BAULDERSTONE

Modification request for an extension to blasting hours, airblast overpressure and vibration limits

Pacific Highway Upgrade
Tintenbar to Ewingsdale

Client: Roads and Maritime Services (RMS)

Document Number: RPT-ENV-004

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APPROVALS	Prepared by: Kieran METCALFE Environmental Coordinator	K Metcalfe	25, 1, 13
	Reviewed by: Chris McCALLUM Environmental Manager	Chris McCall	25/ 1/ 13
	Approved by: Vince NEWTON Project Director	pp DJ Pache.	25/1/13

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Acronyms and Glossary

ANZECC	Australian and New Zealand Environment Conservation Council
AS	Australian Standard
BPL	Baulderstone Pty Ltd
CEMP	Construction Environmental Management Plan
DEC	Department of Environment and Conservation (now OEH)
DECC	Department of Environment and Climate Change (now OEH)
DECCW	Department of Environment, Climate Change and Water (now OEH)
EA	Environmental Assessment
EPA	Environment Protection Authority
EPL	Environment Protection Licence
ERG	Environmental Review Group
MCoA	Minister's Conditions of Approval
MPa	Megapascal
NSW	New South Wales
NVMSP	Noise and Vibration Management Sub-Plan
NVIA	Noise and Vibration Impact Assessment
PPV	Peak Particle Velocity
RMS	Roads and Maritime Services
SoC	Statement of Commitment
SWTC	Scope of Work Technical Criteria
OEH	Office of Environment and Heritage
TCC	Tunnel Control Centre

EXECUTIVE SUMMARY

RMS is seeking formal approval from the Department of Planning and Infrastructure to modify the Project Approval for the Pacific Highway Upgrade - Tintenbar to Ewingsdale Project under section 75W of Part 3A of the *Environmental Planning and Assessment Act 1979* (the Act). This report has been prepared to support the request for approval for an extension of approved blasting hours and an increase in airblast overpressure and blasting vibration limits associated with the tunnel works at St Helena Hill.

The subject modification would result in various positive impacts to external stakeholders such as nearby residences, commuters, Local, State and Federal Government. These positive impacts are attributable to the changes in excavation methodology that can be achieved with the proposed modifications. These positive impacts include, but are not limited to:

- A reduction in the total noise impact of the St Helena tunnelling works from reduced drilling and rock breaking,
- Improved traffic conditions due to fewer road closures from blasting and a reduced period during which construction traffic is operating in the area;
- A reduction in the total number of blasting events.

The expected reduction of these activities over the entire St Helena tunnelling works is summarised below:

- 80 per cent reduction in the volume of rock requiring breakage by hydraulic hammers at the Tunnel Control Centre (TCC). This corresponds to 20 fewer days during which hammering is being undertaken for the TCC excavation,
- Approximately three week's reduction in total construction time for the excavation of the TCC. This would correspond to a 25 per cent reduction in the original programme of 12 weeks,
- 40 per cent reduction in the total number of blasts,
- An approximate eight day reduction in the construction time for the box cuts to 37 days from an expected 45 days,
- 32 day reduction in the construction schedule for the excavation of the tunnelling works, reducing the total construction time from approximately 210 days to 178 days.
- 15 per cent less drilling — reducing the duration of noise and vibration that residents would be exposed to.
- 50 per cent fewer rolling stoppages of the Pacific Highway reducing traffic delays.
- 50 per cent fewer closures of St Helena Road reducing traffic stoppages and delays.

Further to this, the modification of blasting hours, airblast overpressure and vibration limits would result in negligible negative impacts to the residents at St Helena Hill and on the surrounding environment. This is attributable to the proposed limits being well below those indicated in relevant standards and literature at which damage to property may occur. Compliance with required blasting limits is to be verified through the implementation of procedures contained within the Project blast management plans and post blast review procedures.

Additionally, extending the controlled blasting hours would allow delays caused by equipment failure or unforeseen geotechnical conditions to be absorbed within the work schedule. Without this time buffer, the second scheduled controlled blast of the day may need to be postponed to the next working day. In every instance, this occurrence has the potential to significantly extend the duration of the tunnel construction and overall controlled blasting program. This may result in increased impacts to external stakeholders as a result of the subject activity.

As with all construction activities, any blasting undertaken during the proposed extended hours would be planned to have minimal impact on the community, especially in terms of school bus routes and persons commuting to and from work. Specifically in relation to the proposed extension of blasting hours, it can be noted that there would be negligible overall negative impacts to the community as a result of the proposed extension of blasting hours, including any traffic impacts, as any impacts resulting from the extension would generally be no greater than the impacts subsequent to general construction activities which are permissible between 7:00am to 6:00pm, Mondays to Fridays.

With regard to potential noise, dust and vibration impacts, it can be noted that the level of impact of blasting that is proposed to take place during the extended hours has the potential to be significantly lower than that of general construction over the same period. This lower impact would be attributable to the blast event taking place over a matter of seconds during an extended break in general construction, whereas general construction and its associated impacts would be ongoing throughout the same period.

There has been extensive community consultation undertaken including consultation with residents within close proximity to the tunnelling works. This consultation demonstrates that the community is generally in favour of a reduction in the construction duration. This is reflected by the 'letters of non-objection' for extension to blasting hours, signed by 11 of the 14 affected residents and 'letters of consent' to increase vibration and airblast overpressure limits for St Helena tunnel construction, signed by all of the five affected residents regarding the modification that has been proposed.

In addition to the above letters of consent that have been received, in accordance with AS 2187.2 the proposed increased limits for vibration and overpressure would only be utilised where consent had been granted by the occupier of the potentially affected residence that the subject limits may apply. In the event that consent had not been granted by the occupier, the existing approved vibration and overpressure limits would apply to the subject residence.

Notwithstanding the above, the following mitigation measures that will be put in place to manage potential noise, vibration and overpressure impacts of the blasting works during construction:

- The implementation of the Blast Management Plan in accordance with AS 2187.2-2006 Australian Standard Explosives – Storage and Use, Part 2: Use of Explosives to formalise procedures so that blasting activities are undertaken in accordance with each blast design and necessary mitigation measures for a particular blast are put in place.
- Monitoring of airblast overpressure and vibration levels from all blasting activities. The results of this monitoring will be made available online in accordance with the Project Instrument of Approval and Environment Protection Licence.
- Careful blast design based on results from a trial blast as well as information from all subsequent blasts. This will include steps to determine if additional mitigation measures other than those relating to charge weights and blast initiation sequencing are required. These measures include placing additional fill or the use of blast mats if deemed appropriate.
- Formalised post-blast review procedures in accordance with AS 2187.2-2006 Australian standard Explosives – Storage and Use, Part 2: Use of Explosives to ensure that the design of any subsequent blasts reflects the performance of previous blasting activities.
- Using appropriate explosives such as electronic detonators in areas of particular sensitivity to ensure accurate blasthole initiation sequences.
- Livestock owners will be informed of blasting activities that have the potential to impact upon livestock.
- Additional monitoring would be undertaken to verify noise levels associated with the subject blasting as detailed within this report.
- Blast management plans in accordance with AS 2187.2-2006 Australian Standard Explosives – Storage and Use, Part 2: Use of Explosives to formalise procedures so that blasting activities are undertaken in accordance with each blast design and necessary mitigation measures for a particular blast are put in place.
- Monitoring of airblast overpressure and vibration levels from all blasting activities. These results will be made available online in accordance with the Project Instrument of Approval and Environment Protection Licence.
- Careful blast design based on results from a trial blast as well as information from subsequent blasts. This will include steps to determine if additional mitigation measures other than those relating to charge weights and blast initiation sequencing are required. These measures include placing additional fill or the use of blast mats if deemed appropriate.
- Formalised post-blast review procedures in accordance with AS 2187.2-2006 Australian standard Explosives – Storage and Use, Part 2: Use of Explosives to ensure that the design of any subsequent blasts reflects the performance of previous blasting activities.
- Using appropriate explosives such as electronic detonators in areas of particular sensitivity to ensure accurate blasthole initiation sequences.

- Flashing warning lights will be attached to vibration monitors, triggered by vibrations in excess of the maximum Peak Particle Velocity limit as prescribed by the Project Instrument of Approval and Environment Protection Licence to provide a 'real time' visual warning of vibration exceedences.
- Additional monitoring would also be undertaken to verify compliance with required vibration and overpressure levels associated with the subject blasting as detailed within this report.
- In addition to the above mitigation measures, blasting in relation to the St Helena Tunnel works would be avoided during periods of high winds where it is determined that to proceed may have the potential to result in the blast exceeding in Project overpressure limits or create unreasonable impacts to nearby sensitive receivers.
- To minimise risk regarding the unlikely event of potential damage to properties occurring from blasting activities, all properties within a 500 metre radius of the tunnel have had detailed property condition reports completed.
- Structural assessments were also carried out on the above properties to assess the structural condition of the property prior to any blasting taking place.
- An assessment of underground water tanks was carried out and a copy of the reports were provided to each property owner and RTA's representative, prior to the commencement of construction.
- Water samples were taken from water tanks prior to blasting to record the quality of the water within 500 metres of the blast zone. These results have been provided to each property owner.
- Real time P10 and depositional dust monitoring would be undertaken to verify compliance with Project dust goals as prescribed by the Project Instrument of Approval and Environment Protection Licence.

In relation to the management of air quality impacts, mitigation measures that will be implemented if dust is being generated in excessive quantities include the potential wetting of the blast area in especially dry and windy conditions, wetting of the blast area after blasting in dry and windy conditions and the use of stemming. Although stemming is primarily used to control flyrock and to ensure safe blasting practices, it has the added effect of controlling dust generation during blasting. The use of mitigation measures other than stemming for the open cut works would be determined by project staff on a blast by blast basis depending on the conditions present. For the underground works, the location of the blasts underground and the selection of an appropriate air velocity for ventilation serve to mitigate issues with dust generation.

In relation to the management of traffic impacts, affected residents will be informed prior to any controlled blast. Public safety and government guidelines require that all people, vehicles and livestock are a safe distance away from the blast zone. To ensure people are at a safe distance from each blast, mitigation measures that would be implemented may include:

- Temporary closure of access locations to local roads, and property accesses (residents will be notified in advance),
- Stopping of traffic on St Helena Road for up to 10 minutes and 'rolling stoppages' on the Pacific Highway. These measures will be coordinated to ensure that they have minimal impact on the local community. Provision will be made to ensure that emergency access is maintained during any road closures,
- For safety reasons, some residents may be asked to remain indoors or be temporarily relocated during controlled blasting. A Project representative will be in contact with these residents in advance.

The above traffic mitigation measures relate to the controlled open cut blasting only. The controlled tunnel blasting is contained within the tunnel and, as such, it is not envisaged that any specific traffic mitigation measures would be required.

In addition to these controls, blasting activities will be scheduled to minimise the impact of road closures to commuters along St Helena Road and the Pacific Highway. However, unforeseen events which could effect public safety may result in the road being closed at any time during which blasting is permitted.

In addition to monitoring overpressure and vibration levels at the most sensitive receiver as required by Condition 2.17 of the Project Approval, monitoring from several other locations will be undertaken to more accurately determine the compliance with required blasting parameters.

These blast monitors will consist of fixed monitors and mobile monitors depicted as the blue and red points within Figure 35 respectively. The fixed monitors will remain in place within the locations depicted within Figure 35 for the duration of blasting activities associated with the St Helena Tunnel. The mobile monitors will be relocated from time to time in order to ensure that they are positioned at locations around the tunnel between the blasting activities and the closest sensitive receivers that are likely to experience the greatest vibration, noise and overpressure exposure levels.

The results of this monitoring, in addition to verifying compliance with Condition 2.17 of the Project Approval, will allow blasting to be progressively designed to minimise impacts on nearby sensitive receivers as the results of each individual blast become available.

Mitigation measures for the community have been established, including a Controlled Blasting Communication Plan, developed specifically for the St Helena tunnel blasting activities. The primary purpose of the plan is to outline the communications activities that will underpin consultation with the residents living within a 500 metre radius of the St Helena tunnel, who will be potentially affected by tunnel construction, particularly controlled blasting and vibration.

A complaints management procedure was also developed as part of the Community Communications Strategy (CCS) and included in the Controlled Blasting Communication Plan (CBCP), and details the process for handling community complaints. The Project has a dedicated toll free 24/7 contact line available (1800 882 787), for inquiries and complaints and it is printed on all published material sent to the community, on the website, at every community information session, and on Project signage.

Following the trial blast, on 19 October 2012, sensitive stakeholders in close proximity to the southern tunnel portal (location of the trial blast) were contacted to ascertain whether they, or their livestock, experienced any effects from the trial blast. All residents advised there were no issues.

As part of the Controlled Blasting Communications Plan, a damage claim procedure for the St Helena tunnel works was developed. This procedure is included as Appendix 10 to this report.

1 INTRODUCTION

1.1 Project Background

The upgrade of the Pacific Highway between Tintenbar and Ewingsdale is part of the Pacific Highway Upgrade Program, being implemented by NSW Roads and Maritime Services (RMS). The upgrade is an important part of the Pacific Highway Upgrade Program as on its completion, the Pacific Highway will be dual carriageway from Ballina to the Queensland border. The Tintenbar to Ewingsdale Project (the Project) will deliver safer driving conditions and improve the Pacific Highway's capacity to move people and freight between capital cities. The total Project cost is $862 million and is jointly funded by the NSW State and federal governments.

The Project site is located approximately 10 kilometres to the north of Ballina. The Project involves the construction of approximately 16.3 kilometres of highway from Ross Lane at Tintenbar and extends north to the existing Ewingsdale interchange, near the settlement of Ewingsdale. At Ross Lane, the upgrade alignment will connect to the northern end of the recently completed Ballina Bypass. Generally the alignment will be in close proximity to the existing highway corridor from Ross Lane to the Bangalow Bypass. The existing highway will be maintained for local and regional traffic.

From Bangalow, the upgrade alignment will diverge to the northeast through Tinderbox valley. From there, the upgrade alignment will avoid the steep grades of St Helena Hill by way of a tunnel approximately 434 metres long and 45 metres below the ridge line. North of the tunnel, the alignment will be located immediately to the east of the existing highway before tying into the Ewingsdale interchange.

Key components of the approved Project include:

- Four-lane divided carriageways (two lanes each way), with a wide median allowing for the future addition of a third lane in each direction.
- Connection to the northern end of the completed Ballina Bypass at the Ross Lane interchange. A new northbound on-ramp and a new southbound off-ramp would be provided. The remainder of this interchange has been constructed as part of the now completed Ballina Bypass project.
- Upgrading of the existing Ewingsdale interchange to provide full access between the modified local and regional road network and the highway.
- A half interchange at Bangalow. South-facing ramps would provide access between the local road network, including to Bangalow and Lismore, and the proposed upgrade to the south. This arrangement would replicate the arrangement with the existing Bangalow Bypass which also has south-facing ramps only.
- Six twin bridges and four underpasses allowing roads and creeks to pass underneath the proposed upgrade. These would include twin bridges above Byron, Emigrant and Skinners Creeks and the existing Casino-Murwillumbah railway on the northern side of Byron Creek.
- Two bridges carrying local roads over the proposed upgrade, one for Broken Head Road and one approximately 500 metres north of Lawlers Lane providing access to several properties east of the upgrade. Protection screens would be provided on both bridges.
- Twin parallel tunnels under St Helena ridge (one tunnel for each carriageway). The tunnels would each be approximately 434 metres long and approximately 45 metres below St Helena Road.
- Retention of the existing highway as a continuous road for local and regional traffic.
- Installation of signage providing clear directions for traffic at the Ross lane, Bangalow and Ewingsdale interchanges.

- Relocation of a number of public utilities and services.

Figure 1 provides an overview of the Project location.

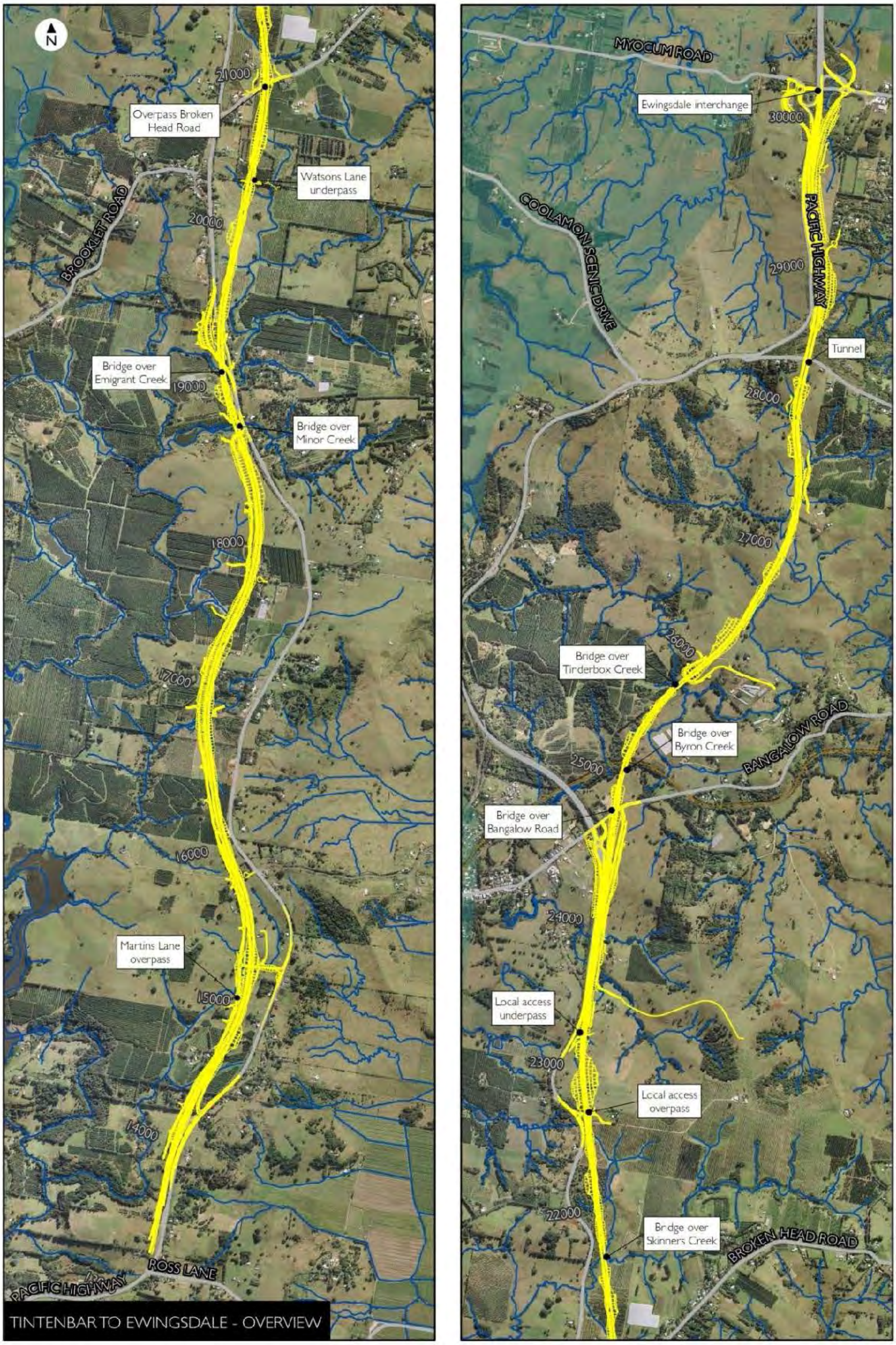


Figure 1 - Project overview

1.2 Project Planning and Approval Background

The following sections detail and consider the two most relevant pieces of legislation that relate to the proposal as detailed within this report being the *Environmental Planning and Assessment Act 1979* and the *Protection of the Environment Operations Act 1997*.

1.2.1 Environmental Planning and Assessment Act 1979

The Roads and Traffic Authority (RTA), now Roads and Maritime Services (RMS), completed an Environmental Assessment (EA) of the Project in 2008 under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The EA addressed a number of key environmental issues in addition to describing the likely Project delivery and construction methods.

The Minister for Planning approved the Project under Part 75J of the EP&A Act on 29 January 2010, subject to a set of approval conditions. Four modifications of the Minister's Conditions of Approval (MCoA) have been granted since Project Approval. These are:

- Modification 1 (approved 13 July 2010) – Modification to MCoA 2.12 to allow certain construction activities to be undertaken as part of the Ballina Bypass project, located immediately south of the Tintenbar to Ewingsdale project. The approved modification allowed works to be undertaken between the hours of 7:00am and 4:00pm on Saturdays between chainages 134810 and 136000 of the Ballina Bypass project, including the operation of the Cumbalum and Ross Lane ancillary facilities for stage 1 of the Bypass project.
- Modification 2 (approved 18 November 2010) – Modification to the Schedule 2 definition of Construction to allow the translocation of Hairy Joint Grass as a pre-construction activity. Schedule 2 of the MCoA defines construction activities as 'including all work other than survey; acquisitions; fencing; investigative drilling or excavation; building/road dilapidation surveys; minor clearing (except where heritage, threatened species, populations, or ecological communities would be affected).'
- Modification 3 (approved 6 November 2010) – Modification to the definition of Ancillary Facility and inclusion of Clause 2.27 to refine the process of the assessment and determination of ancillary facilities and various other administrative amendments.
- Modification 4 (approved 1 November 2010) – Modification to remove the requirement to protect heritage sites H29 and H39.

A copy of the Project Instrument of Approval incorporating the above modifications has been provided as Appendix 1 to this document.

1.2.2 Protection of the Environment Operations Act 1997

The Project incorporates the scheduled activities of Crushing, Grinding and Separating, Extractive Industries and Road Construction under the definitions of the *Protection of the Environment Operations Act 1997 (POEO Act).* Consequently, the Project was licensed following application pursuant to section 55 of the POEO Act on 19 September 2012 (Licence 20138).

The location of the proposed modification would apply to works entirely within the licenced premises as defined by Licence 20138.

The provisions of Licence 20138 that relate specifically to blasting are as follows:

L3 Blasting

L3.1 The overpressure level from blasting operations at the premises must not exceed 120dB (lin Peak) at any time. Error margins associated with any monitoring equipment used to measure this are not to be taken into account in determining whether or not the limit has been exceeded.

L3.2 The overpressure level from blasting operations at the premises must not exceed 115dB (LinPeak) for more than 5 per cent of the total number of blasts over each reporting period. Error margins associated *with any monitoring equipment used to measure this are not to be taken into account in determining whether or not the limit has been exceeded.*

L3.3 Ground vibration peak particle velocity from the blasting operations at the premises must not exceed 10mm/sec at any time. Error margins associated with any monitoring equipment used to measure this are not to be taken into account in determining whether or not the limit has been exceeded.

L3.4 Ground vibration peak particle velocity from the blasting operations at the premises must not exceed 5mm/sec for more than 5 % of the total number of blasts over each reporting period. Error margins associated with any monitoring equipment used to measure this are not to be taken into account in determining whether or not the limit has been exceeded.

L3.5 to determine compliance with condition(s) L3.1 and L3.3

a) Airblast overpressure and ground vibration levels must be measured and electronically recorded at the most affected residence or noise sensitive location that is not owned by the licensee or subject to a private agreement between the owner of the premises or noise sensitive location and the licensee for all blasts carried out in or on the premises; and

b) Instrumentation used to measure the airblast overpressure and ground vibration levels must meet the requirements of Australian Standard AS 2187.2-2006.

L4 Hours of operation

L4.5 Blasting hours

Blasting operations at the premises may only take place between 9:00am and 5:00pm Monday to Friday and 9:00am and 1:00pm Saturday. (Where compelling safety reasons exist, the EPA may permit a blast to occur outside the above hours. A prior written request for approval of any such blast must be made to the EPA).

With regard to the provisions of the licence that relate to vibration, overpressure and blasting hours, Licence 20138 may be required to be amended in order to ensure that the modifications detailed within this report are consistent with Licence 20138. The subject amendment would be sought following approval of the subject modification in accordance with the provisions of the *Environmental Planning and Assessment Act 1979*.

2 PROPOSED MODIFICATION

2.1 Purpose of this Report

RMS is seeking formal approval from the Department of Planning and Infrastructure to modify the Project Approval under section 75W of the *Environmental Planning and Assessment Act 1979* (the Act). This report has been prepared to support the request for approval for an extension of approved blasting hours and an increase in airblast overpressure and blasting vibration limits associated with the tunnel works at St Helena Hill. Details of the proposed modification are outlined below.

2.2 Modification Process

Section 75W of the Act provides that a proponent may request the Minister to modify an approval for a project under Part 3A of the Act. A modification is defined under section 75W of the Act as:

…means changing the terms of a Minister's approval, including:

(a) revoking or varying a condition of the approval or imposing an additional condition of the approval, and
(b) changing the terms of any determination made by the Minister under Division 3 in connection with the approval.

In accordance with section 75W (4) of the Act the Minister may modify the approval (with or without conditions) or disapprove of the modification.

