BLAST MANAGEMENT PLAN

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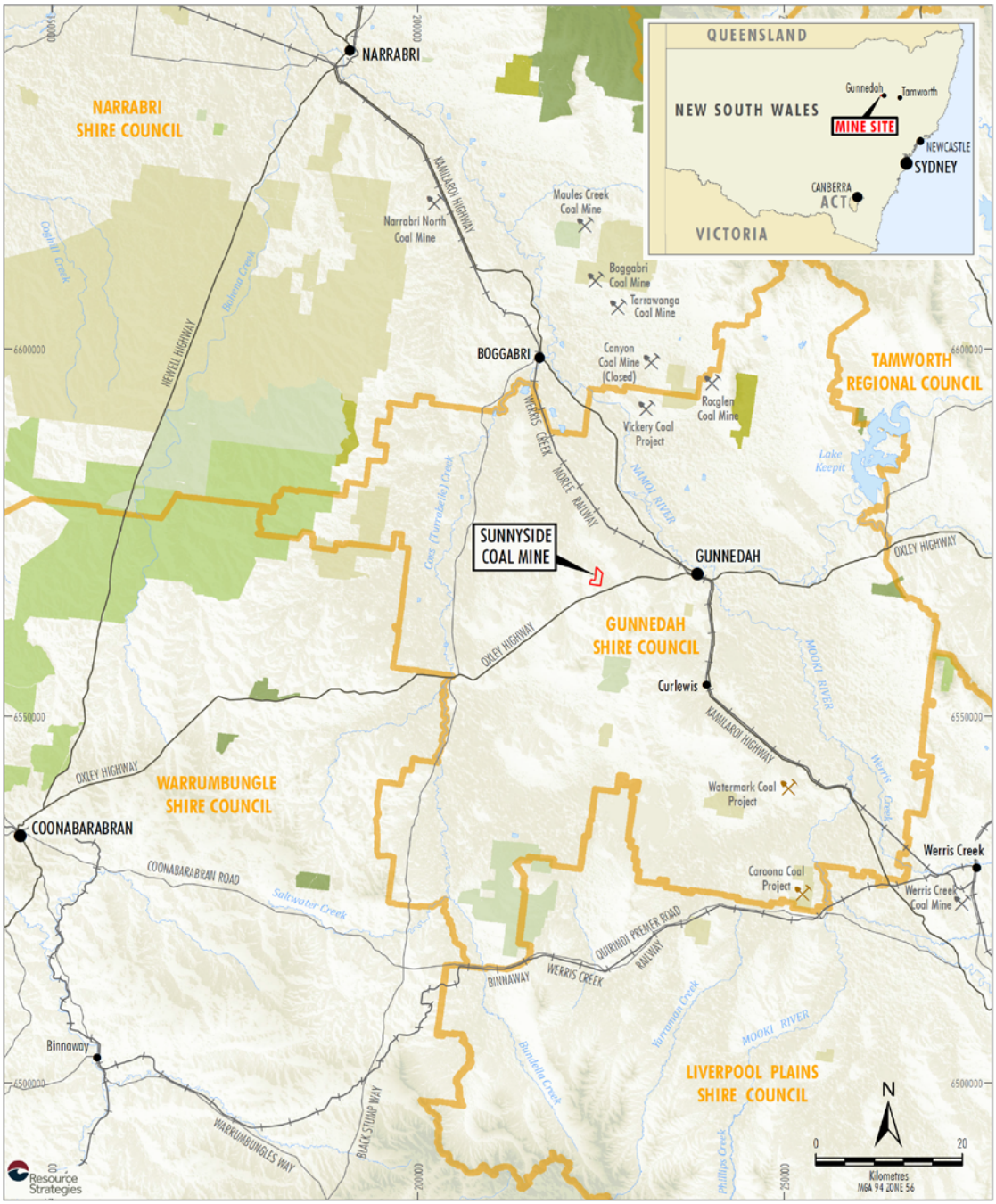
ACRONYMS USED THROUGHOUT THIS DOCUMENT

BMP	-	Blast Management Plan
EPA	-	Environment Protection Authority
NMPL	-	Namoi Mining Pty Ltd

1 INTRODUCTION

This Blast Management Plan (BMP) has been prepared in accordance with Condition 3(17B) of Project Approval (PA) 06_0308 for the Sunnyside Coal Project (Sunnyside). Sunnyside is operated by Namoi Mining Pty Ltd (NMPL), a subsidiary company of Whitehaven Coal Limited. Mining operations at Sunnyside were suspended in late November 2012 and recommenced in late 2017. This document considers the area of land corresponding to the project site boundary for Sunnyside, referred to as the “mine site”.

As illustrated in Figure 1, Sunnyside is located approximately 15km west of Gunnedah. The project layout is shown in Figure 2.



LEGEND
- National Park
- Nature Reserve
- State Conservation Area
- Aboriginal Area
- NSW State Forest
- Local Government Area Boundary
- Mining Lease Boundary
- Mine Site
- Mine Project

Source: Geoscience Australia (2006); NSW Department of Premier and Cabinet, Office of Environment and Heritage (2011) and Minerals NSW (2012)

