HEGGIES

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Revision 0

Pipeline Construction

Noise and Vibration Assessment

PREPARED FOR

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Pipeline Construction

Noise and Vibration Assessment

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1 INTRODUCTION

Heggies Pty Ltd (Heggies) has been commissioned by Unidel Group Pty Ltd (Unidel) to prepare a study of noise and vibration impacts associated with certain construction equipment and scenarios associated with pipeline construction works. This report is intended to form the basis for various environmental impact studies (noise and vibration) over-seen by Unidel.

The report includes predicted noise and vibration emission levels from various construction activities associated with the construction of a pipeline.

The report will include the legislative requirements for noise and vibration in Queensland (Qld), New South Wales (NSW) and in accordance with the noise guidelines contained in International Finance Corporation's (IFC) document '*Environmental, Health and Safety (EHS) Guidelines*'.

2 TECHNICAL INFORMATION

2.1 Noise

2.1.1 Standard Noise Indices

This report makes repeated reference to certain noise level descriptors, in particular the L_{A1}, L_{A10}, L_{A90}, and L_{Amax} noise levels.

- The L_{A10} is the A-weighted sound pressure level exceeded for 10% of a given measurement period and is utilised normally to characterise typical maximum noise levels.
- The L_{A90} noise level is the A-weighted sound pressure level exceeded for 90% of a given measurement period and is representative of the average minimum background sound level (in the absence of the source under consideration), or simply the "background" level.
- The L_{A1} noise level is the A-weighted sound pressure level exceeded for 1% of a given measurement period.
- The L_{Amax} noise level is the maximum A-weighted noise level measured over a given measurement period.

2.1.2 Typical Noise Levels

Table 1 presents examples of typical noise levels

Table 1 Typical Noise Levels

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130 120 110	Threshold of pain Heavy rock concert Grinding on steel	Intolerable Extremely noisy
100 90	Loud car horn at 3 m Construction site with pneumatic hammering	Very noisy
80 70	Kerb side of busy street Loud radio or television	Loud
60 50	Department store General Office	Moderate to Quiet
40 30	Inside private office Inside bedroom	Quiet to Very quiet
20	Unoccupied recording studio	Almost silent

2.1.3 A-Weighting or dBA Noise Levels

The overall level of a sound is usually expressed in terms of dBA, as is the case in Australian Standards *AS 1055 Acoustics – Description and measurement of environmental noise* which is measured using the "A-weighting" filter incorporated in sound level meters. These filters have a frequency response corresponding approximately to that of human hearing. People's hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound.

Different sources having the same dBA level generally sound about equally as loud, although the perceived loudness can also be affected by the character of the sound (eg the loudness of human speech and a distant motorbike may be perceived differently, although they are of the same dBA level).

2.1.4 Sensitivity of People to Noise Level Changes

A change of up to 3 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness.

2.2 Vibration

Humans are far more sensitive to vibration than is commonly realised. They can detect and possibly even be annoyed at vibration levels which are well below those causing any risk of damage to a building or its contents.

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard *DIN 4150 Part 2: Human exposure to vibration in buildings.* On this basis, the resulting degrees of perception for humans are suggested by the continuous vibration level categories given in **Table 2**.

Table 2 Vibration Levels and Human Perception of Motion

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 mm/s	Noticeable
2.2 mm/s	Easily noticeable
6 mm/s	Strongly noticeable
14 mm/s	Very strongly noticeable

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

Table 2 suggests that people will just be able to feel continuous floor vibration at levels of about 0.15 mm/s and that the motion becomes "noticeable" at a level of approximately 1 mm/s.

Noise and vibration terminology is discussed further in detail in **Appendix A**

3 DESCRIPTION OF PIPELINE CONSTRUCTION WORKS

Construction of a pipeline will require a number of operations to be undertaken consecutively as follows:

1. Survey, fencing and set up of temporary facilities;
2. Clear and grade of the right of way;
3. Blasting (including preparation);
4. Trenching, pipe stringing and bending;
5. Pipe welding and joint coating;
6. X-ray and pressure test (inspection);
7. Backfilling and compaction;
8. Tie-ins, push sections and road crossing; and
9. Hydro-testing and rehabilitation.

The suite of activities shown is referred to as a spread.

For conventional pipeline laying (land clearing, trench digging and pipe placement) each crew works at the rate of between 1km and 4 km per day depending on the terrain (ie if there are more trees or the ground is very rocky progress may be slower). To enable the crews to work safely and efficiently there is often a delay between the arrival dates of each crew. Typically it will take up to 12 weeks for all the crews to pass through an area and complete their tasks.

Blasting is also required in areas of rock which cannot be removed by mechanical plant items.

Typical aspects of a pipeline construction program are summarised in **Table 3**.

Table 3 General Pipeline Construction Characteristics

Construction Element	Details
Width of vegetation clearing	30 m
Depth of Cover (AS2885) [1]	Generally 750 mm Deep Cultivated Areas 1200 mm Road Crossings 1200 mm River Crossings 1200 mm (minimum)
Construction Hours	6:00 am – 6:00 pm / 7 Days a Week
Construction Duration	Variable
Refuelling	Mobile fuel truck and construction depot
Time between clear and grade and reinstatement	Up to 3 Months [2]

Note 1: The depth of cover will vary depending on the size of the pipe.

2: Whilst the time from commencement of works to completion at any site along the route is expected to be up to 3 months, during this period intensive activities such as land clearing and trench construction will occur for less than one month.

The majority of pipeline construction works are typically located at significant distances from populated centres and rural residences. Throughout these areas, noise and vibration impacts are likely to be limited. However, if it passes adjacent to more densely populated areas, the likelihood of sensitive receivers being sufficiently close to the route to experience potential noise and vibration impacts are likely to increase.

Potential noise and vibration impacts at populated centres and isolated residences will be a function of the distance to the construction works.

It is expected that construction would generally occur from 6 am to 6 pm, seven days per week. Sensitive receivers within close proximity to a pipeline easement would be temporarily affected during periods of activity that would occur from time to time throughout the construction phase. This is due primarily to the transient nature of pipeline construction, whereby construction teams completing specific activities move along the route, completing one aspect of construction (for example clearing vegetation), prior to another team subsequently coming through and performing another activity (for example the removal of topsoil and excavation). A pipeline is excavated using conventional techniques an is typically located in a trench with the minimum cover being in accordance with AS2885. A minimum cover of 750 mm is nominated for this assessment, however it is noted that the depth of cover for the pipeline would not impact significantly on the noise emissions from pipeline operations. Typically, this will involve bulk excavating machinery such as bulldozers, excavators and chain or wheel trenchers. Blasting of rock is also proposed for regions where the rock is not rippable.

The potential impacts from noise and vibration that may result during construction include:

- Noise and vibration created by study teams, such as geotechnical surveys, vehicles and aircraft (similar noise and vibration sources would be associated with the operational phase of the pipeline).
- Noise and vibration created by construction teams and associated machinery, including camps, affecting sensitive receivers during the construction period.

Noise and vibration emission from activities associated with the construction teams are considered to be the most significant.

4 NOISE AND VIBRATION GUIDELINES AND CRITERIA

The following section discusses the relevant noise and vibration criteria in Qld, NSW and in accordance with the noise guidelines contained in IFC's '*Environmental, Health and Safety (EHS) Guidelines'*.

4.1 Construction Noise Criteria

4.1.1 Queensland Guidelines

For construction work occurring during normal daytime hours, provided all mechanically powered plant is fitted with appropriate mufflers, specific noise limits are generally not warranted. In this regard, it may be noted that the *Queensland Environmental Protection Policy (Noise) 1997* [EPP(Noise)] does not include construction noise limits (other than those which apply to blasting).

Noise impacts are usually minimised by limiting the hours of operation and, in particular circumstances, scheduling the noisiest activities to occur at times when they would generate least disruption. Where construction noise may affect adjacent residential premises or other residential accommodation (including hotels, motels, serviced units or backpacker accommodation), it is usually recommended to limit the hours of construction to:

- Monday to Friday - 7.00 am to 6.00 pm
- Saturday - 7.00 am to 1.00 pm

For construction works extending outside normal working hours, particular noise limits should be applied. The noise limits detailed below are recommended, based on the former EPA E1 Environmental Guideline and contemporary sleep disturbance limits.

- Monday to Friday:
  - 6.00 pm to 10.00 pm - background + 10 dBA $L_{Amax,adj,15min}$
  - 10.00 pm to 7.00 am - sleep awakening criterion of 45 dBA L_{Amax} internal
- Saturday:
  - 1.00 pm to 10.00 pm - background + 10 dBA $L_{Amax,adj,15min}$
  - 10.00 pm to 7.00 am - sleep awakening criterion of 45 dBA L_{Amax} internal
- Sunday/Public Holidays:
  - Sleep awakening criterion of 45 dBA L_{Amax} internal

The $L_{Amax,adj, 15min}$ noise limits refer to the average maximum A-weighted noise level from the construction activity measured over a 15 minute period, with adjustments for tonality or impulsiveness as applicable (as documented in full in *AS 1055: Acoustics – Description and Measurement of Environmental Noise*). The $L_{Amax,adj, 15min}$ is typically equivalent to the L_{A10} noise level for most construction activities.

Based on a typical attenuation of 5 dBA through an open window, an L_{Amax} (external) criterion of 50 dBA is recommended for sleep disturbance, assessable at four metres from the building facade.

The applicable noise criteria during 6pm to 10pm (Monday to Friday) and 1pm to 10pm (Saturday) is based on the existing background noise level at the receiver. Therefore it is necessary to summarise the typical background noise levels for various land use areas which may be located in the vicinity of pipeline construction works. **Table 4** contains background noise levels for various land uses, as shown in Table 1 of Queensland's Environmental Protection Agency's (EPA) *EcoAccess Guideline: "Planning for Noise Control*". These background levels are consistent with those contained in *AS 1055: Acoustics – Description and Measurement of Environmental Noise*.

