BEST PRACTICE
ENVIRONMENTAL
MANAGEMENT
IN MINING

Noise, Vibration and Airblast Control

Environment Australia
Department of the Environment

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The series illustration of the Koalas by Christer Eriksson, commissioned by BHP Transport 1988. Reproduced courtesy of BHP Transport.

Cover photo: Blasting underway at Mt Tom Price in Western Australia.

Photo: DFAT

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FOREWORD

Environment protection is a significant priority for our society. A major role for government is setting environment standards and ensuring that individuals and organisations meet them. Increasingly, however, government, industry and community organisations are working as partners in protecting our environment for present and future generations.

Representatives of the minerals industry in Australia and Environment Australia, (the environment arm of the Federal Government), are working together to collect and present information on a variety of topics that illustrate and explain best practice environmental management in Australia's minerals industry. This publication is one of a series of booklets aimed at assisting all sectors of the minerals industry—minerals, coal, oil and gas—to protect the environment and to reduce the impacts of minerals production by following the principles of ecologically sustainable development.

These booklets include examples of current best practice in environmental management in mining from some of the recognised leaders in the Australian industry. They are practical, cost-effective approaches to environment protection that exceed the requirements set by regulation.

Australia's better-performing minerals companies have achieved environmental protection of world standard for effectiveness and efficiency—a standard we want to encourage throughout the industry in Australia and internationally.

These best practice booklets integrate environmental issues and community concerns through all phases of mineral production from exploration through construction, operation and eventual closure. The concept of best practice is simply the best way of doing things for a given site.

The case studies included in these booklets demonstrate how best practice can be applied in diverse environments across Australia, while allowing flexibility for specific sites. Each booklet addresses key issues by presenting:

- basic principles, guidance and advice;
- case studies from leading Australian companies; and
- useful references and checklists.

Mine managers and environmental officers are encouraged to take up the challenge to continually improve their performance in achieving environment protection and resource management and to apply the principles outlined in these booklets to their mining operations.

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EXECUTIVE SUMMARY

Noise, vibration and airblast are among the most significant issues for communities located near mining projects. The growth in public awareness and expectations of environmental performance has led mining companies to focus their attention on the potential impacts arising from noise, vibration and airblast generated by mining activities.

Best practice environmental management of noise, vibration and airblast involves a three staged approach incorporating:

- Impact Assessments—identifies potential impacts and mitigation methods including optimisation of the mine layout or the way in which the exploration program is conducted.
- Management Plans—establishes the existing environmental conditions and details the methods for monitoring and complying with the mine's environmental objectives.
- Monitoring and Audit Programs—assures the Management Plan and quality objectives are verified.

The first step in implementing best practice is to conduct an environmental impact assessment that examines the proposal in detail and identifies all the potential sources of noise, vibration and airblast impact. After establishing existing environmental conditions within a potentially affected community, quality objectives are set for assessing adverse impacts. Where this assessment shows that the predetermined design goals will be exceeded, costed mitigation measures are incorporated which will enable impacts to be effectively reduced.

Developing a Management Plan for noise, vibration and airblast emissions is the second step of best practice. The Management Plan demonstrates the mining company's commitment to achieving environmental goals. The detailed design of noise and blast mitigation measures arises from implementing the Management Plan. Control measures that have been used successfully by companies employing best practice include:

- Selecting low noise plant.
- Additional silencing of fixed and mobile plant and mine ventilation fans.
- Acoustic enclosures around process plant.
- Use of "smart alarms" to minimise complaints regarding reversing alarms.
- Optimising mine layout to shield noise generating plant and haul roads.
- Eliminating tonal components or intermittent characteristics.
- Providing bund walls for acoustical screening.
- Incorporating buffer zones and landscaped setbacks.
- Acoustic treatment of dwellings.
- Reducing the maximum instantaneous charge (MIC).
- Altering the blast drilling pattern and delay layout.
- Using the minimum sub-drilling possible.
- Using alternative rockbreaking techniques.
- Blasting at times that suit local conditions.
- Conduct blasts at a set time or use a pre-warning system.
- Implementing an effective community liaison program.

The third step in the management of noise and blast emissions is to implement a monitoring and audit program. This program provides the mining company with a means to maintain a continuous record of environmental and blast emissions. The audit program also addresses the company's procedures for dealing with complaints and ensuring quality objectives are met.

The benefits of best practice environmental management to minimise noise and blast impacts are immediate and include cost savings through increased efficiency and improved occupational health and safety. In addition to benefiting individual companies in the short-term, the mining sector will profit both economically, and in the improved community acceptance and attitudes towards mining activities.

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1 INTRODUCTION

1.1 SOURCES OF NOISE, VIBRATION AND AIRBLAST GENERATION

Resource exploration, extraction, processing and transportation generally involve plant, equipment and techniques which have the potential to produce significant levels of noise, vibration and airblast, and which may impact on the surrounding environment.

Even at the exploration stage, significant levels of noise, vibration and airblast can be produced, for example from engines, airblast drilling equipment, shot hole drilling and blasting or vibrating machines for seismic exploration (mostly in the search for oil and gas).

With the exception of hand excavation, all other mining and some exploration methods generate noise and/or ground vibration which may disturb the surrounding community unless properly managed through design, choice of equipment, operational controls, physical barriers or a combination of these approaches.

Seismic exploration requires a series of explosive charges to determine underlying geology. In open-cut and strip mines, draglines and large mobile equipment are used in prestripping, topsoil and overburden removal and extraction. Blasting is often used to remove material which is too hard for ripping. In underground mines, drilling, boring, blasting and excavating are used in the extraction process. Hard rock quarries and open pit ore mines generally use blasting or mobile equipment to remove material. Mineral sands and gravels are generally extracted by means of draglining or by bucket, cutter suction or trailer suction dredge.

In each case, the extracted material is subsequently loaded for transportation to a processing plant where crushing, screening, washing, drying and various other processes are conducted prior to final loading and product dispatch.

Good planning is essential to mitigate noise, vibration and airblast impacts which might otherwise lead to unacceptable effects on the community or the natural environment. Optimising the design and layout of a mine, or the way in which an exploration program is conducted, will avoid or minimise adverse impacts and assist in meeting community expectations. In addition, best practice environmental management to minimise noise, vibration and airblast produces long-term benefits to the mining sector by increasing efficiency and improving community acceptance of local mining activities and general community attitudes towards mining. Furthermore it will improve occupational health and safety on site.

While onshore exploration activities are relatively benign, noise and vibration from offshore oil exploration activities is technically different and its environmental effects are distinctive. Therefore it is not considered within the scope of this booklet.

Other booklets in this series which are relevant to noise, vibration and airblast control include *Mine Planning for Environment Protection, Environmental Impact Assessment, Onshore Minerals and Petroleum Exploration* and *Community Consultation and Involvement.*

1.2 WHY NOISE, VIBRATION AND AIRBLAST ARE CONCERNS TO THE COMMUNITY

Noise from mining is a common source of community concern because operational noise emissions frequently occur on a continuous basis. This can interfere unreasonably with day to day activities, particularly concentration, recreation and sleep, and result in an adverse impact on residential amenity.

Vibration and airblast from blasting can lead to community concern primarily due to the fear of structural damage. This fear occurs because people are able to detect vibration at levels which are well below those which result in even superficial damage to buildings and items of heritage value. In Australia this concern may extend beyond man-made structures, to sites of natural or cultural significance such as Aboriginal art and sacred sites and valued landscapes.

Communities can experience noise and vibration impacts from mining operations in many ways. Measures are proposed to limit such impacts in NSW's Hunter Valley, with coal trains affecting residents. These include sound barriers, rubber buffering for rail line supports and additional rail electricification so fewer diesels were needed for haulage.

1.3 BEST PRACTICE MANAGEMENT OF NOISE, VIBRATION AND AIRBLAST

Effective management of noise, vibration and airblast involves a three stage approach incorporating:

- Noise, Vibration and Airblast Impact Assessment—potential impacts are identified and approaches for mitigation are devised.
- Noise, Vibration and Airblast Management Plan—establishes baseline data for existing conditions (of both the acoustic and built environment). It details the methods for monitoring and achieving compliance with the consent conditions and clearly defines the mine's environmental quality objectives.
- Monitoring and Audit Program—assures the means by which the management plan and quality objectives will be verified, documented and modified to meet noise, vibration and airblast levels acceptable to all stakeholders.

It is the purpose of this booklet to set out some of the ways in which a mine can achieve best practice during each of these stages. Case studies have been included throughout to illustrate the effective use of best practice techniques to mitigate noise, vibration and airblast impacts.

2 CHARACTERISING NOISE, VIBRATION AND AIRBLAST AND THEIR EFFECTS

2.1 NOISE, VIBRATION AND AIRBLAST

The word "noise" is generally used to convey a negative response or attitude to the sound received by a listener. There are four common characteristics of sound, any or all of which determine listener response and the subsequent definition of the sound as "noise". These characteristics are:

- Intensity
- Loudness
- Annoyance
- Offensiveness

Of the four common characteristics of sound, intensity is the only one which is not subjective and can be quantified. Loudness is a subjective measure of the effect sound has on the human ear. As a quantity it is therefore complicated but has been defined by experimentation on subjects known to have normal hearing.

The annoyance characteristics of noise are also subjective. Whether or not a noise causes annoyance mostly depends upon its reception by an individual, the environment in which it is heard, the type of activity and mood of the person and how acclimatised or familiar that person is to the sound.

The NSW *Noise Control Act 1975* defines offensive noise as noise which due to its level, nature, character, quality or the time at which it is emitted, is likely to be harmful or offensive to, or to interfere unreasonably with, the comfort of a listener. This definition again serves to highlight the subjective nature of response to noise and shows that there are factors other than loudness and intensity which may lead to a noise being found offensive.

Vibration is the term used to describe the reciprocating motion in a mechanical system and can be defined by the frequency and amplitude of the oscillations. The motion of an object or structure or the moving force applied to a mechanical system is also described as vibration.

