ALPHA FOUNDATION FOR THE IMPROVEMENT OF MINE SAFETY AND HEALTH

Final Technical Report

Project Title:	Improved Safety through Application of Risk Management in U.S. Underground Coal Mines: A RISKGATE Approach
Grant Number:	AFC-113-13
Organization:	Virginia Tech
Principle Investigator:	Kray Luxbacher, PE, PhD Professor, Mining and Minerals Engineering
Contact Information :	100 Holden Hall (0239) 445 Old Turner Street Blacksburg, VA 24601 Email: kraylux@vt.edu Phone: (540) 231-2244 Fax: (540) 231-4070
Period of Performance:	November 1, 2013 to September 30, 2017

Acknowledgement/Disclaimer: This study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

2.0 Executive Summary

The development of a body-of-knowledge used for risk management is detailed in three areas for underground coal mining in the US context: ground control, moving equipment and ventilation. This knowledge was captured from over 100 expert participants in the US coal industry with over 1200 years of experience in 10 workshops held around the US, and best practice for such workshops was detailed. This knowledge was then formatted into an online database that allows users to customize plans for risk management as appropriate at their own sites, is freely available at http://riskgate.alpha.org/, and is known as US-RISKGATE. Finally, to explore whether risk management can be used effectively in the US context in regular interactions with miners, US-RISKGATE was used to develop a series of safety meetings which were delivered to a cohort of miners at a site in Central Appalachia over two months. They were also introduced to risk management in an intake meeting that lasted approximately an hour. At the end of two months 60% of participants agreed that the approach improved safety at the operation. This work was adopted from RISKGATE, an ACARP initiative in Australia, and the research is a collaborative effort between Virginia Tech, the University of New South Wales, and the University of Queensland.

3.0 Problem Statement and Objectives

Problem Statement

Risk management is the state-of-the-art approach to safe operations utilized in heavy industries, including mining, in developed nations worldwide. The benefits of risk management include ready identification and mitigation of risk, inclusive stakeholder engagement, and rapid integration. However, these approaches are best applied in industries where the regulation is based on best practices and technology; in contrast, the US coal industry operates under a fairly prescriptive regulatory system which is based on the 1977 Mine Act. US coal mining operations have consistently improved in several measures of safety over the long term, with American companies sincerely professing a goal of zero harm. Risk management has the potential to contribute to this zero harm goal, and has demonstrated great success in other countries, including Australia. Safety cultures, mining practice, and regulatory systems do differ significantly between the two countries, so application of RISKGATE in the US must account for these differences. This work aims to utilize and refine the RISKGATE body of knowledge to apply risk management to US underground coal mines in a practical way through a targeted pilot of RISKGATE in the field with concentration on fires/explosions, ground control, and moving equipment.

Objectives

The objective of the proposed research was to affect the utilization of risk management in the US underground coal industry through transfer of the Australian RISKGATE approach to improve safety and contribute to an engineered zero harm environment in underground coal mines. Several outcomes were realized as a result of this objective. First, a thorough analysis of US and Australian regulatory systems was undertaken to identify barriers and incentives to risk management. The Australian RISKGATE body of knowledge was transferred and adapted as appropriate for the US industry. Next, a pilot study at an operating underground mine utilizing risk management in three high risk areas, fires/explosions, ground control, and moving equipment was conducted and analyzed. Finally, an assessment of the pilot US-RISKGATE project developed recommendations for comprehensive system application and dissemination.

Motivation and Brief Background

Recent accidents in the US and worldwide have renewed the drive for innovative approaches to mine safety. In the US, the federal government responded with additional mine safety legislation with the MINER Act of 2006 following the Sago and Darby explosions and Aracoma mine fire, all of which occurred in 2006. The Upper Big Branch disaster of 2010 resulted in 29 fatalities, but little change at the federal regulatory level was noted with the exception of several draft bills that were ultimately defeated or languished in committee. Several industrial initiatives followed this disaster, most notably the National Mining Association CORESafety program, which takes a safety and health management systems approach to improving mine safety and health.

Risk assessment is a necessary and crucial part of any successful operation. When used properly, risk assessment allows for risk management and mitigation, with risk identified, prioritized, and systematically reduced (Moteff 2005). The International Organization of Standards states,

Risk management is the identification, assessment, and prioritization of risks, followed by the coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events (ISO 31000, 2009).

The ability of a mining operation to characterize the potential risk incidents and prioritize them allows operators to focus on the most pressing needs of the organization. Risk can be reduced for each incident by either reducing event likelihood or mitigating the situation to reduce the overall severity of the incident.

Risk management is well established within a number of industries in the United States such as oil and gas services and infrastructure development (PWC 2012 and "*Environmental Risk Assessment"* 1998), but the US coal mining industry has not comprehensively utilized risk management techniques (e.g., Kinilakodi and Grayson 2011). The use of risk management in US mining has focused mostly on financial business practice without making the parallel between health and safety performance and financial repercussions. In contrast, the coal mining industries in the United Kingdom and Australia utilize risk management in a number of ways (Weyman, Clarke & Cox, 2003; Cliff 2012.) In Australia, mining operations are required to develop and implement risk-based principal/major hazard management plans for hazards that have the potential to cause injury or fatalities, including explosions and strata failure (e.g., Cliff 2012). Mitigation strategies typically include careful characterization of the geological and geotechnical domain, selection of appropriate mining methods and equipment, ventilation and strata management plans, gas and strata monitoring systems, emergency response plans and training, and competent and licensed personnel. A key factor influencing Australia's improved safety performance was the Australian coal mining industry's wholesale adoption of risk-based management of principal hazards in the late 1990's (e.g., Cliff 2012, Joy, 2004).

As noted above, the Australian regulatory system requires operators to implement risk based hazard plans. The US system differs substantially, with Title 30 of the Code of Federal Regulations (30 CFR) regulating the mining industry. Specifically, section 75 addresses mandatory safety standards for underground coal mines. 30 CFR is a fairly prescriptive regulatory approach, as noted by several researchers (Yang, 2011; Griffin et al., 2013), and provides little incentive for risk based approaches.

Specifically, the Australian Coal Association Research Program (ACARP) in partnership with the Minerals Industry Safety and Health Centre at the University of Queensland initiated a multi-million dollar, multi-year project for development of RISKGATE (Worden et al., 2013.) RISKGATE addresses eleven high risk areas related to mining, and uses bow-tie analysis, which allows unwanted events to be analyzed so that preventative controls or consequence mitigation can be emplaced to avoid an unwanted event or consequence. RISKGATE incorporates an impressive amount of technical expertise, with more than 400 days of industry expert time contributed.

Three high risk areas were chosen for the US for application in this research: fires/explosions, ground control, and moving equipment. Careful consideration was given to the selected high risk areas. Major fires and explosions in US underground coal mines, occurring in 2001, 2006, 2010, have had a considerable impact on the number of recent underground coal mine fatalities in the US as evidenced in Figure 1.

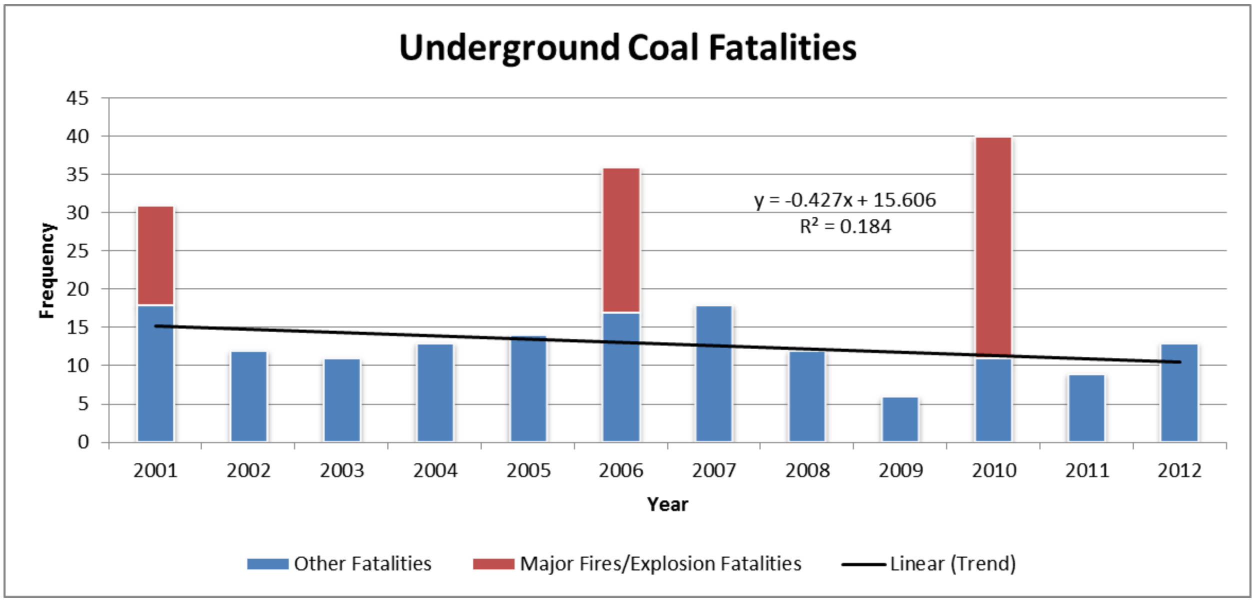


Figure 1. Underground coal fatalities in the US between 2001 and 2010 (fatalities due to major fires and explosions are shown in red) (NIOSHa, 2013.)

Additionally, 16.4% of nonfatal injuries between 2001 and 2011 were credited to fall of ground (NIOSHb 2013), and more recently, 2 of 9 (22%) of fatalities in underground coal in 2013 were due to fall of ground (MSHAb 2013). At the specific request of one of the corporate partners supporting this project, struck by and caught by and between accidents related to moving equipment (referred to as "moving equipment" in the remainder of the proposal) are also being addressed. There is alarming evidence to support inclusion of this high risk area; 6 of 9 (67%) US underground coal fatalities in 2013 were related to moving equipment (classified as hoisting, powered haulage, and machinery) (MSHAb 2013.)

4.0 Research Approach

Four specific aims, developed to meet the project objective, and relating to each of the four major project tasks are detailed below.

Aim 1. To document a Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis of factors that that can contribute to successful application of risk management in US underground coal operation via a three-fold approach.

Aim 2. To develop interactive materials for application of the Australian RISKGATE method to the US in three major areas relating to underground coal mine safety: explosion prevention, ground control; and moving equipment.

Aim 3. To deploy a field scale application of US-RISKGATE at an operating underground coal mine in the US, training users, and evaluating effectiveness.

Aim 4. To prepare a set of recommendations based on the success of Aim 3, for comprehensive deployment of US-RISKGATE.

SWOT Analysis and Comparison

A SWOT analysis was completed after examining Australian and US Regulation, discussing practice and culture with mining groups in both countries, and investigating regulatory and economic atmospheres, and is detailed in Figure 2, below.

<table>
<tr><th></th><th>STRENGTHS</th><th>WEAKNESSES</th></tr>
<tr><td>INTERNAL</td><td>Leaders in development of several key safety technologies
An evolved safety culture with heavy emphasis on BBS
A vision among companies (e.g., NMA CORESafety) that is critical for developing an industry wide body of knowledge
Interest in risk management and early stage development in many companies
A general “no secrets in safety” atmosphere, and willingness to share
RISKGATE is a unique tool – No alternative for US underground coal exists
First major effort for development of risk management control database for US mining
Emphasis on performance of engineering controls rather than worker behavior modification</td><td>Limited experience with risk management for application to operational safety – lack of risk management dialogue among US operators
Poor coal economy, limited resources
Large geographic area, several coal basins, all with distinct cultures and practices</td></tr>
<tr><td>EXTERNAL</td><td>The relative immaturity of risk management in US coal does allow for best practice transfer (as opposed to a longer best practice evolution).
RISKGATE US can bring US best practice to a single source: more rapid transfer of best technology and best practice
The US platform will be easily accessible and may be continuously modified to ensure adequacy and integrity of controls
Improvement of corporate reputation, generation of social license, minimization of worker injury/fatalities are increasingly becoming principal considerations for US mining practitioners</td><td>Increased enforcement as a result of beyond compliance approach
Few regulatory incentives for using risk management approach
Comfort with risk management requires repeated exposure and training, fairly sizeable time commitment
Competing safety models (e.g. BBS) with greater depth of expertise may be perceived as more compatible with American culture
Limited knowledge of RISKGATE project by individuals with the opportunity to drive up standards within companies</td></tr>
<tr><td></td><td>OPPORTUNITIES</td><td>THREATS</td></tr>
</table>

Figure 2. SWOT Analysis for application of RISKGATE in the US.

Site visits to Australia were, and Australian Co-PIs also completed visits of US mines. Appendix A lists the field visit schedule, and major findings. In summary the major findings from the field visits were:

1. Comprehensive use of risk management in Australia was affected by a complete overhaul of the regulatory system.
2. Risk management in Australia relies on a productive relationship between labor, operators, and regulators; alternatively, most operators in the U.S. do not believe that is a relationship that currently exists.
3. Operations that have productively implemented risk management utilize knowledge at every level of the organization, and found this sort of implementation to be a process.

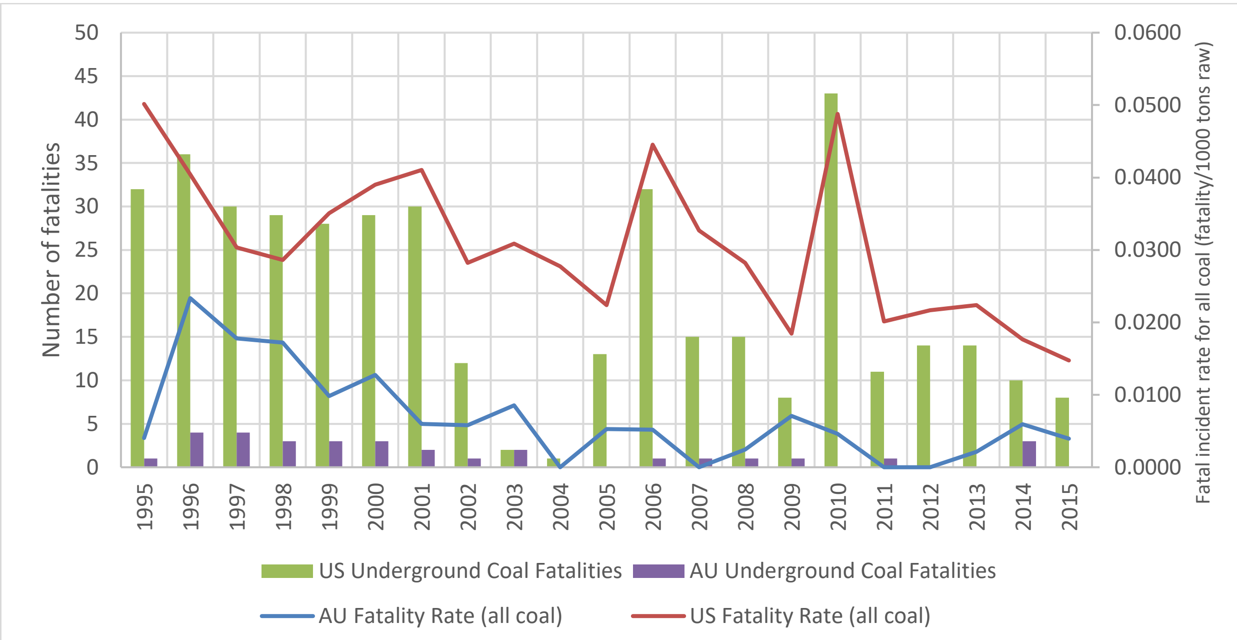
The Australian system of risk assessment and management required a complete overhaul of regulation and was developed in response to the Moura Mine disaster (Windridge et al., 1994), the third major explosion in that area, the latter killing 11 men. The system has its roots in British mining risk assessment practice (Robens, 1972; Hermanus, 2007), a response to the Aberfan Disaster, which killed 144 people, including 116 children. This system requires tripartite participation and collaboration from labor, the regulator, and the operator. Tripartite participation does appear to be highly collaborative and the relationships between the regulator and the operator to be productive in terms of improving safety in Australia, while generally more antagonistic in the U.S. The burden of ensuring a safe work environment ultimately lies with the operator in Australia. The practice of developing risk-based plans in Australia does appear to be somewhat onerous and generates many documents. While the companies we were working with were actively involved in development of risk assessment and management, they did indicate that some companies hired consultants to do the work and gained little perspective from employees.

In exploring and discussing the idea of risk based regulation with U.S. mine operators and workers, most are supportive of the idea, and can quickly give examples where the U.S regulation might actually hamper safety, the authors of this report included. However, in visiting operations in both countries it is undeniable that regulation *can, in fact*, drive leading practice and rapid uptake of safety technology. Ultimately, an adaptive regulatory system that also incorporates risk management would appear to be the best approach. The two following examples serve to illustrate some of the inconsistencies in the arguments that risk management approaches will always drive the leading technology and practice (and the alternative argument that prescriptive regulatory approaches do not drive technology uptake or leading edge practice).

First, in touring one underground coal mine in Australia a large diameter pressured methane pipe in the mine was observed, moving degasified methane through the mine and outside, common practice in both the US and Australia. However, the pipe had no fragile line to alert miners to potential damage and automatically shut in wells. Fragile lines are standard on such a system in the US. Fragile lines are relatively low technology solutions – simple small diameter PVC pipes pressured with air. The fragile lines are installed on top of the methane pipes. Valves are installed where methane leaves the borehole and enters the methane pipe; these valves are sensitive to fragile line pressure. If the fragile line loses pressure any valves on that portion of the network automatically close. The idea is that if the fragile line is damaged it is possible that the pressured methane line is damaged – the implications for safety in that scenario are obviously dire. Fragile lines can be maintenance intensive; they often break with no subsequent break in the methane line. However, the potential consequences of a pressured methane line failure are considerable, so the control is deemed appropriate and worth the maintenance in the US. *Why not in Australia?*

Second, The MINER Act of 2006 required that all underground coal mines in the US implement wireless communication. Operators immediately countered such regulation, with good reason – the technology simply was not available in 2006. While the process for developing and implementing the new technology was problematic, we can now observe wireless communication technology in every underground coal mine in the US. Alternatively, only some mines in Australia are using this readily available technology. While risk management and assessment approaches in Australia are rigorous by design, we have also learned that they are fallible.

On the other hand, in the US, we can give numerous examples where rigorous risk assessment would probably require operators to go beyond compliance, or even to implement plans that might be in direct violation of prescriptive regulation. One of the findings of the Lord Robens Report (Robens, 1972) was that too much regulation can create an apathetic health and safety environment. It is difficult to say definitely that the qualitative data we collected during this project prove that a purely risk based regulatory system is superior. Certainly, data from the AU industry indicate a lower number of total fatalities, but discussion of these data with US operators and experts often points to substantial differences in operating conditions, including lower conditions and more small mines in the US. Complete and comparable historical data for each country comparing mining height and number of total underground coal mines is difficult to secure. Nonetheless, the data in Figure 3 are compelling[1], and do indicate that the average US fatal incident rate is roughly five times that of the average Australian fatal incident rate over the period 1995 to 2015 (BP Global, 2017; Minerals Council of Australia, 2007, 2009; NSW Government Planning and Environment, 2008; NSW Government Trade and Investment, Resources and Energy, 2014; NSW Government Industry and Investment, 2010, 2016; Queensland Government, 2018). Further, if we examine the last five years, 2010 to 2015, the gap only widens – with an average US fatal incident rate that is roughly eight times that of the average Australian fatal incident rate.



	Australia	United States
Average Production, 1995-2015 (raw tons x 1000)	374.8	978.5
Average Fatality Rate, 1995-2015 (fatality/1000 tons)	0.00676	0.03063
Average Production, 2010-2015 (raw tons x 1000)	464.7	919.0
Average Fatality Rate, 2010-2015 (fatality/1000 tons)	0.00277	0.02423

Figure 3. Number of fatal accidents in underground coal mines for Australia and the US compared with fatal incident rates in all coal mines, 1995-2015.

[1] Note that the incident rates published here may not match other published incident rates (e.g., MSHA, 2017). In an effort to provide a fair comparison, raw coal tonnage from the BP World Energy Data Sheets were used, number of fatals per annum in the US were sourced from MSHA and fatalites per annum in Australia were converted from fiscal year to calendar year by reading multiple reports from New South Wales and Queensland governments and the Minerals Council of Australia to ascertain calendar year of death for fatalities after 2008. Fatalities before 2008 came from the International Mining Fatality Review.

Finally, we can conclude that risk based health and safety programs have the following advantages:

1. They are site and case specific, allowing for identification and remediation of specific hazards.
2. They can be used to drive conversations and critical thought about health and safety at every level of an organization.
3. They put the burden of safety on the operation, but allow everyone to take responsibility
4. They appear to drive more collaborative relationships between labor, operators, and regulators.
5. They create formal documents and knowledge bases (with RISKGATE being a leading practice example) that allow collaboration and communication of leading practices in the industry.

Risk based approaches in concert with careful regulation and other safety programs are without a doubt superior to systems that do not incorporate risk management.

Development of US Materials

After comparing regulatory systems and operating practices in the two countries, a total of 10 workshops and focus groups were held in the US, with over 100 participants with total mining experience of more than 1200 years. Figure 4 shows scenes from a workshop in Julian, WV. The workshop schedule is shown in Appendix A, Table A.2.

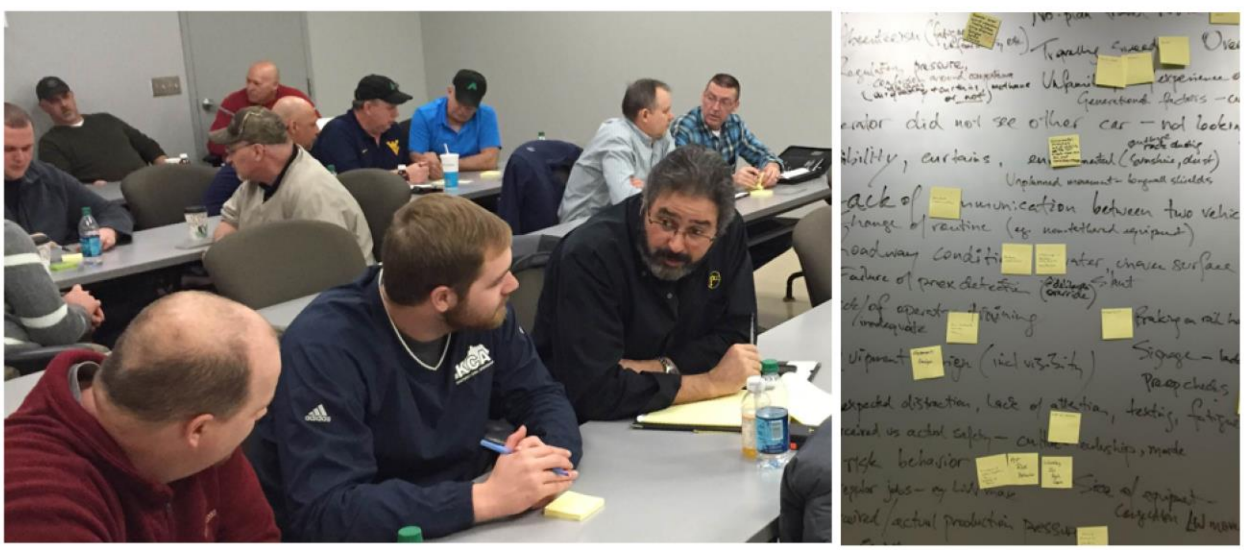


Figure 4. Scenes from workshop in Julian, WV.

To prepare for holding workshops in the US, US researchers joined a RISKGATE workshop in Australia and Australian researchers traveled to the US to assist in leading workshops. The original and evolved lesson formats are displayed in Table 1.

Table 1. Original and Evolved Workshop Formats (breaks and lunch not included).