WHITEHAVEN COAL
SUNNYSIDE COAL MINE
Regional Location

Figure 1 – Regional Location

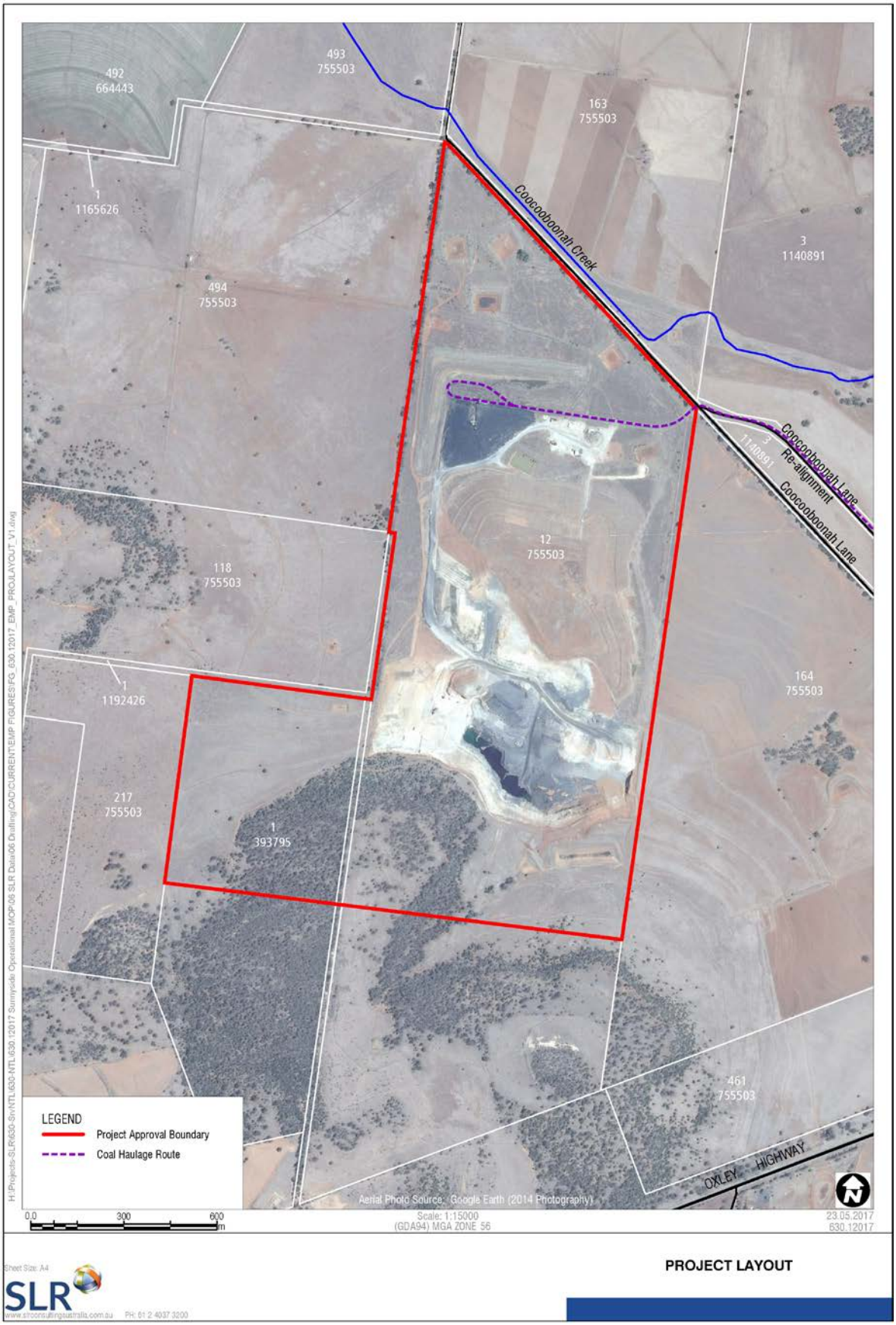


Figure 2 - Project Layout

2 BLASTING CRITERIA

The airblast overpressure and ground vibration blasting criteria, as per Conditions 3(10) and 3(11) of PA 06_0308, is detailed in Table 1.

Table 1 - Blasting Criteria

Location	Airblast overpressure (dB(Lin Peak))	Ground vibration (mm/s)	Allowable exceedance
Residence on privately-owned land	115	5	5% of the total number of blasts in a 12 month period
	120	10	0%

However, these criteria do not apply if Sunnyside has a written agreement with the relevant landowner to exceed the criteria, and has advised the Department in writing of the terms of this agreement.

3 BLASTING CONTROLS AND MANAGEMENT MEASURES

3.1 Blasting Hours and Frequency

In accordance with Condition 3(12) of PA 06_0308, blasting will be carried out between 10am and 5pm each Monday to Friday and 10am to 2pm on Saturdays (except Public Holidays).

In accordance with Condition 3(13) of PA 06_0308, there will be no more than:

- 2 blasts a day; and
- 5 blasts a week, averaged over any 12 month period.

3.2 Blast Design

Whitehaven will implement best practice blast design to manage potential blasting impacts associated with the project to:

a. protect the safety of people and livestock in the surrounding area;

b. protect public or private infrastructure/property in the surrounding area from any damage; and

c. minimise the dust and fume emissions from any blasting.

In order to minimise airblast overpressure impacts blasting will utilise appropriate stemming material and will be conducted before the establishment and after break up of low level atmospheric temperature inversions, where practicable. Ground vibration will be controlled by appropriate design.

The following blast design controls are used to minimise impacts:

- Blast design and implementation will be undertaken by suitably qualified personnel and/or experienced and appropriately certified shot-firer.
- Blast design will continue to include the following features to ensure industry standards are met:

  - Ensuring that burden distances and stemming lengths are such that explosion gases are almost completely without energy by the time they emerge into the atmosphere; and

  - Ensuring that charges consistently detonate in carefully designed sequences.

- Whitehaven will continue to analyse meteorological conditions prior to blasting to avoid times when the potential for impact is heightened, and also endeavour to blast at around midday over the winter period to avoid temperature inversions.
- Blasts will be postponed when wind speeds are greater than 7m/s in any direction unless the blast is required to be fired for safety reasons or to avoid more detrimental impacts that may result from the blast being delayed. Blasting under any weather condition is at the discretion of the Operations Superintendent.

Further to above, all blast design will be undertaken in accordance with internal blast planning design and record keeping procedures.

3.3 Air Vibrations (Overpressure)

Noise (the audible part of the air vibration spectrum) and airblast (the remaining sub-audible part of the air vibration spectrum) generation can be controlled by ensuring that all, or nearly all, of the explosion energy is consumed in fragmenting and displacing the overburden by the time the gases vent (via the broken burden rock and/or ejected stemming material) into the atmosphere.

This objective is met by ensuring that:

- Blasthole spacing is implemented in accordance with blast design;
- The burden distance and stemming length are in accordance with blast design;
- Appropriate quality materials are used for stemming;
- Charges detonate in the correct sequence and with inter-row delays that provide good progressive release of burden.
- The maximum weight of explosive detonated in a given delay period (the MIC) is limited to conservative and proven levels; and
- Refining these controls on the basis of the blast monitoring program.

3.4 Ground Vibrations

When a confined explosive charge detonates, a fraction of the liberated energy is manifested as seismic energy (ie. as ground vibrations). The magnitude of ground vibrations depends upon:

- The MIC for the blast;
- The distance between the blast and a residence or sensitive structure; and
- The characteristics of the intervening material (rock, soils, geological structures, etc) through which the ground vibration wave propagates.

