Caving 2022 - Y Potvin (ed.)

doi:10.36487/ACG_repo/2205_02

A risk-based approach to practical scope definition and management at PT Freeport Indonesia

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Abstract

PT Freeport Indonesia's (PTFI) Grasberg mining complex consists of some of the largest and deepest mines in the world, set within a complex geological, hydrogeological, and geotechnical setting. A risk-based approach to scope definition is implemented practically to manage hazards at underground operations. The approach focuses on identifying hazards, managing those hazards, and communicating risk from planning through operational stages. Risk management is centred around an online platform that enables users to reference hazards and determine initial, current, and residual risk ratings. PTFI's approach to risk assessment enables management to understand the divisional risk across multiple technical disciplines and focus their efforts on scope definition, manpower and budget allocation to promote safety and achieve stated production targets. This paper provides details of PTFI's approach to risk management, highlights challenges and realised benefits, and outlines the path forward for continued risk-based scope definition and hazard management.

Keywords: *geoengineering, risk management, planning, scope definition*

1 Introduction

Sources of risk in a mining project are many and varied and no project is without risk. Risk can be managed, minimised, shared, transferred, or accepted but it cannot be ignored. The route by which a mining project develops, from the earliest scoping study to the final construction stage through to operation, reflects an ever-increasing level of complexity with more and more detail added (Summers 2000). Cave mining projects, despite low-cost operations, are counted among the riskier mining methods. Applying appropriate and practical methods for ranking risks can help to perform better risk management (Oraee et al. 2011). A mine plan and company objectives require that the ore resource and geotechnical models perform as predicted to meet productivity goals in a cost-efficient way. In an operating mine, geomechanical risk is often associated with operational goals, as well as health and safety considerations. In all cases, it is necessary to have access to risk-management skills, leadership, and human capital to develop and implement an effective risk-management strategy (Hadjigeorgiou 2019).

A risk-based design or risk-informed decision is a process that provides a technically defensible basis for making decisions and helps to identify the greatest risks and prioritise efforts to minimise or eliminate them. It is based primarily on a narrow set of model-based risk metrics, and generally does not leave much space for interpretation (Zio & Pedroni 2012). A risk-informed decision-making process provides an avenue to make informed risk decisions while being a platform for defining the acceptance criteria. The process also allows the risk and acceptance criteria to be updated periodically, so that changes in the operation and/or performance can be considered (Lupo 2019). A 'risk-informed' decision process has formed the basis for the PTFI approach to risk management with periodic updates being carried out based on how the operation evolves and changes.

Hadjigeorgiou (2019) highlights issues within the mining industry on understanding, managing and communicating geomechanical risk and concludes that critical assessments of effectiveness of risk management tools is required. There are also complications in administering the geomechanical risk management process due to the asymmetry of knowledge between the different levels within a mining company and information that is provided to the decision-makers. Some of the pitfalls of risk management are down to complacency, inappropriate team selection, poor documentation and implementations. And evidence suggests that the mining industry may have become so entrenched in conducting risk assessments that sight has been lost over the purpose or the importance of some of the assessments conducted, resulting in a degree of complacency, and inadequate follow-through of risk controls and actions. There is a need for greater diligence moving to the future and use of more rigorous assessment techniques to provide even more effective and appropriate management controls, leading hopefully to continuing improvements in mine safety and mine operational performance (Hebblewhite 2019).

Cave mining will continue being an attractive extraction method, as long as low operating costs and high productivity can be achieved. However, hazards associated with cave mining will only increase in severity as operational depths continue to push deeper. These challenges, which are significantly outside past experiences and are present now, dictate that significant changes to current practices to manage the major caving hazards are required (Flores-Gonzalez 2019).

2 PTFI risk management framework

PT Freeport Indonesia's (PTFI) Grasberg mining complex consists of some of the largest and deepest mines in the world, set within a complex geological, hydrogeological, and geotechnical setting in mountainous terrain in West Papua, Indonesia. Mining at the Grasberg (GRS) open pit finished in Q1–2021 and the Grasberg Block Cave (GBC), situated below the GRS, is currently ramping up to full production averaging roughly 110 kt/day at approximately 1.1% Cu and 1.0 g/t Au. The GBC mine is a typical copper-gold porphyry style deposit with a diorite intrusion with varying intensities of alteration types hosted in a sedimentary rock package. The Deep Mill Level Zone (DMLZ) is the third lift in a series of block cave mines located some 2 km away from GBC and ramping up to full production averaging around 80 kt/day with average grades around 1.8% Cu and 1.4 g/t Au. The DMLZ is a sedimentary hosted skarn deposit broadly characterised as massive, veined, a strong and brittle rock mass at 1,400 m below surface level. The DMLZ cave breakthrough to the above Deep Ore Zone (DOZ) cave mine subsidence zone occurred in 2021 in the same year that GBC broke into GRS open pit. The DOZ cave mine finished production in 2021. The Big Gossan (BG) mine is a longhole open stope mine currently with nine active levels and 1 km footwall drive averaging around 8.5 kt/day of 3% copper and 1 g/t Au. The Kucing Liar (KL) is a block cave mine located below and slightly offset from the GBC with projected 6 billion lbs copper and 5 million ounces of gold, currently in the Feasibility Study phase.