Typical Workshop Format (Australian and First US Workshops)		
Topic	**Time**	**Description**
Introduction to RISKGATE	10-15 minutes	Overview of the Australian practice, the US research project.
Introduction of participants	10-15 minutes	Participants have a chance to introduce themselves and describe their experience relative to the topic.
Discussion of risk management	20-25 minutes	Describes the bowtie technique
Determination of the specific topic	15 minutes	Includes wording and scoping of the topic – input from group
Whiteboarding	2.5 hours	The group is looking for causes and controls, brainstorming and building consensus. This is when participants seem most engaged.
Organization	1.5 to 2 hours	Taking everything the group has produced and distilling it in the actual body of knowledge that will be included in the web interface.
Wrap up and review	0.5 hours	Review of the work product
Evolved Format (Later US Workshops)		
Topic	**Time**	**Description**
Introduction to RISKGATE	10-15 minutes	Overview of the Australian practice, the US research project.
Introduction of participants	10-15 minutes	Participants have a chance to introduce themselves and describe their experience relative to the topic.
Discussion of risk management	5 minutes	Describes the bowtie technique
Presentation of the topic	5-10 minutes	The topic is scoped and worded. The group is invited to change the scope and wording.
Case Study Discussion	1 hour	A relevant case study is presented and discussed in detail, along with causes, controls, and consequences.
Whiteboarding	2-2.5 hours	The group begins organizing the content from the case study discussion, and then we expand the scope and look for other causes, controls and consequences.
Organization	45 minutes – 1 hour	The work product is organized for the web interface, but there is far less emphasis on wording and format – rather, the facilitators ask the group questions regarding specific wording and organization and build consensus.
Review	30 minutes	The group reviews the work product, and corrects any problems.
Evaluation	10 minutes	Participants are invited to voice any comments or suggestions and are given opportunity for anonymous feedback.

Using case studies and reducing the emphasis on detailed wording and organization seems to keep participants much more engaged, and reinforces what we know about pedagogy and active learning. It is worth noting that when the Australian material was developed there was absolutely no framework, and one of the great strengths of RISKGATE is that it was user developed, so their emphasis on these organizational details is understandable. However, given that we are translating a useful framework, we can spend more time gathering content rather than organizing it. Going forward with any similar workshops, the case study model is much more engaging and is recommended, at least for US audiences. For the last two workshops, related to i) mine fires; and ii) ground control, the Brody Mine fatal coal bump (Barker et al., 2014) and the Aracoma fatal mine fire (Murray et al., 2006) were presented as detailed case studies. Because both of these were fatal incidents sufficient data are available through MSHA to present detailed case studies. With the completion of this subtask we have conducted 10 workshops. Only six US workshops were originally proposed, but we feel the additional workshops led to a much more comprehensive body of knowledge. The comprehensive body of knowledge is displayed in Appendix B, and includes 3 topic areas, with 7 bowties, 175 causes, 932 preventive controls, 219 mitigating controls, and 43 consequences. The body of knowledge is best viewed in a web browser at http://alpha.riskgate.org/, but Appendix B gives all of the information in the online database.

Pilot Study at Partner Mine

Finally, our aim was to understand and describe alternative uses of Riskgate in the US context by utilizing the body of knowledge at a field site. A field site in Central Appalachia was identified. The site is an underground coal mine, with two supersections. Each supersection has two continuous mining units. Mining height is approximately 48 to 52 inches. However, poor roof conditions may lead to higher roof in places. The mine employs just over 100 non-union miners, running three shifts per day, usually six days per week. Finally, the mine and its parent company have been recognized in leaders in the implementation of proximity detection. After meeting with mine and corporate management, we determined that we would use RISKGATE to generate approximately two months worth of safety meetings that would entail some discussion of risk management in every meeting.

VT researchers held informational meetings with miners on every shift to describe our research and risk management approaches. Prior to discussing risk management approaches miners were give a voluntary survey to assess their feelings about safety at the site and risk management generally. During the first week of research, VT researchers delivered the safety meetings on every shift personally, and discussed their delivery with foreman. Thereafter, foreman were given written meetings to deliver. Approximately, every two weeks researchers contacted mine management to determine if (i) they had received any feedback about the meetings that should be considered, and (ii) if any special meeting topics were requested due to mining conditions at the site, near misses or accidents.

On July 11, 2017, Virginia Tech researchers met with each shift at the parter mine and distributed intake surveys to all miners (including salary and management/supervisors), and received 98 surveys back. We did not discuss the research project until after the surveys were completed, as we wanted to gauge miners' perceptions prior to any discussion of risk. The intake survey form is given in Appendix C, along with the collated response data, also in Appendix C. Respondents generally indicate agreement with all of the site specific safety related questions, although there may some differences in "Strongly Agree" versus "Agree" responses. More miners indicated "Strongly Agree" when asked, "I value safety more than anything else in the workplace," than for any other question. There were not any significant differences noted between shifts in terms of agreement. There were far fewer responses for the midnight shift. as this is a maintenance shift. It seemed from the beginning that miners had a fairly positive view of safety at this site.

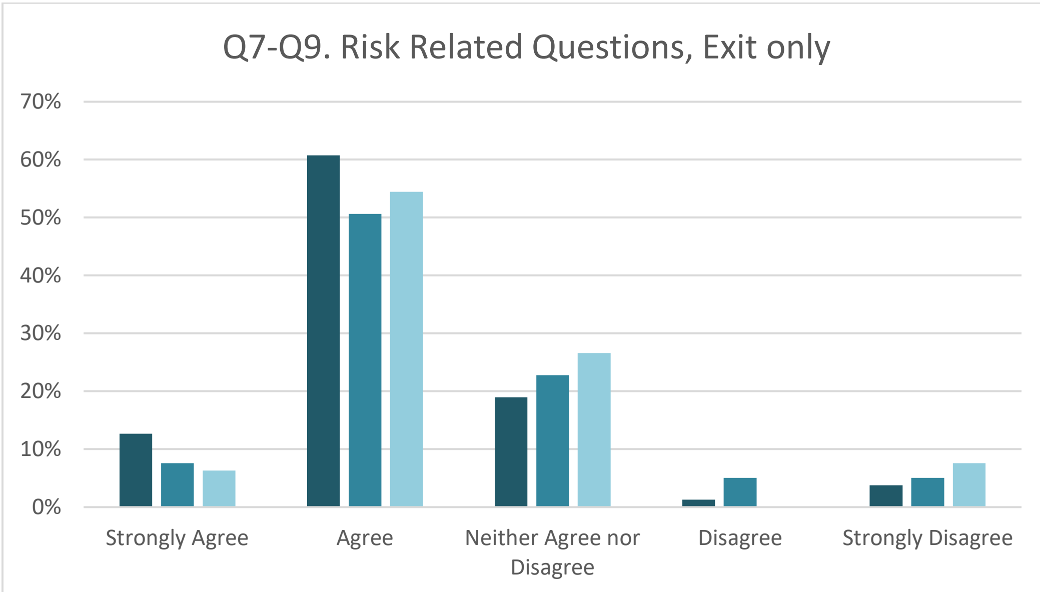
From July 11 to September 11, 2018, three safety meetings were provided, six days per week, to be used on every shift. Occasionally, safety meetings were repeated, particularly meetings that were only given on a maintenance shift. In addition to the three major RISKGATE areas, other safety meetings were included with a risk approach (e.g., hearing protection; slips, trips, and falls). Also, at the request of mine management meetings regarded the use of hand tools were included because the mine had several accidents involving injuries to hands. Appendix D gives an index and all the safety meetings provided. Each meeting attempted to emphasize a risk-based approach including mitigating and preventive controls without becoming repetitive.

Exit surveys were completed on September 25, 2018. These surveys and corresponding detailed data are provided in Appendix E. In summary, if we examine the first six questions related to perceptions of safety and risk, and respondents who marked "Strongly Agree" and "Agree" there was relatively little change between intake and exit surveys for questions 1,2, and 5. There was minor change (less than 10%) for questions 3, 4, 6. It bears noting that towards the end of this study a fatality occurred at another operation owned by the mine operator. Overall, respondents perceptions of safety at the mine is fairly positive and there was minor change over the study period, as shown in Table 2.

Table 2. Percentage respondents answering "agree" or "strongly agree" to questions 1-6 on intake and exit surveys.

Questions	**Intake**	**Exit**
Q1. Mine management is firmly committed to protecting the safety and health of workers, myself included.	73%	72%
Q2. I value safety more than anything else in the workplace.	86%	84%
Q3. The people I work with daily value safety more than anything else in the workplace.	71%	82%
Q4. I feel empowered to speak up when I observe an unsafe situation.	77%	70%
Q5. When I approach a job task I think about risk as I plan the task.	89%	90%
Q6. My ability to work safely is tied to my ability to assess and manage risk	86%	73%

Figure 5 shows exit responses to risk related questions. Overall, respondents agreed that the risk approach positively impacted respondents. However, it is worth noting that relatively few respondents indicated *strong* agreement.



Q7. The RISKGATE approach and risk assessment tools have changed the way I approach and manage risk.
Q8. The RISKGATE approach and risk assessment tools have changed the way mine management approaches and manages risk.
Q9. The RISKGATE approach and risk assessment tools have made me feel safer when I work.

Figure 5. Exit Responses to Risk Related Questions.

Detailed comments are shown in Appendix D. Initially, in planning this work with the operator, VT researchers were going to collaborate with the mine superintendents and general mine foreman to develop a risk informed plan for a section move. Generally, these only happen ever several months, and a move was planned for mid-September. Roof conditions on this section deteriorated to the point that an emergency move was carried out with less than twelve hours notice and this approach could not be implemented. This would have allowed respondents more experience with risk management.

5.0 Summary of Accomplishments

The following were accomplished over the course of this project.

A SWOT analysis was developed that details the use of formal risk assessment and management under US mine safety culture and regulation. This analysis makes clear that that RISKGATE can be utilized under a different context in the US. Additionally, in investigating the differences in the use of risk management in the US and Australia it is clear that while prescriptive regulation does occasionally undermine efforts towards best practice and innovation it occasionally drives innovation (e.g., wireless communication)

We interacted with over 100 miners and technical staff in Colorado, West Virginia, Virginia, and Illinois in a workshop context gathering over 1200 years of mining experience into the US-RISKGATE body of knowledge. That body of knowledge has been formatted, debugged, and is now freely available at http://alpha.riskgate.org/.

In running workshops in the US to gather knowledge, we encountered two additional findings. First, participants valued the opportunity to brainstorm about safety and risk in a particular technical area with members of industry from other companies. They repeatedly indicated this was a very valuable experience they wish there was more opportunity for during their careers. Second, the workshop in the US evolved to more of a case study based active exercise than in Australia. US participants indicated that time spent on wording and terminology was not valuable.

We developed a pilot study tailored to US industry presenting risk based safety meeting derived from RISKGATE. Fifty risk-based safety meetings were delivered to about 100 miners. Perceptions of safety at the operation and safety as personal value did not change significantly over the course of the study. 60% of participants indicated at the end of the study that the RISKGATE approach and risk assessment tools made them feel safer when they work (only 8% disagreed).

6.0 Dissemination Efforts and Highlights

The following have been published as a result of this work:

Barczak, T., Agioutantis, Z.A., Restrepo, J. (2016.) The Contributions of the Alpha Foundation to Ground Control Research and Development. The 35th International Conference on Ground Control in Mining, Morgantown, WV.

Jong, E.C., Restrepo, J.A., Luxbacher, K.D., Kirsch, P.A., Mitra, R., Hebblewhite, B.K., Schafrik, S.J. (2016.) Risk management: Adapting RISKGATE for underground coal mines in the United States. Mining Engineering, Vol 68 (3): 51-57.

Restrepo, Julian. (2017). Development and Application of a Risk-Based Online Body-of-Knowledge for the U.S. Underground Coal Mining Industry: RISKGATE-US COAL. M.S. Thesis, Virginia Tech.

Restrepo, J., Luxbacher, K., Ripepi, N., Schafrik, S., Kirsch, P., Shi, M., Mitra, R., Hebblewhite, B. (2015.) Barriers and Incentives: The application of comprehensive risk management in the US underground coal mining industry. SME Annual Meeting Preprints 15-059, Denver, CO, Feb. 15-18, 2015.

Presentation

Luxbacher, K. (2015.) The Potential Use of RISKGATE for Environmental Issues. The 2nd Environmental Considerations in Energy Conference. Pittsburgh, PA. September 23, 2015.

Planned Presentation

Turner, M., Luxbacher, K., and Ripepi, N. (2018). RISKGATE: A Pilot Study in a Central Appalachian Coal Mine. SME Annual Meeting and Conference. Minneapolis, MN, February 26-28, 2018.

Finally, we also intend to publicize the US RISKGATE website from the Virginia Tech Booth at SME with business cards that briefly describe RISKGATE and give the web address.

7.0 Conclusions and Impact Assessment

The first aim of this project was to document a Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis of factors that that can contribute to successful application of risk management in US underground coal operation via a three-fold approach. This work allowed us to compare and contrast the use of risk management in the US and Australia. The US regulatory framework allows for each company to develop a site specific risk based program, only in cases where such a program always goes beyond compliance. While risk based programs are encouraged, the US Federal Mine Safety and Health Act of 1977 (the Act) did not consider the incorporation of site specific risk based approaches. In fact, regulation was identified as a barrier to risk management in the Australian mining industry, and the mining regulation in both Queensland and New South Wales was streamlined and changed to be consistent with risk management approaches in the 1990s. It is difficult to imagine that stakeholders, including Congress, would readily agree to major changes to the Act; in the meantime, operators must look for ways to improve safety via risk management while simultaneously complying with the regulation.

We worked in three different coal basins with over 100 participants to develop a body-of-knowledge that outlines initiating incidents and controls around three topic areas: roof control, ventilation, and moving equipment. We published this body-of-knowledge, US-RISKGATE in an online format that allows users to customize controls to their own sites, and made it freely available to industry. We found that the US industry is quite willing to work toward such collaborative projects in the spirt of “no secrets in safety,” and we found that there was value in the process for the participants.

US companies readily see the advantages of risk management and many already use it in the planning of major or unusual projects (e.g., longwall moves, mining near gas wells, etc.), but did not see how it might be used daily with miners in concert with Behavior Based Safety Programs. We demonstrated daily use of a risk management approach, and the majority of participants (60%) agreed that it enhanced safety at their operation.

This work details the use of industry wide workshops toward safety solutions that could easily be customized to other applications. Also, any operation could use US-RISKGATE to customize safety meetings that detail risk management approaches to everyday tasks and hazards that miners face. The fifty meetings detailed here could easily be utilized or adapted.

Acknowledgement

This study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

The investigators wish to acknowledge the many mining professionals in the US and Australia who were so generous with their time and knowledge in risk management and risk associated with underground coal mining. We also appreciate ACARP's willingness to share the approach they originally funded in Australia. Academic contributors to this work include:

Philipp Kirsh, the University of Queensland
David Cliff, the University of Queensland
Jill Harris, the University of Queensland
Bruce Hebblewhite, the University of New South Wales
Rudrajit Mitra, the University of New South Wales
Nino Ripepi, Virginia Tech
Steven Schafrik, Virginia Tech
Edmund Jong, Virginia Tech
Michael Turner, Virginia Tech
Julian Restrepo, Virginia Tech

References

Barker, D.L. jr., McNeely, J. (2014.) US Department of Labor, Mine Safety and Health Administration. Report of Investigation, Underground Coal Mine, Fatal Rib Burst Accident, Brody Mine No. 1. http://arlweb.msha.gov/FATALS/2014/FTL14c04-05.asp

BP Global. (2018.) Statistical Review of World Energy, all data, 1965-2017. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Hermanus, M.A. (2007.) Occupational health and safety in mining – status, new developments, and concerns. The Journal of the South African Institute of Mining and Metallurgy. Volume 107 (531-538) https://www.saimm.co.za/Journal/v107n08p531.pdf.

Mine Safety and Health Administration, United States Department of Labor (2017.) Coal US Mines - Fatality and All-Injury Rates CY 1977 – 2015. https://dol-msha-peir-mshagov-prod.s3.amazonaws.com/s3fs-public/Data_Reports/Charts/Coal_US_Mines_-_Fatality_and_All-Injury_Rates_CY__1-5-17.pdf

Minerals Council of Australia. (2007.) Safety Performance Report of the Australian Mining Industry, 2006-2007. http://www.mineralscouncil.com.au/file_upload/files/resources/safety_health/performance_reporting/annual_saftey_reports/2006_2007_Safety_Performance_Report.pdf

Minerals Council of Australia. (2009.) Safety Performance Report of the Australian Mining Industry, 2008-2009. http://www.mineralscouncil.com.au/file_upload/files/resources/safety_health/performance_reporting/annual_saftey_reports/2008_2009_Safety_Performance_Report.pdf

Murray, K.A., Pogue, C.W., Stahlhut, R.W., Finnie, M.G., Webb, A.A., Burke, A.L., Beiter, D.A., Francart, W.J., Tjernlund, D.M., Waggett, J.N. (2006.) US Department of Labor, Mine Safety and Health Administration. Report of Investigation, Fatal Underground Coal Mine Fire, Aracoma Alma Mine #1. http://arlweb.msha.gov/Fatals/2006/Aracoma/FTL06c1415total.pdf

NSW Government Planning and Environment. (2008.) International Mining Fatality Review. https://www.resourcesandgeoscience.nsw.gov.au/miners-and-explorers/safety-and-health/incidents/international-mining-fatality-review

NSW Government Trade and Investment, Resources and Energy. (2014.) New South Wales Coal Industry Profile, Volume I https://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0005/664826/CIP-2014-Vol-1-final.pdf

NSW Government Industry and Investment (2010.) NSW Mine Safety Performance Report, 2009-2010. https://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0005/540185/NSW-Mine-Safety-Performance-Report-2009-10.pdf

NSW Government Industry and Investment (2016.) NSW Mine Safety Performance Report, 2015-2016. https://www.resourcesandgeoscience.nsw.gov.au/__data/assets/pdf_file/0007/692152/nsw-mine-safety-performance-report-2015-16.pdf

Queensland Government. (2018.) Queensland Government Data, Coal Industry Review Statistical Tables. https://data.qld.gov.au/dataset?q=coal+production+2012

Robens, Alfred (1972.) Safety and Health at work: report of the Committee 1970-1972. (Cmnd 5034) London: H.M.S.O.

Windridge, F.W. (1996.) Report on an accident at Moura No. 2 Underground Mine on Sunday, 7 August 1994: Wardens inquiry conducted pursuant to Section 74 of "The Coal Mining Act, 1925". Queensland Wardens Court. http://trove.nla.gov.au/work/21826860?selectedversion=NBD12093043

Appendix A

Workshop and Field Visit Schedules

Table A.1. Australian RISKGATE Schedule and Major Findings

Date	Activity	Major Findings
03/09/2014	Meeting with Prof. Jim Joy Sydney, AU	General discussion of risk management and assessment as applied to the mining industry. Discussion of development of the AU regulation and risk-based approach as well as RISKGATE specifically.
03/10/2014	Meeting with Paul Catrone, attorney at Sparkes Helmore retained by ACARP, Centennial Coal Sydney,	Discussed evolution of the Australian regulatory system, major accidents, influence of British risk assessment and management techniques, and the journey to a mature risk assessment and management culture. Finally, reviewed application of RISKGATE at Centennial operations from a corporate perspective.
03/10/2014	Meeting with Andrew McMahon, New South Wales Minerals Council, near office in Sydney.	Discussed challenges in the Australian industry and uptake of RISKGATE by companies other than Centennial Coal.
03/11/2014	Meet with the New South Wales (NSW) state regulator, Rob Regan, and prosecutor, Jenny Nash Near Maitland, AU	Discussed the regulatory perspective on RISKGATE and RA/RM generally. They feel the system works very well, and acknowledge genuine respect between the operators and regulators. System relies on a collaborative atmosphere.
03/12/2014	Mandalong Mine, Centennial Coal	Met at Mandalong Mine, Centennial Coal, met with John Turner, Mine Manager and John Hempenstall. Discussed application of RISKGATE at Centennial, specifically development of in-house risk analyses. Toured the mine including longwall and development sections. Meet with upper mine management to discuss routine application of RISKGATE as well as application during a major ground event that involved unplanned failure of a longwall setup room prior to starting a new panel. Examined application of RA/RM during the events, and post event.
03/13/2014	Meeting with David Cliff, Minerals Industry Safety and Health Centre, University of Queensland Brisbane, AU	Discussed Cliff's involvement with US self-escape study and general observations in differences in US and Australian mining culture. In-depth discussion of RA/RM as applied to spontaneous combustion, mine fire, and ventilation issues.
02/13/2014	Meeting with Mark McCamley, Director of Hawcroft Consulting International Brisbane, AU	Discussed his experience in comprehensive risk assessment, contrasting the US and AU

3/14/2014	University of Queensland Brisbane, AU	Attended a RISKGATE workshop focusing on fitness for work, facilitated by Philipp Kirsh and attended by academics, and representatives from industry in both New South Wales and Queensland. This was a full day active workshop addressing a range of issues including substance abuse and fatigue.
07/28/2014	Cumberland Mine Visit	Met with Alpha Natural Resources personnel, touring the mine and specifically discussing ground control and their work in implementing risk assessment and management (primarily from an engineering design standpoint, as well as hazard location – e.g., gas wells).
09/29/2014	Beckley Mine Complex Visit and Focus Discussion	Met with Arch personnel, Joe Tussey, and others to discuss any experience in use of risk assessment and management, specific hazards at Beckley (moving equipment), and the use of RA/RM plus behavior based safety programs. Most of their experience in using RA/RM was in planning for large, unusual jobs – e.g., changing out a large motor underground.
10/03/2014	Peabody Wildcat Hills Mine Visit	Met with Peabody coal personnel and toured mine. Discussed hazards, particularly moving equipment (there was a fairly recent fatal incident at the mine). The supersections do have high traffic. Australian investigators noted that there was much higher traffic than in a typical AU mine.
11/ 06/2015	Wambo Mine Visit Near Singleton, NSW	Discussion of general safety practice at Wambo Mine. Riskgate is used there as a resource in development of risk management plans, but does not see direct use by the mine worker. Posted risk matrices are directed toward the mine worker.

