Appendix K

Blasting Specialist Response

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RIX'S CREEK PTY LTD

EFFECTS OF BLASTING IN THE CONTINUATION AREA

FINAL – 2
Amended 14th March, 2017 (Table 4A)

Adrian J. Moore
14th March, 2017

RIX'S CREEK PTY LTD
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EFFECTS OF BLASTING IN THE CONTINUATION AREA

FINAL – 2
Amended 14th March, 2017 (Table 4A)

1. INTRODUCTION

Terrock Consulting Engineers were requested by Rix's Creek to investigate the effects of blasting in the continuation area located North West of the existing operations in the West Pit and South West of the New England Highway. A smaller southern extension of the North Pit is also planned to be mined. The Location Plan in **Figure 1** which shows:

- Current extraction area;
- Both continuation areas;
- Sites sensitive to blast vibration (residential areas);
- Current monitoring locations;
- The New England Highway;
- Historic Coking Oven remains.

Currently the blast vibration is monitored at:

West Pit:	Dunn Residence - Maison Dieu Rd	**North Pit:**	Ernst Residence - Camberwell
	Wright Residence - Maison Dieu Rd		Retreat – Bridgeman Hill
	Mines Rescue – Singleton Heights		Mines Rescue - Singleton Heights

2. ENVIRONMENTAL BLASTING RELATED ISSUES

The related issues for blasting in the continuation areas are:

- Ground vibration control;
- Airblast control;
- Flyrock control;
- Dust and Fume Management;
- Traffic management on New England Highway;
- Stability of the New England Highway;
- Protection of the Historic Coking Oven remains.

Figure 1 – Location Plan

3. REGULATORY BLAST VIBRATION LIMITS

3.1 The nature and measurement of blast vibration

When an explosive charge is fired, explosive energy produces the following effects:

- Rock shattering and displacement
- Ground transmitted blast vibration - (ground vibration)
- Air transmitted blast vibration - (airblast overpressure)

3.1.1. Ground Vibration

Ground vibration radiates outwards from the blast site and gradually reduces in magnitude, in the same manner as ripples behave when a stone is thrown into a pool of water, schematically shown in **Figure 3.1**. The motion of the wave can be defined by taking measurements of a float on the surface of the water. With suitable instruments we can measure the displacement or amplitude, the velocity, the acceleration of the float and the wave length of the waves.

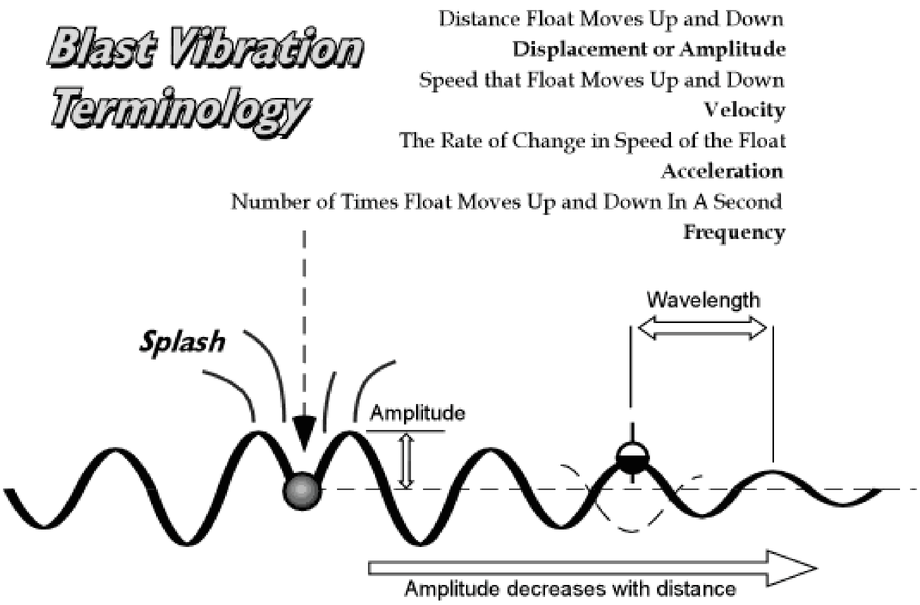


Figure A1.5 - Schematic diagram of vibration terminology

With ground vibration, the motion of the surface of the ground can be measured by coupling a suitable instrument directly to the surface.

For regulatory purposes, it has become common practice to measure ground vibration using a seismograph with a geophone securely attached to the ground.

The geophone measures the velocity that a point (or particle) on the ground moves in three dimensions at the measurement location as the vibration waves pass.

This is called the particle velocity, and the maximum value is called the peak particle velocity (PPV), measured in terms of millimetres per second (mm/s).

To define the motion in three dimensions, it is necessary to use three transducers to measure the vibration in three mutually perpendicular directions and then determine a Peak Particle Velocity or Peak Vector Sum (PVS), which is the instantaneous maximum vector of the three individual measurements:

$$\text{ie. PPV (PVS)} = \sqrt{v_t^2 + v_l^2 + v_v^2}$$

Ground vibration from blasting must be measured with a blast vibration meter that complies with the requirements of AS2187.2 – 2006.

3.1.2. Airblast Overpressure

When air transmitted vibration is within the range of hearing it is called sound (with frequencies in the range 20 Hz to 200,000 Hz). When its frequencies are below the range of hearing is generally referred to as concussion or airblast.

Noise is generally measured with a sound level meter that simulates the ear by filtering out frequencies below 20 Hz, the results obtained are specified as decibels (A), or dBA.

Airblast overpressure is substantially sub-audible. Although these frequencies are below the range of hearing they affect structures, and the response of the structures can be sensed by people who are inside. This explains why a blast that is barely noticed outside can be noticed by people inside a building.

Airblast overpressure is measured with special sound level meter that does not filter out the low frequencies below 20 Hz that affect structures, and the results obtained are specified as decibel (linear), or dBL.

Airblast overpressure must be measured with a meter that complies with the requirements of AS2187.2-2006.

3.2 Human and Structure Response

3.2.1 Human Response

Humans are more sensitive to blast vibration than structures, and this has resulted in human response limits that are well below levels that will cause damage to structures.

Human response to blast vibration, which is based by the experience of the Terrock personnel over a period of 40 years, is summarised in the table below:

	Ground Vibration	Airblast Overpressure
Threshold of human response	0.1 to 0.5 mm/s	90 to 100 dBL
Levels that acceptable to most people and not result in complaint.	Up to 2 mm/s	Up to 110 dBL
Levels that are likely to cause complaint.	2 to 5 mm/s	110 to 115 dBL
Levels that will result in an increased number of complaints.	5 to 10 mm/s	115 to 120 dBL.
Levels that are generally unacceptable to the Australian community.	Above 10 mm/s	Above 120 dBL.

3.2.2 Structure Response

Structural damage will occur at levels that are well above levels that are considered unacceptable to humans.

Authoritative research (ref ACARP Project C.9040 – Effect of Blasting on Structures) shows that at a ground vibration level of 10 mm/s, the stress induced into a brick veneer house is less than 10% of the strength of the weakest structural element (the interior plasterboard).

AS2187.2-2006 includes recommended ground vibration and airblast overpressure limits for damage control. These structural limits are well above the human response limits specified in environmental licences and development consents.

It should be noted that AS2187.2-2006 does not include a specific limit for historic structures. Appropriate limits for historic structures should be assessed on an individual case basis.

3.3 Development Consent Conditions

The following human ground vibration and airblast limits are specified in the current Development Consent conditions.

Ground Vibration	≤ 5 mm/s for 95% of blasts in a 12 month period ≤ 10 mm/s for all blasts
Airblast	≤ 115 dBL for 95% of blasts in a 12 month period ≤ 120 dBL for all blasts.

These human response limits are based on the Australian & New Zealand Environmental Council (ANZEC) "Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration". This publication specifies the following guideline limits at sensitive sites:

- Ground vibration: 5 mm/s for 95% of blasts within a 12 month period, with exceedence permitted to 10 mm/s for 5% of blasts.
- Airblast overpressure: 115 dBL for 95% of blasts within a 12 month period, with exceedence permitted to 120 dBL for 5% of blasts.

4. DESCRIPTION OF THE BLASTING ENVIRONMENT

Blasting of overburden and interburden is necessary to break the rock to enable it to be removed and the coal seams beneath uncovered. The thickness of the rock layers varies considerably from about 2m to over 30m in the Northern Pit. In the Western Pit the thickest interburden blasting is currently 35m but this may increase to over 40m as the pit advances to the North West. Geological cross sections through both pits are shown in **Figures 2a** and **2b**. Individual blasts are designed and the specifications altered to comply with the regulatory environmental ground vibration and airblast limits at the nearby sensitive sites.

