cut mines. To demonstrate the effects of meteorology on noise propagation, a range of indicative diagrams have been developed. Figures 1 – 6 provide an approximation of the influence of a range of typical meteorological effects on a cluster of up to 5 mines surrounding a receiver location. It is recognised that these diagrams do not represent every possible permutation, however they do conservatively represent a range of the worst case scenarios.

Figure 1 is a construction of 2 mines whose noise emissions combine to impact on a receiver location. In this scenario, propagation of noise from both mines is enhanced by the same meteorological condition which results in a logarithmic addition of the individual noise contributions. Where both mines contribute X dB(A), then the resultant impact will approximate X + 3 dB(A), i.e. 40 dB(A) + 40 dB(A) = 43 dB(A).

For the more complicated scenario's in Figures 2 - 6 the sound power level is the same at each mine, however the contribution of each mine has been conservatively adjusted to account for the directivity effect of wind. These figures provide a conceptualised representation of the impact that each individual mine has on a receiver, along with the cumulative impact that would potentially occur under the relevant meteorological conditions.

Table 1 informs the construction of Figures 2 – 6 with calculations based on equation 1.

$$\text{Equivalent Lapse Rate } ^{0}\text{C /100m} = 2.5 \times \text{wind speed (m/s)} + \text{Lapse Rate } ^{0}\text{C /100m} \quad (1)$$

Table 1. Equivalent Lapse Rates

Measurement Parameter	Equivalent Lapse Rate ^{0}C /100m	Approximate Effect dB	Relative to Adverse Prediction of 37 dB(A) at 3 m/s wind
A - C	$^{-}2.0$ - $^{-}1.5$	- 4	27
D	$^{-}1.5$ - $^{-}0.5$	- 1	30
Neutral	*0*	*0*	*31*
E	$^{-}0.5$ - 1.5	1	32
1 m/s (based on D class)	2	2	33
F	1.5 - 4	3	34
2 m/s (based on D class)	4.5	4	35
F + 1 m/s	6.5	5	36
3 m/s (based on D class)	7	6	**37**
G	4 - 8^{+}	7^{+}	38^{+}
F + 2 m/s	9	8	39
4 m/s (based on D class)	9.5	9	40
G + 1 m/s	10.5^{+}	10^{+}	41^{+}
F + 3 m/s	11.5	10	41
5 m/s (based on D class)	12	11	42

Figure 1. Two Mines, Source-to-Receiver Wind

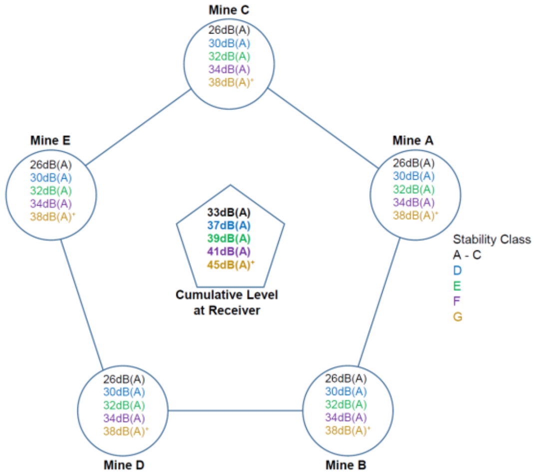

Figure 2. Various Inversions – Calm

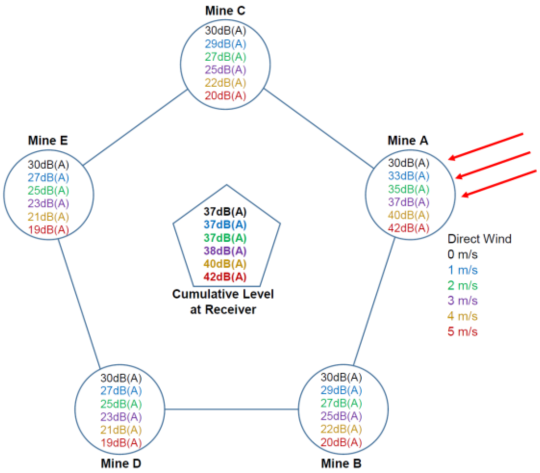

Figure 3. Source – Receiver Direct Wind. Neutral Stability except for calm (0 m/s) which assumes D Class Stability

