TERROCK
CONSULTING ENGINEERS

P O Box 829
Eltham Vic 3095
Phone: (03) 9431 0033
Fax: (03) 9431 1810
URL: http://terrock.com.au
Email: terrock@terrock.com.au
ABN: 99 005 784 841

Alan B. Richards
Ph.D, F.I.E.Aust., F.Aust.I.M.M.,F.I.Q.

Adrian J. Moore
Dip.C.E.,B.E.(Min.), M.Eng.Sc., M.I.E.Aust.

BORAL RESOURCES (VIC) PTY. LTD.

BLAST IMPACT ASSESSMENT

PROPOSED MONTROSE QUARRY EXTENSION (WA100)

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TABLE OF CONTENTS

Appendices - *To be produced*

Appendix 1 – Montrose Quarry Ground Vibration Contour Assessment
Appendix 2 – Montrose Quarry Airblast Overpressure Contour Assessment

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BLAST IMPACT ASSESSMENT

PROPOSED MONTROSE QUARRY EXPANSION (WA100)

1 INTRODUCTION

Terrock Consulting Engineers was engaged by Boral Resources (Vic) Pty. Ltd. to conduct a Blast Impact Assessment for a proposed extension of Boral Montrose Quarry, Montrose, Victoria. The existing quarry (operating within Work Authority No. 100) has been in operation for several decades and the stone resource available within the current approved extraction area is nearing exhaustion. The proponent seeks approval to expand the current extraction area through a Work Authority variation and amendment of the site's planning permit.

The resource available within the current approved extraction area is near-depleted and recent operations have been limited to production blasts at lower elevations in the pit and small-scale blasts to trim and form upper berms and batters. Recent production is also supplemented by rock extracted from Boral Coldstream Quarry and transported to Montrose for processing.

The purpose of this assessment is to determine the effects risks and impacts of blasting in the proposed extension area and identify control measures required to ensure blasting is undertaken safely, with minimal impact to offsite receptors, and in accordance with regulations, standards and guidelines that apply to blasting under the regulatory framework for Victorian quarries.

The primary blasting risks and impacts considered in this report are;

- Ground vibration and airblast overpressure levels from blasting
- Flyrock risk and control
- Impacts of blasting to local amenity
- Risk of blasting to domestic animals and native fauna

Predictive blast models have been developed using site data from recent and historic blasting to determine if compliance with regulatory ground vibration and airblast limits can be achieved under the proposal. The risk presented by rock fragments thrown from blast sites is also assessed by predictive modelling and application of Safety Factors to maximum throw calculations. The effects of blasting on local amenity and the natural environment including native species is also considered.

2 ASSESSMENT LIMITATIONS

Some potential impacts from blasting are outside the author's qualifications and may require assessment by experienced consultants in these fields. Such subjects are shown below, followed by a general comment based on the author's experience of the contribution of blasting.

2.1 BLAST DUST

The quantities of dust generated from individual blasts vary depending on factors including local ground structure, rock weathering and seasonal ground moisture levels. Dust loads from blasting are generally higher where the ground structure has high clay content, particularly during dry periods.

Dust from blasting dissipates over distance as particles drift in the direction of the prevailing wind. For blasts at lower benches/levels of a quarry pit, blast dust may largely settle or dissipate within the extraction area as it swirls around the altered landform of surrounding benches. In light or still wind conditions, dust largely settles within the quarry and becomes non-visible after a few minutes.

While dust from blasting is more visible than other sources, it is considered to present a relatively small proportion of potential dust loads from whole quarry operations as its occurrence is limited to a few minutes immediately after a blast. If required, the impacts and risks presented by dust and the regulation and management of dust loads from whole quarry operations (including blasting) can be addressed by an air quality consultant

2.2 NITROGEN OXIDES

Blasting produces nitrogen oxide (NOx) gases that can be harmful to human health at high concentrations. High levels of NOx can be produced by a reaction between some explosives mixes and water in blast holes, or when inadequate mixing of ammonium nitrate and sensitising agents occurs during blast hole charging. The presence of high concentrations of NOx from a blast can be identified by the yellow-orange fumes produced. NOx is also produced by common sources such as motor vehicles and other fuel burning processes.

NOx emissions require consideration at large open-cut mines where explosives loaded into large diameter blast holes (220mm +) may sit in a watery environment for a number of days. The likelihood of high NOx emissions from quarry blasting is greatly reduced due to the smaller scale of blasts, improvements in explosives products and mixing techniques, and because blasts are loaded and fired within a few hours on blast days without prolonged exposure to water. While high concentrations of NOx from quarry blasts have become uncommon, as a precaution, shotfirers are required to wait a few minutes after firing for dust and NOx to dissipate before inspecting the blast site. Boral's in-house protocols for managing exposure to NOx emissions can be found in the Boral Montrose Quarry Blast Management Plan.

2.3 BLAST NOISE

Both audible noise and sub-audible overpressure from blasting may be referred to as "airblast". Airblast is a brief fluctuation of air pressure that occurs as explosives energy radiates from a blast site through the surrounding atmosphere. The higher frequency component of airblast (>20 Hz) is audible to the human ear and may be heard by people within a few kilometres of a blast site. The low frequency component of airblast (<20 Hz) is sub-audible and may be termed "overpressure" or "airblast overpressure". For the purpose of this assessment, the term "airblast" furthermore refers to sub-audible overpressure from blasting that can induce structural responses and is subject to regulation.

If required, the audible noise level from a blast can be estimated from measurements of overpressure by reducing the recorded level by 25 decibels to determine the dBA level. From AS2187.2-2006 Section J2.2, "*For example, if a blast monitor gives a reading of 115 dBL, a sound level monitor would measure approximately 90 dBA for the same event*". The topic of audible noise from quarry activities including blasting may be addressed in more detail by an acoustic specialist.

2.4 BLAST MANAGEMENT

Blasting procedures and risk control measures for transport, handling and use of explosives within quarries is detailed in a Blast Management Plan (BMP) that forms part of a quarry's approved Work Plan. A BMP details a quarry's blasting practice and procedures, key roles and responsibilities of personnel, blasting risks and control measures, site communications, emergency contacts, etc. that must be observed for all blasting operations. BMPs are guided by explosives regulations, Australian standards, industry guidelines, the Occupational Health and Safety Act (2004), in-house policies and site-specific work authority conditions. BMPs also include details of environmental considerations that inform blasting practice such as blast vibration limits, the locations of sensitive receptors and off-site infrastructure, blast monitoring procedures and any control measures required to mitigate offsite risks and impacts.

Details pertaining to individual blasts are contained within Blast Plans that are produced by shotfirers and consist of various documents detailing all stages of the blast process including design, survey reports, driller's logs, hole loading records, Risk Assessments, details of blast crew personnel, blast monitoring results and post-blast performance records. Blast Plan documents must be retained by quarry management for at least five years and be available for inspection or audit at the request of industry authorities.

Blast Impact Assessments (i.e. this report) largely pertain to offsite blasting effects, risks and impacts, and findings may be used to guide a quarry's blasting procedures and ongoing development of BMPs. The requisite details for Blast Management Plans and related documents are listed in *AS1287.2-2006 Appendix A*.

3 QUARRY LOCATION AND BACKGROUND

Boral Montrose Quarry is located at the corner of Canterbury Road and Fussel Road, Montrose, Victoria. The site is approximately 32 km east of Melbourne, 1.4 km southwest of Montrose township, and is within the Yarra Ranges Council local government area. Quarrying has occurred at the site for around 60 years, producing stone aggregate and concrete for Melbourne's eastern metropolitan region. The quarry's existing Work Authority covers 47.5 hectares. A proposed Work Authority variation to incorporate 30.5 ha of Boral-owned land to the adjacent south and east is currently under application as part of the extension proposal.

4 SITE GEOLOGY

The bulk of the resource underlying Montrose Quarry is classified by Geosciences Victoria as Coldstream Rhyolite located in the north, west and central pit areas, and Mount Evelyn Rhyodacite in the south and east. The units have similar characteristics (hardness, density, etc.) and both exhibit structures from highly weathered to fresh. A lesser quantity of welded tuff/breccia can be found in the southwest area and all units separated by clearly defined contact zones and faults. The structural characteristics of the rock and its behaviour under blasting is well known to quarry management and Boral's in-house drill and blast crew.

The type of rock being blasted at quarries has some influence on the blast vibration levels that result, though levels are mostly a function of ground structure and conditions across the wider surrounds. Along with blast design specifications, blast vibration transmission is influenced by an interplay of numerous factors including:

- the location, depth, structure, weathering and extent of the rock mass being blasted (in relation to receptor locations).
- ground structure and between individual blast sites and receptors, including the length, width, depth and orientation of jointing planes, faults, seams, dykes, folds, geological contact zones and basement geology.
- near-surface ground conditions including soil type, soil depth and subsurface moisture levels.

Because blast vibration levels are influenced by numerous variables, ground vibration levels at individual locations vary between blasts, even blasts at similar distances and of similar design. This normal variation is accounted for in the blast vibration models used in this assessment.

5 PROPOSED EXTENSION AREA AND LIMIT OF BLASTING

The extension area is immediately south and southeast of the current WA100 boundary and covers ~7 hectares of the proposed 30.5 hectare Work Authority variation area. Approximately 3.9 hectares would be subject to extraction by blasting. The remaining 3.1 hectares would consist of overburden batters formed by mechanical excavation. The extension footprint is reduced from a previous proposal and covers just 13% of the proposed Work Authority variation area. However, a substantial quantity of rock (an estimated 9,658,000 m^3) would be extractable under the proposal due to the depth of the existing pit.

Under current pit designs blasting would occur on benches with maximum face heights of 16m and minimum berm widths of 10m. Extraction would occur from elevations RL 21 (the current and terminal pit floor level) to maximum elevations of RL 160 (south wall) and RL 176 (east wall). Further extraction is also proposed within the current Work Authority with production blasts along the east wall and limited blasting along northern benches to form terminal batters for site rehabilitation. Conceptual rehabilitation plans show infilling of the pit to commence from the north and east during latter stages of the proposed extraction phase.

The minimum distances between blast sites and residences is determined by the width of the overburden batters that would be formed from the proposed extraction limit to the top of the hard rock mass. Overburden depths were surveyed by GHD and the outer limit of rock is shown as a dashed line in GHD plans labelled '*Overburden Intersect'*. This line is referred to as the 'Limit of Blasting' in this report and denotes the locations of the closest (terminal) blasts to offsite receptors.

A simplified site plan showing the current and proposed Work Authority boundaries, extraction limit, and the Limit of Blasting is presented as **Figure 1**. Further details of pit design, staging of works, geotechnical considerations and rehabilitation options can be found in the GHD report '*Montrose Quarry Staging Plan & Rehabilitation Concept, May 2023'* and latest pit plan '*Montrose Quarry Extension-Final Batters' (Drawing No. 31-12559266-C003)*.

Figure 1 – Boral Montrose Quarry site plan showing site boundaries, proposed extraction limit and Limit of Blasting

6 SURROUNDING ENVIRONMENT AND LAND USE

Montrose Quarry and adjoining Boral-owned land is a Special Use Zone (Extractive Industries) under State planning provisions. An industrial zone lies to the immediate north and west, a residential zone to the northeast, and a green wedge zone with small private acreages to the south.

The quarry has been subject to urban encroachment since its inception and some houses on Ash Grove, Kirkwood Court and Jeanette Maree Court are located relatively close to historic and proposed future extraction areas. Attention is given to these residences and the blast vibration levels and impacts that may occur during the closest stages. More distant residences are located on properties south with frontages to Sheffield Road and Glascow Road, and medium density residential streets further south and south east. Industrial land to the immediate west (Fussel Road) remains largely undeveloped though public access to businesses along Fussel Road requires consideration with respect to flyrock and blast clearance.

Dr. Ken Leversha Reserve is located adjacent to Boral-owned land southeast of the quarry. Existing bushland in the proposed Work Authority variation area would remain largely undisturbed to provide wide buffers between the extraction area and residential properties to the south and east.

7 SENSITIVE SITES/RECEPTORS

Like other metropolitan quarries, numerous residences are located within a few kilometres of Montrose Quarry and blast vibration and associated effects are perceptible to a relatively large number of people. Blast vibration levels reduce rapidly over distance and ground vibration and airblast levels are typically low in areas more than 1 km from blast sites, becoming imperceptible beyond 1.5 km. Ground vibration and airblast levels at residences less than 500m of the proposed extraction area are the primary focus of this assessment as these areas are where the highest levels would occur. Maintaining compliance with regulatory blast vibration limits at the closest houses will effectively ensure compliance is achieved in more distant areas.

There is estimated to be 150-200 residences (occupied houses) within 500m of proposed future operations, the closest located at Ash Grove and Kirkwood Court to the immediate northeast. Eight residences within 500m are identified along Jeanette Maree Court to the southwest, and five residences on Sheffield and Glascow Roads to the south.

The closest houses and their minimum separation distance to the proposed Limit of Blasting are;

- 33 Ash Grove, 160m northeast
- 13 Jeanette Maree Court, 205m southwest
- 245 Sheffield Road, 385m south-southeast

A site plan showing the quarry boundaries, surrounding land areas and features, radial distances from the proposed Limit of Blasting, and the locations of the closest houses in key directions is presented as **Figure 2**.

Figure 2 – Site plan showing Boral Montrose Quarry, surrounding area and closest sensitive sites in key directions

8 PRESCRIBED CRITERIA

The transport, handling and use of explosives at Victorian quarries are highly regulated activities that must be undertaken in accordance with Australian Standards and State and Federal codes, regulations and guidelines. Site-specific conditions may also apply as included in a quarry's Work Plan, Planning Permit or Work Authority conditions. Blasting regulations and other conditions must be observed to maintain a high level of safety for quarry personnel and the public, minimise blasting impacts, and protect private property and infrastructure from blast-induced damage. Blast vibration limits also apply at dwellings to help minimise disturbance and annoyance to residents from excessive levels of ground vibration and airblast.

Standards, guidelines and regulations that apply to quarry blasting operations in Victoria include;

- *Dangerous Goods (Explosives) Regulations 2011* [State of Victoria]
- Australian Standard AS2187.2-2006: *Explosives – Storage and Use, Part 2: Use of Explosives*
- *Ground Vibration and Airblast Limits for Blasting in Mines and Quarries, Environmental Guidelines* (Department of Energy, Environment and Climate Action-Earth Resources Regulator)
- *Occupational Health and Safety Act 2004* (OHS Act)
- *Environmental Effects Act 1978 (Victoria),* including the '*General Environmental Duty'*
- *Australian Code for the Transport of Explosives by Road and Rail-3rd Edition (2009)*
- *Mineral Resources (Sustainable Development) (Extractive Industries) Regulations 2019.*

Key criteria that would apply proposed future blasting at Montrose Quarry are detailed in the following sections.

8.1 GROUND VIBRATION AND AIRBLAST LIMITS

The offsite impacts of quarry blasting (namely ground vibration and airblast levels) are regulated under Victorian State Legislation by the Department of Energy, Environment and Climate Action (DEECA). The Department's Earth Resources Regulator (ERR, a sub-branch of Resources Victoria)) provides guideline limits for ground vibration and airblast overpressure that must be adhered to as a Work Authority condition. Blast vibration limits apply at "*sensitive sites*" defined by ERR as *"…any land within 10 metres of a residence, hospital, school, or other premises in which people could reasonably be expected to be free from undue annoyance and nuisance caused by blasting.*" The limits are sourced from a 1990 guideline of the Australia and New Zealand Environment Council and are reproduced in AS2187.2-2006, Appendix J.