Ground vibration is controlled by ensuring:

- The minimum practicable weight of explosive detonates at an instant (ie. minimising the MIC) by using the number of delay periods in each blast in accordance with blast design; and
- Most of the energy liberated by the charge(s) on a given delay number is consumed in providing good fragmentation, adequate displacement and/or a loose, highly dig-able muckpile, rather than in creating ground vibrations (ie. by ensuring that the burden distance and effective sub-drilling are not too large).

3.5 Fume and Other Post-Blast Emissions

Management of post blast fume is undertaken in accordance with Appendix 1.

3.6 Public Roads and Non-Project Land

No blasting will occur within 500m of public roads.

As blasting will occur within 500m of land that is not owned by Whitehaven Coal or its subsidiaries, the requirements of Condition 3(17A) of PA 06_0308 will be met prior to blasting occurring.

3.7 Archaeological Impacts From Blasting

The axe grinding groove is covered with rubber matting to prevent any possible flyrock damage. Additionally, when within 150m to 210m of the axe grinding groove site the Maximum Instantaneous Charge of the blast will not exceed 960kg.

4 INSPECTIONS AND NOTIFICATIONS

4.1 Pre-Blasting Inspections

Property inspections will be offered in accordance with Condition 3(14) of PA 06_0308 and undertaken in accordance with Condition 3(15).

4.2 Blasting Notification

Blast notifications will occur by the following means:

- Signage at the front entrance which is updated at least 24 hours prior to each blast
- Direct notification to individuals who have requested notification.

5 MONITORING AND REPORTING

5.1 Monitoring Program

5.1.1 Parameters Measured and Monitoring Frequency

Monitoring for the parameters specified in Table 2 must be undertaken for each blast.

Table 2 - Monitoring Parameters

Parameter	Units of Measure	Frequency
Airblast Overpressure	DB(Lin Peak)	Every Blast
Ground Vibration	mm/s	Every Blast

5.1.2 Monitoring Locations

Monitoring is to be conducted at the residences listed in Table 3 and shown in Figure 3. The locations presented in Table 3 are used to determine compliance as representative locations of receive impact and irrespective of land ownership.

Table 3 – Blast Monitoring Locations

Property
Innisvale
Ivanhoe
Illili
Plainview
Ferndale

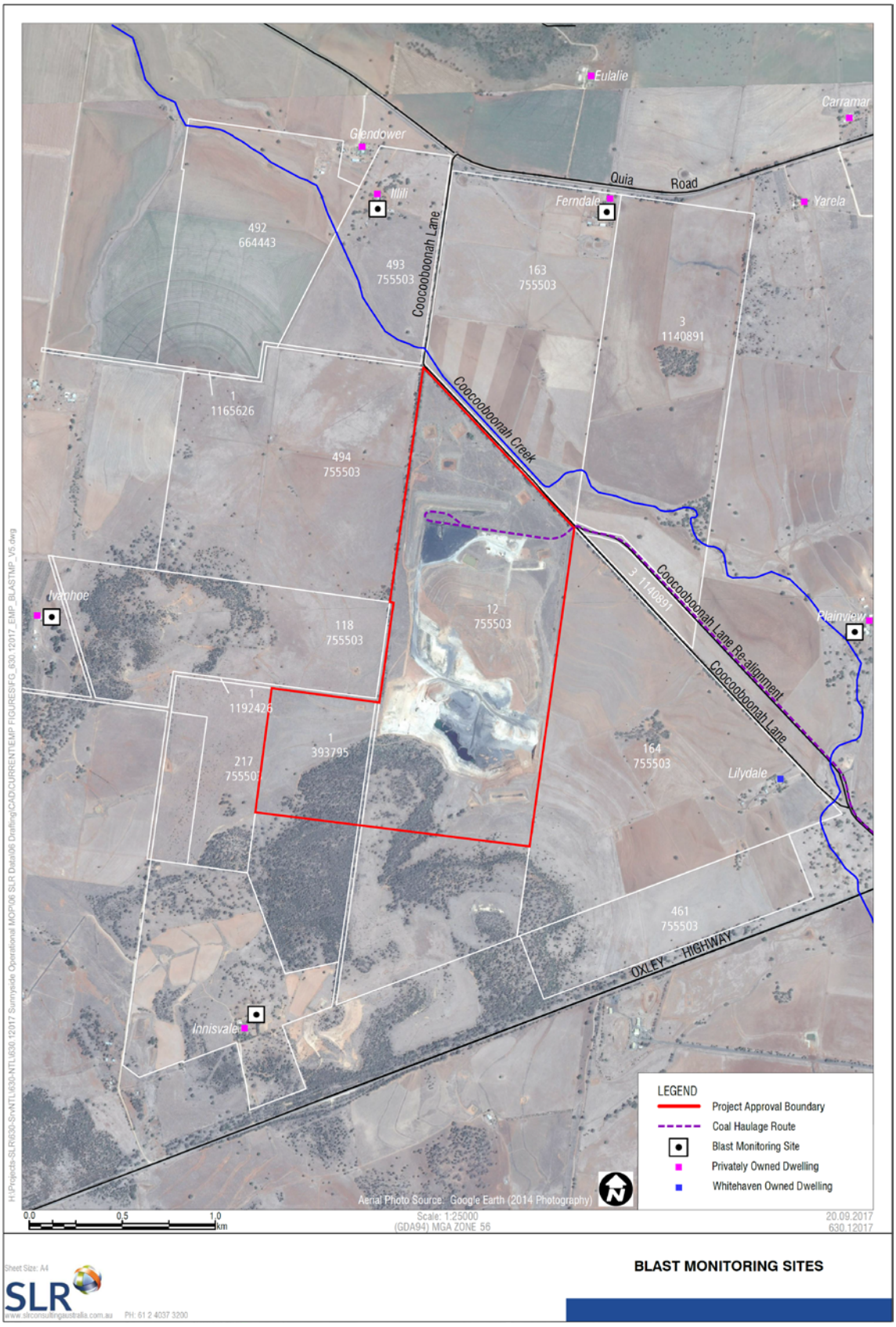


Figure 3 - Blast Monitoring Locations

5.2 Property Investigations

In accordance with Condition 3(16) of PA 06_0308, if any landowner within 2km of proposed blasting activities, or any other landowner nominated by the Secretary, claims that his/her property, including vibration-sensitive infrastructure such as water supply or underground irrigation mains, has been damaged as a result of blasting at Sunnyside, Whitehaven shall within 3 months of receiving this request:

(a) commission a suitably qualified person whose appointment has been approved by the Secretary to investigate the claim and prepare a property investigation report; and
(b) give the landholder a copy of the report.