Table A.2. US Workshop Schedule

Date	Activity	Locations	Participants
05/19/2014	Scoping Workshop and Focus Groups	Grundy, VA	VT (3), multiple SW VA industry
09/29/2014	Beckley Mine Complex Visit and Focus Discussion	Near Beckley, WV	UNSW (2), VT (3), UQ (1), Arch Coal
09/30/20114	US RISKGATE Workshop: Moving Equipment	Running Right Academy, Julian, WV	UNSW (2), VT (3), UQ (1), Alpha Natural Resources
10/02/2014	US RISKGATE Workshop: Moving Equipment	Harrisburg, IL	UNSW (2), VT (3), UQ (1), Peabody Energy
02/19/2015	US RISKGATE Workshop Mine Fires and Explosions	Near Steamboat Springs, CO	UNSW (2), VT (3), UQ (1), Peabody Energy
02/23/2015	US RISKGATE Workshop Moving Equipment	Running Right Academy, Julian, WV	VT (3), UNSW (2), UQ (1), United Coal, Alpha Natural Resources, Patriot Coal, Arch Coal, Cliffs Natural Resources
02/24/2015	US RISKGATE Workshop Ground Control	Running Right Academy, Julian, WV	VT (3), UNSW (2), UQ (1), United Coal, Alpha Natural Resources, Patriot Coal, Arch Coal, Cliffs Natural Resources
09/16/2015	US RISKGATE Workshop Mine Fires and Explosions	Near Steamboat Springs, CO	VT (1), Peabody Energy
11/17/2015	US RISKGATE Workshop Ground Control	Bluefield, VA	VT (2), Cardno MM&A
11/18/2015	US RISKGATE Workshop Mine Fires and Explosions	Bluefield, VA	VT (2), Cardno MM&A

Appendix B

RISKGATE Body of Knowledge

Table C.1 – RISKGATE-US COAL bowtie: Spontaneous combustion

<table>
<tr><th colspan="3">Initiating Event: Spontaneous combustion</th></tr>
<tr><td rowspan="5">Cause: Air leakage (negative pressure) through mine seal causes coal heating in sealed gob area</td><td colspan="2">Control: Inertization of gob atmosphere through inert gas (nitrogen) injection</td></tr>
<tr><td rowspan="3">Control: Conduct regular visual inspections and gas monitoring to expose seal deficiencies</td><td>Sub Control: Maintenance or reconstruction of damaged or deficient seals</td></tr>
<tr><td>Sub Control: Injection of grout to repair seal fractures</td></tr>
<tr><td>Sub Control: Gas monitoring of gob area enclosed by seals rated to less than 50 psi (e.g. use of boreholes to monitor gob area)</td></tr>
<tr><td colspan="2">Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)</td></tr>
<tr><td rowspan="5">Cause: Air leakage through caving of underlying mined out area causes coal heating in sealed gob area</td><td colspan="2">Control: Inertization of gob atmosphere through inert gas (nitrogen) injection</td></tr>
<tr><td rowspan="3">Control: Conduct regular visual inspections and gas monitoring to expose seal deficiencies</td><td>Sub Control: Maintenance or reconstruction of damaged or deficient seals</td></tr>
<tr><td>Sub Control: Injection of grout to repair seal fractures</td></tr>
<tr><td>Sub Control: Gas monitoring of gob area enclosed by seals rated to less than 50 psi (e.g. use of boreholes to monitor gob area)</td></tr>
<tr><td>Control: Modification of mining near underlying mine</td><td>Sub Control: Alternative panel geometry (e.g. reduce panel width)</td></tr>
<tr><td rowspan="3">Cause: Seal failure from seismic event causes coal heating in sealed gob area</td><td rowspan="2">Control: Conduct a detailed seal inspection immediately following a seismic event</td><td>Sub Control: Replace damaged seals following a seismic event</td></tr>
<tr><td>Sub Control: Install new mine seal if damaged seal is inaccessible following a seismic event</td></tr>
<tr><td colspan="2">Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)</td></tr>
<tr><td rowspan="5">Cause: Air leakage through fracture coals or rock around a seal causes coal heating in sealed gob area</td><td colspan="2">Control: Inertization of gob atmosphere through inert gas (nitrogen) injection</td></tr>
<tr><td rowspan="3">Control: Conduct regular visual inspections and gas monitoring to expose seal deficiencies</td><td>Sub Control: Maintenance or reconstruction of damaged or deficient seals</td></tr>
<tr><td>Sub Control: Injection of grout to repair seal fractures</td></tr>
<tr><td>Sub Control: Gas monitoring of gob area enclosed by seals rated to less than 50 psi (e.g. Use of boreholes to monitor gob area)</td></tr>
<tr><td colspan="2">Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)</td></tr>
</table>

	Control: Modify seal design to ensure air leakage does not occur	
Cause: Air leakage through gas monitoring borehole causes coal heating in sealed gob area	Control: Inertization of gob atmosphere through inert gas (nitrogen) injection	
	Control: Injection of grout to seal borehole	
	Control: Modify borehole drainage design/location to prevent or limit air leakage	
Cause: Oxygen from longwall face moves into the gob causing coal heating	Control: Ventilation design limits oxygen flow through/around gob area (e.g. U-system layout, limited bleeder/fringe system)	
	Control: Modify mining rate (e.g. stop mining, shorter shifts, slower, faster, etc.))	
	Control: Cross-cut panel seals	
	Control: Continuously monitor explosive gas levels at longwall face	
	Control: Ensure gate road design limits airflow through the longwall face (e.g. yield pillar)	
	Control: Maximize extraction percentage of the coal seam	
	Control: Inject nitrogen	
Cause: Oxygen from tailgate/previous panel moves into gob causing coal heating	Control: Ventilation design limits oxygen flow through/around gob area (e.g. U-system layout, limited bleeder/fringe system)	
	Control: Alter retreat mining rate (1/2 days)	
	Control: Cross-cut panel seals	
	Control: Continuously monitor gas levels at longwall face	
	Control: Ensure gate road design limits airflow through the longwall face (e.g. yield pillar)	
	Control: Maximize extraction percentage of the coal seam	
	Control: Reduce panel width	
Cause: Oxygen from borehole in the longwall face moves into gob area causing coal heating	Control: Monitor and seal the borehole	Sub Control: Verify or stop oxygen intake through borehole into gob area
Cause: Oxygen from fringe area of bleeder system moves into gob area causing coal heating	Control: Continuously monitor gas levels in fringe area	
	Control: Ensure ventilation design can regulate or shut-down the bleeder system if dangerous atmospheric conditions are encountered	
Consequence: Fire in sealed gob area	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident

	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Explosion in sealed gob area	Control: Use seals which provide maximum resistance to explosive force (e.g. 120 psi seals)	
	Control: Ensure roadways are properly rock dusted	
	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. move fresh air to trapped miners)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to coal heating in sealed gob area	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	
	Control: Notify the proper authorities/agencies immediately following a heating incident	
Consequence: Fire in gob area at active longwall face	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	

	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Explosion in gob area at active longwall face	Control: Use seals which provide maximum resistance to explosive force (e.g. 120 psi seals)	
	Control: Ensure roadways are properly rock dusted	
	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. move fresh air to trapped miners)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to coal heating in gob area at active longwall face	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	
	Control: Notify the proper authorities/agencies immediately following a heating incident (note: there are no incentives for self-reporting heating events. Heating events do not need to be reported by law.)	
Consequence: Coal loss due to coal heating in gob area at active longwall face	Control: Modification of mine plan/mining method (e.g. switch from longwall mining to room and pillar mining)	
	Control: Secure mine insurance policy for lost mineral assets	
	Control: Ensure water spray system is in place to minimize coal loss	
Consequence: Equipment damage or loss due to coal heating in gob area at active longwall face	Control: Secure equipment insurance policy for major mine equipment	
	Control: Ensure water spray system is in place to minimize damage to equipment	
	Control: Implement an emergency equipment recovery plan	
Consequence: Accumulation of toxic gases in mine atmosphere due to coal heating in gob area at active longwall face	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)

	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Disclaimer RISKGATE is a free service. RISKGATE does not purport to be a guideline or code of practice but rather is a reference source and may not necessarily be current. RISKGATE is not intended to be and should not be relied upon as legal or technical advice. RISKGATE is a database of information from various sources, including the host providers, that may be of some assistance to its users. RISKGATE does not give any guarantee, undertaking or warranty that the information provided is comprehensive and covers every case/incident/safety alert/bulletin potentially relevant in the mining industry. Users should consult other sources of information and not rely on RISKGATE as the only source of information. RISKGATE does not invite reliance upon, nor accept responsibility for, the information it provides. RISKGATE makes every effort to provide a high quality service. However, neither RISKGATE, the host providers nor the providers of data on RISKGATE, give any guarantees, undertakings or warranties concerning the accuracy, completeness or up-to-date nature of the information provided. Users should confirm information from another source if it is of sufficient importance for them to do so. Hypertext links on RISKGATE are inserted by RISKGATE, not by the data providers. RISKGATE is operated by the Minerals Industry Safety and Health Centre at the University of Queensland.		

Table C.2 – RISKGATE-US COAL bowtie: Fire on/near Conveyor Belt

Initiating Event: Fire on/near conveyor belt		
Cause: Buildup of combustible materials on belt	Control: Consider use of alternate coal transportation (e.g. ram cars, battery-operated shuttle cars, etc.)	
	Control: Prevent buildup of combustible material on/near the conveyor belt	
	Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.	Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.
	Control: Adjust wipers to prevent coal-roller interaction	
	Control: Third party examination to ensure conveyor belt is constructed appropriately	
	Control: Regulate feed rate and feed size	
	Control: Consider roof/skin control measures to prevent additional material from falling on belt	
Cause: Belt is misaligned near/in takeup	Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.	Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.

	Control: Install and maintain instrumentation to monitor belt performance	Sub Control: Overload sensor, fault sensor, slippage sensor, etc.
Cause: Improper maintenance of belt rollers	Control: Provide belt operator training to identify faulty/worn rollers	
	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Install and maintain instrumentation to monitor belt performance	Sub Control: Overload sensor, fault sensor, slippage sensor, etc.
	Control: Confirm belt splice conditions meet appropriate operating standards	Sub Control: Consider vulcanization of belt splice
Cause: Wiper malfunction	Control: Provide belt operator training to identify irregular wiper performance	
	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Confirm wipers are in the proper position	
Cause: Plugged chutes	Control: Prevent buildup of combustible material on/near the conveyor belt	
	Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.	Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.
	Control: Develop/confirm appropriate chute design	
	Control: Use magnetic removal system for metallic objects including bolts, etc.	
Cause: Inadequate ventilation to belt	Control: Inertization of combustible atmosphere through automated system	
	Control: Consider installation of belt temperature monitor (e.g. infrared gun for distribution sensing)	
	Control: Ensure air flow/quantity adheres to design specifications	
	Control: CO monitoring to detect fire	
	Control: Monitor for combustible atmosphere while undertaking welding/cutting procedures	
Cause: Belt control equipment (PLC) malfunction	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Electro-mechanical belt monitoring	Sub Control: Appropriate sequence design (PLC)
		Sub Control: Automated spillage switch
Cause: Damage to friction drive	Control: Provide adequate protection to friction drive	Sub Control: Isolation from loose material (e.g. belt flaps)
	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.	Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.

	Control: Electro-mechanical belt monitoring	Sub Control: Appropriate sequence design (PLC)
		Sub Control: Automated spillage switch
	Control: Install and maintain instrumentation to monitor belt performance	Sub Control: Overload sensor, fault sensor, slippage sensor, etc.
Cause: Roller failure (e.g. damaged/worn bearing)	Control: Provide belt operator training to identify irregular roller performance	
	Control: Undertake preventive maintenance program to ensure roller functionality	Sub Control: Appropriate roller maintenance (e.g. prohibit improper bearing lubrication)
Cause: Slippage of belt (e.g. hydraulic failure at takeup)	Control: Undertake preventive maintenance program to ensure equipment functionality	
	Control: Ensure belt design parameters and location are appropriate for maintenance, belt examination, housekeeping, travel, etc.	Sub Control: Parameters for consideration include: clearance, alignment, geometry, sizing, etc.
	Control: Electro-mechanical belt monitoring	Sub Control: Appropriate sequence design (PLC)
		Sub Control: Automated spillage switch
	Control: Install and maintain instrumentation to monitor belt performance	Sub Control: Overload sensor, fault sensor, slippage sensor, etc.
Consequence: Fire on/near belt resulting in injury or fatality	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to fire	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	

<table>
<tr><td>on/near belt</td><td colspan="2">Control: Notify the proper authorities/agencies immediately following a heating incident (note: there are no incentives for self-reporting heating events. Heating events do not need to be reported by law.)</td></tr>
<tr><td rowspan="2">Consequence: Coal loss due to fire on/near belt</td><td colspan="2">Control: Secure mine insurance policy for lost mineral assets</td></tr>
<tr><td colspan="2">Control: Ensure water spray system is in place to minimize coal loss</td></tr>
<tr><td rowspan="3">Consequence: Equipment damage or loss due to fire on/near belt</td><td colspan="2">Control: Secure equipment insurance policy for major mine equipment</td></tr>
<tr><td colspan="2">Control: Ensure water spray system is in place to minimize damage to equipment</td></tr>
<tr><td colspan="2">Control: Implement an emergency equipment recovery plan</td></tr>
<tr><td rowspan="7">Consequence: Accumulation of toxic gases in mine atmosphere due to fire on/near belt</td><td rowspan="3">Control: Monitoring to determine the extent of the affected area</td><td>Sub Control: Evacuation of mine employees</td></tr>
<tr><td>Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust</td></tr>
<tr><td>Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)</td></tr>
<tr><td rowspan="2">Control: Implement comprehensive emergency response plan</td><td>Sub Control: Mobilize mine rescue team</td></tr>
<tr><td>Sub Control: Notify the proper authorities/agencies immediately following an incident</td></tr>
<tr><td colspan="2">Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)</td></tr>
<tr><td colspan="2">Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies</td></tr>
<tr><td colspan="3">Disclaimer RISKGATE is a free service. RISKGATE does not purport to be a guideline or code of practice but rather is a reference source and may not necessarily be current. RISKGATE is not intended to be and should not be relied upon as legal or technical advice. RISKGATE is a database of information from various sources, including the host providers, that may be of some assistance to its users. RISKGATE does not give any guarantee, undertaking or warranty that the information provided is comprehensive and covers every case/incident/safety alert/bulletin potentially relevant in the mining industry. Users should consult other sources of information and not rely on RISKGATE as the only source of information. RISKGATE does not invite reliance upon, nor accept responsibility for, the information it provides. RISKGATE makes every effort to provide a high quality service. However, neither RISKGATE, the host providers nor the providers of data on RISKGATE, give any guarantees, undertakings or warranties concerning the accuracy, completeness or up-to-date nature of the information provided. Users should confirm information from another source if it is of sufficient importance for them to do so. Hypertext links on RISKGATE are inserted by RISKGATE, not by the data providers. RISKGATE is operated by the Minerals Industry Safety and Health Centre at the University of Queensland.</td></tr>
</table>

Table C.3 – RISKGATE-US COAL bowtie: Methane ignition resulting in fire (face/gob) or explosion

Initiating Event: Methane ignition resulting in fire (Face/Gob) or explosion		
Cause: Accumulation of methane due to: poor ventilation, infiltration from adjacent seam (stratigraphic interactions), geologic anomaly, change in barometric pressure, coal burst, leakage in gathering system, borehole/gas well interaction with mine, seismic event, or unknown source	Control: Inertization of gob atmosphere through inert gas (nitrogen) injection	
	Control: Conduct regular visual inspections and gas monitoring to expose seal deficiencies	Sub Control: Maintenance or reconstruction of damaged or deficient seals
		Sub Control: Injection of grout to repair seal fractures
		Sub Control: Gas monitoring of gob area enclosed by seals rated to less than 50 psi (e.g. use of boreholes to monitor gob area)
	Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)	
	Control: Modification of mining near underlying mine	Sub Control: Alternative panel geometry (e.g. reduce panel width)
	Control: Conduct a detailed seal inspection immediately following a seismic event	Sub Control: Replace damaged seals following a seismic event
		Sub Control: Install new mine seal if damaged seal is inaccessible following a seismic event
	Control: Ensure underlying panel locations protect mainline seals (in the case of over mining)	
	Control: Ventilation design limits oxygen flow through/around gob area (e.g. U-system layout, limited bleeder/fringe system)	
	Control: Continuously monitor gas levels in fringe area	
	Control: Ensure ventilation design can regulate or shut-down the bleeder system if dangerous atmospheric conditions are encountered	
	Control: Alter retreat mining rate (1/2 days)	
	Control: Cross-cut panel seals	
	Control: Continuously monitor explosive gas levels at longwall face	
	Control: Ensure gate road design limits airflow through the longwall face (e.g. yield pillar)	
	Control: Maximize extraction percentage of the coal seam	
	Control: Monitor and seal the borehole	Sub Control: Verify or stop oxygen intake through borehole into gob area
Cause: Spark generated by: dull/missing bits on shearer, electrical fault/arc (DC trolley), lightning, roof fall, roof bolt shear/general roof bolting process, shearer interaction with Sulphur ball	Control: Ensure equipment meets/exceeds regulatory permissibility standards (e.g. use of non-sparking equipment, diesel equipment, hydraulic equipment, etc.)	
	Control: Equip shearer with water spray system to reduce probability of ignition	
	Control: Consider use of plow if mining conditions allow	

	Control: Ensure ventilation design can regulate or shut-down the bleeder system if dangerous atmospheric conditions are encountered	
	Control: Alter mining rate to prevent sparking	
	Control: Ensure proper isolation of electrical energy from distribution stations/battery charging stations	
	Control: Confirm shield advance procedure is designed to prevent shield scraping	
	Control: Mapping of abandoned or previous mine workings to prevent interaction with active mining	
	Control: Halt mining during inclement weather (high-intensity electrical storm)	
Cause: Belt friction	Control: See Initiating Event: Fire on/near conveyor belt	
Cause: Inadequate ventilation to active face/battery charging stations	Control: Inertization of combustible atmosphere through automated system	
	Control: Consider installation of temperature monitor for working face equipment (e.g. infrared gun for distribution sensing)	
	Control: Ensure air flow/quantity adheres to design specifications	
	Control: CO monitoring to detect fire	
	Control: Monitor for combustible atmosphere while undertaking welding/cutting procedures	
	Control: Ensure equipment meets/exceeds regulatory permissibility standards	
Cause: Collision between moving equipment	Control: See RISKGATE Topic: Moving Equipment, Initiating Event: Loss of control of mobile equipment (including events caused by less than adequate operation/design of equipment)	
	Control: Ensure equipment meets/exceeds regulatory permissibility standards	
Cause: Blasting	Control: Provide adequate training and supervision to blasting crews	
	Control: Use of permissible blasting equipment	
	Control: Isolation of combustible material when blasting (e.g. compressed cylinders containing explosive chemicals)	
	Control: Take measures to prevent unplanned caving/falls of roof while blasting	
Consequence: Fire in sealed gob area	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident

	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Explosion due to methane ignition	Control: Use seals which provide maximum resistance to explosive force (e.g. 120 psi seals)	
	Control: Ensure roadways are properly rock dusted	
	Control: Optimization of rock dust characteristics to prevent propagation of explosive force	
	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. move fresh air to trapped miners)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to methane ignition	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	
	Control: Notify the proper authorities/agencies immediately following a heating incident (note: there are no incentives for self-reporting heating events. Heating events do not need to be reported by law.)	
Consequence: Methane ignition at longwall face	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an

		incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Methane ignition in gob area at active longwall face	Control: Use seals which provide maximum resistance to explosive force (e.g. 120 psi seals)	
	Control: Ensure roadways are properly rock dusted	
	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees
		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. move fresh air to trapped miners)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Consequence: Regulatory action imposed due to methane ignition	Control: Ensure compliance with federal, state, and site-specific mining rules and regulations	
	Control: Notify the proper authorities/agencies immediately following a heating incident (note: there are no incentives for self-reporting heating events. Heating events do not need to be reported by law.)	
Consequence: Coal loss due to methane ignition	Control: Modification of mine plan/mining method (e.g. switch from longwall mining to room and pillar mining)	
	Control: Secure mine insurance policy for lost mineral assets	
	Control: Ensure water spray system is in place to minimize coal loss	
Consequence: Equipment damage or loss due to methane ignition	Control: Secure equipment insurance policy for major mine equipment	
	Control: Ensure water spray system is in place to minimize damage to equipment	
	Control: Implement an emergency equipment recovery plan	
Consequence: Accumulation of toxic gases in mine atmosphere	Control: Monitoring to determine the extent of the affected area	Sub Control: Evacuation of mine employees

due to methane ignition and resulting fire/explosion		Sub Control: Inertization of gob atmosphere through inert gas (e.g. nitrogen, carbon dioxide) injection, water injection, or jet engine exhaust
		Sub Control: Alteration/management of ventilation system (e.g. redirect smoke into a return airway)
	Control: Implement comprehensive emergency response plan	Sub Control: Mobilize mine rescue team
		Sub Control: Notify the proper authorities/agencies immediately following an incident
	Control: Provide adequate personal protective equipment (PPE) for miners (e.g. self-contained self-rescuers, lifelines, refuge chambers)	
	Control: Provide adequate training and ensure adequate awareness and competency of all miners with respect to mine fire emergencies	
Disclaimer RISKGATE is a free service. RISKGATE does not purport to be a guideline or code of practice but rather is a reference source and may not necessarily be current. RISKGATE is not intended to be and should not be relied upon as legal or technical advice. RISKGATE is a database of information from various sources, including the host providers, that may be of some assistance to its users. RISKGATE does not give any guarantee, undertaking or warranty that the information provided is comprehensive and covers every case/incident/safety alert/bulletin potentially relevant in the mining industry. Users should consult other sources of information and not rely on RISKGATE as the only source of information. RISKGATE does not invite reliance upon, nor accept responsibility for, the information it provides. RISKGATE makes every effort to provide a high quality service. However, neither RISKGATE, the host providers nor the providers of data on RISKGATE, give any guarantees, undertakings or warranties concerning the accuracy, completeness or up-to-date nature of the information provided. Users should confirm information from another source if it is of sufficient importance for them to do so. Hypertext links on RISKGATE are inserted by RISKGATE, not by the data providers. RISKGATE is operated by the Minerals Industry Safety and Health Centre at the University of Queensland.		