Table 4 Recommended Outdoor Background Noise Planning Levels (RBL)[1]

Receiver Land Use	Land Use Type	Receiver Dominant Land Use (Description of Neighbourhood) [2]	RBL (dBA) Time Period		
			Day	Evening	Night
Purely residential	R1	Very rural	35	30	25 [3]
	R2	Rural residential, church, hospital	40	35	30
Residential area on a busy road or near an industrial / commercial area	R3	Residential, church, hospital, school	45	40	35
Industrial Area	R4	Residential, church, hospital, school	50	45	40
Passive recreation area	R5	Picnic grounds, bush walks, public gardens	35	35	35

Note 1: RBL - "Rating Background Level" is the median of the 90th percentile of the background (LA90) noise levels in each assessment period (day, evening and night).

Note 2: The dominant land use is defined by a radius of 200m from the receiver location under consideration.

Note 3: A minimum background noise level of 30 dBA has been adopted for works undertaken in NSW in accordance with the guidelines provided in the *New South Wales Industrial Noise Policy*

Table 5 shows the relevant noise criteria for various land use areas based on the background noise levels shown in **Table 4**.

Table 5 Queensland Construction Noise Criteria

Time	Criteria - By Land Use Type $L_{Amax,adj,15min}$				
	R1	R2	R3	R4	R5
Monday to Friday					
7.00 am to 6.00 pm	No limit				
6.00 pm to 10.00 pm	40	45	50	55	45
10.00 pm to 7.00 am	50 [1]				
Saturday					
7.00 am to 1.00 pm	No limit				
1.00 pm to 6.00 pm	45	50	55	60	45
6.00 pm to 10.00 pm	40	45	50	55	45
10.00 pm to 7.00 am	50 [1]				
Sunday and Public Holidays					
All periods	50 [1]				

Note 1: LAmax

It is noted that the noise criteria in **Table 5** are based on typical background noise levels for various land use types. The actual noise criteria for each receptor would vary depending on the actual measured background noise level in the surrounding area.

Background noise monitoring may be considered on a project specific basis for potentially affected residential areas in close proximity to pipeline construction.

If background noise monitoring cannot be undertaken, it is recommended that the minimum background noise level of 25 dBA nominated in **Table 4** be adopted for purposes of determining relevant noise criteria.

4.1.2 NSW Guidelines

When dealing with construction noise, the Department of Environment and Climate Change (DECC) recognises that higher levels of noise than would be emitted from long-term operational developments are likely to be relatively more tolerable to receptors in view of the relatively short duration of construction works.

As a result of this, and in consideration of the inherently noisy nature of construction works and the practical difficulties in controlling these noise emissions, the DECC has published guidelines in Chapter 171 of its Environmental Noise Control Manual (ENCM) for the assessment and minimisation of construction noise impacts. In addition to the published guidelines, standard practices have evolved which are applicable to construction noise and vibration relating to normal contact with affected communities (eg liaison protocols, appropriate notification to affected residents, etc).

Chapter 171 of the ENCM provides the following guidelines for the management of construction noise.

Level Restrictions

- For a cumulative period of exposure to construction activity noise of up to 4 weeks, the $L_{A10(15minute)}$ noise levels emitted by the works to specific residences should not exceed the L_{A90} background level by more than 20 dBA.
- For a cumulative construction noise exposure period of between 4 weeks and 26 weeks, the emitted $L_{A10(15minute)}$ noise level should not exceed the L_{A90} background level by more than 10 dBA.
- For a cumulative construction noise exposure period of greater than 26 weeks, the emitted $L_{A10(15minute)}$ noise level should not exceed the L_{A90} background level by more than 5 dBA.

In relation to the above noise criteria, the L_{A90} background noise level is the background noise at affected premises prior to the commencement of construction. Further, a 5 dBA penalty must be added to the L_{A10} noise level if the noise is substantially tonal or impulsive in character.

Time Restrictions

Recommended standard hours for construction activities in Chapter 171 of the ENCM:

Monday to Friday	7 am to 6 pm
Saturday	7 am to 1 pm (if inaudible at residential premises) 8 am to 1 pm (if audible at residential premises)
Sundays, Public Holidays	No work permitted

Silencing

All practical measures should be used to silence excavation and/or construction equipment, particularly in instances where extended hours of operation are required.

Works Undertaken Outside of Preferred Construction Hours

The DECC guidelines do not provide noise criteria for work outside of the recommended standard hours specified above. However, where it is necessary for construction works to be undertaken outside the DECC's preferred daytime construction hours, the $L_{A10(15minute)}$ noise level emitted by the works should not exceed the L_{A90} noise level during the relevant evening or night-time period by a margin of more than 5 dBA.

Table 6 shows the relevant noise criteria for various land use areas based on the background noise levels shown in **Table 4** and an expected construction working period of 4 to 26 weeks.

Table 6 NSW Construction Noise Criteria

	Criteria - By Land Use Type $L_{A10,15min}$				
Time	**R1**	**R2**	**R3**	**R4**	**R5**
Monday to Friday					
7.00 am to 6.00 pm	45	50	55	60	45
6.00 pm to 10.00 pm	35	40	45	50	40
10.00 pm to 7.00 am	35	35	40	45	40
Saturday					
8.00 am to 1.00 pm	45	50	55	60	45
1.00 pm to 6.00 pm	40	45	50	45	40
6.00 pm to 10.00 pm	35	40	45	50	40
10.00 pm to 7.00 am	35	35	40	45	40
Sunday and Public Holidays					
7.00 am to 6.00 pm	40	45	50	45	40
6.00 pm to 10.00 pm	35	40	45	50	40
10.00 pm to 7.00 am	35	35	40	45	40

The actual noise criteria at a sensitive receptor may vary from those nominated in **Table 6** depending on the actual measured background noise level at the site.

Background noise monitoring may be considered on a project specific basis for potentially affected residential areas in close proximity to pipeline construction.

If background noise monitoring cannot be undertaken, it is recommended that a minimum background noise level of 30 dBA be adopted for purposes of determining relevant noise criteria in accordance with the recommendations provided in the *New South Wales Industrial Noise Policy*.

General Comment on DECC Construction Noise Criteria

In the case of major excavation and construction projects in close proximity to residential and even commercial buildings, it can be difficult to comply with the DECC's ENCM construction noise criteria (for example, construction activities occurring across the street or in a neighbouring property). However, the following is noted:

- The criteria nominated in the ENCM are adopted as "noise design goals". Where these goals cannot be achieved in practice, the DECC recommends the use of best practice and management measures in order to minimise the risk of potential noise impacts.

The essence of the ENCM-based approach then is that:

- The potential for residential (and other receiver) disturbance should firstly be established, regardless of the practicality of achieving the resulting noise goals in specific instances; and
- Once the potential exceedances are identified, all possible measures should be investigated in order to minimise the risk of adverse impacts.

4.1.3 International Finance Corporation Guidelines (Noise)

The International Finance Corporation (IFC) has published guidelines for the minimisation of adverse impacts of humans on the environment in its *"Performance Standards on Social and Environmental Sustainability"* (April 2006) document. *"Performance Standard 3 Pollution Prevention and Abatement"*[1] outlines approaches to pollution prevention in line with current technologies and best practice technologies. One of the main objectives of Performance Standard 3 is:

- *"To avoid or minimise adverse impacts on human health and the environment by avoiding or minimising pollution from project activities"*

General requirements of Performance Standard 3 state that:

> *"The project-specific pollution prevention and control techniques applied during the project-cycle will be tailored to the hazards and risks associated with project emissions and consistent with good international industry practices, as reflected in various internationally recognised sources, including IFC's Environmental, Health and Safety Guidelines (the EHS Guidelines)"*

Section 8 of Performance Standard 3 refers to Technical Guidance and states the following:

> *"The client will refer to the current version of the EHS Guidelines when evaluating and selecting pollution prevention and control techniques for the project. These Guidelines contain the performance levels and measures that are normally acceptable and applicable to projects. When host country regulations differ from the levels and measures presented in the EHS Guidelines, clients will achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific projects circumstances, the client will provide full and detailed justification for any proposed alternatives. This justification will demonstrate that the choice for any alternate performance levels is consistent with the overall requirements of this Performance Standard"*

Section 1.7 (Noise) of the IFCs EHS Guidelines[2] provides noise level guidelines for the prevention and control of noise impacts at receivers. The noise level guidelines specified in Section 1.7 of the EHS Guidelines are shown in **Table 7** below.

Table 7 IFCs EHC Noise Level Guidelines

Receptor	LAeq(1hour) (dBA)	
	Day-time (7am – 10pm)	Night-time (10pm – 7am)
Residential; institutional; educational	55	45
Industrial; commercial	70	70

Note: Guidelines values are for noise levels measured externally.

[1] International Finance Corporation *"Performance Standard 3: Pollution Prevention and Abatement"* http://www.ifc.org/ifcext/sustainability.nsf/Content/PerformanceStandards (2006)

[2] International Finance Corporation *"Environmental, Health, and Safety (EHS) Guidelines - General EHS Guidelines: Environmental (Noise Management)"* (2007)

4.1.4 Summary of Construction Noise Guidelines – NSW, Qld and IFC

Both Qld and NSW Guidelines nominate recommended hours for construction activities to be carried out in order to minimise the potential for adverse noise impacts at nearby receivers. These recommended construction hours are typically:

- Monday to Friday – 7am to 6pm
- Saturday – 7am to 1pm

Where construction noise criteria apply, these criteria are generally determined based on the existing ambient background (L_{A90}) noise levels prior to commencement of construction works. The exception to this is where the sleep awakening criteria applies (L_{Amax} 45 dBA internal) under the Qld Guidelines during the night-time period and all day Sunday and Public holidays.