The Grasberg mining complex, with mines at different stages of mining from design through to operation and closure, includes a spectrum of hazards with varying levels of associated risk. A risk-based approach to scope definition is implemented practically to manage hazards at underground operations at PTFI combined with hazard control monitoring as proposed by Diederichs & Langford (2013). The approach focuses on identifying hazards, managing those hazards, and communicating risk from planning through operational stages. Risk management is centred around an online platform that enables users to reference hazards and determine initial, current, and residual risk ratings. The approach to risk assessment enables management to understand the divisional risk across multiple technical disciplines and focus their efforts on scope definition, manpower and budget allocation to promote safety and achieve stated production targets. This paper provides details of PTFI's approach to risk management, highlights challenges and realised benefits, and outlines the path forward for continued risk-based scope definition and hazard management. Figure 1 sets out the framework for the risk register and process for the project.

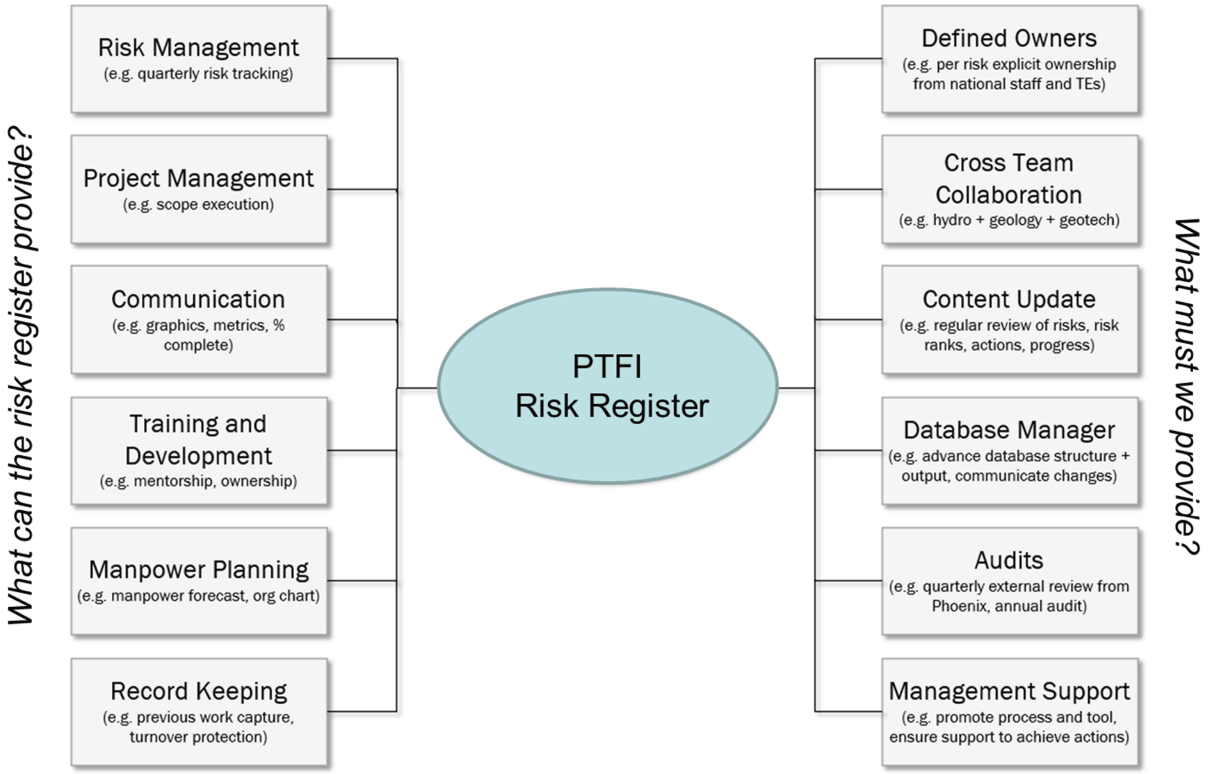

Figure 1 Framework for PTFI risk register

3 PTFI risk-based approach and supporting tools

The risk-based approach is centred around an online platform supported by a linked database that is easy to use, understand and audit. The approach is dynamic as updates are made regularly and in real time by authorised users. All risk data are securely stored in a central database. Within PTFI, the database is known as the risk register and draws on the benefits of using Acquire™ for storing the data, excel templates for reports and Microsoft PowerBI™ for visualisations, data interrogation and scope planning. The following sets out the approach for how to calculate risk in the register tool.

