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# A framework for airblast analysis and risk management for early-stage caving

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## Abstract

*Managing the airblast principal hazard through the establishment of a cave is essential to mitigate operational risk to personnel and infrastructure. Early stages of undercutting and cave propagation present unique risks due to the low height of the muckpile, and the uncertainty in early measurements to confirm cave initiation. Currently there is a lack of reliable data and many assumptions that need to be input into airblast models, which results in inherent uncertainty in the calculation of the risk that is not well understood. The proposed process outlined in this paper looks to address these concerns and presents the strategies developed during the cave establishment process for the PC2-3 cave at Cadia Valley Operations in New South Wales, Australia.*

*The proposed methodology first collects data from multiple monitoring and material movement tracking sources and compiles them into one model for cave back position and airgap volume estimation. Then using the geometrical estimates of the status of the cave, a VentSim™ CAST model is developed to enable the modelling of airblast velocities and pressures which may be experienced in the event of a sudden cave crown collapse. The results from data collection and modelling are then incorporated into an early caving airblast risk framework, where feasible failure mechanisms are considered alongside the theoretical calculations to derive implementable controls for effective management of the hazard.*

**Keywords:** *airblast, block caving, cave initiation, risk management*

## 1 Introduction

Airblast is identified by industry as a principal hazard for caving operations due to its potential to cause loss of life for personnel and widespread damage to underground equipment and infrastructure. An airblast event is defined by Fowler & Hebblewhite (2003) as “a sudden movement of air, displaced by a collapse of rock into an underground void, which causes the air to move through the adjacent openings”. However, airblast is more widely known as any event causing the sudden movement of air underground with the potential to cause injury to personnel or damage to equipment (Logan & Tyler 2004). This hazard was unfortunately realised at the Northparkes Mine in 1999 where 4 miners lost their lives in the large-scale collapse of the cave crown pillar leading to the mass injection of air into the underground workings (Vejrazka 2016).

Due to the high risk associated with airblast, it is necessary to quantify and track the airblast hazard across all planning horizons for a block cave mine. Previous attempts to quantify the scale of the hazard can be grouped into:

- first principle nomogram methods, where fundamental laws are used to determine the estimates for pressure and velocity caused by sudden collapse of the cave back (Logan & Tyler 2004)

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- numerical methods such as the VentSim™ Caving Airblast Simulation Tool (CAST) (Vejrazka 2022; Ormerod et al. 2024)
- discrete element methods (DEM) (Galindo-Torres et al. 2018; Palma et al. 2019).

Typically, the first principles approach tends to be over simplified and does not consider the effect of time of failure and can result in very high pressures if applied to a mine scale ventilation model (Ormerod et al. 2024). Furthermore, it is often impossible to model the pressure requirements of plugs or other engineered obstructions. In contrast, the more sophisticated DEM methods tend to rely on many variables which are in practice difficult to define, such as particle size distribution and volume of failed material. Therefore, the most commonly adopted approach in industry to evaluate the airblast hazard is the use of the VentSim CAST module. The CAST model is based on the isentropic compression of air within the airgap with velocities in the mine network calculated for each time step of the simulated cave back collapse. As a result, all potential cave connections and airways can be modelled to determine the magnitude and extent of the airblast hazard.

The airblast hazard can be split into 3 main phases which require consideration:

- pre-critical hydraulic radius (pre-cHR) phase
- early propagation phase
- late propagation phase.

The pre-cHR phase occurs when the undercutting has begun but the cave has not yet initiated and commenced propagation. Correspondingly, the early propagation phase is just after the cave has commenced propagation but potentially still has a low hydraulic radius which could cause stall and sudden collapse. On the other hand, late-stage propagation of a block or panel cave usually shifts the risk of airblast to overlying levels which can connect to the void in the event of sudden collapse. Previously the focus of airblast analysis has been on overall cave propagation and the formation of nomograms which can be used to adjust long-term production schedules or ramp-up strategies (Vejrazka 2016, 2022) or the management of large airgaps during later stage propagation (Ormerod et al. 2024).

For high-left caves, such as Cadia, during the 2 initial phases of cave growth, the airblast hazard is focused on the undercut level and there is often high airgap to muckpile ratios compared with later stage caving. Therefore, the measurement of cave geometry and subsequent airblast modelling for these 2 phases is paramount to personnel safety due to the increased exposure during undercutting and establishment. This paper focuses on the pre-cHR and early cave propagation phases of airblast hazard quantification and management processes developed during the establishment of the PC2-3 block cave at Cadia East Mine in New South Wales. The cave geometry and feasible failure mechanism are discussed with respect to early stages of establishment and the development of appropriate inputs to the airblast model within the VentSim software package. Then the model results and application to the onsite planning horizons are presented alongside site-proven strategies for early cave airblast risk management.

# 2 Early cave geometry and cave back failure

To date, the estimation of airgap size and muckpile cover has been focused on later stages of cave propagation to determine the risk profile of large-scale crown pillar or plug type failure interacting with drives intersecting the cave at higher elevations (Vejrazka 2022; Ormerod et al. 2024). However, for a cave close to, or just past, the critical hydraulic radius, the muckpile cover between the undercut level and the expected airgap is relatively small which enables potential smaller scale cave back collapse to induce potentially dangerous airblast events. As such, this section presents the pre-cave initiation and early propagation geometries typically found during the establishment of a post undercut cave such as PC2-3 at Cadia East Mine. Using these geometries and the feasible failure mechanism, it is then possible to develop robust inputs into the airblast simulation to determine the scale and extent of the early cave airblast hazard to enable the development of management strategies.

## 2.1 PC2-3 pre-cave initiation geometry

The pre-cave initiation geometry is defined as the dimensions and characteristics of the cave prior to any propagation being confirmed for the cave under establishment. Prior to the cave initiating or the critical hydraulic radius being reached, the cave back is defined by the blasted shape of the undercut completed. Therefore, the cave back height is assumed to be constant for this stage of establishment. As can be seen in Figure 1, the cave back is close to the undercut drives where drill and blast activities occur. Therefore, if a sudden collapse was to occur, it would not require large quantities of air to be forced into the drive before air velocities become elevated.

To provide some level of resistance to flow, it is necessary to establish and maintain muckpile cover at the brow of the connected workings. This can be achieved in practice by limiting the bogging to only the swell required to perform successful subsequent blasts of the undercut rings. The exact control methodology would vary depending onsite-specific dimensions; however, in principle, the muckpile can be maintained at the brow by ensuring no further draw is conducted for drawbells which could influence the level of cover at the undercut brows. This principle can be seen in Figure 1 where draw is only allowed in the second fully undercut drawbell behind the undercut front and is still managed closely to ensure even drawdown. Often, depending on the geometry and swell bogged, it is necessary for further material to be bogged to open a sufficient span and airgap for cave initiation. This is to be managed carefully, and the maximum allowable draw is to be determined by the nomograms created from the airblast analysis (see Section 4).