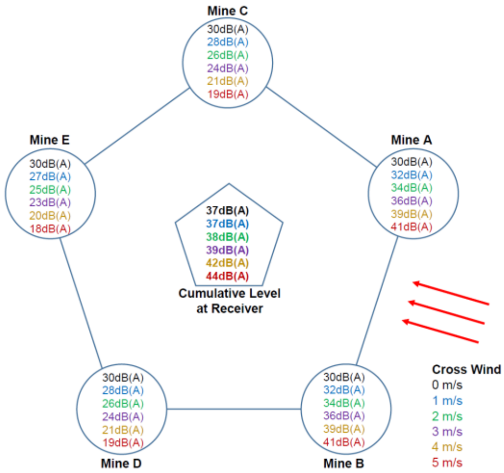

Figure 4. Source – Receiver Cross Wind. Neutral Stability except for calm (0 m/s) which assumes D Class Stability

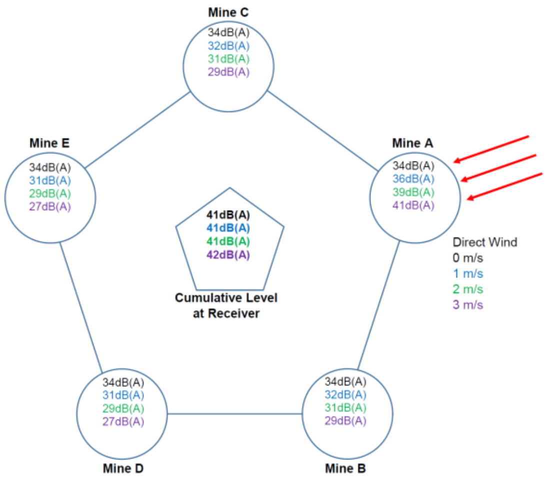

Figure 5. Source – Receiver Direct Wind with F Class Stability

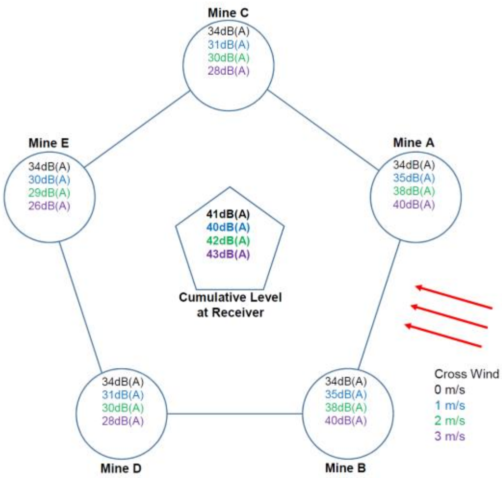

Figure 6. Source – Receiver Cross Wind with F Class Stability

Tables 2 – 5 extrapolate on Figures 2 – 6 and also present the noise impact that would result from a lesser number of mines. The X axis represents the level predicted from the adverse impact from a source-to-receiver direction, being either a 3 m/s wind or an F Class inversion with a 2 m/s wind. For Table 2, given that inversions are present it is assumed that F-Class inversion with a 2 m/s wind would have been modelled as the worst case. In this case an F-Class inversion + 2 m/s wind prediction of 40 dB(A) would equal 35 dB(A) under F-Class Calm conditions.