The relevant background plus noise criteria are in terms of the L_{A10} parameter (or equivalent) and are set at either 5 dBA or 10 dBA (depending on time period and state) above the ambient background noise levels for residential receptors (refer to **Table 5** and **Table 6** for QLD and NSW noise criteria respectively). The relevant range of L_{A10} (or equivalent) noise criteria applicable to each of the land use types are provided below:

- R1: 35 – 45 dBA
- R2: 35 – 50 dBA
- R3: 40 – 55 dBA
- R4: 45 – 60 dBA
- R5: 40 – 45 dBA

The noise levels nominated in the IFC EHS Guideline are in terms of the $L_{Aeq(1hour)}$ parameter. Based on the typical measured difference between the L_{A10} and L_{Aeq} noise level for construction activities, it is expected that where the Qld and NSW Guidelines are achieved the IFC EHS Guideline would also be achieved.

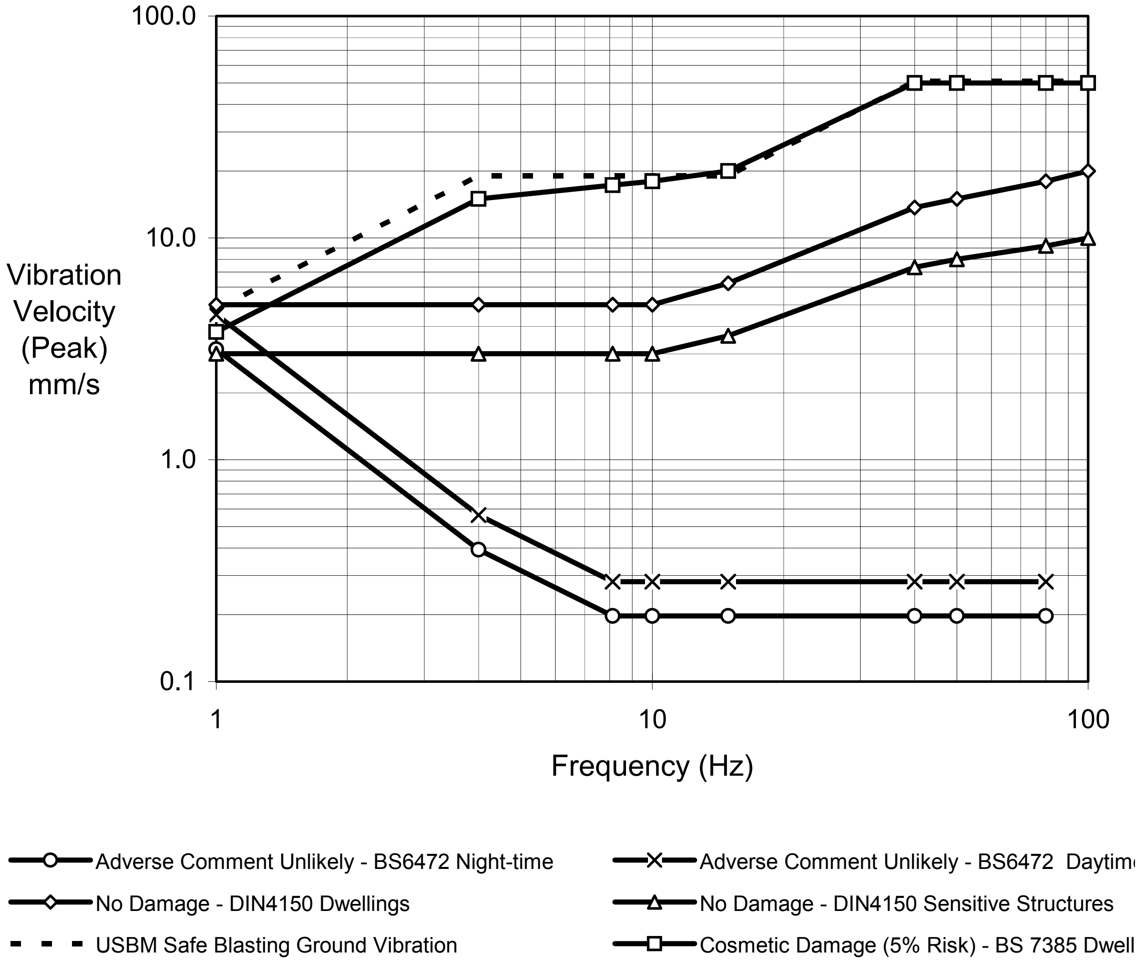
4.2 Construction Vibration Guidelines – NSW and Qld

When dealing with construction vibration, the effects in buildings can be divided into the following main categories:

- Human comfort
- Structural damage
- Safe vibration levels for common services
- Effects of vibration on building contents

Humans are far more sensitive to some types of vibration than is commonly realised. They can detect and possibly even be annoyed at vibration levels which are well below those causing any risk of damage to a building or its contents. **Figure 1** illustrates this difference in susceptibility by comparing widely accepted human disturbance criteria (BS 6472) with various threshold damage levels (DIN 4150, US Bureau of Mines and BS 7385).

Figure 1 Human Disturbance Criteria and Building Damage Limits



Notes: BS 6472 "Adverse Comment" disturbance criteria are for continuous vertical vibration at point of entry to body. DIN 4150 "No Damage" threshold criteria are peak particle velocity on building footings. BS 7385 5% Risk of Cosmetic Damage criteria are peak particle velocity on building footings (or in ground nearby). US Bureau of Mines Safe Blasting criteria are peak particle velocity in the ground

4.2.1 Human Comfort

Guidance in relation to assessing the potential human disturbance from ground-borne vibration inside buildings and structures is contained in *British Standard 6472-1992: Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz) (BS 6472).*

Satisfactory magnitudes of peak vertical vibration velocity (ie below which the probability of "adverse comment" is low) from BS 6472 are shown in **Table 8** (for generally sinusoidal vibration).

Table 8 Satisfactory Levels of Peak Vertical Vibration Velocity (8 Hz to 80 Hz)

Type of Space Occupancy	Time of Day	Satisfactory Peak Vibration Levels in mm/s Over the Frequency Range 8 Hz to 100 Hz			
		Continuous Vibration		Impulsive Vibration with up to 3 Occurrences per Day	
		Vertical	Horizontal	Vertical	Horizontal
Critical working areas (eg some hospital operating theatres, some precision laboratories, etc)	Day Night	0.14 0.14	0.4 0.4	0.14 0.14	0.4 0.4
Residential	Day Night	0.3 to 0.6 0.2	0.8 to 1.6 0.6	8.4 to 12.6 2.8	24 to 36 8
Offices	Day Night	0.6 0.6	1.6 1.6	18 18	51 51
Workshops	Day Night	1.2 1.2	3.2 3.2	18 18	51 51

Source - After BS 6472-1992

The DECC's *"Assessing Vibration: a technical guideline"* is based on the guideline vibration levels contained in British Standard BS 6472-1992.

The DECC nominates the following objective for vibration from construction activities:

- Continuous vibration (vertical):
  - Residential – 0.4 mm/s
  - Commercial – 0.8 mm/s
- Impulsive vibration (vertical):
  - Residential – 12 mm/s
  - Commercial – 26 mm/s

The vibration levels nominated by the DECC are consistent with those stated in **Table 8** above.

Table 8 indicates that continuous floor vibration levels above which "adverse comment" in residences and offices may arise during daytime range from approximately 0.3 mm/s to 0.6 mm/s.

4.2.2 Structural Damage

In terms of relevant vibration damage criteria, *British Standard 7385: Part 2-1993 Evaluation and measurement for vibration in buildings Part 2* is a definitive standard against which the likelihood of building damage from ground vibration can be assessed.

Although there is a lack of reliable data on the threshold of vibration-induced damage in buildings both in countries where national standards already exist and in the UK, BS 7385: Part 2 has been developed from an extensive review of UK data, relevant national and international documents and other published data. The standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration which are considered in the standard include blasting, demolition, piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

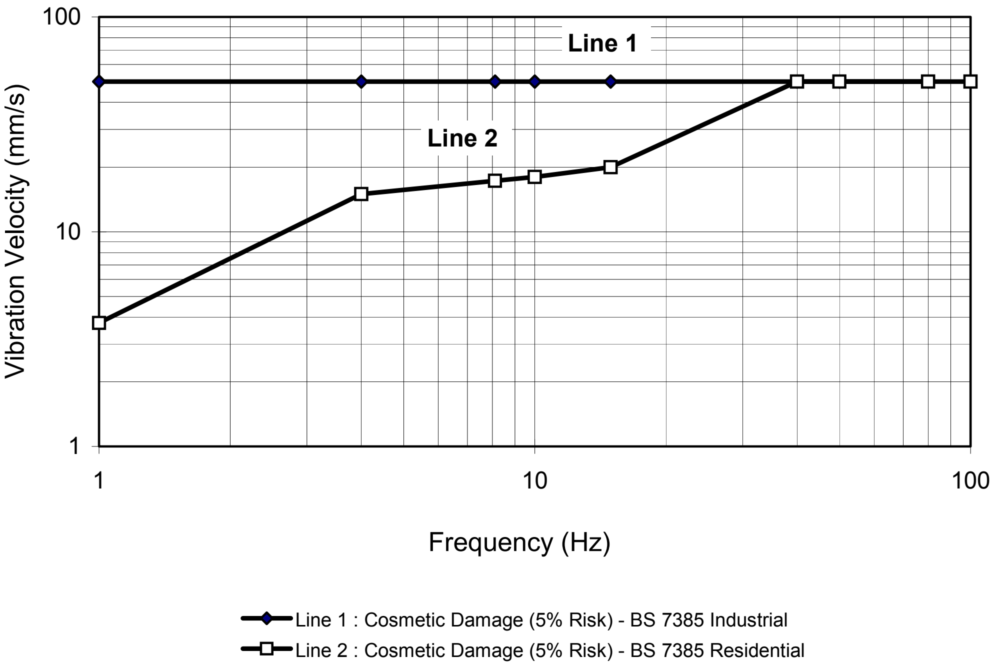
As the strain imposed on a building at foundation level is proportional to the peak particle velocity but is inversely proportional to the propagation velocity of the shear or compression waves in the ground, this quantity (ie peak particle velocity) has been found to be the best single descriptor for correlating with case history data on the occurrence of vibration-induced damage.