In the mining industry, vibration is experienced and/or generated by many items of plant and equipment. The major source of vibration emission, which can be of sufficient strength to cause community concern, is blasting. Also of significance is vibrating machinery, such as crushing and grinding circuits and vibrating screens, which emit very low frequency airborne sound energy. This energy has been described by receivers as "vibration". While this description is not always strictly correct, the low frequency airborne sound waves can sometimes result in what appears as vibration in a structure.

The use of explosives creates airborne pressure fluctuations (airblast) over a wide frequency range. When in the higher frequency range, this energy is audible and is perceived as "noise". At frequencies of less than about 20 Hz, the sound energy is inaudible but is capable of causing objects to vibrate such as the rattling of loose windows and crockery.

A summary of typical levels of noise, vibration and airblast is shown in **Table 1.0.**

By considering noise, vibration and airblast during the mine design and planning phase, control measures can be incorporated, as required, which reduce potential impacts. By so doing, adverse community reaction can be avoided and operations can proceed efficiently. It is generally easier and cheaper to implement appropriate controls (mine staging, use of low noise plant and equipment, screening and optimum blast design etc) in the design phase rather than trying to mitigate adverse impacts once the mine is operational.

Table 1.0 Mining Plant and Operations—Typical Measured Levels

Plant/Activity	**Operating Condition**	**Typical Measured Level**
Noise	**Vibration**	**Airblast**
Haul Truck	Laden Passby	91 dBA Lmax @ 7 m
Haul Truck	Empty Passby	87 dBA Lmax @ 7 m
Product Truck	Laden Passby	88 dBA Lmax @ 7 m
Frontend Loader	Loading	85 dBA Lmax @ 7 m
Primary Jaw Crusher	Crushing	104 dBA Lmax @ 4 m
Haul Truck	Laden/Uphill	98 dBA Lmax @ 7 m
Rockbreaker	Breaking	100 dBA Lmax @ 7 m
Hydraulic Drill	Maximum	100 dBA Lmax @ 7 m
Secondary Screen		98 dBA Lmax @ 1 m
Scalping Screen		92 dBA Lmax @ 2 m
Excavator	Scraping	90 dBA Lmax @ 7 m
Reversing Alarm		92 dBA Lmax @ 4 m
Production Blast		110 dBA Lmax @ 100 m 1.3 mm/s (MIC 50 kg @ 500 m) 113 dB Linear (MIC 50 kg @ 500 m)

2.2 MEASUREMENT AND PERCEPTION ON NOISE, VIBRATION AND AIRBLAST

2.2.1 Units of Measurement

Sound is measured in decibels (dB). When measuring environmental noise, a weighting network is used which filters the frequency of the sound so that it corresponds to the response of the human ear. Noise measurements made using this filtering network are expressed as dBA.

The decibel scale is logarithmic to manage the enormous range of sound pressures able to be detected by the human ear. This often leads to confusion. For instance, if two machines emit exactly the same noise level of 80 dBA, the total noise level is not 160 dBA, but 83 dBA. Also, a 10 dBA increase in sound level represents a doubling of loudness. Typical examples illustrating the decibel scale are shown in **Figure 1.0.**

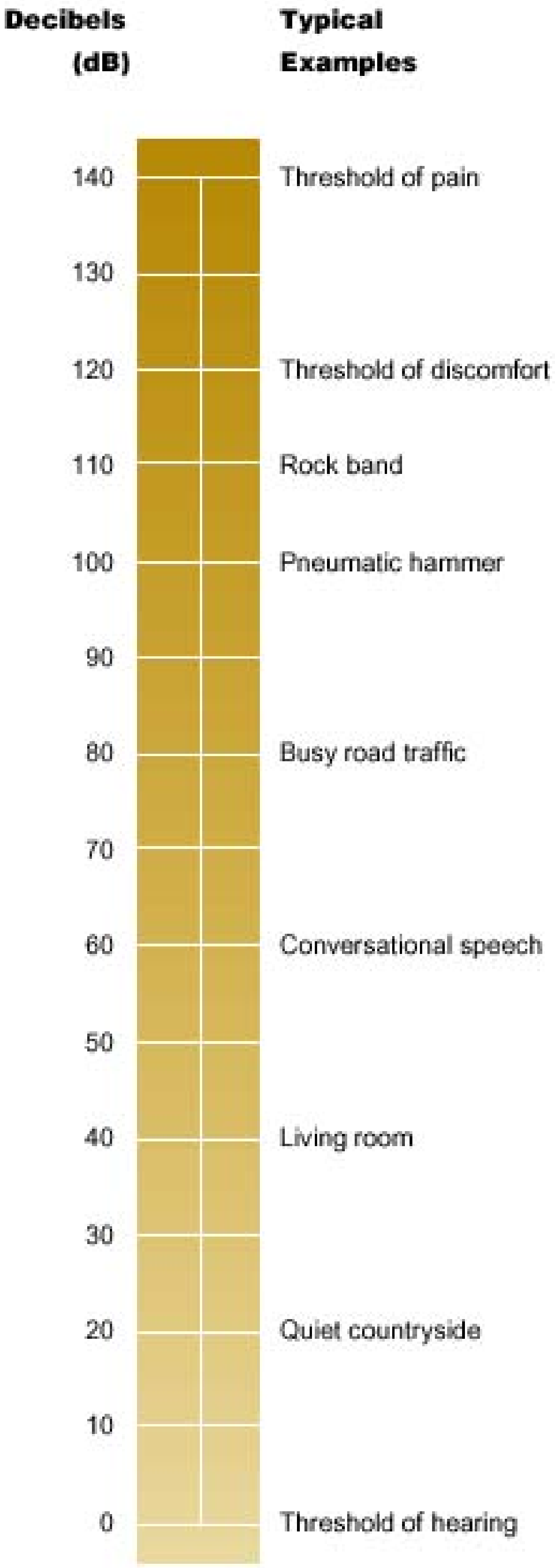

Figure 1.0 The Decibel Scale

Environmental noise levels frequently vary from minute to minute and day to day. To establish a representative overall level, noise surveys are conducted over an extended period of time. The results are statistically analysed and statistical descriptors such as La1, La10, La90 and Laeq are used to refer to environmental noise levels. These quantities are defined in **Appendix A** and a hypothetical noise signal is presented in **Appendix D**.

Ground vibration is measured in terms of velocity and expressed as mm/s which is considered to best describe human comfort and the potential for damage to structures.

Airblast is measured in decibels but no weighting scale is used so the results are expressed as dB Linear.

A more detailed discussion of noise and vibration descriptors is contained in **Appendix A**.

2.2.2 Measuring Noise, Vibration and Airblast

Noise emissions are measured using sound level meters which detect and record changes in sound pressure. Integrating meters also perform statistical analysis and statistical descriptors of interest, such as the La1, La10, La90 and Laeq, can be determined directly from the meter.

For surveys of ambient noise, environmental noise loggers are generally used. This equipment can be set up and left unattended to monitor at suitable locations. The monitoring period selected should be considered sufficient to provide a representative picture of the noise environment. Generally, one week is considered the minimum time required to determine representative noise levels from a site. Of course, the longer the survey period the greater the confidence in the results obtained. Best practice allows for surveys to be conducted continuously over a 12 month period to enable seasonal variations to be recorded. However, this period may be impractical in some cases.

Vibration and airblast levels are detected using transducers (microphones, geophones or accelerometers) and recorded with digital equipment (seismographs or DAT recorders). Seismographs and blast monitors can be left unattended and set to trigger when an emission level exceeds a predetermined level. Ideally, the waveforms of the event should be recorded in order to determine the magnitude and frequency of emissions.

2.3 NOISE, VIBRATION AND AIRBLAST EFFECTS ON PEOPLE AND STRUCTURES

The effects of noise and vibration on the health of people exposed to excessive levels have been extensively documented. Investigations have found that prolonged exposure can adversely affect mental and physical health.

In addition to effects on the body, noise and vibration also cause psychological reactions. The psychological response is determined by personal factors and by factors associated with the noise or vibration itself. The attitude or mood of the person, his or her environment, the degree of arousal or distraction and whether the noise or vibration is felt to be an invasion of privacy or disruptive (particularly involving concentration such as studying, etc) will dictate personal response. The importance of the task being performed, the relationship of the noise or vibration to personal activity, its predicability and how frequently it occurs will also influence the reaction.

There are very specific ways that noise produces psychological effects. These are, essentially, interference with communication and concentration, sleep disturbance and in inspiring fear. These factors lead to irritability which is the first sign of the psychological impact of noise.

Excessive levels of structural vibration caused by ground vibration can result in damage to, or failure of, a structure. People are able to detect vibration at levels much lower than those required to cause even superficial damage to the most susceptible of structures.

Because people are able to "feel" very low levels of vibration (even though they may not be disturbed by the motion), they often over-estimate the risk of damage associated with vibration in buildings. This is particularly true when the source of that vibration is outside the building, and generally not within the occupant's control or when damage may be due to ground subsidence, not current mining operations.

On the other hand, sources of much higher levels of vibration (eg wind, domestic appliances, people walking on floors, slamming of doors etc) are readily accepted due to their day to day familiarity or because they are "within the control" of the occupant.

It is primarily these effects which cause the gradual, long-term fatigue-induced deterioration in most structures considered to be normal ageing. Provided the levels of vibration-induced stress from an additional source are well below those of these "normal" stress-inducing events, then the additional source of vibration is unlikely to accelerate the normal ageing process. A comparison of internal wall strains in buildings is shown in **Table 2.0.**

Table 2.0 Internal Wall Strains in Buildings corresponding to blast vibration levels

Activity	Induced Strain μ m/m	Corresponding Blast Vibration Level (mm/s)
Daily environmental changes	149—385	30—76
Walking	9	0.8
Heel Drops	16	0.8
Jumping	37	7.1
Door Slams	49	12.7
Driving Nails	89	22.4

2.4 EFFECTS OF NOISE AND BLASTING ON ANIMALS

The effect of noise on animals can be similar to the effects observed in humans. Noise can adversely affect wildlife by interfering with communication, masking the sounds of predators and prey, cause "stress" or avoidance reactions and (in the extreme) result in temporary or permanent hearing damage. Experiments have also shown that exposure to noise impulses throughout the night-time sleep period resulted in poorer daytime task performance by animals (see Fletcher & Busnel, 1978).