Table 2. Cumulative Noise Levels that will occur under F Class Stability Calm

Number of Impacting Mines		**Predicted Individual Mine Noise Level (F Class + 2m/s direct source-to-receiver)**					
		39	**40**	**41**	**42**	**43**	**44**
1	(A)	34	35	36	37	38	39
2	(A+B)	37	38	39	40	41	42
3	(A+B+C)	39	40	41	42	43	44
4	(A+B+C+D)	40	41	42	43	44	45
5	(A+B+C+D+E)	41	42	43	44	45	46

Table 3. Cumulative Noise Levels that will occur under 3m/s Direct Wind from A

Number of Impacting Mines		**Predicted Individual Mine Noise Level (direct 3m/s source-to-receiver)**					
		39	**40**	**41**	**42**	**43**	**44**
1	(A)	39	40	41	42	*43*	44
2	(A+B)	39	40	41	42	*43*	44
3	(A+B+C)	40	41	42	*43*	44	45
4	(A+B+C+D)	40	41	42	*43*	44	45
5	(A+B+C+D+E)	40	41	42	*43*	44	45

Table 4. Cumulative Noise Levels that will occur under 3m/s Cross Wind from A - B

Number of Impacting Mines		**Predicted Individual Mine Noise Level (direct 3m/s source-to-receiver)**					
		39	**40**	**41**	**42**	**43**	**44**
1	(A)	38	39	40	*41*	*42*	*43*
2	(A+B)	41	42	*43*	44	45	46
3	(A+B+C)	41	42	*43*	44	45	46
4	(A+B+C+D)	41	42	*43*	44	45	46
5	(A+B+C+D+E)	41	42	*43*	44	45	46

Table 5. Cumulative Noise Levels that will occur under F Class Stability + 2m/s Direct Wind from A

Number of Impacting Mines		**Predicted Individual Mine Noise Level (F Class + 2m/s direct source-to-receiver)**					
		39	**40**	**41**	**42**	**43**	**44**
1	(A)	39	40	41	42	*43*	44
2	(A+B)	40	41	42	*43*	44	45
3	(A+B+C)	40	41	42	*43*	44	45
4	(A+B+C+D)	41	42	*43*	44	45	46
5	(A+B+C+D+E)	41	42	*43*	44	45	46

Table 6. Cumulative Noise Levels that will occur under F Class Stability + 2m/s Cross Wind from A - B

Number of Impacting Mines		**Predicted Individual Mine Noise Level (F Class + 2m/s direct source-to-receiver)**					
		39	**40**	**41**	**42**	**43**	**44**
1	(A)	38	39	40	*41*	*42*	*43*
2	(A+B)	41	42	*43*	44	45	46
3	(A+B+C)	41	42	*43*	44	45	46
4	(A+B+C+D)	42	*43*	44	45	46	47
5	(A+B+C+D+E)	42	*43*	44	45	46	47

N.B. *Italics* highlight the point at which the number of mines and the individual mine contributions combine to approximate the Amenity noise objective of $Leq_{(15\ minute)}$ 43 dB(A).

The INP sets default 'adverse meteorology' conditions as being either a 3 m/s source-to-receiver wind, or a F-Class temperature inversion combined with a 2 m/s source-to-receiver wind. Conditions that result in more enhanced propagation are generally considered to be non-typical, and therefore not valid for the purpose of compliance assessment.

Table 6 shows the two adverse meteorological conditions and what level each mine would need to contribute (up to 5 mines configured as in Figures 2 – 6) in order to achieve a cumulative level of 43 dB(A).

Table 6. Number of Mines and noise level required to meet a total $Leq_{(15\ minute)}$ 43 dB(A)

Number of Impacting Mines		**Adverse Meteorology to Meet 43 dB(A)**			
		Neutral + 3 m/s Wind		F Class + 2 m/s Wind	
		Direct	Cross	Direct	Cross
1	(A)	43	44	43	44
2	(A+B)	42	41	42	41
3	(A+B+C)	42	40	41	40
4	(A+B+C+D)	42	40	41	40
5	(A+B+C+D+E)	42	40	41	40

In summary, these theoretical diagrams and tables show that as a minimum, the Intrusive level of any individual mine would need to have a predicted worst case $Leq_{(15\ minute)}$ noise level of greater than 40 dB(A) in order to equal or exceed the Amenity noise objectives, even where up to 5 mines are located in a noise catchment.

6. EMPIRICAL STUDIES

The second part of this report considers empirical data collected at residential receivers located in close proximity to multiple mines. The Hunter Valley near Singleton has traditionally been home to some of the most intensive mining activities in NSW and provides two excellent examples to test the hypothesis that Intrusive noise limits will be the ruling criterion.