Understanding the geometry of the pre-caving stage of establishment is then used to determine the cave back height (undercut blast height), muckpile cover (mass balance) and volume of air currently in the cave. These can then be used in the model to determine airblast potential. It should be noted that localised fallout in the backs of the fired undercut replenishes the muckpile and reduces the size of the airgap and thus does not need to be considered.

At this stage, it is also possible to determine if there are variable resistances either as varying muckpile heights or drive fill. For example, if an undercut drive has its last firing conducted, the swell can be left within the cave to provide a greater level of muckpile resistance to potential airblast. However, this has to be incorporated into the modelling to ensure that the air does not find an alternate pathway or concentrates into fewer connections which in turn could raise velocities and pressures.

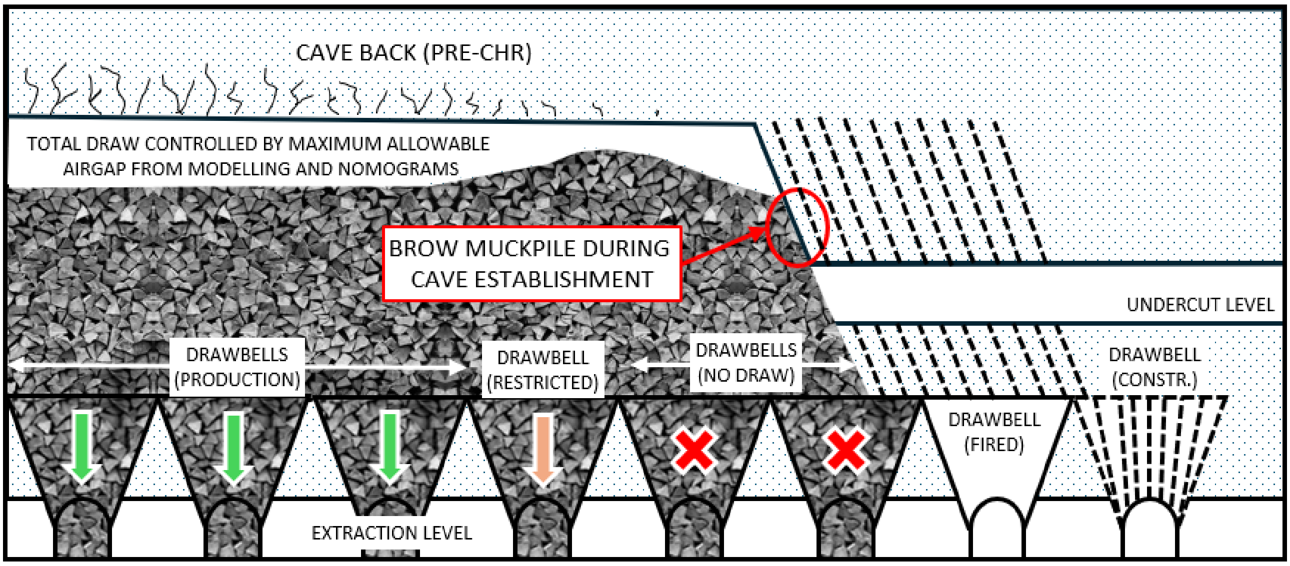



**Figure 1 Conceptual geometry and muckpile controls for the pre-cave initiation phase of airblast assessment for a post undercut cave**

## 2.2 PC2-3 early cave propagation geometry

Once the cave has initiated and begins its propagation to surface or the base of a previous lift, the geometry used for modelling more closely resembles the late propagation modelling common in industry. However, due to the proximity of the airgap to the undercut level, there is a requirement to evaluate the impact of cave refill and drawdown at a higher cadence (typically monthly). Shown in concept in Figure 2, there are commonly 2 airgaps associated with early post undercut cave propagation, the main volume associated with the cave back and one created during undercut blasting and swell bogging. Due to the small span and buttressing of blasted material, the airgap at the undercut front is now not considered to be the main risk. However, it is good practice to maintain choked undercut drive brows to ensure any small-scale failure at the undercut front doesn’t result in a direct connection for air. The airgap associated with the propagating cave back has the highest potential airblast risk as the cover of the muckpile is still low compared to how quickly the volume of the airgap can grow. The growth of the airgap can be rapid during this time as the cave is propagating with limited available span and the bogging of the few underlying drawbells is normally the focus of production targets during cave ramp-up.

Key inputs to airblast modelling required for this phase of hazard quantification are the interpreted cave back height, cave back span, muckpile height and spatial separation from the undercut front. To determine the key inputs the interpretation of the cave ‘as built’ is required via the review of available monitoring data (details in Section 2.4) and detailed production bogging data. Additional to the measured parameters, it may also be necessary to conduct sensitivity analysis within the airblast model to account for any unknowns or low confidence assumptions.