The blast vibration limits for quarries are shown in *ERR Guidelines and Codes of Practice; Ground Vibration and Airblast Limits for Blasting in Mines and Quarries, Section 3.2: New Sites*. The limits apply at sensitive sites as defined above, being:

Ground Vibration:	5 mm/s (95% of blasts within a 12-month period) 10 mm/s (all blasts)
Airblast:	115 dBL (95% of blasts within a 12-month period) 120 dBL for all blasts

The upper limits (10 mm/s and 120 dBL) are provided as an allowance for the occasional, unexpected exceedance of the lower (95%) limits and may apply to 1 in 20 blasts within a 12-month reporting period. However, compliance with the lower limits (5mm/s and 115 dBL) is considered by quarry operators to be the performance target for all blasting.

The limits above apply to new quarries and extensions of existing operations approved since the late 1990s. Legacy limits of 10 mm/s (ground vibration) and 120 dBL (airblast) still apply at Montrose Quarry as an existing Work Authority condition though it is anticipated the new, lower limits would apply if the extension proposal gains approval. However, the lower limits have been observed by quarry management as an in-house performance target over recent years.

Compliance with blast vibration limits is assessed by the results of blast monitoring, where portable monitors are installed at locations of interest prior to blast times. Exceedances of the limits are reportable to the Regulator and subject to investigation or audit of blasting operations. Failure to achieve or maintain compliance may result in ERR infringement notices and penalties for quarry operators and shotfirers.

The ERR blast vibration limits for mines and quarries are based on human comfort considerations and are set below levels at which blast-induced damage to light framed, residential-type buildings is known to occur. More information on ground vibration and airblast damage thresholds and limits used to prevent damage to buildings is shown in **Section 11.2**.

There are currently no regulatory blast vibration limits for commercial and industrial premises in Victoria. If needed, reference can be made to damage criteria where higher limits apply.

8.2 BLAST FIRING TIMES

To help minimise disturbance, quarries are restricted to firing blasts during business hours when nearby residents are less likely to be in their homes. Blasting at Montrose Quarry is currently permitted between 8am - 5pm Monday to Friday and 8am - 1pm on Saturdays. However, blasts are only fired between 10am-4pm on weekdays to minimise disturbance. It is likely that blasting would be formally restricted to these hours and prohibited on weekends and public holidays as part of future operating conditions.

8.3 FLYROCK AND BLAST CLEARANCE

A blast clearance zone is an area around a blast site from which people are evacuated at blast times to provide protection in the event that rock fragments are thrown well beyond anticipated distances, an occurrence known as ‘flyrock’. Blast clearance distances are not specified in current industry regulations and guidelines though blast safety is enforced by ERR and WorkSafe Victoria under the *Occupational Health and Safety Act 2004*. Recent advice from regulators is, “*Operators are required to satisfy the department as to the safety of blasting practices and rigorous control of flyrock is an important consideration*”.

In practice, it is the responsibility of quarry operators and shotfirers to ensure that;

- flyrock is prevented/controlled through blast hole surveying techniques, appropriate blast design, and accurate hole loading practices and record keeping.
- rock throw is not excessive and all fragments are fully contained within Work Authority or title property boundaries at all times.
- flyrock does not present an unacceptable risk of injury to quarry personnel and members of the public.
- rock fragments from blast sites do not strike or cause damage to offsite infrastructure and private property.

Operators may be required to provide regulators with evidence that the requirements above are achieved and appropriate blast clearance zones and procedures are being observed. Flyrock events that result in injury, property damage or near misses are reportable to WorkSafe Victoria and ERR, and can result in penalties or prosecution of shotfirers and quarry operators. The topic of flyrock risk and blast clearance requirements for Montrose Quarry is addressed in more detail through **Section 11.1**.

8.4 BLAST MONITORING

Blast monitoring requirements for quarries are largely driven the by number of receptors exposed to perceptible levels of blast vibration, or the number of resident complaints and concerns that emerge. At metropolitan quarries (including Montrose Quarry) monitoring is conducted as part of the routine procedure for all blasting. Monitors are installed at or near the closest residences and locations near the Work Authority boundary. Blast monitoring has been conducted around Boral Montrose for many years and a large dataset of results is available for analysis. More information on blast monitoring requirements at Montrose Quarry is provided in **Section 13.5.**

8.5 EXPLOSIVES STORAGE

In line with current industry practice, explosives products are not stored at Montrose Quarry. All explosives and accessories are brought to the quarry on blast day mornings by a licenced explosives supply company. All unused products are returned to the supplier's company's offsite storage facility after each blast is loaded and all items are accounted for.

8.6 BLASTING NEAR INFRASTRUCTURE

Blasting operations may also be required to comply with conditions ordered by the owners of critical infrastructure assets to prevent blast-induced damage. Ground vibration limits for infrastructure vary depending on the type, location and sensitivity of the asset. Conservative, non-damaging PPV limits commonly observed in Victoria are;

- 100 mm/s - Electricity transmission lines, poles, high voltage pylons and wind turbines
- 20 mm/s - Buried fuel and high-pressure gas mains
- 20 – 50 mm/s - Water supply and drainage infrastructure
- 50 mm/s - Earthen bund and dam walls

There are no critical pipelines, dams or high voltage transmission lines known within several hundred metres of the proposed Montrose Quarry extension area and PPV levels at distant assets would be well below applicable limits.

9 BLAST DESIGN SPECIFICATIONS

The risks and impacts of blasting are strongly associated with a blast's scale and design. Future blasting at Montrose Quarry would generally follow current practice excluding in areas identified in this report where design modifications may be needed to maintain compliance with ERR limits. The standard or typical design specifications used for production blasts at Montrose Quarry are listed in **Table 1**.

Table 1 – Standard design specifications for production blasts, WA100

Face height (max.)*	16 m
Hole diameter	89 mm
Standard hole angle (from vert.)	10°
Sub drill	1.0 m
Hole length (max.)	17 m
Front row burden	3.5 m
Hole spacing	3.0 m
Inter-row burden	3.0 m
Stemming height (min.)	3.0 m
Explosives column length (max.)	10 m
Linear charge mass**	7.2 kg/m
MIC – Max. Instantaneous Charge/delay	100.2 kg
Powder factor	0.6-0.7 kg/m^3

**maximum face height under quarry expansion proposal*
***based on a bulk explosives density of 1.15 s.g.*

The specifications above include charge mass for the maximum face height of 16m and therefore represents the highest ground vibration and airblast levels that could ordinarily occur. As with many quarries, bench heights vary and many (if not most) future blasts would have somewhat lower charge masses due to shorter faces or other design requirements for individual blasts.

Montrose Quarry also undertakes occasional pre-split and mid-spilt blasting, where a row of closely-spaced blast holes are fired among the rows of a production blast to help maintain stable and uniform faces and batters. Hole loadings for such blasts are the same as for production blasts and because they are fired as part of the main blast, vibration and airblast levels from pre and mid-split holes do not require separate assessment.

At all quarries, standard designs may be modified to control blast vibration levels, reduce rock throw or improve blast performance (fragmentation, heave and efficiency). The need for modifications is guided by shotfirers inspection of localised rock structure, blast hole surveying and drillers observations, and ongoing review of blast monitoring results.

Efficient quarry blasting occurs within a limited range of specifications and substantial design modifications may result in poor blast performance and lower yields. Inefficient blasting can lead to a greater number of blasts required to meet production targets, or longer blast durations due to the need to use more holes per blast. Excessive front row burden and stemming heights can also increase secondary breaking requirements where large oversize blocks need to be reduced to manageable size by hydraulic hammering or small explosives charges (i.e. secondary breaking), resulting in additional dust and noise impacts.

10 BLAST IMPACT & RISK MODELLING

The levels of ground vibration, airblast overpressure from blasting, and distances rock fragments may be thrown from blast sites can be assessed with predictive formulae. The following models have been developed over decades of research and studies of blast vibration and flyrock undertaken by Terrock and other Australian and overseas researchers, and are used to guide numerous mining, quarrying and construction blasting operations across Australia and overseas. This section details the predictive formulae used to assess blasting impacts around the proposed Montrose Quarry extension area, modelled results, and introduces some of the factors that influence blast vibration levels and flyrock throw.

10.1 BLAST MONITORING DATA

For the purpose of this assessment, a total of 240 blast vibration measurements were analysed from 106 blasts fired at the quarry between August 2020 and July 2023. Blasting during this period was conducted from Benches 6 to 11 with MICs ranging from 27 to 143 kg/delay. Monitoring data and assessments from previous years was also reviewed though due to some errors, notable outliers and incomplete distance records the historic data is less reliable than data from recent operations. Monitor locations from the recent dataset and historic monitor locations are shown in **Figure 3**.

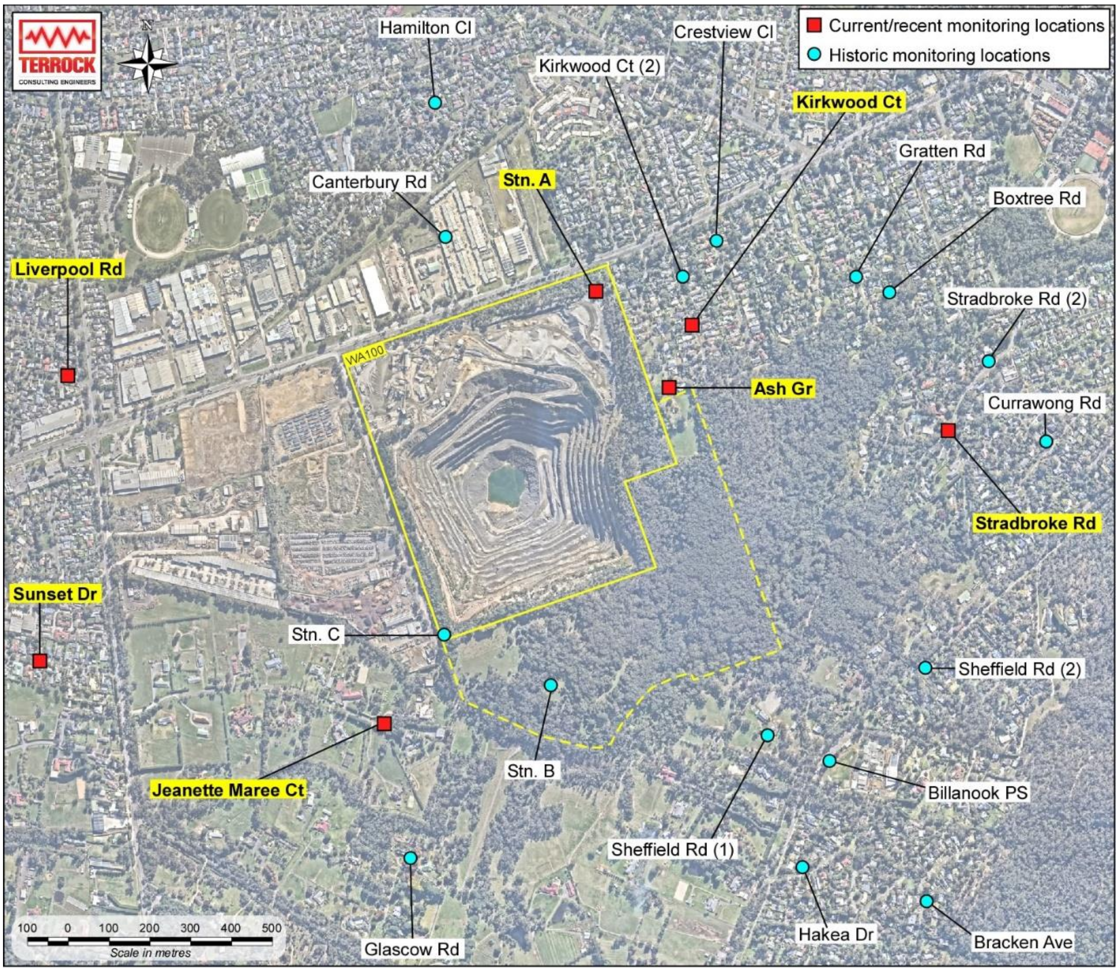

Figure 3 - Blast monitoring locations, Boral Montrose Quarry (1992-present)

Currently three monitors are installed every blast day with most recent measurements obtained at Stn. A and the southern end of Ash Grove. In some cases ground vibration levels were too low to trigger the monitors recording function, indicating PPV levels <0.4 mm/s. While higher, legacy PPV and airblast limits still apply at Montrose Quarry, all levels recorded in recent years are below the current standard ERR limits of 5 mm/s and 115 dBL.

10.2 GROUND VIBRATION ASSESSMENT

When explosives detonate there is a sudden release of high-pressure gas that fractures and displaces rock within a few metres of each blast hole. Beyond the fracture zone, the energy is converted to elastic waves that radiate from the blast site and decrease in magnitude over distance, in a similar fashion as the ripples from a pebbles dropped in a pond. Ground vibration levels generated by blasting are measured in terms of the Peak Particle Velocity (PPV) of the ground motion, expressed in units of millimetres per second (mm/s). PPV has a close relationship with wave frequency, ground displacement and the structural response of buildings, and is the near-universal measure for regulating ground vibration from blasting.

Ground vibration levels from blasting are a mostly a function of charge mass (Maximum Instantaneous Charge or *MIC,* being the maximum quantity of explosive that detonates at an instant of time), distance from the blast site, and local geology and ground conditions. The following formula [1] for predicting PPV levels is widely used around Australia and overseas and can be found in AS2187.2 -2006, Appendix J.

$$PPV = k_v \left(\frac{\sqrt{m}}{D}\right)^{1.6} \quad [1]$$

Where:
- PPV = Peak Particle Velocity (mm/s)
- m = Charge mass/MIC (kg/delay)
- D = Distance from blast (m)
- k_v = A site constant

10.2.1 Site constant determination

The PPV model's site constant (k_v) represents local ground conditions that influence the transmission of vibration waves around blast sites. AS2187.2-2006 suggests a k_v of 1,140 for predicting PPVs in "*average field conditions*" though this value provides results with a 50% probability of exceeding predicted levels. Transposition of the site law model using PPV's, distances and MICs from Montrose Quarry blasts allows site-specific k_v values be determined, as summarised in **Table 2**.

Table 2 – Range of PPV site constants (k_v) from Montrose Quarry blast monitoring dataset (2020-2023)

Monitor	k_v - Maximum	k_v - Minimum	k_v – Mean	k_v – 95th percentile
Stn. A	2,464	148	934	1,522
Ash Grove	2,260	397	968	1,525
14 Jeanette Maree Court	1,944	118	1,099	1,920
20 Kirkwood Court	1,395	324	815	1,377
62 Stradbroke Road*	1,775	1,434	1,593	1,752
13 Sunset Drive#	1,187	1,187	1,187	1,187

Note: PPV levels at Liverpool Rd were too low to trigger recording
**Limited data available (four blasts)*
#Single blast

Both mean and 95th percentile values are adopted for PPV modelling, noting the latter provides conservative results that are regarded 'maximum' levels from various blast designs. Observing an MIC of 100.2 kg/delay as standard, the PPV models adopted for residential areas northeast of the quarry (based on Ash Grove results) are;

Northeast - Mean

$$PPV = 968\left(\frac{\sqrt{100.2}}{D}\right)^{1.6} \qquad [2]$$

Northeast – Maximum

$$PPV = 1{,}525\left(\frac{\sqrt{100.2}}{D}\right)^{1.6} \qquad [3]$$

Higher k_v values are shown at Jeanette Maree Court, the difference attributed to localised geology and ground conditions. From review of historic monitoring results and previous assessments, the higher values are also appropriate for assessing ground vibration at more distant areas to the west (Liverpool Road), south (Sheffield and Glascow Roads) and southeast (Stradbroke Road, Currawong Drive, etc). The models for standard blasts are;

West/south/SE - Mean

$$PPV = 1{,}099\left(\frac{\sqrt{100.2}}{D}\right)^{1.6} \qquad [4]$$

West/South/SE - Maximum

$$PPV = 1{,}920\left(\frac{\sqrt{100.2}}{D}\right)^{1.6} \qquad [5]$$

10.2.2 PPV levels from standard blasts

From the models above, the distance to milestone PPV levels are calculated as shown in **Table 3**.