3.1 Hazards and initial risk

A hazard is an action, situation or behaviour that has the potential to cause injury to employees, damage to property or the environment, interruptions to production, legal non-compliance or loss of social license and stakeholder support. The initial risk is calculated for each hazard using defined likelihood of occurrence and consequence ratings. All rating descriptions were adopted from the Freeport-McMoRan Corporate (FCX) organisational risk framework. The likelihood ratings range from Unlikely, Possible, Likely and Almost Certain with descriptors as shown in Table 1. The consequence ratings range from Minor, Moderate, Significant and Catastrophic with descriptors linked to Safety and Health, Legal and Compliance, Environmental, Stakeholders, Production Capacity and Financial impact. The descriptions for each are shown Table 2. The risk rating is then calculated using the Probability and Impact (PI) model risk assessment matrix to calculate an unmitigated initial risk rating as shown in Table 3. The likelihood is multiplied by the highest consequence rating to give an initial risk rating.

Table 1 Likelihood descriptors

Unlikely	Possible	Likely	Almost certain
Highly unlikely to occur during the lifetime of an operation/project.	Event that may occur during the lifetime of an operation/project.	Event that may occur (<once per year).	Recurring event during the lifetime of the operation/project or >once per year.

Table 2 Consequences descriptors

Safety and health	Legal/ compliance	Environmental	Stakeholders (regional, national, international)	Production capacity	Financial
Multiple fatalities which may result from a physical event (slope failure, personnel transport accident), chemical release event, or clusters of cancer or terminal disease	Major and/or chronic non-compliance issue or Administrative Order/class action lawsuits with merit	Major onsite degradation or irreparable offsite environmental damage	Loss of social license and/or community support or tangible expressions of mistrust across the entire community, setting the agenda for decision-makers and key stakeholders	Shut down	>$100 M
One or more fatalities, permanent disabilities, or isolated cancers or terminal/disabling disease	Significant non-compliance issue with regulatory requirement NOV with fine potential >$100 K	Significant degradation – onsite impacts or local offsite impacts or reversible impacts	Organised opposition to operations or tangible expressions of mistrust amongst a majority of community members with significant influence on public opinion and decision-makers	~50%	$100–$50 M
Medical treatment or restricted duty or lost time injury, or reversible health effects, or hearing loss	Moderate non-compliance issue with regulatory requirements NOV/NOC with minimal fine	Short-term onsite impact but correctable or repairable	Organised group opposition or tangible expressions of mistrust amongst a minority of community members with moderate influence on public opinion and decision-makers	~75%	$50–$25 M
Minimal injury or first aid	Not a compliance issue with minor regulatory requirements or informal notice	Minimal measurable onsite temporary impact	Minimal reaction from external parties or tangible expressions of mistrust amongst a few community members with some influence on public opinion and decision-makers	≥95%	$25 M–$0

Table 3 PTFI risk assessment matrix

PTFI risk assessment matrix				Consequence
4	8	12	16	Catastrophic (4)
3	6	9	12	Significant (3)
2	4	6	8	Moderate (2)
1	2	3	4	Minor (1)
Unlikely (1)	Possible (2)	Likely (3)	Almost certain (4)	Likelihood of occurrence

3.2 Risk reduction measures and actions

Each hazard is assigned a risk reduction measure and relevant actions to manage those risks. Defining the measures and actions are driven by risk rating levels. The response required for each risk rating level is as shown in Table 4. The actions are linked to the risk reduction measures. The database records both the user and date of the last update related to action achievement. The tool enables users to manage the action in the database by recording the following data:

- Status: Not Started, In Progress, Ongoing, Complete are used to describe the status of the action. The descriptor ongoing is used for an established action that is set up and ongoing and complete is used for a one-off action that is completed.
- Achievement: Allows for recording progress achievement as a percentage.
- Hierarchy control: Engineering, Administrative, Work Practice and PPE.
- Deliverable: Range of deliverable formats.
- Start and end dates.
- Budget proposals.

Table 4 Response required for action level

Rating Level	Response required for risks
Very high – actionable	Action plan required. Identify key actions/milestones to be accomplished. Determine if interim controls are needed to allow the activity to continue pending completion of action plan.
High – monitor	Monitoring plan required.
Medium	Monitoring required; proactive measures needed to prevent transition to actionable. No action or monitoring plan required.
Low	Monitor for trends and patterns which may indicate increasing risk.

3.3 Current and residual risk

The final component of the risk register enables the user to assess the impacts of the risk reduction measures and actions on the initial risk and calculate the current and residual risk. Residual risk is defined as the risk rating after completing and maintaining the risk reduction measures and actions. Current risk is defined as the risk at this time based on achievement of risk reduction measures and actions. Diederichs & Langford's (2013) approach to using descriptions of controls, managed and detection and/or verification are applied to the combined actions achievement to calculate the current and residual risk. These were modified to apply to the 4 × 4 risk matrix by removing the Absent code from the control and Clear Warnings and Observation codes from the detection Categories. Data fields to record Total Action Achievement for the risk, Persons in Charge (PIC) with associated Technical Expert (TE), parties involved such as external departments, contractors and consultants, risk relationships/conflicts with others are required in the database. An example of the 'Hazard Control and Residual Risk' section of the database is shown in Figure 2.