Table C.4 – RISKGATE-US COAL bowtie: Loss of roof control at advancing section (feeder inby)

Initiating Event: Loss of roof control at advancing section (feeder inby)		
Cause Category: Geology		
Cause: Changing geology/roof conditions, including known anomalies	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Mine mapping

	Control: Develop mine geological model (hazard maps, geological influence, and mapping)	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause: Strata transition causing weak bedding plane/laminations (e.g. shale-shale, limestone-shale, rider seams, rider faults, stack rocks)	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence, and mapping)	
	Control: Modify design of support system to address strata transition	
	Control: Schedule independent audit of mine geological model	
Cause: Insufficient characterization of geology	Control: Secondary exploration drilling to update the mine geological model	
	Control: Targeted drilling	
	Control: Consider surface lineament mapping	
Cause: Changes in overburden, depth of cover leading to variation in vertical stress conditions	Control: Mine mapping of topography and depth of cover	
	Control: Recognition of impact of overburden variation on mining conditions	
	Control: Modify design of support systems to address changes	
Cause: Insufficient understanding of rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure)	Control: Characterize rock layer strength (laboratory testing)	
	Control: Rock mass classification	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Cleat pattern, orientation, spacing	Control: In situ geological mapping (swillies)	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Known geological structures (faults, dykes, slickensides, rolls, swillies, washouts, intrusions, channels)	Control: Exploration drilling	
	Control: In situ geological mapping	
	Control: Geophysical surveys	
	Control: Consider surface lineament mapping	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Kettlebottoms	Control: In situ observation	
	Control: Obtain and review historical data from parallel panels	
Cause: Horizontal stress (including valley bottom stress effects)	Control: Consider stress outcomes from mining in adjacent mines	
	Control: Mapping of in situ features (e.g. cutters)	
	Control: Mine mapping of topography to consider alignment of valleys, lineaments	
	Control: Measurement of horizontal stress direction and magnitude	
	Control: Design of support system	
	Control: Mine planning and orientation	

Cause: Water bearing layer	Control: Permeability and piezometer tests on targeted water bearing horizons	
	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification methods (boreholes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence mapping)	
	Control: Update geological model with observations from mining	
	Control: Schedule independent audit of mine geological model	
Cause Category: Design		
Cause: Inadequate roof support/roof control results in fall of ground	Control: Identify weak and competent strata	
	Control: Consideration for conditions and effective intervention methods in adjacent mines, historical data	
	Control: Consider abutment stress	
	Control: Select appropriate modeling approach (e.g. FLAC, ARBS, ALPS, STOP)	
	Control: Consult with bolt suppliers (provide rock strength properties)	
	Control: Develop roof support plan	
	Control: Consider life cycle requirements (time/length of support required)	
	Control: Apply adequate safety factors to account for purpose of entry	
	Control: Revise and/or update roof support plans with input from operational roof conditions (driller reports, etc.)	
	Control: Consider regulatory agency recommendations	
	Control: Schedule independent audit of roof support design	
Cause: Insufficient characterization of geology	Control: Increase safety factors to compensate for unknown geological conditions	
Cause: Changes in overburden and/or depth of cover	Control: Design base plan for maximum cover that could be encountered	
	Control: Design base plan for actual cover (e.g. variation in support plan that matches specific stress conditions)	
	Control: Develop designs that identify and communicate changes in cover depth to operations personnel (e.g. triggers that lead to modification in mining practice)	
Cause: Valley bottom stress effects	Control: Identify areas with expected valley bottoms (e.g. topography, degree of gradient change between low and high coverage)	
	Control: Consider roof type (eg. laminated shale vs massive sandstone) and fracturing	
	Control: Consider orientation	
	Control: Re-evaluate primary roof support	

	Control: Consider supplemental roof support to manage elevated horizontal stresses
	Control: Consider potential for increased floor and rib problems (e.g. heave, rib sloughing)
Cause: Mining under/around water	Control: Identify bodies of water (e.g. historical records - overlying map and elevation of water; aquifers marked on geological model; inseam horizontal drilling to confirm absence of water)
	Control: Orient mining to minimize interaction with water bodies
	Control: Routine preshift and onshift inspections/monitoring for water hazards
	Control: Establish monitoring wells for water hazards
	Control: Consider dewatering
	Control: Establish and model barriers to calculate stability
Cause: Insufficient consideration for rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure; strata mineralogy - especially clay minerals)	Control: Select appropriate bolt length
	Control: Select appropriate pillar size
	Control: Incorporate outcomes from models, sensitivity analysis
	Control: Increase factor of safety
	Control: Consider rib bolting
	Control: Integrate findings into the mine geological model and mine design
	Control: Install pumping and drainage systems to manage water on floor or face
	Control: Remove thin clay layer (cutting out) as part of mining process
	Control: Select appropriate equipment for floor bearing pressure and water usage
	Control: Consider using wetting agents in water supply to reduce volume of water used
	Control: Floor treatment (e.g. lime)
	Control: Use rail instead of rubber tires for transportation
Cause: Inadequate pillar dimensions (size, shape) by design	Control: Consider overburden depth and variation
	Control: Reevaluate all design parameters (e.g. stress, geology, abutment stresses, mine layout)
	Control: Review and select appropriate modeling software and approach
	Control: Consider prior experience in the same seam (own or adjacent mining)
	Control: Consider future mining activity (e.g. retreat mining or longwall) when selecting dimensions
	Control: Schedule peer or independent audit/review of pillar design
Cause: Cleat pattern, orientation, spacing	Control: Consider rib support
	Control: Consider primary production method in selection of orientation
Cause: Known geological structures (faults, dykes, slickensides, rolls, swillies, washouts, etc.)	Control: Adjust mine geometry and panel orientation
	Control: Include geological structures within the mine geological model

	Control: Consider structures in development planning, equipment selection and scheduling
	Control: Adjust bolting, strapping, grouting, secondary support activities to manage known structures
Cause: Excessive depth of cut or unsupported standing time relative to roof conditions	Control: Adjust depth of cut, review of depth of cut relative to geological conditions
	Control: Reduce maximum standing times
	Control: Adjust the cutting height (e.g. incompetent layer, different equipment to cut down)
	Control: Narrow the entry width
Cause: Inadequate bolt selection and anchorage relative to geology	Control: Detailed characterization of geotechnical and geological domain
	Control: Consider geotechnical domain when selecting appropriate support mechanism (e.g. beams building, anchorage)
	Control: Consider roof geology when selecting appropriate anchorage horizon
	Control: Consider full or partial encapsulation
	Control: Calculate appropriate bolt pattern (spacing and height)
	Control: Consider horizontal stress factors
	Control: Calculate maximum potential load on bolts and consider known failure rates
Cause: Horizontal stress (magnitude and orientation)	Control: Consider mining outcomes in adjacent mines
	Control: Mine mapping of topography to consider alignment of valleys, lineaments
	Control: Measure horizontal stress direction and magnitude
	Control: Consider horizontal stress in design of support system (primary and secondary)
	Control: Mine planning and orientation
Cause Category: Operating practice (training, supervision, monitoring, audits, etc.)	
Cause: Deviation from bolt pattern - installation/design, bolt anchorage	Control: Bolt crew training (type of bolts, speed of glue, etc.)
	Control: Train section foreman
	Control: Provide section plan
	Control: Monitor and supervise bolt installation
	Control: Audit and disciplinary action for deviation from bolt pattern
Cause: Insufficient characterization of geology on the section (not drilling test	Control: Characterize strata and match/overlay with mine map
	Control: Provide training regarding drilling location and depth

holes to confirm)/inadequate test holes (not deep enough, etc.)	Control: Confirm transfer of information from bolt crew to section boss	
	Control: Monitor and report any changes in strata data	
	Control: Independent visual or auditory inspection/check of test holes	
Cause: Failure to recognize changing vertical stress (changes in overburden, depth of cover)	Control: Increase number of core holes	
	Control: Horizontal drilling when laying out panels	
	Control: Integrate core hole drilling information into overlay maps	
	Control: Establish triggers and communicate support changes	
	Control: Confirm and maintain continuous feedback from bolt crew	
Cause: Valley bottom stress effects	Control: Review past mining history in same seam	
	Control: Train operators to identify this type of hazard	
	Control: Highlight valley bottoms in topography map and consider mine plan adjustments	
Cause: Mining under/around water (water make at face/probe drilling/ground water)	Control: Review past mining history in same seam	
	Control: Train operators to identify this hazard	
	Control: Highlight water bodies on topography map	
	Control: Undertake directional drilling as needed	
	Control: Confirm availability of discharge line/sumps for dewatering	
Cause: Mining off center line	Control: Select equipment to achieve planned pillar size	
	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Maintain spads (survey markers) at current or reasonable distances	
	Control: Use laser sights (or sight rods) to orient mining direction	
	Control: Update maps to communicate section progress	
	Control: Ensure good center transition or entries when changing pillar size	
	Control: Designate different center line colors for different shifts	
	Control: Paint center lines and guidance lines	
	Control: Increase roof and/or rib support as required	
	Control: Provide adequate training for turning angles (you don't learn till you mess up)	
Cause: Excessive span or reduced pillar width due to rib sloughing	Control: Consider effect of rib sloughing when developing entries	Sub Control: Reduce entry width so the final is acceptable
	Control: Ensure initial bolt pattern is tight to the rib to decrease sloughage	
	Control: Implement secondary support as required	Sub Control: Rib bolting
		Sub Control: Pillar wrap, wire mesh, polyfabric
		Sub Control: Timbering, cribs
		Sub Control: Wooden strap supports

		Sub Control: Jacks
	Control: Increase safety factor	
	Control: Maintain square instead of angled/rectangular pillars	
Cause: Excessive cutting height	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Install height indicators (e.g. sight onto the face, using laser)	
	Control: Increase or maintain supervision	
	Control: Select equipment to achieve desired entry height	
	Control: Characterize the roof geology to determine if different cutting heights are required	
	Control: Consider cutting the height out of the bottom	
Cause: Improper application of bolt torque	Control: Confirm manufacturer specifications for bolt installation	
	Control: Select bolt type for geological conditions	
	Control: Consider alternate bolt types (eg. glue/tension); and/or consider changing glue	
	Control: Establish test procedure to validate bolt performance	
	Control: Provide bolter training	
	Control: Audit and replace bolter operator if required	
	Control: Test and calibrate that bolt installation equipment can achieve full torque	
	Control: Monitor and supervise bolt installation	
	Control: Train foremen with respect to bolt quality control or replacement	
Cause: Cutting too low, equipment damage	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Take the height out of the bottom when required	
	Control: Match bit selection to the rock type	
	Control: Install height indicator if needed	
	Control: Assign difficult travelling to one shift	
	Control: Drill and shoot	
	Control: Match miner operator to height of cutting	
Cause: Abutment stress/barrier width inadequate	Control: Reduce number of entries	
	Control: Install supplementary support	
	Control: Build a barrier	
	Control: Install standing support	
	Control: Change adjacent pillar size	
	Control: Reduce entry width or height	
	Control: Rib support including grouting into barrier to stabilize	
Cause: Deviation from cleat	Control: Install rib support	

pattern, orientation, spacing, penetration rate	Control: Reduce height	
	Control: Provide miner crew training	
	Control: Audit and replace with faster mining crew if conditions require	
	Control: Reduce number of idle shifts	
	Control: Match bit type to geologic conditions	
	Control: Change orientation of entries (e.g. orient pillars perpendicular to face cleat)	
	Control: Advance belt sooner, reduce haulage distance to increase cutting rate (i.e. less down-time waiting for shuttle cars due to long travel distances)	
Cause: Nonconformance to development procedure (e.g. mining speed, advance rate, depth of cut, bolt installation timeframe)	Control: Review and/or adjust depth of cut relative to geological conditions	
	Control: Reduce maximum standing times	
	Control: Adjust the cutting height (e.g. incompetent layer, different equipment to cut down)	
	Control: Narrow the entry width	
	Control: Increase speed of bolt installation (e.g. select bolts with shorter install times)	
Cause: Geological structures (faults, dykes, slickensides, rolls, swillies), known/unknown	Control: Map the geology and the extent of structure interference	
	Control: Communication of geological/structural conditions	
	Control: Ensure availability of sufficient supplies (e.g. support materials) and additional equipment	
	Control: Install supplementary support	
	Control: Match entry width to conditions (e.g. narrow entries)	
	Control: Reduce the number of entries	
	Control: Reduce depth of cut	
	Control: Lengthen the pillars	
	Control: Preplan to identify optimal location to start grading	
	Control: Consider alternate bolt types including cables, torque-tension, glue	
	Control: Relocate the section	
Cause: Bottom conditions, soft undercut affecting ribs	Control: Use lighter equipment	
	Control: Reduce number of entries	
	Control: Install pumping and drainage system to manage water on floor	
	Control: Relocate the section	
	Control: Mine the bottom	
	Control: Temporarily increase pillar size	
	Control: Install additional rib support at the base of the rib	
	Control: Adjust or relocate hauling route	
	Control: Program off sequence belt move	
Cause: Rib failure leading to roof failure	Control: Install supplementary rib support including mesh	Sub Control: Including mesh
		Sub Control: Straps
		Sub Control: Standing support
		Sub Control: Cribs

	Control: Reduce entry width	
	Control: Bolt closer to the rib	
	Control: Relocate the section	
	Control: Reduce the number of entries	
	Control: Increase pillar size	
Cause: Equipment and supplies not available or not compatible with mine plan or mine conditions	Control: Selection of mining equipment and supplies that match mining conditions	
	Control: Purchase supplemental or new equipment if required to match mine plan or mine conditions	
	Control: Modification of mine plan to match available equipment and supplies	
	Control: Undertake preventive maintenance program to ensure equipment availability	
	Control: Adjust availability of equipment and supplies	
	Control: Improve or maintain communication between miners and support team (e.g. procurement, maintenance, warehouse, operations)	
	Control: Do not mine if equipment is not fit for conditions	
Consequence: Roof fall at advancing section resulting in injury or fatality	Control: Remove personnel from potential secondary fall zones after a primary failure while remediation activities are in-progress at the working face	
	Control: Define high risk areas for roof falls and barricade against entry in the working section with exception to personnel responsible for roof control remediation (e.g., roof control crews, foreman, etc.)	
	Control: Ensure that the number of operators working on the section at any one time is not excessive	
	Control: Automate equipment to maintain planned operating procedures and designed extraction geometry	Sub Control: Automate horizon control equipment to maintain designed cutting height
		Sub Control: Automate chock and armored face conveyor (AFC) advance to maintain designed shield and AFC advance sequence and timing
	Control: Implement remotely operated equipment (e.g., roof bolters, shuttle cars, etc.) to physically separate the operator from the working face (red zone)	
	Control: Design drilling and support installation equipment to maximize distance and create physical barriers between the operator and the roof to allow operators to work in safe zone (e.g., under protective canopy)	
	Control: Equipment design and selection to consider operator protection	
	Control: Personnel protective equipment (PPE) beyond minimum standard	Sub Control: Full face masks/hardhat for protection from dust and flyrock - specific to site conditions
		Sub Control: Metatarsal boots
	Control: Training and awareness of safe operating procedures including safe zones and accepted operational practices in the working section	

	Control: Training on roof control plan and operating sequence under varying roof conditions	
	Control: Communication of hazards to personnel (e.g., red zones, roof control plan, mine emergency plan including mine escape procedures, communication methods, etc.)	
	Control: Establish active section roof failure remediation plan (i.e., re-supporting roof, fall cleanup, equipment recovery, etc.)	Sub Control: Define safe practices (e.g., use of temporary support, etc.)
	Control: Ensure that local agreements are in-plan for medical services and transport. If practical, implement on-site medical personnel (i.e., mine workers who are EMT certified, etc.) and transportation	
	Control: Minimize emergency response time	
	Control: Ensure availability of first-aid and emergency response resources across all shifts (e.g. equipment, kits)	
Consequence: Frictional ignition at working face, see RISKGATE Fires / Explosions Topics	Control: Implement fire suppression systems, gas monitoring, temperature sensors, etc.	
Consequence: Equipment damage or loss at working face	Control: Design equipment to withstand impact from rock fall	
	Control: Ensure equipment insurance policies are in place	
	Control: Ensure availability of equipment recovery resources	
Consequence: Production disruption and/or loss of resources	Control: Spare equipment and parts readily available to continue operations	
	Control: Relocate to alternative mining area for production supplementation	
	Control: Design roof fall response plan to minimize disruption	
	Control: Ensure personnel are trained to implement response plans in a timely manner	
	Control: Agreements in place to guarantee the availability of specialized services and resources - consolidation products, teams and suppliers, consultants	
	Control: Ensure insurance policies are in place	

Table C.5 – RISKGATE-US COAL bowtie: Loss of roof control at longwall face

Initiating Event: Loss of roof control at longwall face		
Cause Category: Geology		
Cause: Changing geology/roof conditions, including known anomalies	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence, and mapping)	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause: Strata transition causing weak bedding plane/laminations (e.g. shale-shale, limestone-shale, rider seams, rider faults, stack rocks)	Control: Forecasting methods	Sub Control: Projection from known geology (own or adjacent mines, historical data)
		Sub Control: Identification (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Mine mapping
	Control: Develop mine geological model (hazard maps, geological influence, and mapping)	
	Control: Modify design of support system to address strata transition	
	Control: Schedule independent audit of mine geological model	
Cause: Insufficient characterization of geology	Control: Secondary exploration drilling to update the mine geological model	
	Control: Targeted drilling	
	Control: Consider surface lineament mapping	
Cause: Changes in overburden, depth of cover leading to variation in vertical stress conditions	Control: Mine mapping of topography and depth of cover	
	Control: Recognition of impact of overburden variation on mining conditions	
	Control: Modify design of support systems to address changes	
Cause: Insufficient understanding of rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure)	Control: Characterize rock layer strength (laboratory testing)	
	Control: Rock mass classification	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Cleat pattern, orientation, spacing	Control: In situ geological mapping (swillies)	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Known geological structures (faults, dykes, slickensides, rolls, swillies, washouts, intrusions, channels)	Control: Exploration drilling	
	Control: In situ geological mapping	
	Control: Geophysical surveys	

<table>
<tr><td rowspan="2"></td><td colspan="2">Control: Consider surface lineament mapping</td></tr>
<tr><td colspan="2">Control: Integrate findings into the mine geological model and mine design</td></tr>
<tr><td rowspan="2">Cause: Kettlebottoms</td><td colspan="2">Control: In situ observation</td></tr>
<tr><td colspan="2">Control: Obtain and review historical data from parallel panels</td></tr>
<tr><td rowspan="6">Cause: Horizontal stress (including valley bottom stress effects)</td><td colspan="2">Control: Consider stress outcomes from mining in adjacent mines</td></tr>
<tr><td colspan="2">Control: Mapping of in situ features (e.g. cutters)</td></tr>
<tr><td colspan="2">Control: Mine mapping of topography to consider alignment of valleys, lineaments</td></tr>
<tr><td colspan="2">Control: Measurement of horizontal stress direction and magnitude</td></tr>
<tr><td colspan="2">Control: Design of support system</td></tr>
<tr><td colspan="2">Control: Mine planning and orientation</td></tr>
<tr><td rowspan="7">Cause: Water bearing layer</td><td colspan="2">Control: Permeability and piezometer tests on targeted water bearing horizons</td></tr>
<tr><td rowspan="3">Control: Forecasting methods</td><td>Sub Control: Projection from known geology (own or adjacent mines, historical data)</td></tr>
<tr><td>Sub Control: Identification methods (boreholes, core drilling, e-logs)</td></tr>
<tr><td>Sub Control: Mine mapping</td></tr>
<tr><td colspan="2">Control: Develop mine geological model (hazard maps, geological influence mapping)</td></tr>
<tr><td colspan="2">Control: Update geological model with observations from mining</td></tr>
<tr><td colspan="2">Control: Schedule independent audit of mine geological model</td></tr>
<tr><td colspan="3">Cause Category: Design</td></tr>
<tr><td rowspan="11">Cause: Inadequate roof support/roof control results in fall of ground</td><td colspan="2">Control: Identify weak and competent strata</td></tr>
<tr><td colspan="2">Control: Consideration for conditions and effective intervention methods in adjacent mines, historical data</td></tr>
<tr><td colspan="2">Control: Consider abutment stress</td></tr>
<tr><td colspan="2">Control: Select appropriate modeling approach (e.g. FLAC, ARBS, ALPS, STOP, etc.)</td></tr>
<tr><td colspan="2">Control: Consult with bolt suppliers (provide rock strength properties)</td></tr>
<tr><td colspan="2">Control: Develop roof support plan</td></tr>
<tr><td colspan="2">Control: Consider life cycle requirements (time/length of support required)</td></tr>
<tr><td colspan="2">Control: Apply adequate safety factors to account for purpose of entry</td></tr>
<tr><td colspan="2">Control: Revise and/or update roof support plans with input from operational roof conditions (driller reports, etc.)</td></tr>
<tr><td colspan="2">Control: Consider regulatory agency recommendations</td></tr>
<tr><td colspan="2">Control: Schedule independent audit of roof support design</td></tr>
<tr><td rowspan="2">Cause: Insufficient characterization of geology</td><td colspan="2">Control: Increase safety factors to compensate for unknown geological conditions</td></tr>
<tr><td colspan="2">Control: Targeted drilling</td></tr>
</table>

	Control: Consider surface lineament mapping
Cause: Changes in overburden and/or depth of cover	Control: Design base plan for maximum cover that could be encountered
	Control: Design base plan for actual cover (e.g. variation in support plan that matches specific stress conditions)
	Control: Develop designs that identify and communicate changes in cover depth to operations personnel (e.g. triggers that lead to modification in mining practice)
Cause: Valley bottom stress effects	Control: Identify areas with expected valley bottoms (e.g. topography, degree of gradient change between low and high coverage)
	Control: Consider roof type (e.g. laminated shale vs massive sandstone) and fracturing
	Control: Consider orientation
	Control: Re-evaluate primary roof support
	Control: Consider supplemental roof support to manage elevated horizontal stresses
	Control: Consider potential for increased floor and rib problems (e.g. heave, rib sloughing)
Cause: Mining under/around water	Control: Identify bodies of water (e.g. historical records – overlying map and elevation of water; aquifers marked on geological model; inseam horizontal drilling to confirm absence of water)
	Control: Orient mining to minimize interaction with water bodies
	Control: Routine preshift and onshift inspections/monitoring for water hazards
	Control: Establish monitoring wells for water hazards
	Control: Consider dewatering
	Control: Establish and model barriers to calculate stability
Cause: Insufficient consideration for rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure; strata mineralogy – especially clay minerals)	Control: Select appropriate bolt length
	Control: Select appropriate pillar size
	Control: Incorporate outcomes from models, sensitivity analysis
	Control: Increase factor of safety
	Control: Consider rib bolting
	Control: Integrate findings into the mine geological model and mine design
	Control: Install pumping and drainage systems to manage water on floor or face
	Control: Remove thin clay layer (cutting out) as part of mining process
	Control: Select appropriate equipment for floor bearing pressure and water usage
	Control: Consider using wetting agents in water supply to reduce volume of water used
	Control: Floor treatment (e.g. lime)
	Control: Use rail instead of rubber tires for transportation
Cause: Inadequate pillar dimensions (size, shape) by design	Control: Consider overburden depth and variation
	Control: Reevaluate all design parameters (e.g. stress, geology, abutment stresses, mine layout)
	Control: Review and select appropriate modeling software and approach

	Control: Consider prior experience in the same seam (own or adjacent mining)	
	Control: Consider future mining activity (e.g. retreat mining or longwall) when selecting dimensions	
	Control: Schedule peer or independent audit/review of pillar design	
Cause: Cleat pattern, orientation, spacing	Control: Consider rib support	
	Control: Consider primary production method in selection of orientation	
Cause: Known geological structures (faults, dykes, slickensides, rolls, swillies, washouts, etc.)	Control: Adjust mine geometry and panel orientation	
	Control: Include geological structures within the mine geological model	
	Control: Consider structures in development planning, equipment selection and scheduling	
	Control: Adjust bolting, strapping, grouting, secondary support activities to manage known structures	
Cause Category: Operating Practice (training, supervision, monitoring, audits, etc.)		
Cause: Excessive cutting height	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Install height indicators (e.g. sight onto the face, using laser)	
	Control: Increase or maintain supervision	
	Control: Select equipment to achieve desired entry height	
	Control: Characterize the roof geology to determine if different cutting heights are required	
	Control: Consider cutting the height out of the bottom	
Cause: Failure of one or multiple shields	Control: Undertake preventive maintenance program to ensure shield functionality	
	Control: Confirm shield specifications meet requirements for mining conditions /mine plan	Sub Control: Size, load capacity, shield reach, shield width, etc.
	Control: Selection of mining equipment and supplies that match mining conditions	
	Control: Purchase supplemental or new equipment if required to match mine plan or mine conditions	
	Control: Modification of mine plan to match available equipment and supplies	
	Control: Correct shield advance procedure	
	Control: Consider manual shield setting	
Cause: Cutting too low, equipment damage	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Take the height out of the bottom when required	
	Control: Match bit selection to the rock type	

	Control: Install height indicator if needed
	Control: Assign difficult travelling to one shift
	Control: Drill and shoot
	Control: Match miner operator to height of cutting
Cause: Abutment stress/barrier width inadequate	Control: Reduce number of entries
	Control: Install supplementary support
	Control: Build a barrier
	Control: Install standing support
	Control: Change adjacent pillar size
	Control: Reduce entry width or height
	Control: Rib support including grouting into barrier to stabilize
Cause: Failure to recognize changing vertical stress (changes in overburden, depth of cover)	Control: Increase number of core holes
	Control: Horizontal drilling when laying out panels
	Control: Integrate core hole drilling information into overlay maps
	Control: Establish triggers and communicate support changes
	Control: Confirm and maintain continuous feedback from bolt crew
Cause: Valley bottom stress effects	Control: Review past mining history in same seam
	Control: Train operators to identify this type of hazard
	Control: Highlight valley bottoms in topography map and consider mine plan adjustments
Cause: Mining under/around water (water make at face/probe drilling/ground water)	Control: Review past mining history in same seam
	Control: Train operators to identify this hazard
	Control: Highlight water bodies on topography map
	Control: Undertake directional drilling as needed
	Control: Confirm availability of discharge line/sumps for dewatering
Cause: Deviation from cleat pattern, orientation, spacing, penetration rate	Control: Install rib support
	Control: Reduce height
	Control: Provide miner crew training
	Control: Audit and replace with faster mining crew if conditions require
	Control: Reduce number of idle shifts
	Control: Match bit type to geologic conditions
	Control: Change orientation of entries (e.g. orient pillars perpendicular to face cleat)
	Control: Advance belt sooner, reduce haulage distance to increase cutting rate (i.e. less down-time waiting for shuttle cars due to long travel distances)
Cause: Nonconformance to development procedure (e.g. mining speed, advance rate, depth of cut, bolt installation timeframe)	Control: Review and/or adjust depth of cut relative to geological conditions
	Control: Reduce maximum standing times
	Control: Adjust the cutting height (e.g. incompetent layer, different equipment to cut down)
	Control: Narrow the entry width
	Control: Reduce panel width