In the first case, Camberwell village has multiple mines located at almost every compass point (similar to mines A – E in the theoretical Figures 2 – 6). For this location, regardless of the directionality of any noise-enhancing meteorology, some mining activity is generally audible.

In the second case of Bulga, multiple mines are all located in a 180 degree arc to the north of the village similar to theoretical mines A – D in Figures 2 – 6. In this scenario, meteorology is such that mine noise is often either enhanced, or is significantly reduced.

6.1 Camberwell

This village is located adjacent to the New England Highway 14 km north of Singleton. As can be seen in Figure 7 it is surrounded by 6 mines located at almost every compass point. Camberwell is a village of approximately 50 residences, however Intrusive noise limits on the mining approvals has meant that offers of voluntary acquisition have been made to more than 90% of the owners. There has been basically full take up of these offers and consequently the surrounding mining companies own the vast majority of residences, with less than 5 remaining in private ownership.

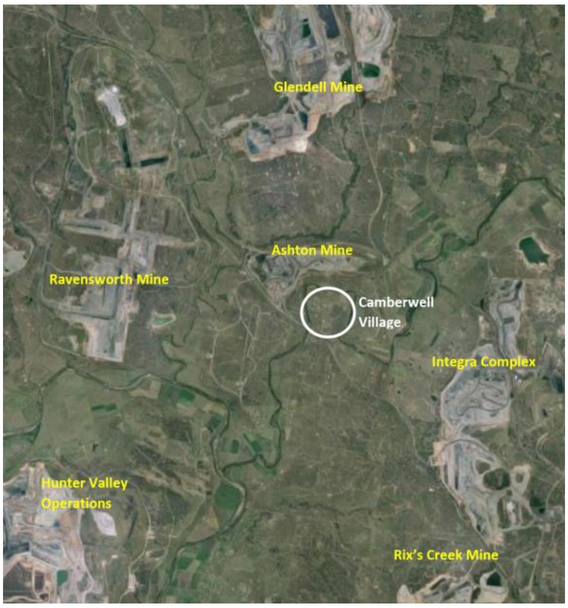

Figure 7. Camberwell

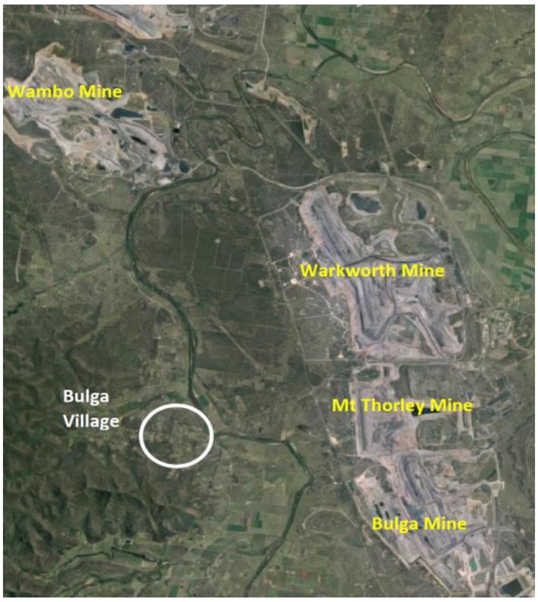

Figure 8. Bulga

In 2009 the author undertook an assessment of noise impacts in Camberwell. The preliminary results of this study indicated meteorological conditions were responsible for significant enhancement of the propagation of mine generated noise towards residences. Further, the findings also indicated that noise was not being enhanced from more than one direction (or mine) at any time.