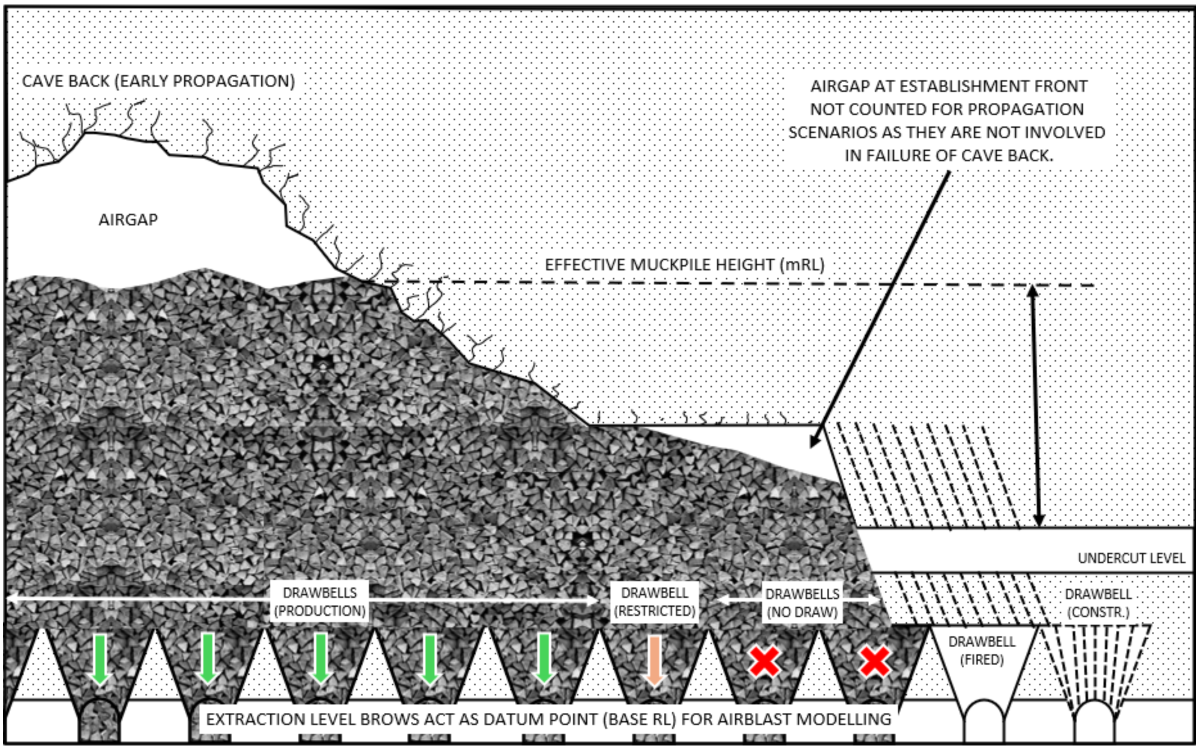



**Figure 2 Conceptual geometry for early propagation phase and draw controls of a post undercut cave**

## 2.3 Feasible cave back failure

Common to all 3 phases of airblast assessment, the potential geometry of the cave back which is likely to fail alongside measured or inferred airgap height results in the available volume for compression. This is straightforward for late-stage assessment where the cave back is close to the plan dimension of the caving footprint or total undercut area. However, for early-stage caving, the cave back can be partitioned or smaller than the total undercut area due to bogging and establishment constraints. Additionally, the mechanism of total crown pillar collapse is less likely for high-lift caves in the initial stages of propagation.

For the early cave scenarios, large slab or unravelling type failures can be more prominent. These types of failure are typically not considered for late-stage caving as they do not compress a large enough volume over a short enough period of time to overcome the relatively large muckpile resistances within the caving column. However, as the airgap is close to underground workings during cave initiation and early propagation, the resultant compression of air in these scenarios should be considered.

The specific dimensions and mechanisms for cave collapse vary from cave to cave. However, Figure 3 presents the key questions and factors to consider when determining the potential mechanism and geometry of the cave back failure. Using this information, it is possible to determine the equivalent circular area of the cave collapse to use in the airblast simulations.

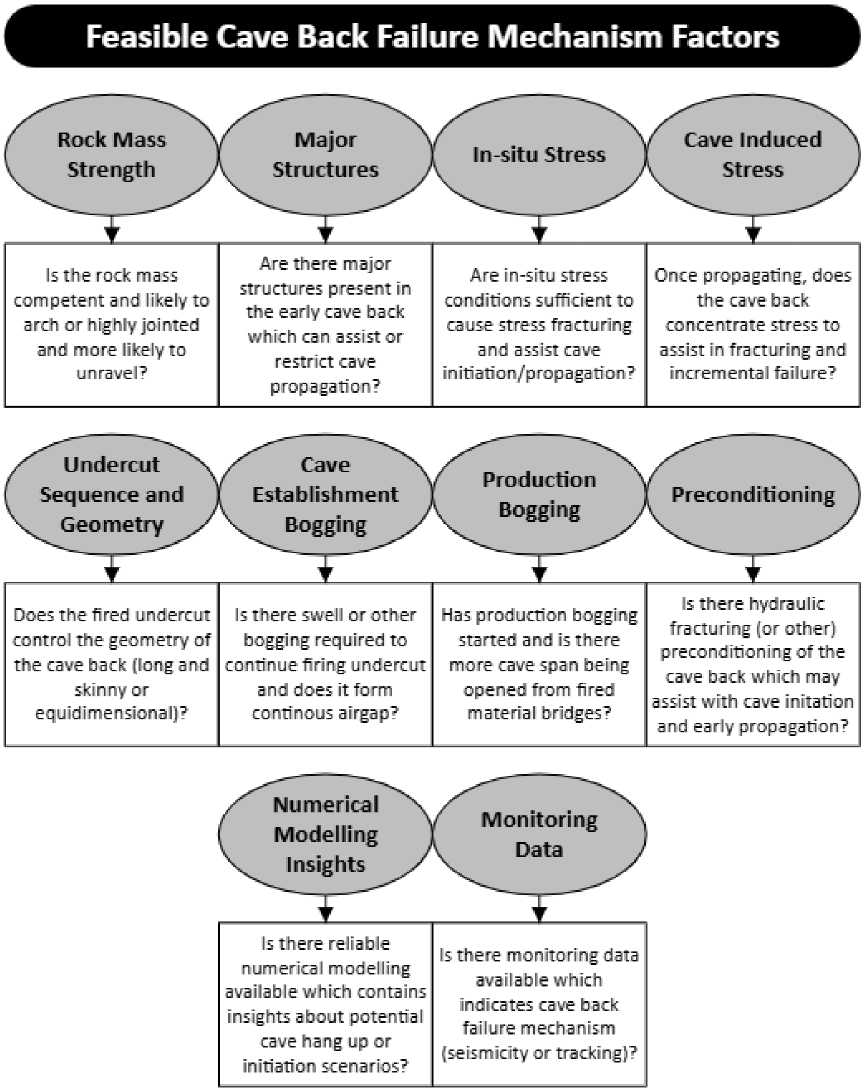



**Figure 3 Key considerations for the determination of cave back failure mechanism and geometry**

## 2.4 The role of cave tracking data and monitoring system design

As detailed in the sections above, it is critical to understand the geometry of the cave to conduct airblast assessment at any stage of the caving process. Often, the only sources of information available during operations are gathered by the cave monitoring and production tracking systems. However, in the author's experience, it is not common to fully integrate these sources of information for use in airblast hazard assessment. Based on site experience from Cadia East Mine, each data source has specific advantages in determining the cave shape, muckpile and airgap levels which is enhanced through integration into a single user interface. Table 1 presents the use cases for each type of monitoring data and Figure 4 displays a typical arrangement of an integrated user interface for cave interpretation and tracking. Using acquired data effectively ensures that assumptions and inputs in the airblast model can be verified or a level of confidence attributed. Often the data available also highlights the required sensitivities to be run during the modelling phase to ensure risk can be appropriately assessed and ranked.

When planning monitoring arrays, assessment of airblast risk particularly in early-stage cave propagation needs to be considered. Typical monitoring systems are often installed offset from the undercut to limit potential for interactions with development and cave establishment activities. As discussed previously, achieving reliable mass balances in those early phases is critical as airgap to muckpile ratios can change significantly within a short time spans and small changes in muckpile height can escalate trigger action response plan (TARP) levels impacting downstream work. Operations should consider using airblast modelling completed during project studies as an additional input to the final design of the monitoring system.