If this independent investigation confirms the landowner's claim, and both parties agree with these findings, then Whitehaven shall repair the damage to the satisfaction of the Secretary.

If Whitehaven or the landholder disagrees with the findings of the independent property investigation, then either party may refer the matter to the Secretary for resolution.

5.3 Reporting

Incident reporting will be undertaken in accordance with Conditions 5(3) and 5(4) of PA 06_0308.

A review of blast monitoring will be included in the Annual Review, in accordance with the requirements of Condition 5(5) of PA 06_0308.

6 DOCUMENT REVIEW

This document will be reviewed in accordance with the requirements of Condition 5(5A) of PA 06_0308.

Appendix 1 - Blast Fume Management Procedure

WHITEHAVEN COAL

SUNNYSIDE COAL PROJECT BLAST FUME MANAGEMENT PROCEDURE

Approval	Name	Position	Signed	Date
Document Owner:	Graham Cope	Drill & Blast Manager		26/5/17
Authorised by:	Nigel Wood	General Manager – Open Cut Operations		26/5/2017

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1. SCOPE

This procedure outlines the specific blast fume management actions to be implemented at the Sunnyside Coal Project (Sunnyside) in line with the strategies outlined in the Australian Explosives Industry and Safety Group (AEISG) Code of Practice – Prevention and Management of Blast Generated NOx Gases in Surface Blasting (2011).

The procedure applies to the Project Area and all personnel involved in the purchasing of explosives, blast design, drilling, loading and firing of explosives.

2. BACKGROUND

Blasting fumes are comprised of a group of gases known as Oxides of Nitrogen or NOx, a combination of post blast gases which are predominantly nitrogen dioxide, but may also include small amounts of nitrous oxide, nitric oxide, carbon monoxide and carbon dioxide. The two main gases, nitric oxide (NO) and nitrogen dioxide (NO2) are found as by-products in the post-blast gases of ammonium nitrate-based explosives, and are generated in greater quantities where incomplete or low-order detonation occurs. Nitric oxide is colourless, but nitrogen dioxide ranges in colour from yellow to dark red / purple depending on the concentration and size of the gas cloud.

Fume generation can be attributed to a number of primary causes that, either singularly or combined, can be managed to minimise or mitigate the production of NOx. These causes are discussed in detail in the AEISG Code of Practice, and are listed below:-.

1. Explosive formulation and quality assurance
2. Geological conditions
3. Blast design
4. Explosive product selection
5. On bench practices
6. Contamination of explosive in the blast hole

Blasting fumes can be harmful to humans if inhaled in sufficient quantities and/or over a prolonged period of time. These fumes can pose a risk to members of the blast crew and sentries in close proximity, or other mine workers exposed in the event that fumes travel outside the immediate blast clearance area without dispersing. Risks to persons outside the mining area also need to be addressed in the event that large fume clouds travel outside the mine lease on to private or public land.

3. RESPONSIBILITIES

Role accountabilities for management of the six AEISG primary causes of fume are provided in detail in Appendix 5.1 and summarised in Table 1.

Table 1 - Role Responsibilities

Primary Cause of Blast Fume	Accountable Roles for Management
Cause 1: Explosive formulation and quality assurance	• Explosives supplier • Drill and blast engineer • Shotfirer • Magazine keeper
Cause 2: Geological conditions	• Mine geologist • Drill and blast engineer • Shotfirer • Drill operators
Cause 3: Blast design	• Shotfirer • Drill and blast engineer
Cause 4: Explosive product selection	• Shotfirer • Drill and blast engineer
Cause 5: On bench practices	• Drill operator • Shotfirer • MMU operator • Drill and blast engineer • Drill supervisor
Cause 6: Contamination of explosives in the blast hole	• Drill operator • Shotfirer • MMU operator • Drill and blast engineer

4. PROCEDURE

4.1 BLAST DESIGN AND PLANNING

Design

Blast designs will be developed to consider:

- Geological constraints such as weak or hard bands of overburden, coal bands and faults.
- Blast performance requirements in terms of fragmentation, heave, dig rates, etc.
- Control of potential blast impacts including flyrock, fume, overpressure, vibration etc.

Blasts design mitigations may include:

- Reducing bench heights or ensuring adequate relief in deep holes.
- Selecting explosives products appropriate to the blast design and ground conditions.
- Following manufacturer's recommendations for priming, timing and sleep time of bulk explosives.
- Increasing the level of control and QA/QC checks on deeper shots.
- Providing appropriate separation of blast holes and explosive decks.
- Reducing the powder factor or modifying the timing, depth or size of a blast.

Geology

Where clay or other unfavourable geological conditions are identified, explosive product selection will be modified to suit conditions. When blasting in soft ground, or areas with a history of producing blast fume, increased blast clearance may also be required to ensure the safety of personnel.

Sleep Time

All blasts will be designed and planned to be fired within 5 days of first being loaded. Approval from the Operations Superintendent is needed for shots requiring longer sleep times up to a maximum of 7 days. The prevailing and forecast weather conditions as well as the Fume Risk rating and manufacturers recommendations will be taken into account when planning the required blast sleep time.

Explosive Selection

The following Table 2 and text define the relative risk levels of fume generation at Sunnyside and explosive product selection guidelines.

Table 2 - Blasting Areas at Sunnyside

STRATA	GROUND CONDITION	FUME RISK
Clay / Weathered conglomerate, Sandstone, Siltstone.	Orange brown, pebbly, unconsolidated weathered. Dark grey moderately hard.	Moderate
Dawson Seam		
Sandstone/ Siltstone	Dark grey moderately hard	Low
Rider Seam		
Sandstone/ Siltstone	Dark grey moderately hard	Low
Hoskisson Seam		

Indicative explosive products typically used for the Sunnyside ground conditions include:

Clayey/Weathered – ANFO, XLOAD 60-90, XLOAD 60-100, HiDEX 10, HiDEX 20

Wet - Generic Pumped Emulsion XLOAD 70-120

Dry – ANFO, XL90, XL100, HiDEX 10, 20, 25

Sunnyside typically uses generic products where the geology has a low fume risk, however hybrid explosives will be used for blasts where there is a higher risk of fume.

XLOAD explosive product range numbering indicates the product density (i.e. XLOAD100 = 1.0g/cm^3) while Pumped Emulsion product range numbering indicates percentage emulsion (i.e. XLOAD 70 = 70% Emulsion).