Research into the effects of noise on animals is relatively scarce. The results obtained from the studies conducted are frequently contradictory or inconclusive. It does appear reasonably conclusive however, that as with humans, animal reactions to noise vary from species to species. Even species that seem perfectly adapted to human noise can show variation in their reactions. It does appear reasonably conclusive however, that as from human to human, animal reactions to noise vary from species to species. Even species that seem perfectly adapted to human noise can vary in their reactions.

It is known that a large number of animals have adapted to the presence of humans and the noise we generate. In fact, many animals live, apparently quite happily, in extremely noisy environments for example, rodents in factories, ships and subways, fish in waters with constant shipping activity and birds and mammals on and around airfields. Although there have been reports of panic and similar "startle" reactions in animals to both fixed and rotating wing aircraft activity, the difference between these reports and field observations around military and commercial airfields may be explained by the learning process and habituation of many animal populations.

Studies conducted on arctic wildlife suggest that the same animal population should be observed over an extended time period at the same location. Busnel (1978) believes that unusual noise, in combination with close proximity visual stimulation, is enough to disturb any animal, including man, and cause panic. He also points out that any sudden and unexpected intrusion, whether acoustic or another nature, can produce a startle or panic reaction. What is due specifically to noise alone is not always known.

Experimentation with the sonic boom, which is a purely acoustic stimulus (with no associated visual or odour stimuli), shows that the behaviour of domestic and also some traditionally shy wild species was unaffected as the result of repeated sonic booms (see Casaday & Lehmann, 1967, Welch, 1970). Bird scare guns are also an acoustic source producing similar results. Farmers have reported birds actually perching on the guns after a couple of days operation.

The learning ability of many animal species is discussed by Busnel (1971). The animal's initial reaction to a new noise source is fright and avoidance but if other sensory systems are not stimulated (for instance optical or smell), the animal learns quite quickly to ignore the noise source, particularly when it exists in the presence of man.

Research into the reactions of marine life to underwater exploratory drilling and extraction suggests considerable variation in the reactions of different species. These variations could be the result of habituation and familiarity effects associated with particular species at each study location and quite possibly could be unrelated to noise.

An excellent review article on the effects of military noise on animals is provided by Larkin R.P (1996).

2.5 METEOROLOGICAL EFFECTS ON NOISE AND AIRBLAST LEVELS

Wind Effects

Steady light to moderate winds produce higher noise levels downwind, and lower noise levels upwind from a given source than in still air. Wind effects on noise are influenced by the following factors.

In general (and depending on the amount and type of local vegetation), a steady, gentle breeze of less than about 1.5 m/s can increase noise levels without increasing background noise levels. On the other hand, winds of higher velocity tend to increase background levels due to turbulence or movement of trees and shrubs, and obscure other noise sources. Downwind, wind velocities up to about 1.5 m/s can enhance noise levels by in the order of 5 dBA relative to still conditions, assuming flat topography between sources and receiver. Conversely, noise levels upwind may be reduced by a similar amount.

It should be noted that noise enhancement due to wind effects is extremely site specific and significant variations from the "typical" changes in level can be expected.

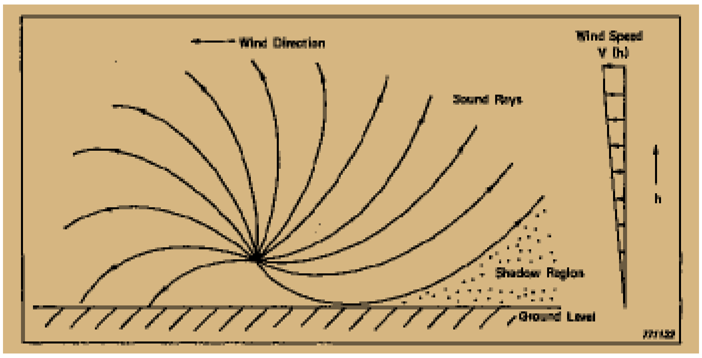

Figure 2.0 Noise Propagation Under Wind Gradient
Source: after Hassall, J R & Zaveri, K, 1979

The second effect, caused by the wind velocity profile in a vertical plane, has a greater effect, and causes refraction of sound radiated at small angles above the horizontal. Some of the upward-directed sound returns to ground level at some distance away, thereby focussing and increasing the sound intensity at that location. This effect is shown in **Figure 2.0.**

The third factor is due to the interaction of the second effect with the intervening ground topography. Under still conditions the natural topography and the developed land profile (ie waste dump and pit) can significantly attenuate mining noise emissions. However, as the wind velocity profile in the vertical plane increases, the sound rays curve downwards, and the mitigative effects of these barriers can be diminished due to noise enhancement which can be in excess of 10 dBA at particular locations.

Airblast is also similarly affected by an increase in wind velocity with altitude. The rate of change of sound speed with altitude modifies the wave front as it propagates from the blast and creates the path that the wave front will follow.

A difference of 5 dB may occur within a 180 degree range in relation to the wind direction at the same distance to the blast site.

Vertical Temperature Gradients

Air temperature normally decreases with altitude, a condition known as temperature lapse. A temperature inversion occurs when a layer of air has its temperature increasing with altitude, or at the boundary between a lower cool layer and a higher warm layer.

Four types of inversion are commonly described: radiation, subsidence, turbulence, and frontal. These are described in **Appendix B**.

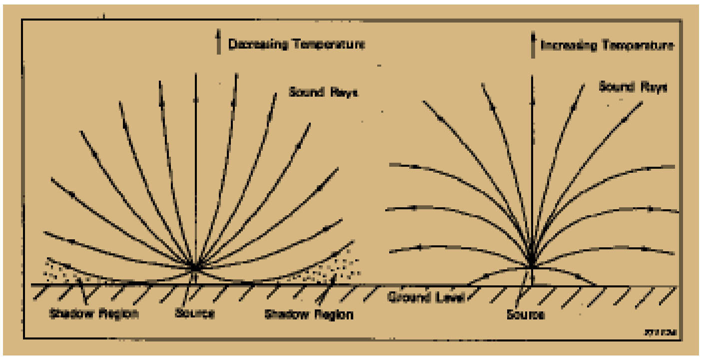

Figure 3.0 Noise Propagation Under a Temperature Inversion
Source: after Hassall, J R & Zaveri, K, 1979

Radiation inversions tend to have a significant impact on noise propagation characteristics, particularly during the winter period. **Figure 3.0** illustrates the mechanism by which noise propagation is enhanced by a temperature inversion. Radiation inversions are normally surface inversions, while the other types are usually upper inversions. It is possible to have simultaneous inversions at different levels.

Low to moderate intensity inversions typically produce a significant acoustical effect at distances of 1 km to 2 km or more from the source. More intense inversions have a significant effect at 300 m to 400 m, and may have an effect at long distance, depending on the depth of the inversion layer. Only surface (i.e. radiation) inversions are significant at shorter ranges.

Radiation inversions are broken by thermal instability in the inversion layer, due to solar heating of the ground. As the inversion breaks, warmer air from above is mixed down into the inversion layer. In winter, inversions commonly break by mid to late morning but can last all day if the upper atmosphere becomes overcast. The break-up is commonly experienced as a very cold morning which becomes quite mild in mid-morning. It can be seen in winter when the brown haze trapped in a distinct layer rapidly spreads to higher levels at some time in the morning. In summer, radiation inversions normally break up within 2-3 hours after sunrise.

In winter, radiation inversions are normally associated with drainage flows. The drainage flow is modified by topography and the extent of this effect would depend on the depth of the inversion layer.

Wind and temperature inversion effects generally apply to all noises. Temperature inversions appear to affect low frequency sound more than higher frequency sound. This is possibly because of the relatively large distances involved, the higher frequency sounds are readily attenuated by other effects (eg atmospheric absorption).

Airblast levels at certain points can be raised by the focussing effects occurring with a temperature inversion. Alternatively sound shadow zones may occur in warmer conditions (towards the middle of the day), in which the airblast levels are lower than would be expected.

Since temperature inversions normally appear at night and disperse an hour or two after sunrise in the summer period, blasting should not be conducted during these periods. During winter, blasting should be confined to the period between mid morning and early afternoon. In areas which are prone to severe inversions, blasting should be avoided on overcast days when possible.

Under extremely adverse temperature inversion conditions, enhancement may be possible at a radius of 2 km or more from the blast site. Substantial variations in the degree of level enhancement can be expected with documented figures of between 8 dB and 20 dB. Similarly, low cloud cover is sometimes reported to "reflect" sound waves thereby increasing their intensity on the ground. This is possibly a result of diffraction (ie bending of sound paths) due to the existence of the atmospheric temperature gradients which occur in the presence of cloud cover, rather than a true "reflection".

In summary, certain meteorological conditions can increase received noise levels.

3 NOISE, VIBRATION AND AIRBLAST MANAGEMENT

3.1 THREE STAGE APPROACH TO NOISE, VIBRATION AND AIRBLAST MANAGEMENT

As discussed in **Section 1.3**, managing of noise, vibration and airblast issues is achieved through a three-stage approach:

Stage 1 Noise, Vibration and Airblast Impact Assessment

Stage 2 Noise, Vibration and Airblast Management Plan

Stage 3 Monitoring and Audit Program

Implementing this approach clearly identifies impacts and issues during the planning phase and appropriate controls can be designed in response. From this process the environmental objectives of the company are easily defined, the methods to meet these objectives are determined and the means of quality verification and documentation established.

3.2 NOISE, VIBRATION AND AIRBLAST IMPACT ASSESSMENT

3.2.1 Major Sources of Noise, Vibration and Airblast

The first stage of the environmental management process is to conduct an environmental impact assessment. The project proposal is examined in detail and all potential sources of noise, vibration and airblast impact are identified. In summary, the major sources of noise, vibration and airblast fall into the following categories:

- Mobile equipment
- Fixed processing plant and equipment
- Transportation (road and rail)
- Blasting
- Construction

For each source of noise, vibration and airblast identified, the proposed operating locations, procedures, schedules and durations are determined for the life of the mining project.