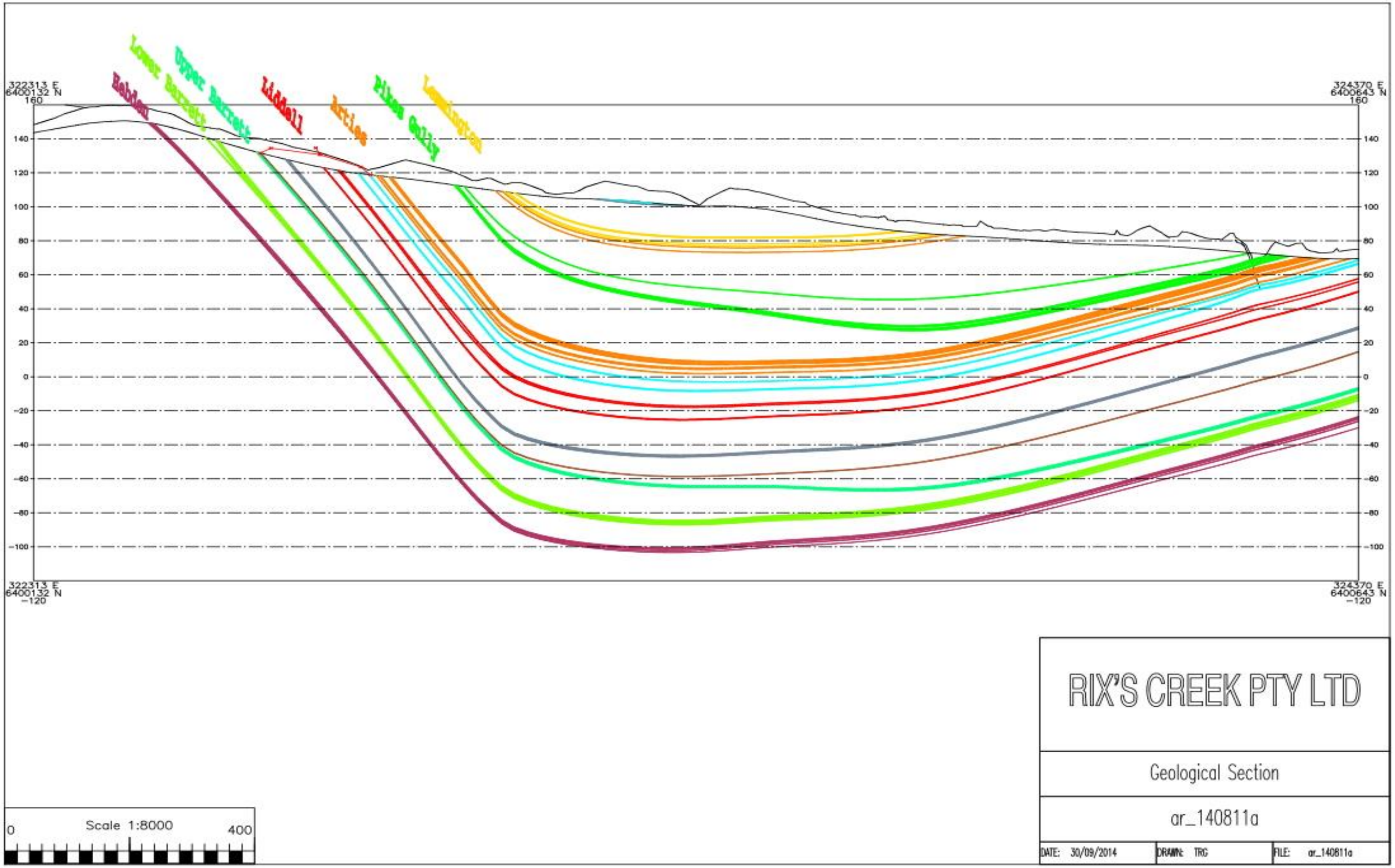


Figure 2a – Geological Cross Section – North Pit

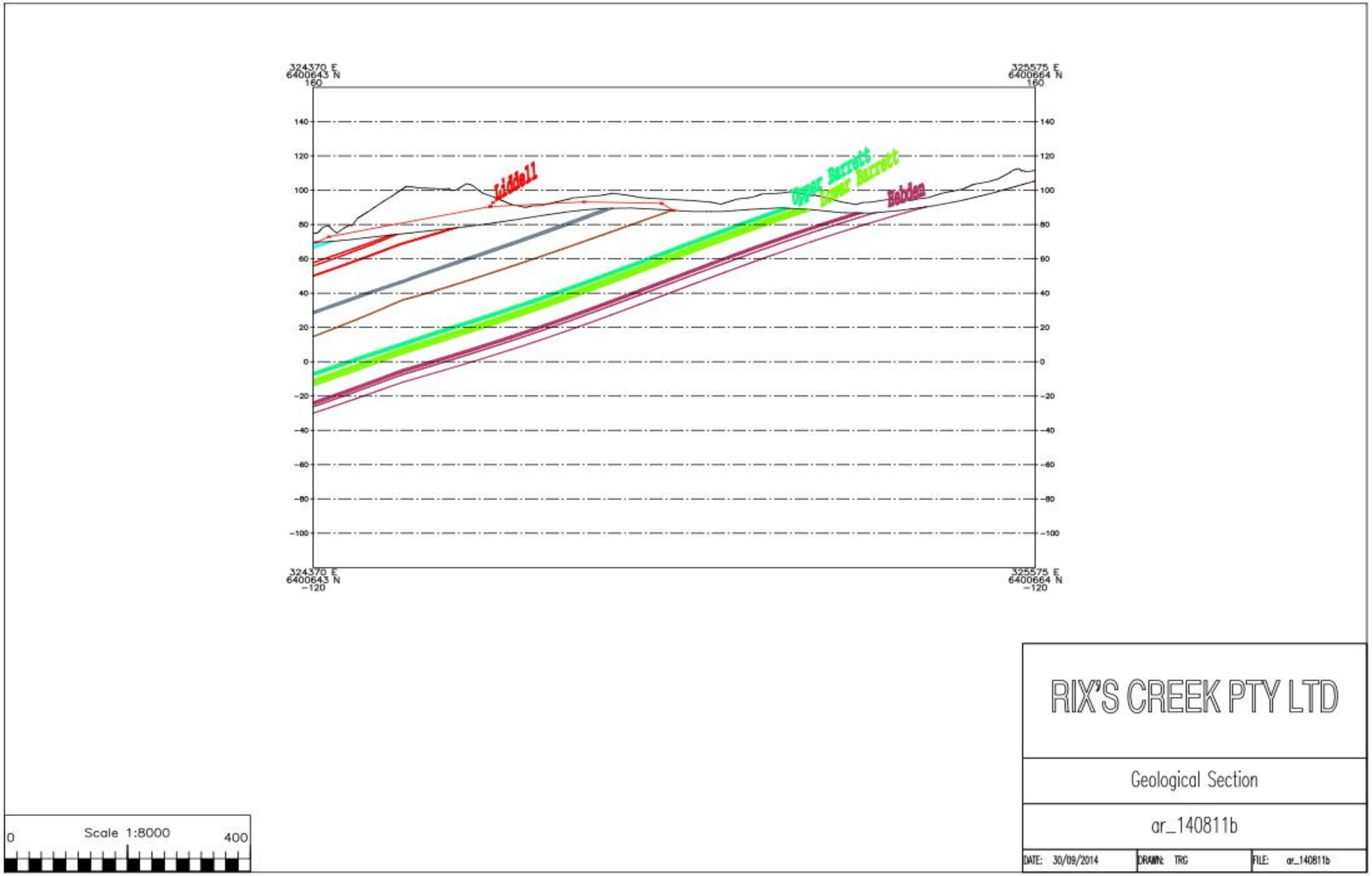


Figure 2b – Geological Cross Section – West Pit

5. DESCRIPTION OF BLASTING PRACTICE

Blasting practice uses environmental blast design principles to adjust the blasting specifications to control airblast and ground vibration to regulatory limits as well as controlling flyrock. To control airblast and flyrock in the shallow partings, the shallowest holes that can be fired are about 2.5m deep and a typical loading would be 0.2 – 0.3m explosives and 2.2 – 2.3m of stemming. In deeper blasts, the burden, spacing and stemming height are varied to achieve the ground vibration and airblast targets.

A range of explosives are also used with densities varying from 0.8 g/cc (ANFO) to 1.1 g/cc (Heavy ANFO 1.1) to 1.3 g/cc (HA 1.3). The explosive is chosen after consideration of the rock blastability and the presence of water in the blast holes.

A typical range of blasting specifications used in the Open Cuts is shown in **Table 1**.