Hanwha Mining Services, who supply and load down hole explosives at Sunnyside, have auger/hose explosive trucks (MPU) and implement a QA system to test and confirm the specification of the bulk explosive formulations used.

Technical and Safety Data Sheets of all products used are maintained on site.

4.2. METEOROLOGICAL CONDITIONS

- Before each blast, weather conditions will be assessed by the site Environmental Officer, or alternate, in accordance with the Environmental Blast Checklist. Shots will not be fired during adverse weather conditions, unless for safety reasons, or to minimise further deterioration of the product due to extended sleep time.
- Any shot that is fired during adverse weather conditions must be approved by the Operations Superintendent.
- Relevant parameters for consideration prior to firing a shot will be:
  - Wind speed and direction
  - The presence of a temperature inversion
  - Low continuous cloud cover
- The assessment of weather conditions will use meteorological data in the form of real-time wind speed and direction.
- When wet weather is forecast prior to or during loading of shots, product selection will be adjusted to suit as required.
- If there is a risk of blast fume, the Shotfirer must extend the blast danger zone to allow for the safety of all personnel. This is particularly important if a shot has had an extended sleep time, where water intrusion may have affected the bulk explosive, and when firing misfires.
- The site plan will have with blast clearance zones identified. Potentially sensitive locations, will be considered when firing blasts, particularly where the risk of significant post-blast fume generation has been identified.
- Main Pit Blasting – If inversion conditions are detected or wind speeds are greater than 8m/s, blasting may be delayed if it is considered these conditions pose a risk to environmental compliance, until more favourable weather conditions are encountered.

4.3. BLAST MONITORING & FUME RATING

For each blast the following monitoring will be carried out:

1. Fixed monitors – measures the peak blast overpressure (dBL) and peak ground vibration (mm/s). Portable blast monitors will be used if the fixed monitors are inoperable.
2. A video record of every blast fired will record the shot initiating, blast movement and post blast fume generation. This will then be reviewed to assist in improving future blasting performance and to further minimise blast fumes, flyrock or vibrations.
3. All blasts will be rated for fume levels on a scale between 0 - 5, based on the AEISG CODE (Appendix 5.2). In the event that a blast produces fume that rates a 3, an Internal ICAM investigation will take place. If the fume leaves site or is rated at 4 or 5, notification will be provided in accordance with 5(3) of PA 06_0308.
4. An Environmental Blast Checklist will be used for each blast. This includes a notification checklist; pre-blast weather conditions and fume assessment prior to and at the time of the blast (commencing at 5 hours prior to the blast); and a post-blast assessment which includes fume rating.

4.4. BLASTING WITHIN 500M OF A PUBLIC ROAD OR PROPERTY

- No blasting will occur within 500m of a public road.
- Blasting within 500m of land not owned by Whitehaven will be undertaken in accordance with Condition 3(17A) of PA 06_0308.
- On request, residents or tenants will be notified of the planned blasting date and time and any updates to the date and time. Notification will also be made via a sign at the front entrance of the site.
- Should an unexpected fume cloud occur, neighbouring properties in line with the fume cloud will be notified in accordance with the site Pollution Incident Response Management Plan (PIRMP), and if necessary evacuated.

4.5. BLAST EXCLUSION ZONES AND TIMING

- Establishment of exclusion zones and the time of blasts will be conducted in accordance with the WHC PRO – OC – Blast Clearance and Firing.
- In accordance with Condition 3(12) of PA 06_0308, blasting will be carried out between 10am and 5pm each Monday to Friday and 10am to 2pm on Saturdays (except Public Holidays).
- In accordance with Condition 3(13) of PA 06_0308, there will be no more than:
  - 2 blasts a day; and
  - 5 blasts a week, averaged over any 12 month period.

4.6. TECHNICAL AND SAFETY DATA SHEETS

- Copies of all relevant Technical and Safety Data sheets shall be supplied to the Drill and Blast Engineer and Shotfirers by the Explosives Manufacturer. Copies will be kept on site for reference.
- The type of explosive product used for individual blasts will be selected to minimise the potential for fume generation.

4.7. INCIDENT AND HAZARD MANAGEMENT

- Blast fume incidents will be managed in accordance with the WHC-STD-Incident and Hazard Management which provides a generic process that is to be followed for all health, environment and safety incidents that may occur at WHC.
- In the event of NOx exposure (or suspected exposure) medical assistance should be engaged, and the Medical Advice from the AEISG COP (Appendix 5.3) provided to medical personnel.
- The basic precautions are:
  - No personnel will enter the fume.
  - Personnel will move away from the path of the fume.
  - If indoors and the fume is heading towards you, close all windows and doors and stay inside.
  - If in a vehicle, wind up windows, close doors, stay inside vehicle and use recirculated air conditioning if possible.

- Those exposed to NOx gases should seek immediate medical treatment and consideration should be given to placing those exposed under observation for at least 24 hours after exposure.

4.8. INVESTIGATION – POST FUME INCIDENT

- Should an excessive blast fume (level 3 or higher that is not localised) be generated from a blast, a fault tree (refer to Figure 1 below) will be used during the ICAM incident investigation to identify contributing factors that caused the excessive blast fume.
- Once the contributing factors have been identified, an appropriate action plan will be developed to mitigate and reduce the generation of fume from future blasts.