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 numerically in **Table 9** and graphically on **Figure 2**.

Table 9 BS 7385 - Transient Vibration Guide Values for Cosmetic Damage

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	Non-reinforced 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

Figure 2 Graph of Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding to Line 2 are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

Fatigue considerations are also addressed in the standard and it is concluded that unless calculation indicates that the magnitude and number of low reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 9** should not be reduced for fatigue considerations.

Nevertheless, the standard states that the guide values in **Table 9** relate predominantly to transient vibration which does not give rise to resonant responses in structures, and to low-rise buildings. Where the dynamic loading caused by continuous vibration is such to give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 9** may need to be reduced by up to 50%.

It is noteworthy that extra to the guide values nominated in **Table 9**, the Standard states that:

> *"Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK."*

Also that:

> *"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive."*

4.2.3 Safe Vibration Levels for Common Services

Vibration due to the construction process has the potential to affect services such as buried pipes, electrical and telecommunication cables.

German Standard *DIN 4150-3 1999: Structural Vibration – Part 3: Effects of vibration on structures* provides guidance on safe vibration levels for buried pipe work. The levels assume "current technology" as special considerations must be applied for systems associated with older structures such as might occur in the vicinity of Heritage Listed buildings. **Table 10** details the DIN 4150-3 limits for short-term vibration. The levels apply on the wall of the pipe. For long-term vibration the guideline levels presented in **Table 10** should be halved.

Table 10 DIN 4150 Part 3 – Damage to Buried Pipes – Guidelines for Short-term Vibration

Pipe Material	Peak Wall Vibration Velocity
Steel (including welded pipes)	100 mm/s
Clay, concrete, reinforced concrete, prestressed concrete, metal with or without flange (other than steel)	80 mm/s
Masonry, plastic	50 mm/s

Note: For gas and water supply pipes within 2 m of buildings, the levels given in Table 3 should be applied. Consideration must also be given to pipe junctions with the building structure as potential significant changes in mechanical loads on the pipe must be considered.

Recommended vibration criteria for electrical cables and telecommunication services such as fibre optic cables range from between 50 mm/s and 100 mm/s.

It is noted however that although the cables may sustain these vibration levels, the services they are connected to, such as transformers and switch blocks, may not. It is recommended that should such equipment be encountered during the construction process an individual vibration assessment should be carried out.

4.2.4 Effects of Vibration on Building Contents

Over the frequency range typical of vibration in buildings from mining excavation, industrial vibration, road and rail traffic (approximately 8 Hz to possibly 100 Hz), the threshold for visible movement of susceptible building contents (eg, plants, hanging pictures, blinds, etc) is approximately 0.5 mm/s and audible rattling of loose objects (eg, crockery) generally does not occur until levels of about 0.9 mm/s are reached.

For delicately balanced objects, rattling may sometimes occur at lower vibration levels. Window rattling may also be excited acoustically (ie by sound pressure waves, which may be thought of as vibration in the air).

In any premises, day-to-day activities (eg, footfalls, doors closing, etc) will cause levels of vibration in floors and walls that exceed 1 mm/s (sometimes by quite considerable margins), and therefore visible movement and rattling are often observed. In most instances however, such movement is considered normal, and vibration levels of even much greater magnitude do not result in damage to the objects or building contents.

Potentially vibration-susceptible building contents include sensitive instrumentation, computers and other electronic equipment, although such items are not usually kept in residences (apart from personal computers which are considerably more robust). Typical maximum floor vibration levels for satisfactory operation of such sensitive items are:

- 0.5 mm/s to 2 mm/s — Precision balances
  Some optical microscopes
- 1 mm/s to 5 mm/s — Large computer disk drives
  Sensitive electronic instrumentation

Very short duration vibration events, for example vibration from infrequent impulsive vibration, could be permitted to cause somewhat higher levels, depending on vibration frequency content and on the specific susceptibility of particular objects and their location.

The actual levels of vibration induced by a source outside a building are a function of the particular ground conditions, the foundation/footing interaction, location of the receiver within the building and the nature of the building and its floor.

4.3 Blasting Criteria

4.3.1 Queensland Guidelines

The *EPP (Noise) Environment Protection Amendment Regulation (No 2) 1999* contains the following blast emissions (airblast and vibration) criteria:

"61 Noise from blasting is not unlawful environmental nuisance for an affected building if:

- *the airblast overpressure is no more than 115 dB Linear Peak for 4 our of 5 consecutive blasts: and*

the ground vibration is:

- *for vibrations of more than 35 Hz – no more than 25 m/s ground vibration, peak particle velocity; or*

- *For vibrations of no more than 35 Hz – no more than 10 mm/s ground vibration, peak particle velocity.”*

The subject Regulation does not nominate times of blasting. However, the Queensland EPA’s document entitled *EcoAccess Guideline: Noise and Vibration from Blasting* contains both blast emissions criteria and times of blasting.

The relevant section is as follows:

“Vibration Criteria”

“Blasting should generally only be permitted during the hours of 9 am to 3 pm, Monday to Friday, and from 9 am to 1 pm on Saturdays. Blasting should not generally take place on Sundays or public holidays.

Blasting outside these recommended times should be approved only where:

a. blasting during the preferred times is clearly impracticable (in such situations blasts should be limited in number and stricter airblast overpressure and ground vibration limits should apply); or

b. There is no likelihood of persons in a noise-sensitive place being affected because of the remote location of the blast site.”

The Guideline further states (under the heading of “Weather Effects”) that:

“When a temperature inversion or a heavy low cloud cover is present, values of airblast overpressure will be higher than normal in surrounding areas. Accordingly, blasting should be avoided if predicted values of airblast overpressure in noise-sensitive places exceed acceptable levels. If this is not practicable, blasting should be scheduled to minimise noise annoyance. An appropriate period is generally between 11 am and 1 pm. Similarly, blasting should be avoided at times when strong winds are blowing from the blasting site towards noise sensitive places.”

4.3.2 NSW

The criteria normally recommended for blasting in NSW, based on human discomfort, are contained in the DECC's ENCM (Chapter 154). However, for recent projects the DECC has advocated the use of the Australian and New Zealand Environment Council (ANZEC) guidelines.

The ANZEC criteria for the control of airblast overpressure and vibration from blasting at residences are as follows:

- The recommended maximum level for airblast is 115 dB Linear.
    - The level of 115 dB Linear may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 120 dB Linear 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 hours to 1700 hours Monday to Saturday. Blasting should not take place on Sundays and public holidays

4.3.3 Project Specific Blasting Criteria

Appropriate criteria for airblast overpressure and vibration from blasting are presented in **Table 11** based on Qld and NSW guidelines.

Table 11 Blast Vibration and Airblast Criteria

Airblast	Maximum	Recommended
All Residences	120 dBL	115 dBL
Blast Vibration	**Maximum**	**Recommended**
All Residences [1]	10 mm/s	5 mm/s

Note 1: Peak Component Vibration Velocity.

5 CONSTRUCTION NOISE AND VIBRATION ASSESSMENT

5.1 Construction Overview

Construction activities have been separated into scenarios as previously mentioned in **Section 3**. A brief description of each construction scenario, including likely plant items, has been summarised in **Table 12** below.

Table 12 Pipeline Construction Scenarios

Stage	Description	Typical Plant Types/No's	Notes
Clear and grade	Graders, bulldozers and rakes are utilised for clearing. Top soil and vegetation are stockpiled for later reuse.	1 14g grader 1 D6 dozer 1 D8 dozer 2 966 FEL 2 30t excavators 4 dump trucks 1 4x4 crew cab	Note that the various pieces of equipment would typically be operating about 700-800m apart. As a worst case assume that the 2 nosiest items are working close together. The crew cab is usually used to transport the crew to and from site.
Blasting - preparation	In areas with large amounts of rock, blasting may be required.	2 Drill rigs 1 4x4 crew cab	Work is carried out by air drills. Holes are usually drilled 1m apart. Actual drilling of a hole would take about 2 minutes and the drill rig would move about every 5 minutes.
Blasting	Blasting of Rock		
Trenching, Stringing and lowering in	Trenches for a pipeline are dug. Steel pipe is laid end to end in the prepared trenches. If required, pipe sections are bent to match changes in the alignment of a pipeline. Side booms are utilised to lower the pipe into the trench.	1 D7 dozer 1 Vermeer T950 Trenchsaw 6 582 sidebooms 4 generator/electric pump 2 4x4 crew cabs 1 572 sideboom	Equipment in this crew would be operating about 30m apart. As for clear and grade the crew cab is used for transport to and from site.

Stage	Description	Typical Plant Types/No's	Notes
Welding and joint coating	Pipe sections are welded together.	1 572 sideboom 3 weld rig 1 4x4 crew cab 1 grit blaster 1 pick up	The welding rigs would be operating at about 200m spacing.
X-raying and pressure testing	The welds are inspected using x-ray detectors and pressure testing is undertaken.	1 50t excavator 2 weld rig 3 pump fill 2 4x4 crew cab 1 squeeze pump 3 air compressors 1 mechanical rig	
Padding and backfilling	Padding machines are used to sift the excavated material. The fine material is used to pad beneath the pipe and to fill the trench.	2 Ozzie 0PP-300 padders 1 D7 dozer 3 dump trucks 1 4x4 crew cab 1 pick up truck 1 loader 2 D6L dozers 2 D8N dozers 4 14G graders	The padders would be operating at about 50m spacing
Tie-ins, push sections and road crossings	These activities are required where tie to existing infrastructure is required or the route crosses existing infrastructure such as a road. (maximum plant for all activities is indicated)	2 20 t excavators 3 582 sidebooms 1 D7 dozer 2 weld rigs 2 6 inch pumps 2 4x4 crew cab 1 D8 dozer 1 bus (24 passenger) 2 draglines 1 boring machine	
Restoration and rehabilitation	This phase may include contouring and revegetation of the work area.	2 30t excavators 2 pick up 2 4x4 crew cab 1 D8 dozer 1 D6 dozer 2 966 FEL 1 bus (24 passenger) 1 grader 1 farm tractor 1 seeder 4 dump truck	

As many of the plant items in **Table 12** are considered to be acoustically insignificant (ie will not dominate or contribute significantly to a stage's overall predicted noise levels), the predicted noise levels from each stage are based on the operation of only the plant items considered to be most significant. The plant items considered to be most significant (and those included in the noise model) for each stage of construction are summarised in **Table 13**.