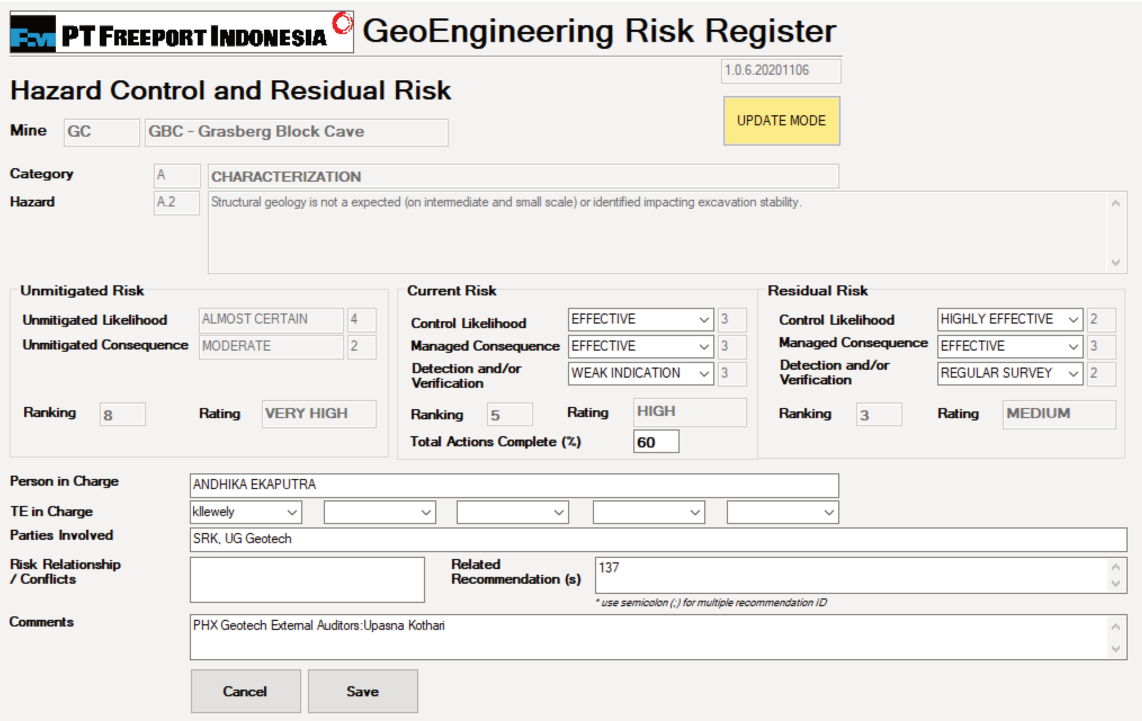

Figure 2 Screenshot of hazard control and residual risk section of tool

4 Hazard identification and action planning

Defining the hazards, risk reduction measures and actions based on this approach was a collaborative effort from Phoenix Corporate, Jobsite and Consultants. Several risk-based workshops were held to primarily:

- Identify the hazards and assess the consequences.
- Define the risk reduction measures and actions based on the initial risk rating.
- Outline the achievement for each action and how it impacted the initial risk.
- Outline the scope required for achieving the residual risk.

Good communication and clear documentation were required during the workshops to ensure that a consistent and repeatable approach was being adopted throughout the process for assessing the risks. The roll out of the approach was followed up with training for all PICs and managers involved to take ownership over management and execution of actions. The PICs are focused on executing the actions and updating the achievement to reduce the risk. An example of the 'Actions' section of the database is shown in Figure 3. The PIC here indicated that this action is complete with 100% achievement and shows that it is ongoing task with planned updates to the vein model with Phase 3 currently in progress.