3.2.2 Existing Noise Environment

Another stage in the assessment procedure is to determine the level and character of the existing noise environment. These results are used to establish noise level design goals. Any likely changes in noise level and character caused by the project can be compared to these design goals and thus managed.

Surveys of ambient noise are conducted at selected sites the project may affect. The surveys should be conducted over a sufficient time period to reflect the true and repeated conditions typically experienced in the area which are not unduly influenced by seasonal variations due to temperature inversions, winds, insects etc. In practice, continuous monitoring is conducted for a one to two week period at each nominated site.

Meteorological conditions can significantly influence noise levels. Steady wind, for instance, generally causes an increase in background noise levels. Strong winds and rain can lead to falsely inflated noise levels. The data obtained during such conditions should therefore be discarded. To enable periods of adverse weather to be identified, a weather station should be set up to continuously monitor temperature, wind speed and direction, relative humidity and rainfall. For example, when rain drumming on the microphone and wind blowing across it creates 'high levels' of noise which are actually bad weather.

3.2.3 Design Goals for Impact Assessment

After establishing the existing background noise environment of the area, the design objectives for noise emissions from the various sources can be determined.

Operational Noise

In setting design criteria for noise emissions from continuous operations there are two main objectives:

- That the noise from a development does not greatly intrude above the prevailing background noise level.
- That the background noise level does not exceed the level appropriate for the particular locality, land use and environmental values of the surrounding area once the development begins to operate.

Ensuring background noise levels are generally not exceeded by more than 5 dBA should limit the potential offensiveness of noise from a specific source. An increase is determined by comparing the LA10 noise level at the receptor, with the potentially intrusive noise occurring with the LA90 value determined in its absence. Limiting the level of intrusive noise is the first objective of environmental noise control.

Imposing planning limits helps achieve the second objective of maintaining background noise levels at acceptable limits according to locality and land use.

Consider the cumulative effects when several developments are in operation, or successive mining projects are likely (as is the case in NSW's Hunter Valley). If each development emitted noise levels of up to 5 dBA above the background level, then a sustained increase in ambient noise would occur. This would exceed the second environmental noise control objective.

To prevent successive developments from causing "background creep", planning levels are often set below the existing background to ensure that the cumulative effect does not result in the background noise environment exceeding an acceptable level.

It is generally recognised, however, that in undeveloped rural areas, the existing background levels can be very low. When development is permitted in such areas (for example, in view of its social worth or as a result of government decisions on resource use and infrastructure development), the land use designation may change and there may be a corresponding change in the noise climate.

Construction Noise

When dealing with construction noise, the community is likely to tolerate a higher level of noise if the duration of works is relatively short. Also, construction stage works are frequently associated with noise mitigation measures such as bund walls which shield machinery noise.

Controlling construction noise involves noise level and time restrictions. The shorter the work phase, the more likely that higher level of construction noise will be tolerated. As the length of the construction period increases, the tolerable exceedance of the background level is reduced.

In New South Wales, the Environment Protection Authority has found that exceedances of between 10 dBA to 20 dBA are tolerable for works of reasonably short duration. For works which continue more than 6 months, the received noise levels are more likely to be perceived as being of a permanent nature (ie becoming a permanent part of the noise environment) and a 5 dBA exceedance of the background level is considered more appropriate. The NSW EPA's guidelines for control of construction noise advocate "best practicable means" to minimise noise impact. By permitting short periods of higher noise emissions, construction works can be programmed to restrict activities which generate high noise levels.

Transportation

Design goals to assess noise impact from transportation at mining projects (such as truck and rail traffic) are based upon absolute levels. Numerous social surveys have determined levels of road and rail traffic noise which, if exceeded, are likely to highly annoy a large percentage of the population. The noise from vehicle movements in the mine's vicinity, or between the mine and the stockpiling or processing plant, is assessed in the same way as any other item of mobile or fixed plant. This approach is generally valid as nearby residents probably do not distinguish between the diesel engine noise of trucks and that of other mining equipment.

Several difficulties arise however, in the use of the La10 noise level (and some other statistical descriptors) for evaluating and assessing the impact of a relatively low number of trucks travelling on a private access roadway (or any roadway) leading past residences near a mine or quarry. It is mathematically impossible to calculate the La10 noise level contributions from intermittent, short-term noise events. If the cumulative duration of the truck noise is less than 10% of the assessment period, then the La10 would be almost completely insensitive to the contributed truck noise.

This difficulty is partly recognised by the use of the Laeq (1 hour) noise index for low or intermittent traffic flows of less than about 1000 vehicles per day. This calculation should be based on the maximum hourly vehicle movements which occur, particularly during the night-time. It is an appropriate method by which to assess the noise from product trucks on roadways which are near mines or quarries but are generally remote from the remainder of the extraction and processing operations.

The layout and location of haul roads, machinery and even the mufflers used can reduce noise impact after assessing the noise level emissions of truck traffic. This aspect is discussed further in the *Mine Planning for Environment Protection* booklet in this series.

Noise from rail traffic associated with a development is generally assessed on both an LAeq (24 hour) and maximum noise level basis.

Blasting

British Standard 6472-1992, **Appendix C** gives guidance on satisfactory levels for human exposure to vibration from blasting. For blast induced vibration, it recommends the satisfactory vibration levels for human exposure should not be exceeded by more than 10% of the blasts and that no blast should give rise to vibration which exceeds the same level by more than 50%. For blast vibration up to three blasts per day, the human exposure vibration level is 8.5 mm/s (peak particle velocity) for occupants of residential buildings during daytime. Normally, night-time blasting is not permitted but, when it is, the nominated acceptable level is 2.8 mm/s.

British Standard 7385:Part 2-1993 is a definitive standard in terms of relevant blast vibration damage criteria for the prevention of structural damage, against which the likelihood of building damage from ground vibration can be assessed.

The guide values from this standard for transient vibration, judged to result in a minimal risk of cosmetic damage to residential buildings and industrial buildings, are presented in **Table 3.0.**

The vibration velocity "damage" criteria recommended in the Australian Standards Explosives Code, AS 2187.2-1993, vary according to the type of building and are defined in terms of peak particle velocity (PPV), as shown in **Table 4.0.**

Table 3.0 Transient Vibration Guide Values for Cosmetic Damage - BS 7385.2

Line	**Type of Building**	**Peak Component Particle Velocity in Frequency Range of Predominant Pulse**	
		4 Hz to 15 Hz	**15 Hz and Above**
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Table 4.0 Recommended Peak Particle Velocity - AS 2187.2

Type of Building or Structure	**Peak Particle Velocity**
Houses and low-rise residential buildings; commercial buildings not included below	10 mm/s
Commercial and industrial buildings or structures of reinforced concrete or steel construction	25 mm/s

The standard goes on to say that:

the likelihood of damage in residential areas starts to increase at ground vibration levels above 10 mm/s (peak particle velocity). Structures which may be particularly susceptible to ground vibration should be examined on an individual basis. Peak particle velocity may not be the appropriate criterion for determination of damage. In the absence of a particular site-specific study which may determine the appropriate damage criterion, then peak particle velocity is suggested as the damage criterion and a maximum level of
5 mm/s is recommended for blast design purposes, as experience has shown that damage is unlikely to occur at ground vibration levels below this level.

In terms of damage from airblast, based largely on work carried out by the US Bureau of Mines, the US Office of Surface Mining has presented the following regulatory limits for airblast from blasting (depending on the low frequency limit of the measuring system):

Low Frequency Limit:

2 Hz or lower
6 Hz or lower

Peak Airblast Level Limit:

132 dB (Linear)
130 dB (Linear)

These levels are generally consistent with the level of 133 dB(Linear) nominated in AS 2187.2-1993.

The criteria normally recommended for blasting in Australia, based on human comfort, are contained in the Australian and New Zealand Environment Council (ANZEC) guidelines. The ANZEC criteria for the control of blasting impact at residences are:

- The recommended maximum level for airblast is 115 dBLinear.
- The level of 115 dBLinear may be exceeded on up to 5% of the total number of blasts over a period of 12 months however, the level should not exceed 120 dBLinear at any time.
- The recommended maximum level for ground vibration is 5 mm/s (peak particle velocity [ppv]).
- The ppv level of 5 mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 10 mm/s at any time.
- Blasting should generally only be permitted during the hours of 0900 hrs to 1700 hrs Monday to Saturday. Blasting should not take place on Sundays and public holidays.

Measuring and recording ground vibration and airblast is conducted at potentially affected residences or sensitive receiver locations.

3.2.4 Modelling and Predicting of Noise and Blast Emissions

Predicting noise emissions from mining projects is usually conducted using environmental noise modelling software. RTA Technology Pty Ltd's Environmental Noise Model is currently the most frequently used package. Although knowledge of atmospheric propagation and ground effects is presently incomplete, the acoustical algorithms used have been endorsed by ANZEC and all state environment authorities throughout Australia as being the most appropriate currently available.

Another such model is SoundPLAN, developed in Germany by Braunstein & Berndt GmbH. This software is written to implement various internationally recognised noise prediction codes. The project model developed using SoundPLAN generates noise emission levels and noise contours taking into account factors such as source sound power levels and location, distance attenuation, ground absorption, air absorption, acoustical shielding and meteorology, including wind effects.

Noise modelling procedures are discussed in **Appendix C**.

3.2.5 Design of Mitigation Measures

Costed mitigation measures should be incorporated where assessments of predicted levels of noise and vibration show the recommended design goals will be exceeded as the result of a mining or quarrying project. These demonstrate that impacts can be effectively reduced and acceptable limits can be achieved within a given budget.

3.3 NOISE, VIBRATION AND AIRBLAST MANAGEMENT PLAN

3.3.1 Development and Implementation

The noise, vibration and airblast management (NVAM) plan should be developed during the mine planning phase. Its major purpose is to demonstrate the company's commitment to achieving environmental goals by clearly establishing the existing environmental noise and structural conditions, stating the design objectives, statutory requirements, control measures, emissions monitoring and reporting program and procedures for handling of any exceedances and complaints and community liaison procedures.

Developing such a plan is often a condition of approval and implementing the plan will fulfil licensing requirements.