Table 3 – Distance to PPV levels, standard blasts (MIC 100.2 kg/delay)

	NORTHEAST		WEST/SOUTH/SE	
PPV (mm/s)	**Mean distance (m)**	**Maximum distance (m)**	**Mean distance (m)**	**Maximum distance (m)**
50	64	85	69	98
20	113	150	122	174
10	174	232	189	268
5*	**269**	**357**	**291**	**413**
2	477	634	516	732
1	735	977	796	1,128
0.5	1,134	1,506	1,228	1,740

**Standard ERR PPV limit (95% of blasts)*

The ground vibration regression analysis **Figure 4** shows PPV levels from recent operations and modelled attenuation of mean and maximum PPV levels from standard blasts in areas northeast of the quarry. The plotted data shows the normal variation of PPV between individual blasts attributed to variable blast designs, charge masses and ground conditions. The threshold of ground vibration perception (regarded to be 0.3-0.5 mm/s) is also shown, the regression lines indicating levels would be generally imperceptible in areas more than ~1.2km northeast of the quarry.

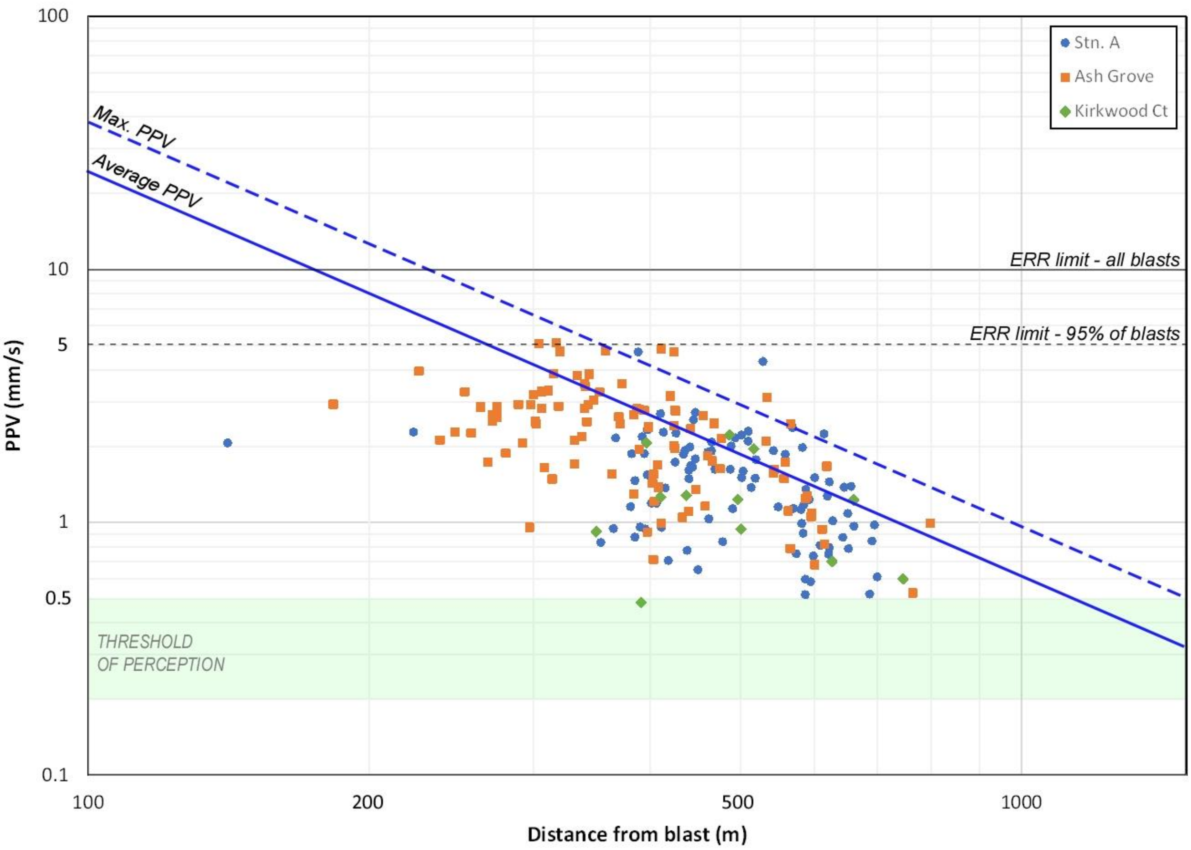

Figure 4 – Ground vibration regression analysis, northeast of Montrose Quarry (MIC 100.2 kg/delay)

Figure 5 shows the attenuation of mean and maximum PPV levels in west, south and southeast directions. Due to limited recent monitoring in this area, a sample of historic results are also shown including levels recorded at more distant locations such as Sheffield Road, Glascow Road and Currawong Drive. The regression lines indicate ground vibration from blasting is generally imperceptible at locations greater than ~1.5km from blast sites.

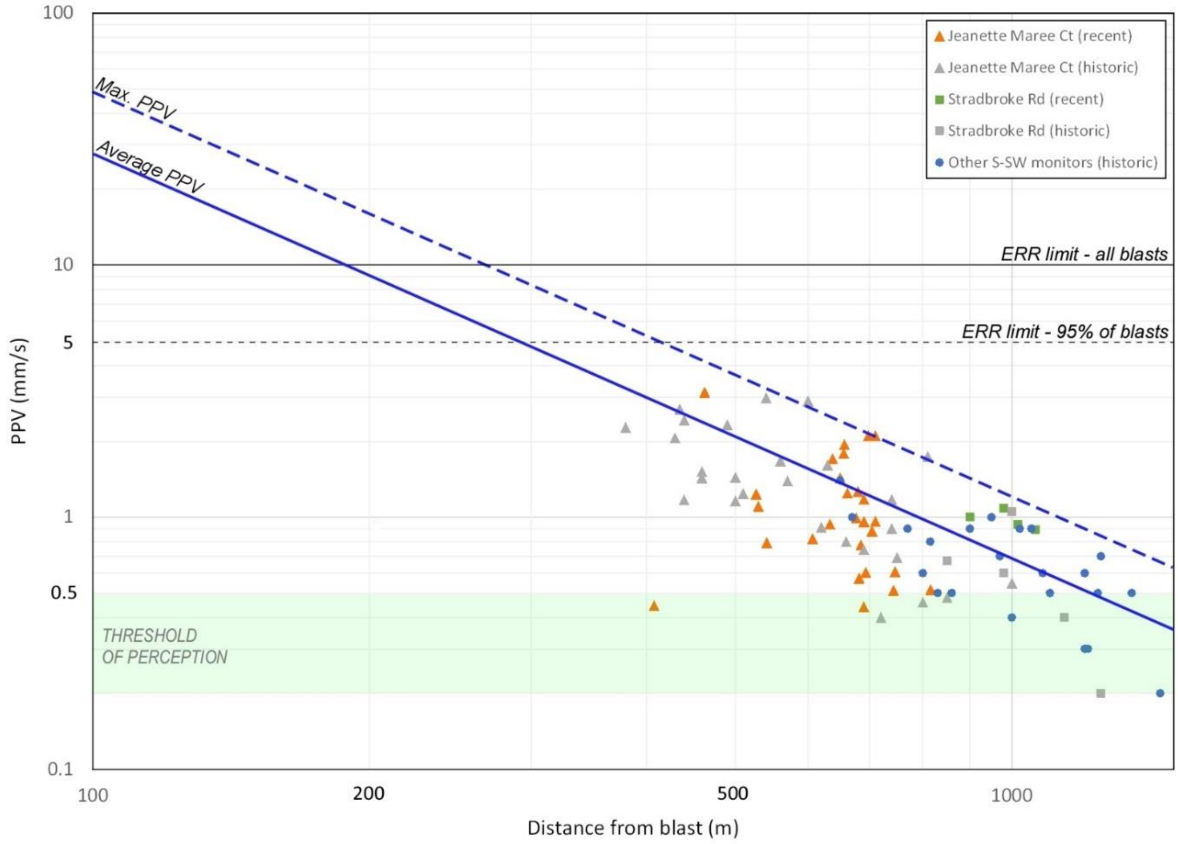

Figure 5 – Ground vibration regression analysis, west, southwest, south and southeast (MIC 100.2 kg/delay)

The analyses demonstrate that, with a few exceptions, actual PPV levels from blasting at Montrose Quarry are below modelled levels and recent operations have achieved compliance with the lower ERR limit (5 mm/s for 95% of blasts), even from blasts relatively close to residences. The mean PPV results also indicate that charge mass would need to be reduced from the 'standard' (i.e. maximum) 100.2 kg/delay for blasts less than ~300m from residences to maintain compliance with the ERR limits for sensitive sites.

10.2.3 Controlling PPV levels at the closest sensitive sites

Monitoring results show that Boral's drill and blast crew have been successful maintaining blast vibration levels below 5 mm/s at the closest houses through careful attention to blast design and loading. This includes a limited number of blasts located between 200-300m from Ash Grove, demonstrating that compliance with ERR limits can also be achieved from proposed future operations.

Analysis of the monitoring data shows reduced charge masses of 33-43 kg/delay resulted in PPVs below 5 mm/s from blasts located 180-300m from Ash Grove. Charge mass reduction in these cases was achieved by splitting benches to 2 x 8m high benches, or deck loading where each blast hole contains two separate, smaller charges. *A degree of assumption is used here, noting "Bench 6.5" in the dataset. It might help to confirm the exact MICs and blast techniques (split-face, deck loading etc) for all recent blasts <300m from Ash Grove. More discussion about this topic is likely to be needed.*

The regression analysis (**Figure 6**) shows mean and maximum PPV levels from full-face blasts (MIC 100.2 kg/delay) >300m from Ash Grove, and split-face blasts (MIC ~40 kg/delay) <300m from Ash Grove. Based on mean levels, reducing charge mass to ~40 kg/delay would maintain PPVs below 5 mm/s at Ash Grove for all but the closest few terminal blasts at the Limit of Blasting. Reducing MIC to approximately 30 kg/delay for the closest one or two blasts is indicated be required and this could be achieved by limiting face height to ~6m, deck loading, or a combination of both techniques.

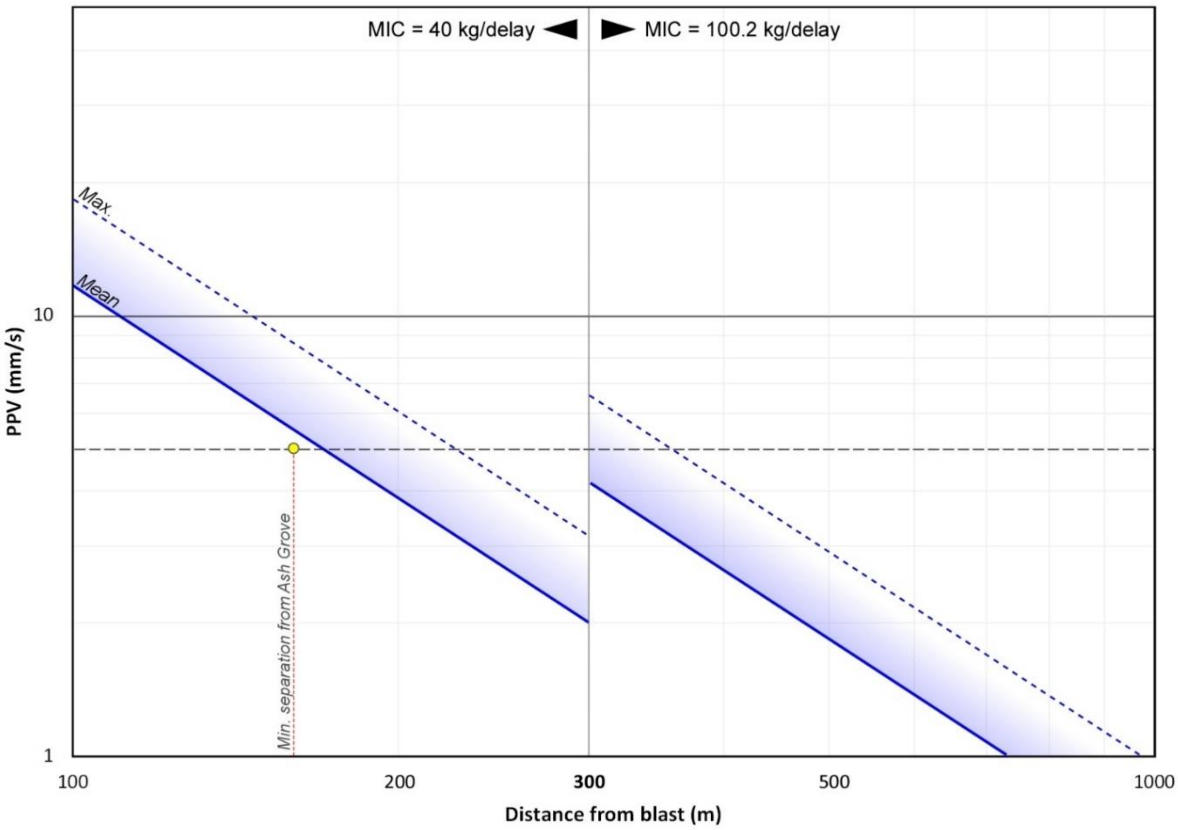

Figure 6 – Effect on PPV levels from reducing charge mass for blasts <300m from Ash Grove.

Due to the normal variation of ground vibration between blasts and variable bench heights, the precise design modifications and locations where they are needed cannot be reliably determined at this stage and should be guided by future blast monitoring results. However, it is indicated that full, 16m face blasts would result in ERR limit exceedances in areas less than 300m from Ash Grove, and MIC-reduced blast designs would be needed. Slightly higher PPV levels are indicated at Jeanette Maree Court to the southwest and charge mass reductions may be needed for blasts less than 350m from the closest house. Indicative areas of the quarry where charge mass reduction is would be needed are shown in **Figure 7**.

Figure 7 – Extraction areas requiring reduced MIC (<100.2 kg/delay) to maintain PPV levels <5 mm/s

10.2.4 Comment on new blast control techniques

With guidance from Boral's explosive supplier (Orica Ltd), advanced digital initiation systems and components are now used at Montrose Quarry as designed to reduce blast durations and increase ground motion frequencies. New blasting techniques may help improve impacts to amenity because (for example) ground vibrations waves with higher frequencies cause reduced structural responses and therefore blast events are somewhat less perceptible to the occupants of houses. Orica have also developed site-specific blast modelling and prediction software to assess the effects of blast design on PPVs, wave frequencies and airblast levels. These new methods show some promise that blasting impacts can be somewhat mitigated, though independent studies are needed to assess their potential and validate such claims.

Montrose Quarry management have reported that resident complaints have reduced over recent years and this may be in part due to the new blasting technologies adopted. However, it is also possible that the reduction of complaints is due to a lower number of blasts fired at the quarry compared to previous years, and because blasts have been at lower benches with reduced airblast levels due to topographic shielding of the surrounding pit walls.