Table 1 – Open Cut nominal blasting specifications

<table>
<tr><td colspan="3">Blast hole diameter:</td><td colspan="5">229mm</td></tr>
<tr><td colspan="3">Face Height (hole depth):</td><td colspan="5">2.5 m – 35m</td></tr>
<tr><td colspan="3">Stemming height:</td><td colspan="5">2.2 m – 5m</td></tr>
<tr><td colspan="3">Explosive column:</td><td colspan="5">0.3 – 30 m</td></tr>
<tr><td rowspan="2">Explosive</td><td rowspan="2">Charge mass/m (kg)</td><td>Hole Depth (m)</td><td>2.5</td><td>10</td><td>15</td><td>20</td><td>35</td></tr>
<tr><td>Stemming Height (m)</td><td>2.2</td><td>4.0</td><td>4.5</td><td>4.5</td><td>5.0</td></tr>
<tr><td>ANFO</td><td>32.6</td><td>Charge Mass (kg)</td><td>10</td><td>195</td><td>342</td><td>505</td><td>978</td></tr>
<tr><td>HA 1.1</td><td>44.0</td><td>Charge Mass (kg)</td><td>13</td><td>264</td><td>462</td><td>682</td><td>1320</td></tr>
<tr><td>HA 1.3</td><td>53.0</td><td>Charge Mass (kg)</td><td>16</td><td>318</td><td>556</td><td>821</td><td>1500</td></tr>
</table>

The specifications may be varied following environmental blast design to ensure compliance with the regulatory limits.

6. BLAST VIBRATION FROM CURRENT BLASTING OPERATIONS

The range of PPV and Peak Airblast for 2013 and 2014 (to date) at the routine monitoring stations is summarised in **Table 2** also. The separation distance from the blasts to the monitors is sufficient that the ground vibration does not approach the 5 mm/s (95%) limit at any monitor from current blasting operations.

Table 2a – Summary of PPV and Peak Airblast - 2013 & 2014 (to July 2014) – West Pit

		Dunn	Wright	Mines Rescue
2014	Distance range	2400 – 3000	2500 – 3100	3600 – 4050
	PPV range	0.36 – 2.05	0.28 – 2.05	0.02 – 0.51
	Airblast range	98.8 – 112.3	79.2 – 109.9	92.0 – 99.18
2013	Distance range	1450 – 2450	1700 – 2350	4200 – 3450
	PPV range	0.12 – 2.8	0.11 – 3.4	0.07 – 0.54
	Airblast range	89.3 – 111.2	87.8 – 112.1	83.0 – 102.7

Table 2b – Summary of PPV and Peak Airblast – 2013 & 2014 (to July 2014) – North Pit

		Ernst	Retreat	Mines Rescue
2014	Distance range	2800 – 2850	3000 – 4900	3600 – 4050
	PPV range	< 0.3*	< 0.3*	0.07
	Airblast range	< 113*	< 113*	95.4
2013	Distance range	3000	4300	6100
	PPV range	0.31 – 0.44	0.08 – 0.11	0.07 – 0.15
	Airblast range	91 – 97.7	98.3 – 100.0	90.2 – 102.6

**0.3 mm/s and 113 dBL are the lowest trigger settings on the instruments used at the time.*

The ground vibration resulting from all blasts in the investigation period was well below the regulatory limit of 5 mm/s (95%) at all monitoring stations. The airblast resulting from all blasts was also below regulatory limits at all monitoring stations.

7. BLAST ANALYSIS

The blast vibration monitoring results for 2013 and 2014 have been analysed to determine what is currently being achieved and how this transfers into the continuation area.

7.1 GROUND VIBRATION

There is a considerable variation in the blasting depths (2m to 35m) and the resulting charge mass. The centroidal contour approach was considered to be the best method to demonstrate the worst case ground vibration situation.

7.1.1 Centroidal Contour Approach

This approach is used to demonstrate the worst case ground vibration levels that are being achieved from current blasting operations. The centroid of the blasting operations is identified and radial lines constructed to the monitoring locations. Using a characteristic attenuation rate of 1.6, the milestone intercepts along the radial lines are determined. The 5, 2, 1 and 0.5 mm/s contours are then determined by connecting the intercepts. This worst case contour assessment is shown in **Appendix 1** - Ground vibration Contour Assessment. Future blasting in the West Pit will result in the blasting centroid moving to the North West which will reduce the ground vibration at the sensitive sites. For example, given the same circumstances, the PPV at the Wright monitor will reduce to below 3.0 mm/s with the centroid 200m further to the North West and below 2.0 mm/s at 1000m further to the North West.

7.1.2 Predictive Model Approach

The worst case ground vibration can be analysed using the following Site Law model [1] by substituting for the measured values and determining *Kv*.

$$PPV = Kv\left(\frac{\sqrt{m}}{D}\right)^{e}$$

Where: *PPV* = Peak Particle Velocity (mm/s) [1]
m = Charge mass per hole or per delay (kg)
D = Distance from blast (m)
Kv = Site constant
e = The attenuation rate (1.6)

The model can be used for future predictions. The highest ground vibration in the West Pit results from the deepest blasts which utilise the highest charge mass per hole. From the Site Law model, for a charge mass of 1500 kg, the worst case *Kv* at the routine monitors is listed in **Table 3.** The North Pit determinations are based on a charge mass of 1000 kg.

Table 3 – Site Constant Determinations

North Pit Monitor	*Kv*	West Pit Monitor	*Kv*
Ernst	234	Wright	2420
Retreat	495	Dunn	1850
Mines	334	Mines Rescue	850

Using the worst case Kv values listed in Table 3, the distances at which "milestone" PPV levels will occur in a direction between the either the North Pit or the West Pit blasting areas, and the Ernst, Retreat, or Mines Rescue Station monitors can be calculated, and these are listed in Table 4.

The most significant "milestone" PPV levels are 5 mm/s and 10 mm/s.

Table 4 – Distances Related to Milestone PPV Levels

	Distance (m)					
	North Pit (charge mass = 1000 kg)			West Pit (charge mass = 1500 kg)		
PPV (mm/s)	Ernst	Retreat	Mines Rescue	Ernst	Retreat	Mines Rescue
10	230	360	280	1190	1010	620
5	350	560	440	1840	1560	960
2	620	990	770	3270	2770	1700
1	960	1530	1190	5040	4270	2620
0.5	1470	2350	1840	7780	6580	4040

The minimum distances between the either the North Pit or the West Pit blasting areas, and the Ernst, Retreat, or Mines Rescue Station (MRS) monitors, and the PPV levels that will result at those monitors using the worst case Kv values listed in Table 4A:

It may be seen that the PPV levels predicted at any sensitive site will be less than the 5 mms (95%) limit.

Table 4A –Highest PPV Levels that will result at Ernst, Retreat, and M.R.S. Monitors

	North Pit (charge mass = 1000 kg)			West Pit (charge mass = 1500 kg)				
Monitor	Ernst	Retreat	MRS	Ernst	Retreat	MRS	Wright	Dunn
Minimum Distance (m)	3190	4500	4885	4420	2690	3460	2350	2350
PPV Level at Min. Dist. (mm/s)	0.15	0.18	0.11	0.119	0.56	0.64	3.4	2.8

7.2 AIRBLAST

A centroidal contour approach was also considered to be the most effective to analyse the results of airblast from current blasting operations.

The airblast analysis for 2013 and 2014 is summarised in the regression analysis summarised in **Table 5**.

Table 5 – Peak Recorded Airblast 2013/2014

North Pit Peak Airblast			West Pit Peak Airblast		
Ernst	**Retreat**	**Mines Rescue**	**Wright**	**Dunn**	**Mines Rescue**
97.7 dBL @	100.0 dBL @	102.6 dBL @	112.1 dBL @	112.3 dBL @	102.7 dBL @
1500m	5000m	6300m	@ 2400m	2400m	4000m

Some circumspection is required with analysis of the peak airblast levels reported. Airblast signals are often affected by wind, either by modifying the airblast portion of the signal because of the change of pressure due to wind velocity, or by a wind event separate from blasting.

Also, the instruments previously used relied on being triggered by ground vibration or airblast to record an event. Consequently, the levels resulting from many of the 2013 events are reported as <0.3 mm/s and <113 dBL (the trigger settings of the instruments). In most of these events, the actual airblast levels from these events were well below 113 dBL.

Recently, continuous recording instruments have been installed, and the accuracy of the reporting for the low level events has improved.

The inaccuracies that resulted from to the use of triggered instruments have resulted in the levels that were officially reported being greater that those that actually occurred.

To overcome reporting limitations, the available wavetraces for measurements that were apparently elevated compared with expectations were reviewed. Detailed examination showed that elevated measurements were found to be either:

- Wind events
- Wind affected events
- The airblast was not recorded.

The peak airblasts reported were re-interpreted where possible to exclude the effects of the wind, and replaced by revised peak airblast levels.

Rix's Creek Blasting Engineers use the EnvMet System as part of the Blast Management Plan to determine the best time to fire the blast to reduce the possibility of elevated airblast levels caused by meteorological reinforcement. There were no obviously elevated airblast readings because of meteorological reinforcement (see Section 8).

The contours of the peak Airblast are shown in **Appendix 2** – Airblast Contour Assessment.

The peak airblast is demonstrated by the regression shown in **Figure 3**. The change of distance resulting from the continuation areas are shown. The indicated change of peak airblast is shown in **Table 6** from the continuation areas using the official reporting.