2.3 Location of the Proposal

This modification request relates to the construction of the dual carriageway roadway (in a north-south alignment) underneath St Helena Hill. Twin parallel tunnels would be constructed within the northern section of the Project at a length of 434 meters and a depth of approximately 45 meters below St Helena Road. The closest residences to the proposal (termed nearby sensitive receivers) are situated along St Helena Road, off the existing Pacific Highway at St Helena Hill. The location of the proposed activity is identified as the 'tunnel' within Figure 1.

2.4 Geographical Definition of Area of the Proposal

For the purpose of clarification, the geographical area where the proposed modifications would be applicable is defined as the St Helena Hill tunnel works.

Figure 2 shows an overlay of the St Helena Hill tunnel works that are referred to in Section 4.

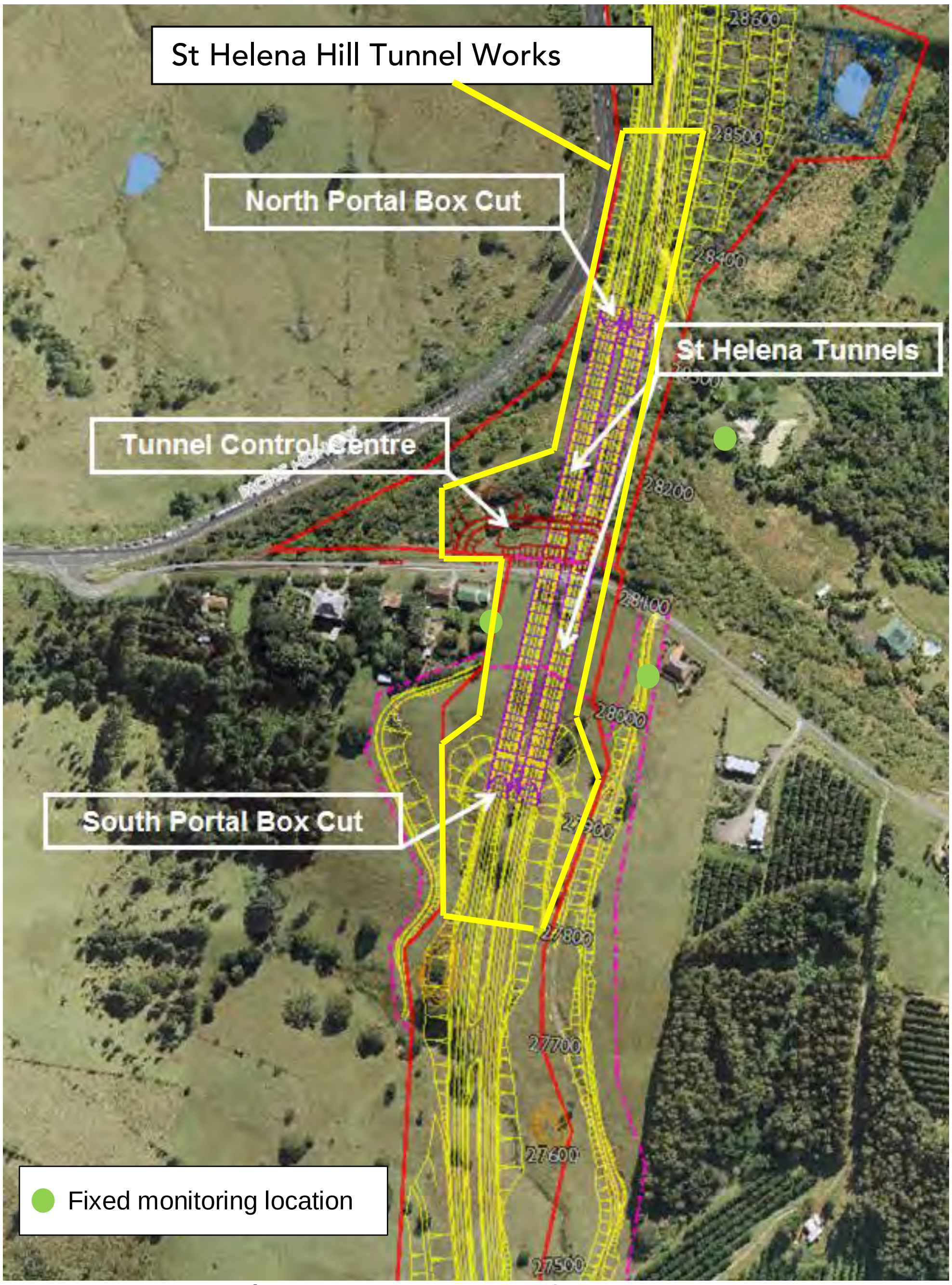


Figure 2 – Overlay of St Helena Hill tunnel works

The St Helena Hill tunnel works are confined between Project Chainage 27800 to 28500.

2.5 Current Approved Blasting Hours

The current approved blasting hours are specified in Condition 2.14 of the Minister's Conditions of Approval (MCoA) for the Project, as:

Blasting associated with the project shall only be undertaken during the following hours:

a) 9:00 am to 5:00 pm, Mondays to Fridays, inclusive;
b) 9:00 am to 1:00 pm on Saturdays; and
c) at no time on Sundays or public holidays.

This condition does not apply in the event of a direction from police or other relevant authority for safety or emergency reasons to avoid loss of life, property loss and/or to prevent environmental harm.

2.6 Proposed Modification to Blasting Hours

This report seeks to modify the current approved blasting hours for the Project, as detailed in Condition 2.14 on Monday to Friday (only) to (as shown in italics):

a) 9:00 am to 5:00 pm, Monday to Fridays, inclusive.
b) 9:00 am to 1:00 pm on Saturdays;
c) at no time on Sundays or public holidays; and
d) 7.00 am to 6.00 pm, Monday to Fridays, inclusive for the St Helena Hill tunnel works between Chainage 27800 and Chainage 28500.

This condition does not apply in the event of a direction from police or other relevant authority for safety or emergency reasons to avoid loss of life, property loss and/or to prevent environmental harm.

There is no proposed alteration to the blasting hours for Saturdays, Sundays or public holidays.

2.7 Current Approved Airblast Overpressure Limits

The current approved airblast overpressure limits are specified in Condition 2.17 of the MCoA for the Project as:

The proponent shall ensure that airblast overpressure generated by blasting associated with the project does not exceed the criteria specified in Table 1 when measured at the most affected residence or other sensitive receiver.

Table 1 - (Table 1 - Airblast Overpressure Criteria)

Airblast Overpressure (dB(Lin Peak))	Allowable Exceedance
115	5% of total number of blasts over a 12 month period
120	Never

2.8 Proposed Modification to Airblast Overpressure Limits

This report seeks to modify the current approved airblast overpressure limits for the Project, as detailed in Condition 2.17 to (*as shown in italics*):

The proponent shall ensure that airblast overpressure generated by blasting associated with the project does not exceed the criteria specified in *Tables 1a and 1b* when measured at the most affected residence or other sensitive receiver.

Table 2 - (*Table 1a* - Airblast Overpressure Criteria)

Airblast Overpressure (dB(Lin Peak))	Allowable Exceedance
115	5% of total number of blasts over a 12 month period
120	Never

Table 3 - (*Table 1b - Airblast Overpressure Criteria, inclusive for the St Helena Hill tunnel works between Chainage 27800 and Chainage 28500 where consent has been granted by the owner/occupier that the subject limits may apply.*)

Airblast Overpressure (dB(Lin Peak))	*Allowable Exceedance*
125	*5 % of total number of blasts over a 12 month period*
130	*Never*

2.9 Current Approved Vibration Limits

The current approved ground vibration limits are specified within Condition 2.18 of the Minister's Conditions of Approval (MCoA) for the Project, as:

The proponent shall ensure that ground vibration generated by blasting associated with the project does not exceed the criteria specified in Table 2 when measured at the most affected residence or other sensitive receiver.

Table 4 - (Table 2 — Peak Particle Velocity Criteria)

Peak Particle Velocity Criteria (mms^{-1})	Allowable Exceedance
5	5% of total number of blasts over a 12 month period
10	Never

2.10 Proposed Modification to Vibration Limits

This report seeks to modify the current approved ground vibration limits for the Project, as detailed in Condition 2.18 to (*as shown in italics*):

The proponent shall ensure that ground vibration generated by blasting associated with the project does not exceed the criteria specified in *Tables 2a and 2b* when measured at the most affected residence or other sensitive receiver.

Table 5 - (*Table 2a* - Peak Particle Velocity Criteria)

Peak Particle Velocity Criteria (mms^{-1})	Allowable Exceedance
5	5% of total number of blasts over a 12 month period
10	Never

Table 6 - (*Table 2b - Peak Particle Velocity Criteria, inclusive for the St Helena Hill tunnel works between Chainage 27800 and Chainage 28500 where consent has been granted by the owner/occupier that the subject limits may apply.*)

Peak Particle Velocity Criteria (mms^{-1})	*Allowable Exceedance*
15	*5 % of total number of blasts over a 12 month period*

20	*Never*

3 CONSULTATION

3.1 Agency Consultation

Two consultation forums, being the Environmental Review Group (ERG) and monthly community information sessions (CIS) currently provide on-going opportunities for agencies and the community to stay informed about environmental aspects of the Project, to keep updated regarding construction and Project information, and provide input and feedback to the Project.

The Community Relations Manager and the Environmental Manager work closely with the Environmental Representative and RTA's Representative in responding to the community concerning the environmental performance of the Project. Both the Environmental Representative and RTA's Representative are represented on the ERG and attend the community information sessions.

The subject modification was discussed at the ERG meeting 21 March 2012, the St Helena street meeting on 21 May 2012 and the community information sessions on 23 May 2012.

This document was circulated to all ERG member agencies for review and comment on 9 January 2013. Following this circulation, on 22 January 2013 a follow up email was circulated to remind all ERG member agencies that comments on the proposed modification were being sought and that the consultation period was soon to elapse.

From this review by ERG member agencies, comments were received only from the Environment Protection Authority. All other agencies consulted stated they either had no comment, or did not provide any feedback. The subject consultation sent to agencies and received by BPL is included within Appendix 13 to this report. Appendix 13 also includes comments provided by the Environment Protection Authority and Project responses to these comments.

3.2 Community Consultation

All community consultation with regard to the Project is managed in accordance with PLAN-CI-001 Community Communications Strategy (CCS), which was approved by the Department of Planning and Infrastructure on 20 September 2012.

Consultation and notification with stakeholders regarding any changes or issues for the Project would continue to be managed in accordance with the PLAN-ENV-001 NVMSP and the Project PLAN-CI-001 Community Communication Strategy (CCS) (as prepared to meet the requirements of MCoA 5.4). These documents would address any concerns or issues from the community arising from the modified blasting hours. A free call Project information and complaints (24 hours a day, 7 days a week) phone number (as required by MCoA 5.3) will be operational throughout the delivery of the Project. Furthermore, regular community information sessions, meetings with residents and stakeholders will be undertaken proactively and as required to address any issues during the delivery of the proposal.

In addition to the implementation of the PLAN-ENV-001 NVMSP and PLAN-CI-001 CCS, a Controlled Blasting Communications Plan (CBCP), included as Appendix 3 and mentioned previously in this document, has been prepared in relation to the subject proposed modification. The primary purpose of the CBCP is to outline the communications activities that have underpinned consultation with the residents living within a 500 metre radius of the St Helena tunnel who will be potentially affected by tunnel construction, particularly controlled blasting.

In order to achieve the objective of ensuring the community is consulted and informed of changes and potential impacts relating to controlled blasting at the St Helena tunnel and tunnel control centre, the CBCP aims to:

- Develop a strategic communications plan to support proactive consultation with residents who will be potentially affected by tunnel construction and blasting activities,
- Identify potential blasting, vibration, over pressure and construction issues for residents and stakeholders and develop key messages to support mitigation strategies,

- Develop communication materials to inform and educate residents and key stakeholders about the tunnel blasting, vibration and construction activities,
- Develop a communication calendar for consultation with directly affected residents within a 500 metre radius of the tunnel;
- Develop a complaints (general)/complaints (damage) procedure/flow chart.

One on one meetings were held with all affected residents within a 500 metre radius of the St Helena tunnel in April/May 2012. The Baulderstone Tunnel Manager, Community Relations Manager, Community Relations Coordinator and the RTAs Representative met with residents at each property to provide detailed information about the tunnel construction and proposal to extend blasting hours, increase vibration and overpressure limits for the tunnel. The meetings enabled the Project team to get an indication of potential issues or concerns. Notes from these meetings are included as Appendix 5 to this report.

Follow up meetings and/or phone calls were made with affected residents after the initial meetings to answer any further questions residents may have had.

Further consultation was undertaken by way of a street meeting, held on 21 May 2012, at the property of a resident on St Helena Road. The St Helena street meeting brought together all residents who are likely to be affected by the blasting activities as part of the St Helena tunnel works.

A detailed presentation was given to attendees to ensure each resident was provided with the same information at the same time. The street meeting presentation provided a further opportunity to answer questions and explain further detail about the tunnel construction, including blasting and vibration, as per questions or concerns raised from the one on one meeting with residents. The street meeting presentation is included as Appendix 7 to this assessment.

Following this, a controlled blasting fact sheet, letters about proposed extended blasting hours, increased vibration and overpressure limits were provided to each resident for their consideration.

The subject modification was also presented to the wider community at the community information sessions on 23 May 2012.

As part of the CBCP, targeted consultation has occurred to identify and communicate with potentially affected residents. This included the consultation that has occurred with local residences to discuss the proposed modification as well as planned consultation as outlined in Table 7 below.

Table 7 - Consultation activities for St Helena tunnel controlled blasting and proposed extension of tunnel blasting hours, increased vibration limits and increased airblast overpressure limits

	Communications calendar	
Date/Timing	*Activity/Communications Tools*	*Stakeholders*
12-13/04/2012 & 3/5/2012	Initial face-to-face consultation with property owners within 500m radius of northern tunnel portal to identify issues and concerns.	Residents within 500m of the St Helena tunnel
21/05/2012	A street meeting for residents affected by construction of the St Helena tunnel, were invited to a meeting where information about the tunnel construction and controlled blasting activities was presented. It provided an opportunity to address issues and concerns. The following topics were presented/discussed regarding controlled blasting in the St Helena tunnel: • Tunnel, including design and benefits • Blasting	Residents within 500m of the St Helena tunnel.

	Communications calendar	
Date/Timing	*Activity/Communications Tools*	*Stakeholders*
	• Why [do we need to blast]? • Potential environmental impacts, including vibration and airblast overpressure • Types of controlled blasting (open cut and tunnel) • What to expect • Mitigation strategies • Vibration measurement • Monitoring • Excavation methodology • Proposed changes — blasting hours/vibration/airblast limits • Benefits of change • Vibration contours The meeting notes are included as Appendix 7 to this document.	
23/05/2012	2 x Community Information Sessions were held at 12 noon and 5.30pm. Information about the Bangalow interchange and St Helena tunnel construction was presented. The same presentation from the St Helena street meeting was provided to the wider community at the community information sessions. Refer to community information session #5 meeting notes at Appendix 7.	Broader community
Week commencing 28/05/2012	Follow up meetings were scheduled with affected residents and letters were distributed. The following letters were distributed in person or via post following the street meeting: 14 'letter of non-objections' for extension to blasting hours for St Helena tunnel construction (all residents). 11 of the 14 letters have been signed and returned to date. Letters attached at Appendix 4. Five 'letters of consent' to increase vibration and airblast overpressure limits for St Helena tunnel construction (potentially affected residents only). All of the five letters have been signed and returned. Letters attached at Appendix 4.	Residents within 500m of the St Helena tunnel
Week commencing 6/10/2012	Publish quarterly construction update advertisement in local newspapers.	Residents within 500m of the St Helena tunnel and broader community

Table 8 outlines the key issues and proposed measures to address issues raised during this consultation.

Table 8 – Analysis of issues discussed at community consultation meetings

Issue	*Response*
Noise	The noise expected from controlled tunnel blasts will be minimal and will only last for a few seconds. The noise expected from controlled open cut blasts at the tunnel control centre and tunnel portals will be more significant, however, it will comply with the Minister's Conditions of Approval. Noise monitoring will be undertaken initially at the start of any controlled blasting (i.e. at the tunnel portals, in the tunnel and at the tunnel control centre) and subsequently on a monthly basis or more frequent as may be required to demonstrate compliance with approval limits and the various management plans for the Project, or respond to community complaints. Results will be published fortnightly on the Project website.
Vibration/airblast overpressure	The vibration and airblast overpressure from controlled blasts is expected to be very minor beyond the immediate vicinity of the blast zone. Trial blasts (and the results from routine controlled blasts) will be undertaken to confirm design blast predictions and parameters and will be used to refine ongoing controlled blast activities. Flashing warning lights will be attached to vibration monitors, triggered by vibrations in excess of the maximum Peak Particle Velocity limit as prescribed by the Project Instrument of Approval and Environment Protection Licence to provide a 'real time' visual warning of vibration exceedences. Monitoring to record vibration and airblast overpressure levels will be carried out for each controlled blast. Results will be published fortnightly on the Project website.
Dust/fly rock	There should be minimal dust and fly rock beyond the immediate vicinity of the blast at the tunnel portals and tunnel control centre. Where there is the potential for fly rock, 'blast mats' (made of thick shock absorbing rubber) may be used or alternatively the overburden earth material may be kept in place. Controlled blasting within the tunnel will be contained, with minimal dust and no fly rock.

Temporary road closures	Traffic and pedestrians on St Helena Road may be stopped for up to 10 minutes and 'rolling stoppages' may be implemented on the Pacific Highway during controlled blasting events for construction of the tunnel portals and the tunnel control centre to ensure the safety of local residents, pedestrians and commuters. These measures will be coordinated to ensure that they have the least impact on the local community. Provision will be made to ensure that emergency access is maintained during any road closures. The community relations team will liaise with residents in advance regarding specific access arrangements/requirements, as necessary. Emergency access would be maintained. Traffic controllers will be in place to direct traffic, whilst variable message signs will be in place to inform the community in advance of any temporary road closures.
Property damage	Detailed property condition surveys (building condition inspection) and structural assessments of all properties and water tanks within 500m radius of blast zones at the St Helena tunnel have been completed and a report issued to property owners and the RTA's Representative prior to the start of construction. Assessments of underground water tanks were also conducted at two properties. As outlined in the Controlled Blasting Communications Strategy, the community relations team will contact all residents who received a building condition inspection and or who are within 500 metres of the controlled tunnel blast zone via regular telephone calls prior to blasting events, to advise impacts and / or safety precautions, and following blasting events to ascertain whether or not there have been any impacts from the controlled blasting and to reassure them that Baulderstone is monitoring the impacts of controlled blasting inside the tunnel, and at tunnel portals and tunnel control centre to ascertain whether or not there have been any impacts from the controlled blasting to date. If a resident believes that damage has occurred to their property as a result of controlled blasting, they should contact the Community Relations Manager immediately on 1800 882 787 (toll free). A property condition survey (building condition inspection) will be conducted within two months of completion of vibration inducing activities, or in response to damage complaints. A written report of the final inspection supported by photographs and a list of any defects will be prepared and submitted to the property owner and RTA's Representative.
Temporary relocation of residents	For safety reasons some residents may be asked to remain indoors or be temporarily relocated during controlled open cut blasting at the tunnel portals and tunnel control centre. After the first trial and controlled blasts, this procedure will be reviewed. If required, the community relations team will notify affected residents of planned blasts in advance, to make arrangements.

	Controlled blasting within the tunnel is contained and will not require residents to remain indoors or be relocated.
Pets and livestock	It is advisable to keep smaller pets inside during blasting for their safety and wellbeing. Animals in paddocks should be checked before and after controlled blasting. The community relations team will provide specific timing details to those residents with nearby animals in paddocks on an individual basis.
Inclement weather	Blasting of the tunnel portals and tunnel control centre may need to be postponed during inclement weather. Controlled blasting inside the tunnel will not be affected by weather.

4 DESCRIPTION OF ST HELENA HILL TUNNEL WORKS

4.1 Box Cuts

Before excavation can begin on the tunnel works, the earth and rock at the tunnel portals (entrances) must be removed. The removal of this material will be undertaken through controlled blasting to create work platforms. The blasting works for the southern box cut are the first blasting activities undertaken at the St Helena Hill area. The earth and rock at the northern end will be removed following the commencement of tunnelling.

Based on the current MCoA, a summary of the excavation volumes, number of blasts and expected duration of the drill and blast activities in relation to the St Helena box cuts is shown within Table 9.

Table 9 - Box cut excavation summary

Box cut	*Blasted material*	*Number of blasts*	*Expected duration*
Southern portal	30640m^3	9	6 weeks
Northern portal	14129m^3	3	3 weeks

The design of the southern box cut is depicted within Figure 3 while the design of the northern box cut is depicted within Figure 4.

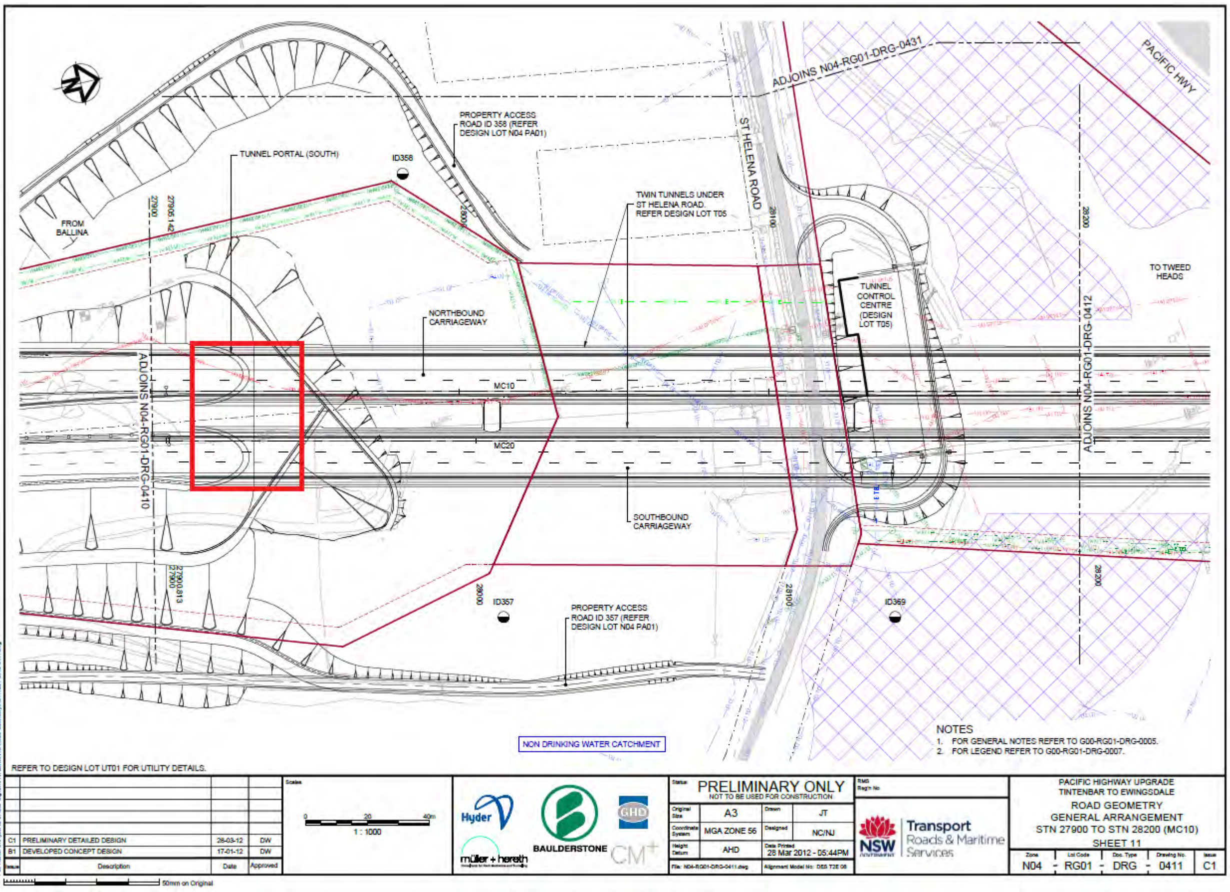


Figure 3 - Southern Box Cut

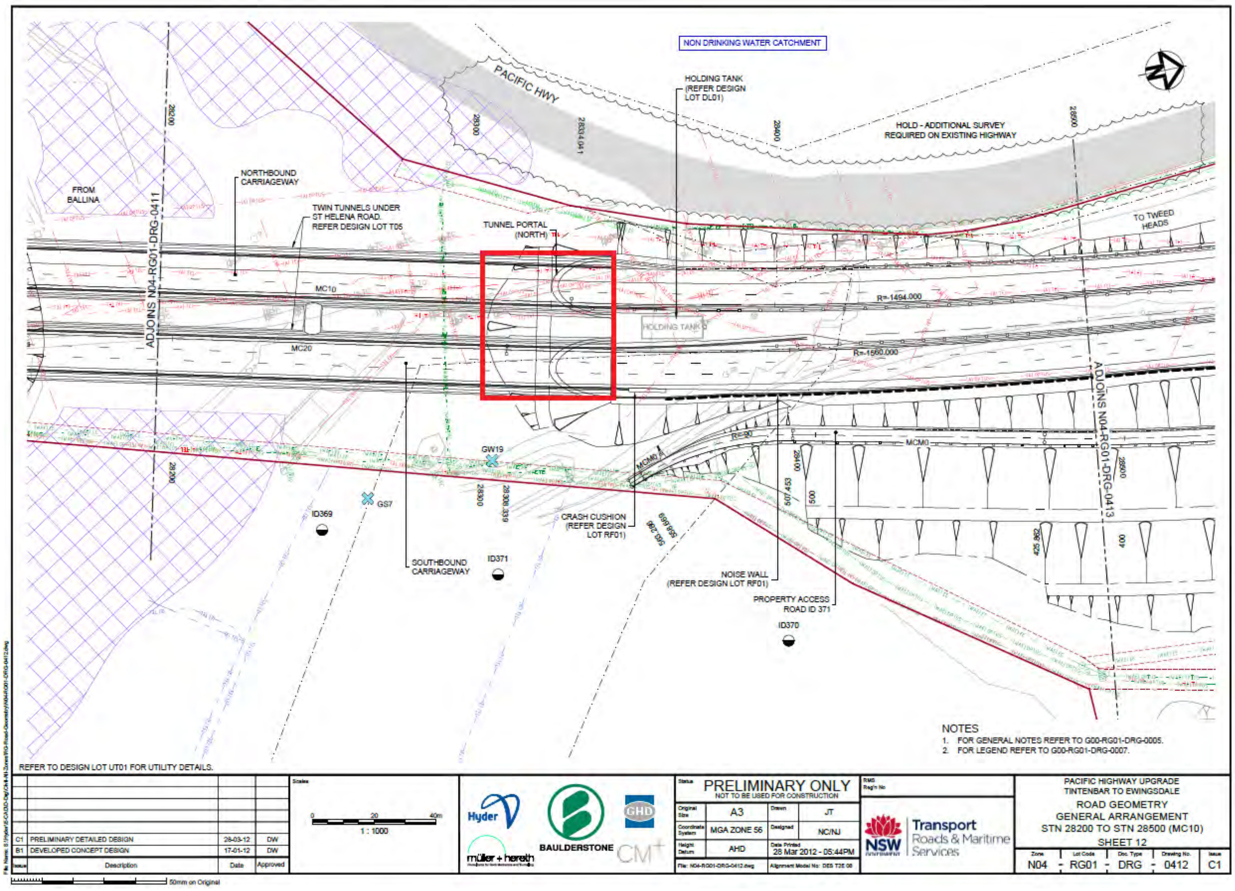


Figure 4 - Northern Box Cut

4.2 Twin Tunnels and Cross Passages

The Approved Project includes the construction of twin tunnels in the St Helena Hill near Ewingsdale on the northern section of the Project alignment.