**Table 1 Cadia East Mine use cases for monitoring data in early cave tracking and airblast management**

| Data source | Early cave tracking | Airblast management |
|---|---|---|
| Seismicity | Seismic event contouring, single force and low log energy index events used to determine cave back position and initiation | Event rates and contouring used to determine if cave is initiated and/or propagating or potentially stalled |
| Tilt markers (Geo4Sight) | Marker loss used to determine cave back position and tilt used to determine zone of loosening | Degree of tilt and marker loss used to determine caving rate and potential stall |
| Cave tracking beacons | Beacons installed immediately above the undercut to determine cave initiation | Movement of beacons used to determine what areas of the cave have initiated |
| Open holes | Open hole dips used to determine cave back and airgap height when possible. Can also be used to map damage evolution in the cave column | Open holes which break through into cave, when available used to directly measure airgap and muckpile height |
| Mass balance/bogging tracking | The tracking of bogged material and oversize can provide insight into cave initiation (larger fragmentation reporting to drawpoints) | Mass balance used to determine muckpile height and airgap volume when direct sources not available (subject to assumed swell of material) |

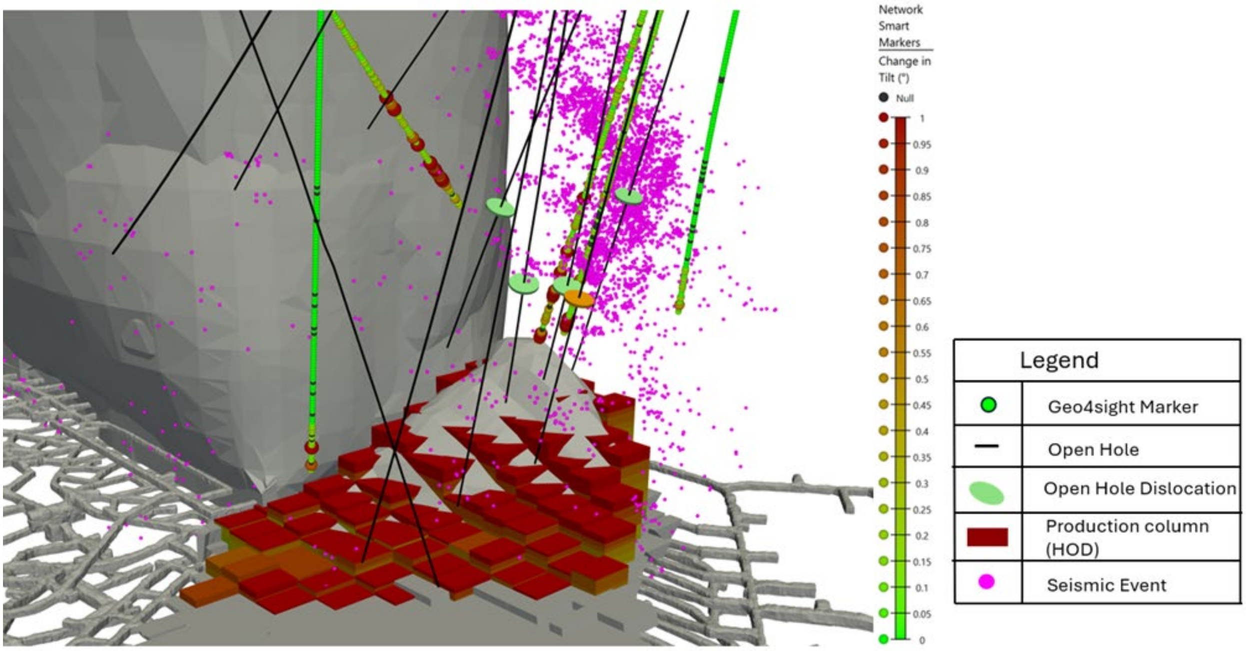



**Figure 4 Integrated user interface for monitoring data and cave interpretation**

## 3 PC2-3 airblast model

The caving airblast tool available in VentSim models the airblast hazard utilising the full mine ventilation network with the benefit that the downstream resistances and obstructions (plugs) can be modelled dynamically as the air is injected into the workings. The model works by considering the heights of all connected drives, the muckpile and the cave back and applies variable resistance vertically based on the level of cover measured for each of the connected drives. Figure 5 shows the simplified geometry used within the model to determine connection points and resistance of the muckpile.

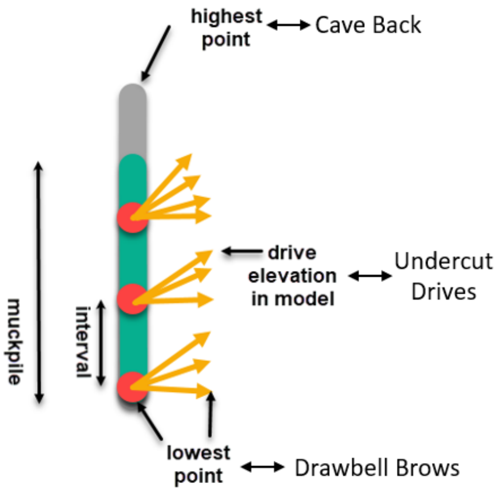



**Figure 5 Graphical input parameters for the VentSim CAST airblast model (after Vejrazka 2022)**

To determine the potential airblast hazard for the pre-cave initiation stage, the following parameters were modelled:

- The feasible failure area of the cave was set to the calculated critical hydraulic radius determined from consideration of the factors summarised in Figure 3
    - For the PC2-3 cave, this was an undercut area of ~24,000 $m^2$.

- The cave back was set to the top of the blasted shapes for undercut firings
  - This is the stage prior to initiation or propagation of the cave and assumes no refill of the airgap with caved material.
- Muckpile height is set at the front of the cave based on mass balance resulting from swell bogging
  - This resulted in a constant muckpile coverage above the brow of the undercut of 4 m.
- Various airgap volumes were run for the cave assuming the feasible failure area does not change for the cave initiation scenario
  - The increase in air volume simulates the commencement of production bogging which is often necessary to remove material buttressing from the cave back to assist with initiation.

Furthermore, the parameters modelled for early propagation scenarios were:

- The feasible failure area of the cave was set to the span calculated from early propagation shapes
  - For the PC2-3 cave this was a span of around 100 m in diameter.
- The cave back was interpreted monthly and the height of the inscribed maximum span was used for the highest point for modelling.
- Muckpile height was informed by direct measurement from open holes where available and mass balance.
- Analysis was run for the interpreted cave and a nomogram was formed to determine the maximum allowable bogging for the period.

Figure 6 gives an isometric view of the VentSim CAST model developed for the PC2-3 cave complete with undercut and extraction level cave connections which enable feasible modelling of the airblast severity.