	Control: Increase speed of bolt installation (e.g. select bolts with shorter install times)
Cause: Geological structures (faults, dykes, slickensides, rolls, swillies), known/unknown	Control: Map the geology and the extent of structure interference
	Control: Communication of geological/structural conditions
	Control: Ensure availability of sufficient supplies (e.g. support materials) and additional equipment
	Control: Install supplementary support
	Control: Match entry width to conditions (e.g. narrow entries)
	Control: Reduce the number of entries
	Control: Reduce depth of cut
	Control: Lengthen the pillars
	Control: Preplan to identify optimal location to start grading
	Control: Consider alternate bolt types including cables, torque-tension, glue
	Control: Relocate the section
Cause: Bottom conditions, soft undercut affecting face	Control: Use lighter equipment
	Control: Reduce number of entries
	Control: Install pumping and drainage system to manage water on floor
	Control: Relocate the section
	Control: Mine the bottom
	Control: Adjust or relocate hauling route
	Control: Program off sequence belt move
	Control: Reestablish face to suitable conditions (scaling, supplemental support, etc.)
Cause: Equipment and supplies not available or not compatible with mine plan or mine conditions	Control: Selection of mining equipment and supplies that match mining conditions
	Control: Purchase supplemental or new equipment if required to match mine plan or mine conditions
	Control: Modification of mine plan to match available equipment and supplies
	Control: Undertake preventive maintenance program to ensure equipment availability
	Control: Adjust availability of equipment and supplies
	Control: Improve or maintain communication between miners and support team (e.g. procurement, maintenance, warehouse, operations)
	Control: Do not mine if equipment is not fit for conditions
Cause: Excessive width of headgate, tailgate, or setup room	Control: Reduce number of entries
	Control: Install supplementary support
	Control: Build a barrier
	Control: Install standing support
	Control: Change adjacent pillar size
	Control: Reduce entry width or height

	Control: Rib support including grouting into barrier to stabilize	
Consequence: Roof fall at longwall face resulting in injury or fatality	Control: Separate personnel from potential fall zones on the longwall face	
	Control: Establish red zones on longwall (e.g. in front of spill plates on the armored face conveyor, AFC)	
	Control: Authorized access to red zones	
	Control: Limit the number of operators working on the face at any one time	
	Control: Automated equipment to maintain planned operating procedures and designed extraction geometry on the longwall face	Sub Control: Automate horizon control equipment to maintain designed cutting height
		Sub Control: Automated chock and armored face conveyor (AFC) advance to maintain designed shield and AFC advance sequence and timing
	Control: Remotely operated equipment to physically separate the operator from the working face (red zone)	
	Control: Design drilling and support installation equipment to maximize distance and create physical barriers between the operator and the face and allow operators to work in safe zone (e.g. under shield canopy and behind AFC spill plate)	
	Control: Remote controlled shearer equipment removes operator from face area where flyrock hazards exist	
	Control: Equipment design and selection to consider operator protection	Sub Control: Side shields reduce probability of roof material falling between the shields into work area
	Control: Guards on transfer point of conveyor prevents coal falling off and also access to block side of conveyor on headgate	
	Control: Personnel protective equipment (PPE) beyond minimum standard	Sub Control: Full face masks/helmet for protection from dust and flyrock - specific to site conditions
		Sub Control: Metatarsal boots
	Control: Training and awareness of safe operating procedures including safe zones and operational practice on longwall face	
	Control: Training on face management plan and operating sequence and under varying roof / face conditions	
	Control: Awareness and establishment of safe operational zones when there is potential for equipment interaction/impact (e.g. potential for impact between shearer drum and shield in thin seam or early advance of shields over shearer)	
	Control: Communication of hazards and awareness to longwall workforce: red zones, roof control plan, mine emergency plan (including mine escape procedures, communication methods, etc.)	
	Control: Face recovery plan - contingency actions related to safe recovery of face fall (e.g. use of temporary support if accessing red zone)	
	Control: On-site medical services and transport	

	Control: Minimized response time and likelihood of elevated consequence
	Control: First-aid and emergency response resources across all shifts (e.g. equipment, procedures, suitably trained personnel)
	Control: Emergency response plan to prevent further consequences from face fall (injury to fatality)
Consequence: Frictional ignition at longwall face, see RISKGATE Fires / Explosions Topics	Control: Fire suppression systems and monitoring
	Control: Statutory gas level monitoring
Consequence: Equipment damage or loss at longwall face	Control: Equipment designed to minimize the extent of face fall and withstand impact from rock fall
	Control: Design of systems to consider sprags, longwall gob shields, canopies, spill plate height, cable and hose protection, side shields, position of controls
Consequence: Production disruption, loss of resources, dilution	Control: Equipment designed to minimize the extent of face fall and withstand impact from rock fall (e.g. sprags, longwall gob shields, canopies, spill plate height, cable and hose protection, side shields, position of controls)
	Control: Spare equipment and parts on-site - to continue operations
	Control: Alternative mining area or stockpile - production substitution
	Control: Response plan to minimize disruption time during operation
	Control: Fall recovery plan and face stabilization plan
	Control: Equipment, skilled people and materials on site to implement above plans in a timely manner
	Control: Agreement in place to guarantee the availability of specialist services and resources - consolidation products, teams and suppliers, consultants (i.e. to reduce down time)
	Control: Ensure equipment insurance policies are in place

Table C.6 – RISKGATE-US COAL bowtie: Burst of coal (at longwall face, development roadway, or outby roadway)

Initiating Event: Burst of Coal (at longwall face, development roadway, or outby roadway)		
Cause Category: Geology		
Cause: Changing geology/roof conditions	Control: Implement forecasting methods	Sub Control: Projection from known geology (e.g., from historical data)
		Sub Control: Detailed geologic characterization (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Historical mine mapping
	Control: Develop mine geological model	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause: Strata transition causing weak bedding plane/aminations (e.g., shale-shale, limestone-shale, rider seams, rider faults, stack rocks)	Control: Implement forecasting methods	Sub Control: Projection from known geology (e.g., from historical data)
		Sub Control: Detailed geologic characterization (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Historical mine mapping
	Control: Develop mine geological model	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause: Insufficient characterization of geology	Control: Secondary exploration drilling to update the mine geological model	
	Control: Targeted core-hole drilling of suspect areas	
Cause: Changes in overburden depth of cover leading to variations in vertical stress conditions	Control: Mine mapping of topography and depth of cover	
	Control: Recognizing the impact of overburden variation on mining conditions	
	Control: Modify design of support systems to address changes in depth (e.g., additional roof and rib supports, adjusting pillar design, etc.)	
Cause: Insufficient understanding of rock and coal properties (strength and susceptibility to water; including conditions that lead to rib failure)	Control: Characterize rock layer strength and composition (e.g., laboratory testing)	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Cleat pattern, orientation, spacing	Control: In-situ geological mapping	
	Control: Integrate findings into the mine geological model and mine design	

Cause: Seismic event	Control: Characterization of proximal seismic activity (i.e., location, magnitude, and extent)	
	Control: Design of support system to minimize damage from seismic event	
Cause: Known geological structures (faults, dykes, slickensides, rolls, washouts, intrusions, channels)	Control: Exploration drilling	
	Control: In-situ geological mapping	
	Control: Geophysical surveys	
	Control: Consider surface lineament mapping	
	Control: Integrate findings into the mine geological model and mine design	
Cause: Horizontal stress (including the valley bottom stress effects)	Control: Consider stress outcomes from mining in adjacent mines	
	Control: Mapping of in-situ features (e.g., cutters)	
	Control: Mine mapping of topography to consider alignment of valleys and lineaments	
	Control: Measurement of horizontal stress direction and magnitude	
	Control: Design of support system sufficient to manage stress variations	
	Control: Mine planning and orientation	
Cause: Water bearing layer	Control: Permeability and piezometer tests on targeted water bearing horizons	
	Control: Implement forecasting methods	Sub Control: Projection from known geology (e.g., from historical data)
		Sub Control: Detailed geologic characterization (boreholes, bore scopes, core drilling, e-logs)
		Sub Control: Historical mine mapping
	Control: Develop mine geological model	
	Control: Modify design of support system to address changing conditions	
	Control: Schedule independent audit of mine geological model	
Cause Category: Design		
Cause: Inadequate roof support and increase in abutment stress	Control: Identify weak strata	
	Control: Consider conditions and effective intervention methods in adjacent mines, historical data	
	Control: Consider abutment stress	
	Control: Consider alarm gauge system which indicates excessive load on mobile roof supports	
	Control: Select appropriate modeling approach (e.g. FLAC, ARBS, ALPS, STOP, etc.)	
	Control: Consult with bolt suppliers (provide rock strength properties)	
	Control: Develop roof support plan	
	Control: Targeted drilling to relieve stress	
	Control: Consider life cycle requirements of mine workings (time/length of support required)	
	Control: Apply adequate factor of safety to design	
	Control: Revise and/or update roof support plans based on roof conditions (driller reports, etc.)	

	Control: Consider regulatory agency recommendations
	Control: Schedule independent audit of roof support design
Cause: Insufficient characterization of geology	Control: Increase factor of safety to compensate for unknown geological conditions
	Control: Targeted drilling
Cause: Changes in overburden and/or depth of cover	Control: Design roof control plan to account for variations in cover (e.g., match specific stress conditions)
	Control: Communicate changes in cover depth to personnel (e.g., conditions that lead to modification in mining practice)
Cause: Valley bottom stress effects	Control: Identify areas with expected valley bottoms (e.g., topography, degree of gradient change between low and high coverage)
	Control: Consider roof composition (e.g., laminated shale vs massive sandstone) and fracturing
	Control: Consider orientation of stress
	Control: Re-evaluate primary roof support
	Control: Consider supplemental roof support to manage elevated horizontal stresses
	Control: Consider potential for increased floor and rib problems (e.g., heaving, rib sloughing)
Cause: Mining under and around water	Control: Identify bodies of water (e.g., historical records - overlying map and elevation of water; aquifers marked on geological model; inseam horizontal drilling to confirm absence of water)
	Control: Orient mining to minimize interaction with water bodies
	Control: Routine preshift and onshift inspections/monitoring for water hazards
	Control: Establish monitoring wells for water hazards
	Control: Consider dewatering small bodies of water
	Control: Identify and model barriers to calculate stability
Cause: Insufficient consideration for rock and coal properties (strength and susceptibility to water; including soft bottom leading to rib failure; strata mineralogy - especially clay minerals)	Control: Select appropriate bolt length
	Control: Select appropriate pillar size
	Control: Incorporate outcomes from computer models, sensitivity analysis to design
	Control: Increase factor of safety
	Control: Consider rib bolting
	Control: Integrate findings into the mine geological model and mine design
	Control: Install pumping and drainage systems to manage water
	Control: Remove hazardous thin clay layers as part of mining process
	Control: Select appropriate equipment for floor bearing pressure
	Control: Consider using wetting agents in water supply to minimize volume of water used
	Control: Floor treatment (e.g., lime)
	Control: Use rail instead of rubber tired vehicles for transportation
Cause: Inadequate pillar dimensions (size, shape) by design	Control: Consider overburden depth
	Control: Reevaluate all design parameters (e.g., stress, geology, abutment stresses, mine layout)

	Control: Review and select appropriate modeling software and approach	
	Control: Consider prior experience in the same seam (i.e., adjacent mining)	
	Control: Consider future mining activity (e.g., retreat mining or longwall) when selecting pillar dimensions	
	Control: Schedule peer or independent audit/review of pillar design	
Cause: Cleat pattern, orientation, spacing	Control: Consider rib support	
	Control: Consider orientation of mine working with respect to cleat properties	
Cause: Known geological structures (faults, dykes, slickensides, rolls, washouts, etc.)	Control: Adjust mine geometry and panel orientation	
	Control: Include geological structures within the mine geological model	
	Control: Consider structures in development planning, equipment selection and scheduling	
	Control: Adjust bolting, strapping, grouting, secondary support activities to manage known structures	
Cause Category: Operating Practices (training, supervision, monitoring, audits, etc.)		
Cause: Excessive mining height	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Install height indicators (e.g., sight onto the face, lasers)	
	Control: Increase or maintain supervision	
	Control: Select equipment to achieve desired entry height	
	Control: Characterize the roof geology to determine if different mining heights are required	
	Control: Consider cutting the floor instead of the top to achieve necessary height	
Cause: Failure of one or multiple shields	Control: Undertake preventive maintenance program to ensure shield functionality	
	Control: Confirm shield specifications meet requirements for mining conditions/mine plan	Sub Control: Size, load capacity, shield reach, shield width, etc.
	Control: Selection of mining equipment and supplies that match mining conditions	
	Control: Purchase new equipment if required to match mine plan or mine conditions	
	Control: Refine shield advance procedure	
	Control: Manually operate shields when needed	
Cause: Insufficient mining height to remove unstable strata	Control: Provide miner operator training	
	Control: Audit and replace miner operator if required	
	Control: Provide foreman training	
	Control: Audit and replace foreman if required	
	Control: Match bit selection to rock type	
	Control: Install height indicator if needed	
	Control: Match equipment to height of cutting	

Cause: Abutment stress/pillar size inadequate	Control: Reduce number of entries
	Control: Install supplementary support
	Control: Change adjacent pillar size
	Control: Reduce entry width or height (i.e., increase pillar size)
	Control: Rib support including grouting in the pillar to stabilize
	Control: Targeted drilling to relieve stress
Cause: Failure to recognize changing vertical stress (changes in overburden, depth of cover)	Control: Increase number of core holes to map stress distribution
	Control: Horizontal drilling when laying out panels
	Control: Integrate core hole drilling information into mine design
	Control: Communicate support changes to mine personnel
	Control: Maintain continuous feedback from roof support crew
Cause: Valley bottom stress effects	Control: Review past mining history in the same seam
	Control: Train operators to identify this type of hazard
	Control: Highlight valley bottoms in topography map and consider mine plan adjustments
Cause: Mining under/around water (water make at face/probe drilling/ground water)	Control: Review past mining history in the same seam
	Control: Train operators to identify this hazard
	Control: Highlight water bodies on topographic map
	Control: Undertake directional drilling as needed for dewatering
	Control: Maintain discharge line/sumps for dewatering
Cause: Deviation from expected cleat pattern, orientation, spacing	Control: Install rib support
	Control: Reduce mining height
	Control: Provide personnel training
	Control: Reduce the time that unsupported roof is left unsecured
	Control: Match bit type to geologic conditions
	Control: Change orientation of entries (e.g., orient pillars perpendicular to face cleat)
Cause: Noncompliance to development procedure (e.g., mining speed, advance rate, depth of cut, bolt installation timeframe)	Control: Review or revaluate development procedures with employees
	Control: Increase the presence of supervisors
	Control: Disciplinary action if noncompliance becomes habitual
Cause: Geological structures (faults, dykes, slickensides, rolls), known/unknown	Control: Map the geology and surrounding structure
	Control: Communication of geological/structural conditions to mine personnel
	Control: Ensure availability of sufficient roof support supplies and equipment
	Control: Install supplementary supports
	Control: Match entry width to conditions
	Control: Reduce the number of entries
	Control: Reduce depth of cut
	Control: Increase pillar size
	Control: Consider alternate bolt types including cable, torque-tension, and resin grouted
	Control: Relocate the active section
Cause: Bottom conditions, soft	Control: Use lighter equipment

undercut affecting face	Control: Reduce number of entries	
	Control: Install pumping and drainage system to manage water on floor	
	Control: Relocate the active section	
	Control: Mine the bottom	
Cause: Equipment and supplies not available or not compatible with mine plan or mine conditions	Control: Select mining equipment and supplies that match mining conditions	
	Control: Purchase new equipment if required to match mine plan or mine conditions	
	Control: Modify mine plan to match available equipment and supplies	
	Control: Undertake preventive maintenance program to reduce downtime	
	Control: Improve or maintain communication between miners and support teams (e.g., purchasing, maintenance, warehouse, operations)	
	Control: Do not use if equipment is not fit for conditions	
Cause: Excessive entry width of headgate, tailgate, or setup room	Control: Reduce entry width	
	Control: Install supplemental support	
	Control: Change adjacent pillar size	
	Control: Rib support including grouting into pillar to stabilize	
Consequence: Injury or fatality	Control: Remove personnel from area until further risk is assessed	
	Control: Minimize the number of personnel working in potential outburst areas	
	Control: Automate equipment to maintain planned operating procedures on the longwall face	Sub Control: Automate horizon control equipment to maintain designed cutting height
		Sub Control: Automate chock and armored face conveyor (AFC) advance to maintain designed shield and AFC advance sequence and timing
	Control: Implement remotely operated equipment to separate the operator from the working face	
	Control: Design drilling and support installation equipment to protect operators from exposure	
	Control: Implemented remote shearer equipped with video monitoring to remove operator from face area where flyrock hazards exist	
	Control: Equipment design and selection to consider operator protection from outbursts	
	Control: Personnel protective equipment (PPE) beyond minimum standard	Sub Control: Full face masks/hardhat for protection from dust and flyrock - specific to site conditions
	Control: Training on safe operating procedures around outburst prone areas	
	Control: Training and awareness of indications of danger including noise (coal bumps), acceptable load on mobile roof support, acceptable load on supplemental roof support, floor heave, and other environmental anomalies	

	Control: Communication of hazards to mine personnel: roof control plan, mine emergency plan (including mine escape procedures, communication methods, etc.)
	Control: Ensure that local agreements are in-plan for medical services and transport. If practical, implement on-site medical personnel (i.e., mine workers who are EMT certified, etc.) and transportation
	Control: Minimize emergency response time
	Control: Ensure availability of first-aid and emergency response resources across all shifts (e.g. equipment, kits)
Consequence: Equipment damage or loss	Control: Design equipment to withstand impact from outburst
	Control: Design of systems to consider longwall gob shields, canopies, spill plate height, cable and hose protection, side shields, position of controls
	Control: Ensure that adequate insurance policies are in-place
Consequence: Production disruption, loss of resources	Control: Design equipment to withstand impact from outburst
	Control: Spare equipment and parts on-site to continue operations
	Control: Design response plan to minimize downtime after outburst
	Control: Institute outburst response plan
	Control: Ensure personnel are available to implement response plans in a timely manner
	Control: Agreement in place to guarantee the availability of specialized services and resources - consolidation products, teams and suppliers, consultants (i.e. to reduce down time)
	Control: Ensure equipment insurance policies are in place
Disclaimer RISKGATE is a free service. RISKGATE does not purport to be a guideline or code of practice but rather is a reference source and may not necessarily be current. RISKGATE is not intended to be and should not be relied upon as legal or technical advice. RISKGATE is a database of information from various sources, including the host providers, that may be of some assistance to its users. RISKGATE does not give any guarantee, undertaking or warranty that the information provided is comprehensive and covers every case/incident/safety alert/bulletin potentially relevant in the mining industry. Users should consult other sources of information and not rely on RISKGATE as the only source of information. RISKGATE does not invite reliance upon, nor accept responsibility for, the information it provides. RISKGATE makes every effort to provide a high quality service. However, neither RISKGATE, the host providers nor the providers of data on RISKGATE, give any guarantees, undertakings or warranties concerning the accuracy, completeness or up-to-date nature of the information provided. Users should confirm information from another source if it is of sufficient importance for them to do so. Hypertext links on RISKGATE are inserted by RISKGATE, not by the data providers. RISKGATE is operated by the Minerals Industry Safety and Health Centre at the University of Queensland.	

Table C.7 – RISKGATE-US COAL bowtie: Loss of control of mobile equipment (including events caused by less than adequate operation/design of equipment)

Initiating Event: Loss of control of mobile equipment (including events caused by less than adequate operation/design of equipment)	
Cause Category: Operations	
Cause: Lack of communication between two vehicles	Control: Radio communications
	Control: Dispatch (especially rail)
	Control: Block lights
	Control: Equipment tracking
	Control: Proximity detection systems
	Control: Transparent ventilation controls
	Control: Visual barriers (including maintenance)
	Control: Lighting (including directional, reflective)
	Control: Training, including default when system fails
	Control: Shut down when proximity detection fails
	Control: Light signals
Cause: Vehicle interactions due to reduced visibility around ventilation controls (e.g. curtains)	Control: Consider matching the regulatory requirements to the actual needs of the mine (e.g. idle face ventilation)
	Control: Transparent materials
	Control: Installation and maintenance
	Control: Standard Operating Procedures (SOP)
	Control: Remove ventilation controls when not needed
	Control: Communication (pedestrian to notify operators that working in section)
	Control: Planning and development
	Control: Signage, use of reflectors or lighting (including individual strobe lights, side lights)
	Control: Consider reflective color spectrum match to cameras
	Control: Training, awareness, compliance
	Control: High visibility personal protective equipment (PPE) (including strobe lights)
Cause: Fatigue (including overwork/absenteeism/change in behavior)	Control: Consideration for automation and mechanization
	Control: Consideration for monitoring/early warning technology
	Control: Integration of fatigue management within workforce health and wellbeing programs
	Control: Achieve effective balance between work load and staffing
	Control: Establish and implement site-based standards with respect to fatigue management
	Control: Consider guidance materials from other high-risk industries
Cause: Excessive payload	Control: Standard Operating Policies for supplies/payloads and loading on equipment
	Control: Buy-in from management regarding load limits
	Control: Clear communication and training regarding impacts of overloading (loss during travel, damage to mine infrastructure, increased maintenance)
	Control: Overload/height indicators

	Control: Understanding of impact of material density (e.g. coal vs rock; braking distance and braking capacity)	
	Control: Weight sensor	
	Control: Clear communication between CM operator and load operators	
	Control: Consideration for auto-stop sensors/technology when payload exceeds operating limits	
Cause: Safety policy is less than adequate	Control: Appropriate and effective policies	
	Control: Development of equipment and operations standards and policies that consider impacts on vehicle interactions (e.g. transport rules)	
	Control: Stakeholder engagement (feedback) in development of policies	
	Control: Audit, regular review/measurement (all stakeholders) and update of policies	
	Control: Compliance and enforcement - management leadership and limits	
Cause: Operational changes (change in routine or due to changing conditions, including alteration of equipment travel routes, planned/unplanned maintenance in roadway)	Control: Planning and development to consider change management	
	Control: Consider impacts of change to mining sequence/procedures (depth of cut, panel design, etc.) on existing travel conditions	
	Control: Establish communication protocols for changes	Sub Control: Routine tool-box talks
		Sub Control: From site level to individual sections
		Sub Control: Thorough communication of change across all workers within a section
		Sub Control: Accurate communication between shifts
	Control: Standard Operating Procedures (e.g. trigger action response) to worsening conditions	Sub Control: Shut down/stop work
		Sub Control: Recognize that the smallest routine changes can result in catastrophic accident)
	Control: Supervision and on-the-job training with respect to managing changes in conditions and/or routines	
Cause: Production pressures (perceived and/or actual) including impacts of corporate culture, generational factors, absenteeism, insufficient size of workforce (increased personal stress, individual workload)	Control: Corporate culture: e.g. do not run if something is wrong	
	Control: Management leadership and commitment to culture that retains workforce	
	Control: Continuous process improvement supported by proactive management	
	Control: Development and communication of clear workforce expectations and accountabilities	
	Control: Employee selection, with consideration for impact/integration of prior workplace cultures	
	Control: Adaptation of workplace culture to engage with younger workers	
	Control: Engagement of seasoned workforce in adaptation and implementation of new technology	

Cause: Incompetent operator (e.g. lack of training, inexperience)	Control: Develop and implement Standard operating procedures (SOPs), safe work procedures that are appropriate for site and workforce	
	Control: Appropriate and effective training	Sub Control: Consider use of advanced training methods (e.g. virtual reality)
		Sub Control: Include adequate training of the trainer
		Sub Control: Standard Operating Procedures (SOPs)
		Sub Control: Safe work procedures
		Sub Control: Confirm equipment operating competency
	Control: Ensure that operator is adequately trained to safely function in designated work zone	Sub Control: Mine layout
		Sub Control: Mine conditions
		Sub Control: Hazards
		Sub Control: Requirements for specific equipment
	Control: Develop and implement mentoring programs	Sub Control: Matching experienced operators to novice operators
		Sub Control: Matching less experienced foremen (e.g. red hat mentors) to those with experience
	Control: Train supervisors to maximize operator competency and identify/manage operators that do not meet required performance levels	
Cause: Mechanical failure (braking system, dynamic conditions of road/rail and load)	Control: Preventive maintenance	
	Control: Pre-op inspection	
	Control: Regular inspection and testing	
	Control: Track maintenance	
	Control: Adequate braking technology	
	Control: Intentional derail	
	Control: Operator training - gentle touch	
Cause: Deviation from planned haulage route (e.g. when running battery, diesel, scoop operators)	Control: Communication	
	Control: Call the road before proceeding (radio communication)	
	Control: Planning and development	
	Control: Change management	
	Control: Signage, use of reflectors/lighting/other to mark routes	
	Control: Standard Operating Procedures (SOP, protocols for scoops, haulers, pedestrians)	
	Control: Training, awareness, compliance	
	Control: High visibility clothing	
Cause: Environmental factors (uphill, downhill, rolling), ambient (rock dusting)	Control: Schedule rock dusting to minimize dust impact on operations	
	Control: Communication of schedules	
	Control: Operate efficiently in challenging conditions to minimize time in those conditions	