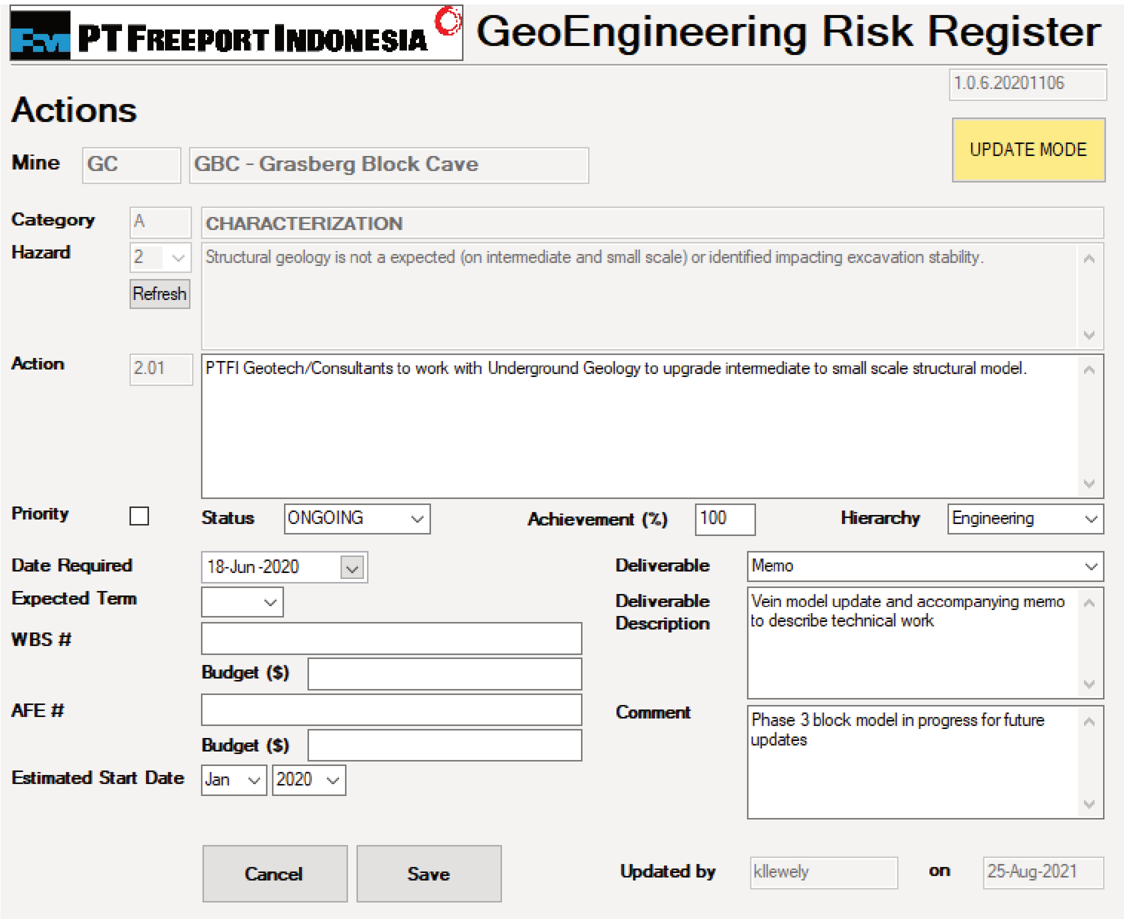

Figure 3 **Screenshot of action section of tool**

5 Project planning and scope definition

An online dashboard developed in Microsoft PowerBI^{TM} enables management to visualise and interrogate the data stored in the Acquire database to define scope and plan activities (Figure 4). The dashboard has capability of filtering and drilling down into data so that management can focus on the different areas, mines, and departments within the division. Figure 3 gives an example of a view mode when it is opened for Risk by Action Status. The screen always shows the initial, current, and residual risk ratings and then the %Risk and %Action Achievements. A report style table can be found at the bottom which can be enlarged or exported and contains the details shown on the view model. The dashboard enables users to click anywhere on the screen and drill down into that data. The following sub-sections set out how the online dashboard is used for project planning and scope definition.