The milestone airblast levels for the peak airblast are listed in **Table 6**.

Table 6 – Milestone Airblast Distances

PAV (dBL)	Distance (front) (m)	Distance (rear) (m)
115	1950	1250
110	2900	1820
105	4300	2800
100	6200	3900

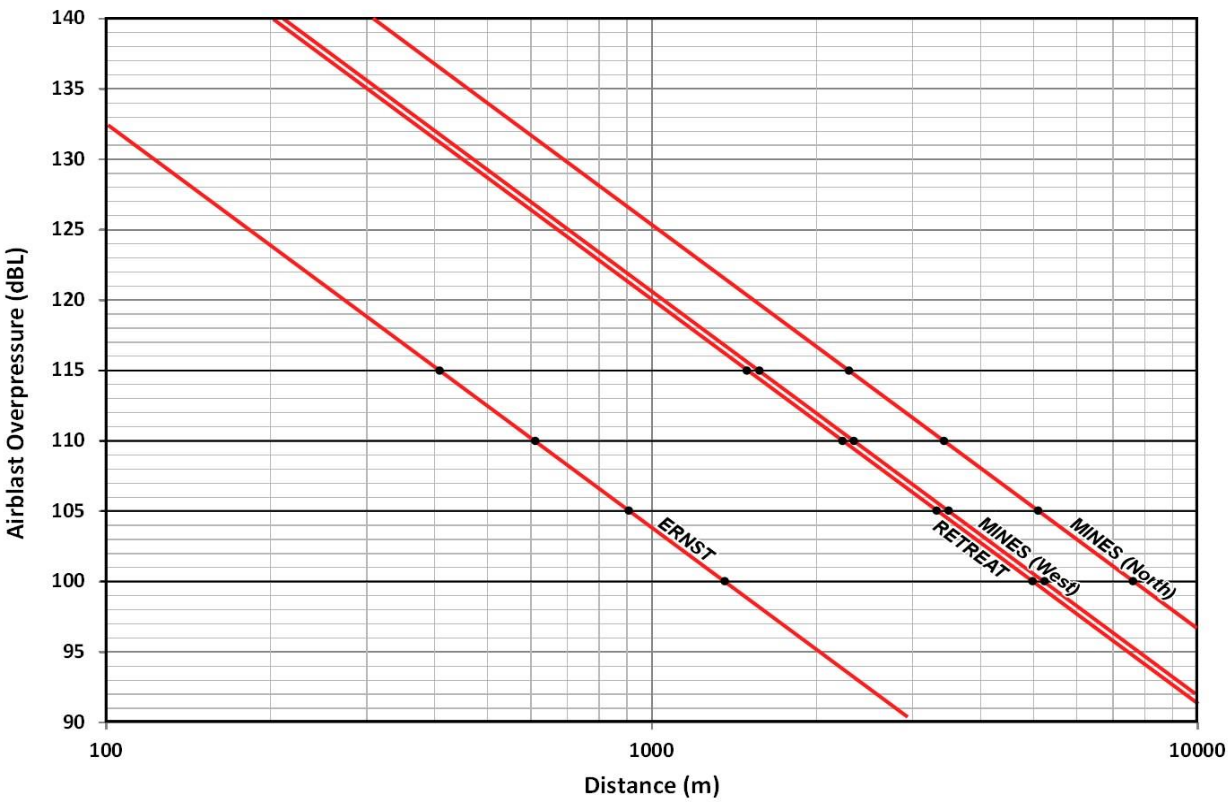


Figure 3 – Airblast Regression Analysis

Table 7 – Peak Airblast Predictions

	Monitor	Peak Levels Measured during 2013/2014 (dBL)	Peak levels predicted at closest distance (dBL)
West Pit	Wright	112.1	105
	Dunn	112.3	105
	Mines Rescue	102.7	99
North Pit	Ernst	97.7	92
	Retreat	100.0	110
	Mines Rescue	102.6	110

This investigation has shown that the airblast levels that will result from the use of current blasting practice in the West Pit will gradually reduce as blasting operations move further away from current levels at the monitor sites to 105 dBL at Wright and Dunn, and 99 dBL at the Mines Rescue Station.

In the smaller North Pit blasting area, the airblast levels that will result from the use of current blasting practice will increase at the Retreat and Mines Rescue Station monitors to about 110 dBL due to the closer distance to these sites. The levels resulting at the Ernst monitor will decrease due to an increased separation distance.

The airblast overpressure levels predicted at all sensitive sites will be less than the 115 dBL (5%) limit.

7.2.2 Predictive Airblast Model Approach

Terrock has developed predictive airblast models for prediction of airblast given changing specifications. The airblast in front of a blast can be predicted from:

$$D_{115} = \left(\frac{ka \times d}{B}\right)^{2.5} \cdot \sqrt[3]{m}$$

Where: D_{115} = Distance to the 115 dBL contour
d = hole diameter (mm)
m = charge mass/hole (kg)
B = face burden (mm)
ka = a site constant

This model is used in conjunction with a regression line using 9 dBL with doubling of distance as the attenuation rate. The airblast contours resulting from a face blast are elliptical with the airblast directly in front of a blast using 6-10 dBL higher than for the same distance behind or at the side of a blast.

For blasts without a free face, choke blasts, the airblast is predicted from:

$$D_{115} = \left(\frac{ka \times d}{S.H.}\right)^{2.5} \cdot \sqrt[3]{m}$$

Where: *S.H.* = stemming height (m)

The airblast contours for these blasts are circular (equal emissions) in all directions.

Analysis of the Rix's Creek data gives the following models:

Face Blasts (Front): $D_{115} = \left(\frac{170 \text{ x } d}{B}\right)^{2.5} \cdot \sqrt[3]{m}$

Face Blasts (Rear) and Choke Blasts: $D_{115} = \left(\frac{130 \text{ x } d}{S.H.}\right)^{2.5} \cdot \sqrt[3]{m}$

7.3 FLYROCK

Flyrock throw and trajectory path can be predicted by the use of the Terrock Flyrock Models:

7.3.1 Burden Control

$$L_{max} = \frac{Kf^2}{g}\left(\frac{\sqrt{M}}{B}\right)^{2.6}$$ [2]

Where:
- L_{max} = Maximum throw (m)
- g = Gravitational constant (g)
- M = Charge mass (kg/m)
- B = Face burden (mm)
- Kf = Flyrock constant (Interim = 13.5 for coal overburden)

L_{max} occurs when the launch angle is 45^o

7.3.2 Stemming Height Control

$$L_{max} = \frac{Kf^2}{g}\left(\frac{\sqrt{M}}{S.H.}\right)^{2.6} \text{Sin } 2\varnothing$$ [3]

- $S.H.$ Stemming height (m)
- $\varnothing$ = Launch Angle = hole angle + 10^0 divergence

Kf could be calibrated for the Rix's Creek Site by a program of video review and flyrock throw measurement.

7.3.1 Burden Control Specifications (in front of face)

For Heavy ANFO 1.3g/cc density; M = 53 kg/m *B* = 5m

$$L_{max} = \frac{13.5^2}{9.8}\left(\frac{\sqrt{53}}{5}\right)^{2.6} = 50\text{m}$$

The minimum recommended exclusion zone in front of face becomes:

- Plant and Equipment: Safety Factor **2.0** Minimum Exclusion Zone = 100m
- Personnel, boundaries etc: Safety Factor **4.0** Minimum Exclusion Zone = 200m

Stemming Height Control (at sides and behind blast)

(i) Full Scaled Blasts

For Heavy ANFO 1.3g/cc density; M = 53 kg/m B = 5m S.H. = 5000 10^{o} holes

$$L_{max} = \frac{13.5^2}{9.8}\left(\frac{\sqrt{53}}{5}\right)^{2.6} \text{Sin } 140^{o}$$

= 32.1m (at high trajectory)

Minimum Exclusion: S.F. **2.0** = 65m

S.F. **4.0** = 130m

(ii) Shallow Blasts

For Heavy ANFO 1.3g/cc density; Charge= 0.2m long = .2 x 53 = 10.6 kg S.H. = 2.3m

$$L_{max} = \frac{13.5^2}{9.8}\left(\frac{\sqrt{10.6}}{2.3}\right)^{2.6} \text{Sin } 160^{o}$$

= 16m

Minimum Exclusion: S.F. **2.0** = 32m

S.F. **4.0** = 64m

The predicted flyrock trajectory paths are shown in **Figure 4** and **4b.**

Current operating practice is to stop traffic on the New England Highway when blasting within 500m of the highway. This incorporates a substantial increase in the safety factors applied to the conservative Terrock flyrock model.