	Control: Traffic management plan, sectional access controls to manage environmental factors	
	Control: Mine design	
Cause: Travelling speed exceeds safe level (different road surface, roadway conditions, visibility)	Control: Mechanical limits	
	Control: Optimize distance to feeder, increase belt moving	
	Control: Consider impact of roadway watering on different road surfaces (e.g. clay)	
	Control: Gravel and grading of roadways	
	Control: Water management plan (pumping)	
	Control: Application of calcium for dust	
	Control: Intentional derails	
Cause: Aging workforce	Control: Consider the time that long-time workers may need to adapt to new technology	
	Control: Correct body movement/posture training for operators	
	Control: Consideration for diminished eyesight, hearing, flexibility in task design (appropriate corrective devices)	
Cause: Congestion/high traffic areas (including new/additional vehicles)	Control: Planning and development	Sub Control: Change out locations
		Sub Control: Right of ways
		Sub Control: Detailed schedule for longwall or other equipment moves
	Control: People management	Sub Control: Asynchronous schedules (e.g. crews start/return at different times)
		Sub Control: Limits on visitors, survey crews, etc.
	Control: Increase sensory awareness	Sub Control: Lights (both mobile and fixed plant, directional lights)
		Sub Control: Signs
		Sub Control: Audible warnings (e.g. back-up horn)
	Control: Develop and implement communication protocols	Sub Control: Dispatch and block light system
		Sub Control: Changed conditions
		Sub Control: Visitors
	Control: Travel way maintenance	
	Control: Proximity detection systems	
Cause: Inadequate or improper signage	Control: Develop and implement site-based signage standards	Sub Control: Choice of materials
		Sub Control: Consideration for impact of rock dusting
		Sub Control: Maintenance plan, including cleaning
		Sub Control: Locate signs where equipment damage to sign is minimized
		Sub Control: Locate signs where they can be seen
	Control: Keep signage current with changes in section	

	Control: Consideration for color-blindedness in workforce	
Cause: Dynamics and congestion of longwall move (including complexity, size, quantity and diversity of equipment, additional new vehicles in traffic flow)	Control: Planning and development	Sub Control: Detailed schedule for longwall or other equipment moves
		Sub Control: Allocation of best operators to the equipment, maximize efficiency and reduce time
		Sub Control: Pre-move audit of haulage system (track, switches, components, clearance)
		Sub Control: Pre-operation checklist on equipment (mules, changes, hooks, etc.)
		Sub Control: Change out locations
		Sub Control: Right of ways
		Sub Control: Longwall move has complete priority over right of way
		Sub Control: Control non-longwall travel during move (e.g. not allowed on track during move, post man at every switch during move to control traffic)
	Control: People management	Sub Control: Asynchronous schedules (e.g. crews start/return at different times)
		Sub Control: Limits on visitors, survey crews, etc.
	Control: Increase sensory awareness	Sub Control: Lights (both mobile and fixed plant, directional lights)
		Sub Control: Signs
		Sub Control: Audible warnings (e.g. back-up horn)
	Control: Develop and implement communication protocols	Sub Control: Dispatch and block light system
		Sub Control: Increased communication and heightened awareness regarding exclusion from area of move
		Sub Control: Transfer dispatch duties underground to near longwall move; or one dispatch for move, and one for remainder of mine; separate radios
		Sub Control: Manage changed conditions
		Sub Control: Manage/preclude visitors
	Control: Travel way maintenance	
	Control: Proximity detection systems	

<table>
<tr><td rowspan="8">Cause: Capacity of available workforce is limited due to geography or demographics</td><td colspan="2">Control: Consideration for automation/mechanization</td></tr>
<tr><td>Control: Build talent pool of suitable workforce in local community</td><td>Sub Control: Investment in community education (high school, community college, youth/adults)</td></tr>
<tr><td colspan="2">Control: Adapt mine operations to characteristics of workforce (e.g. times of shift for farmers, car pooling for people with no license, work release, school bus times)</td></tr>
<tr><td colspan="2">Control: Recruitment/HR practice that engages available workers (e.g. consideration for local factors)</td></tr>
<tr><td colspan="2">Control: Consideration and accommodation for worker literacy (e.g. color coding buttons)</td></tr>
<tr><td colspan="2">Control: Consideration and accommodation for ESL employees (e.g. Hispanic)</td></tr>
<tr><td colspan="2">Control: Make GED/other education available as a sign of corporate commitment to individual employees</td></tr>
<tr><td colspan="2">Control: Develop and implement corporate culture that retains workforce</td></tr>
<tr><td rowspan="5">Cause: Prescriptive regulation may increase risk for certain operations</td><td colspan="2">Control: Prescriptive regulation may preclude an adaptive risk-based approach that considers the unique requirements of each site</td></tr>
<tr><td colspan="2">Control: Notification to operators of visitors could be construed as prior notice for inspections</td></tr>
<tr><td colspan="2">Control: Required minimum air quantities -> unnecessary ventilation controls -> creates risk</td></tr>
<tr><td colspan="2">Control: Differences between regulatory requirements (e.g. red zone interpretation)</td></tr>
<tr><td colspan="2">Control: Prescriptive proximity detection systems may not be fit for purpose</td></tr>
<tr><td rowspan="9">Cause: Personnel working in red zone</td><td rowspan="3">Control: Define red zone for all equipment (continuous miner, roof bolter, haulage equipment, etc.)</td><td>Sub Control: Consider undertaking risk assessment to define red zone for all equipment based on operating conditions and procedures (operating, moving, maintenance, etc.)</td></tr>
<tr><td>Sub Control: Establish high risk areas for each activity (e.g. pinch points, warning areas)</td></tr>
<tr><td>Sub Control: Document outcomes in roof control plans, tramming procedures, personnel training programs</td></tr>
<tr><td colspan="2">Control: Adequate training, awareness, and competency of all personnel with respect to red zones</td></tr>
<tr><td rowspan="2">Control: Provide personnel supervision</td><td>Sub Control: Voice/audio communication with others</td></tr>
<tr><td>Sub Control: Communication by signaling</td></tr>
<tr><td rowspan="3">Control: Ensure adequate engineering controls for tramming</td><td>Sub Control: Remote control</td></tr>
<tr><td>Sub Control: Dual controls</td></tr>
<tr><td>Sub Control: Operator guards</td></tr>
</table>

	Control: Use of proximity detection systems (e.g. CMS)	Sub Control: Ensure comprehensive coverage of all personnel with respect to red zones
		Sub Control: Calibrate proximity detection systems to abide by red zone criteria
		Sub Control: Ensure proximity detection equipment is reliable and tamper-proof
Cause: Failure of proximity detection system (also see "Cause: Personnel working in red zone")	Control: Ensure collision management systems (CMS) are not a primary control technology for interactions between personnel and mobile equipment	
	Control: Ensure mine road design, traffic management plans, operating and maintenance practices, etc. are in place prior to integration of personal detection devices	
	Control: System setup based on outcomes of risk assessment for red zone delineation, and individual units maintained and calibrated	
	Control: Confirm comprehensive coverage - all pedestrians in the CM section are equipped with transmitters/receivers	
Cause: Noise level due to mining environment interferes with personnel ability to perceive hazards	Control: Redesign/reengineer moving equipment with objective to reduce noise generation	
	Control: Ensure adequate visibility in all roadways (see "Cause: Equipment operator has restricted visibility")	Sub Control: Measures to increase visibility
		Sub Control: High viz PPE, directional lighting, signage, clear curtains, lights on pagers, beacons
	Control: Hearing PPE (including moulded silicone earplugs)	
	Control: Implementation of other communication modes to compensate for noise impacts	
	Control: Enhanced visibility (e.g. mirrors at turns)	
	Control: Dosimeter readings on equipment	
	Control: Wear strips, noise damping blankets	
Cause: Poor ground conditions affect traverse capability (excess water, slippery floor, etc.)		
Cause: Deviant practice of personnel (short-cuts, recklessness, etc.)		
Cause Category: Equipment		
Cause: Failure of communication system between two vehicles (including failure of communication devices, radios, lights, horns, etc.)	Control: Dispatch (especially rail)	Sub Control: Communication alert
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
	Control: Improved visibility	Sub Control: Lighting (including directional, reflective, light signals)
		Sub Control: Transparent ventilation controls

		Sub Control: Highly visible protective barriers (including durability and maintenance)
	Control: Routine maintenance and verification of communications systems	Sub Control: Check and maintain radios, lights
		Sub Control: Block lights
	Control: Training in use of communication protocols	Sub Control: Including default procedures when system fails (e.g. standby, shut down)
Cause: Equipment operator has restricted visibility (equipment design and/or modifications/retrofit)	Control: Conduct design risk assessment of vehicle visibility for all mobile equipment, and any equipment modifications or retrofit	Sub Control: Identify and map blind spots
		Sub Control: Include engineering, and equipment operators in risk assessment
		Sub Control: Modify or optimize equipment design to maximize visibility
	Control: Ensure adequate visibility from cab for equipment operators	Sub Control: Provide adequate lighting on equipment
		Sub Control: Mirrors
		Sub Control: Install directional lighting on mobile equipment
		Sub Control: Install LED lights on mobile equipment
		Sub Control: Install cameras on mobile equipment
		Sub Control: Schedule routine verification and maintenance for all visibility-related devices
	Control: Maximize visibility of mine environment to equipment operator	Sub Control: Use of reflective/high visibility clothing
		Sub Control: Provide personnel with strobe lights
		Sub Control: Ensure rock dust is sufficiently applied to roadways
		Sub Control: Adequate ventilation controls, including water sprays, transparent fly pads, etc.
		Sub Control: Schedule routine verification and maintenance for lighting and other controls
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
Cause: Operational changes (e.g. deployment of different equipment, downtime due to planned/unplanned maintenance, retrofit)	Control: Planning and development to in response to equipment changes	Sub Control: Consider impact of equipment changes on travel plan and modify travel plan as required
		Sub Control: Workforce training in adaptation to equipment

		changes
	Control: Establish communication protocols for changes	Sub Control: Routine tool-box talks
		Sub Control: From site level to individual sections
		Sub Control: Thorough communication of change across all workers within a section
		Sub Control: Accurate communication between shifts
	Control: Modification of Standard Operating Procedures (e.g. trigger action response) for unplanned/planned equipment change	Sub Control: Shut down/stop work
		Sub Control: Recognize that the smallest routine changes can result in catastrophic accident
		Sub Control: Different routes
	Control: Supervision and on-the-job training with respect to managing changes in conditions and/or routines	
Cause: Mechanical failure (braking system, dynamic conditions of road/rail and load, load not properly secure)	Control: Schedule routine equipment inspections	Sub Control: Pre-op inspection
		Sub Control: Regular inspection and testing
	Control: Establish preventive maintenance program	Sub Control: Consider supplier guidelines
		Sub Control: Adapt maintenance schedule in response to operating conditions and outcomes (e.g. increased maintenance if increased wear and tear on equipment)
		Sub Control: Track maintenance programs are essential in rail environments
		Sub Control: Roadway maintenance programs enhance operability of mobile equipment
	Control: Undertake risk assessment regarding equipment braking requirements and operating environment	Sub Control: Ensure selection of braking technology that is fit for purpose
	Control: Operator training	Sub Control: Gentle touch
		Sub Control: Importance of inspections and maintenance - awareness of required schedules
		Sub Control: Ensure that operators understand correct procedures for securing loads
		Sub Control: Conditions and procedures for intentional derail (equipment out of control, mechanical failure)

	Control: Operator supervision, audit, spot-checking	
Cause: Equipment not fit for purpose (inappropriate design, dynamic mining conditions, geologic anomalies, grandfathered equipment, “that’s all we got”)	Control: Conduct mobile equipment risk assessment (including equipment modifications or retrofit) to identify operating requirements	Sub Control: Develop procurement specifications that incorporate risk assessment outcomes
		Sub Control: Include engineering, and equipment operators in risk assessment
		Sub Control: Procurement to purchase equipment for optimal performance in mine operating conditions
	Control: Modify or optimize equipment design to maximize safe operations	Sub Control: Consider retrofitting equipment in the field
		Sub Control: Changing drums, bit patterns, tire size, sideboards, canopy heights
		Sub Control: Add cameras
		Sub Control: Add proximity detection systems
		Sub Control: Switch to LED lighting
		Sub Control: Adapt operator seat height/position to conditions
		Sub Control: Directional lighting or illumination
	Control: Select equipment appropriate to task	
	Control: Redesign roadway layout, dimensions in mine plan (e.g. new section) to match the requirement available equipment	
Cause: Personnel working in red zone	Control: Accurately define red zone for all equipment (continuous miner, roof bolter, haulage equipment, etc.)	Sub Control: Consider undertaking risk assessment to define red zone for all equipment based on operating conditions and procedures (operating, moving, maintenance, etc.)
		Sub Control: Establish high risk areas for each activity (e.g. pinch points, warning areas)
		Sub Control: Document outcomes in roof control plans, tramming procedures, personnel training programs
	Control: Ensure adequate engineering controls for tramming	Sub Control: Remote control
		Sub Control: Dual controls (e.g. operator with flexibility to drive equipment by remote controls or controls on vehicle)
		Sub Control: Operator guards

	Control: Use of proximity detection systems (e.g. CMS)	Sub Control: Ensure comprehensive coverage of all personnel with respect to red zones
		Sub Control: Calibrate proximity detection systems to abide by red zone criteria
		Sub Control: Ensure proximity detection equipment is reliable and tamper-proof
Cause: Failure of proximity detection system (also see "Cause: Personnel working in red zone")	Control: Ensure collision management systems (CMS) are not a primary control technology for interactions between personnel and mobile equipment	
	Control: Ensure mine road design, traffic management plans, operating and maintenance practices, etc. are in place prior to integration of personal detection devices	
	Control: System setup based on outcomes of risk assessment for red zone delineation	
	Control: Individual proximity detection units maintained and calibrated	
	Control: Remove equipment from operations until proximity detection units are fully repaired and verified	
Cause: Noise level due to mining environment interferes with personnel ability to perceive hazards	Control: Redesign/reengineer/retrofit moving equipment with objective to reduce noise generation	
	Control: Enhanced visibility (e.g. mirrors at turns)	
	Control: Dosimeter readings on equipment	
	Control: Wear strips to reduce vibration/breakdown of bolts/bits	
	Control: Noise damping blankets	
Cause Category: Environment		
Cause: Equipment operator or pedestrian has restricted visibility (low seam/confined mining space, roadway design, etc.)	Control: Ensure adequate visibility in all roadways, intersections	Sub Control: Provide adequate area lighting
		Sub Control: Use of reflective/high visibility clothing
		Sub Control: Provide personnel with strobe lights
		Sub Control: Install directional lighting on mobile equipment
		Sub Control: Ensure rock dust is sufficiently applied to roadways
		Sub Control: Install LED lights on mobile equipment
		Sub Control: Install cameras on mobile equipment
		Sub Control: Adequate ventilation controls, including water sprays, transparent fly pads, etc.
	Control: Conduct risk assessment of mobile equipment procedures for traffic interactions when moving where	Sub Control: Develop and implement procedures and controls determined pertinent by the risk assessment

	pedestrians in area	Sub Control: Consider equipment tag out, use of spotters, communication protocols, etc.
	Control: Establish equipment tramming speed limits that are consistent with prevailing visibility and environmental conditions	
Cause: Vehicle interactions due to reduced visibility around ventilation controls (e.g. curtains, flypads)	Control: Conduct risk assessment of mobile equipment procedures for traffic interactions around ventilation controls	
	Control: Develop and implement procedures and controls determined pertinent by the risk assessment	Sub Control: Consider equipment tag out, use of spotters, communication protocols, etc.
		Sub Control: Consider matching the regulatory requirements to the actual needs of the mine (e.g. idle face ventilation)
		Sub Control: Communication (pedestrian to notify operators that working in section)
		Sub Control: Remove ventilation controls when not needed
	Control: Use of transparent materials for ventilation controls	
	Control: Standard Operating Procedures (SOP) for navigating ventilation controls	Sub Control: Appropriate speeds
		Sub Control: Communication (visual/lights, noise/horn) prior to passing through
		Sub Control: Positive communication and confirmation with others on section
		Sub Control: Training of all personnel with respect to SOPs
		Sub Control: Supervision, auditing, compliance with SOPs
	Control: Determine optimum location of ventilation controls to minimize unwanted interactions	Sub Control: Do not install where mobile equipment is required to turn
	Control: Visibility, signage, use of reflectors or lighting on both equipment and personnel including individual strobe lights, side lighting	Sub Control: Consider reflective color spectrum match to cameras
		Sub Control: High visibility PPE (including strobe lights)
Cause: Operational changes due to changing environmental conditions (including geological conditions, water, etc.)	Control: Planning and development to consider change management	
	Control: Consider impacts of change to mining procedures on existing travel conditions	
	Control: Establish communication protocols for changes	Sub Control: Routine tool-box talks
		Sub Control: From site level to individual sections

		Sub Control: Thorough communication of change across all workers within a section
		Sub Control: Accurate communication between shifts
	Control: Adapt Standard Operating Procedures (e.g. trigger action response) to worsening conditions	Sub Control: Shut down/stop work
		Sub Control: Recognize that the smallest routine changes can result in catastrophic accident
		Sub Control: Implement and audit reduced speed limits
	Control: Supervision and on-the-job training with respect to managing changes in conditions and/or routines	
Cause: Environmental factors (uphill, downhill, rolling), ambient conditions (rock dusting)	Control: Supervision and on-the-job training with respect to managing changes in environmental conditions and changed routines	Sub Control: Training with respect to reduced visibility inherent to uphill, downhill, rolling roadways
		Sub Control: Audit operator performance in difficult conditions
	Control: Schedule rock dusting to minimize impact on visibility while traveling	Sub Control: Communication of rock dusting schedules
	Control: Traffic management plan	Sub Control: Establish sectional access controls in response to environmental factors
		Sub Control: Operate efficiently in challenging conditions to minimize time in those conditions
	Control: Modify mine design to account for environmental factors	
	Control: Dispatch to recognize specific zones of environmental challenge	Sub Control: Communication alert
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
	Control: Lighting (including directional, reflective, light signals)	
Cause: Roadway conditions require reduced speeds (different road surface, roadway conditions, visibility, water, gravel, uneven/broken surface, slants)	Control: Adapt/modify mechanical limits (e.g. governor) for changed roadway conditions	
	Control: Consider impact of roadway watering on different road surfaces (e.g. clay)	
	Control: Maintain drivability of roadways	Sub Control: Gravel and grading of roadways
		Sub Control: Water management plan (pumping, dewatering)
		Sub Control: Application of calcium for dust
	Control: Supervision and on-the-job training with respect to	Sub Control: Training with respect to reduced visibility

	changes in roadway conditions	Sub Control: Audit operator performance in difficult conditions
	Control: Dispatch to recognize specific zones of environmental challenge	Sub Control: Communication alert
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
	Control: Lighting (including directional, reflective, light signals)	
Cause Category: Behavior		
Cause: Lack of communication between two vehicles (e.g. distraction, inattention, not looking)	Control: Establishment, training, monitoring of safety culture	
	Control: Training, including default when system fails	
	Control: Dispatch (especially rail)	Sub Control: Communication alert
	Control: Proximity detection systems	Sub Control: Equipment tracking with automated/triggered warning, shut down
		Sub Control: Shut down when proximity detection down/fails
	Control: Lighting (including directional, reflective, light signals)	
Cause: Working under the influence (drugs, alcohol)	Control: Development and communication of workplace standards or policies	
	Control: Compliance with mandatory state regulations	
	Control: Compliance with workplace standards or policies	Sub Control: Develop approach to situations issues where choice made to keep good worker, ignore substance usage
	Control: Consideration for routine drug and alcohol monitoring programs (e.g. start of shift)	
	Control: Integration of drug/alcohol education within workforce health and wellbeing programs	
	Control: Availability of rehabilitation programs	
	Control: Random testing	
	Control: Consider guidance materials from other high-risk industries	
Cause: Fatigue (including overwork/absenteeism/change in behavior)	Control: Consideration for automation and mechanization	
	Control: Consideration for monitoring/early warning technology	
	Control: Integration of fatigue management within workforce health and wellbeing programs	
	Control: Achieve effective balance between work load and staffing	
	Control: Establish and implement site-based standards with respect to fatigue management	
	Control: Consider guidance materials from other high-risk industries	
Cause: Excessive payload	Control: Standard Operating Policies from suppliers for payloads and loading on equipment	
	Control: Training and clear communication	Sub Control: Training regarding payloads

		Sub Control: Training regarding impacts of overloading (loss during travel, damage to mine infrastructure, increased maintenance)
		Sub Control: Impact of material density (e.g. coal vs rock, braking distance and braking capacity)
	Control: Buy-in from management regarding load limits	
	Control: Overload/height indicators	Sub Control: Weight sensor - dynamic in cab
		Sub Control: Labeling equipment with weight/height limits
		Sub Control: Maintain visibility of labels in operating environment
		Sub Control: Consideration for ‘auto-stop’ sensors/technology when payload exceeds operating limits
		Sub Control: Validate operating performance of overload/height indicators
		Sub Control: Ensure overload/height indicators are reliable and tamper-proof
	Control: Clear communication between CM operator and load operators	
Cause: Production pressures (perceived and/or actual) including impacts of corporate culture, generational factors, absenteeism, insufficient size of workforce (increased personal stress, individual workload)	Control: Corporate culture: “do not run if something is wrong”	
	Control: Management leadership and commitment to culture that retains workforce	
	Control: Human resources to ensure sufficient workforce availability, including personnel redundancy in critical positions (e.g. continuous miner operator)	
	Control: Development and communication of clear workforce expectations and accountabilities	
	Control: Selection/hiring of employees to consider impact/integration of prior workplace cultures	
	Control: Adaptation of workplace culture to engage with younger/new workers	
Cause: Mechanical failure (braking system, dynamic conditions of road/rail and load)	Control: Operator training	Sub Control: Gentle touch
		Sub Control: Importance of inspections and maintenance - awareness of required schedules
		Sub Control: Conditions and procedures for intentional derail (equipment out of control, mechanical failure)
	Control: Pre-op inspection	
	Control: Regular inspection and testing	
	Control: Operator supervision, audit, spot-checking	

Cause: Travelling speed exceeds safe level (different road surface, roadway conditions, visibility)	Control: Operator training	Sub Control: Clear communication of operating speed limits
		Sub Control: Consequences of exceeding operating speed limits
	Control: Operator supervision, audit, spot-checking	
	Control: Mechanical limits	Sub Control: Regular inspection
		Sub Control: Validation of governor performance
		Sub Control: Ensure mechanical limiting equipment is reliable and tamper-proof
	Control: Promote safe operating speeds	Sub Control: Optimize distance to feeder, move belt more frequently
	Control: Roadway maintenance	Sub Control: Grading of roadways
Cause: Aging workforce	Control: Open communication between management and workforce	
	Control: Consider the time that long-time workers may need to adapt to new technology	
	Control: Correct body movement/posture training for operators	
	Control: Consideration and accommodation for diminished eyesight, hearing, flexibility in task design (appropriate corrective devices)	
Cause: Incompetent operator (e.g. lack of training, inexperience)	Control: Develop and implement Standard operating procedures (SOPs), safe work procedures that are appropriate for site and workforce	
	Control: Appropriate and effective training	Sub Control: Consider use of advanced training methods (e.g. virtual reality)
		Sub Control: Include adequate training of the trainer
		Sub Control: Standard operating procedures (SOPs)
		Sub Control: Safe work procedures
		Sub Control: Confirm equipment operating competency
	Control: Ensure that operator is adequately trained to safely function in designated work zone	Sub Control: Mine layout
		Sub Control: Mine conditions
		Sub Control: Hazards
		Sub Control: Requirements for specific equipment
	Control: Develop and implement mentoring programs	Sub Control: Matching experienced operators to novice operators
		Sub Control: Matching less experienced foremen (e.g. Red hat mentors) to those with experience