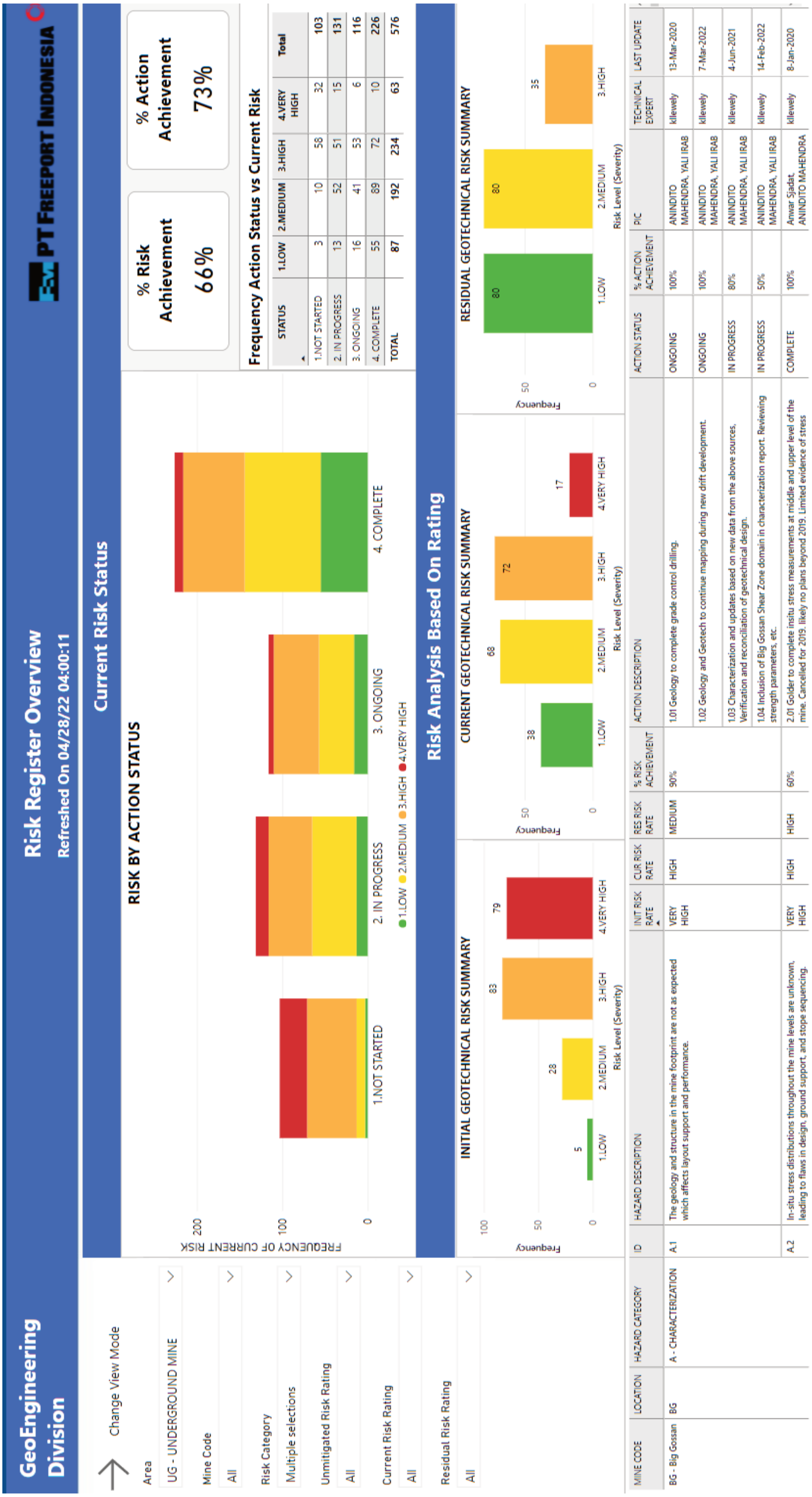

Figure 4 Risk register online dashboard view in Microsoft PowerBI

5.1 Risk by action status and deliverables

The '*risk by action status*' chart as shown in Figure 3 provides a basis for planning workload and activities. The chart illustrates action status as Not Started, In Progress, Ongoing or Complete. Planning workload is carried out by prioritising the '*Not Started*' and '*In Progress*' actions taking into consideration the severity of the risk. Drill down capability enables users to go into the database from the dashboard by clicking directly on the bar chart for the risk by actions status and the data is instantly updated in the table below. This data table is then exported and used in planning activities.

The '*risk by action status*' is also used for scope definition for actions that have not been included in the risk register. The '*Ongoing*' and '*Complete*' actions that have Very High and High risks associated to them, indicates that either there are actions that are needed to be completed or that additional actions are required to reduce risk. Clicking on the red or amber portion of the column on the bar chart for *'Ongoing'* and *'Completed'* actions updates the table at the bottom and allows users to interrogate what next steps are needed for risk mitigation.

The '*risk by deliverables*' is used to understand how the actions are being documented in terms of the deliverable and where time and effort is being spent. Preparing reports can take up a large portion of someone's time and by interrogating this information, the users of the dashboard are able to check if these reports are suitable or if time can be saved by using a different type of deliverable. Also, the other deliverable types such as meetings are checked to ensure that they are suitable for the severity of the risk.

5.2 Risk by FRM and hierarchy

Fatal Risk Management (FRM) is a safety programme implemented by PTFI's Occupational Health & Safety (OH&S) Division to aid in the prevention of fatal accidents in the workplace. Fatal risks are assigned to the safety and health consequences for each hazard so that the distribution of fatal risks linked to the current risk rating can be analysed. This information is relayed back to the safety division and used to focus safety initiatives for the division and considered in the daily safety talks and weekly safety meetings.

The '*risk by hierarchy*' field enables management to understand what controls are being used to mitigate the risk and where effort is required to target those risks and apply more robust controls if needed to manage them. Periodically the team carries out a review of the administratively controlled risks to check that they are still suitable and if any updates are needed. Experience has shown that sometimes working practices change and an administrative action such as a Standard Operating Procedure (SOP) are not updated to reflect the changes. This periodic check enables managers to plan the updates of supporting documents.

5.3 Historical risk and action

The *'historical risk and action*' dashboard view enables users to see how risk and action achievement changes over time. The screenshot from Figure 5 shows how the risk profile has changed over the last two years. The images shows that there is a positive trend in risk and action achievement over the last two years. The risk achievement is the % completion of all the risks and the action achievement is the % completion of all the actions associated with the risks. Both are linked, as progress is made on actions and the % achievement increases causes the % risk achievement to increase. This capability of viewing historic risk and action achievement enables management to analyse how the division is managing its risk profile over a longer period. Similar filters and drill down options can be applied at the different quarterly periods to understand how conditions have changed.