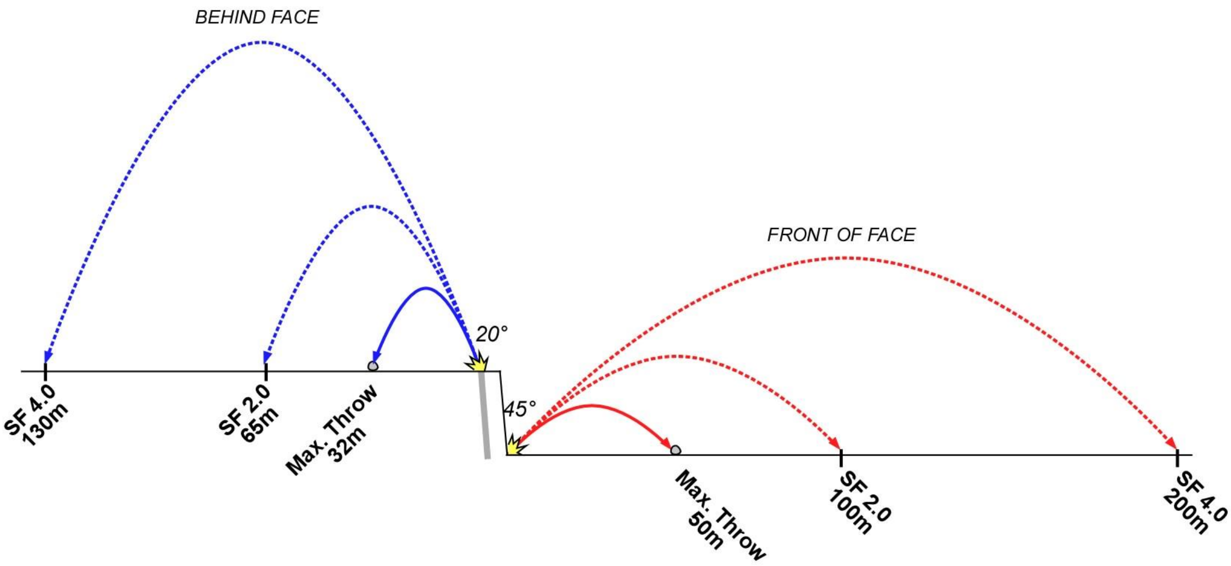


Figure 4a – Flyrock Trajectory Paths, 10° blast holes

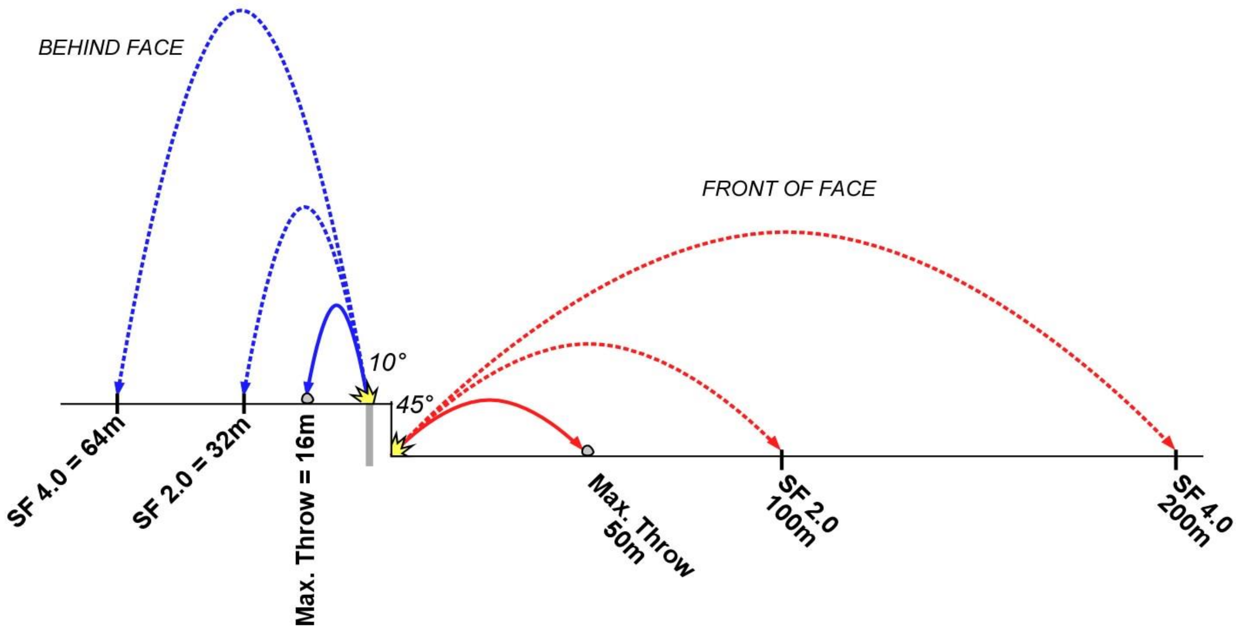


Figure 4b – Flyrock Trajectory Paths, vertical blast holes

8. EFFECT OF METEOROLOGICAL CONDITIONS ON ENVIRONMENTAL BLAST IMPACTS

8.1 METEOROLOGICAL DATA

Meteorological conditions can have a significant effect on airblast overpressure, dust and fume emission.

Control systems that have been developed for use in Hunter Valley open-pit coal mines constitute worlds-best-practice, and Rix's Creek Colliery has strongly supported these developments.

Predictive meteorological data that provides details of temperature and wind velocity at levels of up to 800 metres above the ground is produced by the Hunter Valley Meteorological Sounding Group (HVMSG), a joint venture between Hunter Valley coal mining companies of which Rix's Creek is a founding member. This meteorological data is used as inputs into models that are used to predict and assess the effect of meteorology on airblast overpressure, dust, and fume emission. Examples of outputs provided by the HVMSG are shown in **Figure 5**:

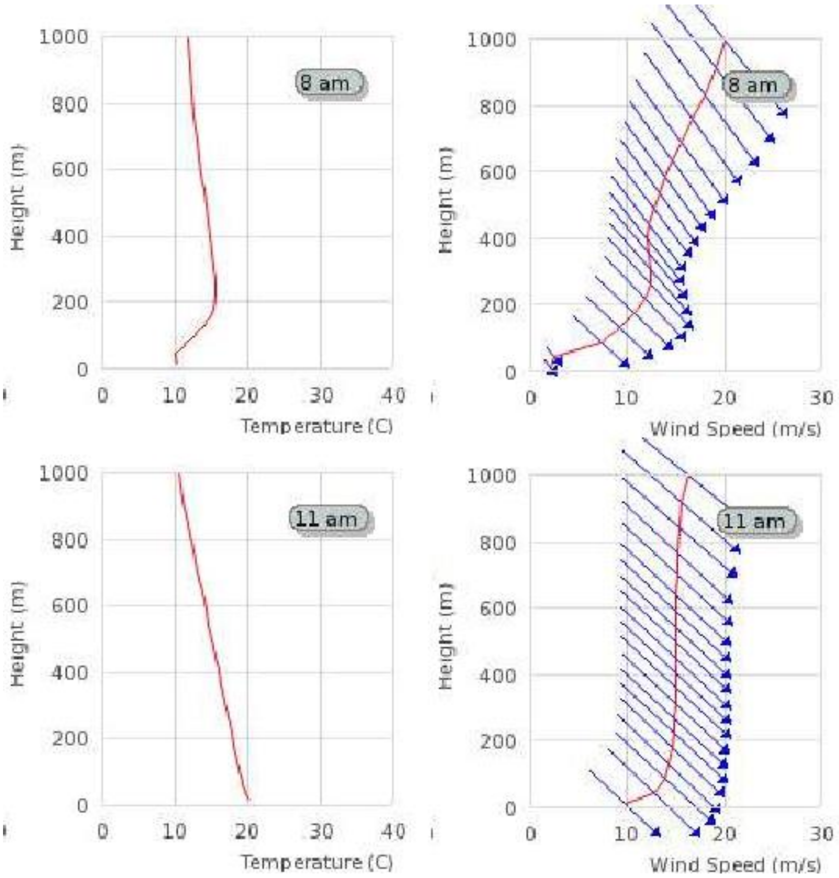


Figure 5 –Predictive HVMSG Data Outputs for 8am and 11am

8.2 AIRBLAST OVERPRESSURE

Rix's Creek uses the EnvMet airblast assessment system to predict the effects of meteorology on airblast overpressure. At 7am each morning, predictive outputs are available that give details of any increases in airblast overpressure levels that will result in the area surrounding the mine. An example of these outputs, which are provided at half-hourly intervals, is shown in **Figure 6** below.