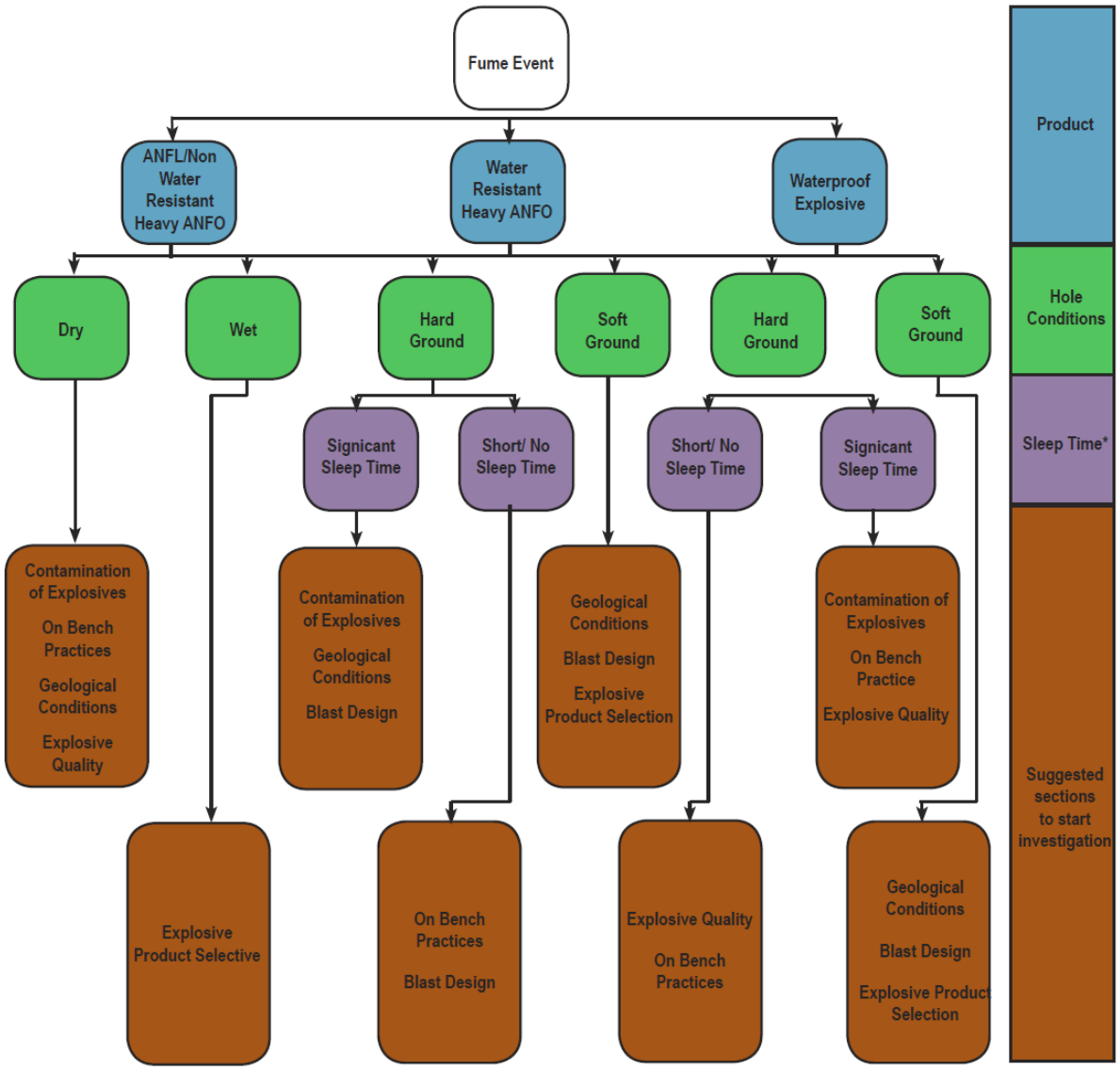

Figure 1 Fault Tree (Source: AEISG, 2011)

4.9. REPORTING

Blast fume reporting includes:-

- All blast fume events (Level 1 and above) are reported internally as Environmental Incidents;
- Significant blast fume events Level 3 and above are investigated using the ICAM incident investigation method;
- Blast fume events Level 3 that leave the mine site or Level 4 & 5 fume events are to be reported as detailed in Section 4.3; and
- All blast fume events leaving the mine site boundary require consideration of the site's PIRMP regulatory/emergency and community notification protocols.

4.10. EDUCATION AND TRAINING

- All employees will have a general blast fume awareness session delivered through the site induction program.
- Additional education and awareness programs will be provided for relevant personnel, as required.

5. APPENDICES

5.1. NOX GASES CAUSES AND CONTROL MATRIX

Cause 1: Explosive formulation and quality assurance			
Potential Cause	Likely Indicators	Possible Control Measures	Responsibilities
Explosive product incorrectly formulated	Abnormal product appearance, poor blast performance, fume generation. Incorrect test results.	Explosives formulated to an appropriate oxygen balance to minimise the likelihood of post-blast fume. Explosives supplier to test and provide QA reports for formulations where any change in ingredients. Explosives/Precursor supplier to provide relevant Technical Data Sheets and Manufacturing directions.	Explosive Supplier Shotfirer
Precursor delivered to mine site out of specification	Traceable to a precursor which has degraded between manufacture and use. Poor blast Performance	Investigate with supplier of explosive precursors. Precursor supplier to provide relevant Technical Data Sheets and Manufacturing directions.	Explosive Supplier

Inadequate mixing of raw materials	NOx emitted from blast holes loaded from a specific delivery system. Product appearance abnormal	Visual check. Density check. Ensure compliance with supplier's / manufacturer's instructions. Explosive supplier to provide QA reports on testing	Explosive Supplier Shotfirer
Product past use by date	Difficulty achieving final density. Separation Crystallising Fines Colour variation Poor blast performance	Once per truck to ensure the product is within the manufacturers specification i.e. pH, density, viscosity	Explosive Supplier D&B Engineer Magazine Keeper
Failure to conduct quality tests	Incomplete documentation/ practices	Conduct observations per shot and/or audits quarterly to ensure compliance with procedures. All blast crew to be trained in the potential consequences of failing to ensure the characteristics of the product loaded.	D&B Engineer
Cause 2: Geological conditions			
Potential Cause	Likely Indicators	Possible Control Measures	Responsibilities
Lack of relief in weak/soft strata. Inadequate confinement.	Recording areas of weak/soft strata. Fume generation Sympathetic detonation Flyrock	Understand geology of each shot and design blast (timing and explosive product) to ensure adequate relief. Minimise blast size and depth. Appropriate explosives product selection. Change design to suit conditions.	Mine Geologist D&B Engineer
Dynamic water in holes	Preceded by the observation of slumped blast holes. Usually when using non	Minimise or eliminate sleep time of shot. Measure recharge rates if dewatering, and choose explosive products according to	Shotfirer D&B Engineer Geologist