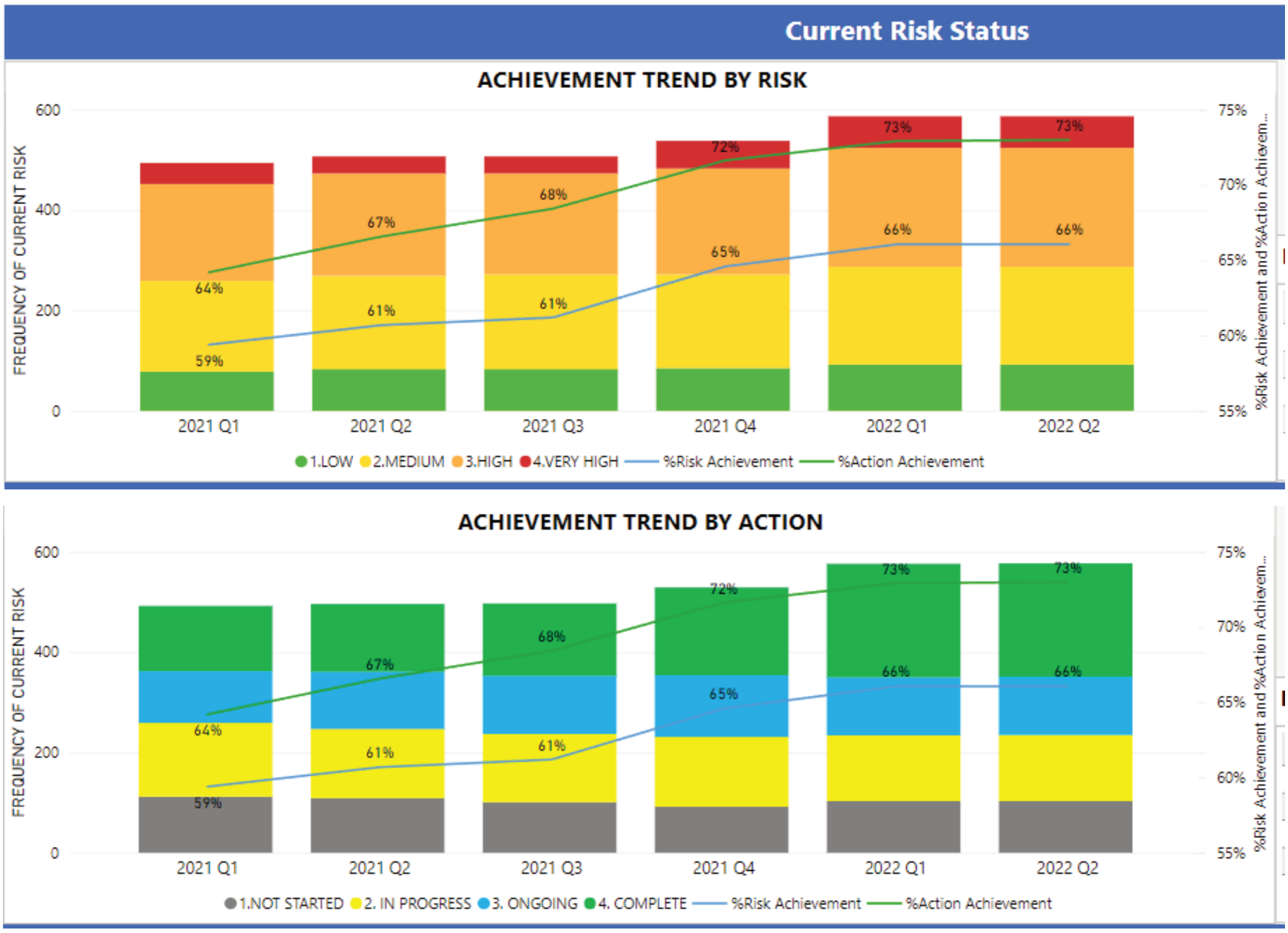

Figure 5 Achievement trends by risk and action

6 Reporting and auditing

The risk register can be accessed by corporate and operations staff on daily basis. Any changes made in the database are updated and reflected when the report is run. The online platform is updated every 24 hrs. The following points summarise standard reports prepared as part of PTFIs approach to risk management:

- A spreadsheet format report is created on a quarterly basis and stored on the mine site server.
- Any reports and proposals prepared by the underground division are linked to the Hazard IDs listed in the risk register.
- Quarterly updates to senior management are provided where each department presents an overview of risks relevant to unique mines/areas from the current period. Updates focus on changes in risk status through the application of risk mitigation actions for the current and upcoming quarter.
- A summary report is generated automatically on the first of the month and sent to the managers for review. A monthly meeting is held in the week following for PIC's to outline what risks and related actions will be focused on for the upcoming month.
- A bi-annual review of the risk register is carried out by the corporate team of to ensure that any updates made by the mine site PICs are representative of the current risk management profile. Feedback is provided by the corporate team and the risk registers are updated as required.

7 Challenges, realised benefits and path forward

The PTFI risk management process has had its challenges since roll out. However, these challenges do not outweigh realised benefits attained by the organisation. Consistency in risk reporting is critical and monthly updates from the different departments are now clear and concise. Budget and manpower planning is easier as the risk ratings demonstrate to the managers where focus should be given to the division. Proposed budget requests are reviewed against the specific risk and decisions made if that level of spending is required with requestors asked to demonstrate the impact of the proposed spending in terms of the risk reduction. Manpower planning has also improved as managers are able to focus on what are the deliverables from the departments and also the efforts to understand how time is being spent.