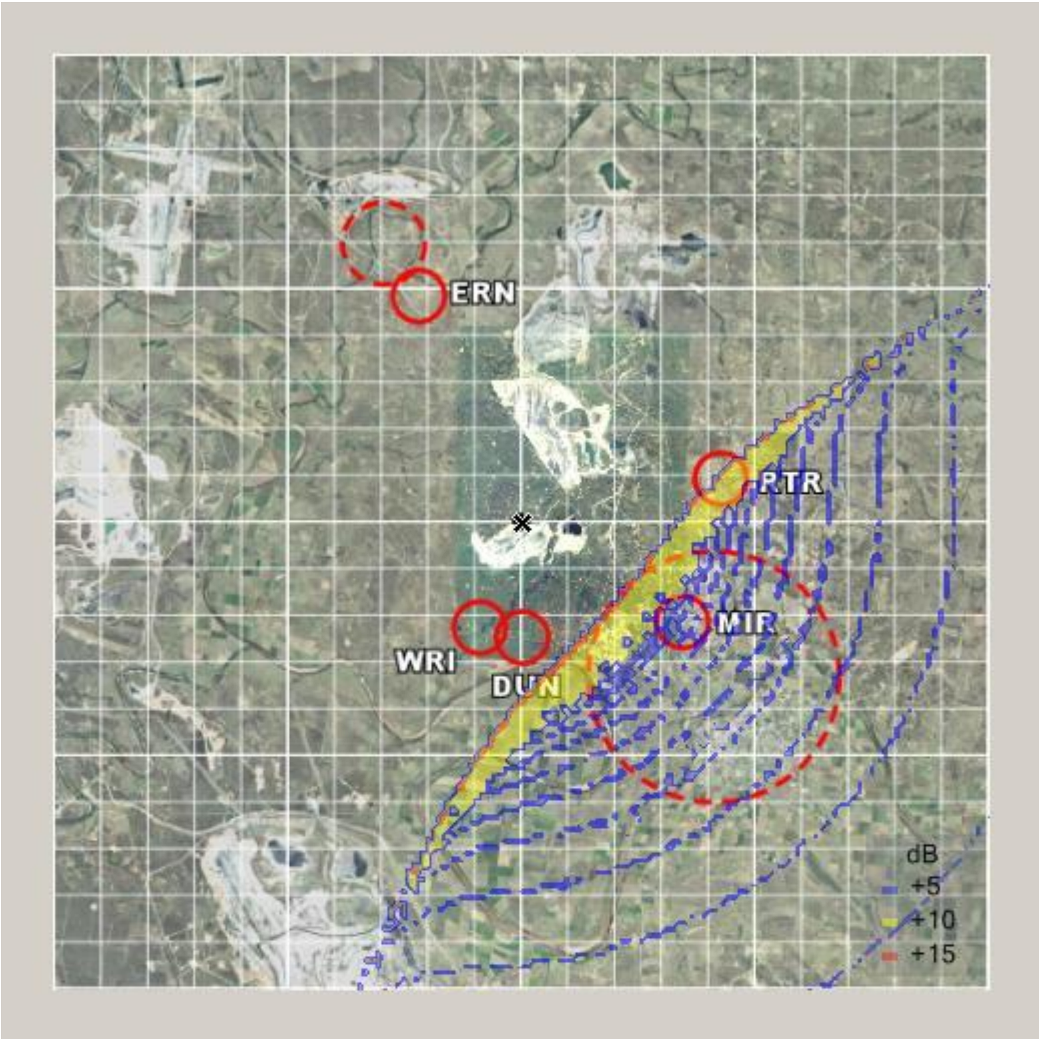


Figure 6 – Increase due to meteorology

The EnvMet system is also used to predict the basic emission levels that will result due to the blast design, as well as providing a prediction of the effect of basic blast emission and meteorological effects. Details of these outputs are shown in **Figures 7 and 8**:

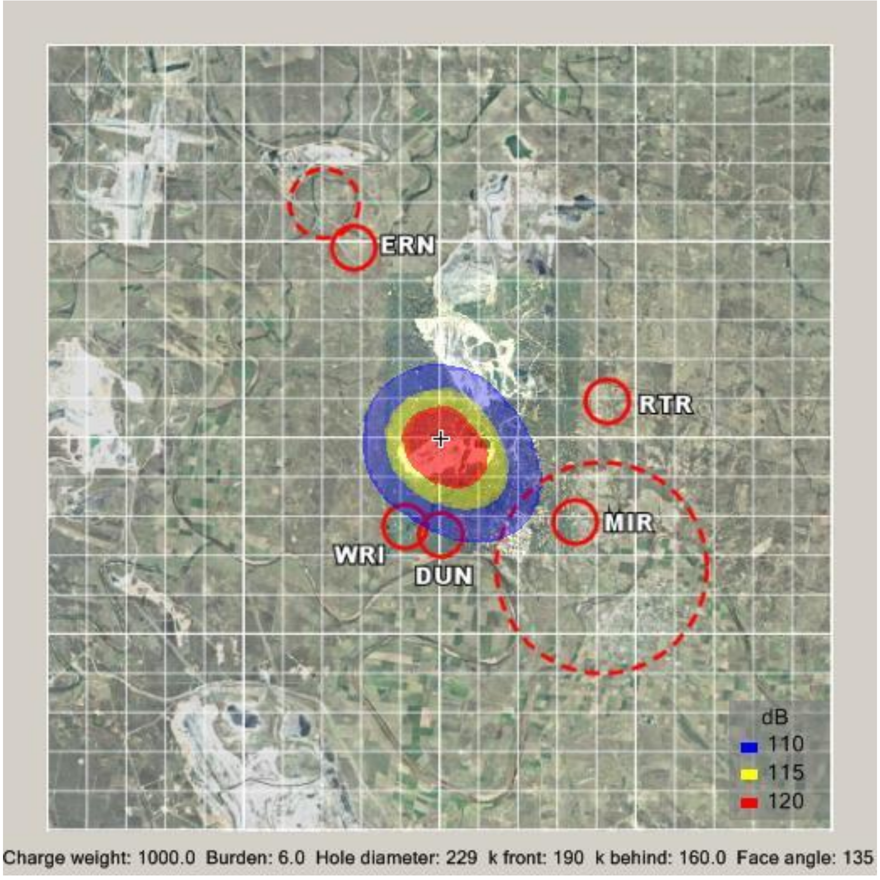


Figure 7 – Basic Emission

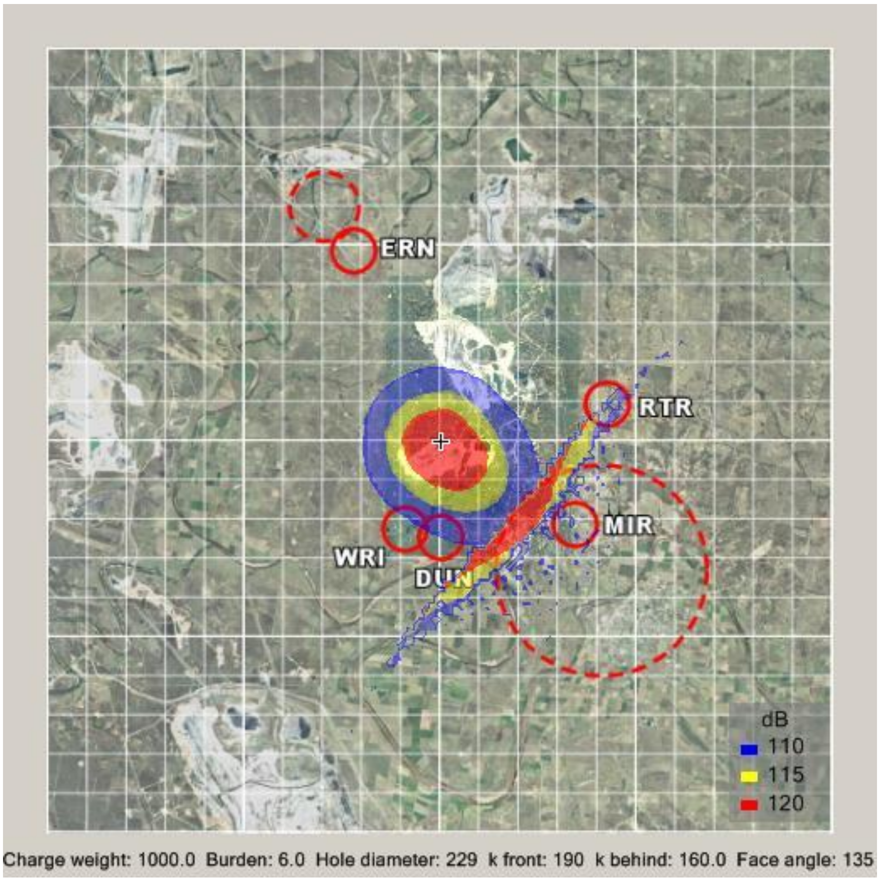


Figure 8 - Combined effect of basic emission and meteorological enhancement

8.3 DUST AND FUME EMISSION

Control of dust and fume plumes is strongly influenced by meteorological conditions.

Rix's Creek has responded rapidly to the need for an effective plume management system and uses a very effective plume modelling system that was developed by Todorovski Air Sciences. Inputs into the system is information about the size of the plume that is created by the blast, meteorological data provided by the HVMSG which is further refined by the Todorovski system, and detailed topographical information.

8.3.1 Fumes

There are two aspects involved in controlling the effect of fumes resulting from blasting.