	Control: Train supervisors to maximize operator competency and identify/manage operators that do not meet required performance levels	
Cause: Safety policy is less than adequate	Control: Develop and implement appropriate and effective training	Sub Control: Consider use of advanced training methods (e.g. virtual reality)
		Sub Control: Include adequate training of the trainer
		Sub Control: Standard operating procedures (SOPs)
		Sub Control: Safe work procedures
		Sub Control: Confirm equipment operating competency
	Control: Consider impacts of equipment and operations standards and policies on vehicle interactions (e.g. transport rules)	
	Control: Stakeholder engagement (feedback) in development of policies	
	Control: Audit, regular review/measurement (all stakeholders) and update of policies	
	Control: Compliance and enforcement - management leadership and limits	
Cause: At risk behavior (e.g. personnel working in red zone; including deliberate override/shutdown of safety controls)	Control: Define red zone for all equipment (continuous miner, roof bolter, haulage equipment, etc.)	Sub Control: Consider undertaking risk assessment to define red zone for all equipment based on operating conditions and procedures (operating, moving, maintenance, etc.)
		Sub Control: Establish high risk areas for each activity (e.g. pinch points, warning areas)
		Sub Control: Document outcomes in roof control plans, tramming procedures, personnel training programs
	Control: Adequate training, awareness, and competency of all personnel with respect to red zones	
	Control: Provide personnel supervision	Sub Control: Voice/audio communication with others
		Sub Control: Communication by signaling
	Control: Ensure adequate engineering controls for tramming	Sub Control: Remote control
		Sub Control: Dual controls
		Sub Control: Operator guards
	Control: Use of proximity detection systems (e.g. CMS)	Sub Control: Ensure comprehensive coverage of all personnel with respect to red zones
		Sub Control: Calibrate proximity detection systems to abide by red zone criteria

		Sub Control: Ensure proximity detection equipment is reliable and tamper-proof
Consequence: Fire and explosions	Control: Emergency response plan (ERP)	Sub Control: Emergency response procedures
		Sub Control: Training
		Sub Control: Mine Emergency Response Development (MERD) exercise
	Control: Fire extinguishers	
	Control: First responder	
	Control: EMT/first aid/AEDs	
	Control: Increased/supplementary first aid supplies	
	Control: Fire suppression equipment	
	Control: Fire detection sensors	
	Control: Mine rescue	
	Control: Fire brigade	
	Control: Relationship with emergency services	
Consequence: Injury and fatality	Control: Emergency response plan (ERP)	Sub Control: Emergency response procedures
		Sub Control: Training
		Sub Control: Mine Emergency Response Development (MERD) exercise
	Control: First responder	
	Control: Ensure availability of EMT/first aid/AEDs	
	Control: Increased/supplementary first aid supplies	
	Control: Availability of tools for entrapment (e.g. Jaws of Life)	
	Control: Risk management of employees that are accident prone (increased supervision, class, training, letter of intent to discharge if no improvement)	
	Control: Reinforced operator compartment (canopy, cages, protection)	
	Control: Personal Protective Equipment (PPE)	
	Control: Seat belts	
	Control: Medical, rehabilitation services	
	Control: Emergency medical transport facilities (helicopter, ambulance) and established relationships with service providers; agreement with local hospitals/facilities to accept patient from the mine	
	Control: Notification during transport to hospital of injury type	
	Control: Communication protocols for mine dispatch	
	Control: Within mine transportation of injured personnel	Sub Control: Stretchers available throughout mine to move injured personnel
		Sub Control: Consider modifying transport equipment to deliver smooth ride out of mine for prone injured personnel

	Control: Use non-energy retaining ropes to prevent whipping cable injuries on winches	
Consequence: Job loss	Control: Consider retraining	
	Control: Replacement worker	
	Control: Consider different duties/part-time duties	
Consequence: Equipment damage or loss	Control: Ensure availability of replacement equipment	
	Control: Ensure adequate supplies stock/personnel for workshop repair	
	Control: Guarding to minimize damage to or from mobile equipment impact	
	Control: Fire extinguishers	
	Control: Availability of tools for recovery of entrapped equipment	
	Control: Permitting in place for recovery of entrapped equipment	
Consequence: Reportable incident	Control: Training in reporting compliance	
	Control: Timely compliance	
Consequence: Increased regulatory pressure, POV (pattern of violations)	Control: Compliance and safety officers	
	Control: Internal audits	
	Control: Maintain high safety standards and awareness	
Consequence: Lost production (including delay due to equipment out of service)	Control: Alternative source for coal, standby production panel	
	Control: Alternative schedules following an accident	
	Control: Stockpile/storage, coal from a different mine to meet contract delivery	
	Control: Reduce the downtime disruption from damaged equipment (accelerate repair time: retrackers on motors, service jacks on shuttle cars; airbags)	
	Control: Specific to longwall moves, observation at switches to see if cars are tracking correctly and stop all other cars if an event happens	
Consequence: Family hardship	Control: Corporate training on communication/liaison with impacted family	
	Control: Counseling and support services	
	Control: Compensation arrangements	
	Control: Corporate insurance policies	
	Control: Management of information (containment process)	
	Control: Incorporate above points within Emergency Response Plan (ERP)	Sub Control: Emergency response procedures
		Sub Control: Training
		Sub Control: Mine Emergency Response Development (MERD) exercise
Consequence: Loss of operation (e.g. close part or all of mine)/social license to operate/regulatory closure	Control: Emergency Response Plan (ERP)	Sub Control: Emergency response procedures
		Sub Control: Training
		Sub Control: Mine Emergency Response Development (MERD) exercise
	Control: Effective media communications, public relations	

	Control: Management of information	Sub Control: Establish and implement incident communication protocols
		Sub Control: Test and validate communication protocols in mock events
		Sub Control: Ensure all tiers of corporation and related stakeholders are familiar and confident with required communication protocols
	Control: Legal counsel, legal defense	
Disclaimer RISKGATE is a free service. RISKGATE does not purport to be a guideline or code of practice but rather is a reference source and may not necessarily be current. RISKGATE is not intended to be and should not be relied upon as legal or technical advice. RISKGATE is a database of information from various sources, including the host providers, that may be of some assistance to its users. RISKGATE does not give any guarantee, undertaking or warranty that the information provided is comprehensive and covers every case/incident/safety alert/bulletin potentially relevant in the mining industry. Users should consult other sources of information and not rely on RISKGATE as the only source of information. RISKGATE does not invite reliance upon, nor accept responsibility for, the information it provides. RISKGATE makes every effort to provide a high quality service. However, neither RISKGATE, the host providers nor the providers of data on RISKGATE, give any guarantees, undertakings or warranties concerning the accuracy, completeness or up-to-date nature of the information provided. Users should confirm information from another source if it is of sufficient importance for them to do so. Hypertext links on RISKGATE are inserted by RISKGATE, not by the data providers. RISKGATE is operated by the Minerals Industry Safety and Health Centre at the University of Queensland.		

Appendix C

Intake Survey and Exit Survey Instruments used at Field Site

Intake Survey

Your participation in this survey is completely voluntary.

1. My age is:

☐ 18-25 years
☐ 26-30 years
☐ 31-35 years
☐ 36-40 years
☐ 41-45 years
☐ 46-50 years
☐ 51-55 years
☐ >50 years

2. I have worked in the mining industry for:

☐ 0-5 years
☐ 6-10 years
☐ 11-15 years
☐ 16-20 years
☐ 21-25 years
☐ 26-30 years
☐ >30 years

3. I work/have worked in the following occupation in the industry (check all that apply and chose jobs that most closely resemble yours):

☐ Outby Laborer

☐ Inby Machine Operator

☐ Mechanic/Electrician

☐ Management

☐ Underground Supervisor/Face

☐ Inby Laborer

☐ Fireboss

☐ Engineer

☐ Safety

☐ Underground Supervisor/Outby

☐ Motorman/Supply

☐ Maintenance foreman

☐ Water Technician

☐ Other________________________

4. To what degree do you agree with the following statements?

Mine management is firmly committed to protecting the safety and health of workers, myself included.

☐ Strongly Disagree

☐ Disagree

☐ Neither agree nor disagree

☐ Agree

☐ Strongly Agree

I value safety more than anything else in the workplace.

☐ Strongly Disagree

☐ Disagree

☐ Neither agree nor disagree

☐ Agree

☐ Strongly Agree

The people I work with daily value safety more than anything else in the workplace.

☐ Strongly Disagree

☐ Disagree

☐ Neither agree nor disagree

☐ Agree

☐ Strongly Agree

I feel empowered to speak up when I observe an unsafe situation.

☐ Strongly Disagree

☐ Disagree

☐ Neither agree nor disagree

☐ Agree

☐ Strongly Agree

When I approach a job task I think about risk as I plan the task.

☐ Strongly Disagree

☐ Disagree

☐ Neither agree nor disagree

☐ Agree

☐ Strongly Agree

My ability to work safely is tied to my ability to assess and manage risk.

☐ Strongly Disagree

☐ Disagree

☐ Neither agree nor disagree

☐ Agree

☐ Strongly Agree

What is your personal definition of risk, as it applies to your work?

Exit Survey

Your participation in this survey is completely voluntary.

My age is:

☐ 18-25 years
☐ 26-30 years
☐ 31-35 years
☐ 36-40 years
☐ 41-45 years
☐ 46-50 years
☐ 51-55 years
☐ >55 years

I have worked in the mining industry for:

☐ 0-5 years
☐ 6-10 years
☐ 11-15 years
☐ 16-20 years
☐ 21-25 years
☐ 26-30 years
☐ >30 years

I work/have worked in the following occupation in the industry (check all that apply):

☐ Underground Supervisor/Face
☐ Fireboss
☐ Outby Laborer
☐ Inby Machine Operator
☐ Mechanic/Electrician
☐ Management
☐ Inby Laborer
☐ Engineer
☐ Water Technician
☐ Maintenance Foreman
☐ Safety
☐ Underground Supervisor/Outby
☐ Motorman/Supply
☐ Other: ___________________

To what degree do you agree with the following statements?

Mine management is firmly committed to protecting the safety and health of workers, myself included.

☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree
☐ Strongly Agree

I value safety more than anything else in the workplace.

☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree
☐ Strongly Agree

The people I work with daily value safety more than anything else in the workplace.

☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree
☐ Strongly Agree

I feel empowered to speak up when I observe an unsafe situation.

☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree
☐ Strongly Agree

When I approach a job task I consider risk as I plan the task.
☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree
☐ Strongly Agree

My ability to work safely is tied to my ability to assess and manage risk.
☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree
☐ Strongly Agree

The RISKGATE approach and risk assessment tools have changed the way I approach and manage risk.
☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree
☐ Strongly Agree
☐ Strongly Agree

The RISKGATE approach and risk assessment tools have changed the way mine management approaches and manages risk.
☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree

The RISKGATE approach and risk assessment tools have made me feel safer when I work.
☐ Strongly Disagree
☐ Disagree
☐ Neither agree nor disagree
☐ Agree
☐ Strongly Agree

What is your personal definition of risk, as it applies to your work?

Do you believe that RISKGATE has affected the safety of work at the mine? If so, how?

Appendix D

Worker perceptions of safety and risk at pilot site (intake and exit)

Table D1. Summary of intake responses to perceptions of safety at pilot mine site

Response	*Q1*		*Q2*		*Q3*		*Q4*		*Q5*		*Q6*	
Strongly Agree	28	*29%*	44	*45%*	26	*27%*	26	*27%*	29	*30%*	25	*26%*
Agree	44	*45%*	40	*41%*	44	*45%*	49	*50%*	58	*59%*	59	*60%*
Neither Agree nor Disagree	16	*16%*	4	*4%*	14	*14%*	6	*6%*	1	*1%*	3	*3%*
Disagree	3	*3%*	1	*1%*	4	*4%*	4	*4%*	0	*0%*	0	*0%*
Strongly Disagree	2	*2%*	2	*2%*	2	*2%*	2	*2%*	1	*1%*	1	*1%*
No Response	5	*5%*	7	*7%*	8	*8%*	11	*11%*	9	*9%*	10	*10%*
Total Responses	98		98		98		98		98		98	

Table D2. Summary of exit responses to perceptions of safety at pilot mine site

Response	*Q1*		*Q2*		*Q3*		*Q4*		*Q5*		*Q6*		***Q7***		***Q8***		***Q9***	
Strongly Agree	20	*25%*	32	*41%*	25	*32%*	19	*24%*	25	*32%*	15	*19%*	**10**	***13%***	**6**	***8%***	**5**	***6%***
Agree	37	*47%*	34	*43%*	40	*51%*	36	*46%*	46	*58%*	43	*54%*	**48**	***61%***	**40**	***51%***	**43**	***54%***
Neither Agree nor Disagree	9	*11%*	3	*4%*	11	*14%*	9	*11%*	4	*5%*	5	*6%*	**15**	***19%***	**18**	***23%***	**21**	***27%***
Disagree	1	*1%*	0	*0%*	1	*1%*	5	*6%*	0	*0%*	1	*1%*	**1**	***1%***	**4**	***5%***	**0**	***0%***
Strongly Disagree	4	*5%*	4	*5%*	2	*3%*	5	*6%*	3	*4%*	9	*11%*	**3**	***4%***	**4**	***5%***	**6**	***8%***
No Response	8	*10%*	6	*8%*	0	*0%*	5	*6%*	1	*1%*	6	*8%*	**2**	***3%***	**7**	***9%***	**4**	***5%***
Total Responses	79		79		79		79		79		79		**79**		**79**		**79**	

Table D3. Survey questions related to perceptions of safety and risk

Q1. Mine management is firmly committed to protecting the safety and health of workers, myself included.
Q2. I value safety more than anything else in the workplace.
Q3. The people I work with daily value safety more than anything else in the workplace.
Q4. I feel empowered to speak up when I observe an unsafe situation.
Q5. When I approach a job task I think about risk as I plan the task.
Q6. My ability to work safely is tied to my ability to assess and manage risk
Q7. The RISKGATE approach and risk assessment tools have changed the way I approach and manage risk.
Q8. The RISKGATE approach and risk assessment tools have changed the way mine management approaches and manages risk.
Q9. The RISKGATE approach and risk assessment tools have made me feel safer when I work.

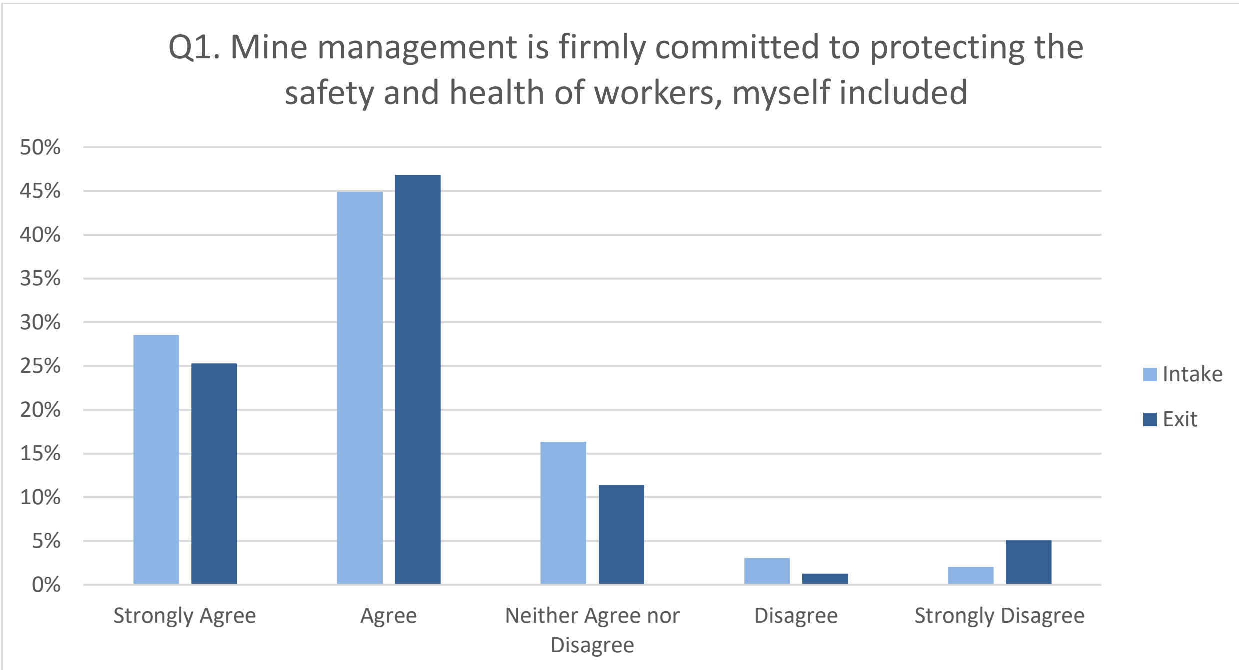


Figure D1. Responses to Question 1.

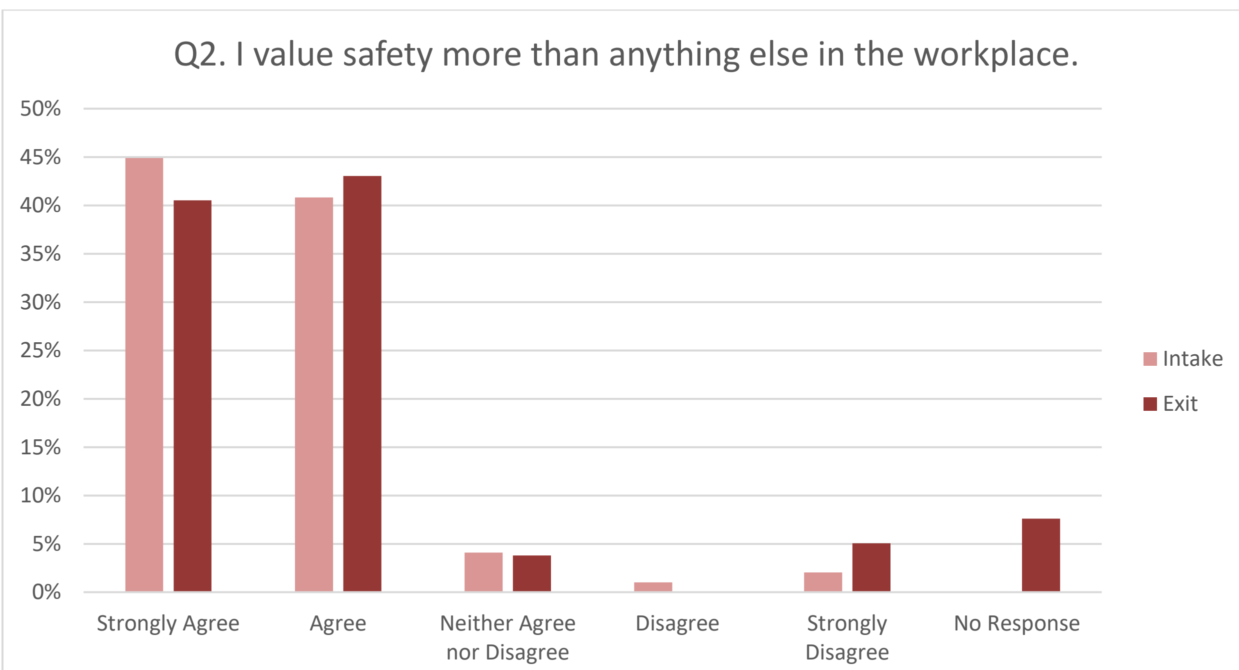


Figure D2. Responses to Question 2.

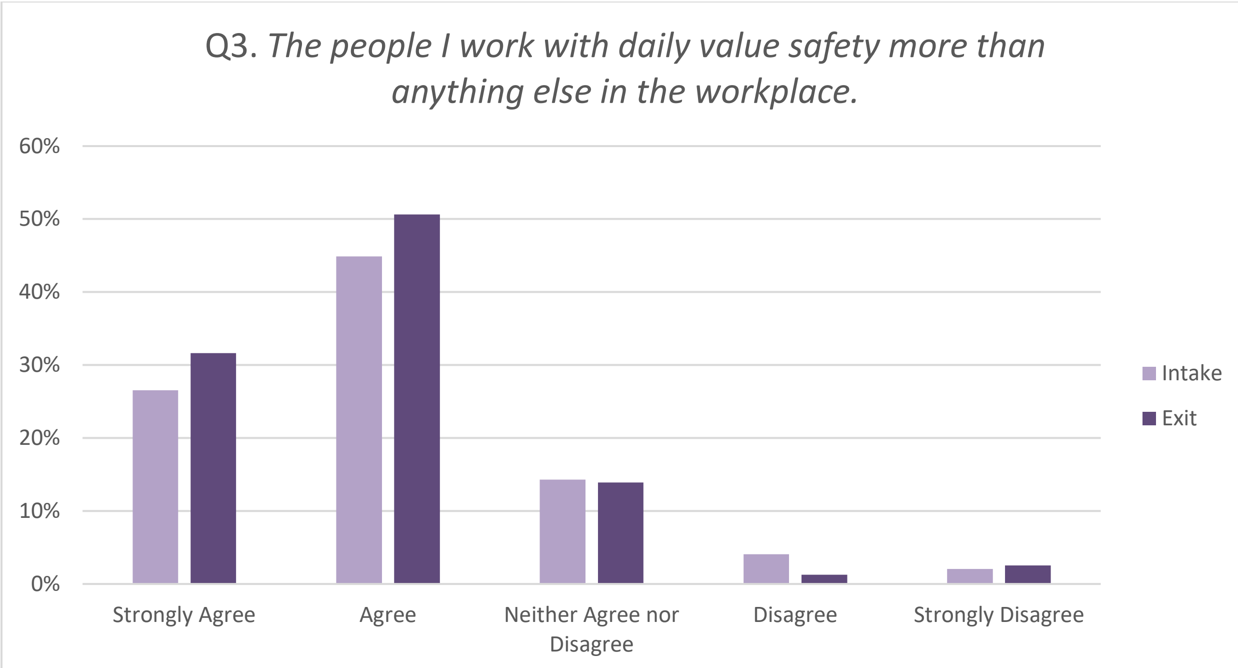


Figure D3. Responses to Question 3.