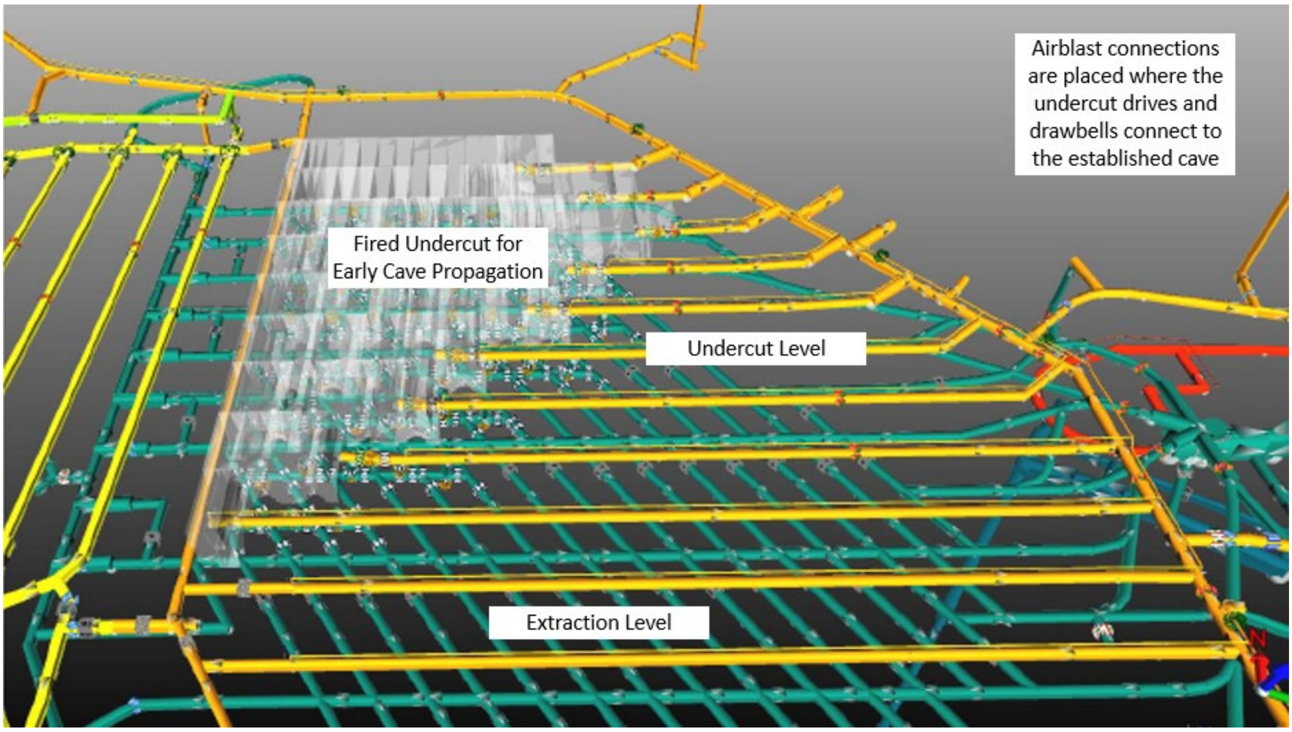



**Figure 6 Early-stage VentSim CAST airblast model for PC2-3 (undercut level shown in yellow and extraction level in green 25 m below)**

# 4 Airblast risk management

The management of airblast risk for early-stage caving requires the incorporation of the modelled outcomes into production planning in the mid-to-short-term (quarterly to monthly) horizons. This requirement is separate from the long-term ramp-up and production strategies employed at the study stage of block caves and provides the operation with implementable TARPs to address the risk and maintain personnel safety. Based on a full operational and planning risk assessment, the TARP should provide the overarching framework to determine if action is required to remediate potentially dangerous conditions due to airblast. An example of a high-level TARP is presented in Figure 7 which considers feasible failure conditions alongside more specific trigger levels of modelled air velocities. It is important to consider the physical potential for failure when evaluating the level of risk. For example, if the geometry or mechanism for sudden collapse is not present for the mine, there may not be a reason to determine air velocities. However, in the event there is any feasible failure mode, the TARP should contain an unambiguous decision flow to ensure timely response and planned mitigation.

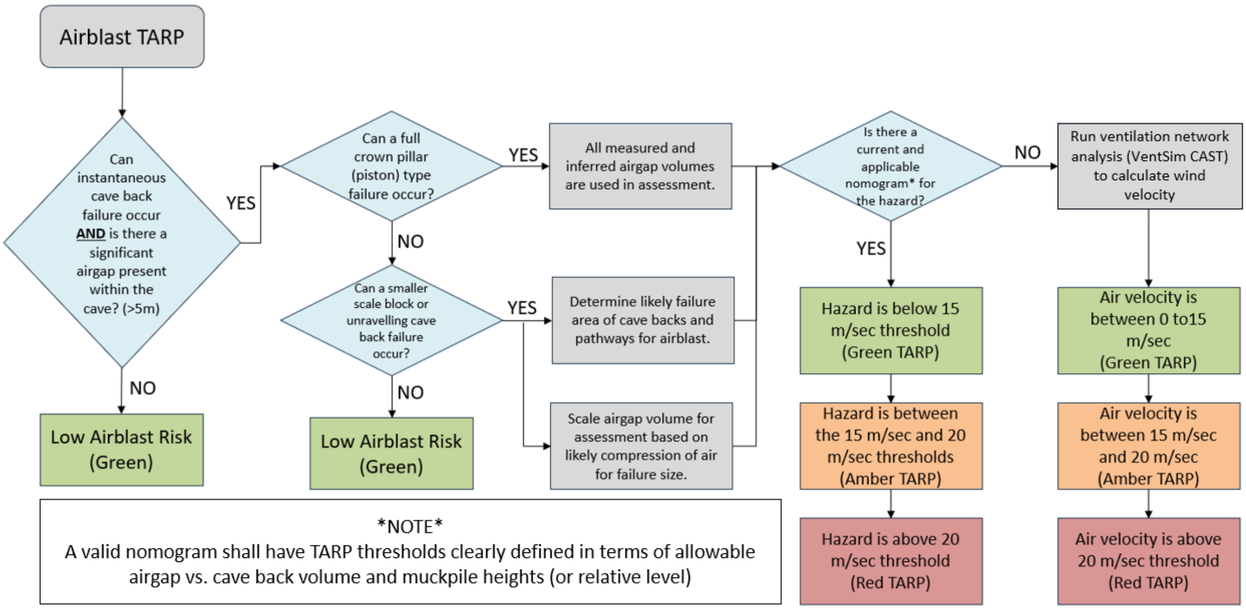



**Figure 7 Example decision matrix for an operational airblast trigger action response plan (TARP)**

In general, there are 6 main methods for mitigating the risk of airblast. These are (in order of control effectiveness and hierarchy):