10.3 AIRBLAST ASSESSMENT

Airblast (overpressure) is a low frequency, sub-audible fluctuation of air pressure that radiates from blast sites through the atmosphere at the speed of sound (340 m/s) and reduces at an approximate rate of 9 decibels with doubling of distance. The velocity of airblast is lower than seismic waves (2,200-750 m/s) and therefore the airblast period occurs after immediate the ground vibration waves arrive. The duration of airblast is that of a blast's initiation period, typically less than 1 second for most quarry blasts. Depending on distance from the blast site, the number of blast holes and initiation sequence used, the combined effects of ground vibration and airblast may be perceptible for 2-5 seconds.

While airblast is sub-audible, it can be perceived by people inside buildings due to structural and audible responses such as a rattling sliding door, a creak of roofing materials or a wobbling window pane. At perceptible levels the effects can be likened to a sudden, short-lived wind gust though the effects are difficult to distinguish from ground vibration responses. The threshold of airblast perception for people inside buildings is considered 100-105 dBL.

The airblast levels that occur are a function of many factors including MIC, front row burden and stemming height provisions, and site-specific factors such as rock structure, face direction, local topography, and weather conditions at blast times. Decibel (Linear) levels can be estimated using the Terrock Airblast Model (Moore et al, 1993) that considers MIC and blast hole confinement (depth-of-burial) provisions to determine the distance to the 115 dBL level (D_{115}). The basic model is broadly conservative and is used to assess airblast impacts from numerous mining and quarrying operations around Australia and overseas.

The basic airblast model and inputs are:

$$D_{115} = \left(\frac{k_a \times d}{B \text{ or } SH}\right)^{2.5} \cdot \sqrt[3]{m} \qquad [6]$$

Where:
- SH = Stemming height (m)
- B = Front Row Burden (m)
- m = Charge mass-MIC (kg/delay)
- D_{115} = Distance to 115 dBL level (m)
- d = Blast Hole diameter (mm)
- k_a = A site constant
  - 190 (behind/side of blasts)
  - 250 (front of face)

For quarry production blasts on benches with a free face, airblast levels are highest directly in front of the face and typically 50% lower in areas behind and to the sides of blasts. Observing the standard design specifications from **Table 1**, the models for assessing airblast at Montrose Quarry is;

Front of face

$$D_{115} = \left(\frac{250 \times 89}{3.5}\right)^{2.5} \cdot \sqrt[3]{100.2} \qquad [7]$$

Behind/side of blast

$$D_{115} = \left(\frac{190 \times 89}{3.0}\right)^{2.5} \cdot \sqrt[3]{100.2} \qquad [8]$$

From the models above, the distances to milestone decibel levels are shown in **Table 4**.

Table 4 – Distance to airblast levels (MIC 100.2 kg/delay, FRB 3.5m, stemming 3.0m)

Airblast (dBL)	Front of Face (m)	Behind/side of blast (m)
120	324	240
115*	**473**	**350**
110	694	514
105	1,019	754
100	1,496	1,107

**ERR airblast limit (95% of blasts)*

Contours from the standard model show the directional nature of airblast with the highest levels occurring directly in front of the blast face. At most quarries (including Boral Montrose) blasts approaching extraction limits face inwards to the quarry pit with lower behind-blast emissions at the closest neighbouring properties.

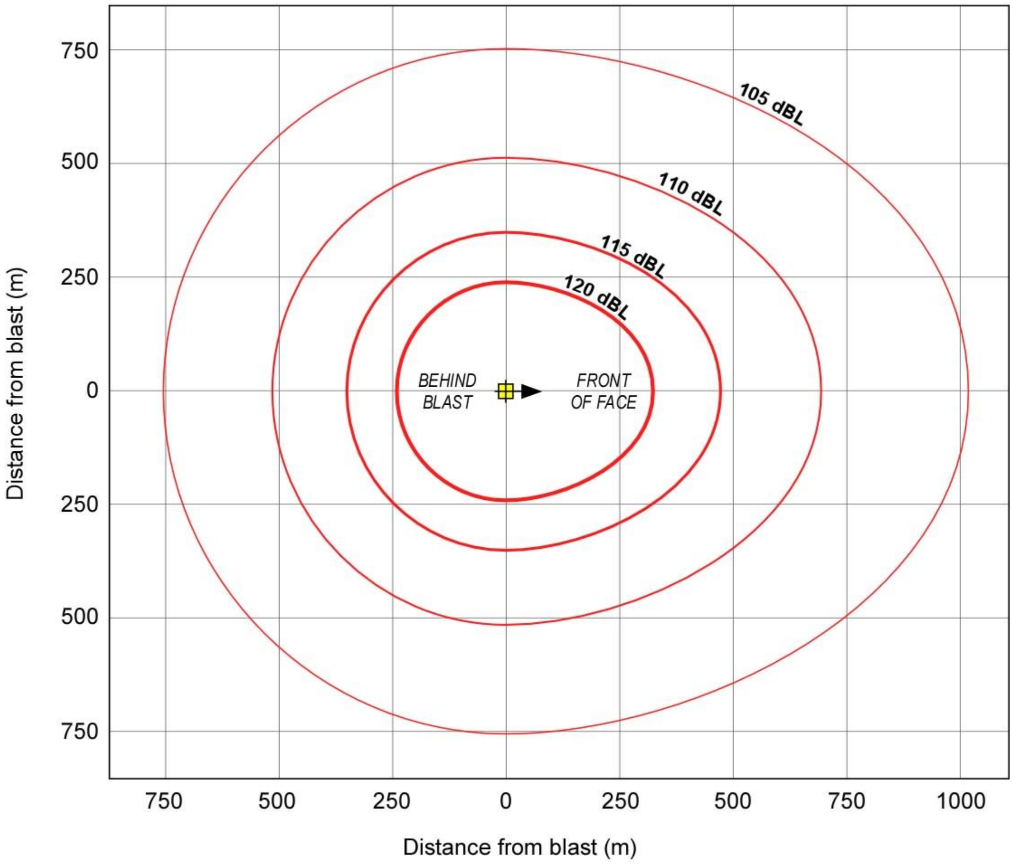

Figure 8 – Basic airblast model contours from standard blast design

The reduction of dBL levels over distance is shown in the regression analysis **Figure 9**. Airblast levels recorded around Montrose Quarry over recent years are also plotted, showing a wide distribution of dBL due to variable factors such as blast site elevation and face direction. Compliance with the lower ERR 115 dBL limit (95% of blasts) has been achieved and peak levels are reduced from historic results, though most recent blasts have occurred on lower benches with levels reduced by topographic shielding.

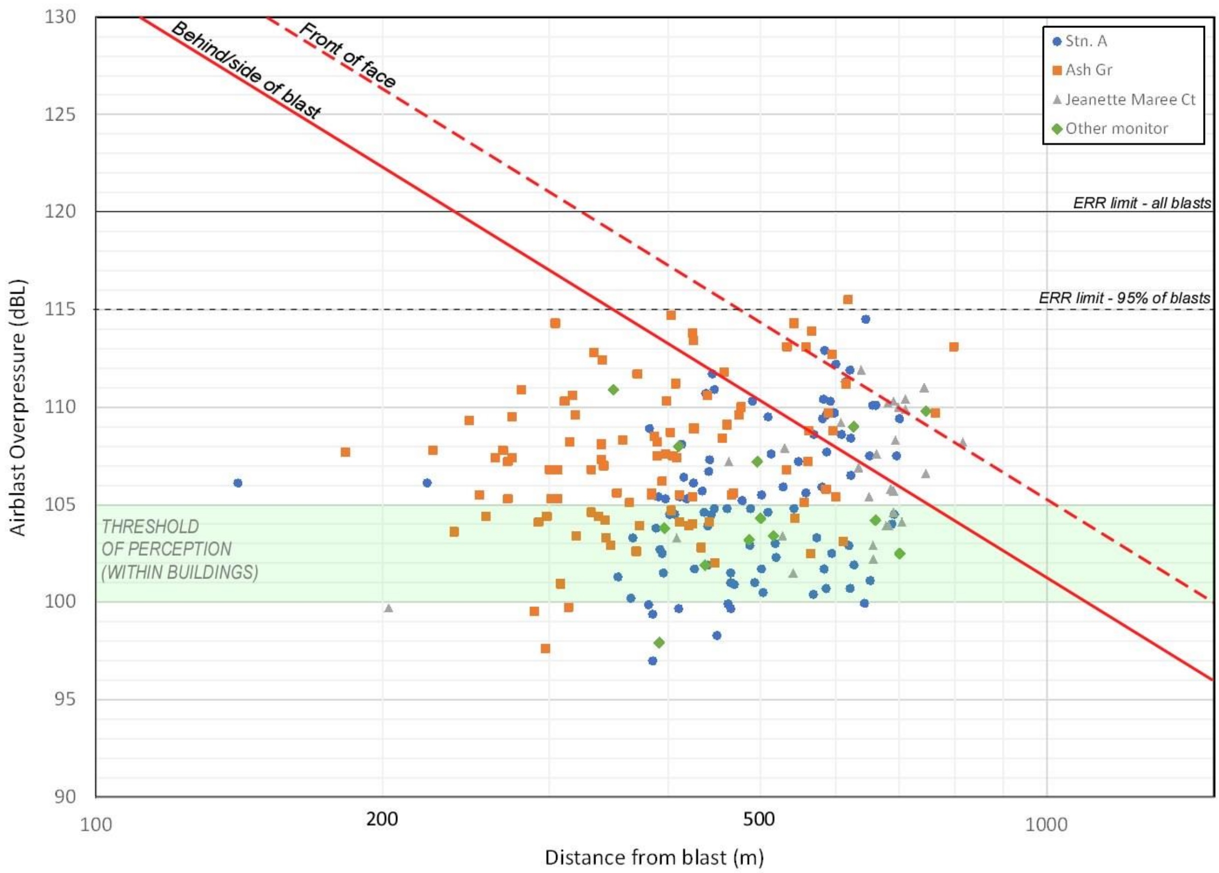

Figure 9 – Airblast overpressure regression analysis (MIC 100.2 kg/delay, 3.5m FRB, 3.0m stemming)

10.3.1 Topographic shielding

From standard blast design (**Table 1**) there is indicated to be potential airblast limit exceedances from blasts less than 350m from houses. However, the basic model results are conservative because airblast levels at Montrose Quarry are reduced by upper benches, bunds, batters and surrounding landforms that form barriers to noise and overpressure, an effect known as topographic shielding. Topographic shielding and its terminology are shown in the following cross-section diagram.

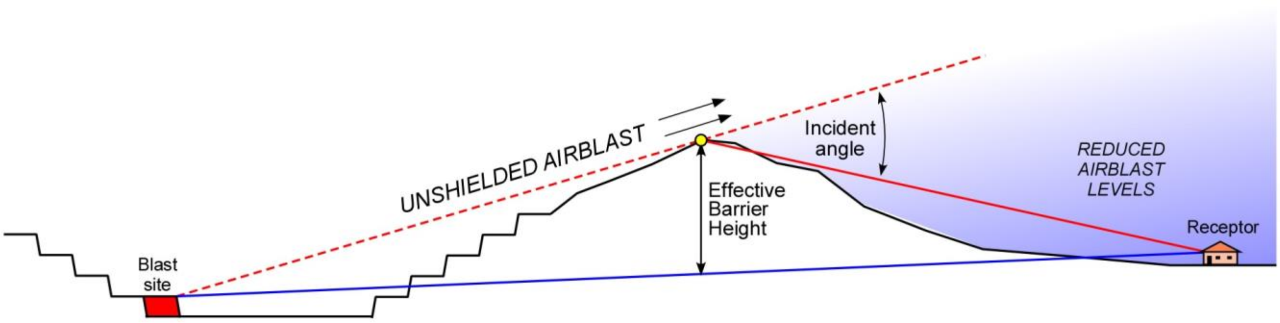

Figure 10 – Topographic shielding and its terminology

Where the effective barrier height and incident angle between a blast site and receptor is known, the approximate dBL reduction can be approximated using the following chart.

Figure 11 – Topographic shielding and dBL reduction

The influence of topographic shielding around Montrose Quarry is shown in the following cross section diagrams **Figures 12a-12d**. The examples show terminal blasts at both upper and lower benches near Ash Grove and Jeanette Maree Court, as interpreted from profiles produced by GHD. Airblast levels are reduced by 2-6 dBL from upper bench blasts and 5-10 dBL at lower benches.

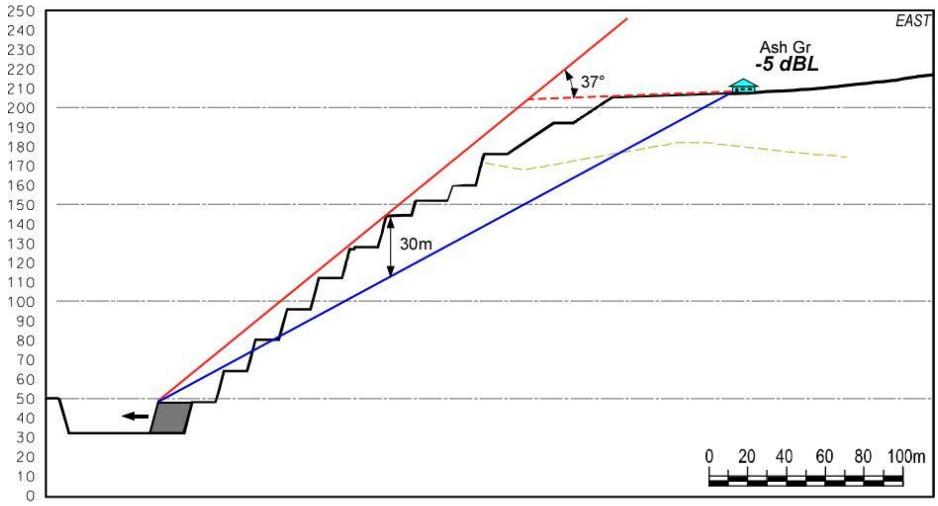

Figure 12a - Topographic shielding example, lower bench, east wall.

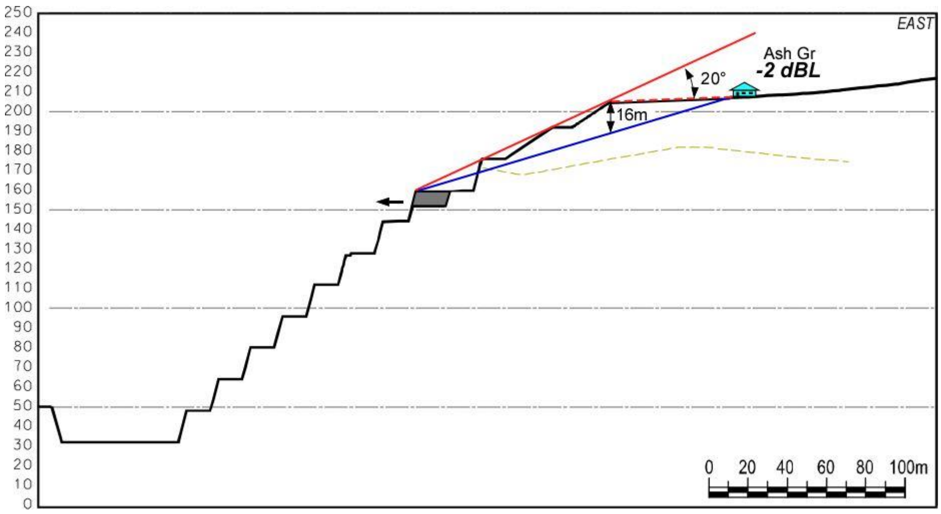

Figure 12b - Topographic shielding example upper bench, east wall.