Table 13 Construction Scenarios – Most Significant Plant Items

Stage	Plant Items	Notes
Clear and grade	1x 14G Grader 1x D8 Dozer	Working ~700-800m apart
Blasting - preparation	1x Air Drill 1x Crew Cab	
Blasting	-	
Trenching, Stringing and lowering in	1x Chain Trencher or Wheel Trencher 1x Excavator (30t) 1x Pump	Working ~30m apart
Welding and joint coating	1x Weld Rig 1x Grit Blaster	Working ~200m apart
X-raying and pressure testing	1x Squeeze Pump 1x Air Compressor	Working ~100m apart
Padding and backfilling	1x Ozzie Padder OPP-300 1x Excavator (30t) 1x 14G Grader 1x D8 Dozer	Working ~200m apart
Tie-ins, push sections and road crossings	1x Boring Machine 1x D8 Dozer	Working ~100m apart
Restoration and rehabilitation	2x Excavator (30t) 2x D8 Dozer 2x 966 Front End Loader (FEL)	Working ~200m apart

5.2 Construction Noise

Assessment of noise impacts associated with pipeline construction works are discussed in the following section. The discussion of construction noise impacts includes:

- Equipment sound power levels;
- Predicted construction noise levels at nominated off-set distances; and
- The influence of meteorological and topographical effects on noise propagation.

5.2.1 Equipment Sound Power Levels

The sound power levels shown in **Table 14** are maximum noise emission levels for plant that would be used for pipeline construction.

Table 14 Sound Power Levels for Construction Plant Items

Plant Item	L_{Amax} Sound Power Level (dBA)
14G Grader	110
966 (FEL)	110
Air Drill	118
Backhoe	108
Compressor (approx 600 CFM)	105
Concrete truck	112
D8 Bulldozer	118
Dump truck (approx 15 tonne)	108
Excavator (30 tonne)	110
Generator	104
Grit Blaster	111
Hand Tools	98
Padder	118
Pump	100
Reversing Alarm	110
Sideboom tractor	110
Trencher – Chain	118
Trencher – Wheel	118
Boring machine	111

The relevant construction noise criteria are generally in terms of either the $L_{Amax,adj,15min}$ or the $L_{A10(15minute)}$, therefore it is necessary to convert the sound power levels shown in **Table 14** to equivalent L_{A10} noise emission levels. From numerous field studies on large construction projects, the measured difference levels between the L_{Amax} and the L_{A10} noise level have been found to be up to 10 dBA, depending on the duration of the measurement, mixture of the plant, intensity of operation and location of the plant relative to the receiver.

In the present study, where the receivers are relatively distant, corrections have been applied to convert the L_{Amax} noise levels shown in **Table 14** to L_{A10} and L_{Aeq} noise levels for comparison with the recommended construction noise criteria. The appropriate corrections are shown in **Table 15.**

Table 15 Corrections to Convert from L_{Amax} to L_{A10} and L_{Aeq}

Description of Noise	Typical Plant Items	Corrections (dBA)		
		L_{Amax}	L_{A10}	L_{Aeq}
Equipment characterised by reasonably continuous noise emissions	Compressors, chain and wheel trenchers, pumps	0	-2	-3
Equipment characterised by intermittent noise emissions or revving engines	Dozers, excavators, sideboom tractors, dump trucks	0	-5	-8

5.2.2 Noise Assessment

In order to assess the noise impacts associated with various pipeline construction activities, calculations were carried as follows:

- A SoundPLAN (Version 6.4) environmental computer model was developed. SoundPLAN is a software package which enables compilation of a sophisticated computer model comprising of contours (in this instance flat ground between the source and receiver), the location and acoustic sound power levels of potentially critical noise sources and the location of receivers for assessment purposes. The computer model can generate noise emission levels taking into account such factors as the source sound power levels and locations, distance attenuation, ground absorption, air absorption, as well as meteorological conditions, including wind effects.
- The CONCAWE prediction methodology was utilised within SoundPLAN. The CONCAWE prediction method is specially designed for industrial calculations and incorporates the influence of wind effects and the stability of the atmosphere.
- Predictions of noise emission levels at various off-set distances from construction activities.
- Buffer distances from construction activities at which the nominated noise emission levels are predicted.

The noise emissions in **Table 16** and **Table 17** assume propagation over flat, soft ground (ie open grassland) to a typical receiver and are correct for "neutral" meteorological conditions. Neutral meteorological conditions are considered to be:

- 10°C
- 70% humidity
- Pasquill stability category D
- 0 m/s wind speed.

The influence of meteorological (wind effects and temperature inversion) and topographical effects on calculated noise levels in **Table 16** and **Table 17** are discussed below.

Table 16 Predicted Noise Levels at Various Offset Distances

Stage	Activity	Predicted Noise Level at Buffer Distance (LA10 dBA)						
		50m	100m	250m	500m	1,000m	2,000m	5,000m
Stage 1	Clear and grade	71	63	51	42	33	24	9
Stage 2	Blasting (preparation)	71	63	52	42	33	23	7
Stage 3	Trenching, stringing and lowering step	77	69	56	47	39	30	15
Stage 4	Welding and joint coating	70	61	49	40	32	24	8
Stage 5	X-ray and pressure test	64	56	43	35	27	18	3
Stage 6a	Padding	69	62	51	43	34	24	7
Stage 6b	Backfilling	71	63	51	42	33	24	9
Stage 7	Tie-ins, push sections and road crossings	71	64	53	44	35	26	11
Stage 8	Restoration and rehabilitation	76	68	57	49	41	33	18

Note: The distance is predicted based on the expected summation of noise sources at the receiver for the noisiest activity. Depending on the scenario the level may result from the noisiest operation, or be from multiple sources. Note as L_{A10} noise levels are statistical they cannot be simply summed based on acoustical energy at the receiver.

Table 17 Buffer Distances for Various Predicted Noise Levels

Stage	Activity	Buffer Distance to Predicted Noise Level (m)							
		85 dBA	55 dBA	50 dBA	45 dBA	40 dBA	35 dBA	30 dBA	25 dBA
Stage 1	Clear and grade	< 15	180	260	375	575	825	1,250	1,800
Stage 2	Blasting (preparation)	< 15	190	280	400	600	825	1,200	1,700
Stage 3	Trenching, stringing and lowering step	20	260	375	575	900	1,350	2,000	2,800
Stage 4	Welding and joint coating	< 15	160	220	325	500	750	1,200	1,800
Stage 5	X-ray and pressure test	< 15	110	150	200	325	500	725	1,150
Stage 6a	Padding	< 15	180	260	400	600	900	1,300	1,850
Stage 6b	Backfilling	< 15	190	270	400	575	825	1,250	1,850
Stage 7	Tie-ins, push sections and road crossings	< 15	200	300	450	675	1,000	1,500	2,100
Stage 8	Restoration and rehabilitation	20	290	450	725	1,100	1,650	2,400	3,300

Note: The distance is predicted based on the expected summation of noise sources at the receiver for the noisiest activity. Depending on the scenario the level may result from the noisiest operation, or be from multiple sources. Note as L_{A10} noise levels are statistical they cannot be simply summed based on acoustical energy at the receiver.

The predicted noise level emissions in **Table 16** and **Table 17** show that the most significant noise generating stages of pipeline construction works are:

- Stage 3 – Trenching, stringing and lowering step; and
- Stage 8 – Restoration and rehabilitation.

Meteorological Effects

As previously noted, the predicted noise level emissions in **Table 16** and **Table 17** are based on neutral weather conditions, which include the following meteorological parameters:

- 10°C
- 70% humidity
- Pasquill stability category D
- 0 m/s wind speed.

The "worst case" weather conditions used to assess the affect of adverse meteorological conditions on noise propagation from the construction activities are:

- 10°C
- 90% humidity
- Pasquill stability category F (to simulate temperature inversion conditions)
- 2 m/s wind speed (source to receiver).

The resulting change in predicted levels due to adverse weather is summarised in the **Table 18.**

Table 18 Increase in Noise Levels due to "Worst Case" Weather Conditions

	Increase in Predicted Noise Level at Offset Distance (dBA)						
	50m	**100m**	**250m**	**500m**	**1,000m**	**2,000m**	**5,000m**
Change due to adverse weather	0	1	2	4	5	6	7

Appendix D of the NSW's '*Industrial Noise Policy'* (INP) provides guidance on estimating the increase in noise levels due to temperature inversion conditions. The increase in noise levels was estimated using similar modelling parameters as those nominated above for "worst case" weather conditions. The increase in noise levels (nominated in NSW IMP) due to temperature inversion conditions is estimated to be between 1 dBA and 6.5 dBA depending on the distance from the noise source and the change in temperature (increase for temperature inversions) with respect to height above ground. The increase in noise level due to temperature inversion conditions, nominated in the NSW IMP (1 dBA to 6.5 dBA) is consistent with the increase in noise levels from the "worst case" weather condition (0 dBA to 7 dBA) shown in **Table 18**.

Table 18 shows that there is negligible change to the predicted noise level for works less than 250m from a sensitive property. Those sensitive properties located at 500m or more from construction activities experience a noticeable change in noise levels as a result of adverse weather conditions.