These are:

- Limiting the amount of fumes that are emitted from the blast to form a fume plume
- Predicting the movement of the fume plume resulting from a blast, and ensuring that the movement of the plume does not result in fume concentrations that exceed permitted levels at sensitive locations.

Fume Emissions from a Blast

Factors influencing fume emissions resulting from a blast include:

- Explosives specifications
- Confinement
- Ground conditions
- The length of time that the explosives remain in the ground before firing.

It is not possible to control these factors precisely. Even minor variations in the characteristics of the chemicals used to make the explosives may result in an increase in fume emission. The degree of fume emission may also increase as ground conditions, including the type and amount of groundwater, vary.

At Rix's Creek Mine, methods such as minimising the 'sleep' time that explosive charges remain in the ground before firing have been developed.

Although precise prediction is not yet possible, a sufficient degree of correlation between significant factors and the amount of fumes produced has developed at Rix's Creek to permit the possibility of fumes resulting from each blast to be predicted using three categories (low, medium, and high).

Fume Plume Movement

The fume plume management modelling system used at Rix's Creek Mine quantifies the size of the fume plume produced from low/medium/ high emission blasts, and then predicts the movement of the plume.

8.3.2 Blast Dust Control

The system, which is used in conjunction with the fume plume system quantifies the size of the dust plume produced, and then predicts the movement of the plume. Although the amount of dust produced by different blasts will vary, the current system assumes worst case conditions.

8.4 USE OF THE FUME/DUST MODELLING SYSTEM

At 7am each morning predictive outputs are available that give details of the dust and fume plume emissions that will result in the area surrounding the mine. Details of these outputs, which are provided at hourly intervals, are shown in **Figure 9** below.

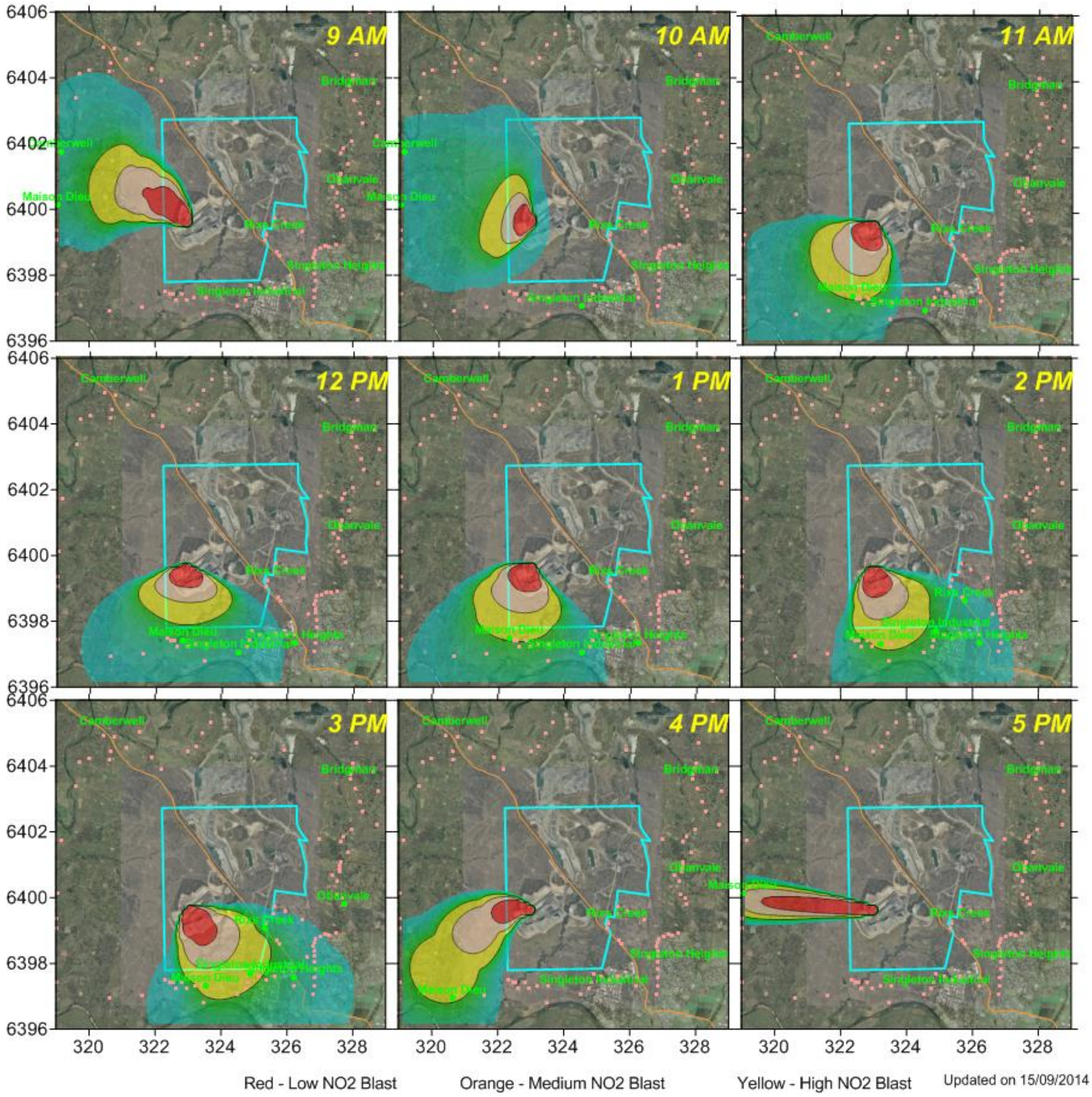


Figure 9 – Fume & Dust Plume Modelling Outputs

Low, medium, and high fume plume emissions are shown in red, pink, and yellow respectively, and a conservative assessment of the maximum dust plume is shown in blue.

Calibration of the dust and fume model was undertaken using App-Tek, model OdaLog Type 7000 gas analysers. Rix's Creek continues to use these gas detectors to monitor for blast gas fumes. This instrumentation allows for continuous refinement of the blasting practices on site.

9. OTHER BLASTING ISSUES

9.1 HIGHWAY STABILITY

The location of the New England Highway in relation to the Continuation Areas is shown in **Figure 10**.

There have been no problems with highway stability in the Singleton area when the underlying rock structure is gently sloping and stable.

Previous mining operations in the Rix's Creek mine north pit area adjacent to the New England Highway from the commencement of mining until 2010 was in stable, gently sloping rock structure. Mining was carried out to within 100 metres of the highway, and the resulting highwall was (and still is) stable.

Most mining in the continuation area adjacent to the New England Highway will be in the same stable rock structure, and there will be no modification to normal blasting practice required to ensure highway stability.

From 2010 – 2014, mining operations in the area adjacent to the New England Highway at the northern end of the north pit were in ground with a steeply sloping rock structure, and modifications to mining practice, including advanced placement of backfill, were required to ensure highway stability.

There is a limited area at the northern end of the western pit in the continuation area where the rock structure will require modifications to mining practice. Further details regarding this are given in the Geotechnical Report.

9.2 HISTORIC COKING OVENS

The location of the Coking Ovens are shown in **Figure 10**.

The ground vibration PPV limits at the historical Coking Ovens are:

≤ 5 mm/s for 95% of blasts

≤ 10 mm/s for all blasts.

Controlling ground vibration to these limits from North Pit blasts in the vicinity of the Coking Ovens has been achieved in the past by environmental blast design. The methodology is:

- Establish the predictive Site Law

$$PPV = Kv\left(\frac{\sqrt{m}}{D}\right)^{e}$$ [1]

Where:
PPV = Peak Particle Velocity (mm/s)
m = Charge mass per hole or per delay (kg)
D = Distance from blast (m)
k = Site constant
e = The attenuation rate (1.6)

- Use the Site Law to determine the charge mass limit appropriate for the distance from the blast to the Coking Ovens;
- To achieve the ground vibration target, it may be necessary to limit the charge mass by such means as:
  - Using a less dense explosive
  - Decking the explosive column
  - Using air decks.

The Site Law at the Coking Ovens should be reviewed by analysis of the measurements and modified if necessary for future blast design.

9.3 BLASTING IMPACT ON EXTERNALLY OWNED/MANAGED INFRASTRUCTURE

Externally owned/managed infrastructure that could be considered as being possibly impacted by blasting in the continuation area are shown in **Figure 10** and includes:

- New England Highway
  - pavement and culverts
  - bridge over Rix's Creek
  - haul road bridge over the highway
  - cut and cover tunnel under the highway
  - A second proposed cut and cover tunnel

- Buried Fibre Optic Cable beside the highway
- Main Northern Rail Line
- 66Kv Ausgrid power line from Maison Dieu Industrial area traversing Rix's Creek Lan (concrete and timber poles) to the Rix's Creek Mine infrastructure
- A Dam certified by the Dam Safety Committed in the Integra Mine
- Other uncertified dams on the Rix's Creek and Camberwell Mine sites.