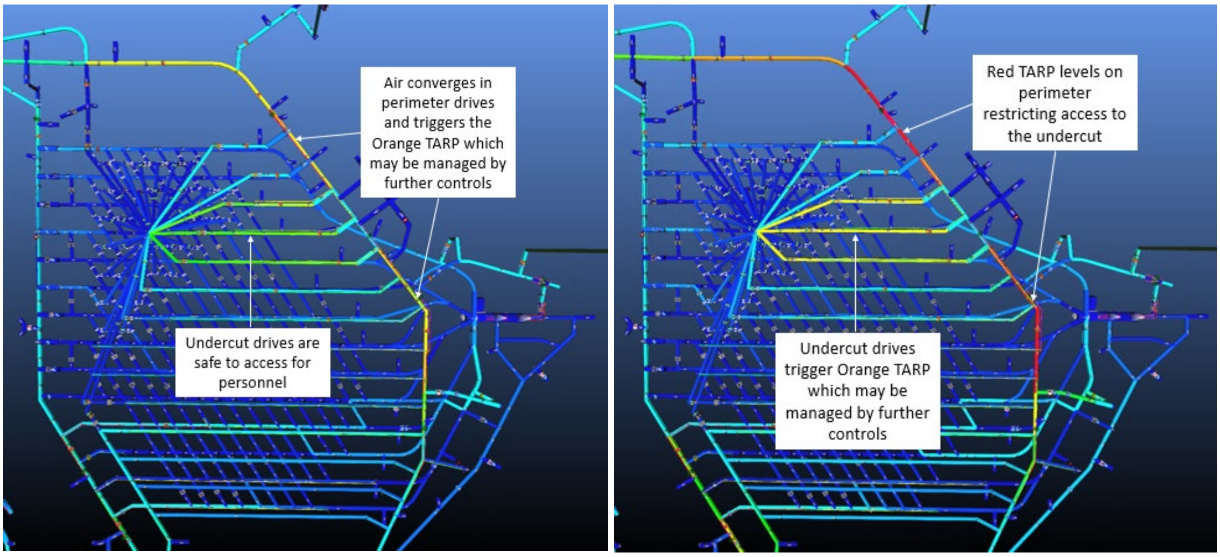
1. Controlled crown pillar failure (elimination)
   a. Artificially inducing failure in the cave crown pillar to break through to surface (or overlying cave). This eliminates the airblast risk.
2. Connections to surface (engineering)
   a. Redirecting airblast flow to surface via existing or additional ventilation pathways (pit adits, shafts, declines and/or raises).
3. Airblast plugs (engineering)
   a. Installation of engineered plugs to isolate high risk areas of the mine circuit.
4. Ventilation circuit changes (engineering, administration)
   a. Opening or closing pathways for air travel to redirect the hazard away from working areas and critical infrastructure. This control can be eroded by operational changes in ventilation circuits down the track, if airblast risk is not fully understood.

5. Void management (administration, engineering)
   a. To minimise the void to keep potential velocities below 15 m/s.
6. Access restrictions (administration)
   a. Removing personnel and equipment from at risk areas or levels of the mine. This can be upgraded to an engineering control if hard barricades are installed preventing access.

Typically, during early cave establishment and the shorter-term planning horizons, it is impossible to eliminate the risk of airblast to personnel through the design of the ventilation circuit or with physical barriers such as engineered plugs. This is because the undercut and extraction levels are the primary potential outlets for air in the event of a sudden collapse, and the continuation of undercutting requires work fronts to be maintained at the connections (brows) of the drives. Controlled crown pillar failure, although technically possible, is also typically not implemented as it adds significant cost, operational complexity and potential exposure to other hazards such as seismicity and subsidence. Therefore, the primary controls which can be implemented during early-stage block caving are the effective management of the muckpile and associated airgap within the cave column. This requires a robust planning and risk management system which was recognised when undertaking cave establishment at PC2-3. The following sections present the hazard quantification and risk management process adopted by the mine during the pre-initiation and early propagation phases of the PC2-3 block cave.

## 4.1 Airblast potential and tracking: pre-cave initiation

Prior to cave initiation, the airgap volume and cave dimensions are assumed to be consistent with the geometry of the undercut area and swell volume bogged during establishment. Based on the parameters presented in Section 3, the airblast model for PC2-3 was run and reviewed for hazard scale and spatial extent. As can be seen in Figure 8, the TARP levels are triggered on the perimeter drive prior to the undercut drives experiencing elevated velocity due to airblast. This is due to the parallel undercut connections converging to a single drive on the perimeter which serves to focus the airflow and increase velocity of the airblast in those areas.




(a) (b)

**Figure 8 Airblast velocity results for the pre-cave analysis for PC2-3 where (a) is an orange trigger action response plan (TARP) threshold scenario and (b) is a red TARP threshold scenario (blue indicates velocities lower than 10 m/s, green indicates 10–15m/s, yellow indicates 15–20 m/s and red shows velocities higher than 20 m/s)**

For the case at PC2-3, it was important to provide operations with a detailed nomogram outlining the trigger levels alongside which drives are impacted to ensure adequate controls could be implemented if required.

Figure 9 gives an example of the type of nomogram created from the model results to help inform planning and operational personnel of the status of the airblast hazard. In the figure, several important points are highlighted to provide clear indication of the status of the airgap's potential to cause a hazardous airblast event. Line 1 in the figure was used to show the current airgap volume with respect to its potential for airblast velocities. Line 2 could then be plotted in relation to the monthly planned airgap created assuming the cave has not initiated. Line 2 provides a visual cue to ensure the production plan does not result in a TARP trigger during the planning period. Furthermore, lines 3 and 4 show the airgap volume quantities required for the triggering of the orange and red TARPs respectively for the perimeter drives. This was used to determine the heightened level of controls that may be required for the perimeter to ensure safe access to the undercut drives, which would still have been safe to operate in. Finally, line 5 was used to show the airgap volume which caused all connected drives to trigger the TARP and require further risk assessment and controls for continued operations.