6.1.1 Camberwell empirical data

Table 7. Measurements at Camberwell dB(A)

Date	Total Leq	Total Leq mine noise	Ravensworth	Ashton	Glendell	Integra	Rixs Ck
31/03/09	48 – 62	IA	IA	IA	IA	IA	IA
1/06/09	40 – 59	36 – 40*	IA	IA	IA	35 – 40*	25
15/06/09	47 – 60	39 – 50*	IA	36 – 50*	36	IA	IA
17/06/09	43 – 63	33	IA	IA	IA	25	32
22/06/09	46 – 59	33 – 44*	IA	32 – 44*	30	IA	IA
Noise Criteria at nearest residential receiver		**43**	**35**	**36**	**35 – 40****	**36**	**35**

NB. * extreme adverse meteorology present.
** some criteria have been established on backgrounds affected by high road traffic noise
IA = Inaudible

6.2 Bulga

The village of Bulga (Figure 8) is located some 20 km to the south west of Singleton and has a population of around 360. Unlike Camberwell, it does not experience the high levels of road traffic noise and consequently has lower background noise levels. While there are 4 major open cut coal mines located within 5 km they are all located within an arc of around 180 degrees of Bulga. Also in contrast to Camberwell, the vast amount of residences have not experienced levels of mine noise that would trigger voluntary acquisition, and hence have remained in private ownership

Between 2010 – 2015 the author conducted numerous noise monitoring exercises and formed the opinion that it was the Intrusive noise criteria that was always the ruling criterion and that it was unlikely that Amenity noise goals would ever be exceeded without first exceeding the Intrusive limits applicable to one of the 4 surrounding mines. In 2015 an extensive noise monitoring study was undertaken to examine the contribution of these 4 mines on the overall noise catchment of Bulga (DP&E, 2016).

6.2.1 Bulga empirical data

From 40 measurements taken over 5 different nights, the following was found:

- Up to 4 individual mines identified;
- 16 times, 2 mines were identified;
- 1 time, no mines were positively identified;
- Of the 16 times that 2 mines were identified, there were 11 occasions when the difference between the dominant mine and the 2nd highest audible mine was 5 dB or more;
- On 3 occasions a 2 dB increase to total mine noise was attributed to 2nd most audible mine;
- There was typically 1 dominant mine and it was usually very difficult to estimate the contribution of the 2nd mine due to low signal-to-noise ratio, very dominate primary mine, or road traffic noise;
- Some mines were generating noise levels much greater than their limits. This was not necessarily a breach of consent, as the meteorology was often invalid.

Table 8. Measurements made at Bulga Village dB(A)

Date	Total Leq	Total Leq mine noise	Wambo Mine	Warkworth Mine	Mt Thorley Mine	Bulga Mine
4-5/3/15	29 - 43	19 - 40	IA	20 - 33	19 - 39	IA - 33
13-14/3/15	34 - 46	26 - 40	IA	25 - 37	20 - 37	IA - 30
14-15/3/15	26 - 40	25 - 38	24 - 31	IA - 37	18 - 37	IA - 36
15-16/3/15	29 - 43	24 - 34	IA	IA - 30	IA - 31	IA - 31
16-17/3/15	30 - 39	29 - 38	IA - 30	21 - 35	27 - 34	IA - 32
17-18/3/15	33 - 43	31 - 40	IA - 30	28 - 39	IA - 33	IA - 28
18-19/3/15	27 - 47	16 - 33	IA - 32	IA - 29	IA - 30	IA - 27
20-21/3/15	34 - 48	28 - 37	IA	IA - 32	26 - 33	IA - 28
21-22/3/15	36 - 43	27 - 38	IA	IA - 36	26 - 36	IA - 33
22-23/3/15	32 - 42	32 - 40	IA	25 - 38	IA - 34	IA - 35
23-24/3/15	30 - 46	29 - 38	IA - 30	26 - 37	26 - 37	IA - 28
14-15/4/15	33 - 39	32 - 38	IA	28 - 36	27 - 34	IA - 34
28-29/4/15	34 - 41	29 - 35	IA	IA - 22	26 - 34	IA - 33
30/4–1/5/15	35 - 44	32 - 40	IA	27 - 37	23 - 36	23 - 34
18/5/15	30 - 42	29 - 37	IA - 26	26 - 33	26 - 34	IA - 30
26/5/15	30 - 37	28 - 36	IA	IA - 21	25 - 32	IA - 35
28/5/15	30 - 38	27 - 35	IA - 29	IA	IA - 34	IA - 28
Noise Criteria at nearest residential receiver		**43**	**35**	**35 - 38**	**35 - 40**	**35**