	water-resistant explosive products Loss of product whilst loading blast hole.	manufacturer's Technical Data Sheets. Record slumped holes and use this information to build understanding of pit hydrology. Selection of appropriate explosives product	
Explosive product seeping into cracks	Slumping Not achieving collar height during loading Poor reconciliation between design and loaded explosives volumes	Maintenance of accurate drill records which are used to map geological conditions. Record and monitor blast holes which are slumped or require excessive explosive product to reach stemming height, but where water is not present.	Drill Operators Shotfirer D&B Engineer
Moisture in clay	Fume Incorrect explosive	Consider water resistant explosive products, blast hole liners and how this may impact sleep time.	D&B Engineer Geologist
Blast hole wall deterioration between drilling and loading e.g. cracks, voids, hole contraction	Traceable to specific geological areas Poor drill and load reconciliation	Employing different drill techniques for soft ground Minimise time between drilling and loading. Use hole savers/water while drilling. Ensure benches are unaffected by back-break from earlier blasts e.g. pre-splits.	Drill Operators D&B Engineer
Cause 3: Blast Design			
Potential Cause	Likely Indicators	Possible Control Measures	Responsibilities
Intra-hole explosive desensitisation in decked blast holes	Fume When using decks only, inconsistent blast performance	Appropriate separation of explosive decks. Initiator timing.	D&B Engineer Shotfirer
Explosive desensitisation due to the blast hole depth	Fume Poor blast performance Poor dig rates	Reduce bench height. Ensure adequate relief in deep holes. Follow manufacturer's Technical Data Sheets on explosive product selection and blast	D&B Engineer

		design for deep holes i.e. decking where appropriate.	
Inappropriate priming and/or placement	Residue product Inconsistent blast performance Misfire	Follow manufacturer's Technical Data Sheets on explosive product initiation.	D&B Engineer Shotfirer
Excessive confinement (Incorrect Timing and Pattern Design)	Fume Specific to blasts known to be confined Poor dig rates No free face present Excessive powder factor	Understand geology of each shot and design blast (timing and explosive product) to ensure adequate relief in all strata. Consider incorporation of a free face, reduction of powder factor, modified timing, depth of blast.	D&B Engineer
Desensitisation of explosive column from in-hole detonating cord initiation	Fume Inconsistent blast performance Only in areas where in-hole cord initiation is used	Follow manufacturer's Technical Data Sheets on compatibility of initiating systems with explosives.	D&B Engineer Shotfirer
Primer of insufficient strength to initiate explosive column	Poor blast performance All blasts using a particular primer type/ size	Follow manufacturer's Technical Data Sheets on compatibility of initiating systems with explosives.	D&B Engineer
Failure to identify potential causes of fume generation	Limited experience designers Inadequate analysis or records	Follow WHC_PRO_OC_BLAST PLANNING, DESIGN & RECORD KEEPING.	D&B Engineer
Excessive energy in weak/ soft strata desensitising adjacent explosive product columns	Fume In specific areas known to contain weak/soft strata	Understand geology of each shot and design blast (timing and explosive product) to match, e.g. reduction of powder factor.	D&B Engineer Geologist
Cause 4: Explosive Product Selection			
Potential Cause	Likely Indicators	Possible Control Measures	Responsibilities

Explosives product selected not suitable for the prevailing ground conditions (water, rock mass strength)	Fume Poor blast performance	Follow manufacturers Technical Data Sheets on explosive product application. Review of the site design records/ results for previous blasts in similar strata.	D&B Engineer Shotfirer
Non water-resistant explosive products loaded into wet or dewatered holes	Fume Poor blast performance	Follow manufacturer's Technical Data Sheets on explosive product selection. Regular education of shot crew on explosive products from supplier. Discipline in on-bench practices. Weather forecasts to be obtained and considered.	Shotfirer D&B Engineer
Cause 5: On Bench Practices			
Potential Cause	Likely Indicators	Possible Control Measures	Responsibilities
Inter-hole explosive desensitisation	Fume Blast holes drilled too close together. Blast hole deviation Inconsistent blast performance	Reduce bench height or ensure adequate relief in deep holes. Product selection. Initiation/timing Increased control on deeper designs/ GPS drilling assist Review product selection, adjusting for actual drilling.	Drill Operator D&B Engineer Shotfirer
Hole condition incorrectly identified	Slumping of holes Unexpected material in drill cuttings	Dip all holes prior to loading. Record wet, dewatered and dry holes on blast plan and use this information as a basis for explosive product selection. Minimise time between drilling and loading, especially in soft and clay strata. Note: Enough time should be allowed for any dynamic water in the hole to be identified. Minimise sleep time. Training/competence of blast crew.	Shotfirer

Blast not drilled as per plan	Can be correlated with inaccurately drilled patterns	Maintenance of accurate drilling records and their review with amendment of blast design if required to compensate for inaccuracies. Record checks by engineer and Shotfirer	Drill Supervisor D&B Engineer Shotfirer
Inadequate mixing of raw materials	Frequent NOx fume in all areas associated with loading from a specific delivery system Product appearance abnormal	Visual check Density check	Shotfirer MMU Operator
Poor bench preparation not allowing for water run-off.	Pooling of water Hole collars show effects of water damage	Ensure all loose material removed. Cut drains where required. Adequate inspection required prior to handing area over to drill team.	Drill Supervisor
Dewatering of holes diverts water into holes previously loaded with dry hole explosive products	Only when using non water-resistant explosive products Fume generation	Adjust explosive product selection according to manufacturer's Technical Data Sheet advice. Bench cleaned up for effective water run-off. Training/competence of blast crew. Location of dry hole explosive products considered in dewatering discharge locations	Shotfirer
Rainfall on a sleeping shot.	Slumping of holes Poor blast performance	Review rainfall forecasts for planned sleep time of a shot and select explosive products according to the maximum sleep time by the specifications details on the Technical Data Sheets (TDS) for each explosive product. Minimise sleep time for dry blast hole explosive products if rain is predicted.	Shotfirer Drill Supervisor

		Ensure bench cleaned up for water runoff as per drill prep procedure. Seal top of blast holes to prevent water ingress e.g. with gas bags. Consider removing water affected product. Consider early firing of blast.	
Blast not loaded as per blast plan	Not achieving collar height during loading Poor reconciliation between design and loaded explosives volumes	Training/competence of blast crew. Effective supervision. Communication of loading requirements. Record actual loadings e.g. product, quantity, height.	Shotfirer D&B Engineer
Blast hole deterioration between drilling and loading	Fume Inconsistent column rise while loading Poor drainage Traceable to specific geological areas	Minimise time between drilling and loading. Use hole savers. Optimise drilling practices to minimise hole damage though rock cracking etc. Where practicable design blast to minimise impact to next bench.	Drill Operator D&B Engineer Shotfirer
Cause 6: Contamination of explosive in the blast hole			
Potential Cause	Likely Indicators	Possible Control Measures	Responsibilities
Explosive product mixes with mud/ sediment at bottom of hole.	Water/mud identified in hole Blasts containing wet/dewatered blast holes only	Optimise drilling practices to minimise blast hole damage. Ensure appropriate loading practices are followed during charging. Ensure primer is positioned in undiluted or contaminated explosive product. Insert gas bag to separate mud/ sediment from explosive product. Use blast hole savers	Drill Operator Shotfirer MMU Operator