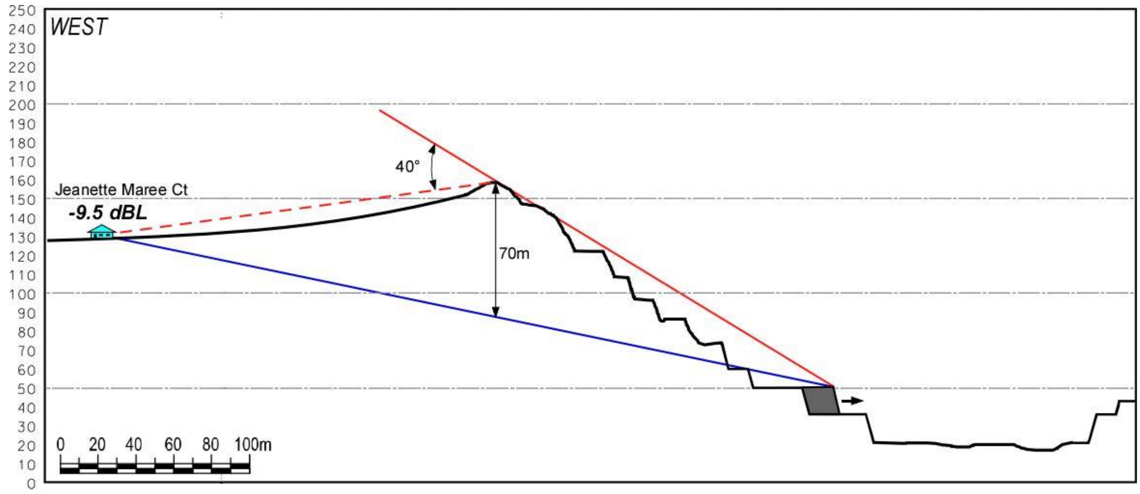

Figure 12c - Topographic shielding example lower bench, southwest corner.

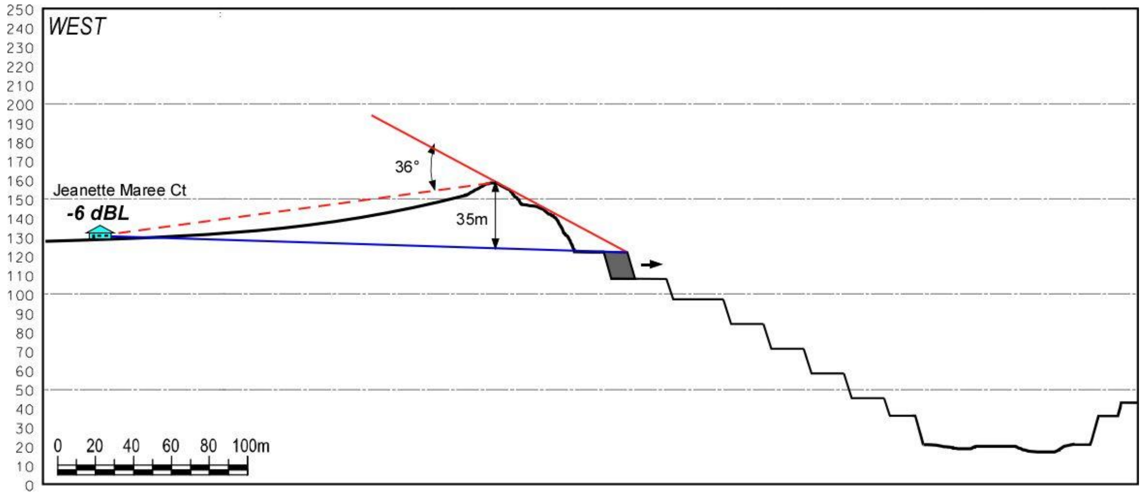

Figure 12d - Topographic shielding example upper bench, southwest corner

The dominant face directions for the extension proposal are north and west with a limited number blasts in the other directions. While shielding and face direction of most blasts would continue to reduce airblast levels and help maintain compliance with the 115 dBL limit, caution is required in areas with less shielding and areas less than ~300m from houses.

10.3.2 Controlling airblast levels

The areas in which airblast levels may exceed 115 dBL at the closest houses are similar to those where PPV limit exceedances are indicated (as shown in **Figure 7**), noting the effect of shielding is reduced for upper bench blasts, i.e., the closest blasts to residences. Airblast levels in these areas can be largely controlled by the charge mass reductions needed to control PPV levels. The effect of face splitting (with MICs ~40 kg/delay) on the distance to the 115 dBL level is;

Standard blast (MIC 110.2 kg)		**Split-face blast (MIC 40 kg/delay)**
D115 = 350m	→	D115 = 258m

For blasts less than 258m from Ash Grove and Jeanette Maree Court, stemming height increases can further reduce dBL levels. Increased stemming and face burden effectively increases the 'depth of burial' of explosives charges resulting in lower airblast levels. The relationship between stemming height and D_{115} is shown as Figure 13 noting a reduced MIC of 40 kg/delay is observed.

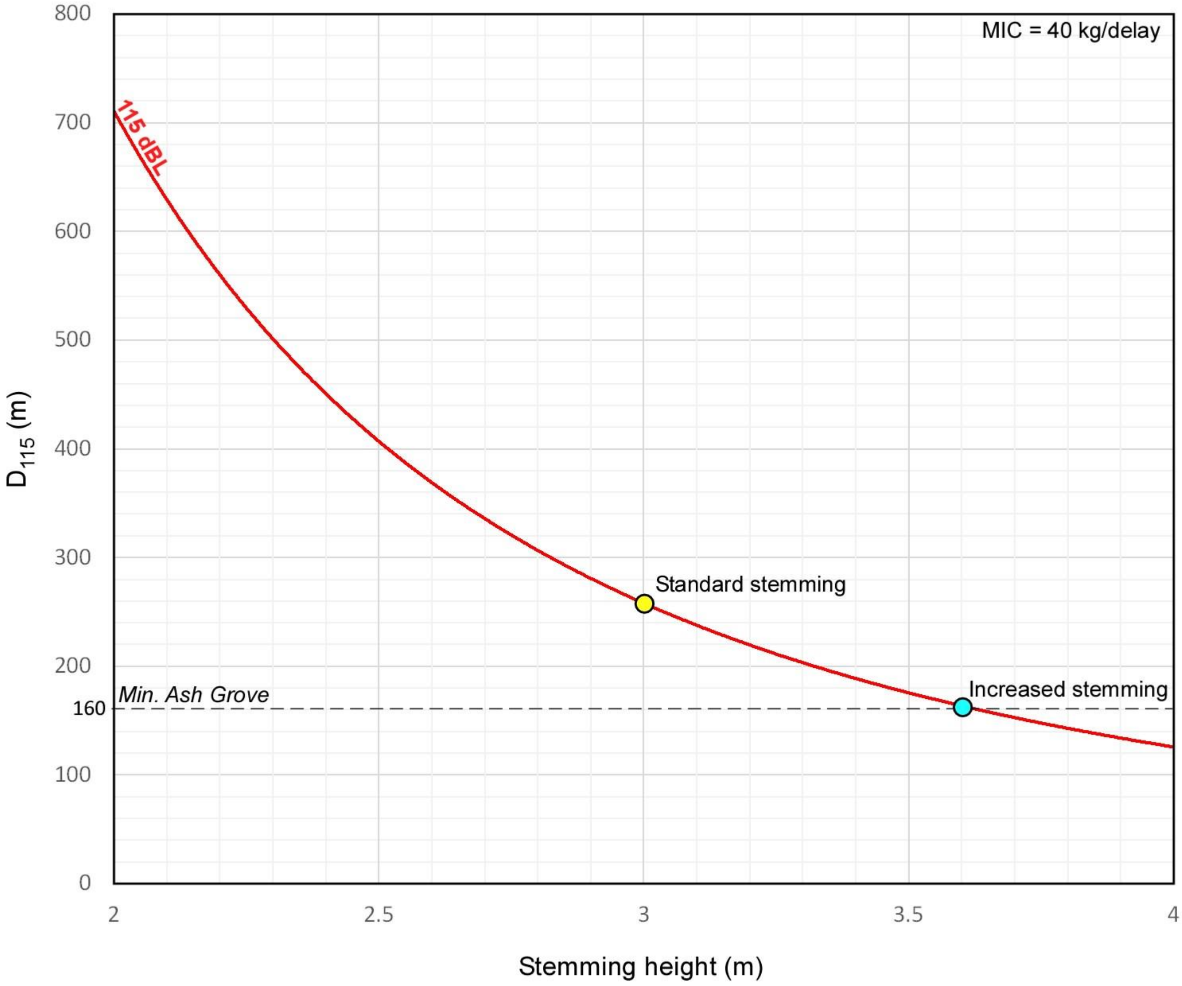

Figure 13 – Stemming - D_{115} relationship, and effect of stemming increase for blasts approaching Ash Grove

Increasing stemming height to 3.6m reduces D_{115} to 164m, the minimum distance to Ash Grove. This assessment is broadly conservative because topographic shielding provided by overburden batters above RL 176 would reduce airblast levels by a few decibels as shown in **Figure 12b**. However, due to normal variation of airblast between blasts it is likely that stemming height would be need to be increased to help ensure compliance with ERR limit and minimise dBL as far as can be practicably achieved. Indicative areas in which MIC and stemming modifications are needed are shown in **Figure 14**.

Figure 14 – Extraction areas requiring MIC + stemming height increases for airblast control

Increasing stemming and face burden well above normal design specifications can compromise blast performance (heave, fragmentation and diggability) and result in oversize rock, large block and boulders too large to haul from the blast site. Oversize blocks present a hazard to quarry personnel (particularly front-end loader operators) and may require secondary breaking using hydraulic rock hammers, resulting in noise and dust. Depending on localised rock structure, stemming heights ~3.6m may be near the upper limit for efficient blasting at Montrose Quarry though such increases may only be needed for few blasts.

10.4 FLYROCK MODEL

A model has been developed by Terrock for determining the maximum horizontal throw distance of rock fragments from blast sites using trajectory formulae and a scaled depth-of-burial model proposed by Workman et al (1994). The model has been refined from observation and measurements of rock throw from blasting and is used at some mines and quarries across Australia and overseas to assess risks and guide blast clearance distances. The model was reviewed in 2007 by Prof. Peter Lilly (former CSIRO Chief Officer of Exploration and Mining) who concluded, "*Terrock's flyrock model greatly simplifies what is dynamically a very complex in physics. However, the algorithm is likely to yield broadly conservative outcomes and is therefore considered to be appropriate by the writer*." For the purpose of this assessment, the term *maximum throw* refers to the maximum distance rock fragments may be thrown under a blast's design specifications.

Fragments thrown well beyond anticipated distances (as a result of significant human error) are referred to as *flyrock*.

The default model (with a site constant of 27) is conservative by design and provides an allowance for minor inconsistencies in rock structure and minor errors that may occur during hole drilling and loading. The distance rock fragments may roll after landing is also considered. Observations and measurements show that that actual throws behind blasts are considerably shorter than calculated with standard flyrock model.

Maximum throw in front of a blast face is largely controlled by front row burden provisions. The maximum throw distance in front of a blast site can be calculated from:

$$Lmax_f = \frac{{k_f}^2}{g}\left(\frac{\sqrt{m}}{B}\right)^{2.6} \qquad [9]$$

Where:

m =	Linear charge mass (kg/m)
B =	front row burden (m)
$Lmax_f$ =	maximum throw in front of face (m)
g =	gravitational constant (9.8)
k_f =	a site constant

Maximum throw behind and to the sides of a blast is largely a function of stemming height and hole angle, and is calculated by:

$$Lmax_r = \frac{{k_f}^2}{g}\left(\frac{\sqrt{m}}{SH}\right)^{2.6} Sin\ (2\ \times \emptyset) \qquad [10]$$

SH =	stemming height (m)
$Lmax_r$ =	maximum throw behind blast (m)
Ø =	launch angle = hole angle from horizontal + dispersal allowance of 10° (eg. Hole angle + dispersal = 70° from horiz.)

From the quarry's standard design specifications (**Table 1**), the maximum throws in front of blast faces are:

$$Lmax_f = \frac{27^2}{9.8}\left(\frac{\sqrt{7.2}}{3.5}\right)^{2.6} \qquad [11]$$

$Lmax_f$ = (37.3) **38m**

Maximum throw behind blasts:

$$Lmax_r = \frac{27^2}{9.8}\left(\frac{\sqrt{7.2}}{3.0}\right)^{2.6} Sin\ (2\ \times 70) \qquad [12]$$

$Lmax_r$ = (35.8) **36m**

If needed, the standard model can be calibrated to site conditions by a program of close observation and measurement of actual throw distances.

At multiple bench quarries, throw distance in front of the face may be increased if there is a difference in elevation between launch and landing sites, such as a terminal blast with a narrow berm in front. The maximum throw increase is approximately equal to the difference in elevation as shown in the trajectory diagram **Figure 15**. In most cases, clearance distances do not need to be increased because the additional risk zone applies to lower benches and because all site personnel are evacuated from the pit at blast times. Conversely, the throw distance behind blasts can be reduced by upper benches and landforms that form a barrier.

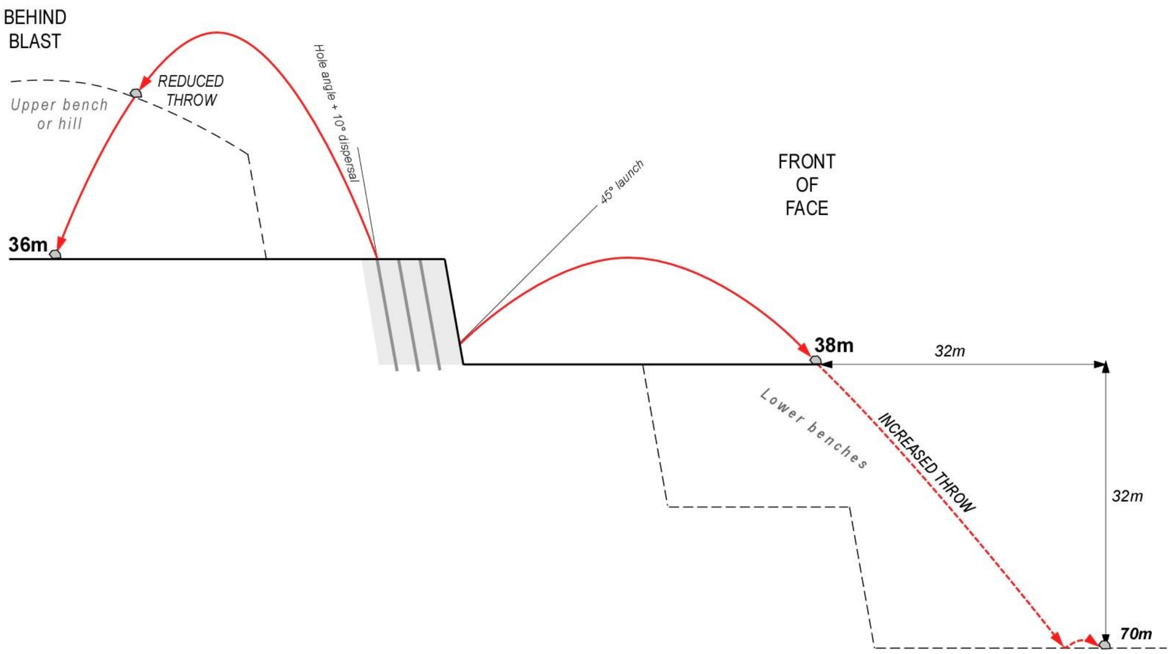

Figure 15 – Maximum throw trajectories for standard blasts, including multiple bench example

The nature, causes and risk posed by flyrock, and approaches for determining blast clearance distances at Montrose Quarry are discussed in the following sections.