It is noted that the predicted construction noise levels at distances greater than 2,000m would be similar to, or below, background levels observed in quiet rural areas.

Topographical Effects

As previously stated, **Table 16** and **Table 17** assume propagation over flat, soft ground (ie open grassland) to a typical receiver.

Local topography can dramatically effect the propagation of noise, especially if the construction works is conducted through areas with steep terrain. The extent of change in noise levels due to topographical effects would be dependant on the level of shielding provided (which would be very much site specific). The actual degree of noise attenuation due to topographical shielding is a function of the frequency spectrum of the noise and the length of the diffracted noise path compared to the direct noise path.

Noise attenuation due to topographical shielding typically ranges from 5 dBA if line-of-sight between the noise source and receiver location is just obscured, and up to approximately 15 dBA where the topography provides optimal blocking of the sound transmission path.

It is noted that during "worst case" weather conditions, noise attenuation due to topographical shielding would be less than that expected during "neutral" weather conditions.

5.2.3 Discussion of Noise Impacts

The majority of pipeline construction works are likely to occur in areas where background noise levels are expected to be relatively low (ie R1, R2 and R3 land use areas). **Table 19** shows the typical buffer distances at which the relevant noise criteria would be achieved for Stage 3 (trenching), Stage 5 (x-raying and pressure testing) and Stage 7 (tie-ins, push sections and road crossings) construction works. Trenching (Stage 3) is predicted to be the most significant noise generating stage, whilst x-raying and pressure testing (Stage 5) is predicted as being the least significant stage in terms of noise generation. The only construction works that may occur during the night time period would be x-raying and pressure testing (Stage 5) and tie-ins, push sections and road crossings (Stage 7) activities.

Table 19 Construction Noise Criteria – Compliance Distances

Stage	Land Use Area [1]	Predicted Distance to Achieve Guideline Noise Levels (m)							
		QLD			NSW			IFC	
		Day	Evening	Night [2]	Day	Evening	Night [2]	Day	Night [2]
Stage 3	R1	-	900	N/A	575	1,350	N/A	250	N/A
	R2		575		375	900	N/A		
	R3		375		260	575	N/A		
Stage 5	R1	-	325	170	200	500	500	100	190
	R2		200		150	325	500		
	R3		150		110	200	325		
Stage 7	R1	-	675	450	450	1,000	1,000	160	360
	R2		450		300	675	1,000		
	R3		300		200	450	675		

Note 1: R1, R2 and R3 refer to those areas classified in **Table 4**.
2: Night works would generally be limited to hydro testing and push sections (Stages 5 and 7 respectively)
Note: Day: Monday to Friday 7am-6pm; Saturday 7am-1pm.
Evening: Monday to Friday 6pm-10pm; Saturday 1pm-10pm.
Night: Monday to Saturday 10pm-7am; Sunday all day.

Table 19 shows that, where construction activities are undertaken during the daytime (as is generally the case), the relevant noise criteria may be exceeded at distances up to approximately 260m for typical residential areas and at distances up to 575m for residences in very rural areas for the highest noise generating construction activities (Stage 3). For the least significant construction activities (Stage 5) the noise criteria may be exceeded at distances ranging from 110m to 200m from the construction source depending on the land use type.

The distance at which the noise criteria would be exceeded is dependant on a number of factors including the proximity of the receiver to the noise source, the level of noise emission from the source, the time of day and prevailing background noise level, intervening topography between the source and the receiver and the prevailing meteorological conditions.

The noise criteria may be exceeded at significantly greater distances than those described above for construction activities undertaken in the evening or night time periods.

5.3 Construction Vibration

The major potential source of construction vibration (other than from blasting) would be due to the operation of bulldozers and the chain and wheel trenchers.

Typical ground vibration levels from bulldozers range from 1 mm/s to 2 mm/s at a distance of approximately 5 m. At distances greater than 20 m, vibration levels are usually below 0.2 mm/s.

Therefore, based on the nominated width of vegetation clearing (30m) and the likely construction activities, vibration levels produced by pipeline construction activities are expected to be below the human comfort vibration criteria of 0.3 mm/s to 0.6 mm/s and significantly below the structural damage vibration criteria of 20 mm/s (at 15 Hz) at nearby receptors.

Heggies do not have any vibration emission data for the operation of a chain or wheel trencher or for a small scale boring machine. If it is proposed to operate the chain trencher, wheel trencher or boring machine in close proximity to sensitive receptors then vibration emission data should be obtained for this equipment to determine the likely impacts. This may include undertaking vibration monitoring at sensitive receivers where appropriate. The need for vibration monitoring would need to be determined on a case by case basis.

However in general, vibration monitoring should be considered where vibration generating construction activities (ie bulldozers, chain/wheel trenchers, boring machines) are carried out within 30m to 40m of sensitive receptors.

6 BLAST NOISE AND VIBRATION IMPACT

Blasting will be required to form the trench in areas of igneous rock which is not rippable by mechanical methods (such as chain/wheel trencher or excavator).

Whilst Heggies has not been provided with details of the blast parameters and design, it is assumed drill and blast techniques incorporating confined blasting will be employed. Further more Heggies has assumed typical blast parameters in order to conduct an assessment of typical blasting impacts. These blast parameters will be required to be reviewed to enable a further detailed assessment once a blast design is confirmed. The typical parameters assumed for this assessment are presented in **Table 20**.

Table 20 Indicative Blast Design Details

Parameter	Free-Face
Bench height	4.2 m
Stemming (using 20 mm aggregate)	2.7 m
Blasthole diameter	102 mm
Blasthole spacing	3.0 m
Burden	3.0 m
Maximum Instantaneous Charge (MIC)	10, 25 and 50 kg

6.1 Blast Emission Levels

By adopting the nominated typical blast design, the level of blast emissions can be predicted using the formula given in the AS 2187-2, 2006 and ICI Explosives Blasting Guide, applicable to blasting in average rock. Also given in the Guide is a formula in relation to the prediction of airblast emissions. Both methods of blast emission estimation are considered conservative.

The relevant formulae are as follows:

$$PVS = 1140\,(R/Q^{0.5})^{-1.6}$$

$$dB = 164.2 - 24(\log_{10} R - 0.33 \log_{10} Q)$$

Where,

PVS = Peak Vector Sum ground vibration level (mm/s)
dB = Peak airblast level (dB Linear)
R = Distance between charge and receiver (m)
Q = Charge mass per delay (kg)

The relationship between distance and the peak vector sum (PVS) ground vibration and peak airblast from the blasting are presented in **Figure 3** to **Figure 8** respectively for an MIC of 10 kg, 25 kg and 50 kg.