3.3.2 Control Measures for Noise

In developing the NVAM plan, acoustical and blast trials are usually conducted. These investigations help optimise the mine plan and blast design. Subsequently, appropriate noise and blast mitigation measures can be selected and designed in detail.

Detailed computer modelling is used to investigate the control measures required to maintain noise emissions at acceptable levels. Measures which are commonly adopted include (in order of decreasing effectiveness):

- Selecting low noise plant and equipment incorporating available noise control kits. This should be among one of the first measures chosen to minimise noise impact. For example, exhaust and radiator silencers on large earthmoving plant will generally result in a 5 dBA noise reduction.
- Adding attenuators to mine ventilation fans. As with silenced plant items, this should be one of the first management options to ensure that fan noise levels will be reduced by a predetermined margin and emissions will not exceed acceptable limits.
- Providing acoustical enclosures and acoustical treatment of process buildings. This is a very effective solution for crushing plant, coal washeries and the like. A reduction in the order of 10 dBA can be expected from a lightweight sheet metal enclosure. Ventilation openings should be oriented away from noise sensitive receivers.
- Regulating emissions from reversing alarms. "Smart" alarms can be selected which limit the reversing signal to 10 dBA above the ambient noise level, thus reducing intrusiveness particularly at night (see Case Study 3).

- Optimum placement of waste dumps, location of haul roads, location of fixed plant such as crushers and loading hoppers. Waste dumps, stockpiles etc can be used to shield fixed items of plant which generate noise. Well considered placement of haul roads is illustrated in Case Study 1.
- Eliminating tonal, impulsive or intermittent noise emission characteristics. These characteristics are more likely to cause annoyance because the likelihood of complaints is less for a continuous broadband noise than one which is intermittent and/or tonal. Tonal components are often due to a fault in the machinery and may be eliminated by appropriate maintenance.
- Provision of sound walls and acoustical screening. This option is generally effective when plant is operating at ground level in close proximity to the bund wall. Also, earth embankments can often be constructed from overburden, etc from stripping and initial excavation works and provide an alternative means of stockpiling soil for future rehabilitation works. However, the use of bunding becomes less effective the further the noise source and the receiver are located from the bund.
- Incorporating optimum buffer zones and setback distances. This is only of use where large distances are involved. In general, doubling the distance between the source and receiver will result in a 6 dBA reduction in noise level.

- Acoustically treating dwellings. This is generally seen as a last resort as the overall reduction achieved often does not justify the cost involved. Also, no improvement in outdoor amenity is achieved.

3.3.3 Control Measures for Vibration

Blast design can be altered to result in reduced levels of ground vibration by:

- Reducing the maximum instantaneous charge (MIC) by using delays, reduced hole diameter and/or deck loading.
- Blast vibration research shows the level of ground vibration is proportional to the Scaled Distance (vibration) which is defined as the distance to the blast divided by the square root of the MIC. So, at a given distance, reducing the MIC will generally result in lower levels of vibration.
- Changing the burden and spacing by: altering the drilling pattern, and/or delay layout, or altering the hole inclination.
- The optimum use of explosives in blasting occurs when the available energy is efficiently used in fragmenting and moving the rock. When the hole inclination (relative to the force angle) is decreased or the burden and/or opening are increased, the explosive energy cannot fully fracture the rock and the energy instead dissipates through the ground in the form of vibration.
- Exercise strict control over spacing and orienting all blast drill holes.
- As mentioned above, greater than optimum blasthole opening and orientation results in a greater degree of confinement and higher levels of ground vibration.
- Use the minimum practicable sub-drilling which gives satisfactory toe conditions.
- Less than optimum sub-drill in blastholes results in "toe" being left after the blast, ie rock remains intact above the level of the previous bench floor. Too great a sub-drill will result in higher levels of ground vibration due to confinement of the explosives.
- Investigate alternative rockbreaking techniques.

- Hydraulic rockbreakers and digging and ripping of product and overburden can (where feasible) ameliorate excessive levels of vibration caused by blasting.
- Establish times of blasting to suit local conditions.
- Least disruption and concern is caused by blasting when firing times are scheduled to coincide with periods of high activity rather than when people are sitting and relaxing in their homes.

3.3.4 Control Measures for Airblast

To reduce airblast the following measures can be investigated and incorporated where found to be effective:

- Reduce the MIC.
- Blast emissions research has shown that the level of airblast at a point is proportional to the Scaled Distance (airblast) which is defined as the distance to the blast divided by the cube root of the MIC. Hence, at a given distance, reducing the MIC will generally result in lower levels of airblast.
- Ensure stemming depth and type is adequate.
- Excessive levels of airblast are often associated with stemming ejection which commonly occurs when drill cuttings are substituted for stemming aggregates. Optimising the depth of stemming should also maximise energy release into the overburden or ore body.
- Eliminate exposed detonating cord and secondary blasting.
- In the event that an explosive detonating cord is used to detonate the blast holes, it should be covered with a suitable aggregate material. However, the potential for initiation-related airblast emissions can be minimised with the use of NONEL (non electric) initiation systems.
- Restrict blasts to favourable weather conditions.
- The propagation of airblast emissions is subject to meteorological conditions including refractions by wind and temperature gradients. Wherever possible blasting should be confined to between 0900 hours to 1700 hours to minimise the noise-enhancing effects of temperature inversions.
- Orient quarry faces away from potentially sensitive receivers.
- Subsonic airblast noise levels are often associated with face heave which generally propagates noise emissions from the blast face. Orientating the blast face away from receiver locations can therefore reduce airblast levels.
- Use a hole spacing and burden which will ensure that the explosive force is just sufficient to break the ore to the required size.
- Excessive use of explosives may result in the release of energy into the atmosphere in the form of acoustic emissions.
- Take particular care where the face is already broken and consider deck loading where appropriate to avoid broken ground or cavities in the face.
- High airblast levels may arise from face "blowout" which commonly results from existing fractures or uneven face burden.
- Bore-Tracking.
- In the quarry industry, recent initiatives to survey blast holes (orientation) have significantly reduced airblast. Uncontrolled drilling of blastholes can result in wide divergence of the hole from the intended position, thus causing blast problems, including "Blowout" airblast.
- Conduct blasting at a set time, or implement a pre-warning signal for nearby receivers.

- The preferred blasting method is to initiate the shot at a predetermined time which is well known to all potential receivers, whilst maintaining all appropriate safety procedures.

In addition to reducing airblast, many of these control techniques will maximise rockbreaking efficiency, which in turn results in the use of less explosives and an associated cost saving.

3.3.5 Noise and Blast Emissions Monitoring Program

To effectively manage noise and blast emissions throughout the life of a project a routine monitoring program must be implemented. Without monitoring, the success of the company in achieving the required environmental goals would be unrecognised. This reduces the company's potential Good Corporate Citizen profile and could be a lost opportunity that cannot be recalled to balance any future difficulty. The management plan should detail the methodologies required for monitoring including:

- The parameter to be monitored ie environmental noise, plant and equipment noise, ground vibration and airblast.
- The monitoring locations.
- The monitoring interval and number of locations.
- The reporting and record keeping system should include the following:
- The reporting intervals.
- Location of attended and unattended monitoring instruments.
- Unattended noise monitoring results.
- Tabulation of statistical noise level descriptors together with notes identifying the principal noise sources.
- Graphs of vibration monitoring results.
- Blast designs and location of blasting.
- Blast emissions monitoring locations and results.
- Summary of measurements exceeding the criteria levels, and description of the plant or operations causing these exceedances.
- Details of corrective action applicable to criteria exceedances and confirmation of its successful implementation. The status of corrective action should be indicated.
- Details of any complaints regarding noise and vibration including the complainants home, address and contact number.
- Details of the response to complaints (including supplementary monitoring, corrective action etc).

3.3.6 Community Liaison

Liaison between mining companies and the community is important at every point, from the beginning of the proposal stage, throughout the investigative, assessment and approval processes, and throughout the mine's operation. The community must be kept informed and involved in the decision-making process affecting them if a good working relationship is to develop between all involved parties. A good working relationship is the keystone to a win/win approach involving mining and the community.

Implementation of an effective community consultation program will gain public confidence and lead to a smoother planning and approval phase and a more efficient operational period. Lack of knowledge and understanding frequently lead to the fears in the community surrounding a mining proposal. The misconceptions which can then arise commonly result in objections and difficulties which serve no constructive purpose and promote a spirit of non-cooperation.

By providing information and a contact point at the onset of a mining project, and continuing to respond to community concerns, mining companies are in a better position to implement a successful environmental management program. Community consultation and involvement aspects are discussed in a separate booklet in this series.

As part of a Noise and Vibration Management Plan, a mining company must develop a policy for community liaison in dealing with noise and vibration issues. The management plan should establish the protocol for handling complaints which will ensure that the issues are addressed and that appropriate corrective action is identified and implemented if and where necessary. This protocol should be pro-active and responsive, and, as a minimum, involve the following (including identifying the people responsible for the various actions):

- Identify contact persons at all potentially affected properties, and give them a project outline (together with details of the procedures for lodging complaints and the expectations they may have about the response mechanisms that will be implemented.
- Forward all complaints to the person responsible for handling them.
- Keep records regarding the source and nature of the complaint.
- Investigate the complaint to determine whether a criterion exceedance has occurred or whether noise and/or vibration have occurred unnecessarily.
- If excessive or unnecessary noise and/or vibration have been caused, corrective action should be planned and implemented.
- Corrective action should be planned and implemented if excessive or unnecessary noise and/or vibration has been caused.
- Report details of complaints and corrective action should be reported.
- Inform complainants that their complaints are being addressed, and (if appropriate) that corrective action is being taken.
- Carry out follow-up monitoring or other investigations to confirm the effectiveness of the corrective action.
- Inform complainants the successful implementation of the corrective action that has been taken to mitigate the adverse effects.

3.4 MONITORING AND AUDIT PROGRAM

The Monitoring and Audit Program developed in the Noise, Vibration and Airblast Management Plan provides the company with a way to maintain a continuous, up-to-date record of the environmental noise and blast emissions throughout the life of the mining project.