11 BLASTING RISKS AND CONTROLS

Controlled blasting practices that adhere to existing standards and regulations present a low risk of harm to people, property and the surrounding environment. The residual risks and control measures required to mitigate them are discussed in the following sections.

11.1 FLYROCK

The greatest blasting hazard to the safety of people and property is flyrock, where rock fragments from a blast are thrown well beyond anticipated distances. Flyrock events at quarries have become uncommon due to improvements of blasting practice and no flyrock injury has been reported from a Victorian quarry for several decades. However, flyrock remains a possibility at all quarries and its prevention and risk mitigation is a critical consideration for shotfirers and quarry managers.

11.1.1 The nature of flyrock

Where blasts are conducted on benches with a free face, fragments of blasted rock heave forward and form a pile in front of the blast site from where they are transported for processing. Sometimes fragments are thrown beyond the pile and land at more distance locations. The furthest potential throws of occur within a 90° arc perpendicular to the face and consists of 100-200mm diameter fragments launched at a 45° angle. Smaller fragments have reduced throw due to wind resistance and the throw of larger blocks and boulders is limited by their mass.

The furthest throws behind blast sites typically consist of small fragments of stemming material or loose collar rock that are launched at the blast hole angle and may disperse a further 10°. If a blast hole is significantly under-stemmed, collar rock can break out at a 45° angle and be thrown further distances, an occurrence known as "cratering". Generally, due to the smaller size of fragments, steep launch angles and lower velocities on landing, flyrock behind blast sites presents a lower risk of serious injury than flyrock thrown in front of the face.

11.1.2 Causes and prevention of flyrock

Excessive flyrock throw is the result of human error where insufficient face burden or stemming, overcharged blast holes or structural weaknesses in face rock are not identified prior to firing. The primary mechanisms for flyrock in front of the face are shown in the following cross section diagrams (**Figure 16a**).

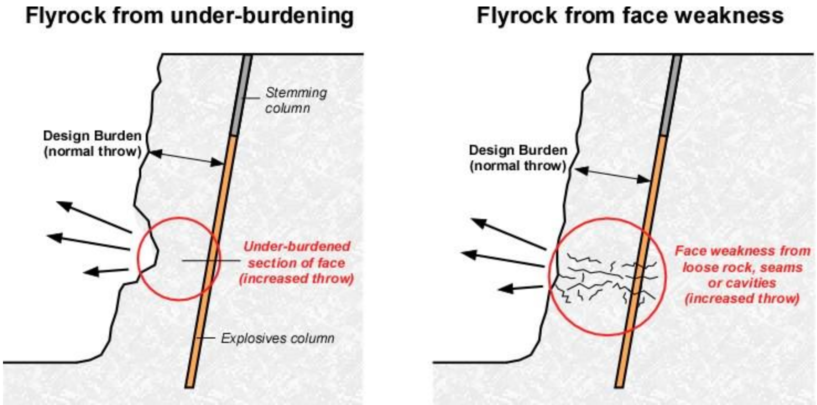

Figure 16a – Mechanisms for flyrock in front of a blast face

Under-burdening is identified by laser face profiling and Boretrak survey techniques that measure the true burden between the face and front row blast holes, and the depth and deviation of each hole. Laser face profiling and Boretrak surveys are conducted as part of routine blasting procedures at Boral Montrose Quarry.

Structural weakness in blast faces (e.g. wide clay seams and pockets of loose or naturally fragmented rock) are not detected by laser profiling but identified by review of driller's logs and visual inspection of blast faces. If under-burdening or structural weakness is identified or suspected, affected holes must be loaded in a manner that prevents explosives being placed in under-confined sections. Flyrock can also be caused when one or more blast holes are overcharged and normal design burden and stemming provisions are insufficient to confine the additional energy. As a rule of thumb, the quantity of explosives loaded into every blast hole should not exceed 10% of the design charge mass.

The mechanisms for flyrock thrown behind and to the sides of a blast are shown in **Figure 16b**.

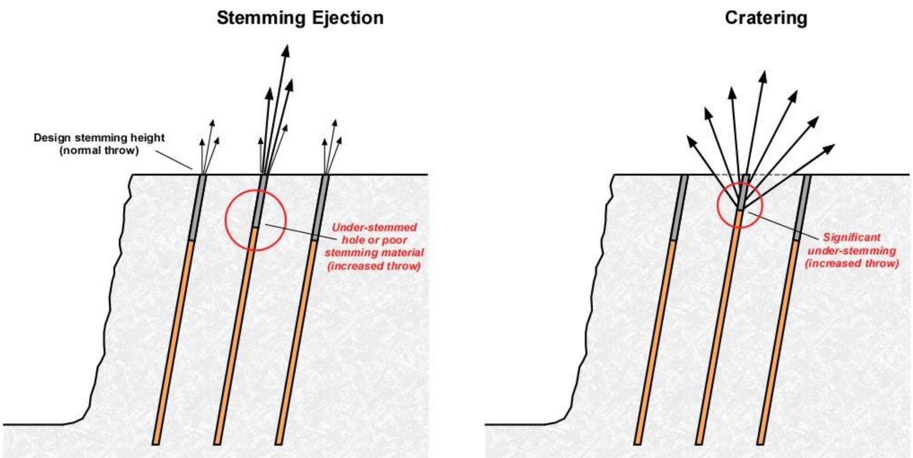

Figure 16b – Mechanisms for flyrock behind and to the sides of a blast

Flyrock behind blast sites is prevented by ensuring an adequate length of stemming is loaded into each hole through careful loading practices and accurate record keeping. The optimum stemming material for 89mm holes is 10-14mm stone aggregate which is used for all blasts at Boral Montrose Quarry. To prevent cratering, the minimum length of the stemming column should be at least 20 x the blast hole diameter (1.8m for 89mm diameter holes). The standard 3.0m stemming height observed at the quarry is sufficient to prevent cratering.

In general, flyrock is successfully prevented by review of driller's logs and blast hole survey results, inspection of face structures, careful attention to hole loading practices, and accurate record keeping and review. These are routine practices at Boral Montrose and no significant flyrock events have occurred at the quarry over recent decades. *Thought to be correct.*

11.1.3 Blast Clearance Zone

The risk presented by unexpected flyrock is mitigated by establishing wide clearance zones around blast sites to account for the possibility of increased throw. Clearance zones are established immediately prior to blast times and are lifted when the shotfirer gives the "all clear" signal after a short post-blast inspection. When all personnel have evacuated the pit and nearby work areas, the zone is secured by blast guards positioned at strategic points on access tracks leading to the clearance area. If a clearance zone extends beyond the boundaries of a quarry, guards may be positioned at the quarry or title property boundary with a clear view of the surrounding area. No blast may be fired until the shotfirer receives confirmation from every guard that the clearance zone remains free of people and it is safe to fire the blast.

At Boral quarries, clearance distances are guided by applying Safety Factors to maximum throw calculations from the Terrock Flyrock Model. The minimum safety factors to have been accepted by quarry operators and authorities are;

- Plant & Equipment - Safety Factor 2 (2 x maximum throw)
- Personnel & Public – Safety Factor 4 (4 x maximum throw)

The current public/personnel clearance distances observed for blasting at Montrose Quarry are;

270m (front of face)
150m (behind/side of blasts)

The distances are based on the 2/4 Safety Factor approach and minimum face burden (3.2m) and stemming heights (3.0m) currently observed at the quarry. For standard blasts in the proposed extension the current distances provide minimum safety factors of 7.1 (front) and 4.2 (behind/side) for public and site personnel. The radial clearance distances are combined to form the clearance zone footprint shown in **Figure 17**.

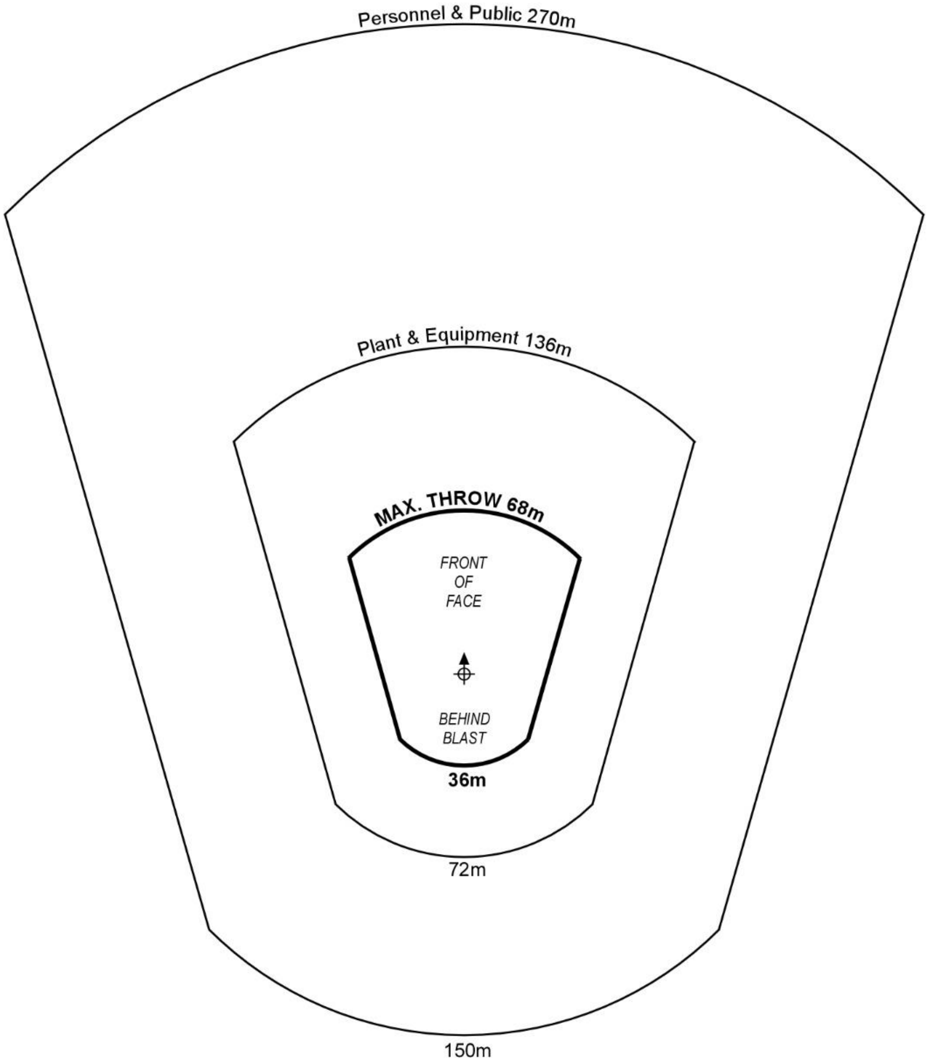

Figure 17 – Standard minimum Blast Clearance Zone used at Boral Montrose Quarry

The current, standard clearance zone would provide a high level for proposed future blasting, is largely workable and should be maintained. Clearance distances are ultimately the responsibility of shotfirers and site managers, and the adequacy of standard provisions must be reviewed prior to every blast. Further details of the quarry's clearance zone and clearance procedures can be found in the Boral Montrose Quarry Blast Management Plan.

11.1.4 Blast clearance outside the quarry

There are sufficient buffers around the proposed extraction area to contain rock fragments from blasting within the quarry. However, the 150m clearance area behind blasts extends beyond the Work Authority boundary onto neighbouring land in some areas, notably for blasts close to the western boundary. Observing standard clearance in these areas would require traffic management on Fussell Road and evacuation of people from some properties to the west. Extraction area less than 150m from the boundary and the maximum extent of clearance outside the quarry (combined for all terminal blasts) are shown in **Figure 18**.

Figure 18 – Maximum (combined) extent of offsite blast clearance (150m), and blast areas <150m from WA100 boundary

To reduce offsite clearance requirements, stemming height increases can be used to reduce the clearance area behind blasts. Increased stemming and face burden also reduces the distance rock fragments are thrown, as shown in the following chart.

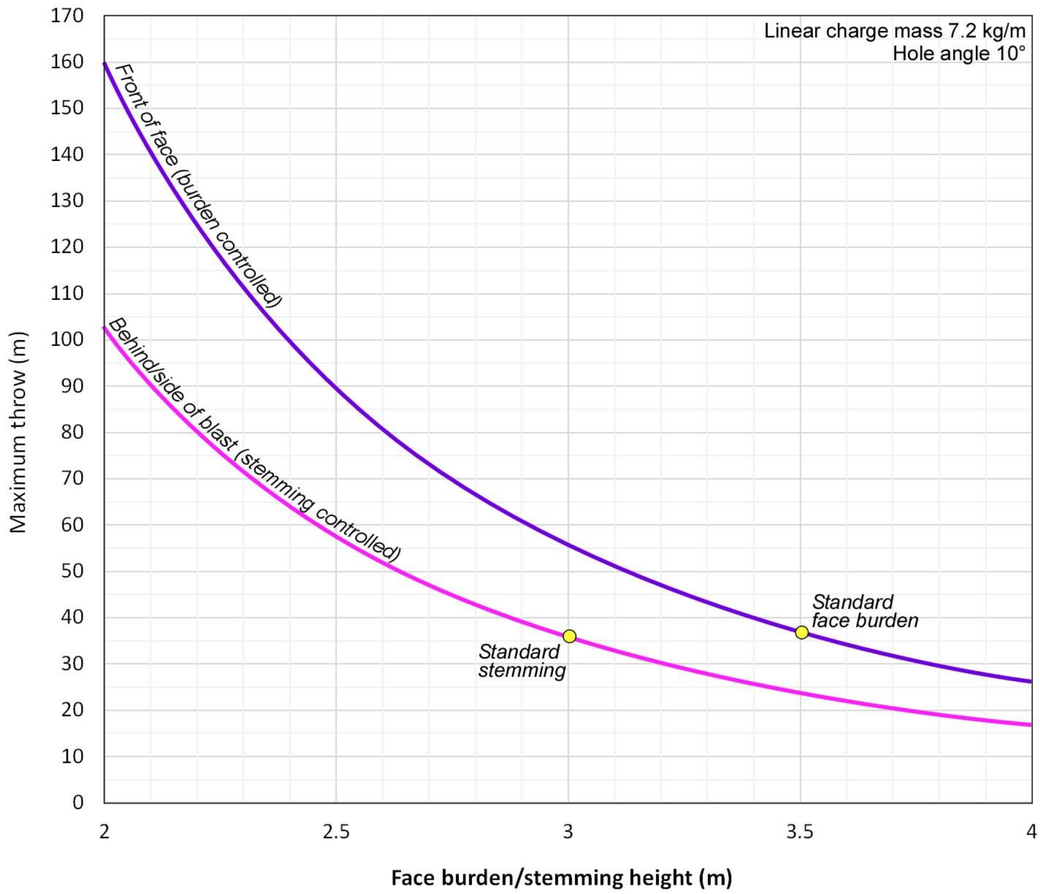

Figure 19 – Relationship between face burden/stemming and maximum throw

The effect of increasing stemming height on maximum throw distance behind blasts is visualised in the following trajectory diagram **Figure 20**.