Due to the size of the tunnels and the local geology, it has been determined that the most feasible method for excavating the tunnels is through the method of drill and blast. The scope of blasting works for the tunnels will consist of two 434 metre long blasted tunnel excavations with a cross sectional area of approximately 200 square metres and three 10 metre long cross passage excavations with a cross sectional area of approximately 52 square metres.

Controlled blasting is a process that can be used to break up material that is unable to be broken up effectively by means of mechanical excavation. It involves using explosive energy to break the rock so that it can be handled and removed by earthmoving equipment. For each blast there may be in excess of 100 holes drilled to allow for insertion of explosives and to fracture rock. To increase the efficiency of the blast and to reduce ground vibration, a number of larger diameter holes known as relief holes are drilled to create a weak zone in the rock face. The production holes (holes in which explosives have been inserted) are then initiated in a predetermined pattern to break the rock. The blasted material is 'mucked out' from the face by specialised underground loaders and trucks.

Controlled blasting is expected to be used to fracture approximately 155,000 cubic meters of rock in St Helena Hill to construct the tunnels and undertake associated works. Based on the current provisions of the Project Ministers Conditions of Approval (MCoA) contained within the Instrument of Approval issued for the Project pursuant to Part 3A of the *Environmental Planning and Assessment Act 1979*, controlled trial blasting for the St Helena Hill tunnel works commenced on 19 October 2012 and would continue for approximately 12 months.

An artist's impression of the completed southern portal is depicted within Figure 5.

Figure 5 - Artist's impression of the completed southern portal

4.3 Tunnel Control Centre

In order to manage the operational aspects of the tunnel, a tunnel control centre (TCC) will be constructed on the top of St Helena Hill. The TCC will include communications, maintenance, ventilation and various emergency systems infrastructure including fire suppression utilising a deluge system. The deluge system will incorporate large underground tanks located above the tunnel and within the visually screened and secured TCC compound.

The tunnel control centre will be located adjacent to St Helena Road above the alignment of the tunnels that will be constructed as part of the Project. Figure 6 shows a plan diagram of the TCC location along St Helena Road. Figure 7 shows an artist's impression of how the TCC will look once completed and the area has been landscaped.

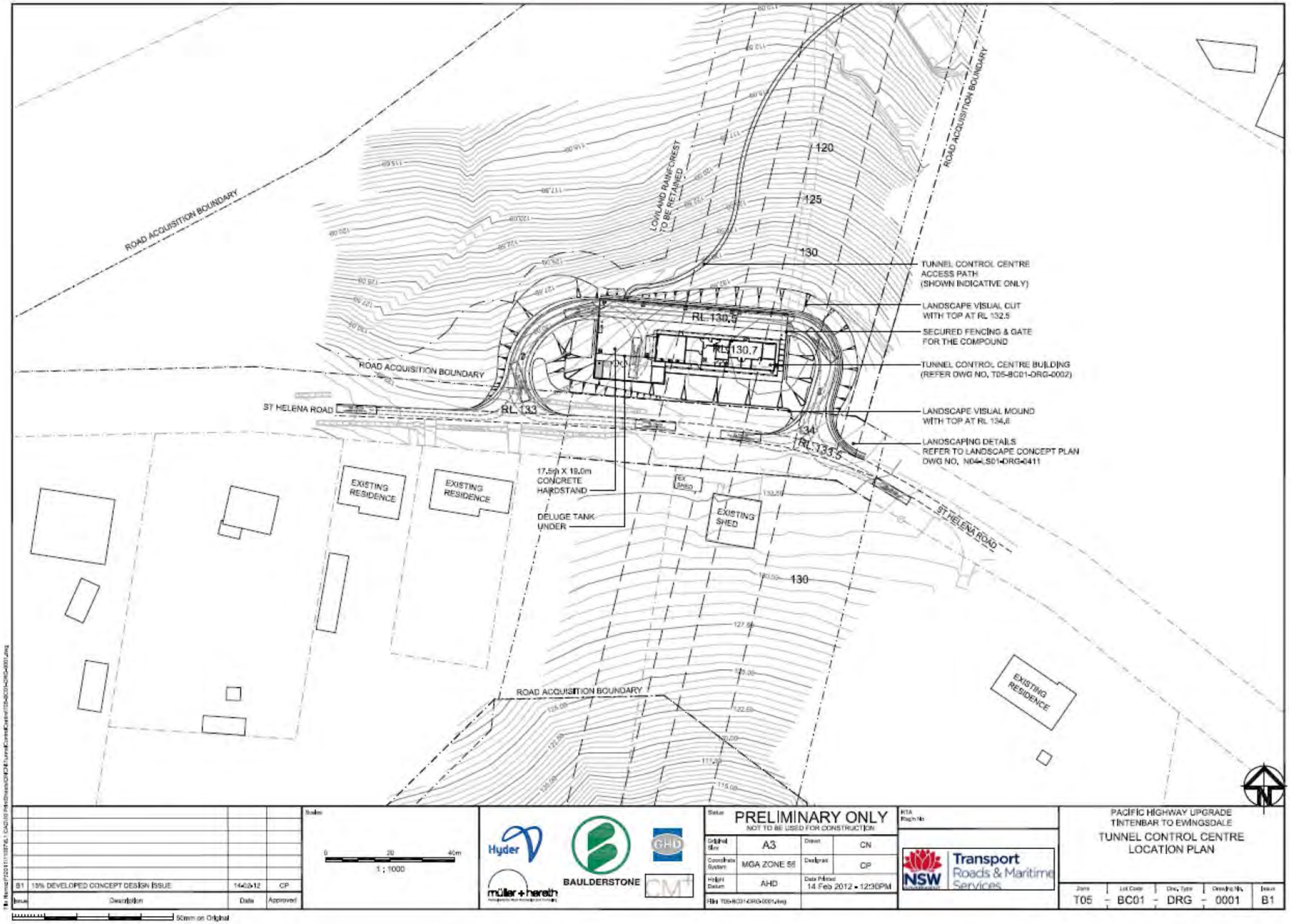


Figure 6 - Location of Tunnel Control Centre adjacent to St Helena Road

Figure 7 - Schematic of completed Tunnel Control Centre

Construction of the TCC will require the excavation of approximately 13,500 cubic metres of material (incorporating 12,000 cubic metres of rock), with the approximately 4,800 cubic metres being required to provide space for the installation of the deluge tanks. Under the current construction program it is anticipated that the excavation works for the TCC will take at least 12 weeks and require three individual blast events. The extensive duration for the excavation is primarily due to the hammering that is required due to blasting being unfeasible for much of the excavation given the current MCoA.

Based on the current MCoA, a summary of the anticipated amount of material to be blasted, number of blasts events and expected duration associated with the blasting of the TCC is provided within Table 10 below.

Table 10 - Summary of TCC blasting schedule

Area	*Blasted material*	*Number of blasts*	*Expected duration*
TCC	Approx 12,000m^3	Dependant on site characteristics – At least 3 expected.	12 weeks

4.4 Construction Methodology of St Helena Hill Tunnel Works

4.4.1 Twin tunnels and cross passages

As previously stated, the twin highway tunnels and cross passages will be built into the St Helena Hill using drill and blast excavation techniques. Other than by drill and blast, tunnels can be excavated using mechanical excavation equipment such as roadheaders or tunnel boring machines. The tunnels were chosen to be excavated using the drill and blast technique primarily due to geotechnical conditions, nearby residences and the dimensions of the tunnel.

To be economically viable, mechanical excavation equipment such as roadheaders and tunnel boring machines must be able to operate 24 hours per day. Due to the location of the St Helena tunnel in relation to the residences on St Helena Road, it was not considered suitable to have mechanical excavation equipment running 24 hours per day as the regenerated noise from these machines would cause unacceptable levels of disturbance during the night. Further to this, due to the large cross sectional area of the tunnels, the capital investment that would be required to purchase sufficient mechanical excavation equipment to excavate the tunnels within the required time frame would not be possible. As such, it was determined that the only viable method for excavating the St Helena tunnels would be to undertake drill and blast excavation. Table 11 shows a comparison of excavation methods and their suitability in relation to the excavation of the St Helena tunnels.

Table 11 - Comparison of excavation methods

Excavation Method	*Suitability to Geology*	*Impact on nearby residences*	*Suitability to geometry of tunnel*	*Overall Suitability*
Roadheaders	Low – Rock particularly hard in some areas.	High – High levels of continuous regenerated noise.	Low – Geometry would require the use of several machines to meet programme, making roadheaders economically unviable.	Low – Economically unviable with high impact on residences.
Drill and Blast	High – Drill and blast is highly versatile and suitable to variable	Low – Short blast events that cause no damage have little effect on	High – Drill and blast allows for flexibility and can be used in large	High – Most appropriate method for all criteria.

	geology.	nearby residences.	excavations.	
Tunnel Boring machines	Low – Slow advance rates in expected hard rock.	High – High levels of continuous regenerated noise.	None – TBMs can only make circular tunnels.	None – Impractical.

There will be two main types of drill and blast excavation used in the construction of the St Helena tunnels. These are blasts with horizontal drill holes known as heading blasts and blasts with vertical drill holes known as bench blasts. While bench blasts are easier and more efficient to undertake, the required method of excavation for the tunnels requires the removal of the top section of the tunnel using heading blasts and removal of the lower section following the removal of the top section through bench blasting. For practical reasons, it is not possible to achieve any advance in the tunnel without blasting the top part of the tunnel using heading blasts.

A tunnel with a heading and bench profile can be seen in Figure 8.

Figure 8 - Underground excavation with a bench and heading split

The expected heading and bench split for the St Helena tunnels can be seen in Figure 9.

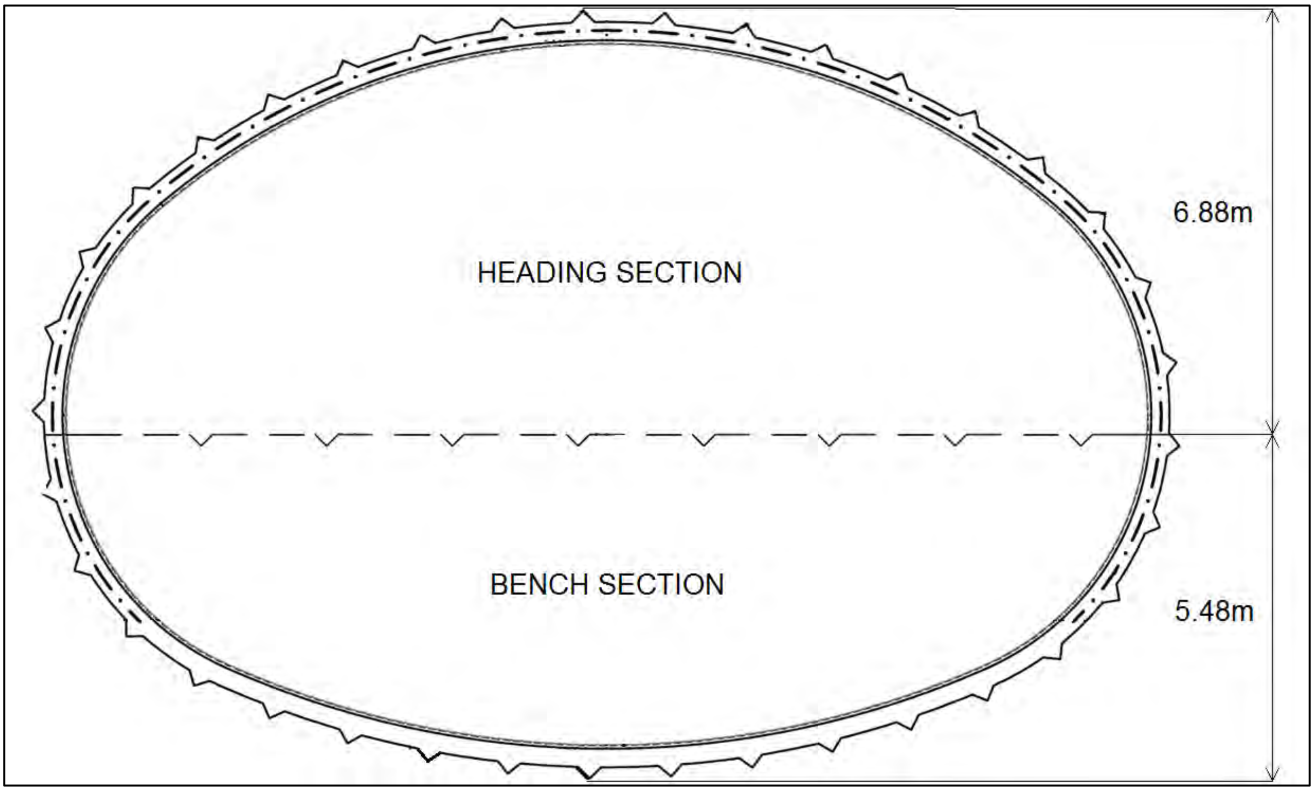


Figure 9 - Expected heading and bench sections for the St Helena tunnels

Further to this, due to scheduling, geotechnical and economic considerations the heading will be split into two separate sections referred to as Heading 1 and Heading 2. The split heading tunnel profile can be seen within Figure 10.

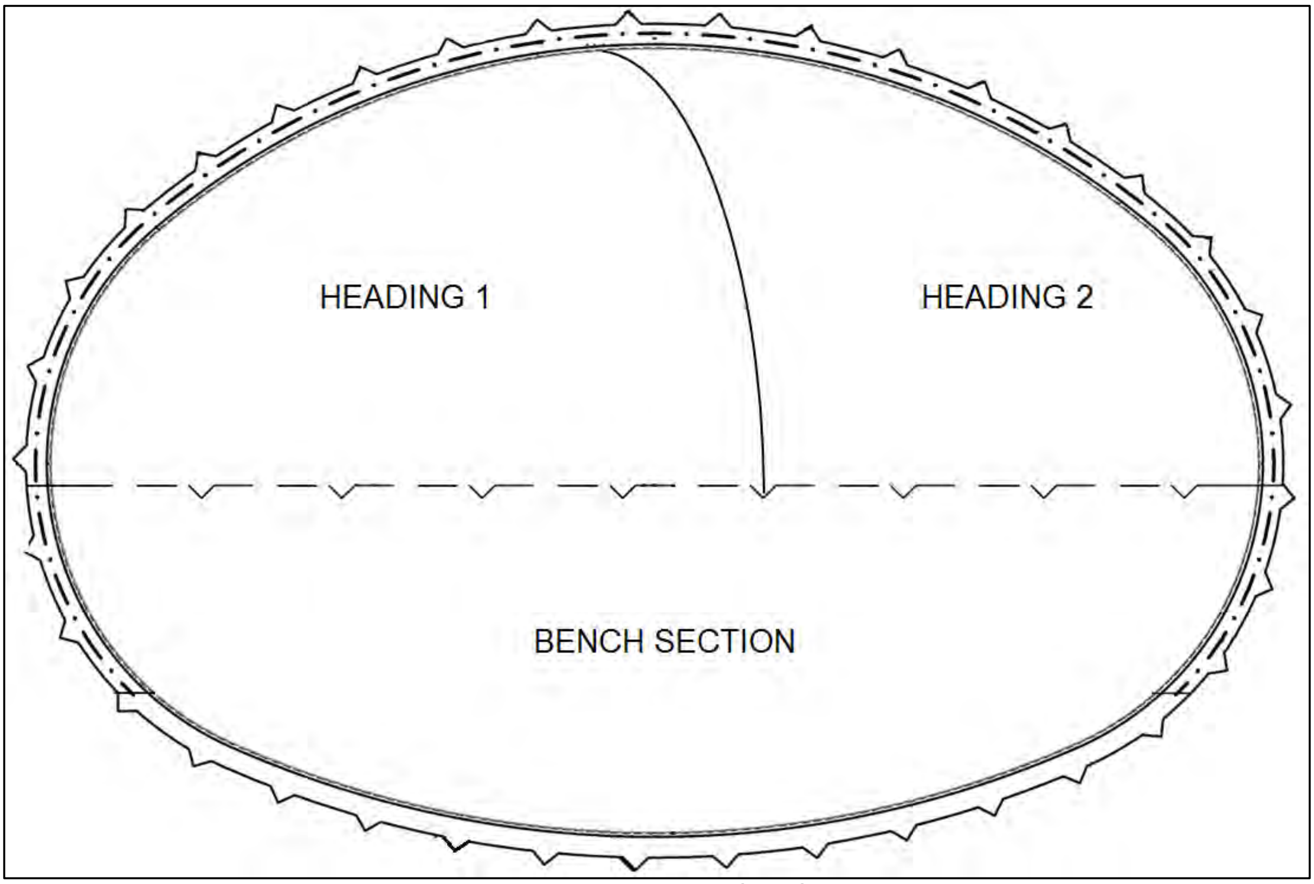


Figure 10 - Split heading and bench profile of tunnel cross section

As previously discussed, bench blasting is significantly faster than heading blasting. As such, the most efficient production rate of drill and blast tunnelling is governed by the most efficient production rate of the heading blasts. In turn, the most efficient productivity of the heading blasts is governed largely by the geological conditions. If the rock is strong and has a high degree of resistance to erosion and deformation, the length of advance per blast can be increased as the roof of the tunnel will remain intact. However, in poor ground conditions the round length (amount of advance) must be reduced so that the profile of the tunnel can be maintained, otherwise extensive costs and time delays are incurred due to additional support requirements and over excavation.

Furthermore, the Heading 2 blast is also more efficient than the Heading 1 blast as it is unconfined in 2 dimensions and requires less explosive energy to fracture and displace the rock. Less explosive energy required means that the number of holes drilled can be reduced and as such a cycle can be completed faster.

The geology in the St Helena Hill is primarily basalt. Within the basalt, geological investigations have identified two different formations of basalt that have different geotechnical properties. The types of basalt defined by the geological investigations are high strength basalts and weathered basalts.

The high strength basalts have an unconfined compressive strength of 80 to 300 megapascals (MPa) which is considered to be hard rock in geological terms. The high strength basalts are also competent (highly resistant to erosion and deformation) and it is expected that they can be excavated in round lengths of up to five meters. It is expected that approximately 75 per cent of the excavation will be performed in high strength basalts.

The weathered basalts also have an unconfined compressive strength of 80 to 300 MPa but are not considered competent in nature. As such, in order to maintain the tunnel profile while advancing through weathered basalts, the maximum round length that can be taken is 1.75 meters per round. It is expected that 25 per cent of the excavation will be performed in weathered basalts.

Both high strength and weathered basalt to be encountered during the subject tunnelling activities is expected to be within the range of 200 MPa.

However, productivity can also be limited by vibration limits, air overpressure limits as well as blasting hours. The reason that these constraints can act as limitations stems largely from the cyclical nature of drill and blast tunnelling and the increased efficiency with increased round lengths. The cycle of drill and blast excavation follows the following steps:

- Drilling,
- Loading,
- Blasting,
- Excavation;
- Support.

Due to the risks associated with leaving ground unsupported or leaving holes charged with explosives for extended periods of time, it is important that an entire drill and blast cycle is completed within the work hours available.

It follows that the total time taken to perform a cycle increases or decreases correspondingly with the volume of rock taken in each blast. However, the increase in time taken to complete a cycle is not directly proportional to the increased volume excavated. Table 12 shows the expected time to excavate different volumes of rock in the Heading 1 section of the tunnel depending on the round length when excavating in the high strength basalts.

Table 12 - Comparison of production rates for increased round lengths

Round length	*Volume excavated*	*Time to complete cycle*	*Minutes per m^3*
1.0m	$59m^3$	341 minutes	5.8
2.0m	$118m^3$	415 minutes	3.5

3.0m	177m^3	488 minutes	2.8
4.0m	236m^3	562 minutes	2.4
5.0m	295m^3	635 minutes	2.2

From Table 12 it can be seen that an increased round length can reduce the construction time for the St Helena tunnels. If the tunnels were not restricted in terms of vibration and overpressure levels or blasting hours to the extent of the current MCoA but rather the constraints as proposed through Section 2.6 of this report, the excavation of the high strength basalts in each tunnel could be completed approximately 25 per cent faster.

As such, it can be noted that the round length can only be increased when the following conditions exist:

- Geology allows for removal of extended round length,
- Time to complete the cycle within available hours;
- Amount of explosive can be detonated without exceeding vibration and overpressure limits.

In order to complete the construction of the St Helena tunnels as efficiently as possible, while minimising impact to nearby sensitive receivers, Baulderstone will be installing structures at the southern portals of each tunnel to mitigate any audible construction noise from activities within the tunnel at night. The purpose of these structures is to allow work to continue during the night, as it will be inaudible at sensitive receivers. While the design of these structures is not discussed further within this report, details of the structures can be found within the Project PLAN-ENV-006 Noise and Vibration Management Sub-Plan (NVMSP). In relation to the installation of the noise mitigating structures, it is estimated that 60 metres of tunnel excavation in the entire top heading section must be completed prior to installation to ensure that there is sufficient space for night activities to be undertaken.

The most significant effect of the noise mitigation structures will be that, once installed, they will allow for an additional blast to be performed each day in Heading 1. Currently, the MCoA allow for blasting activities between the hours of 9:00am to 5:00pm Monday to Friday and between 9:00am and 1:00pm on Saturdays with no blasting activities allowed on Sundays or public holidays. Given these hours, it has been calculated that the most efficient method for developing Heading 1 and Heading 2 (when geological conditions permit) is to perform blasting in the following sequence:

- Perform one 2.5 metre Heading 1 blast at approximately 9:00am, but under no circumstances earlier than 9:00am;
- Perform one 2.5 metre Heading 1 blast simultaneous to 1 one 5m Heading 2 blast at approximately 5:00pm, but under no circumstances later than 5:00pm.