The records kept enable the company or any other interested party, such as a statutory authority, to audit the project operations to ensure all relevant approval and licensing conditions are achieved. A simple checklist, such as the one contained in Appendix E, can provide an easy way a company can track environmental performance.

The audit program must also address procedures covering non-compliance with consent limits or failure to meet environmental quality objectives. These procedures should be outlined in the Noise, Vibration and Airblast Management Plan and include identification of non-compliance and the planning and carrying out of such corrective action as may be necessary. These procedures should be outlined in the Noise, Vibration and Airblast Management Plan and include identifying non-compliance and planning and implementing any necessary corrective action.

The corrective action may involve supplementary monitoring to identify the source of the non-conformance and/or may involve modifying operational procedures to avoid any occurrence or minimise any adverse effects.

In this way, mining companies can demonstrate their commitment to continuing to manage noise and blast impacts and improving environmental quality.

4 CONCLUSION

Noise, vibration and airblast are unavoidable by-products of extractive operations which involve using large mobile equipment, fixed plant and blasting. The initial planning phase of a mining project should recognise the potential for adverse impacts due to noise, vibration and airblast emissions. The construction and operational staging of the project should be designed and managed to best minimise these impacts.

The extent of noise, vibration and airblast emissions should be quantified during the impact assessment phase of the project. Predictions of the levels received at potentially sensitive locations form the basis on which to modify the project design to mitigate any impacts to within acceptable limits.

As part of approval and/or licensing conditions, a management plan, involving the surrounding community, should be prepared. This plan frequently results in additional investigations to identify sources of potential impact. Specific measures are then developed to minimise environmental emissions. The ongoing monitoring program detailed in the management plan provides the basis for the continuous maintenance of environmental quality objectives and efficient auditing throughout all stages of a project's life span.

The three stage approach to best practice environmental management in mining involves:

1. Noise, vibration and airblast impact assessment
2. Developing and implementing a noise, vibration and airblast management plan, and
3. A monitoring and audit program.

The use of this strategy clearly demonstrates a mining company's commitment to improve its environmental performance and meet with community expectations. Such an environmentally responsible approach is consistent with the community's demands for a sustainable future.

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CASE STUDY 1

OBERON QUARRY, NEW SOUTH WALES

Operation and Transportation—Noise Control

In 1996 Oberon Quarries Pty Ltd began extractive and processing operations at the Oberon Quarry following a 10 month construction phase. The hard rock quarry is located on Racecourse Hill approximately 4 km south of Oberon, NSW, with consent to operate for 20 years.

Average annual production is expected to reach 200,000 tonnes per year within the first 10 years of operation. Raw material is extracted using drill and blast techniques then loaded into 35 tonne haul trucks and delivered to the crushing plant for processing. Quarry products are transported off site using 10 and 25 tonne capacity product trucks.

Several of the potentially affected residences nearest to the processing plant area are from 670 m to 1340 m away, with one residence positioned 400 m from the future extractive area and another residence just 125 m from the quarry product transportation route.

It was essential during the quarry design process that all potential adverse acoustical impacts were addressed in order to meet the appropriate environmental noise emission criteria. Given best practice environmental management, the noise controls incorporated in the development include:

Extractive Operations

An "enclosed" pit design shields quarry operations on four sides for the majority of the life of the quarry. This design enables mobile equipment in less acoustically screened position for short periods when it is necessary to operate equipment within 2 m to 3 m of the top of Racecourse Hill.

The quarry floor is approximately 1140 m AHD with equipment operating the majority of time either on the quarry floor or on a bench within the quarry at approximately 1150 m AHD. During these times, quarry activities are visually and acoustically shielded from all distant dwellings by a 10 m to 20 m high rock wall.

By necessity, a narrow opening cut into the side of Racecourse Hill which accesses the quarry floor. The position and orientation of this opening has been optimised to reduce adverse acoustical effects.

Processing Operations

The crushing and processing facilities are on a level area at approximately 1125 m AHD adjacent to a 6 m to 8 m high wall of undisturbed material. Additional acoustic bunding 2 m high and approximately 80 m long, will also significantly attenuate noise from the crushing/processing area.

Noise emission from the permanent crushing plant will be further attenuated by enclosing the primary and secondary crushers, and by providing additional bunding around the end of the product storage bays. Maintaining all permanent crushing and screening equipment in a serviceable condition also reduces the potential for noise emission.

Transportation

To minimise potential impacts associated with transportation noise, a new access road has been sealed and is maintained in a good condition from the edge of the processing area to the public road. Sealing the access road minimises potential noise emissions from trucks clattering over rough roads.

Drilling and Blasting Controls

Drilling periods are minimised by using modern and efficient hydraulic drilling equipment. Drilling could occasionally become audible when working in exposed locations so a lightweight, partial enclosure will be used around the drill when drilling in exposed areas.

All best practice design noise control measures have been implemented in the construction and operation of the Oberon Quarry and, as a result, negligible noise impact has occurred at the nearby residential locations.

(For details, refer to Report N32-R1 'Oberon Quarry—review of Noise and Vibration Impacts', Richard Heggie Associates 30 April 1995. [Phone 2 9427 8100].)

CASE STUDY 2

ELLALONG COLLIERY, NEW SOUTH WALES

Located approximately 10 km south of Cessnock in the Hunter Valley of NSW, Oakbridge Pty Ltd, Ellalong Colliery is the last active coal mine in the area and has operated since the late 1970s. The surrounding land uses are State Forest to the northeast, rural to the west and urban residential on the adjoining southern and eastern sides.

As with the majority of the Hunter Valley, the area surrounding Ellalong Colliery experiences temperature inversions particularly during August and September.

During August 1990, the Colliery received a complaint about noise from the main ventilation fans particularly in the early hours of the morning. Located approximately 1250 m due east of the fans, the property concerned was a recent construction. The Colliery had not previously experienced noise complaints about the ventilation fans from existing residences which are located only 200 m to the south of the fan site.

Acoustic surveys were conducted around the fan site and the residence concerned. The measured noise levels gave a constant 40 dBA at the residence with peaks up to 57 dBA. The surveys concluded that the presence of adverse conditions such as a temperature inversion enhanced reception of any fan noise.

Detailed investigations by acoustic engineers and the fan manufacturer, in consultation with the Colliery, determined that the most appropriate method of reducing the noise levels at the residence affected was to modify the fan discharge. This involved redirecting the exhaust downwards by inserting an additional curved section in a discharge outlet. The existing high level discharge arrangement was particularly influenced by inversion conditions. For safety reasons this modification required that both the fans and underground mining operations be shut down for a period of 48 hours.

On completing the fan modification works, follow up surveys measured noise levels at the residence peaking at 35 dBA LA90 with the average level being 32 dBA. Under neutral conditions, the noise level from the operation of the fans was calculated to be approximately 28 dBA.

Even though the investigation and implementation of the required modifications occurred over an extended period, the end result was a solution appropriate to the needs of both the community and the Colliery.

CASE STUDY 3

KALGOORLIE CONSOLIDATED GOLD MINES, WA

Since 1893 gold has been mined at Kalgoorlie-Boulder. The historical development of the town has led to mining and processing operations occurring in close proximity to residential areas. As recently as 1988, there were six underground mines operating on a continuous basis on the Golden Mile. These operations have now been replaced with open cut mining which has led to a substantial change in the previous noise environment. The Fimiston "Super Pit" will eventually result in a pit approximately 4 km long and 1 km wide and 500 m deep.

This change in mining technique has presented an environmental challenge, to assess the changing conditions and determine appropriate management programs to contain noise to within acceptable limits.

Modelling of the open pit operations identified that noise levels in excess of 45 dBA would be detected within a 1 km radius of the mine. These levels could increase by up to 10 dBA under adverse weather conditions.

The model also demonstrated that the Croesus Mill, which has been in operation for around 60 years (long before the open pit era) was the most significant source of noise emissions to residential areas. As is often the case with noise sources of long standing, the operation has not been the subject of any public complaint.

In 1991, the EPA indicated that the following noise standards were likely to be introduced:

0700 hours to 1900 hours 50 dBA

1900 hours to 2200 hours 45 dBA

2200 hours to 0700 hours 40 dBA

These levels would seriously affect KCGM operations, particularly at night. The fact that existing noise levels in residential areas frequently exceeded 40 dBA at night was presented to the EPA and following further negotiations, noise standards which represented more realistic and achievable levels were introduced.

In order to operate on a continuous basis however, the company has had to implement an environmental noise control program. This has involved the change over to "smart alarms" on trucks and mobile plant. These alarms adjust the noise output during reversing to no more than 10 dBA above the ambient level, making it far less intrusive at night.

Screening around the primary crusher at the Croesus Mill and around exploration drilling rigs has been designed and installed.

Frequency analysis has been used to identify a prominent tonal component from a conveyor gearbox at the Oroya Mill. The gearbox was subsequently adjusted to rectify the problem by eliminating the annoying tonal noise emission.

The construction of a 20 m high noise control barrier between the mine and the residential areas was also identified as effective in reducing noise levels due to the close proximity of residential premises to the mining operations. The availability of waste rock made the construction of this bund wall feasible along the full length of the Super Pit.

By implementing best practice, KCGM have been able to successfully operate the largest open pit gold mining project in far closer to the residential area of Kalgoorlie-Boulder than would normally be acceptable.

CASE STUDY 4

CADIA GOLD MINE, NEW SOUTH WALES

In August 1996 Newcrest Mining Limited was granted approval to develop the Cadia Gold Mine (CGM) near Orange, New South Wales, as an open-cut copper/gold mine with staged flotation and extractive processing operations (with consent to operate for a 14 year period). The project area is located 25 km southwest of Orange, NSW.

The 24 month construction phase of the project commenced in October 1996 and includes periods of excavation and quarry blasting. Normal mine operations are scheduled to commence in mid 1998 and may involve blast designs to fragment up to an approximate maximum of 280,000 tonnes of ore and waste, nominally on a daily basis throughout the life of the mine.

A Program of Blast Emission Monitoring has been developed with reference to the procedures described in AS 2187.2-1993, *Explosives—Storage, Transport and Use* in order to meet the requirements of the mines Development Consent Conditions, NSW Environment Protection Authority's Noise Licence and Department of Mineral Resources approvals.