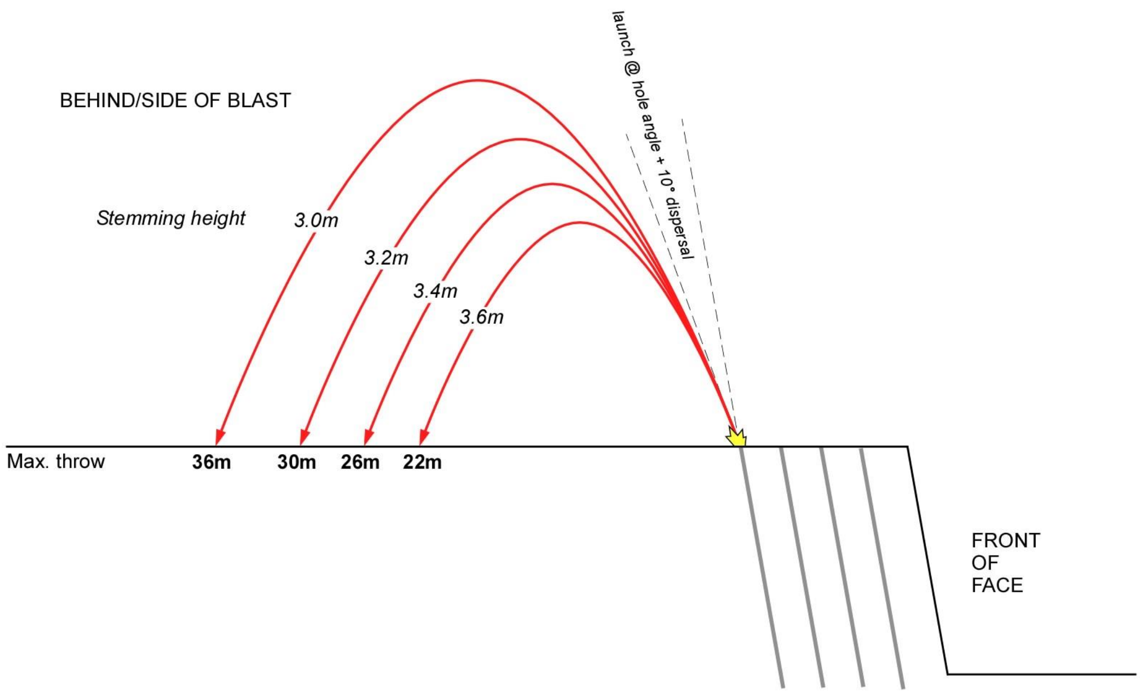

Figure 20 – Maximum throw trajectories for increased stemming heights

Following Safety Factor 2/4 approach, the minimum clearance distances for blasts with increased stemming are shown in **Table 5**. The maximum throw distances are conservative due to the (conservative) default flyrock model, and because horizontal throw distance would be somewhat reduced by physical barriers of upper benches and overburden batters.

Table 5 – Minimum Safety Factor clearance for blasts with increased stemming height

Stemming height (m)	Max. throw (m)	Safety Factor 2 – Plant & site infrastructure	Safety Factor 4 – Site personnel and public
3.0	36	72m	144m
3.2	30	60m	120m
3.4	26	52m	104m
3.6	22	44m	88m

The areas in which stemming height increases can reduce the need for clearance outside the quarry is shown on the following site plan (Fig T). Under this method, offsite clearance and traffic management would only be required in limited areas for a few blasts less than 88m from the western Work Authority boundary, and no offsite clearance is required for blasts at the east wall. The minimum buffer between the north wall and is 150m and traffic control on Canterbury Road is not warranted.

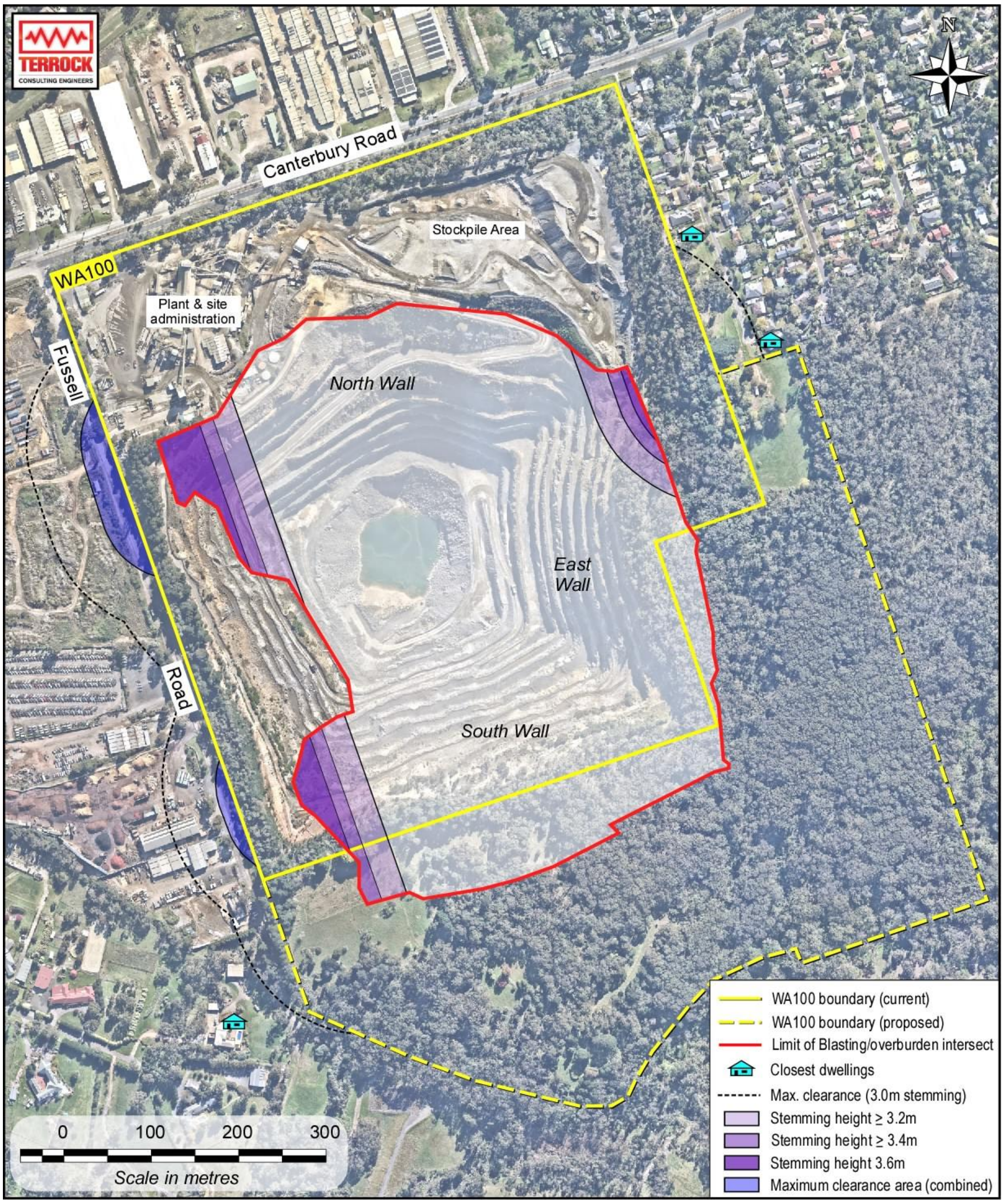

Figure 21 – Areas where stemming height increases can be used to reduce offsite blast clearance

At other quarries and civil blasting projects, increased stemming has been successful to reduce clearance areas and the need for road closures while maintaining a minimum Safety Factor 4. For the closest few blasts (<88m from the western boundary), 5-10 minute closures of Fussell Road would be needed as conducted in accordance with the local roads authority requirements. In addition, owners/managers of affected properties would need to be informed of road closures, clearance requirements and firing procedures ahead of scheduled blast times. It is important to secure the cooperation of neighbouring property owners/tenants in advance to prevent blasts being delayed.

11.1.5 Blasting near quarry plant and equipment

Blasts located close to fixed processing plants and other quarry infrastructure may also require increased stemming or face burden to mitigate the risk of flyrock damage. Such damage can be expensive to repair and result in production delays and site hazards. Managing the risk to quarry plant and equipment is largely a financial consideration for quarry operators. Broadly speaking, minimum Safety Factor 2 clearance distances are appropriate for fixed site infrastructure (see **Table 5**).

11.2 BLAST-INDUCED DAMAGE TO BUILDINGS AND OTHER STRUCTURES

Buildings and other structures can be damaged if exposed to very high levels of airblast and ground vibration. However, the known thresholds of cosmetic and minor damage such as hairline cracks in plasterboard are above the prescribed limits for quarries and well above levels that typically occur in beyond 100m from a quarry blast site.

Australian Standard AS2187.2-2006 Appendix J contains frequency-dependent criteria from overseas standards and guidelines that are used to determine thresholds of cosmetic damage (e.g. hairline cracks in plaster) for residential, commercial and industrial type buildings. The criteria are frequency-dependant because high magnitude ground vibration waves with low frequencies have a greater damage potential than vibrations with high frequencies. Ground vibration frequencies from blasting reduce with increasing distance, with a typical dominant frequency of around 10 Hz at around 500m from blast sites.

Damage criteria from the Australian Standard is sourced from British Standard BS7385.2-1993 (shown as **Figure 22**) and research from the United States Bureau of Mines (USBM RI 8507). At a dominant ground vibration frequency of 10 Hz, the threshold of cosmetic damage is 18 mm/s from both criteria, above which there is an "*increasing possibility of damage"*. From the British Standard, the major/structural damage threshold is four times the cosmetic damage values (i.e. 72mm/s). Australian research into the effects of blasting on structures has shown PPV levels below 70 mm/s to be wholly non-damaging to common brick-veneer type houses (ref. ACARP study C9040).

TABLE J4.4.2.1

TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE (BS 7385-2)

Line	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structure. 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

NOTES:

1 Values referred to are at the base of the building.

2 For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

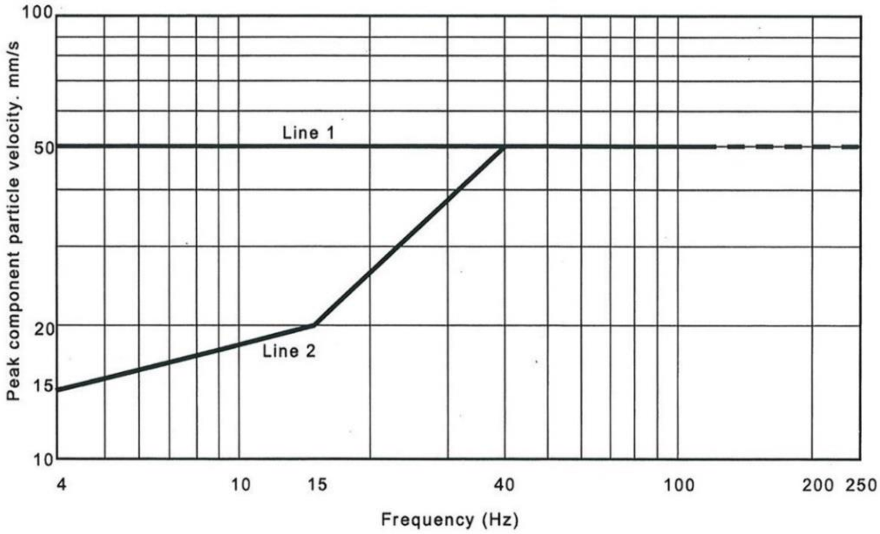

FIGURE J4.4.2.1 TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE (BS 7385-2)

Figure 22 – Threshold/cosmetic damage criteria from AS2187.2-2006 (source: BS7385.2-1993)

The building elements most sensitive to airblast overpressure are glass window panes. AS2187.2-2006 recommends a limit of 133 dBL to prevent damage though the Standard notes, "*damage at levels below 140 dBL is improbable*". In terms of real air pressure measured as Pascals, 140 dBL (or 200 Pa) is eighteen times the ERR limit of 115 dBL (11.2 Pa).

It is common for some people living near quarries to believe blast vibration is the cause of cracks and defects that develop in all houses over time, regardless of the blast vibration levels that occur. Numerous investigations of blast damage claims have shown such cracks and defects are cosmetic or minor in nature and can be attributed to normal mechanisms that affect all houses including seasonal movement of foundation soils (particularly clay soils), poor drainage around houses, lack of property maintenance, and the effects of ageing and weathering. In most cases damage claims and concerns can be addressed by blast monitoring at the property and providing relevant information from blasting guidelines and regulations to concerned residents. If a damage claim is persistent or escalated, it is recommended that an experienced structural engineer is engaged to investigate the claim and identify the cause(s) of the alleged damage.

The risk of blast vibration-induced damage to houses from blasting the proposed Montrose Quarry extension is low and PPV and airblast levels can be maintained below the ERR limits for human comfort. However, it is likely that blast-related complaints and concerns would occasionally arise, as is the experience of all metropolitan quarry operators.

11.3 TRANSPORT, HANDLING AND USE OF EXPLOSIVES

Blasting at Victorian quarries is undertaken by qualified personnel who are trained and licensed to use blasting explosives in the State of Victoria. Blasting is conducted in accordance with National and State regulations, standards and guidelines including:

- *Victorian Dangerous Goods (Explosives) Regulations 2022,*
- Earth Resources Regulation (ERR) guidelines for quarries
- *Australian Standard AS2187.2-2006*
- *Occupational Health and Safety Act 2004*
- *Australian Explosives Code 3rd Edition*
- Work Authority conditions, as well as any site-specific blasting conditions that may apply as part of a quarry's approved Work Plan.

Blasts at Montrose Quarry are designed, loaded and fired by Boral's in-house drill and blast team with assistance provided by technicians from the explosive supply company. It is the responsibility of the shotfirer and all blast crew personnel to work to Victorian blasting regulations and relevant standards, site rules, the procedures of the quarry's Blast Management Plan and Work Authority conditions. It is the responsibility of quarry management to ensure blasts are fired in accordance with prescribed regulations, maintain site safety and security, and coordinate the clearance procedure.

The risk control measures for explosives transport, and onsite handling and security procedures can be found in the quarry's Blast Management Plan, Risk Assessments and Blast Plans for individual blasts, and Material Data Safety Sheets provided by the explosives supplier.

11.4 RISK OF BLAST VIBRATION TO HUMAN HEALTH

Regulated blasting not known to cause adverse physiological effects to humans or animals. Ground vibration waves that travel along the surface cause small displacements and have insufficient duration and intensity to cause falls or whole-body shock and associated harms.

The part of the human body most susceptible to injury from very high airblast levels is the ear drum. However, the audible noise and overpressure from quarry blasting does not present a risk of such injury, even to shotfirers that are located close to blast sites and exposed to relatively high levels. This is due to several reasons including;

- The confinement/burial of explosives within blast holes where most of the blast's energy is consumed by fragmentation and displacement of surrounding rock.
- The rapid reduction of airblast levels over distance and the requirement for quarries to comply with airblast limits to minimise annoyance.
- The brief duration of airblast emissions that occur for around 1 second per blast.

Military research into the effects of blast overpressure show that explosives may present a risk of ear drum injury when a person is located close to an unconfined charge. Ear injury is only known to occur from extreme sudden increases of pressure with a 50% chance of injury at overpressure levels above 104,000 Pa (Cho, 2013). For perspective, an airblast level of 120 dBL (the upper regulatory limit for quarry airblast) has an equivalent air pressure of 20 Pa, a tiny fraction (~0.02%) of potentially harmful levels.