Figure 3 Peak Vector Sum Ground Vibration for an MIC of 10 kg

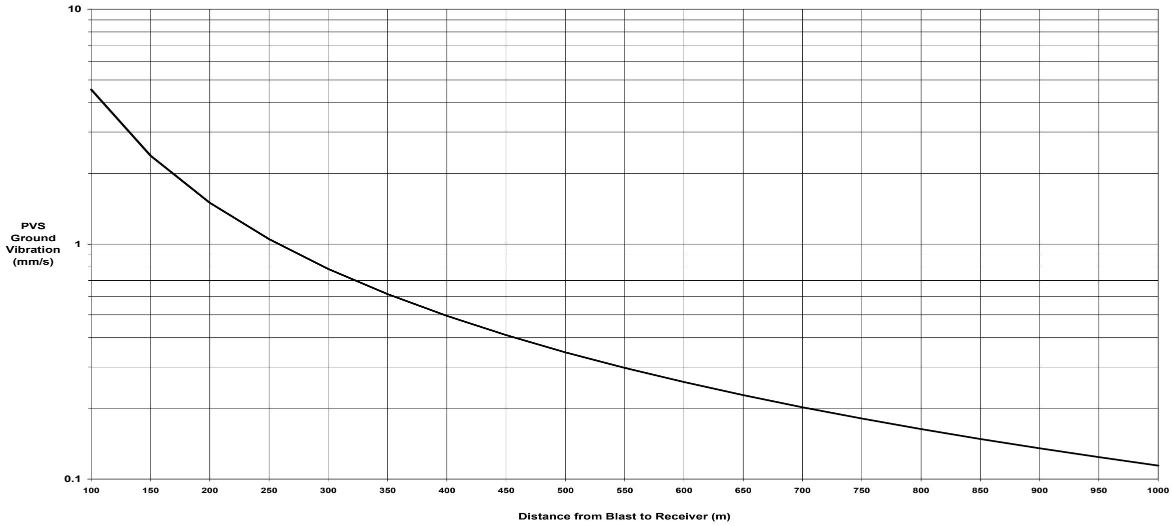


Figure 4 Peak Airblast for an MIC of 10kg

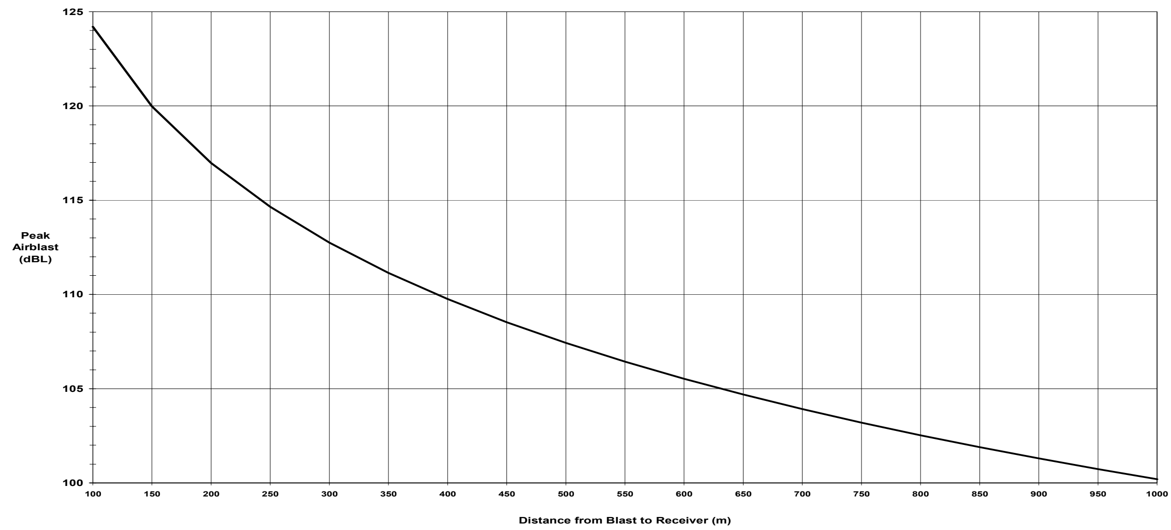


Figure 5 Peak Vector Sum Ground Vibration for an MIC of 25 kg

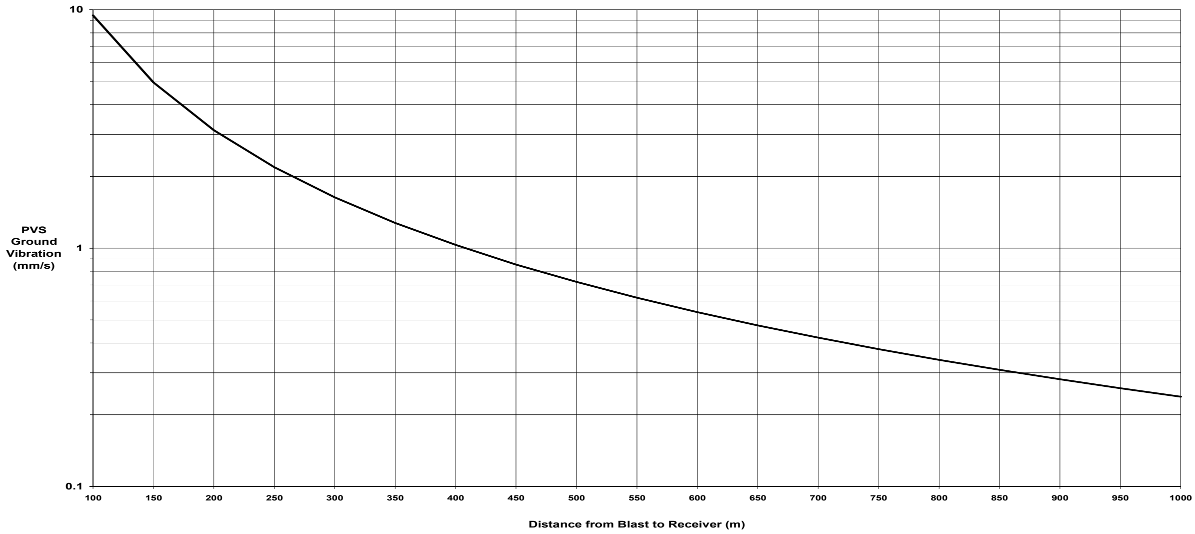


Figure 6 Peak Airblast for an MIC of 25kg

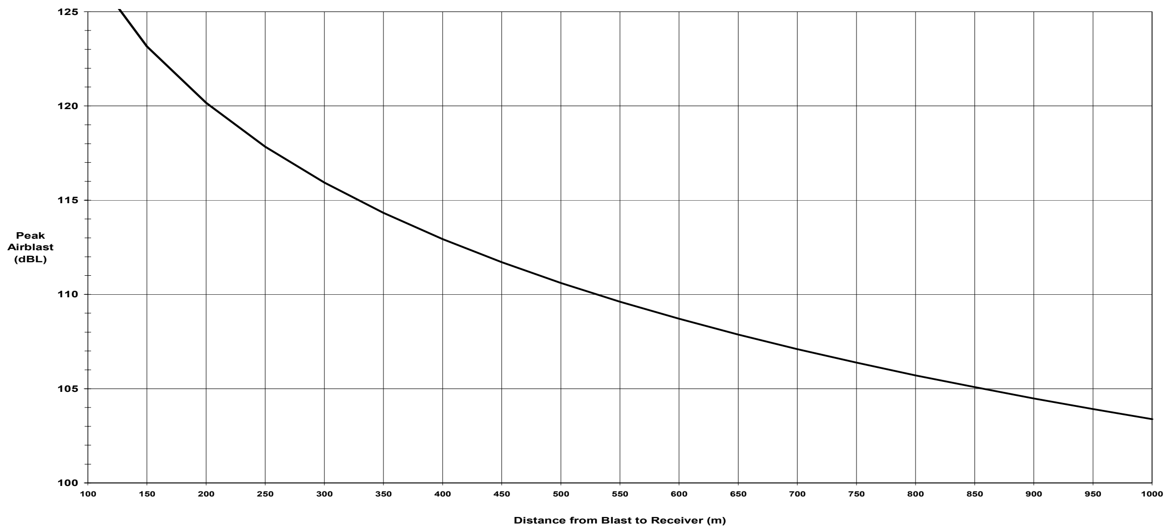


Figure 7 Peak Vector Sum Ground Vibration for an MIC of 50 kg

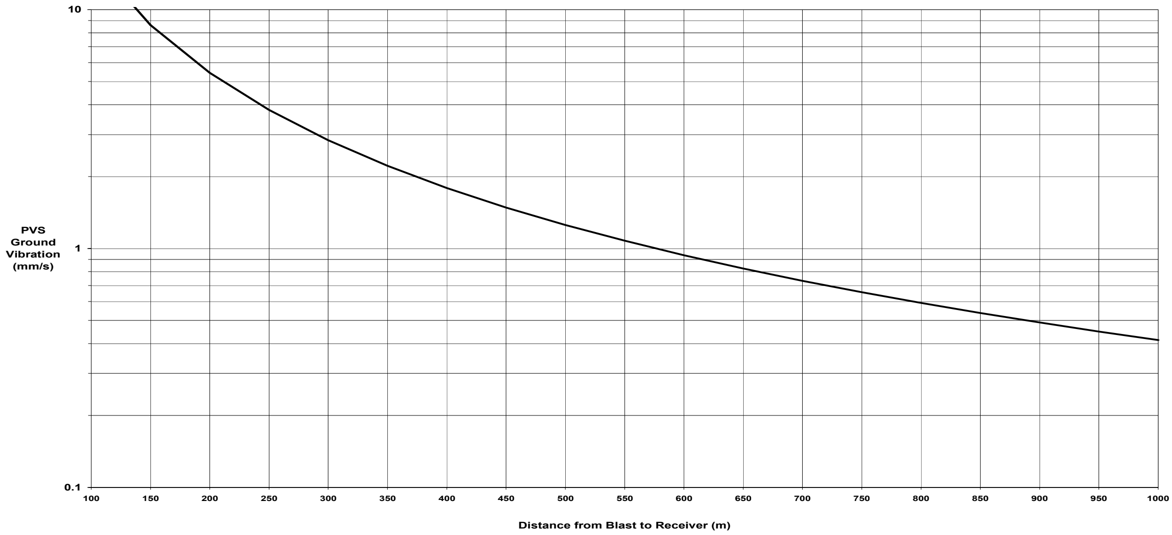
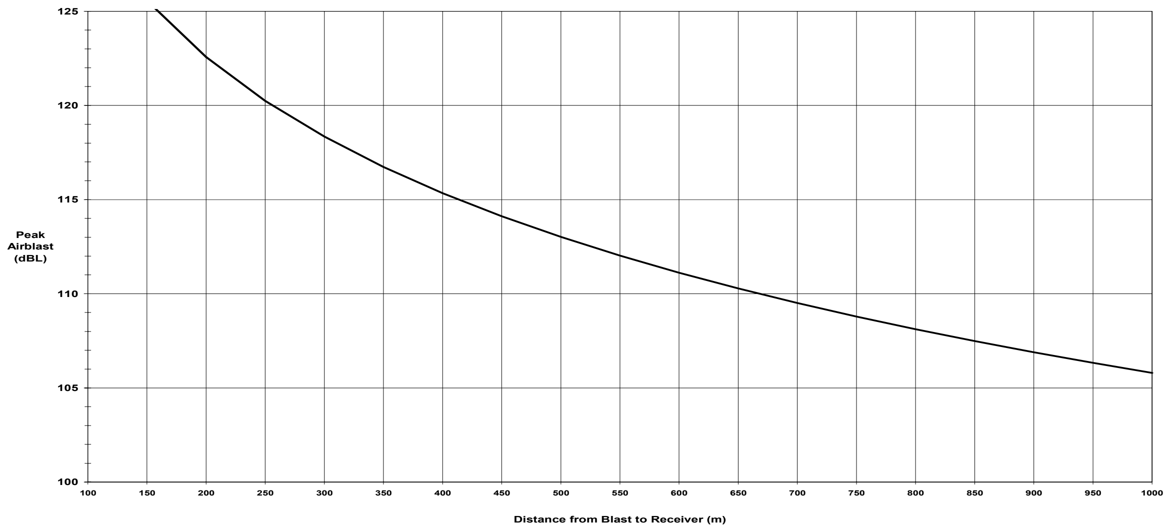


Figure 8 Peak Airblast for an MIC of 50kg



The graphs are used to determine predicted level of blast emissions at appropriate distances to the blast site. Offset distances required to meet the airblast criterion of 115 dBL and PVS ground vibration criterion of 5 mm are summarised respectively in **Table 21** and **Table 22** below.

Table 21 Offset Distances to Comply with Airblast Criterion

MIC	Offset Distances (m)	
	115 dBL	120 dBL
10 kg	250	160
25 kg	330	210
50 kg	420	260

Table 22 Offset Distances to Comply with PVS Ground Vibration Criterion

MIC	Offset Distances (m)	
	5 mm/s	10 mm/s
10 kg	<100	<100
25 kg	150	<100
50 kg	220	130

Following identification of the potentially affected residences in the vicinity of the blast sites, refinement of the potential impacts of the typical blast designs can be reviewed.