Prior to starting construction blasting, a number of residential dwellings located beyond the Mine Lease Area (MLA) were identified as potential measurement locations and extensive dilapidation surveys were conducted to quantify the existing structural integrity of the buildings. The nearest potentially affected structure within the MLA is a restored historic Engine House and Chimney which is located approximately 1100 m from the initial open-cut area.

In order to ensure compliance with the consent conditions and other approvals the program of monitoring includes the installation of permanent remote blast emission monitoring equipment at the historic chimney and the nearest potentially affected dwelling. Additional portable blast emission monitors are rotated about the remaining residences to provide "spot checks" or to address the particular concerns of a property owner, as required.

Blast design records are maintained for individual blast events to assist in the design and optimisation of future events, planning and control of blasting emissions, and to provide a traceable system of documentation in case of accident or complaint.

In order to maximise the benefits of the blast monitoring process, the significant blast design parameters, emission levels and meteorological data are collated on a concise Blast Emissions Summary Record. The record forms the basis for updating the blast emission site laws for vibration and airblast at appropriate intervals.

CASE STUDY 5

ALCOA OF AUSTRALIA, WESTERN AUSTRALIA

Alcoa of Australia Limited mines bauxite at three mines in the Darling Range in Western Australia south of Perth. The mines are near the townships of Jarrahdale, Dwellingup and Waroona. Blasting operations can occur, with agreement from neighbours, within 350 m of the boundaries of private farming properties, many of which contain occupied dwellings. More usually, blasting is done several kilometres from private properties or townships.

Over the 30 years since operations began, a variety of techniques have been developed to minimise the noise and vibration from blasting.

In the early 1980s a Blast Acoustics Model (BAM) was developed to predict the noise levels produced by a blast at locations out to a distance of about 40 km. It also predicts regions where focussing due to weather conditions is likely to occur. It is still used today and is largely unmodified.

In addition to the BAM predictions, Alcoa uses "pilot shots" to confirm the blast modelling, these being a small unconfined charge initiated at the blast site shortly prior to the main blast. Fixed noise monitoring stations are remotely operated to monitor the resultant noise as well as a number of portable, manned units which are placed at locations of interest according to the BAM output. These pilot shots have a consistent noise output and the anticipated noise level from the main blast can be determined from measuring the pilot shot noise.

Alcoa's blast techniques vary according to the proximity of private properties. The blast is designed to break a relatively thin (less than 2 m) layer of ironstone caprock below which is a friable layer.

Blast parameters are usually 1.8 m deep holes of 130 mm diameter, drilled on a 3.5 m by 3.5 m staggered pattern and charged with 10 kg of bulk emulsion explosive product. Stemming length is about 1.1 m.

Initiation techniques vary according to weather conditions and the proximity of neighbours. Blast size varies from 200 holes to more than 3,000 holes per blast.

Alcoa never fires more than four holes per delay period and the resultant ground vibration is below required levels within 200 m to 300 m distance from the blast perimeter. Ground vibration due to blasting is not monitored on a routine basis, but auditing by independent experts confirm the above information.

Substantial experimentation has been undertaken over the years and continues in order to minimise the impact of Alcoa's operations on the surrounding area.

CASE STUDY 6

LUCAS HEIGHTS, NEW SOUTH WALES

The Lucas Heights Recycling and Landfill Depot located in Sydney's south-west is operated by Cleary Bros (Bombo) Pty Ltd on behalf of the Waste Service of NSW.

Prior to 1992 the landfill operation involved the excavation of large quantities of in situ sandstone using rock rippers attached to Caterpillar D10 and D11 bulldozers. The ripped material was crushed and deposited over compacted waste using scrapers. The presence of high to very high strength competent sandstone made mechanical ripping uneconomic and often unachievable, so drill and blast operations were required.

A critical requirement of the blasting was to conduct it in a manner which did not interfere with the operations or activities of the Australian Nuclear Science and Technology Organisation (ANSTO) nearby, which operates a nuclear reactor and ancillary facilities for nuclear research and producing medical isotopes. In particular, the MOATA reactor was fitted with sensitive seismic switches intended to detect early tremors associated with an earthquake and to shut down the reactor in a controlled sequence before the arrival of higher levels of vibration from a quake.

In November 1992, a trial blast was conducted at the Depot to assess the possible adverse impacts of blast emissions from the site to the ANSTO facility and other land uses in the locality.

The trial blast impact assessment established that blast emission levels clearly complied with the NSW Environment Protection Authority's (EPAs) guidelines for residential land use at all localities in the vicinity of the Waste Depot. The levels of ground vibration received at the ANSTO facility were lower than the seismic switch trip levels by an acceptable safety margin. Consequently, Cleary Bros obtained approval from the relevant authorities to incorporate excavation blasting into their existing recycling and waste disposal operations.

It was essential that a thorough blast emissions monitoring and quality assurance program was implemented to ensure that routine blasting did not exceed the seismic switch level of 0.47 mm/s at approximately 1600 m from the blast site. This value is approximately 10 times less the nominal EPA residential human comfort criterion of 5 mm/s.

A Quality Manual was prepared which detailed the Quality Assurance requirements to the approval of all interested parties including the landfill operator, blasting contractor, the Workcover Authority and ANSTO. The Quality Manual sets out the procedures to be carried out in relation to all critical stages of the blasting process including:

- Determining of the maximum permissible explosive charge mass for a particular blast site, based on site specific blast emission data.
- Approval procedures for the proposed blast design and confirmation that shot loading conforms to the design parameters.

- A detailed blast monitoring methodology for quantifying the level of ground vibration and airblast at appropriate reference locations.
- Maintaining a traceable system of documentation and record keeping in case of exceedance or complaint which also facilitates independent auditing.

From 1993 to 1996 Cleary Bros successfully conducted approximately 150 excavation blasts employing a total of 30 tonnes of explosive.

CASE STUDY 7

STRATFORD COAL MINE, NEW SOUTH WALES

In June 1995, Stratford Coal Pty Ltd commenced mining and processing operations at the Stratford Coal Mine following a six month construction phase. The mine is situated between the townships of Stratford and Craven NSW, with consent for an operating period of fourteen years.

In July 1996 Stratford Coal Pty Ltd obtained approval to vary the mine's production rate from 1.2 Mtpa to 1.7 Mtpa of saleable coal. The approval process required a detailed evaluation of existing mine noise emissions as well as predicting and impact assessing potential noise emissions arising from the production increase.

Stratford Coal commissioned their environmental acoustical consultants to prepare a detailed environmental noise model with the following specifications:

- Noise model algorithms which predicted of noise propagation for complex meteorological conditions (ie refractions due to wind and temperature inversions).
- Noise source sound power levels determined from field measurements of existing fixed plant and mobile equipment.
- Importation of three dimensional topographic contours at 1 m intervals from the mine's ground surveyor database.
- The generation of noise contours for a 96 km^2 area surrounding the project site.

The noise model was calibrated to accurately predict the existing mine noise levels prior to the production increase, which had been measured at a number of key monitoring locations under a variety of meteorological conditions. The prediction of mine noise emissions at the increased rate of production indicated that while mine noise emissions at most of the nearest potentially affected residential receivers met with the mine's noise emission limits under neutral meteorological conditions, appreciably higher noise levels were anticipated during adverse atmospheric conditions, particularly at night-time.

The noise model predictions and impact assessment indicated that night-time noise emission levels could be mitigated by implementing the following noise controls:

- At the noise source, including both fixed plant and haul trucks,
- At the noise propagation path, including the construction of large earth barriers,
- At the noise receiver, including improved sound insulation of dwellings.

Stratford Coal is currently investigating or implementing all noise control measures in accordance with their approval conditions.

APPENDIX A

NOISE, VIBRATION AND AIRBLAST

Auditory perception of increasing loudness is logarithmic and encompasses a large dynamic range. It is therefore necessary that the scale used to measure sound should cover an equivalent range. The ratio of the lowest and the highest audible sound pressures is enormous. The decibel scale was therefore introduced to reduce this ratio to a more practical size by the use of logarithms.

The decibel scale gives the level of sound in decibels, above or below a reference level, which is generally taken as 10-12 watts or 2 x 10-5 Pa, the threshold of normal hearing. Because the frequency response of the human ear is biased towards higher frequencies, a filtering (or A-weighting) network is used in the measurement of environmental noise. The A-weighting network results in a decibel reading which is similar to, and reflects the response of, the human to the perceived sound. Noise measurements made using this weighting network are expressed as dBA.

The logarithmic nature of the decibel scale frequently leads to confusion. For instance, if two machines each emit exactly the same noise level of, say 80 dBA, the total noise level is not 160 dBA, but 83 dBA. Also, a 10 dBA increase represents a perceived doubling of loudness. A range of typical noise levels is presented in the Table below:

Sound Pressure Level - dBA	Typical Source	Subjective Evaluation
130 (Threshold of pain)	-	Extremely noisy/Intolerable
120	Jet take-off	
110	Rock concert	
100	Pneumatic hammer	Very noisy
90	Heavy truck	
80	Busy street traffic	Loud
70	Loud radio or television	
60	Department store	Moderate to quiet
50	General office	
40	Living room	Quiet to very quiet
30	Bedroom	
20	Unoccupied recording studio	Almost silent
10/0 (Threshold of hearing)	-	Silent

Any physical quantity which is subject to fluctuations in level from day to day is generally surveyed over an extended period of time to obtain a statistically repeatable result. The major statistical noise level descriptors which are used in reference to environmental noise are as follows:

LA1	The noise level which is exceeded for 1% of the measurement period.
LA10	The noise level which is exceeded for 10% of the measurement period, frequently referred to as the average maximum noise level.
LA90	The noise level which is exceeded for 90% of the measurement period, frequently referred to as the average minimum noise level and used to represent the background sound level.
LAeq	The equivalent continuous sound pressure level represents the steady sound level which is equal in energy to the fluctuating level over a measurement period. It is essentially an energy average.

Airblast is measured in decibels, using the linear (or unweighted) scale to obtain an unfiltered reading of the change in pressure. The unit used is dB Linear.