11.5 RISK TO DOMESTIC AND NATIVE ANIMALS

There is no evidence that quarry blasting alone has adverse impacts to native animals in habitat areas near quarries. Numerous native species are found in active work authorities around Victoria, often very close to extraction areas. A recent fauna and flora survey undertaken for a quarry northeast of Melbourne found a native habitat area adjacent to the pit is in good condition and the presence of a wide range of native species (including threatened species) was found or inferred. *Any recent fauna survey for Montrose?*

Overpressure and blast noise could result in a brief disturbance to animals located very close to a blast site, though the effect can be likened to that of a brief thunderclap. The typical response of birds within 100-200m to a blast is to take flight before settling or returning to the area shortly after when the perceived threat has gone. The potential disturbance caused by blasting is considered too infrequent and brief in duration to prevent native animals residing in or visiting habitat areas near quarries, including nesting birds. Animals have evolved to withstand high levels and long durations of noise and overpressure during thunderstorms, and it is reasonably concluded the impacts from the occasional blast event at a quarry present a low or negligible risk to the health and wellbeing of native species.

Some dogs are known to bark or howl around blast times though this is usually a response to the warning sirens that are sounded immediately before and after blast times. There is no evidence that blast vibration at regulated levels causes stress to domestic animals, though the sensitivities of individual animals cannot be entirely discounted.

11.6 IMPACT TO LOCAL AMENITY

Ground vibration and overpressure waves from blasting can cause short-lived structural responses in nearby houses and other buildings. These are largely perceived by the audible effects that can occur such as rattling or squeaking noises, and secondary movement of some internal fixtures and items, e.g. the brief wobble of a computer monitor on a desk. While most people living near quarries tolerate the effects of occasional, brief blast vibration events, some people express concern and annoyance and consider the amenity of their residence to be affected, even when PPV and airblast levels are relatively low.

The question of amenity impacts from blasting is highly subjective and difficult to quantify due to variable tolerances, sensitivities and attitudes among individuals Responses to blasting range from complete disinterest to annoyance and high levels of concern. Anecdotally, blasting complaints and concerns are more likely in areas where PPV levels exceed 2 mm/s, though complaints can arise at any perceptible level of vibration, airblast or blast noise. Factors known to influence human perception and responses to blasting include;

- A blast's instantaneous charge mass, number of blast holes, etc. (the "scale" of a blast)
- the separation distance from a blast site to a receptor location.
- When the PPV and airblast levels that occur are higher than previous experience.
- a person's location at blast time, where blasts are more perceptible to people inside a building due to structural responses and associated effects.
- a person's activity at blast time, where blasting effects are more perceptible to people at rest or concentrating, and less perceptible to people in noisy environments or engaged in physical activity.
- weather conditions at blast time, where overpressure effects and blast noise may be more perceptible on still days or at downwind locations.
- startling when a blast occurs unexpectedly.
- the frequency of blasting, i.e. the number of blasts fired per week/month/year.
- concerns about blast vibration damage to buildings and property.
- blasting complaints as part of broad objections to whole quarry operations.
- the individual's tolerance that may be affected by stress, anxiety or other personal circumstances.

From experience, the number of complaints a quarry receives is broadly proportionate to the number of residences in the surrounding area and therefore quarries in urban areas receive more complaints than remote, rural operations. As with most hard rock quarries, Boral Montrose receives blast-related complaints from a limited number of residents though the overwhelming majority of people living within a kilometre of blast sites tolerate the generally low blast vibration levels that occur. As at many quarries, the number of resident complaints would most likely increase during the closest stage blasting, and reduce when extraction occurs in more distant areas of the quarry.

On consideration of the proposed extension footprint and its separation from the closest houses, the potential change of amenity impacts levels from recent operations is a moderate increase of PPV and airblast levels from upper level blasts near the northeast, south and southwest Limit of Blasting. It is emphasised that PPV and airblast levels at houses must comply with the current ERR limits as a Work Authority condition, and Boral must modify blast designs where needed to achieve this for all blasts. The quarry's limits would be halved from previous operations and therefore maximum future PPV and airblast levels would be lower than maximums recorded in the past.

12 RISK RATINGS

The blasting risks from the previous sections are rated in accordance with a Risk Matrix (**Figure 23**) provided by ERR in the document *Preparation of Work Plans and Work Plan Variations – Guideline for Extractive Industries* (December 2020). Risks are rated as Low, Medium, High or Very High in accordance with their likelihood and potential consequences. The risks and controls associated with transport, storage and handling of explosives products are detailed in a quarry's Blast Management Plan, documentation for individual blasts, and information provided by the explosives supplier.

Likelihood		Consequence				
		Insignificant	Minor	Moderate	Major	Critical
Likelihood	Almost Certain	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	High	High
	Rare	Low	Low	Medium	Medium	High

Figure 23 – ERR Risk Matrix

The inherent risks of blasting, control measures to be observed, and residual risks (after controls are in place) are rated in accordance with the matrix in **Table 6**. Most controls are not specific to Montrose Quarry and are standard industry practice. Further details of risk controls observed by Boral can be found in the site's Blast Management Plan.

The risk presented by flyrock requires special consideration due to limitations of the ERR risk matrix definitions. While reportable flyrock events are uncommon and the probability of a person being struck by flyrock is statistically insignificant, the consequence of flyrock strike is critical and therefore the risk is rated high. In practice, the risk presented by flyrock from well-controlled, regulated quarry blasting with proportionate clearance zones (min. Safety Factor 4) in place is low.

Table 6 – Risk ratings and required control measures

RISK	INHERENT RISK RATING	RISK CONTROL MEASURES	RESIDUAL RISK RATING
FLYROCK (AREAS WITHIN THE QUARRY)	**VERY HIGH** Likelihood **POSSIBLE** Consequence **CRITICAL**	- Laser Face Profiling & Boretrak survey conducted for all blasts. - Visual inspection of blast site/face and review of drillers log and survey results to identify structural weaknesses and guide individual blast hole loading requirements. - Ensure each blast's design minimum stemming heights are loaded into each blast hole. - Review hole loading records including treatment methods used for under-confined blast holes. - Blasts inspected and signed off by authorised persons in accordance with regulations. - Clearance Zone (min. 270m front and 150m behind/side of blasts) established inside quarry. - All site personnel evacuated from pit to designated assembly area. - Blast guards positioned at internal access tracks to clearance zone, and WA boundary/Fussell Road area as required. - All site personnel to be accounted for prior to commencing the firing procedure. - ***No blast may be fired until the shotfirer receives confirmation from all blast guards that the clearance area is free of people and it is safe to fire the blast.*** - Flyrock observations and video recording of blasts conducted for performance review and to guide any blast design modifications required for further blasting.	**HIGH** Likelihood **RARE** Consequence **CRITICAL**
FLYROCK (NEIGHBOURING LAND AREAS)	**HIGH** Likelihood **POSSIBLE** Consequence **MAJOR**	- Observe standard flyrock risk controls (see above). - Stemming height gradually increased from 3.0m → 3.6m for blast holes less than 150m from WA100 boundary. - Prior notification and blast/clearance information provided to managers/tenants of properties within clearance zone area (i.e., limited areas west of Fussell Road. - Traffic management required to conduct 5-10 min closures of Fussell Road during western-most blasts.	**MEDIUM** Likelihood **RARE** Consequence **MAJOR**

Table 6 (continued)

DAMAGE TO BUILDINGS/ STRUCTURES	**MEDIUM** Likelihood **UNLIKELY** Consequence **MODERATE**	- Maintain appropriate blast designs and accurate hole loading practices. - Observe flyrock control techniques and procedures (as shown above). - Modify blast design (MIC and stemming heights) in areas <300m from houses to control PPV and airblast levels. - Undertake routine blast monitoring at closest sensitive sites, and occasional monitoring at more distant locations to assess compliance with damage thresholds from AS2187.2-2006. - Investigate damage claims in a timely manner	**LOW** Likelihood **RARE** Consequence **MINOR**
IMPACT TO LOCAL AMENITY	**HIGH** Likelihood **LIKELY** Consequence **MODERATE**	- Maintain Compliance with ERR Ground Vibration & Airblast Limits at sensitive sites, as confirmed by blast monitoring at the closest sensitive sites. - MIC reduction implemented in areas <300m from houses to reduce/control PPV and airblast levels at residences. - Stemming height increased for blasts <285m from houses to further reduce/control airblast levels/ - Provide notifications of scheduled blasts to subscribing residents. - Blasts only fired within quarry's approved firing time window (10am-4pm Monday-Friday only). - Details of all blast-related complaints to be recorded in a Complaints Register. - Individual complaints and concerns to be followed up by quarry management in a timely manner. - Undertake monitoring at complainant's houses to check compliance and help alleviate concerns. - Engage with community to provide general information about quarrying, regulations, and blast performance.	**MODERATE** Likelihood **POSSIBLE** Consequence **MINOR**

13 MANAGING BLAST IMPACTS

13.1 BLAST MANAGEMENT PLAN

Blasting procedures and risk control measures for transport, handling and use of explosives within quarries is detailed in a Blast Management Plan (BMP) that forms part of a quarry's approved Work Plan. A BMP details a quarry's blasting practice and procedures, key roles and responsibilities of personnel, risks and control measures, site communications, emergency contacts, etc. that must be observed for all blasting operations. BMPs are guided by explosives regulations, Australian standards, industry guidelines, the Occupational Health and Safety Act (2004), in-house policies and site-specific work plan conditions. BMPs also include details of environmental considerations that inform blasting practice such as blast vibration limits, the locations of sensitive receptors and off-site infrastructure, blast monitoring procedures and any control measures required to mitigate offsite risks and impacts. BMPs are subject to periodic review and revision as site conditions and blasting requirements may change over time.

Details pertaining to individual blasts are contained within Blast Plans that are produced by shotfirers and consist of various documents detailing all stages of the blast process including design, survey reports, driller's logs, hole loading records, Risk Assessments, details of blast crew personnel, blast monitoring results and post-blast performance records. Blast Plan documents must be retained by quarry management for at least five years and be available for inspection or audit at the request of industry authorities.

13.2 COMMUNITY ENGAGEMENT

While the effects of blast vibration cannot be eliminated, community perceptions of quarry operations can be improved by engaging with affected residents to listen to concerns and provide blast information, updates and advice. Community engagement is an important activity for quarry operators to maintain 'social licence' and many residents are receptive to learning about blasting, its effects and regulation. Boral quarries management are proactive in this regard, providing channels for community feedback and addressing the concerns of individual residents. *Any formal engagement activities? Is there a community reference group, open days, public quarry tours, etc?*

13.3 BLAST NOTIFICATIONS

The potential for blasting to generate annoyance and complaint is greatly reduced by providing personal blast notifications to subscribing residents. Notifying people of scheduled blast times on blast day mornings (or earlier) helps prevent startling that can occur when a blast occurs unexpectedly. Offering and providing blast notifications to neighbours/stakeholders is usually required as a Work Plan condition and personal notifications are routinely provided by Boral to residents around their country and metropolitan quarries including Montrose. Notifications are provided by email, SMS or phone call.

13.4 BLAST COMPLAINTS

A complaints register must also be maintained at quarries, recording the time, date, nature of the complaint and resident details. Managers are encouraged to address complaints in a timely manner by listening to resident concerns and providing relevant information such as blast monitoring results, damage criteria or regulatory information. Conducting some blast monitoring at a complainant's location (with permission of the landowner) and sharing the results with residents can be effective to alleviate concerns.

Most quarries receive (or hear of) informal damage claims at some stage of operation though it is rare for claims to be escalated or pursued through legal action. A few people may refuse to engage directly with quarry management and prefer to express their disapproval through complaints to industry regulators, local council, members of parliament or social media groups.

13.5 BLAST MONITORING

Blast monitoring is currently undertaken by Boral personnel as a routine procedure using portable Instantel monitors that comply with the specifications of AS2187.2-2006. Monitoring is important to;

- assess compliance with ERR limits.
- address blast-related complaints and potential damage claims.
- validate or calibrate predictive blast vibration models.
- identify areas in which blast design modifications may be needed to mitigate potential impacts and maintain compliance with prescribed criteria.

Future monitoring at Montrose Quarry should continue at or near the closest residences (Ash Grove and/or Jeanette Maree Court) with occasional monitoring at another locations such as Sheffield\Glasgow Roads and

Landy Court to the north. Close attention to monitoring is required for blasts within ~300m of results to guide the design modifications needed to control ground vibration and airblast levels.

13.6 RECORD KEEPING

Blast monitoring records including full wavetraces should be retained at the quarry for inspection by ERR, future reference or the investigation of high blast vibration or exceedance events. Quarries are advised to maintain a detailed spreadsheet of information pertaining to every blast including blast design specifications, blast monitoring results, weather observations and blast and monitoring locations. The critical information for assessing blast design and impacts includes;

- Blast MIC (actual loading)
- Minimum stemming height used
- Minimum face burden
- PPV and airblast levels recorded
- Blast location and face orientation
- Surface wind speed and direction at blast time
- Blast monitoring locations and results
- Flyrock observations
- Distance between blast sites and monitors

Under regulation, all documentation pertaining to blasts must be retained by quarry operators for a minimum period of five years.

14 CONCLUDING COMMENTS

This assessment demonstrates that blasting operations within the proposed extension area of Boral Montrose Quarry can be undertaken safely, comply with prescribed regulatory criteria for quarry blasting, and would not result in substantially increased impacts from previous operations. Key findings of the assessment are summarised below.

- Ground vibration and airblast levels at sensitive sites (occupied houses) can be maintained below regulatory limits of 5 mm/s and 115 dBL for 95% of blasts, and 10 mm/s and 120 dBL for all blasts. However, it is highly improbable that compliance would be achieved with a standard 16m face height in all areas of the pit. It is recommended that development plans are revised to reduce the 16m bench height currently shown in areas less than 300m from Ash Grove and Jeanette Maree Court. Reducing or splitting maximum bench height in these areas (e.g. 2 x 8m) would greatly assist the control of blast impacts and ongoing compliance with ERR limits.

- Other design modifications likely to be needed include increased stemming heights for blasts less than 258m from houses, and additional MIC reduction (<40 kg/delay) for the closest few blasts to Ash Grove. The areas in which modified blasting could be needed, and the design changes identified in this report are guided by conservative modelling of recent and historic monitoring results and actual results would vary. The precise design specifications to be used for each blast must be determined by qualified shotfirers as informed by site and rock structure inspection, ERR limits, review of blast monitoring results, general observations, community feedback and local experience.

- It is likely that blast-related complaints would continue to be raised from some community members as occurs at all metropolitan quarries. The potential for adverse responses can be reduced through ongoing community engagement including blast notifications, blast monitoring at or near the closest sensitive sites, and providing general information to residents in a timely manner.

- Maintaining the current standard clearance zone of 270m in front of blast faces and 150m behind blasts would to provide a high level of protection from flyrock in the proposed extension area. To reduce the extent of blast clearance needed on adjacent land areas, stemming can be increased from 3.0m to 3.6m for blasts near the western boundary to reduce potential throw distance and Safety Factor 4 clearance distances. Traffic control and limited clearance on a few Fussell Road properties would be required for the closest few blasts.

- Boral have operated Montrose Quarry for several decades and recent years' blast results demonstrate compliance with current ERR limits and flyrock control requirements. While standard blasting is viable in most in the proposed extraction area, careful attention to blast design (particularly instantaneous charge masses) would be essential in some areas to help ensure ground vibration and airblast levels are not substantially increased and compliance with ERR limits is achieved.

- While low-impact blasting relatively close to houses is viable from a technical and engineering perspective, a reduced scale of blasts in these areas could affect blast efficiency, production rates, blasting costs and proposed staging, and should be factored into future development plans.

DRAFT 1.0

James Richards
Technical Services Manager
Terrock Pty Ltd

14 May 2024

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APPENDICES