		Use end of loading hose dispersers to minimise contamination. Decking to eliminate contact with known dynamic water. Verify correct hose handling practices are in place. Use suitable, safe dewatering techniques. Training/competence of blast crew.	
Penetration of stemming material into top of explosive column (fluid/ pumpable explosive products only)	Fume Increased stemming usage Blasts charged with fluid/ pumpable explosive products only	Use appropriate stemming material. Seal top of explosives column prior to stemming e.g. gas bag.	Shotfirer MMU Operator
Moisture in ground damaging explosive product	Wet ground occurrence Fume generation Consistent level of surrounding groundwater	Explosives product selection. Use hole liners where product not water resistant. Load wet holes first and dip remaining holes prior to loading. Adjust explosive product selection according to manufacturer's Technical Data Sheets.	Shotfirer MMU Operator D&B Engineer
Contamination of explosives column by drill cuttings during loading	Hole collars not consistent size Inside of hole collars show disturbance Column rise varied from design	Verify correct hose handling practices are in place e.g. operator competence, procedures, use explosives supplier's personnel. Training/competence of blast crew. Minimise vehicle contact near blast holes. Use hole savers.	Drill Operator Shotfirer MMU Operator

5.2. FUME RATING SYSTEM

Level	Typical Appearance
Level 0 No NOx gas	
Level 1 Slight NOx gas	
1A Localised	
1B Medium	
1C Extensive	
Level 2 Minor yellow/orange gas	
2A Localised	
2B Medium	
2C Extensive	
Level 3 Orange gas	
3A Localised	
3B Medium	
3C Extensive	
Level 4 Orange/red gas	
4A Localised	
4B Medium	
4C Extensive	
Level 5 Red/purple gas	
5A Localised	
5B Medium	
5C Extensive	

(Source: AEISG, 2011)

Assessing the amount of NOx gases produced from a blast will depend on the distance the observer is from the blast and the prevailing weather conditions. The intensity of the NOx

gases produced in a blast should be measured on a simple scale from 0 to 5 based on the table above. The extent of the NOx gases also needs to be assessed and this should be done on a simple scale from A to C where:

A = Localised (i.e. NOx gases localised across only a few blast holes)

B = Medium (i.e. NOx gases from up to 50% of blast holes in the shot)

C = Extensive (i.e. extensive generation of NOx gases across the whole blast).

Level	Colour	Pantone Number
Level 0 No NOx gas		Warm Grey 1C (RGB 244, 222, 217)
Level 1 Slight NOx gas		Pantone 155C (RGB 244, 219, 170)
Level 2 Minor yellow/orange gas		Pantone 157C (RGB 237, 160, 79)
Level 3 Orange gas		Pantone 158C (RGB 232, 117, 17)
Level 4 Orange/red gas		Pantone 1525C (RGB 181, 84, 0)
Level 5 Red/purple gases		Pantone 161C (RGB 99, 58, 17)

5.3. MEDICAL ADVICE

Advice to Medical Staff

in the Treatment of Those Who Have Been Exposed to NOx Gases.

The patient may have been exposed to NOx. This is a gas usually produced on mines after the use of explosives. NOx consists of multiple combinations of nitrogen and oxygen (N_2O, NO, NO_2, N_2O_4, N_2O_3, N_2O_5). Nitrogen dioxide (NO_2) is the principle hazardous nitrous gas. NOx irritates the eyes and mucous membranes primarily by dissolving on contact with moisture and forming a mixture of nitric and nitrous acids. But this is not the only mechanism by which injury may occur. Inhalation results in both respiratory tract irritation and pulmonary oedema. High level exposure can cause methhaemoglobinaemia. Some people, particularly asthmatics, can experience significant broncospasm at very low concentrations.

The following effects are commonly encountered after NOx exposure:

ACUTE

- Cough
- Shortness of breath
- Irritations of the mucous membranes of the eyes, nose and throat

SHORT TERM

- Pulmonary oedema which may be delayed for up to 4-12 hours

MEDIUM TERM

- R.A.D.S. (Reactive Airways Dysfunction Syndrome
- In rare cases bronchiolitis obliterans which may take from 2-6 weeks to appear

LONG TERM

- Chronic respiratory insufficiency

High level exposure particularly associated with methhaemoglobinaemia can cause chest pain, cyanosis, and shortness of breath, tachapnea, and tachycardia. Deaths have been reported after exposure and are usually delayed. Even non irritant concentrations of NOx may cause pulmonary oedema. Symptoms of pulmonary oedema often don't become manifest until a few hours after exposure and are aggravated by physical effort. Prior to transfer to you the patient should have been advised to rest and if any respiratory symptoms were present should have been administered oxygen. The patient will need to be treated symptomatically but as a base line it is suggested that the following investigations are required:

- Spirometry
- Chest x-ray
- Methheamoglobin estimation

Because of the risk of delayed onset pulmonary edema it is recommended that as a precaution the patient be observed for up to 12 hours. As no specific antidote for NOx exists, symptoms will have to be treated on their merits.

6. DEFINITIONS

Adverse Weather	Includes rainfall, lightening, low continuous cloud, presence of upper class inversion, wind speeds greater than 8m/s
Dewatered hole	Wet hole removed of water with no water recharge
Dry hole	Hole identified as being dry in the bottom and no wet or damp sides
Wet hole	Hole identified as containing free water
Wet weather	>20mm rainfall

7. REFERENCES

- AEISG Code of Practice – Prevention and Management of Blast Generated NOx Gases in Surface Blasting, 2011
- Australian Standard AS2187 Part 2-2006, Use of Explosives
- WHC-PLN-OC-Explosives Control Plan
- WHC-PLN-SUN-Blast Management Plan
- WHC-PRO-OC-Loading and Stemming Blast Holes
- WHC-PRO-OC-Tying up shots
- WHC-PRO-OC-Working in a Blast Area
- WHC-PRO-OC-Blast Clearance and Firing
- WHC-PRO-OC-Blast Planning and Record Keeping
- WHC-CHK-Blasting
- WHC-CHK-Shotfirers