In order to completely define ground vibration, the amplitude and frequency of the motion are measured in the three orthogonal directions generally in terms of velocity which is considered to be the best descriptor for assessing human comfort and the potential damage response of structures. The vibration velocity signals are summed (in real time) and the maximum amplitude of this vector sum is defined as the Peak Vector Sum (PVS). An indication of the resulting degrees of human perception of continuous vibration levels are presented in the following table:

Approximate Vibration Level	**Degree of Perception**
0.10 mm/s	Not felt
0.15 mm/s	Threshold of perception
0.35 mm/s	Barely noticeable
1.0 mm/s	Noticeable
2.2 mm/s	Easily noticeable
6.0 mm/s	Strongly noticeable
14.0 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of buildings) are for vibration with a frequency content in the range of 8 Hz to 80 Hz.

APPENDIX B

VERTICAL TEMPERATURE GRADIENTS

Radiation inversions result from cooling of the ground on a clear night, with associated radiant cooling of a layer of air near the ground.

Subsidence inversions result from descent of air over a large area such that the upper layers descend further than, and therefore are heated more than, the lower descending layers. This implies an anticyclone, with the inversion above divergent flow at low levels.

Turbulence inversions result from mixing of a layer of stable air near the ground, due to wind flow around rough terrain. The inversion is formed at the interface between the layers.

Frontal inversions are part of either a cold front, as cold air wedges under a warm air mass, or a warm front, as warm air overrides a cooler air mass.

The acoustical effect of temperature inversions is due to the increase of sonic velocity with increased air temperature. In a temperature lapse condition, sound rays will be refracted upwards, and there will be a decrease in received sound intensity at a distant location on the ground.

Under temperature inversion conditions, air temperature increases with altitude, and sound rays are diffracted downwards. This causes focussing of sound intensity at some radius from the source, and an increase in received sound levels.

APPENDIX C

NOISE MODELLING

For the purpose of predicting noise emission levels during the construction and operational phases of a development, representative scenarios are selected for computer modelling using the Environmental Noise Model (ENM) or SoundPLAN. The sound power level data obtained from previous measurements of similar items of mobile equipment and fixed plant are input to the model and adjusted where necessary to suit the overall mechanical and electrical power rating of the project specific plant. The overall maximum contributed noise emission levels at the receiver locations under consideration are then calculated from the concurrent operation of all items of equipment located in "typical" operating positions for each scenario assessed.

The calculated overall maximum level is subsequently converted to an LA10 (or average maximum) noise level and compared with the design objective to assess the potential noise impact throughout the project life.

Until relatively recently the accepted convention has been to adopt neutral weather conditions (no wind or temperature inversion) for the purposes of noise impact assessment. It has now become common however, in applying best practice, to examine adverse meteorological conditions and include such influences in a calculation scenario to demonstrate the anticipated seasonal variation in received noise levels when such conditions are prevalent for extended periods.

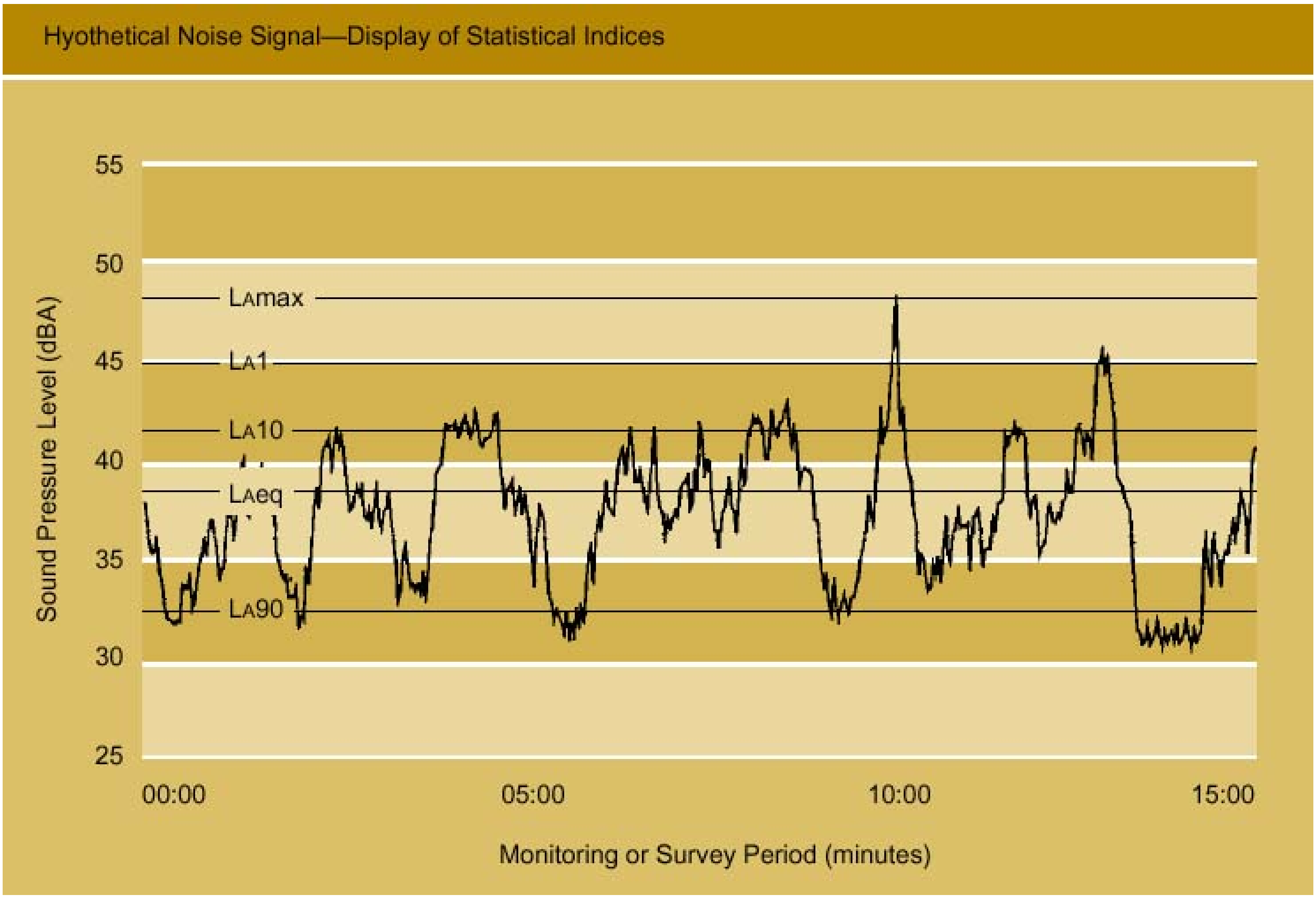
In order to determine the levels of blast emissions, a typical blast design is proposed based upon which, trial blasting is generally conducted. The measurements of ground vibration and airblast levels from these trial blasts are then used to develop blast emission prediction site laws to aid optimisation of blast design. After adjusting the site law formulae developed from the trial blasts, assuming the trial blast holes are fully confined, the levels of ground vibration and airblast can be predicted for ongoing blasting at the nearby receiver locations. The predicted levels are then compared with the recommended limits for structural damage and human comfort and the impact of blasting assessed.

APPENDIX D

ACOUSTICAL TERMINOLOGY AND GLOSSARY OF ACOUSTICAL TERMS

Term	Definition
Air Absorption	The phenomena of attenuation of sound waves with distance propagated in air, due to dissipative interaction within the gas molecules.
Ambient Sound (or noise)	The all-encompassing sound at a point being composite of sounds from near and far.
Background Noise Level	The level of the ambient sound indicated on a sound level meter in the absence of the sound under investigation (eg sound from a particular noise source or sound generated for test purposes). Refer statistical sound levels.
Diffraction	Modification of the progressive wave distribution due to the presence of obstacles in the field. Reflection and refraction are special cases of diffraction.
Direction of Propagation	The direction of flow of energy associated with a wave.
Loudness	The attribute of an auditory sensation which describes the listener's ranking of sound in terms of its audibility.
Masking	The raising of a listener's threshold of hearing for a given sound due to the presence of another sound.
Noise	a. Sound which a listener does not wish to hear. b. Sound from sources other than the one emitting the sound it is desired to receive, measure or record. c. A class of sound of an erratic, intermittent or statistically random nature.
Noise Level	The term used in lieu of sound level when the sound concerned is being measured or ranked for its undesirability in the contextual circumstances.
Reverberant Sound	The sound in an enclosure excluding that which is received directly from the source.
Reverberation	The persistence, after emission of a sound has stopped, of a sound field within an enclosure.
Sound Level	The level of the frequency weighted and time weighted sound pressure as determined by a sound level meter.
Sound Power	Of a source, the total sound energy radiated per unit time.
Sound Pressure Level (SPL)	Of a sound, 20 times the logarithm to the base 10 of the ratio of the RMS sound pressure level to the reference sound pressure level. International and Australian values for the reference sound pressure level are 20 micropascals in air and 100 millipascals in water.
Statistical Sound Levels	Of a fluctuating sound pressure (usually "A" frequency weighted and fast time response), the level which exceeded for N% of the sample period. The most frequently used are defined and presented graphically below:

Hypothetical Noise Signal - Display of Statistical Indices



LA1 The noise level exceeded for 1% of the sample period

LA10 The noise level exceeded for 10% of the sample period. This is commonly referred to as the average maximum noise level

LA90 The noise level exceeded for 90% of the sample period. This is commonly referred to as the average minimum or background noise level.

LAeq The equivalent continuous sound pressure level and represents the steady sound level which is equal in energy to the fluctuating level over the interval period.

APPENDIX E

NOISE AND VIBRATION MONITORING CHECKLIST

Parameter NOISE	
Description	Ambient Plant/Equipment
Location	
Monitoring Interval	
Design Goal	
Date of Survey	
Measured Level	
Compliance/ Non Compliance	
Action	

Parameter BLASTING	
Description	Vibration Airblast
Location	
Monitoring Interval	
Design Goal	
Date of Survey	
Measured Level	
Compliance/ Non Compliance	
Action	