7 NOISE MITIGATION OF CONSTRUCTION ACTIVITIES

Section 5.2 identifies buffer distances at which the relevant noise criteria may be exceeded. Exceedance of the noise criteria would be dependant on a number of factors including the proximity of the receiver to the noise source, the level of noise emission from the source, the time of day and prevailing background noise level, intervening topography between the source and the receiver and the prevailing meteorological conditions.

The need for noise mitigation measures would be determined on a project specific basis taking into consideration all of the factors identified above. **Section 7.1** outlines a selection of noise mitigation measures which may be applied to attenuate construction noise where appropriate.

7.1 Noise Mitigation Strategies

AS 2436-1981 "*Guide to Noise Control on Construction, Maintenance and Demolition Sites*" sets out numerous practical recommendations to assist in mitigating construction noise emissions. Examples of strategies that could be implemented on the project are listed below, including the typical noise reduction achieved, where applicable.

Construction Strategies

- Where possible, construction hours should be limited to the recommended standard hours nominated in **Section 4.1**, or as specified in an approved noise management plan prepared in consultation with the relevant government body (ie DECC or EPA). It is noted that construction activities would typically be undertaken between the hours of 6am to 6pm on a roster cycle (ie 28 days on, 9 days off). Where construction activities are undertaken outside of the recommended standard hours, appropriate community consultation should be carried out for potentially affected receptors. This may include not undertaking construction activities in close proximity to sensitive receptors outside the recommended standard construction hours (particularly in rural areas).
- Particularly important will be adherence to standard DECC and EPP[Noise] recommended hours for any blasting activities required.
- When working adjacent to schools, scheduling of noisy activities to outside of normal school hours, where possible.
- Avoiding the coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers would also result in reduced noise emissions.
- Where possible, the offset distance between noisy plant items and nearby noise sensitive receivers should be as great as possible.
- Regular compliance checks on the noise emissions of all plant and machinery used for the project would indicate whether noise emissions from plant items were higher than predicted.

- In cases where construction activities are carried out in close proximity to sensitive receptors or where there is potential for adverse impact, a project specific construction noise and vibration management plan may be prepared to detail how construction noise and vibration impacts would be minimised and managed.

Source Noise Control Strategies

- Engines and exhausts are typically the dominant noise sources on mobile plant such as graders, excavators, trucks, etc. Residential grade mufflers fitted on this mobile plant would minimise noise emissions from these sources.
- Regular maintenance of all plant and machinery used for the project will assist in minimising noise emissions.
- In particular as the chain/wheel trenchers have been identified as a dominant source during trenching contractual specifications for maximum noise emission should be considered.

Noise Barrier Control Strategies

Temporary noise barriers may be incorporated where feasible, between the noise sources and nearby potentially affected noise sensitive receivers. Typically, 7 dBA to 15 dBA of attenuation can be achieved with a well constructed barrier.

Community Consultation

Active community consultation and the maintenance of positive relations with schools, local residents and building owners would assist in alleviating concerns and thereby minimising complaint.

Prior advice should be given to the community regarding any works outside standard construction hours.

Achievable Noise Reduction

The noise mitigation strategies discussed above would typically result in noise level reductions ranging:

- From 10 dBA in instances where space requirements place limitations on the attenuation options available.
- To potentially up to 25 dBA where equipment controls (mufflers, silencers, etc) can be combined with noise barriers and management techniques (eg avoidance of clustering).

8 CONCLUSION

Heggies has been commissioned by Unidel to prepare a study of noise and vibration impacts associated with certain construction equipment and scenarios associated with pipeline works. This report is intended to form the basis for various environmental impact studies (noise and vibration) over-seen by Unidel. This report includes the legislative requirements for noise and vibration emissions in both Queensland and NSW as well as the requirements contained within the IFC Guidelines.

The results of the study are summarised in the following points:

- Applicable criteria have been nominated for the assessment of noise and vibration impacts associated with pipeline construction activities.
- The criteria are based on the relevant Qld and NSW legislative requirements as well as the relevant IFC Guidelines.
- The relevant noise criteria for pipeline construction activities (other than blasting) are based on typical background noise levels for the applicable land use area.
- For the suite of construction activities expected (such as clearing, trenching, pipe laying), typical offset distances have been determined to allow compliance with the noise criteria to be achieved. Typical distances to comply with construction vibration activities have also been nominated.
- It is noted that noise levels and appropriate offset distances may vary from those nominated as a result of topographical and/or meteorological effects (see **Section 5.2.2**)
- Blasting may be required in areas where rock is not rippable via mechanical methods. Based on a typical blast design, typical offset distances to comply with blasting criteria have been nominated.

1 Sound Level or Noise Level

The terms "sound" and "noise" are almost interchangeable, except that in common usage "noise" is often used to refer to unwanted sound.

Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

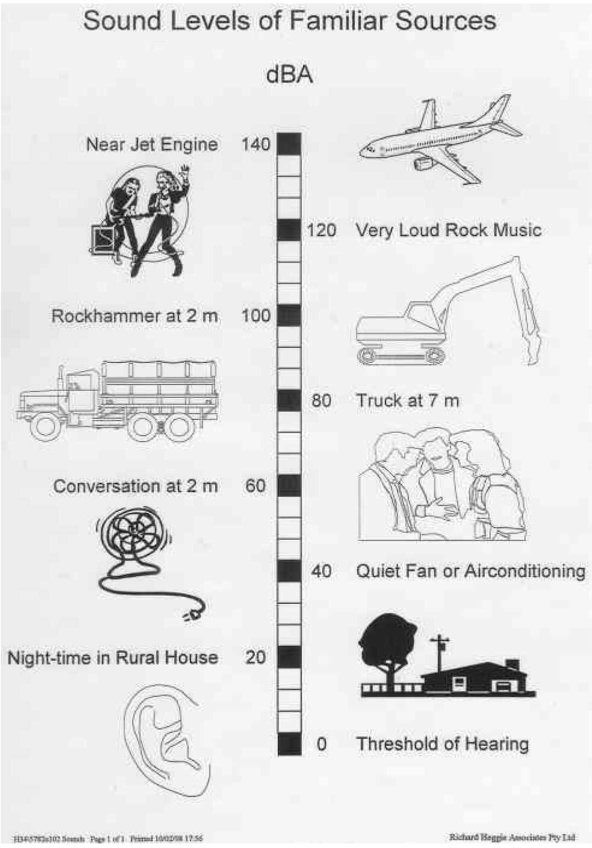
The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2 x 10^{-5} Pa.

2 "A" Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an "A-weighting" filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People's hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness. The figure below lists examples of typical noise levels



Other weightings (eg B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as "linear", and the units are expressed as dB(lin) or dB.

3 Sound Power Level

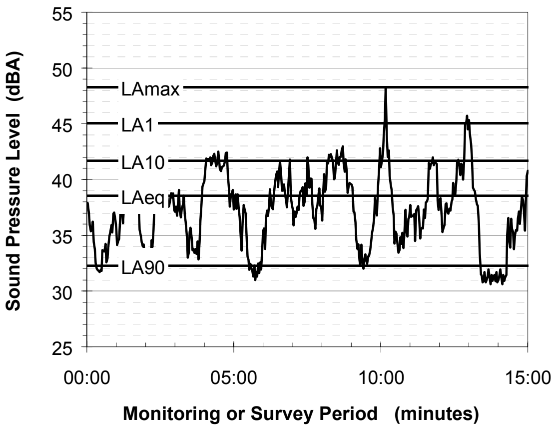
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

The relationship between Sound Power and Sound Pressure may be likened to an electric radiator, which is characterised by a power rating, but has an effect on the surrounding environment that can be measured in terms of a different parameter, temperature.

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.



Of particular relevance, are:

L_{Amax} The maximum noise level during the 15 minute interval

L_{A1} The noise level exceeded for 1% of the 15 minute interval.

L_{A10} The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

L_{A90} The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

L_{Aeq} The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels.

This method produces a level representing the "repeatable minimum" L_{A90} noise level over the daytime and night-time measurement periods, as required by the EPA. In addition the method produces mean or "average" levels representative of the other descriptors (L_{Aeq}, L_{A10}, etc).

5 Tonality

Tonal noise contains one or more prominent tones (ie distinct frequency components), and is normally regarded as more offensive than "broad band" noise.

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.

7 Frequency Analysis

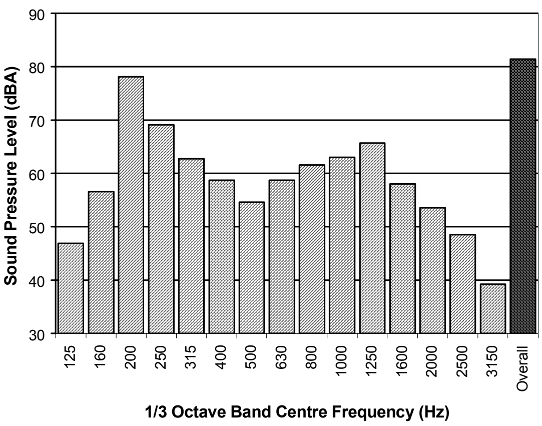
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



8 Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of "peak" velocity or "rms" velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as "peak particle velocity", or PPV. The latter incorporates "root mean squared" averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (10^{-9} m/s). Care is required in this regard, as other reference levels may be used by some organizations.

9 Human Perception of Vibration

People are able to "feel" vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

10 Over-Pressure

The term "over-pressure" is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

11 Ground-borne Noise, Structure-borne Noise and Regenerated Noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed "structure-borne noise", "ground-borne noise" or "regenerated noise". This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (eg rockbreakers), and building services plant (eg fans, compressors and generators).

The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.