The infrastructure associated with the New England Highway has been assessed and approved by RMS as part of the approval process.

The owner/managers of the fibre optic cable are aware of the project having been involved with design and installation of the cut and cover tunnels.

The Main Northern Railway Line is located over 1.3km from the nearest blasting in the Northern Continuation Area. This affords sufficient separation that observance of the appropriate procedures and protocols of the Rail Track Authority for blasting closer than 600m is not necessary.

The Ausgrid Power line is located about 500m from the Northern Pit continuation area blasting. Ausgrid routinely applies a limit of 100mm/s on their poles. There is sufficient separation that compliance with their limit can be readily achieved by environmental blast design.

The Certified Possum Skin Dam in the Integra property is over 4.0km from the continuation area blasting so controlling ground vibration to the Dam Safety Committee limit is not an issue.

There are no specified vibration limits on the other dams not under the Dam Safety Committee regulation. The inspection regimes will continue to ascertain any change of condition.

9.4 BLASTING IMPACT ON OTHER MINES

The nearest mine to the continuation area is the Camberwell Mine which has been placed on Care and Maintenance by Integra, the owners. Negotiations are well advanced for Bloomfield (the owners of Rix's Creek Mine) to purchase the Camberwell Mine from Integra.

The main infrastructure of the Camberwell Mine is over 3km from the nearest continuation area blasting and the predicted peak ground vibration levels are less than 0.3mm/s, which is at human threshold perception levels with no potential structural issues.

Blasting in the continuation area is a progression of blasting that has been conducted over many years and will impose no additional impacts on the Camberwell mine compared to what has previously happened.

9.5 BLASTING IMPACTS ON LIVESTOCK

Blasting in the continuation areas is not expected to have any impact on live stock because, even in a new mine, the general experience is that domestic animals rapidly become acclimatised to blasting.

At the opening of the Bengalla open-cut coal mine near Muswellbrook, the behaviour of thoroughbred horses to the initial blasts was observed specifically because of concern of the stud owners. The horses were observed to look up momentarily after the blasts and then continued grazing. At the same mine, two commercial dairies (Wantana and Lumeah Dairies) operating on river flats of mine owned land reported that blasting had no adverse impacts on its cows which were exposed to blast vibration levels up to at least 10mm/s without detriment to milk production or animal welfare.

The continuation area is not a new mine and blasting is a progression of blasting that has occurred in the general area from the two adjoining mines over many years. The only possible impact of blasting would be on livestock brought into the area from a non mining area. The experience is that they will rapidly become accustomed once they perceive they are not threatened.

Figure 10 – Location Plan With Nearby Infrastructure

10. CONCLUSIONS

- The airblast and ground vibration from current blasting operations complies with the regulatory limits at all sensitive sites.

- Future blasts in the West Pit extension move further away from the sensitive sites and will result in lower ground vibration and airblast at the sensitive sites than at present.

- The Northern Pit extension moves closer to the Retreat and Mines Rescue Sites which may result in an increase in ground vibration and airblast. However, there is sufficient separation distance for ready compliance with the regulatory limits and this will not be an issue.

- Compliance with ground vibration limits at the Coking Ovens may further reduce the scale of blasting operations which will be reflected at Retreat and Mines Rescue by lower ground vibration than predicted.

- Dust and fumes are limited by the practices described in this report and further detailed in the Blast Management Plan.

- Mining in the area adjacent to the New England Highway will be predominantly in stable ground. Previous experience when blasting in stable ground in the northern pit has shown that no modification to normal blasting practice to ensure highway stability. There is a limited area at the northern end of the western pit in the continuation area where the rock structure will require modifications to blasting practice, and these will be applied as required.

- Flyrock can be readily controlled by appropriate blast design and loading practice, and if the recommended exclusion zones are observed, will not present a danger to personnel within the mine lease or outside the extraction area.

- Traffic control on the New England Highway will resume when blasting approaches closer than 500m to the Highway.

- The limitations of the previous blast vibration monitoring instrumentation have been overcome by the installation of replacement continual recording instruments and monitoring at additional locations.

- The wavetraces from the new instrumentation will permit closer scrutiny of the actual airblast measurements and more accurate reporting of what becomes the official record.

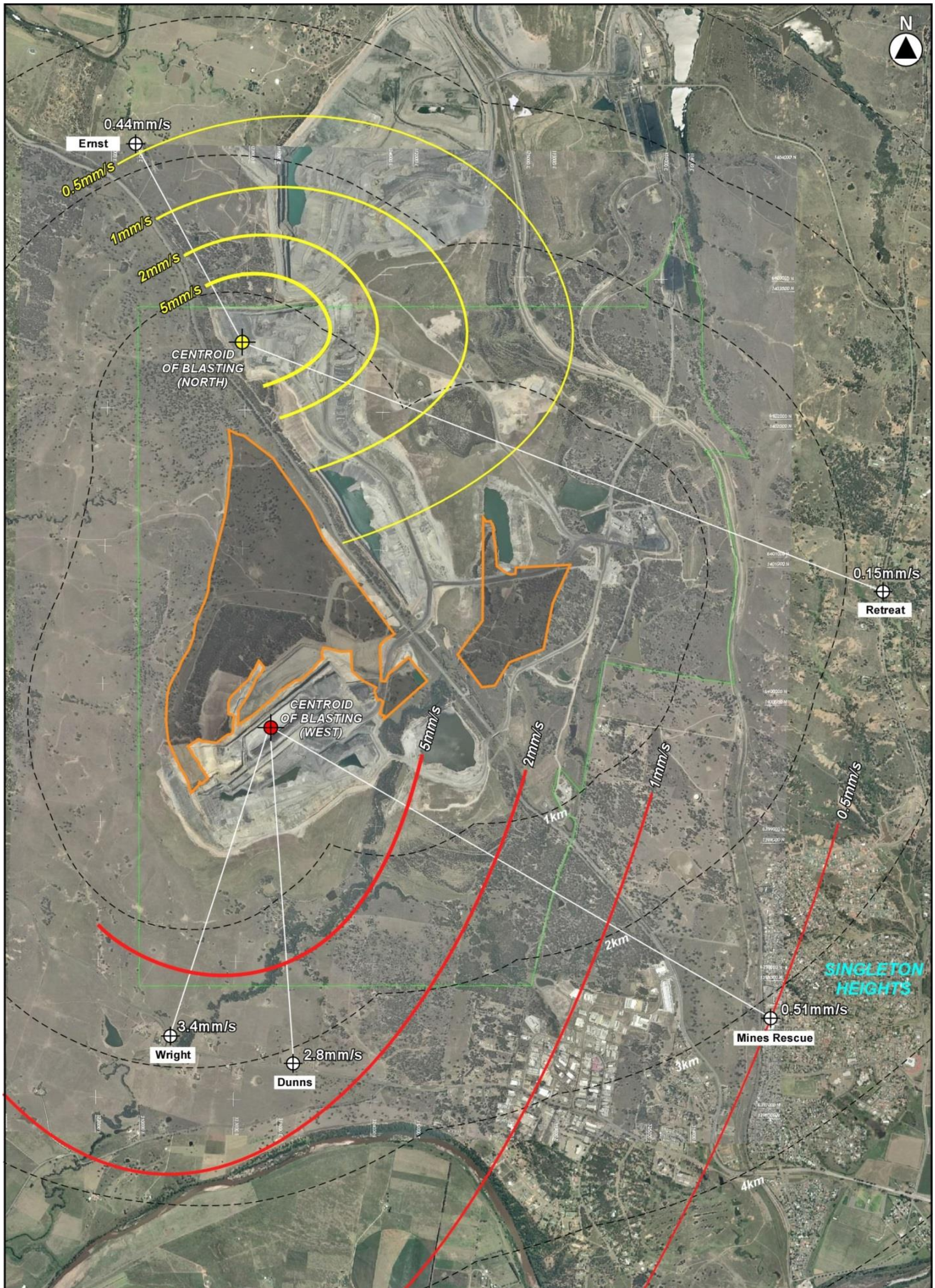
- Blasting in the continuation area will have no significant impact on nearby infrastructure or the adjoining Camberwell Mine.

- Blasting will continue to have no impact on livestock.

Adrian Moore
14th March, 2017

APPENDICES

APPENDIX 1 - GROUND VIBRATION CONTOUR ASSESSMENT


N
0.44mm/s
Ernst
0.5mm/s
1mm/s
2mm/s
5mm/s
CENTROID OF BLASTING (NORTH)
CENTROID OF BLASTING (WEST)
0.15mm/s
Retreat
5mm/s
2mm/s
1mm/s
0.5mm/s
1km
2km
3km
4km
5km
SINGLETON HEIGHTS
0.51mm/s
Mines Rescue
3.4mm/s
Wright
2.8mm/s
Dunns
500 0 500 1000 1500 2000 2500 meters

APPENDIX 2 - AIRBLAST CONTOUR ASSESSMENT