Due to the additional support requirements when tunnelling through the weathered basalts, it is expected that only a single Heading 1 blast will be performed per day. However, in order to maintain the progression of Heading 2, blasting will most likely be performed in the afternoon. This will results in the following blasting sequence to progress the headings at the most efficient rate:

- Perform one Heading 1 blast at approximately 9:00am, but under no circumstances earlier than 9:00am;
- Perform one Heading 2 blast at approximately 5:00pm, but under no circumstances later than 5:00pm.

The length of each round would be determined by the geological conditions.

Any bench blasting would be arranged so that it is undertaken in sequence with either the morning or afternoon blast so that the disruption to the community and tunnel works through exclusions zones and other blast management procedures are minimised as these procedures would be in place for the heading blasts.

4.4.2 Box cuts

Drill and blast design and methodology

The excavation of the box cuts in relation to the St Helena works can be broken into the following sequential tasks:

- Prepare access tracks and install erosion and sediment controls,
- Clear and grub,
- Topsoil strip,
- Strip other than rock (OTR);
- Blasting and excavation of rock.

A brief description of each of these tasks is shown within Table 13.

Table 13 - Description of box cut works

Task name	*Description*
Prepare access tracks and install erosion and sediment controls	Preparatory work to allow access to the work area and ensure that sediment will be controlled once works commence removing vegetation and exposing soil.
Clear and grub	Clear and grubbing involves the removal of vegetation from the work area including any necessary weed and disease controls.
Topsoil strip	The top soil strip is the removal of the top soil from the site which, depending on the quality of the soil and the presence of any weeds, may be reused for revegetation.
Strip other than rock (OTR)	Stripping other than rock (OTR) involves the removal of material that is not competent enough to require the use of blasting. Typically, this material is comprised of loosely compacted rock that can be mechanically excavated without the use of explosives or hydraulic hammers to assist breakage.
Blasting and excavation of rock	Blasting and excavation of rock is performed to remove material that is too strong to be excavated prior to being broken using controlled blasting techniques. Blasting is used for primary breakage where volumes are large and the use of rock breakers is impractical from a timing and resident impact perspective.

A summary of the construction schedule for the excavation of the box cuts including works that do not require controlled blasting methods can be seen in Table 14.

Table 14 - St Helena tunnel works box cut schedules

Task	*Southern portal time to complete*	*Northern portal time to complete*
Prepare access tracks and install erosion and sediment controls	4 weeks	2 weeks
Clear and grub	3 days	4 weeks
Topsoil strip	1 week	1 week

Strip other than rock (OTR)	2 weeks	2 weeks
Blasting and excavation of rock	6 weeks	3 weeks

It can also be noted that the blasting and excavation of the rock in the box cuts is generally undertaken in a series of benches that progressively allow the rock to be excavated down to the required design level for the Project.

The controlled blasting works in the box cuts are planned in order to comply with the current MCoA as well as Australian Standard 2187.2: Explosives — Storage and use — Part 2: Use of Explosives (AS2187.2). The primary factors that need to be controlled and managed in order to perform the blasting works safely and effectively are as follows:

- Public safety,
- Ground vibration limits,
- Airblast overpressure limits,
- Flyrock;
- Fragmentation.

Controlling each of these factors to allow safe and effective removal of the rock in the box cuts is performed by adjusting the following interrelated blasting parameters:

- Maximum instantaneous explosive charge,
- Drill hole diameter,
- Drill hole spacing,
- Drill hole depth,
- Stemming length,
- Decking of holes;
- Road closures.

It should be noted that above all else the works are planned to ensure the safety of the public and protection of property as well personnel undertaking the works.

Generally speaking, blasting operations are most efficient if they are being performed in areas where they are not restricted by ground vibration or airblast overpressure limits. For example, in remote large open-cut mines there may not be any nearby sensitive receivers and the maximum instantaneous charge can be optimised along with the drill depth, drill diameter and the stemming length to provide the best fragmentation of the rock. For clarity, the maximum instantaneous charge refers to the charge weight being detonated within an eight millisecond window and is the value used as the explosive quantity in modelling airblast overpressure and ground vibration.

The reason for optimising fragmentation is that the final blasted product should be fragmented in a way that is practical for the downstream uses. For example, if rock is over fragmented, during excavation there will be an unacceptably high level of dust generated. Conversely, if the rock is under fragmented the excavation equipment will not be able to handle the large boulders left over. Other factors include achieving a sizing that can be handled by any downstream crushing, milling or other processing operations. However, the fragmentation must also be optimised in a way that keeps the amount of drilling to a practical level so that operations can continue in an economic manner. For example, in the case of quarry aggregate for use in concrete production, while the final aggregate may be in the order of 10 millimetres, it is more efficient to blast the rock to a much larger size and then use a secondary means of breakage to achieve the final product.

For the box cuts at St Helena Hill, the primary objective in relation to fragmentation is to keep drilling to a minimum level, whilst ensuring fragmentation of the rock is to a level that it can be effectively handled by mechanical excavation equipment. The reason for this is that it will allow construction of the tunnels in the St Helena Hill to progress efficiently with as minimal impact to adjacent residents as possible through minimisation of the scope of works to be undertaken as greater efficiency in the operation is experienced.

In order to achieve the desired fragmentation, a certain amount of explosive energy must be imparted into the rock by each drill hole. The spacing between the drill holes will determine the amount of explosives required. However, the explosive energy must be contained within the rock. This is achieved through the use of stemming, which is a material that is placed on top of the explosive column in a drill hole to contain the explosive energy. If stemming is not present, the explosive energy will tend to mostly be lost as it takes the path of least resistance straight out of the top of the charged hole. Furthermore, if the stemming column is too small, there is a high risk of flyrock from the blast. However, if the column of stemming is too large, the energy will be completely contained and a crown of competent rock will remain. These situations are illustrated within Figure 11.

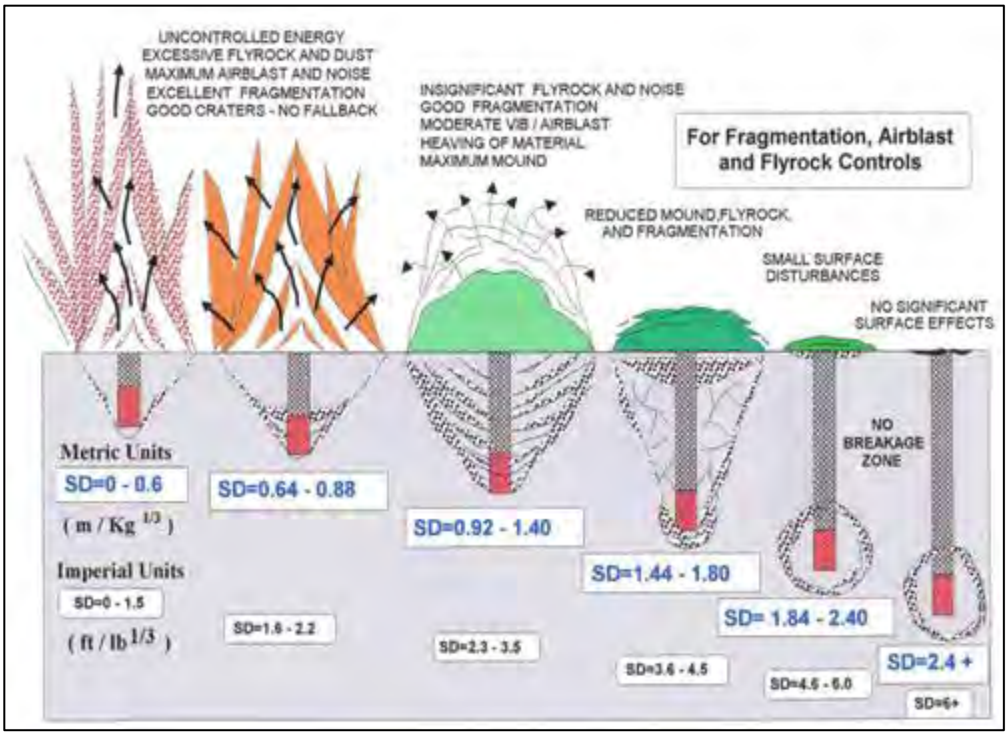


Figure 11 - Effect of stemming column on surface fragmentation and flyrock

As such, the amount of stemming must be carefully chosen so that there is adequate fragmentation above the explosive column whilst preventing flyrock. It can be seen within Figure 11 that the different flyrock and fragmentation scenarios are associated with a range of the variable 'SD'. SD in Figure 11 refers to the scaled depth of burial for the explosive charge. In order to determine the scaled depth of burial the following equation is used:

$$SD = \frac{D}{W^{\frac{1}{3}}}$$

Where;

SD = Scaled Depth of Burial
D = Distance from surface to centre of crater charge
W = Explosive weight of crater charge

Figure 12 illustrates the measurements used to determine the scaled depth of burial. In order to determine the explosive weight of the crater charge, the volume of the crater charge is multiplied by the density of the explosive used. It should be noted that in some cases, the depth of burial can be increased by the introduction of fill and the risk of flyrock reduced by the use of blast mats. These mitigation measures may be put in place if it is determined that there is a significant risk of flyrock whilst undertaking the risk assessment that will be completed for each blast.

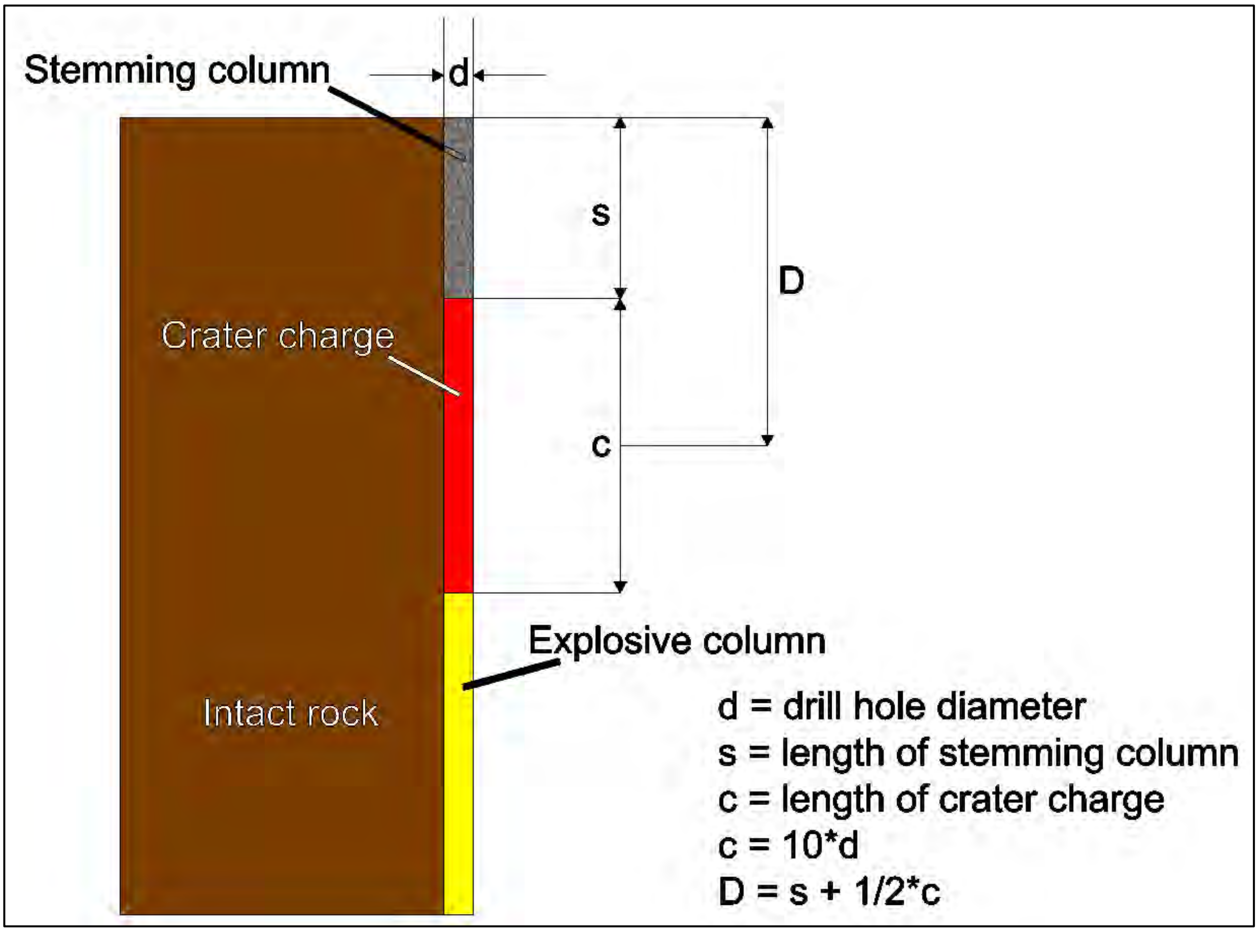


Figure 12 - Measurements to determine scaled depth of burial

From these formulas, it can be seen that given a particular hole diameter the desirable length of the stemming column can be back calculated to achieve the desired scaled depth of cover. However, this does not capture the entire picture in optimising the drilling pattern. This is because although it can be used to estimate the level of fragmentation at the surface, it would be inefficient to only blast the length of the crater charge due to increased use of detonating explosives, blast crew labour, and number of holes drilled as well as underutilising the earth moving equipment for each blast. As such, the available equipment, the vibration and airblast restrictions and the requirement to achieve a desirable level of fragmentation throughout the blast will determine the optimum drill hole length, drill hole diameter and stemming length for the final drill pattern. In general, the trade-offs in performing these calculations involve finding a drill hole diameter that will allow a bench of suitable depth for the equipment to be utilised effectively, whilst keeping the maximum instantaneous charge at a level that will not produce excess vibrations and is not overly conservative resulting in significantly more drill holes.

In the case of the St Helena box cuts, given the current MCoA, the optimum drill diameter was determined to be 76 millimetres. This was determined based on allowing the construction to be completed efficiently and for the blasting activities to comply with the MCoA in relation of vibration and airblast as well as the safety requirements to minimise flyrock and ensure public safety.

One additional mitigation measure that will be implemented in relation to the subject box cut blasting will be blast hole decking. Blast hole decking involves creating a separation within a single drill hole so that it effectively contains two or more separate charges. These separate charges are detonated at different times so that the maximum instantaneous charge and hence the vibration and airblast at sensitive receivers is reduced while exploiting the productivity increases from having increased hole lengths.

A diagram of a decked blast hole is shown in Figure 13.

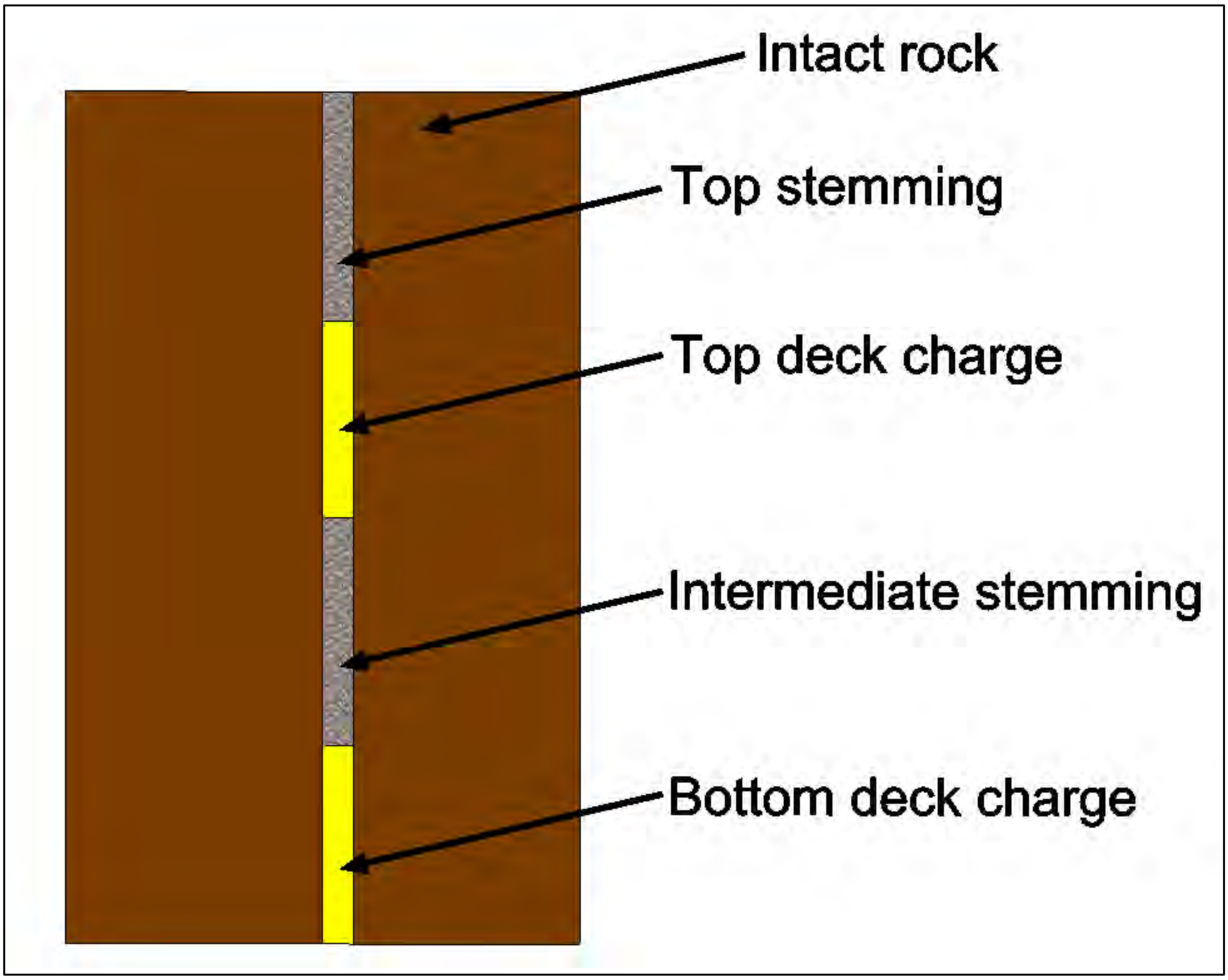


Figure 13 - Schematic of decked blast holes

Given the increased productivity from decked blast holes in areas where vibration is constrained, the box cuts for the St Helena tunnel works will be blasted using decked blast holes. Each hole is currently planned to be six metres deep with two explosive charges. In some cases, the holes will be less than six metres so that the floor of the bench is on the same elevation so that the next shot can be undertaken from a flat working area to improve safety and productivity.

In summary, the bench height and drill patterns for the box cuts have been designed so that they minimise impacts to adjacent residences as much as possible while maximising productivity within the box cuts and therefore the delivery of the Project in the interests of the community and other stakeholders.

Planned southern portal excavation sequencing

For the excavation at the southern portal, the box cut at the portal will require the drill and blast excavation of 30640 cubic metres of material. A 3-dimensional model of the material requiring blasting is shown in Figure 14.

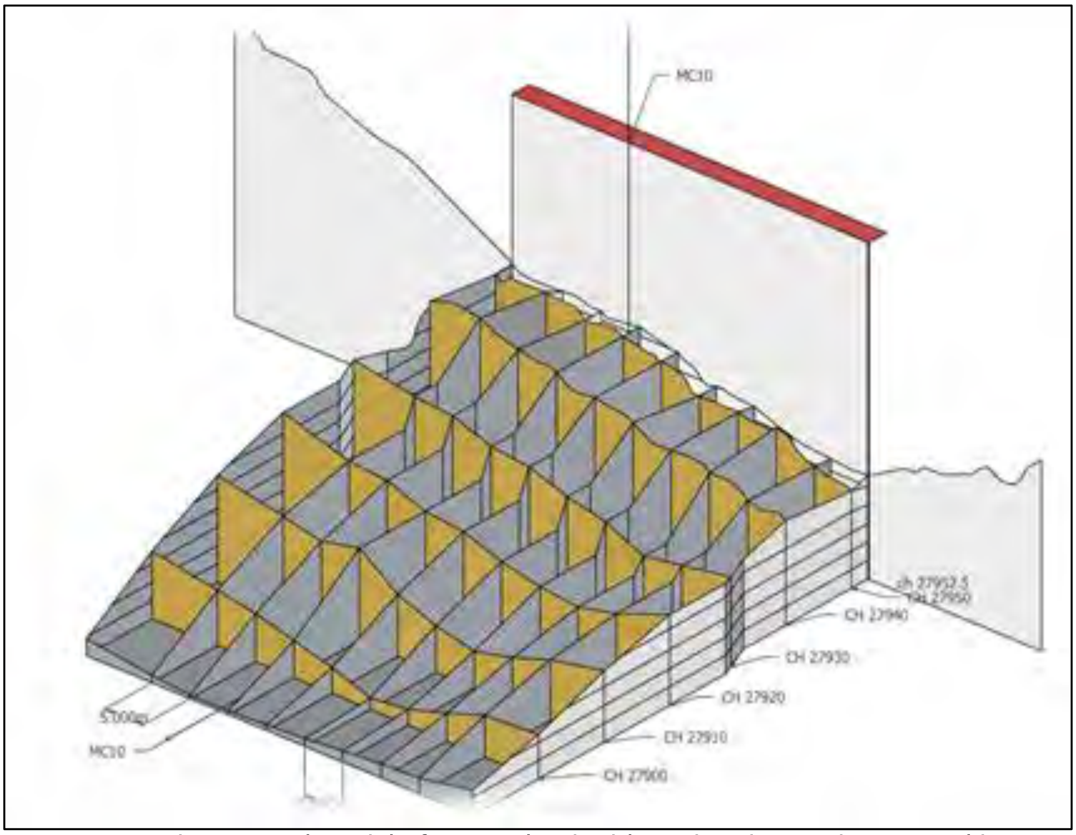


Figure 14 - 3-dimensional model of material to be blasted at the southern portal box cut

It can be seen from the model that the topography of the box cut is highly uneven. To effectively remove the material blasting is performed in sections (also known as benches) that maintain access for the equipment and progressively create a larger, level working area to allow production to continue in the following sequence:

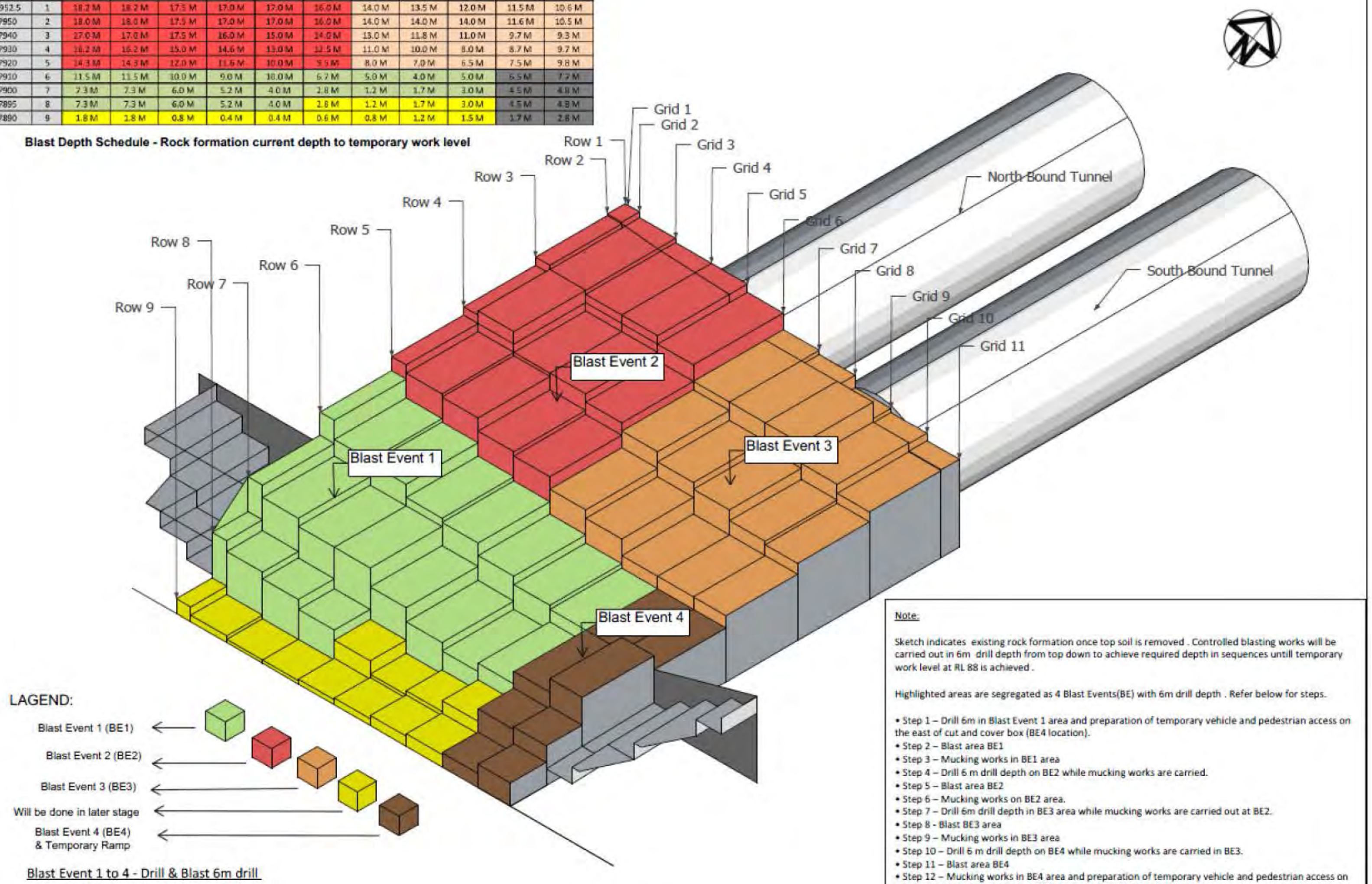
- A designed pattern of vertical holes are drilled using drilling equipment,
- Each hole is filled with the designed amount of explosive and stemmed with an appropriate amount of material to control airblast and flyrock,
- A section of material is blasted so that it can be removed by excavation equipment;
- Material is removed and the floor of the bench is prepared for the next drill pattern.