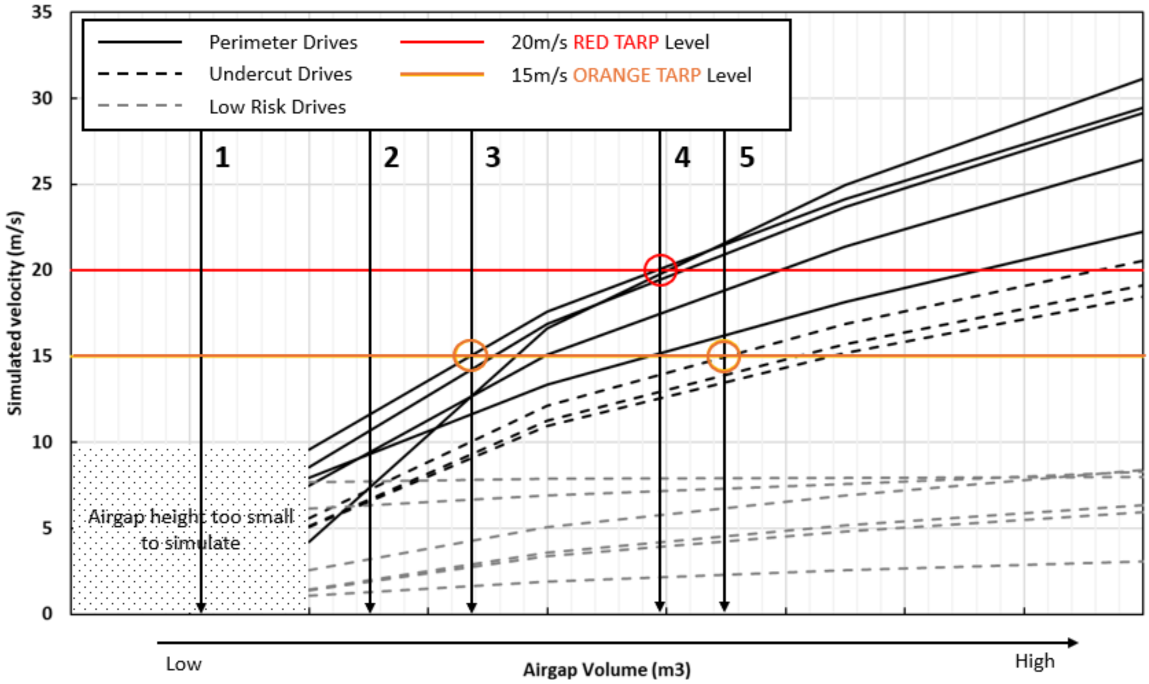



**Figure 9 Example nomogram for pre-cave initiation airblast tracking for PC2-3**

Using this nomogram and understanding of spatial variance of the airblast hazard enabled geotechnical and planning teams to ensure that the production and cave establishment activities were planned in accordance with minimising the airblast hazard and to highlight where controls or additional risk assessment was required in advance of the TARP actually being triggered.

## 4.2 Early cave propagation planning process

Once the cave is proven to have initiated and begun its propagation toward surface, the airblast hazard quantification and planning process needs to evolve to adequately track risk potential. The first step is implementing a robust procedure for interpreting the position and geometry of the cave. Although touched upon in previous sections, this process has been widely documented and is omitted from this study. However, the outputs of that interpretation should be used to determine failure mechanisms and modelled geometry for airblast hazard determination. The interpreted cave shape can then be combined with updated knowledge on mass balance and mine as-builts to produce an integrated approach to production planning for the early stages of cave propagation. Shown in concept in Figure 10, the planning process can be set up to ensure all production to be planned within the period is considered safe from an airblast hazard perspective. The outcome of the planning process still takes the form of tracking nomograms such as the one in Figure 9 coupled with more detailed mass balance which accounts for refill of the cave due to continued propagation.

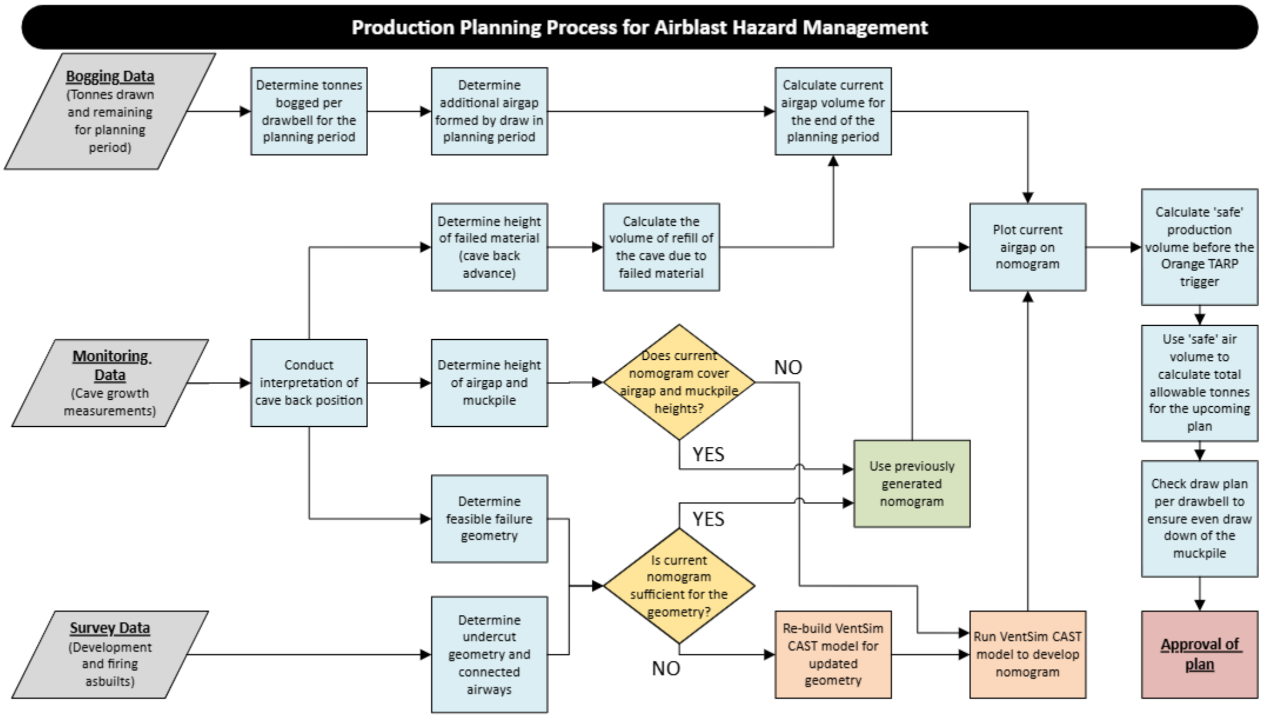



**Figure 10 Production planning process for a cave in the early stages of propagation**

To determine the amount of air still theoretically present in the cave, a more detailed mass balance procedure was derived. First, the interpreted height of the cave above the undercut backs can be measured for the plan view centroid of each underlying drawbell. This provides an approximate measure of the amount of failed material which, once a swell factor is applied, has the effect of partially filling the total volume of air due to bogging. An example of the breakdown of the cave into drawbell districts and measured cave back heights is provided in Figure 11.