N.B. IA = Inaudible

From 199 measurements (4 were discarded due to high wind) made over 17 nights, the following was found:

- 60 times, 3 mines were identified;
- 1 time 4 mines were identified;
- Of the 61 times that 3 or more mines were identified, there were 48 occasions when the difference between the dominant mine and the 3rd highest audible mine was 5 dB or more including when 4 mines were identified (on this occasion the 4th highest audible mine was 9 dB less than the dominant mine);
- On 3 occasions a 2 dB increase was attributed to 3rd most audible mine, however this only occurred at low levels when dominant mine was 30 dB or less. This indicates that no noise enhancement by meteorology was occurring;
- Highest Amenity level recorded was 40 dB(A) which is some 3 dB below the upper objective for total industrial noise. At some times during the measurement period, the mines were generating noise levels that approximated their approved limits.

7. DISCUSSION

Tables 7 and 8 present data, some of which was most likely to have been collected under extreme adverse meteorological conditions that are considered invalid under the INP for assessment of compliance. For example, the extreme measurements attributed to Ashton and Integra appear to be a result of strong temperature inversion coupled with light source-to-receiver wind, whereas the lower readings were likely to have been measured under more neutral conditions. Notwithstanding, this data is useful in that it supports the hypothesis that when total mine noise approaches the Amenity objectives (i.e. $Leq_{(15\ minute)}$ 43 dB(A)), then it is individual mines that are responsible for the high readings. Furthermore, the data shows that these individual mines are exceeding their Intrusive criteria (usually 35 – 38 dB(A)) well before the Amenity objectives would be triggered.

As discussed previously, the Intrusive noise objectives are based on background noise levels, whilst compliance of the project depends on being able to meet these objectives under adverse meteorology (typically light winds). Throughout this study it has been shown both theoretically and empirically that when worst-case noise-enhancing conditions are present for one mine due to factors such as wind direction, they will not be present to the same extent for the other mines. Moreover, such conditions will often reduce the impacts of those other mines. It is therefore expected to see one dominant mine when noise-enhancing meteorology is present, and more likely to see multiple mines contributing similar levels under neutral meteorology.

A review of noise compliance data in both the Camberwell and Bulga areas did not identify any times when cumulative noise objectives were being tripped. It was also found that there were no residential receivers with either predicted or assigned Intrusive noise levels greater than 40 dB(A) $Leq_{(15\ minute)}$ unless they were also subject to noise agreements. Furthermore, the author is unaware of any location in NSW where there are multiple mines which would have noise objectives based on the Amenity criteria.

8. CONCLUSIONS

Empirical results show that mines typically operate well below their Intrusive noise limits when neutral meteorological conditions occur, or there are receiver-to-source winds. Under neutral or even slightly enhancing conditions the contribution from 2 – 3 mines and on very rare occasions 4 mines may be able to be distinguished in noise catchments with low ambient noise. Whilst under these conditions, cumulative impacts were recorded, the ability of the 3rd mine to contribute to the noise catchment becomes very limited once it is 5 dB below the dominant mine. It was found that when present, the 3rd greatest contributor was only able to contribute more than 1 dB on a very limited number of occasions. Moreover, this occurred when there were low noise-enhancing conditions with no particular mine being dominant, and the level of any individual mine was 30 dB or less.

When the meteorology is such that noise from a particular mine begins to be enhanced, then there tends to be a corresponding loss of signal from another mine and consequently the number of audible mines reduces. Where background or predictions are such that the individual mines have Intrusive noise criteria of 40 dB or less, then it would require at least one of these mines to exceed its Intrusive limit in order to cause the Amenity level to be exceeded. Therefore, the hypothesis that it should not be necessary to consider cumulative noise impacts is supported - where the surrounding mines have individual Intrusive $Leq_{(15\ minute)}$ noise criteria no more than 40 dB(A).

ACKNOWLEDGEMENTS

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