In order to maximise the efficiency of the works, the blasts need to be scheduled in such a way so to allow the drilling, loading and excavating equipment to be utilised effectively throughout work hours. This is generally achieved by sequencing benches into several smaller blasts so that each class of equipment can operate in a separate area.

The sequencing for the drill and blast works and the sequence of work areas based on the designs to comply with the current MCoA can be seen within Figures 15 to 18.

Chainage	Row	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	Grid 8	Grid 9	Grid 10	Grid 11
27952.5	1	18.2 M	18.2 M	17.5 M	17.0 M	17.0 M	16.0 M	14.0 M	13.5 M	12.0 M	11.5 M	10.6 M
27950	2	18.0 M	18.0 M	17.5 M	17.0 M	17.0 M	16.0 M	14.0 M	14.0 M	14.0 M	11.6 M	10.5 M
27940	3	27.0 M	17.0 M	17.5 M	16.0 M	15.0 M	14.0 M	13.0 M	11.8 M	11.0 M	9.7 M	9.3 M
27930	4	16.2 M	16.2 M	15.0 M	14.6 M	13.0 M	12.5 M	11.0 M	10.0 M	8.0 M	8.7 M	9.7 M
27920	5	14.3 M	14.3 M	12.0 M	11.6 M	10.0 M	9.5 M	8.0 M	7.0 M	6.5 M	7.5 M	9.8 M
27910	6	11.5 M	11.5 M	10.0 M	9.0 M	10.0 M	6.7 M	5.0 M	4.0 M	5.0 M	6.5 M	7.2 M
27900	7	7.3 M	7.3 M	6.0 M	5.2 M	4.0 M	2.8 M	1.2 M	1.7 M	3.0 M	4.5 M	4.8 M
27895	8	7.3 M	7.3 M	6.0 M	5.2 M	4.0 M	2.8 M	1.2 M	1.7 M	3.0 M	4.5 M	4.8 M
27890	9	1.8 M	1.8 M	0.8 M	0.4 M	0.4 M	0.6 M	0.8 M	1.2 M	1.5 M	1.7 M	2.8 M

Blast Depth Schedule - Rock formation current depth to temporary work level



Note:

Sketch indicates existing rock formation once top soil is removed . Controlled blasting works will be carried out in 6m drill depth from top down to achieve required depth in sequences untill temporary work level at RL 88 is achieved .

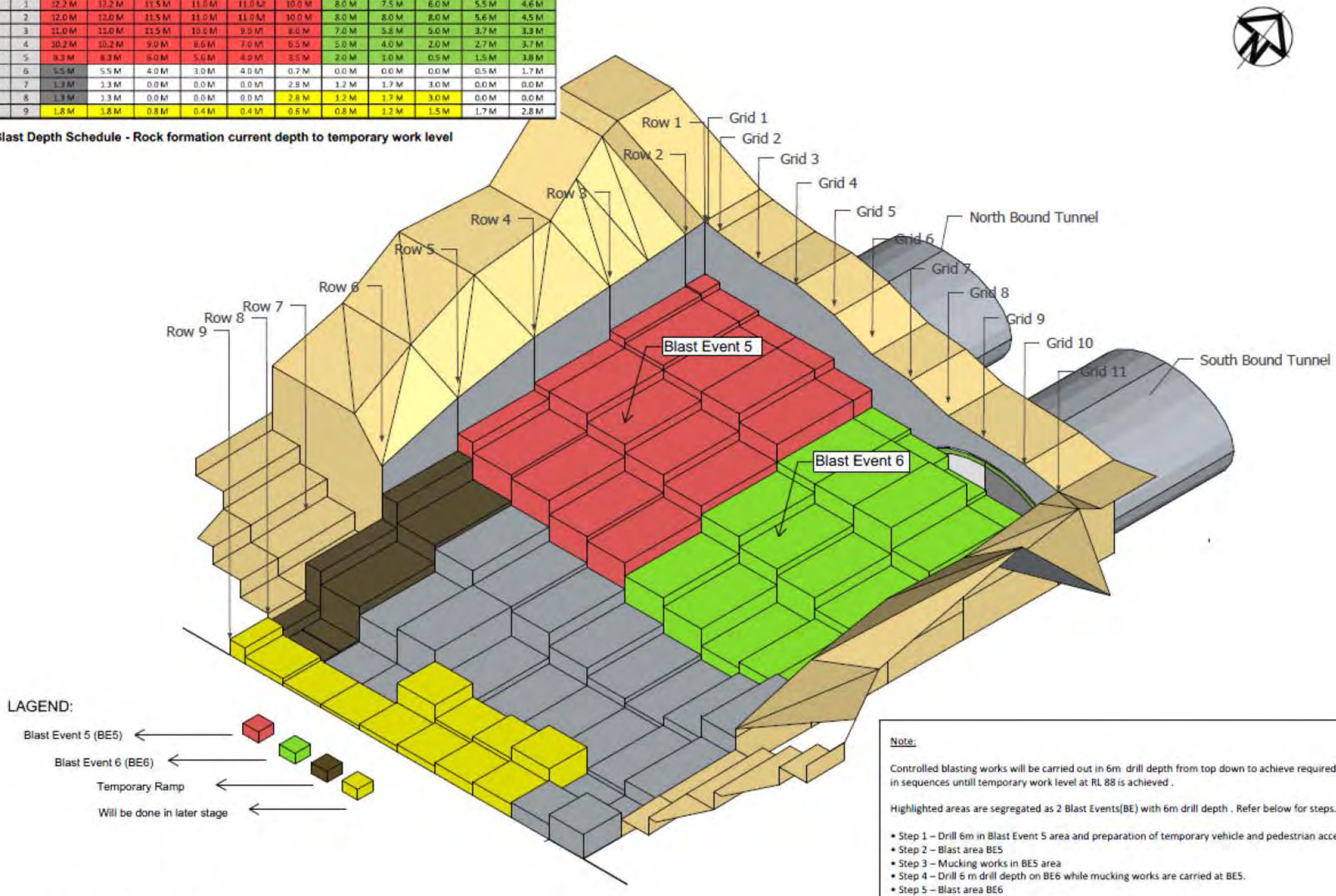
Highlighted areas are segregated as 4 Blast Events(BE) with 6m drill depth . Refer below for steps.

- Step 1 – Drill 6m in Blast Event 1 area and preparation of temporary vehicle and pedestrian access on the east of cut and cover box (BE4 location).
- Step 2 – Blast area BE1
- Step 3 – Mucking works in BE1 area
- Step 4 – Drill 6 m drill depth on BE2 while mucking works are carried.
- Step 5 – Blast area BE2
- Step 6 – Mucking works on BE2 area.
- Step 7 – Drill 6m drill depth in BE3 area while mucking works are carried out at BE2.
- Step 8 - Blast BE3 area
- Step 9 – Mucking works in BE3 area
- Step 10 – Drill 6 m drill depth on BE4 while mucking works are carried in BE3.
- Step 11 – Blast area BE4
- Step 12 – Mucking works in BE4 area and preparation of temporary vehicle and pedestrian access on the west of cut and cover box. Refer next page for further details.

Figure 15 – Blast event 1 to blast event 4 for the southern portal box cut

Chainage	Row	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	Grid 8	Grid 9	Grid 10	Grid 11
27952.5	1	12.2 M	12.2 M	11.5 M	11.0 M	11.0 M	10.0 M	8.0 M	7.5 M	6.0 M	5.5 M	4.6 M
27950	2	12.0 M	12.0 M	11.5 M	11.0 M	11.0 M	10.0 M	8.0 M	8.0 M	8.0 M	5.6 M	4.5 M
27940	3	11.0 M	11.0 M	11.5 M	10.0 M	9.0 M	8.0 M	7.0 M	5.8 M	5.0 M	3.7 M	3.3 M
27930	4	10.2 M	10.2 M	9.0 M	8.6 M	7.0 M	6.5 M	5.0 M	4.0 M	2.0 M	2.7 M	3.7 M
27920	5	8.3 M	8.3 M	6.0 M	5.6 M	4.0 M	3.5 M	2.0 M	1.0 M	0.5 M	1.5 M	3.8 M
27910	6	5.5 M	5.5 M	4.0 M	3.0 M	4.0 M	0.7 M	0.0 M	0.0 M	0.0 M	0.5 M	1.7 M
27900	7	1.3 M	1.3 M	0.0 M	0.0 M	0.0 M	2.8 M	1.2 M	1.7 M	3.0 M	0.0 M	0.0 M
27895	8	1.3 M	1.3 M	0.0 M	0.0 M	0.0 M	2.8 M	1.2 M	1.7 M	3.0 M	0.0 M	0.0 M
27890	9	1.8 M	1.8 M	0.8 M	0.4 M	0.4 M	0.6 M	0.8 M	1.2 M	1.5 M	1.7 M	2.8 M

Blast Depth Schedule - Rock formation current depth to temporary work level



Blast Event 5 to 6 - Drill & Blast 6m drill depth.

Note:

Controlled blasting works will be carried out in 6m drill depth from top down to achieve required depth in sequences untill temporary work level at RL 88 is achieved .

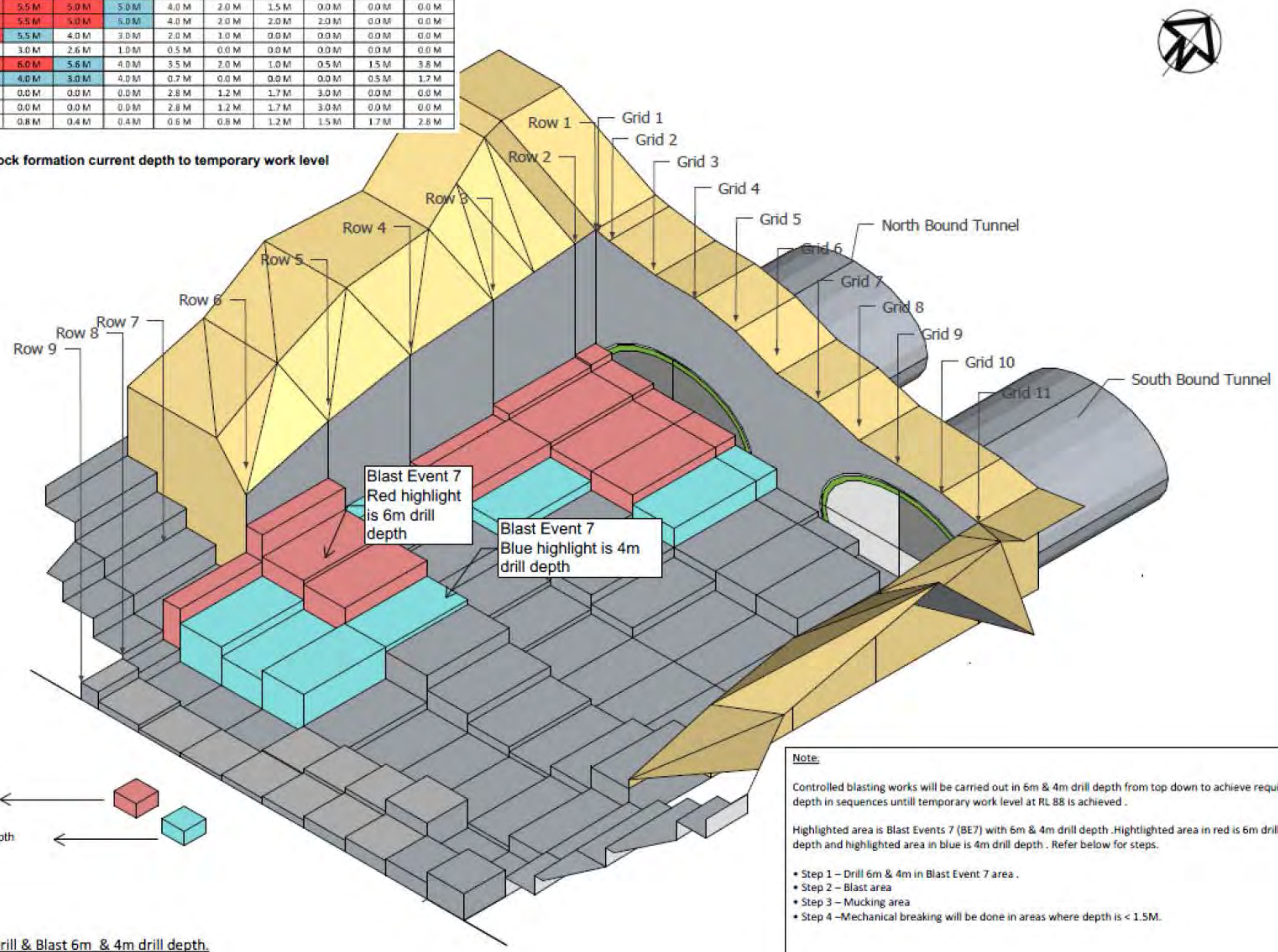
Highlighted areas are segregated as 2 Blast Events(BE) with 6m drill depth . Refer below for steps.

- Step 1 – Drill 6m in Blast Event 5 area and preparation of temporary vehicle and pedestrian access on
- Step 2 – Blast area BE5
- Step 3 – Mucking works in BE5 area
- Step 4 – Drill 6 m drill depth on BE6 while mucking works are carried at BE5.
- Step 5 – Blast area BE6
- Step 6 – Mucking works on BE6 area.

Figure 16 - Blast event 5 and blast event 6 for the southern portal box cut

Chainage	Row	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	Grid 8	Grid 9	Grid 10	Grid 11
27952.5	1	6.2 M	6.2 M	5.5 M	5.0 M	5.0 M	4.0 M	2.0 M	1.5 M	0.0 M	0.0 M	0.0 M
27950	2	6.0 M	6.0 M	5.5 M	5.0 M	5.0 M	4.0 M	2.0 M	2.0 M	2.0 M	0.0 M	0.0 M
27940	3	5.0 M	5.0 M	5.5 M	4.0 M	3.0 M	2.0 M	1.0 M	0.0 M	0.0 M	0.0 M	0.0 M
27930	4	4.2 M	4.2 M	3.0 M	2.6 M	1.0 M	0.5 M	0.0 M	0.0 M	0.0 M	0.0 M	0.0 M
27920	5	8.3 M	8.3 M	6.0 M	5.6 M	4.0 M	3.5 M	2.0 M	1.0 M	0.5 M	1.5 M	3.8 M
27910	6	5.5 M	5.5 M	4.0 M	3.0 M	4.0 M	0.7 M	0.0 M	0.0 M	0.0 M	0.5 M	1.7 M
27900	7	1.3 M	1.3 M	0.0 M	0.0 M	0.0 M	2.8 M	1.2 M	1.7 M	3.0 M	0.0 M	0.0 M
27895	8	1.3 M	1.3 M	0.0 M	0.0 M	0.0 M	2.8 M	1.2 M	1.7 M	3.0 M	0.0 M	0.0 M
27890	9	1.8 M	1.8 M	0.8 M	0.4 M	0.4 M	0.6 M	0.8 M	1.2 M	1.5 M	1.7 M	2.8 M

Blast Depth Schedule - Rock formation current depth to temporary work level



LAGEND:

Blast Event 7 (BE7) 6m drill depth

Blast Event 7 (BE7) 4m drill depth

Blast Event 7 - Drill & Blast 6m & 4m drill depth.

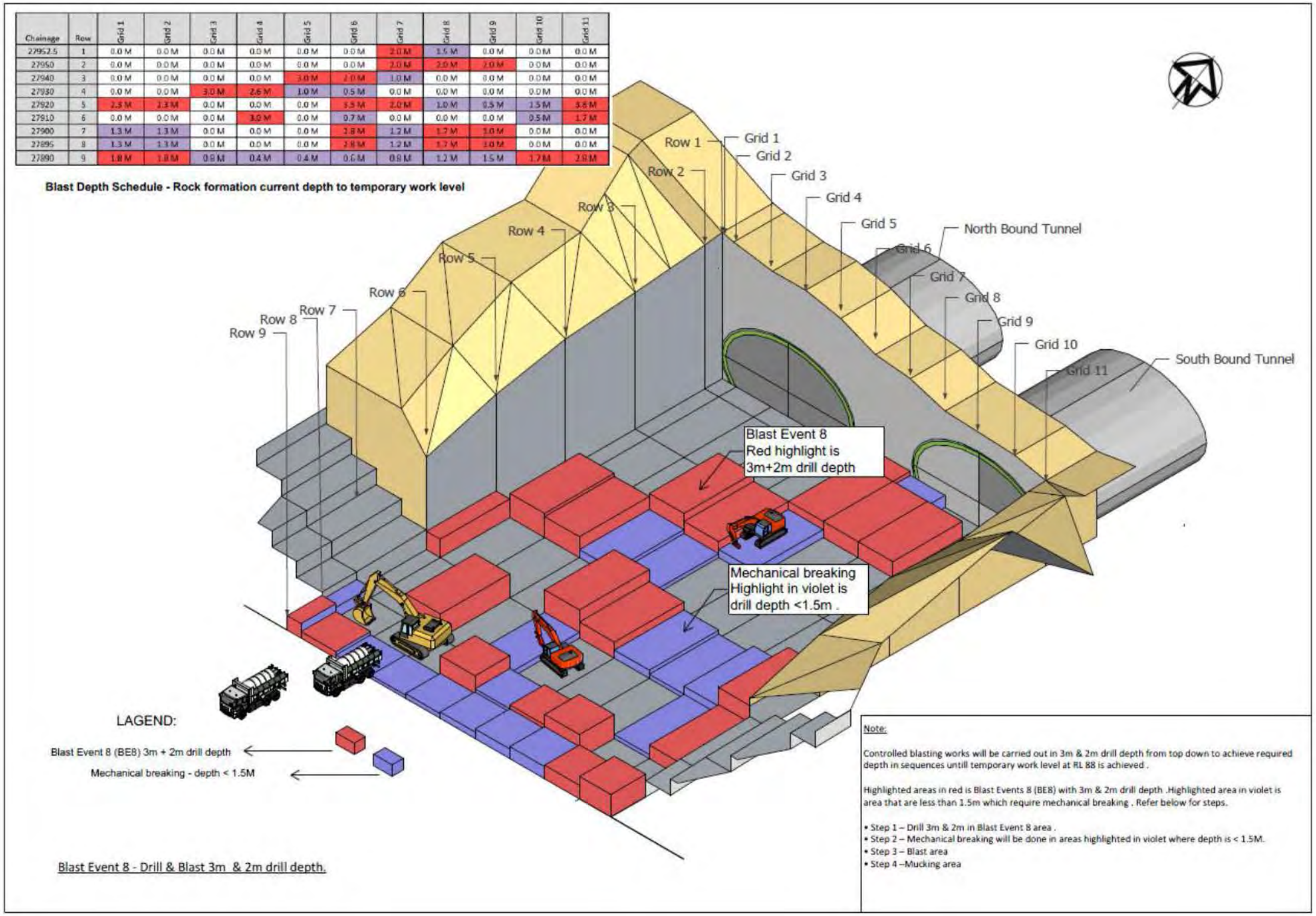
Note:

Controlled blasting works will be carried out in 6m & 4m drill depth from top down to achieve required depth in sequences untill temporary work level at RL 88 is achieved .

Highlighted area is Blast Events 7 (BE7) with 6m & 4m drill depth .Hightlighted area in red is 6m drill depth and highlighted area in blue is 4m drill depth . Refer below for steps.

- Step 1 – Drill 6m & 4m in Blast Event 7 area .
- Step 2 – Blast area
- Step 3 – Mucking area
- Step 4 –Mechanical breaking will be done in areas where depth is < 1.5M.

Figure 17 - Blast event 7 for southern portal box cut



Chainage	Row	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	Grid 8	Grid 9	Grid 10	Grid 11
27952.5	1	0.0 M	0.0 M	0.0 M	0.0 M	0.0 M	0.0 M	2.0 M	1.5 M	0.0 M	0.0 M	0.0 M
27950	2	0.0 M	0.0 M	0.0 M	0.0 M	0.0 M	0.0 M	2.0 M	2.0 M	2.0 M	0.0 M	0.0 M
27940	3	0.0 M	0.0 M	0.0 M	0.0 M	3.0 M	2.0 M	1.0 M	0.0 M	0.0 M	0.0 M	0.0 M
27930	4	0.0 M	0.0 M	3.0 M	2.6 M	1.0 M	0.5 M	0.0 M	0.0 M	0.0 M	0.0 M	0.0 M
27920	5	2.5 M	2.3 M	0.0 M	0.0 M	0.0 M	3.5 M	2.0 M	1.0 M	0.5 M	1.5 M	3.8 M
27910	6	0.0 M	0.0 M	0.0 M	3.0 M	0.0 M	0.7 M	0.0 M	0.0 M	0.0 M	0.5 M	1.7 M
27900	7	1.3 M	1.3 M	0.0 M	0.0 M	0.0 M	2.8 M	1.2 M	1.7 M	3.0 M	0.0 M	0.0 M
27895	8	1.3 M	1.3 M	0.0 M	0.0 M	0.0 M	2.8 M	1.2 M	1.7 M	3.0 M	0.0 M	0.0 M
27890	9	1.8 M	1.8 M	0.9 M	0.4 M	0.4 M	0.6 M	0.8 M	1.2 M	1.5 M	1.7 M	2.8 M

Figure 18 - Blast event 8 and mechanical final trimming for southern portal box cut

Planned northern portal excavation sequencing

For the excavation at the northern portal, the box cut at the portal will require the drill and blast excavation of 14129 cubic metres of material. A 3-dimensional model of the material requiring blasting is shown within Figure 19.

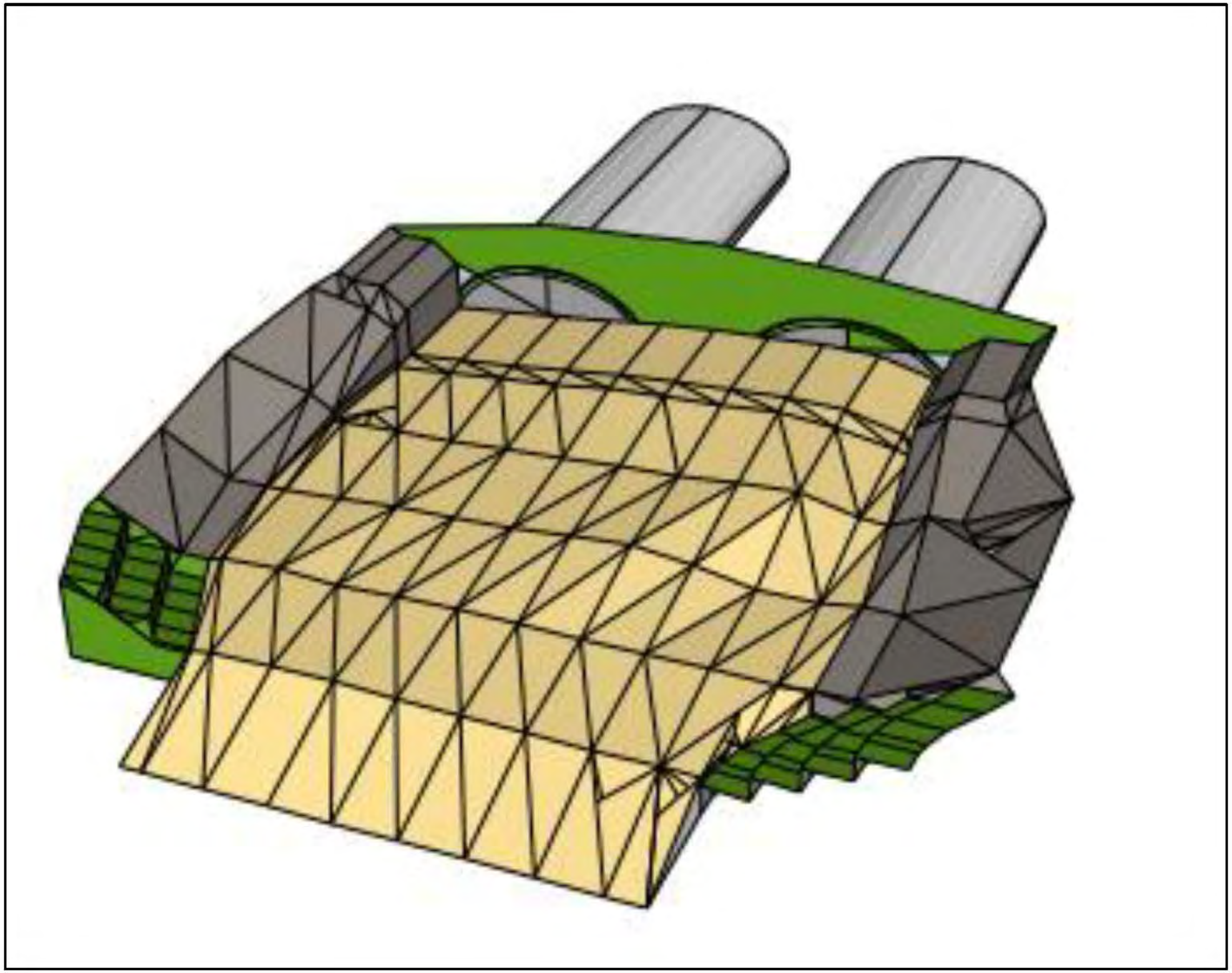


Figure 19 - 3-dimensional model of material to be blasted at the northern portal box cut

It can be seen from the model for the material to be blasted at the northern portal that the expected topography is significantly more regular than that at the southern portal. The effect of this is that the blasting can be staged in fewer blast events. The blasts at the northern portal will be staged in three blasts progressing from north to south in order to utilise the equipment effectively. The sequencing of works will follow the same sequence as that for the southern portal as listed below:

- A designed pattern of vertical holes are drilled using drilling equipment,
- Each hole is filled with the designed amount of explosive and stemmed with an appropriate amount of material to control airblast and flyrock,
- A section of material is blasted so that it can be removed by excavation equipment;
- Material is removed and the floor of the bench is prepared for the next drill pattern.