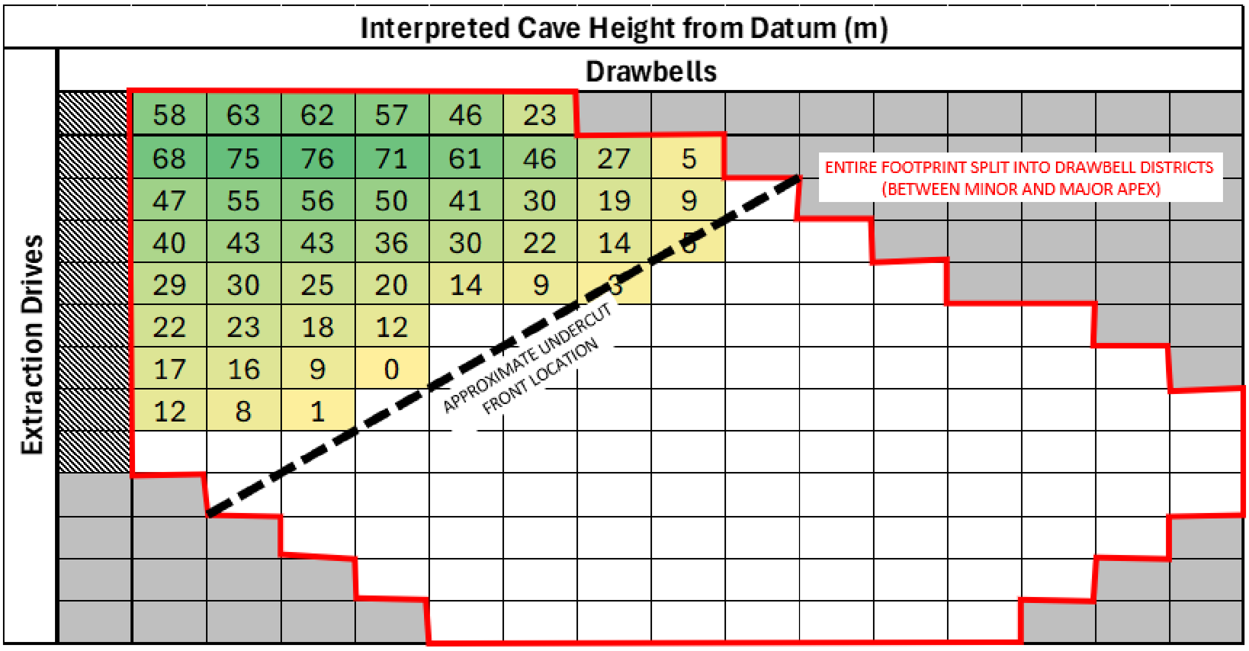



**Figure 11 Cave footprint split into drawbell districts for mass balance and cave refill calculations**

The equations used to estimate the total failed volume and level of refill due to cave propagation are presented below:

$$FailedVolume = CaveHeight \times d_{major} \times d_{minor} \quad (1)$$

$$Refill = (FailedVolume \times SF) - FailedVolume \quad (2)$$

where:

| | | |
|---|---|---|
| $d_{major}$ | = | distance of the major apex spacing (32 m) |
| $d_{minor}$ | = | distance of minor apex spacing (20 m) |
| $SF$ | = | swell factor. |

Then to calculate the remaining theoretical airgap due to mass balance the following formula can be used:

$$Airgap_{DB} = Airgap_{TB} - Refill \quad (3)$$

where:

| | | |
|---|---|---|
| $Airgap_{DB}$ | = | airgap above each drawbell with any refill associated with the interpreted cave |
| $Airgap_{TB}$ | = | total bogged airgap for the drawbell (no refill) |
| $Refill$ | = | volume of material refilling the airgap due to cave growth and bulking. |

This derives a final theoretical amount of air per drawbell area which would be mobilised during an airblast event (if it was to occur). Finally, the total airgap available for potential airblast can be derived using the equation:

$$TotalAirgap = \sum Airgap_{DB\varphi} \quad (4)$$

Using this set of equations and the process outlined in Figure 10, it is then possible to determine the current volume of the airgap and safe operating limits for the production plan when plotted against relevant modelled nomograms.

# 5 Conclusion

Airblast is recognised as a principal hazard for block caving mines and poses a significant risk to personnel and operations if not managed correctly. This is of particular importance during the pre-cave initiation and early propagation phases of a project as the risk is often heightened due to the close proximity of the airgap to workings and active areas. As such, this paper presented a practical framework for identification of critical geometric and cave back failure parameters for input into ventilation network modelling to enable the estimation of airblast for these early cave stages.

Application of the framework to the PC2-3 block cave at Cadia East Mine demonstrated that robust parameters and inputs can lead to simple, yet effective operational and planning nomograms to be generated which can track the current status and planned change to the airblast hazard due to continued cave establishment and production. While higher-order controls such as engineered plugs or ventilation circuit redesign are often impractical at the execution stage of a cave, the proactive control of airgap growth through draw management and carefully managed undercut firing and bogging has proved to be an effective and implementable risk mitigation strategy.

The framework presented can be adapted and applied to other early-stage caving operations with different layouts, undercutting methodologies, depths and cave geometries. By embedding airblast assessment into short-to-medium-term planning cycles, mine operations can move from reactive management toward a proactive, risk-informed approach that enhances personnel safety without unduly constraining cave establishment activities.

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## Disclaimer

This paper is for informational and academic discussion purposes only and is strictly site-specific to Newmont's Cadia East operations. The predictive models, VentSim™ CAST workflows, and safety frameworks (TARPs) presented involve inherent geomechanical uncertainties and are based on localised operational variables. Newmont Corporation makes no warranties, express or implied, regarding the accuracy of these simulations or their applicability to other mining environments. Any reliance on or replication of these methodologies by third parties is done entirely at their own risk, and Newmont expressly disclaims all liability for resulting operational outcomes, property damage, or injury. Nothing herein constitutes investment advice or a solicitation regarding Newmont securities.

## References

Fowler, J & Hebblewhite, B 2003, 'Managing the hazard of wind blast/air blast in caving operations in Australian underground mines', *Ground Control in Mining: Technology & Practice*, UNSW School of Mine Engineering, Sydney.

Galindo-Torres, S, Palma, S, Quintero, S, Scheuermann, A, Zhang, X, Krabbenhoft, K, ... Finn, D 2018, 'An airblast hazard simulation engine for block caving sites', *International Journal of Rock Mechanics and Mining Sciences*, vol. 107, pp. 31–38.

Logan, A & Tyler, D 2004, 'Air inrush risk assessment for caving mines', *Proceedings of Massmin 2004*, University of Chile, Santiago, pp. 717–720.

Ormerod, T, Cox, D, Vejrazka, C & Poulter, M 2024, 'Case study management of the risk of air blast at Carrapateena', in D Johansson & H Schunnesson (eds), *MassMin 2024: Proceedings of the International Conference & Exhibition on Mass Mining*, Luleå University of Technology, Luleå, pp. 373–384, https://doi.org/10.36487/ACG_repo/2435_C-06

Palma, S, Galindo-Torres, S, Delonca, A, Ruest, M, Scheuermann, A & Finn, D 2019, 'Universal laws for air velocities in airblast events during block caving', *International Journal of Rock Mechanics and Mining Sciences*, vol. 113, pp. 303–309.

Vejrazka, C 2016, 'Northparkes Mines' Current Air Blast Risk Assessment Practices for Block Caving Operations', in *Seventh International Conference & Exhibition on Mass Mining*, Australasian Institute of Mining and Metallurgy, Melbourne, pp. 257–263.

Vejrazka, C 2022, 'Quantitative airblast risk assessments for block and sublevel caves', *Australian Mine Ventilation Conference*, Australasian Institute of Mining and Metallurgy, Melbourne, pp. 145–164.