The risk register has been used in addition to other safety initiatives to ascertain the ISO45001:2018 (ISO 2018) accreditation as demonstrates how safety is being managed, stored and actioned upon. Risks are being managed and a general positive trend has been observed over the past two years. Whilst the risk-based approach is not the sole driver for safety and production targets being met, management have noted a change in mindset on how the workforce carries out day to day activities.

As with any risk register or risk-based approach, the initial work to develop, train and roll out the approach had to be effectively managed as change to daily activities is difficult. Developing the content for the risk register required effort from the team at jobsite, corporate and input from external consultants. Whilst there is some subjectiveness to any risk register, it is imperative that time is given to work through and discuss the content before finalising.

The path forward for this risk-based approach to management is to incorporate the Lessons Learnt and Opportunities Register and develop a more holistic encompassing approach. Given that Kucing Liar Project is currently in the feasibility stage of the study, the team is focused on ensuring that these three registers are used to drive some of the key strategic decisions. Integration of cost control models and the budgeting proposals database will be an initiative to further assist management to understand how costs can be saved. Whilst there is data input for budget requests, these are not consistently used as there is an entirely different database set up for these requests.

8 Conclusion

It’s clear that there are issues within the mining industry on understanding, managing and communicating geomechanical risk and that the industry has lost sight over the purpose or importance of risk management. Cave mining inherently has risk through early-stage planning to operations and closure. PTFI currently have a mine at each stage of the process within the Grasberg Mining Complex and a risk-based approach has been developed to manage the risks to cover the entirety. The approach was developed within the GeoEngineering division and given the successes, is now being used by the underground division for risk management. This is enabling the underground to be more consistent on how risk is managed and reported so that management can make effective strategic decisions. Scope definition can be a difficult task when teams have existing daily activities that have been ingrained over many years of operation, however this approach gives managers and their teams a platform to define what scope is needed to mitigate risks. This risk-based management approach and register tool has improved how PTFI plan and execute workload and activities. It has made the operation more efficient in scope planning, budget allocation and there is a general improvement in cohesiveness within the organisation with a clear understanding of the purpose of the approach, why it is important and when it should be used. Attitudes towards risk within the mining industry must change, and risk management should be at the forefront of a project so that any risk is managed to improve safety for the workforce and reduce impact on production on costs.

Acknowledgement

The authors of this paper would like to acknowledge the input of Allan Moss at Sonal Mining for technical guidance on the development of this approach and for input to the content. Also to recognise the efforts from the Jobsite and Corporate GeoEngineering departments and especially the GeoScience Database team from the Centre of GeoScience Information Department in developing, managing and continuing to improve this risk-based approach project.

References

Diederichs, M & Langford, C 2013, ‘Reliability Approaches in the Geotechnical Design of Underground Works Notes’, from workshop held at ARMA Conference in San Francisco.

Flores-Gonzalez, G 2019, ‘Major hazards associated with cave mining: are they manageable?’, in J Wesseloo (ed.), *MGR 2019: Proceedings of the First International Conference on Mining Geomechanical Risk*, Australian Centre for Geomechanics, Perth, pp. 31–46, https://doi.org/10.36487/ACG_rep/1905_0.3_Flores-Gonzalez

Hadjigeorgiou, J 2019, ‘Understanding, managing and communicating geomechanical mining risk’, in J Wesseloo (ed.), *MGR 2019: Proceedings of the First International Conference on Mining Geomechanical Risk*, Australian Centre for Geomechanics, Perth, pp. 3–20, https://doi.org/10.36487/ACG_rep/1905_0.1_Hadjigeorgiou

Hebblewhite, BK 2019, ‘Geotechnical risk in mining methods and practice: critical issues and pitfalls of risk management’, in J Wesseloo (ed.), *MGR 2019: Proceedings of the First International Conference on Mining Geomechanical Risk*, Australian Centre for Geomechanics, Perth, pp. 299-308, https://doi.org/10.36487/ACG_rep/1905_17_Hebblewhite

International Organization for Standardization (ISO) 2018, ‘ISO45001:2018 – International Standard for Occupational Health and Safety Management Systems – Requirements with guidance for use’, 41 p.

Lupo, JF 2019, ‘Geotechnical risk-informed decision-making in mining’, in J Wesseloo (ed.), *MGR 2019: Proceedings of the First International Conference on Mining Geomechanical Risk*, Australian Centre for Geomechanics, Perth, pp. 61–68, https://doi.org/10.36487/ACG_rep/1905_0.5_Lupo

Oraee, K, Basiri, MH, Sajidan, MH & Hayati, M 2011, ‘Risk assessment in block cave mining’ in *SME Annual Meeting & Exhibit and CMA 113th National Western Mining Conference ‘Shaping a Strong Future Through Mining’*, Denver, Colorado, pp. 331–335.

Summers, J 2000, ‘Analysis and Management of Mining Risk’ in *Proceedings of Massmin 2000*, The Australasian Institute of Mining and Metallurgy, Melbourne.

Zio, E & Pedroni, N 2012, ‘Risk-Informed Decision-Making Processes’, in *An Overview, Foundation for an Industrial Safety Culture, Foundation for an Industrial Safety Culture*, Toulouse.