Current sequencing for the drill and blast works at the northern portal box cut can be seen within Figure 20 to Figure 22.

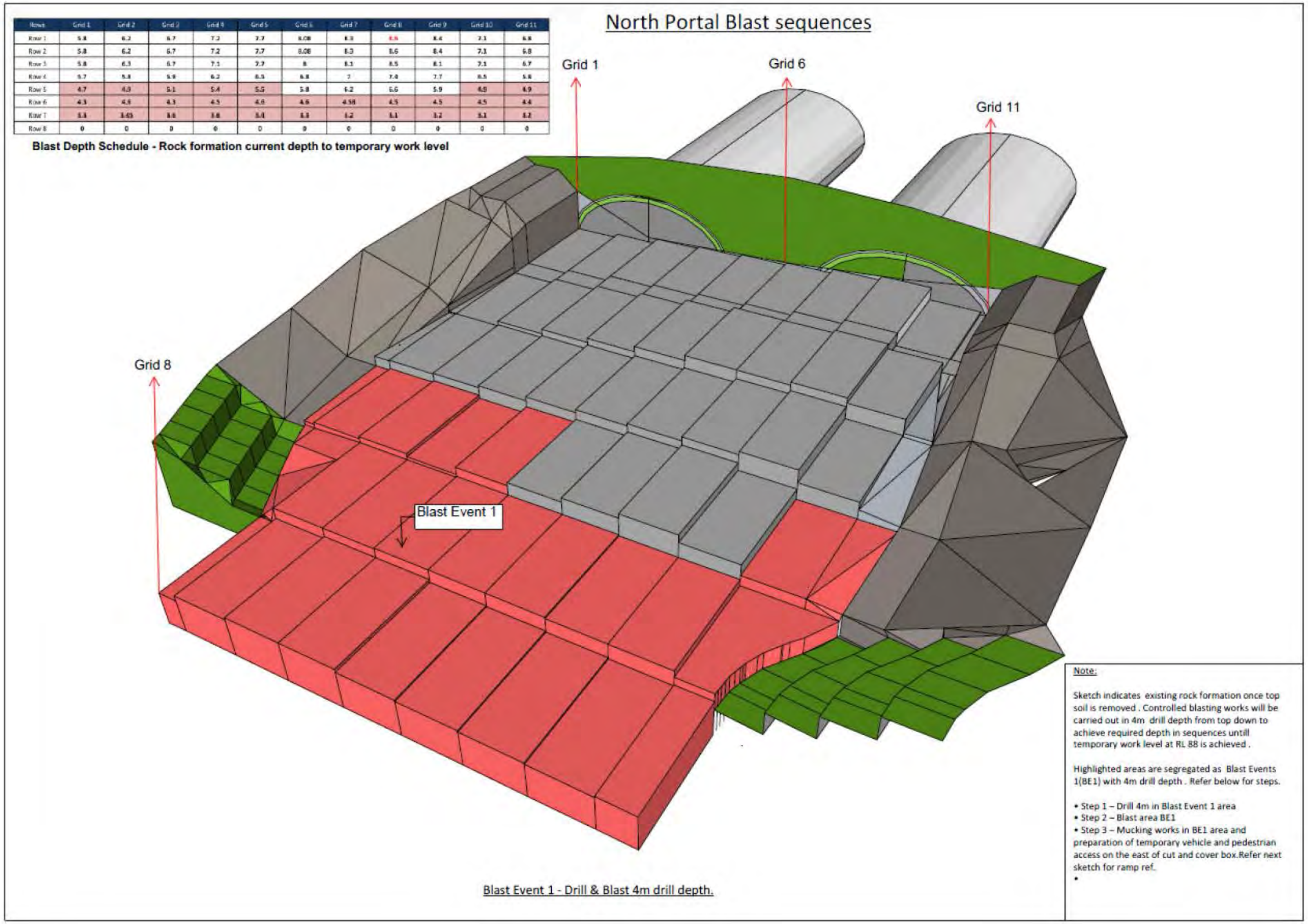
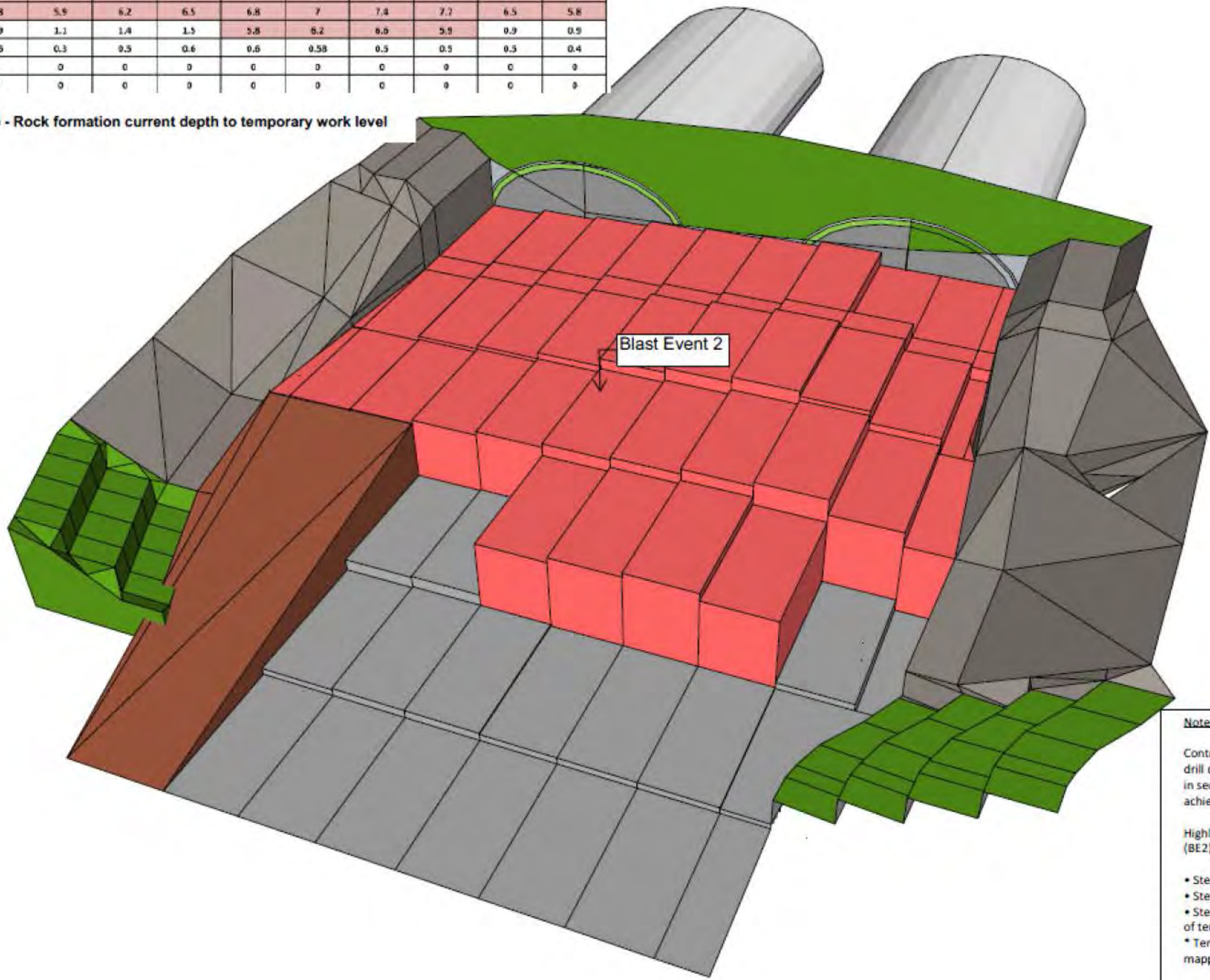


Figure 20 - Blast event 1 for northern portal box cut

Rows	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	Grid 8	Grid 9	Grid 10	Grid 11
Row 1	5.8	6.2	6.7	7.2	7.7	8.08	8.3	8.6	8.4	7.1	6.8
Row 2	5.8	6.2	6.7	7.2	7.7	8.08	8.3	8.6	8.4	7.1	6.8
Row 3	5.8	6.3	6.7	7.1	7.7	8	8.1	8.5	8.1	7.1	6.7
Row 4	5.7	5.8	5.9	6.2	6.5	6.8	7	7.4	7.7	6.5	5.8
Row 5	0.7	0.9	1.1	1.4	1.5	5.8	6.2	6.6	5.9	0.9	0.9
Row 6	0.3	0.6	0.3	0.5	0.6	0.6	0.58	0.5	0.5	0.5	0.4
Row 7	0	0	0	0	0	0	0	0	0	0	0
Row 8	0	0	0	0	0	0	0	0	0	0	0

Blast Depth Schedule - Rock formation current depth to temporary work level

North Portal Blast sequences



Note:

Controlled blasting works will be carried out in 6m drill depth from top down to achieve required depth in sequences untill temporary work level at RL 88 is achieved .

Highlighted areas are segregated as Blast Events 2 (BE2) with 6m drill depth . Refer below for steps.

- Step 1 – Drill 6m in Blast Event 2 area
- Step 2 – Blast area BE2
- Step 3 – Mucking works in BE2 area and removal of temporary vehicle and pedestrian access.

* Temporary support will be installed based on rock mapping and geologist advise.

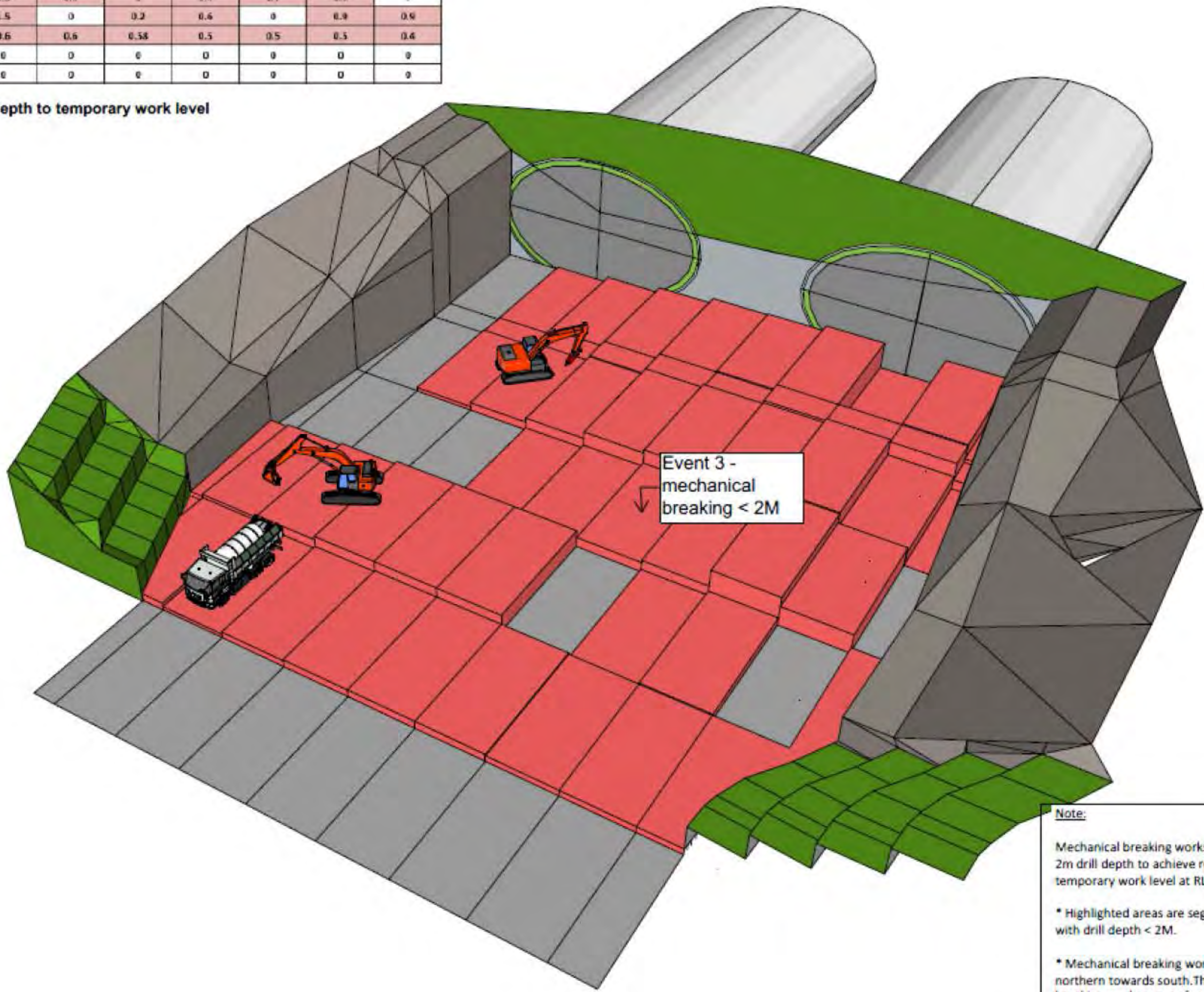
Blast Event 2 - Drill & Blast 6m drill depth.

Figure 21 - Blast event 2 for northern portal box cut

Rows	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Grid 7	Grid 8	Grid 9	Grid 10	Grid 11
Row 1	0	0.2	0.7	1.2	1.7	2.08	2.3	2.6	2.4	1.1	0.8
Row 2	0	0.2	0.7	1.2	1.7	2.08	2.3	2.6	2.4	1.1	0.8
Row 3	0	0.3	0.7	1.1	1.7	2	2.1	2.5	2.1	1.1	0.7
Row 4	0	0	0	0.2	0.5	0.8	1	1.4	1.7	0.5	0
Row 5	0.7	0.9	1.1	1.4	1.5	0	0.2	0.6	0	0.9	0.9
Row 6	0.3	0.6	0.3	0.5	0.6	0.6	0.58	0.5	0.5	0.5	0.4
Row 7	0	0	0	0	0	0	0	0	0	0	0
Row 8	0	0	0	0	0	0	0	0	0	0	0

Blast Depth Schedule - Rock formation current depth to temporary work level

North Portal Blast sequences



Note:

Mechanical breaking works will be carried out in > 2m drill depth to achieve required depth untill temporary work level at RL 88 is achieved .

* Highlighted areas are segregated as Events 3 (BE3) with drill depth < 2M.

* Mechanical breaking works will be done from northern towards south.These is to clear mucking as breaking works moves forward .

* Temporary support will be installed based on rock mapping and geologist advise.

Event 3 - Mechanical breaking < 2M drill depth.

Figure 22 – Final mechanical trimming for northern portal box cut

4.4.3 Tunnel control centre

The Tunnel Control Centre (TCC) requires the excavation of approximately 12,000 cubic metres of competent rock to house the completed building and deluge tanks. This site is particularly sensitive due to its close proximity to nearby residences. The nearest residence to the TCC site is 30 metres. However, the residence is approximately 40 metres from any areas of potential blasting.

The depth of the excavation for the TCC varies in both Cross Section and in Long Section. In areas where the depth of earthworks is very low, hydraulic rock breakers would likely be used to remove any rock. The reason for this is that at very shallow depths blasting is often impractical and therefore the removal of this material requires hammering. However, breakage using rock hammers is extremely disruptive to the community in terms of noise and vibration. As such, the preference is to use controlled blasting as much as practically possible, whilst ensuring the safety and amenity of nearby residences is maintained as well as ensuring compliance with relevant blasting restrictions such as those prescribed by the MCoA. This may include measures such as introducing fill to control flyrock as well as blast mats, drill hole decking and possible temporary barriers.

The profile of the excavation for the TCC can be seen in Figure 23 as well as a geological section of the TCC in Figure 25. The location of this section is shown in Figure 24.

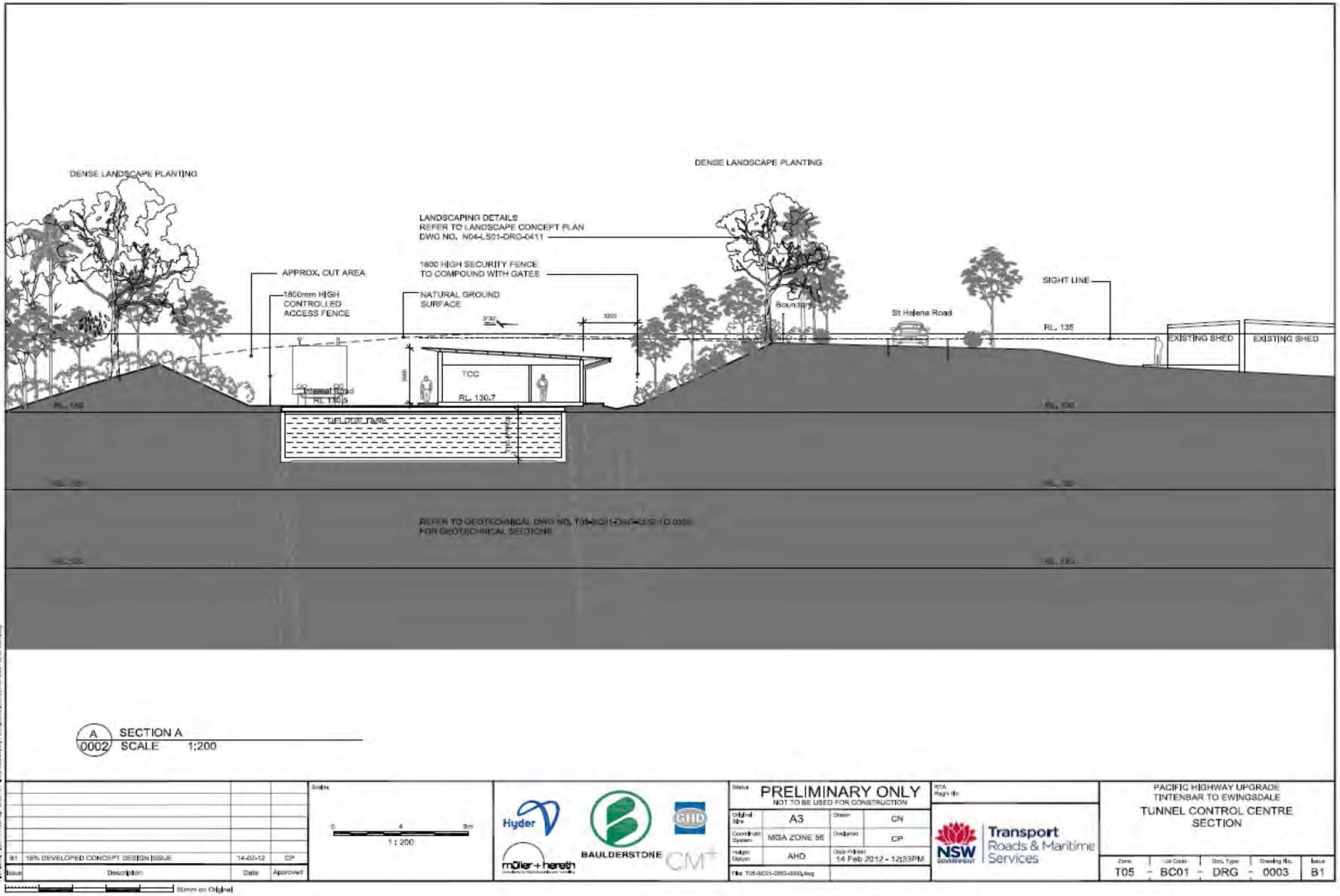


Figure 23 - Cross-sectional profile of completed TCC

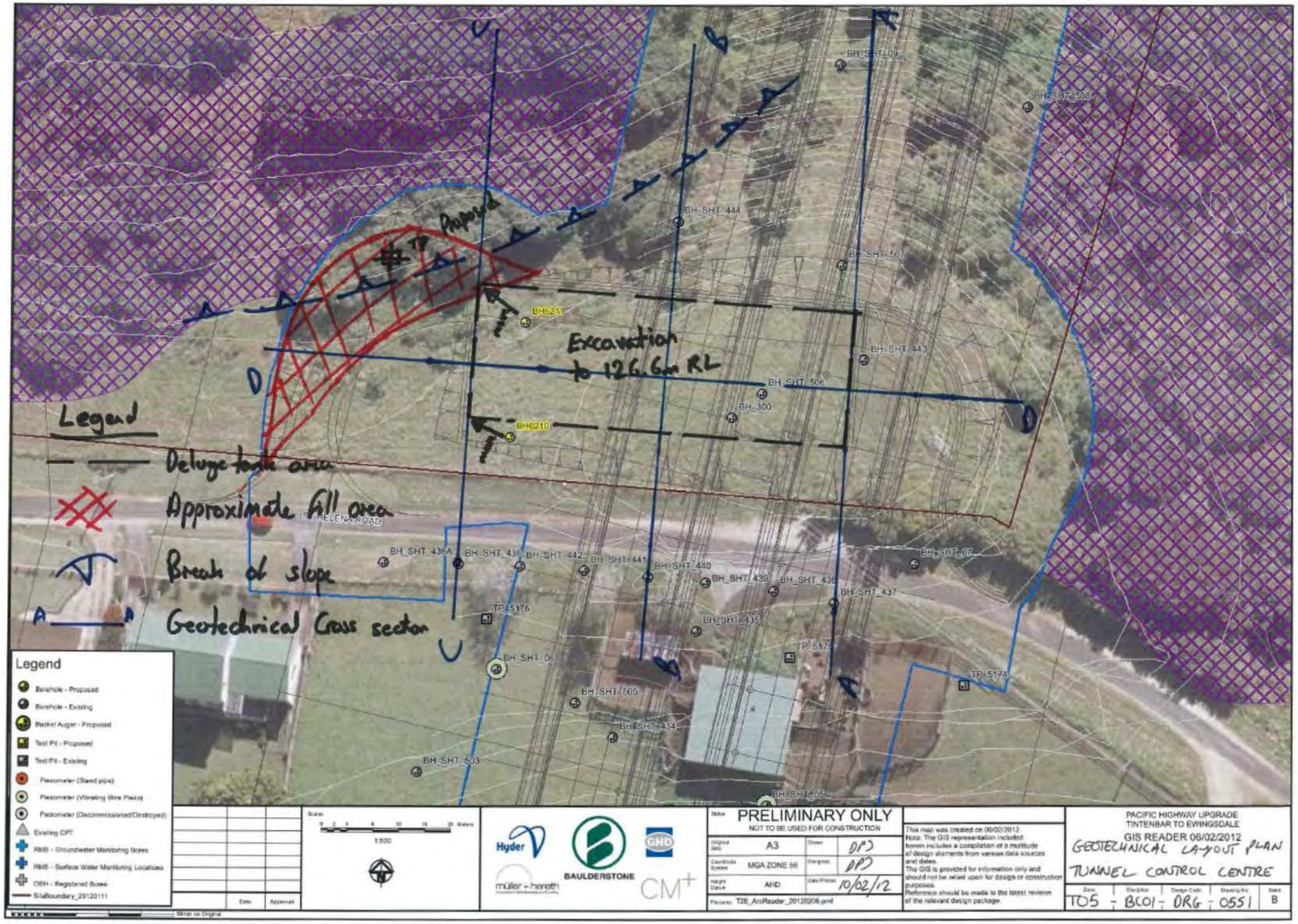


Figure 24 - Location of geological cross sections

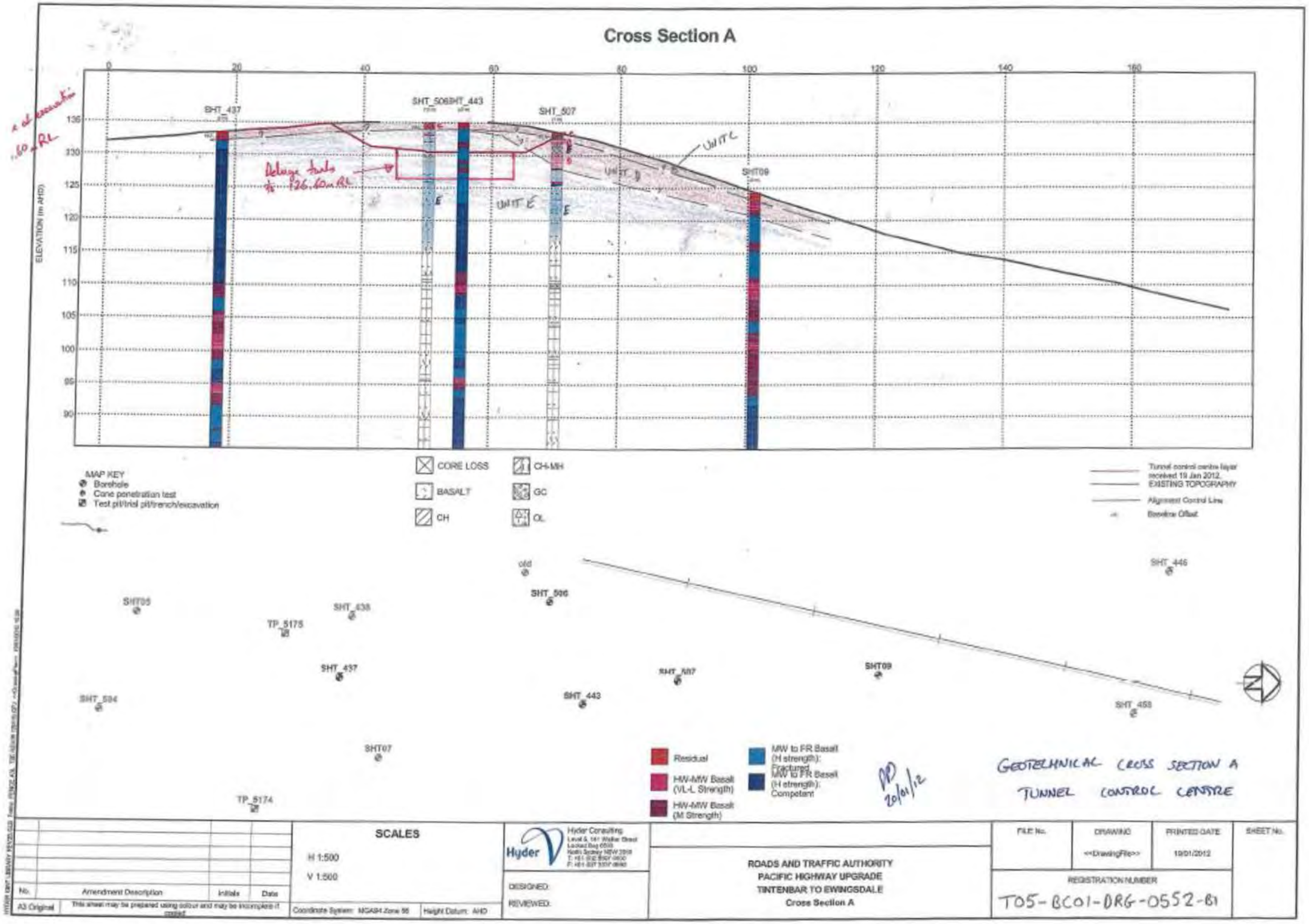


Figure 25 - Geological Cross Section A of TCC excavation

The geological section shows that the majority of the excavation for the TCC is undertaken in high strength basalt (shown in diagrams as Type E). As previously mentioned, the high strength basalts require either controlled blasting or hydraulic hammering to remove. The principles behind any controlled blasting at the TCC are the same as those for the box cuts. In areas where blasting is practical, controls will be put in place to ensure compliance with the MCoA as well as to ensure that flyrock is managed. The extent of the controls will be determined through a risk assessment process undertaken for each individual blast. It is expected that controls may include measures such as importing fill as well as blast mats to control flyrock depending on information that is obtained during the excavation of the box cuts on the geological performance during blasting.

Once broken, the removal of spoil will be undertaken using conventional excavation equipment. It is expected that these works will require extensive traffic control along St Helena Road due to truck movements and movement of plant to and from the TCC area.

To determine the suitability of blasting of the TCC area, the charge weights required to comply with the current MCoA for vibration were modelled by Heilig and Partners on behalf of Baulderstone Pty Ltd (BPL). The results of this modelling are shown within Figure 26. From this modelling, it can be seen that due to the proximity of the excavation area to the sensitive receivers along St Helena Road, in order to comply with the current MCoA for vibration, the charge weights for approximately half of the excavation would need to be below two kilograms. Charge weights below two kilograms are impractical for blasting as the required length of stemming to control flyrock would result in an insufficiently long explosive column to fracture only a small band of rock well below the unbroken surface. As a result of this, hydraulic hammering would be required to be undertaken for a large amount of the excavation.

The disruptive and noisy nature of hydraulic hammering and the vicinity of the TCC to sensitive receivers would result in far greater noise impacts to local residents than a combination of efficient blasting through the subject modification with respective minimisation rock breaking.

Given the expected conditions, the excavation of the rock for the construction of the TCC is expected to take approximately 12 weeks with compliance to the existing MCoA, six weeks more than predicted with the proposed modification to the MCoA.

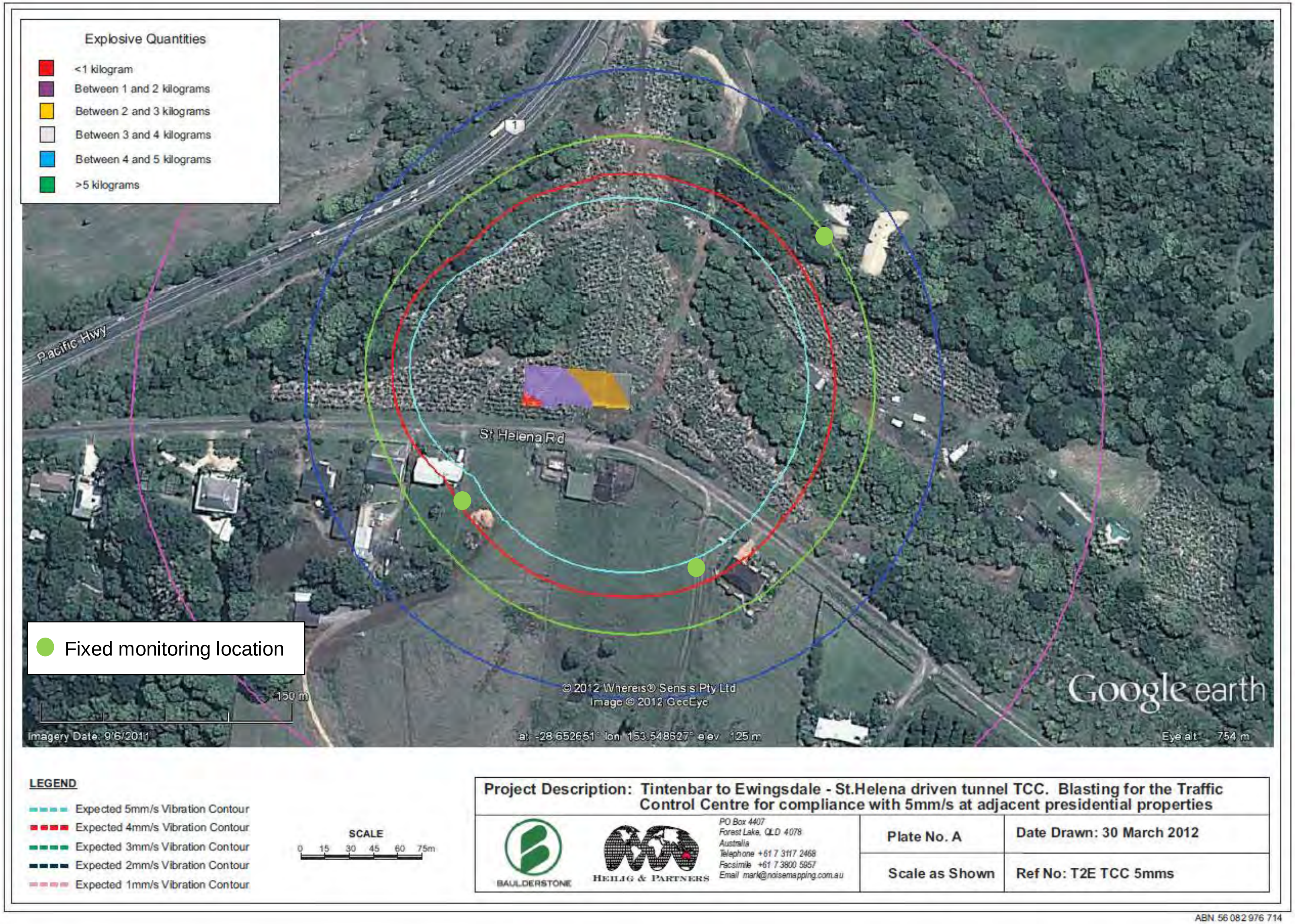


Figure 26 - Maximum explosive charge weights to comply with current MCoA limits

4.5 Determination of Proposed Limits

4.5.1 Airblast overpressure

The revised airblast overpressure limits as proposed within this report were chosen to achieve the following goals:

- To maintain safety and amenity of the area in relation to the public and property,
- To facilitate optimum efficiency in excavation associated with the works, thereby reducing the duration of the impact of the works on nearby residences;
- To reduce the scope of high impact works on nearby residences such as mechanical excavation through rock hammering.

With regard to ensuring compliance with the first goal, BPL consulted blast engineering experts from Heilig and Partners and reviewed relevant literature to determine safe levels of airblast overpressure to ensure the safety of public and property. It was determined from this that the lowest airblast overpressure level at which damage can occur is approximately 136 decibels. Note that the damage incurred at this level pertains to superficial damage such as cracking in windows and not structural damage.

It was determined that the upper overpressure limit should be a level of energy at least 100 per cent less than 136 decibels to ensure a factor of safety of at least 2. Given that overpressure is measured on a logarithmic scale, a factor of safety of 2 relates to an overpressure level of 133 decibels. This is not the proposed limit as further investigation determined that overpressure levels to achieve the other goals are lower than 133 decibels.

Currently, excavation associated with the subject works requires a significant amount of rock hammering. These activities are expected to produce high levels of noise and take an extended time to complete, impacting significantly on residences nearby to the works. To reduce the impacts of rock hammering, it is necessary to revise the limits associated with blasting activities. Given the relatively close proximity of residences to the works, investigations showed that with maximised blasting volumes the highest expected overpressure at the nearest sensitive receiver would be approximately 125 decibels. This limit is higher than those previously granted for other Pacific Highway upgrades and this is likely due to the close proximity of the works to the nearest sensitive receiver without the presence of any natural barriers to reduce the impact. It can be noted that as overpressure decreases exponentially with distance from the source of blasting, the distance to the sensitive receiver is particularly significant in predicting overpressure levels.

Based on an expected maximum of 125 decibels at the nearest sensitive receiver, this limit was proposed as the lower limit for airblast overpressure (95 per cent compliance) and 130 decibels as the upper limit (never to be exceeded) to allow for some error should unforseen variations in the blast execution be experienced. Given that these were below the 133 decibel limit to provide a factor of safety of 2, they were seen as appropriate in ensuring that the safety of the public and property can be maintained.

To give some indication of the overpressure experienced at 130 decibels, wind events often exceed overpressure levels of 130 decibels for several hours without any adverse effects. This is particularly relevant as windy conditions are prevalent in geographical locations such as ridgelines, such as where the subject works will be undertaken. In comparison to wind, a blasting event would only be perceptible for several seconds, depending on the size of the blast.

Recently, monitoring was undertaken during trial blasting at the St Helena Hill on 19 October 2012 and overpressure levels caused by wind were frequently in excess of 115 decibels, reaching as high as 123 decibels during relatively still conditions. A report showing the overpressure levels recorded during the trial blasts can be found in Appendix 12. It is worth noting that no damage was caused to any properties or persons along the St Helena Ridgeline on any of these days. Previous work by Dr John Heilig in Brisbane monitored wind events and the overpressure experienced to show that people and houses are frequently subjected to overpressure levels in the range proposed within this report with no adverse effects. Table 16 shows the categorisations of wind and their expected overpressure levels and Figure 27 shows the overpressure levels recorded during an 8 hour period in the suburbs of Brisbane. During this period, no damage was experience within the vicinity of the monitor.

Table 16 - Categorisations of wind and their expected overpressure levels

Wind Category (km per hour)	Description	Expected Overpressure Level (decibels)
Light winds (<10 knots)	Wind felt on face, leaves rustle	<118 decibels
Moderate winds (10 to 16 knots)	Raises dust and loose paper, small branches move in wind	119 to 126 decibels
Fresh winds (16 to 21 knots)	Small trees begin to sway, small waves form on inland water	127 to 131 decibels
Strong winds (21 to 27 knots)	Large branches in motion	132 to 135 decibels

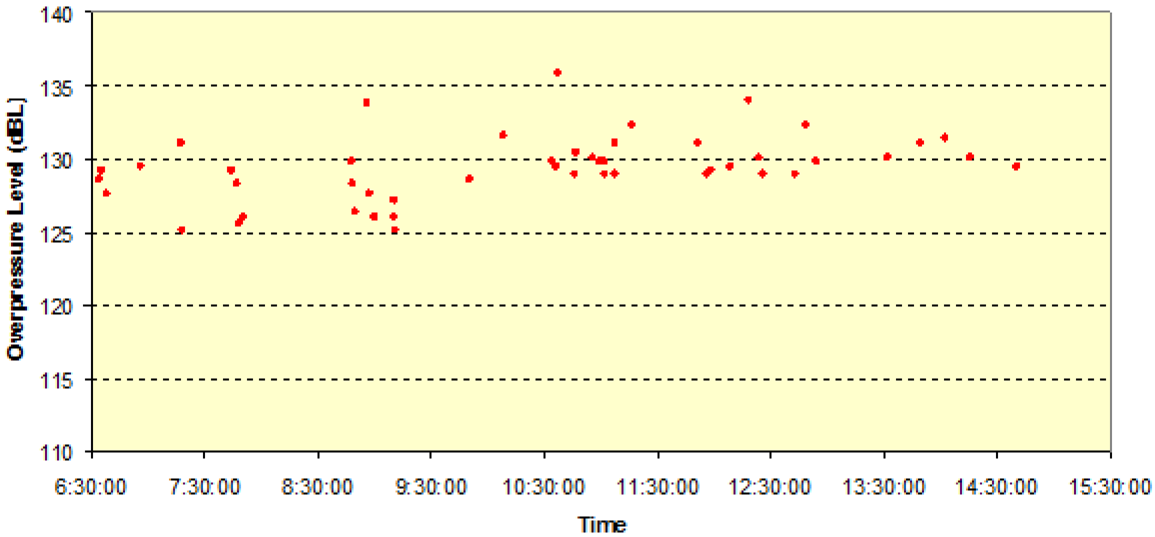


Figure 27 - Overpressure levels recorded in typical suburban environment

For reference, Figure 28 has been included to show the windspeeds observed at the weather station at Cape Byron. This station, while not at the exact location of the subject works, is representative of the weather conditions within the area. It can be seen in Figure 28 that the wind speeds experienced on 19 October 2012 were not particularly high – 15 out of 31 days in October experienced a higher maximum wind speed than that experienced on the 19th. This is important in demonstrating the influence that wind can have on overpressure levels.

Byron Bay, New South Wales
October 2012 Daily Weather Observations

Most observations from Byron Bay automatic weather station, but some from Byron Bay (Cape Byron Lighthouse).

Date	Day	Temps Min	Temps Max	Rain	Evap	Sun	Max wind gust Dir	Max wind gust Spd	Max wind gust Time	9 am Temp	9 am RH	9 am Cld	9 am Dir	9 am Spd	9 am MSLP	3 pm Temp	3 pm RH	3 pm Cld	3 pm Dir	3 pm Spd	3 pm MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	8th		km/h	hPa	°C	%	8th		km/h	hPa
1	Mo	14.9	18.5	4.4			ENE	39	10:05	17.8	66		ESE	24	1025.5	18.1	62		S	17	1024.4
2	Tu	13.8	19.0	2.8			SSW	63	12:28	17.5	70		SSW	43	1029.4	18.0	68		S	50	1027.2
3	We	13.4	23.3	0.2			SSE	39	00:07	18.2	65		SW	20	1028.2	22.6	56			20	1024.2
4	Th	16.2	22.8	0			N	44	18:56	20.3	66		N	13	1023.6	21.7	70		N	28	1018.8
5	Fr	17.7	24.9	0			N	43	13:06	21.6	70		N	13	1020.9	22.8	69		N	28	1017.0
6	Sa	17.3	23.7	0			NNW	33	00:07	23.5	63		NE	15	1017.6	22.4	78			17	1014.3
7	Su	17.7	29.6	0				57	11:58	21.6	73		N	15	1011.5	21.2	78		SSE	39	1009.5
8	Mo	14.9	22.3	0			S	39	23:22	16.8	74		SSW	20	1015.3	20.5	69		S	20	1012.1
9	Tu	16.2	26.4	0			SW	37	10:32	20.4	66		NW	13	1011.3	24.6	44		NE	24	1008.4
10	We	15.2	22.8	0			N	56	14:40	19.6	72		N	17	1014.4	22.7	79		NNE	31	1009.2
11	Th	19.6	21.5	0			N	69	02:45	20.5	80		NNW	30	1008.3	16.6	90		WSW	17	1007.6
12	Fr	12.3	19.2	11.0			W	76	14:39	14.0	54		W	33	1011.3	19.1	36		W	37	1010.8
13	Sa	11.6	24.0	0			WSW	43	23:31	17.2	46		WSW	17	1021.3	22.7	32		NE	15	1018.4
14	Su	14.9	24.5	0			ESE	67	17:56	18.1	59		SSW	11	1023.3	21.0	65		NE	19	1021.3
15	Mo	12.8	22.3	6.0			WSW	35	00:47	16.7	72		SW	17	1026.5	21.6	60		NE	22	1024.6
16	Tu	14.3	22.2	0			N	44	19:40	19.5	71		N	11	1024.2	21.9	62		NNE	30	1020.5
17	We	18.2	22.8	0			NNE	56	12:56	20.3	66		N	26	1019.0	22.3	69		NNE	31	1014.9
18	Th	18.7	22.5	0			S	56	14:01	20.3	80		SW	31	1020.5	20.7	81		S	46	1018.9
19	Fr	18.1	23.1	0			NNE	54	11:10	21.3	81		N	20	1019.1	22.5	74		N	31	1015.1
20	Sa	18.8	23.7	0			NNE	70	15:56	20.7	83		N	26	1014.8	23.1	75		NE	37	1009.6
21	Su	19.6	27.1	0			SSW	50	00:37	21.1	83		S	24	1015.5	26.3	71		NE	13	1013.0
22	Mo	18.7	28.9	0			S	89	19:23	22.5	65		NW	6	1013.6	28.6	64			24	1009.1
23	Tu	11.5	19.9	1.8			SSW	85	06:57	13.1	94		SW	39	1021.0	19.5	33		S	54	1019.5
24	We	12.2	21.0	2.2			SE	67	01:01	19.5	49		SE	33	1022.7	20.5	60		SE	31	1019.7
25	Th	14.3	25.8	0			N	48	19:11	19.2	61		SSW	11	1017.8	24.4	51		NE	22	1013.4
26	Fr	18.2	25.0	0			N	50	18:10	20.8	68		NNW	20	1009.3	24.3	71		N	24	1006.7
27	Sa	18.4	23.0	0			S	61	12:25	21.9	77		SSW	30	1011.6	20.7	71		S	39	1013.3
28	Su	18.6	21.7	0			ESE	59	22:53	19.8	62		SE	35	1021.8	21.0	55		S	33	1021.7
29	Mo	17.4	22.9	0			ESE	57	23:05	20.7	54		ESE	39	1021.9	21.7	48		SE	22	1020.6
30	Tu	14.4	25.1	0.2			WSW	31	05:39	16.4	84		WSW	17	1020.1	24.3	41		E	24	1017.2
31	We	15.7	27.5	0.6			NE	31	15:08	20.7	73		SE	11	1018.3	27.1	56		NE	22	1015.5
Statistics for October 2012																					
	Mean	16.0	23.5							19.4	69			21	1018.7	22.1	62			27	1016.0
	Lowest	11.5	18.5	0						13.1	46		NW	6	1008.3	16.6	32		NE	13	1006.7
	Highest	19.6	29.6	11.0			S	89		23.5	94		SSW	43	1029.4	28.6	90		S	54	1027.2
	Total			29.2																	

IDCJDW2022.201210 Prepared at 13:00 UTC on Wednesday 7 November 2012

Figure 28 - Wind speeds experienced at Cape Byron

The above information highlights the highly conservative nature of the current limits and also indicates that residents around St Helena are used to experiencing overpressures around the levels proposed within this report and likely higher as indicated by wind speeds often in excess of those experienced on 19 October 2012.

Table 17 summarises the proposed limits indicating how they relate to blast design as well as their relative strength to the 136 decibels at which damage may occur.

Table 17 - Summary of proposed limits

Airblast Overpressure (dB(Lin Peak))	*Allowable Exceedance*	*Blast design implications*	*Relative energy to level at which damage to property may occur*
125	5% of total number of blasts over a 12 month period	All blasts to be designed to comply with this limit. The upper limit exists only to allow for error.	Approximately 400 per cent lower than level expected to cause damage to property
130	Never	No blast is to be designed to this limit and this limit should never be exceeded.	Approximately 200 per cent lower than level expected to cause damage to property

Although the proposed limits are considerably lower than those at which damage may occur to property, condition surveys have been undertaken and will be undertaken again following the commencement of blasting to ensure that no damage was caused to property by the subject blasting activities. Mitigation measures including the use of flashing lights on monitors that will turn on if the limits are exceeded and continuing consultation with residences will also be undertaken throughout the duration of the subject blasting activities to mitigate any impacts associated with overpressure attributable to these activities.

4.5.2 Vibration limits

As with the proposed airblast overpressure limits, the proposed limits for vibration were chosen to achieve the following goals:

- To maintain safety and amenity of the area in relation to the public and property,
- To facilitate optimum efficiency in excavation associated with the works, thereby reducing the duration of the impact of the works on nearby residences;
- To reduce the scope of high impact works on nearby residences such as mechanical excavation through rock hammering.

In order to maximise the efficiency of the construction of the box cuts, the tunnels and the TCC, vibration levels of approximately 15 millimetres per second were predicted at the nearest sensitive receiver. This limit was seen as appropriate for the lower limit (95 per cent compliance) as according to AS 2187.2, cosmetic damage to properties is expected to occur at vibration levels of approximately 50 millimetres per second peak particle velocity. Following similar logic to the determination of the upper limit for airblast overpressure, 20 millimetres per second was chosen as the limit never to be exceeded to account for any unforseen variations in the blast execution.

Although the proposed limits are considerably lower than those at which damage may occur to property, condition surveys have been undertaken and will be undertaken again following the commencement of blasting to ensure that no damage was caused to property by the subject blasting activities. Mitigation measures including the use of flashing lights on monitors that will turn on if the limits are exceeded and continuing consultation with residences will also be undertaken throughout the duration of the subject blasting activities to mitigate any impacts associated with vibration attributable to these activities.

Illustration of the impact of the limitations on blasting under the current MCoA for vibration limits can be seen in Figure 29. This shows large areas in the southern end of the excavation where the vibration limits will restrict the maximum instantaneous charge resulting in shorter round lengths and hence a longer period of excavation and an increased number of blasts.

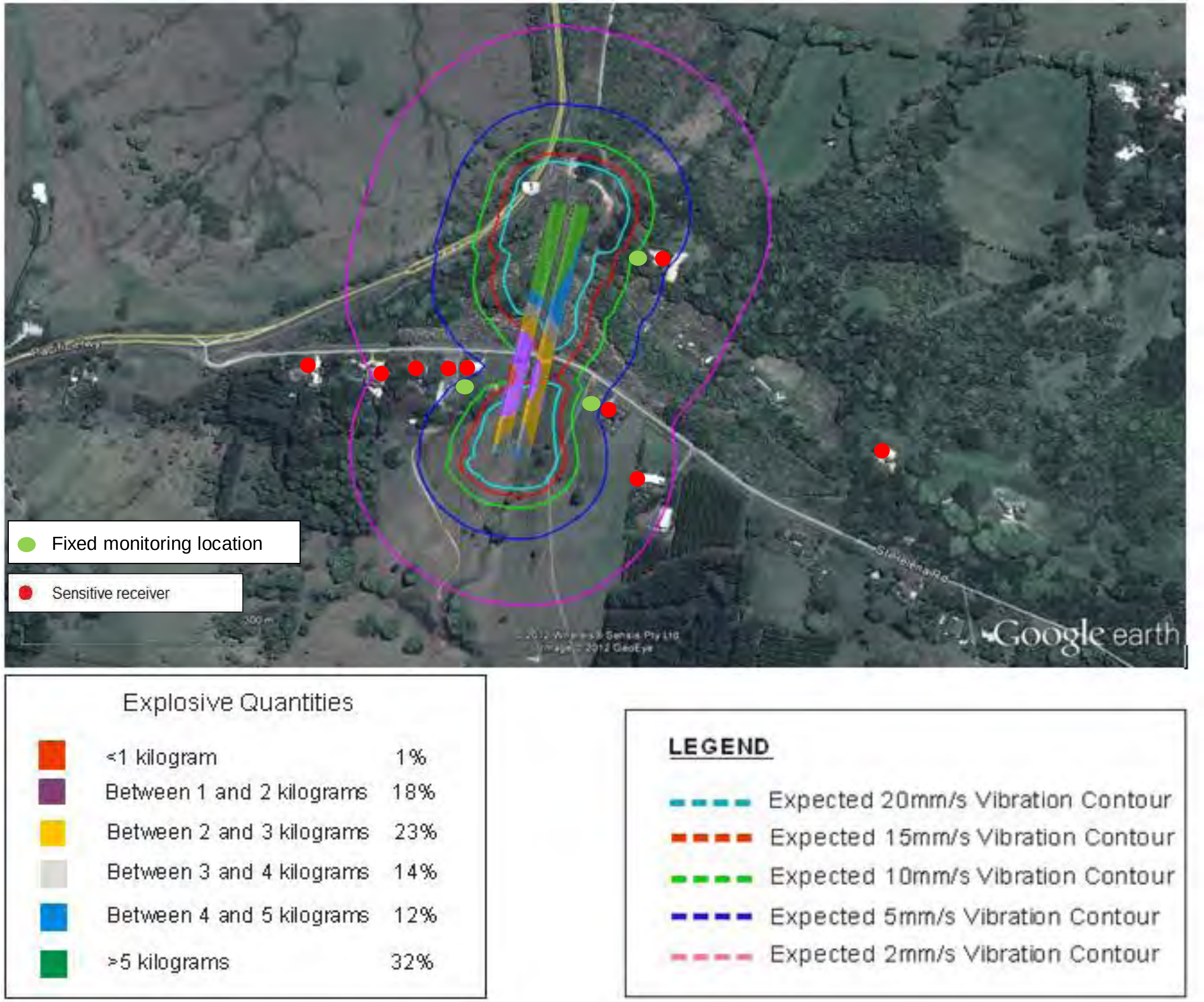


Figure 29 - Maximum instantaneous charge to comply with current MCoA

4.5.3 Extension of hours

The proposal to modify the permitted blasting hours is based on two key factors:

- To seek consistency between the approved blasting hours and approved construction hours;
- The proposed extension to permitted blasting hours significantly increases the benefits to Project Stakeholders and the wider community gained from the proposed modifications to vibration and overpressure limits.

Currently, the Project is permitted to undertake construction activities during the following times in accordance with MCoA 2.12:

- 7:00am to 6:00pm, Mondays to Fridays, inclusive;
- 8:00am to 1:00pm on Saturdays; and
- At no time on Sunday or public holidays.

As such, the proposed extension of blasting hours has been derived with the intention of allowing maximum flexibility with regard to blasting activities without increasing the hours during which construction can be undertaken generally as part of the Project. As with all construction activities, any blasting undertaken during the proposed extended hours would be planned to have minimal impact on the community, especially in terms of school bus routes and persons commuting to and from work. Specifically in relation to the proposed extension of blasting hours, it can be noted that there would be negligible overall negative impacts to the community as a result of the proposed extension of blasting hours as any impacts resulting from the extension would generally be no greater than the impacts subsequent to general construction activities which are permissible between 7:00am to 6:00pm, Mondays to Fridays.

With regard to potential noise, dust and vibration impacts, it can be noted that the level of impact of blasting that is proposed to take place during the extended hours has the potential to be significantly lower than that of general construction over the same period. This lower impact would be attributable to the blast event taking place over a matter of seconds during an extended break in general construction, whereas general construction and its associated impacts would be ongoing throughout the same period.

The benefits of the extended hours with regard to the progression of construction and subsequent realisation of benefits to Project stakeholders and the wider community is two-fold in that it provides opportunity to excavate more within a single day and also provides a buffer against unforseen downtime.

As such, the additional hours help to act as a buffer for unexpected delays in construction as delays are less likely to cause a blast to be 'missed' due to the restriction in hours. Figure 30 shows the effect of the proposed revised hours on providing additional contingency for the progression of construction when night works have begun. A diagram which was shown to the community describing the planned work hours and the proposed modifications can be seen in Figure 31.

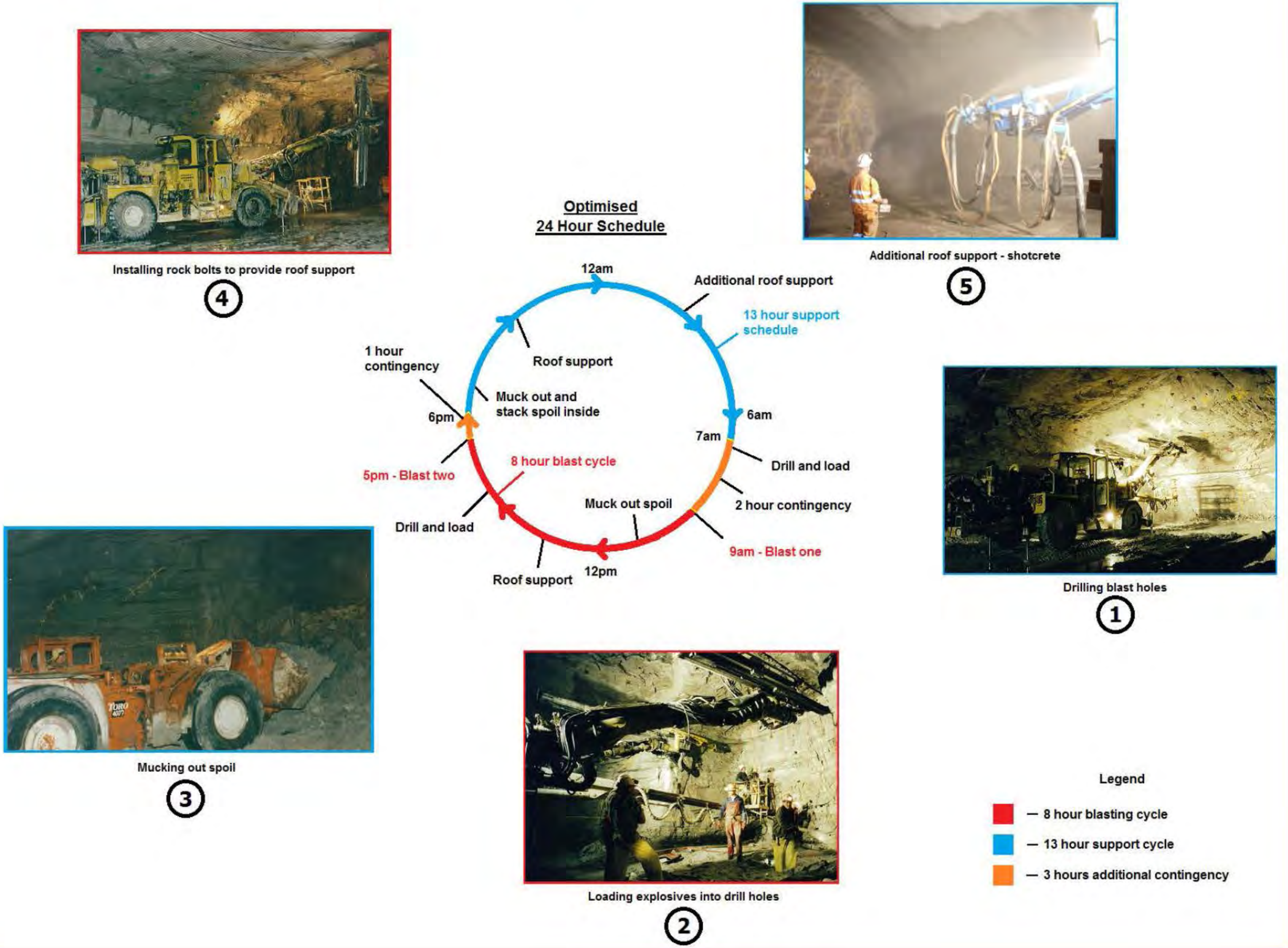
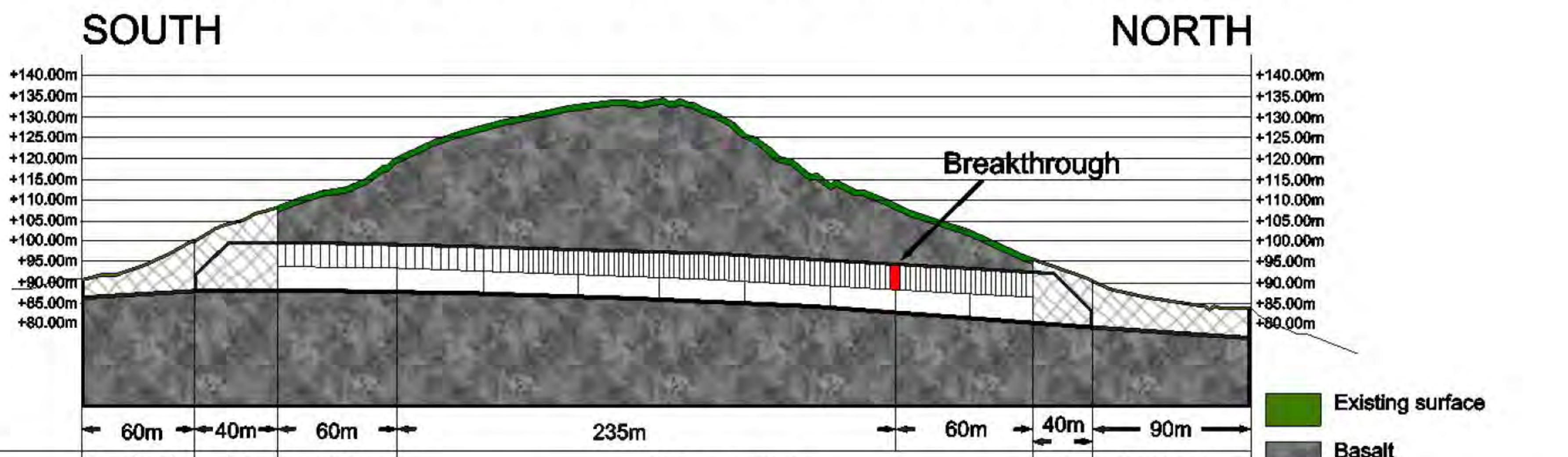


Figure 30 - Contingency benefit of additional hours

ST HELENA TUNNEL CONSTRUCTION SCHEDULE



	60m	40m	60m	235m	60m	40m	90m
Section:	Roadworks	SP	Initial	Main construction		NP	Roadworks
Work hours:	7:00am to 6:00pm			24 hour construction	7:00am to 6:00pm		
Audible hours:	7:00am to 6:00pm						
Inaudible hours:	N/A			6:00pm to 7:00am	N/A		
Proposed blasting hours:	7am to 6pm Weekdays and 9am to 1pm Saturday						
Noise shed:	NO			YES	NO		
Duration*:	1	1	2	9		0.5†	1.5†

*All durations in calendar months
†Concurrent with Southern works

Direction of construction

Figure 31 - Work hours in relation to proposed blasting hours

4.5.4 Modification to MCoA with regard to blasting - case studies

A number of Pacific Highway Upgrade Projects have successfully implemented higher blast vibration and overpressure levels than those originally prescribed by the respective Instruments of Approval issued under the *Environmental Planning and Assessment Act 1979*. In the case of vibration associated with the Banora Point Upgrade, a modification to the Project Approval was successful in achieving a peak particle velocity as detailed within Table 18 below.

Table 18 - peak particle velocity, Pacific Highway Upgrade – Banora Point

Criteria	Peak Particle Velocity (mm/s)	Allowable Exceedance
Criterion 1 – if no written agreement with the affected receiver.	10	Never
Criterion 2 – if a written agreement has been entered into with the affected receiver and the Director General has approved the terms of the written agreement prior to the commencement of any blasting at higher limits.	10	5% of total number of blasts over 12 month period
	15	Never

In the case of the Pacific Highway Upgrade - Sapphire to Woolgoolga, a modification was successful to achieve a maximum peak particle velocity vibration level of 25 millimetres per second and maximum airblast overpressure level of 125 decibels where the subject blasting level has been agreed to with the with the relevant effected landowner.

In the case of the Pacific Highway Upgrade – Kempsey to Eungai, a conditional modification was successful to increase blasting limits to a maximum overpressure of 125 decibels and vibration to a maximum of 25 millimetres per second where the Proponent had a written agreement with the relevant landowner to exceed the standard criteria, and the Proponent had advised the Department in writing of the terms of this agreement.

The implementation of the above modifications has demonstrated that proposals similar to those detailed within this report can be successfully executed to the benefit of Project stakeholders and the wider community.

4.6 Reduction in Impact from the Proposed Modification

4.6.1 Reduction in impact – tunnelling works

In relation to the tunnelling works as defined within Section 1.2.1, the benefit to the local community and other external stakeholders gained from the proposed modifications are as follows:

- Reduced construction traffic on St Helena Road,
- Reduced impact of noise and dust from construction related activities,
- Reduced number of blast events;
- Overall reduction in construction duration and therefore reduced overall timeframe over which residents may experience impacts.

Table 19 details the expected reductions in impact to residents through a reduction in the total number of blasts associated with the construction of the tunnels.

Table 19 - Reduction in construction duration and blasts for the construction of the tunnels

Tunnel	*Current MCoA duration*	*Proposed MCoA duration*	*Reduction in duration*	*Current MCoA number of blasts*	*Proposed MCoA number of blasts*	*Reduction in blasts*
Northbound	207 days	178 days	29 days (14 per cent)	235	141	94 blasts (40 per cent)
Southbound	206 days	178 days	28 days (14 per cent)	232	140	94 blasts (40 per cent)

As an estimate of the geological breakup of the tunnels is known, as well as the expected advance rates and blast rates per day under the current MCoA and the proposed MCoA, it is possible to estimate the increased benefit from reducing the duration of impact and the number of blasts for the construction of the tunnels.

Summaries comparing the construction times and numbers of blasts required to construct the northbound and southbound tunnels under both the current and proposed MCoA are shown in Tables 20 and 21.

Table 20 - Comparison of Northbound construction duration and number of blasts for current and proposed MCoA

Section No.	*Shifts*	*Section Length*	*Tunnel Chainage*	*Time to complete - Current MCoA*	*Total number of blasts – Current MCoA*	*Time to complete - Proposed MCoA*	*Total number of blasts – Proposed MCoA*
1	Day only	20m	0m – 20m	40 days	20 blasts	27 days	17 blasts
2	Day only	40m	20m – 60m	24 days	22 blasts	23 days	15 blasts
3	Day and night	53m	60m – 113m	16 days	29 blasts	14 days	12 blasts
4	Day and night	23m	113m – 136m	6 days	12 blasts	5 days	8 blasts
5	Day and night	113m	136m – 249m	34 days	62 blasts	30 days	34 blasts
5	Day and night	97m	249m – 345m	76 days	78 blasts	68 days	44 blasts
7	Day and night	11m	345m – 356m	11 days	11 blasts	11 days	11 blasts
TOTAL		356m	356m	207 days	235 blasts	178 days	141 blasts

Table 21 - Comparison of Southbound construction duration and number of blasts for current and proposed MCoA

Section No.	*Shifts*	*Section Length*	*Tunnel Chainage*	*Time to complete - Current MCoA*	*Total number of blasts – Current MCoA*	*Time to complete - Proposed MCoA*	*Total number of blasts – Proposed MCoA*
1	Day only	20m	0m – 20m	40 days	20 blasts	35 days	17 blasts
2	Day only	40m	20m – 60m	24 days	22 blasts	20 days	16 blasts
3	Day and night	191m	60m – 251m	57 days	105 blasts	48 days	35 blasts
4	Day and night	94m	251m – 345m	74 days	74 blasts	66 days	63 blasts
5	Day and night	11m	345m – 356m	11 days	11 blasts	9 days	9 blasts
TOTAL		356m	356m	206 days	232 blasts	178 days	140 blasts

4.6.2 Reduction in impact – box cuts

For the box cuts, the current schedule is based on the most efficient blasting that can be performed given the current MCoA. Similar to the tunnelling works, an increase in the vibration and airblast limits allows for more efficient excavation works. This has a result in decreasing the construction duration and hence the benefits to the external community from decreases in the construction duration which can be realised. Although the proposed changes would increase the maximum instantaneous charge of each shot, the same principles would still be applied to control flyrock and ensure the safety of all persons in the vicinity of any blasting works.

To conform with the current MCoA, in terms of both airblast and vibration as well as ensuring management of flyrock, the current plan is to use 76 millimetre holes with two explosives. In order to achieve fragmentation, this will require a drill hole pattern of approximately one metre x one metre. With the proposed changes, it is expected that holes of 89 millimetre diameter could be used. These would be expected to achieve the same fragmentation results using a drill hole pattern of 1.1 metre x 1.1 metre. This would reduce the total number of holes drilled for the excavation of the box cuts by 15 per cent. In total, the number of holes drilled would reduce from approximately 5500 holes to approximately 4700 holes. This would also reduce the total drilling meters from 33 kilometres of drilling to 28 kilometres of drilling. As the drilling is expected to be the 'bottleneck' for the box cut works and accounting for slower drilling rates for the larger holes, the reduced drilling requirements from the proposed modifications would reduce the time to complete the box cuts by approximately eight days.

The reduction in the total drilling meters means that the excavation can be undertaken faster than that originally planned. At the Southern Portal, the construction duration would decrease from six weeks to five weeks. In the Northern Portal it is expected to reduce the total construction duration from 15 work days to 12 work days. In total this corresponds to an eight day reduction in the construction duration.

It is expected that the number of blasts that require the closure of either the Pacific Highway or St Helena Road would be reduced from six to three. This would result in a 50 per cent reduction in the number of closures to both the Pacific Highway and St Helena Road.

Furthermore, as the drilling would be more efficient, it is expected that there would be a reduction in the total number of blasts for the box cuts to reduce from a total of 11 blasts to seven blasts combined.

4.6.3 Reduction in impact – tunnel control centre

In the areas where blasting would be possible, it is likely that given the current MCoA, in order to comply with the limits for airblast and vibration, the excavation would need to be taken in at least two benches due to the restriction on the maximum charge per hole. Unlike the box cuts, this could not be overcome through the use of blast hole decking as the stemming required to mitigate fly rock would make the charge ineffective in fragmenting the rock. Although fill could be introduced, this would not overcome that such low charge weights would only be able to fracture the rock to depths less than 500 millimetres. This would have the effect that the removal and reintroduction of fill for each blast would make blasting operations infeasible. As such, given the current MCoA, the only viable option for the removal of the rock closest to the sensitive receivers – where charge weights below two kilograms are required, is to use hydraulic rock breaking hammers. However, the use of rock breakers results in a high impact to residents through disturbance from high levels of noise, vibration and dust.

Excluding areas where the rock is too shallow to ever justify the use of controlled blasting, it is estimated that at least 2500 cubic metres of rock in the deeper sections of the TCC excavation will require breakage by hydraulic rock breakers with the current MCoA.

Realistically, in using multiple rock breakers it would be possible to break the rock at approximately eight cubic metres per hour in the high strength basalt. This estimate includes allowance for periods of respite and mitigating disturbance by reducing the hours at which rock breaking activities are undertaken. At this rate, it is expected that the excavation of this 2500 cubic metres would take approximately eight weeks of the expected 12 week construction duration.

With the proposed changes to the MCoA, it is expected that the volume of rock that would required breakage using rock hammers could be broken using controlled blasting. This is taking into account mitigation measures to ensure that nearby residences are not at risk being affected by flyrock. Drilling and blasting of this rock would be expected to take approximately two weeks. This would result in a reduction in the construction programme of six weeks to an expected duration of six weeks from the original 12 week programme. The most significant benefit of the proposed changes to the MCoA is that it would reduce the total amount of rock hammering by an expected 40 days. Table 22 summarises the reduction in total days of disturbance, as well as the reduction in total days of hammering. Given the continuous noise and vibration expected from rock hammering, the proposed modification would significantly reduce the impact of the TCC works on nearby residences.

Table 22 - Comparison of TCC excavation construction schedules

MCoA	*Days to complete*	*Days of Hammering*
Current	60	50
Proposed	30	10

4.6.4 Summary of reduced impact from proposed modification

The proposed modification to the MCoA would reduce the following disruptive activities:

- Use of hydraulic rock breakers,
- Total number of blasts,
- Total holes drilled and duration of drilling activities,
- Duration of construction activities;
- Traffic disruptions.

The expected impacts of the tunnelling works and the increased benefit to residences from the proposed mitigations are summarised in the following table:

Table 23 - expected impacts of the tunnelling works and the increased benefit to residences

Area	*Expected impacts*	*Revised impacts*	*Benefits to residences*
Tunnel	207 day construction schedule	178 day construction schedule	29 days reduced disturbance from construction activities.
	467 blasts	281 blasts	186 less blast events experienced.
	250km drilling activities	218km drilling activities	Reduced dust and noise caused from drilling activities
TCC	60 day construction schedule	30 Day construction schedule	30 less days of disturbance from works at highly visible and nearby TCC
	50 days hydraulic	10 days hydraulic	40 less days of

	hammering	hammering	noisy hammering operations
	33km drilling activities	20km drilling activities	Reduced dust and noise caused from drilling activities
	3 blasts	4 blasts	Additional blast mitigates need for 40 days of hydraulic hammering operations
Box cuts	11 blasts	6 blasts	5 less blasts than previously planned
	45 day construction schedule	37 day construction schedule	8 less days of impacts from works at nearby box cuts
	4 expected closures of St Helena Road	2 expected closures of St Helena Road	50% reduction in the number of closures to St Helena Road.
	2 expected closures of the Pacific Highway	1 expected closure of the Pacific Highway	50% reduction in the number of closures to the Pacific Highway
	87km drilling activities	77km drilling activities	Reduced dust and noise caused from drilling activities

In summary, all three proposed modifications to the MCoA would result in the following reductions in impacts as a result of the proposed works:

- 80 per cent reduction in the volume of rock requiring breakage by hydraulic hammers at the Tunnel Control Centre (TCC). This corresponds to 20 fewer days during which hammering is being undertaken for the TCC excavation,
- Approximately three week's reduction in total construction time for the excavation of the TCC. This would correspond to a 25 per cent reduction in the original programme of 12 weeks,
- 40 per cent reduction in the total number of blasts,
- An approximate eight day reduction in the construction time for the box cuts to 37 days from an expected 45 days,
- 32 day reduction in the construction schedule for the excavation of the tunnelling works, reducing the total construction time from approximately 210 days to 178 days.
- 15 per cent less drilling — reducing the duration of noise and vibration that residents would be exposed to.
- 50 per cent fewer rolling stoppages of the Pacific Highway reducing traffic delays.
- 50 per cent fewer closures of St Helena Road reducing traffic stoppages and delays.

As a result of the above reduction in impacts, residents are less likely to experience anxiety caused by the unfamiliar vibrations from the blasting works and less disruption due to a reduced number blasting events. The reduced blasting events in the box cuts and during the construction of the TCC would also reduce the number of road closures, delays and potential requests for residents to remain indoors or move livestock. This would in turn, reduce the impact on the day-to-day lives of nearby residents. Furthermore, community consultation that has been undertaken regarding the proposed changes shows that the majority of residents in close proximity to the St Helena tunnel works are in favour of reducing these impacts and the duration of the tunnel construction.