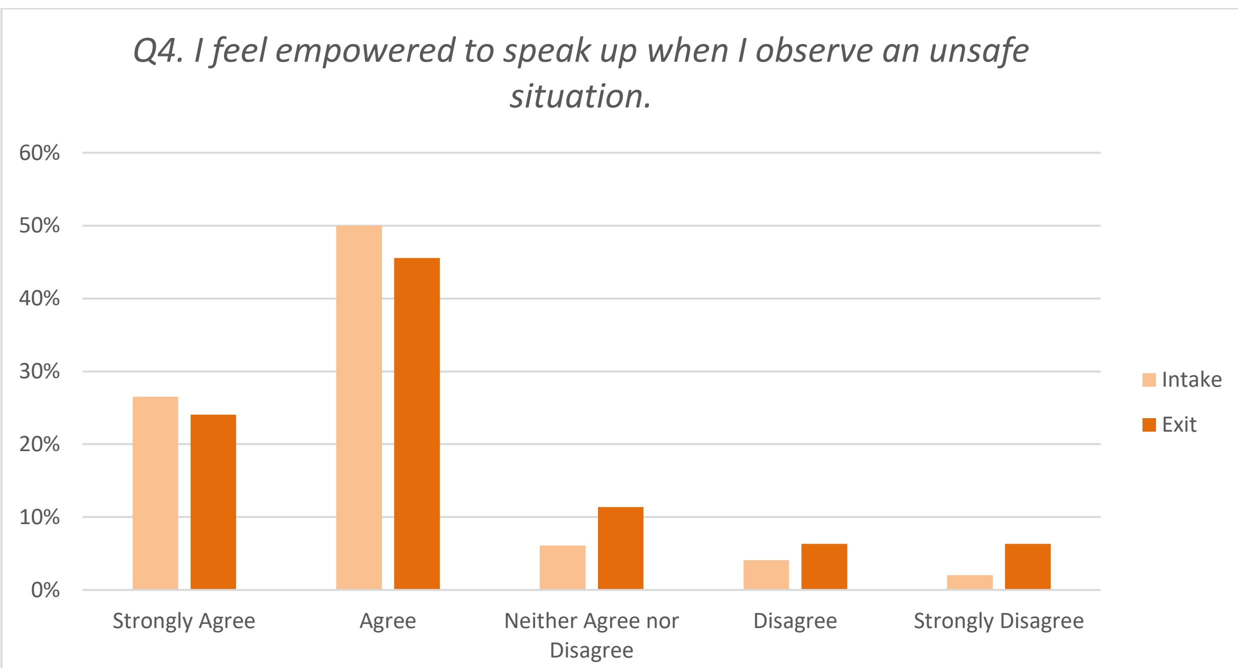


Figure D4. Responses to Question 4.

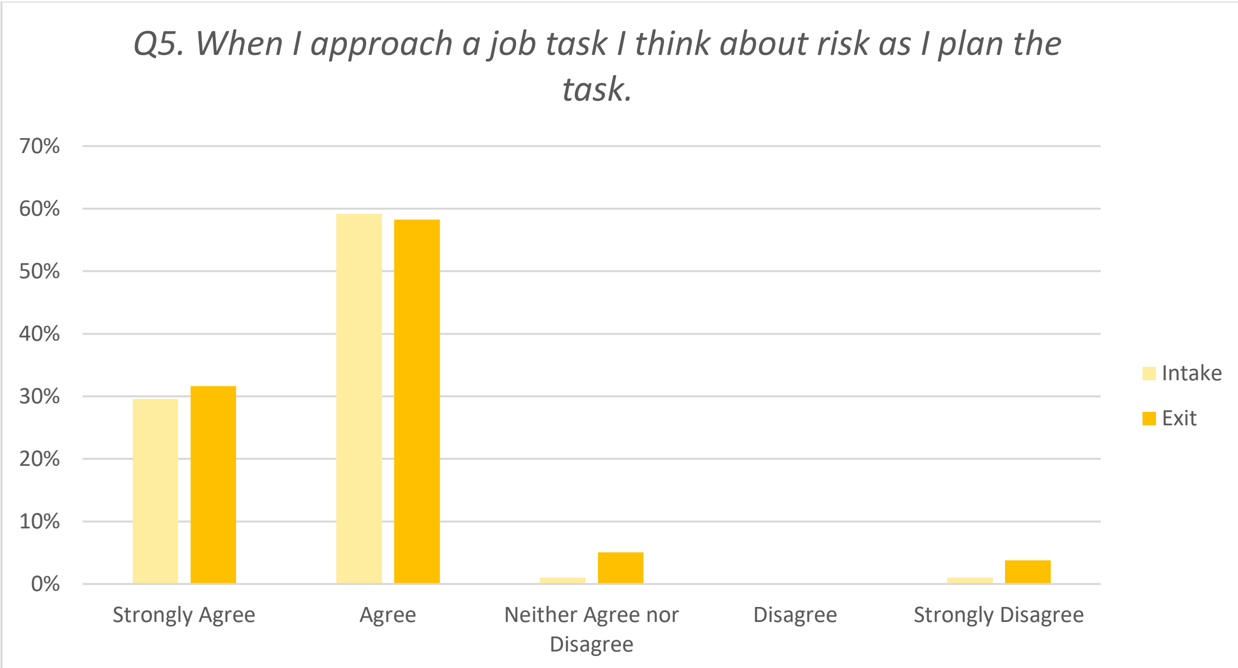


Figure D5. Responses to Question 5.

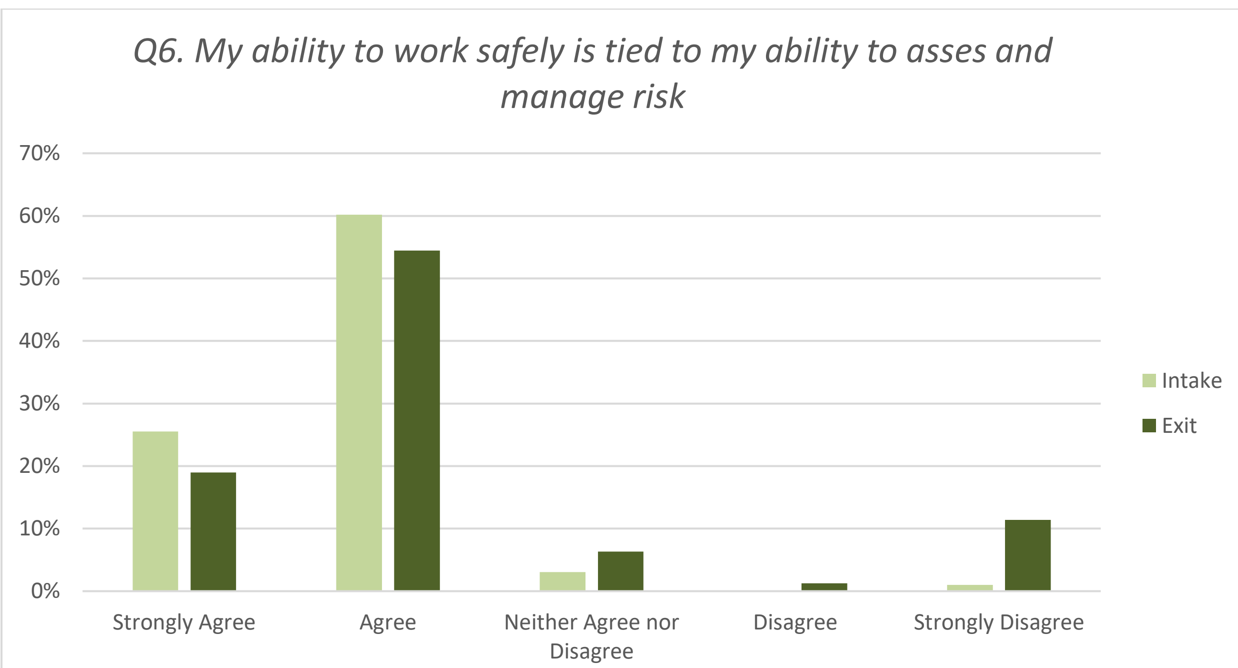


Figure D6. Responses to Question 6.

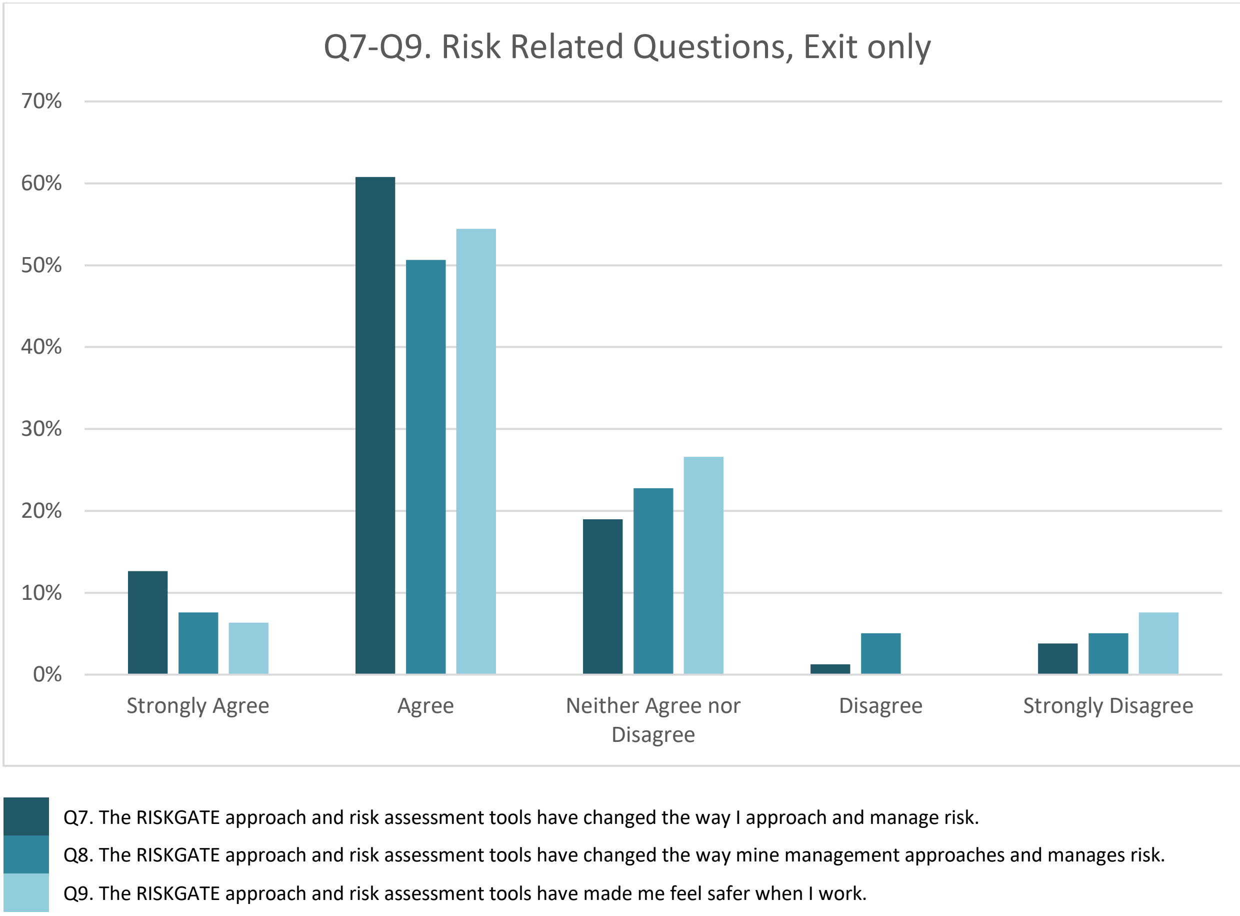


Figure D7. Responses to Q7-Q9.

Table D4. Responses to Question 7, intake.

Q7. What is your personal definition of risk, as it applies to your work?
Any potential to injury
Anything that can cause harm to me or others
Doing something unsafe to get the job done faster
Don't take risks
Draw rock, electrical hazards, red zone in equipment
Draw rock, roadway debris, lifting, loading, unloading, handling equipment
If you can get hurt in any way, don't do it, it's a risk
Is the juice worth the squeeze
Keep mind on my job, my surroundings, going home safe
Keep mind on your work
Roof fall
Safety is first to me cause I think about my family
Take a chance on something that can or could get you hurt
Taking a chance knowing better
Taking a chance on your life and other peoples life
Taking chances, not thinking the process through, overlooking policies and laws
Taking risk that don’t need to be taken, don’t take risk
Well to get the job done
What will be safe
Willing to take a chance on your life and your fellow workers' life. Taking changes will finally run out, then can you live with yourself knowing your action has harmed you or someone else
You have a chance of getting injured

Table D5. Responses to Question 7, exit

Q7. What is your personal definition of risk, as it applies to your work?
a dangerous situation that may have a fatal outcome
All jobs
any hazard condition
anything that can result in injury or death
Anything that has the potential to injury me or my coworkers
Anything you get hurt by
Chance of safety
doing things that could lead to personal injury or death
draw rock
Great Program
if it can harm or kill you
if it can hurt you or someone else
Not bad
Risk is always in workplace
Risk when you take a chance without proper tools and proper blocking
roof hazards, rib hazards, redzones
take a chance that could get someone hurt
taking chances when you don’t have to
Taking unnecessary chances
the value of my personal safety and wellbeing
To take a change

Table D6. Responses to Question 10, exit

Q10. Do you believe that RISKGATE has affected the safety of work at the mine? If so, how?
100%
im not sure
Makes you think more
makes you think more about risks involved
No
No
No
no
no
no, waste of time
safety has always been #1 here
yes
yes
yes
yes
yes - greater awareness of the risk involved in job performance
yes better planning
yes better safety talks
Yes made everyone alost (sic)
yes talk about it in safety meetings
Yes, it has helped us to identify and address risks as they prevent themselves

Appendix D

Risk-based Safety Meetings Delivered at Partner Mine

Index of Meetings

Day	Date	Title
Tuesday	7/11/2017	RISKGATE Info Session/Survey
Wednesday	7/12/2017	Ground control
Thursday	7/13/2017	Prevention of hand injury
Friday	7/14/2017	Continuous Miner Red Zone
Saturday	7/15/2017	Methane Control
Sunday	7/16/2017	--
Monday	7/17/2017	Watch out for drawrock
Tuesday	7/18/2017	Take care of your back
Wednesday	7/19/2017	Stay visible and communicate
Thursday	7/20/2017	Stay clear of scoops
Friday	7/21/2017	Slips, trips, and falls – exiting equipment
Saturday	7/22/2017	Lock out/tag out
Sunday	7/23/2017	--
Monday	7/24/2017	Mine Emergencies
Tuesday	7/25/2017	Check your top
Wednesday	7/26/2017	Moving Equipment at Shift Change
Thursday	7/27/2017	Dust – you can't always see it
Friday	7/28/2017	Watch your hands
Saturday	7/29/2017	Maintenance Work – explosions and Ignitions
Sunday	7/30/2017	--
Monday	7/31/2017	Stay out of the Red Zone, get in the Blue Zone
Tuesday	8/01/2017	Think like a kid – protect your back
Wednesday	8/02/2017	Don't slip, trip, or fall
Thursday	8/03/2017	Get a good start on the day or night
Friday	8/04/2017	Fall of roof – keep your eyes up
Saturday	8/05/2017	Cutting coal is not quiet business
Sunday	8/06/2017	--
Monday	8/07/2017	Keep your eyes on cables
Tuesday	8/08/2017	Thinking about risk – look up
Wednesday	8/09/2017	Mind on controls – catch some zzz's
Thursday	08/10/2017	Positive Communication on the Surface
Friday	08/11/2017	The importance of pre-op checks
Saturday	08/12/2017	Remember rescuers
Sunday	08/13/2017	--
Monday	08/14/2017	Summer roof
Tuesday	08/15/2017	Working around belts
Wednesday	08/16/2017	Risk Management Every Day
Thursday	08/17/2017	Risk of Fire
Friday	08/18/2017	Protect your hands
Saturday	08/19/2017	The risk of stored energy

Sunday	08/20/2017	--
Monday	08/21/2017	Common injuries: Slips, trips and falls
Tuesday	08/22/2017	Ventilation keeps you safe and healthy
Wednesday	08/23/2017	Lessons learned: Risk of roof fall
Thursday	08/24/2017	Moving Equipment – Levels of Control
Friday	08/25/2017	Electrical Safety
Saturday	08/26/2017	Working around conveyor belts
Sunday	08/27/2017	--
Monday	08/28/2017	Roof conditions
Tuesday	08/29/2017	Noise is a major health hazard
Wednesday	08/30/2017	Fire Prevention
Thursday	08/31/2017	--
Friday	09/01/2017	Protect your eyes
Saturday	09/02/2017	Watch your hands
Sunday	09/03/2017	--
Monday	09/04/2017	Proximity detection
Tuesday	09/05/2017	Electrical safety
Wednesday	09/06/2017	Take care of your back
Thursday	09/07/2017	Mitigating Controls | Mine Emergencies
Friday	09/08/2017	Check your top
Saturday	09/09/2017	The risk of stored energy
Sunday	09/10/2017	--
Monday	09/11/2017	Electrical safety
Tuesday	09/12/2017	Stay visible and communicate
Wednesday	09/13/2017	Watch out for draw rock

Saturday, July 15, 2017

Methane Control

While this may not be a particularly gassy mine, it is important to stay on top of methane control. Geological changes in a mine can't always be anticipated, and can include localized areas of higher gas content. The consequences of losing control of methane are serious, and include ignition, fire, and explosion.

What controls do you have in place to lessen the risk of losing control of methane?

PREVENTIVE	**MITIGATING**
Gas checks (calibrated detector)	Fire deluge systems
Proper function of machine mounted sensors	SCSRS
Sharp bits reduce sparking	Escapeways and evacuation training
CM water sprays	Refuge alternatives
Ventilation air (maintenance of face ventilation dilutes gas)	Rock dust

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Monday, July 17, 2017

Watch out for Draw Rock

Draw rock is fairly common here at <mine name>. In particular the water present in the mine during summer tends to loosen the roof even more, and the risk is present outby and on the production sections. Be attentive to cutter rib and especially to draw rock on the corners of a pillar. Often the rib has sloughed out leaving a corner of rock exposed that can be a foot thick and over two feet wide. Clearly, a piece of rock this size can do serious damage and is usually sharp enough to cause serious lacerations.

What controls do you have in place to manage this risk?

PREVENTIVE	**MITIGATING**
Standard Bolting (plus pizza pans)	PPE (hard hat)
Good observation, sounding, pulling loose rock	First aid
Drive and travel center of the entry	
Spot bolting as needed	
Cribs, timbers, jacks	
Cutting down draw rock on the corners if discovered early enough for CM access	

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, July 18, 2017

Take care of your back

Back injuries are especially prevalent among underground coal miners, and as many of you know a serious back injury can really reduce your quality of life. In low coal you may not have to lift a load as far, but you still have heavy loads to move, often in awkward positions. What are the controls you have in place to protect your back?

PREVENTIVE	MITIGATING
Proper positioning	First aid
Good communication (when lifting with others)	
Keep walkways clear	
Use proper tools	
Use mechanical (such as come-a-longs) and human help as necessary	

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, July 19, 2017

Stay visible and communicate

When we consider the causes of moving equipment accidents they often occur because an equipment operator either could not see another person or did not know their location. In low coal, visibility is further impaired. What are some controls that you have to enhance visibility and communication? These are almost all preventive.

- Reflective stipes on clothes, materials on hats
- Headlights on front of hats – light signals
- Blinking lights on back of hats
- Radio communication
- Mine phones (particularly during emergency)
- Horns/bells – particularly when starting up, approaching blind turns, fly pads
- Eye contact and a verbal confirmation (for example, "I'm walking in front of you")
- Making a plan before a big or unusual job (something like major unplanned belt maintenance) – this is good time to use STAR cards.

As you travel your work area today remind yourself of the importance to visibility and communication:

Am I doing everything I can to be visible to equipment operators?

Am I communicating my position and intentions well?

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Thursday, July 20th, 2017

Stay clear of scoops

Over the last 20 years there have been multiple fatalities involving miners and scoops. Scoops are absolutely necessary to our everyday jobs and we interact with them in multiple ways:

- Unloading/loading materials
- Cleaning areas
- Changing batteries

Don't become complacent around scoops just because you interact with them often and in multiple ways. What are some controls that allow you to work safety around scoops?

PREVENTIVE	**MITIGATING**
Proximity detection (not on all scoops?)	PPE
Proper positioning – no red zone	First Aid
Communicate clearly (bother operator and pedestrian)	
Deenergize/drop bucket when people are unloading/loading	
Directional lighting on scoop (lights in direction of tramming)	

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Friday, July 21, 2017

Slips, Trips, and Falls | Exit equipment safely

Slips, trips and falls can be responsible for many types of injuries from back injuries to lacerations. In fact, they are so prevalent in all mining commodities that NIOSH is examining how miners walk while wearing equipment, and even how tread wear on your boots can affect your risk of slip, trip, and fall. Exiting equipment cabs in the mine is an especially high risk time for slips, trips and falls because it can involve awkward positioning, poor visibility, and the floor often has potholes, puddles, mud, and other debris. What controls do you have in place to prevent slips, trips, and falls?

PREVENTIVE	MITIGATING
Proper PPE (boots with good tread!)	PPE (hardhat, knee pad)
Good housekeeping	
Take time to observe conditions	

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Saturday, July 22, 2017

Electrical Safety

Since 1990, there have been at least 75 fatal and 1,850 non-fatal accidents in the mining industry which were classified by MSHA as "Electrical." Many of these could have been prevented if the circuits would have been locked, grounded, and tagged prior to any maintenance work being performed.

What controls are in place to prevent loss of control of electricity during maintenance work?

Preventive	Mitigating
Lock out/tag out procedures	PPE (rubber soled boots, gloves)
Communication with everyone working around tagged out equipment	First aid
	Rubber mats at electrical installations
	Grounded circuits

- Don't forget to take these simple steps prior to performing any electrical work:
- Determine the location of the disconnecting means for the circuit to be worked on.
- Carefully de-energize the circuit.
- Each employee working on the circuit should place his/her own lock and tag on the disconnecting device.
- The circuit to be worked on should be tested for voltage to ensure no electricity is present.
- Ground all the phase conductors to the equipment, grounding conductor with a jumper.

Source: MSHA's Accident Prevention Program, Miner's Tip: https://arlweb.msha.gov/Accident_Prevention/Tips/eleclock.htm#.WW8dZ4grJeU

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Monday, July 24, 2017

Mitigating Controls | Mine Emergencies

When we consider mitigating controls, especially in mine wide and critical (serious injury) emergencies we have several major mitigating controls that we spend a great deal of time on:

- Mine Evacuation
- Donning an SCSR (multiple types, and changing them!)
- Providing first aid
- Providing timely and complete details to mine management/responsible person in the event of an emergency

Sometimes all this training becomes something that we no longer carefully consider. In several fires and explosions in the last 15 years there is evidence that miners did not know how to use SCSRS as well as would be expected, and did not have a good grasp of how to get outside on foot. Ask yourself a few questions:

Can I envision exactly how to get from my regular work area out of the mine – both in the primary and secondary? What controls are there to help me?

- Mine map
- Lifeline
- Reflectors

Can I envision how to don and change a rescuer? Imagine each step in sequence as if you had to teach one of your loved ones how to use it.

Do I remember major points of first aid? When was the last time someone in this room had to give first aid?

Could I stay calm and let people know what is going on in an underground emergency? What are some techniques for calming your own panic in an emergency? Take deep breaths (SCSRS can make you feel additional panic if you have one on), remember that you have been trained for this.

Do I know how to deploy our RA? ***What are the steps?*** Under what conditions would I do this?

Finally, don't forget to check in/check out!

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, July 25, 2017

Check your top

During the summer, draw rock can pose a greater risk than during other times of year. There tends to be increased water movement in the roof. Additionally, temperature changes throughout the day can drive loosening of rock. Today, make a point to keep an on what is over year head as well as the person working near you. Sometimes a different vantage point can give you a completely different view of the top – it could save your life, or your buddy's. Describe the controls you have in place for IDENTIFYING bad roof:

- Visual examination
- Test holes
- Sounding
- Roof noise

Keep an especially close eye on cutter roof near the ribs and drawrock near pillar corners. And watch out for the guy working next to you.

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, July 26, 2017

Moving Equipment | Shift Change

<mine name> Mine has excellent proximity detection systems, but the outside facilities are located in a fairly tight configuration. Today, as you prepare to go underground be especially care to note moving equipment outside the mine office, as well as the risk it poses to you. This includes man trips, light road vehicles, haul trucks, scoops, and dozers. If you're on foot or in a smaller piece of equipment position yourself out of the red zone, and communicate clearly with other equipment operators. Make sure you receive clear confirmation from them that you've been seen and they understand your intentions. We're all in a hurry to get our work done, but consider your safety first.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Thursday, July 27, 2017

Dust – you can’t always see it

During the last decade the percentage of cases of black lung reported in the coal mining sector in the US have been on the rise. Dust standards are at the lowest ever – in fact, the US has the lowest respirable dust standard in the world for coal workers. This increased incidence of black lung is especially prevalent in Central Appalachia, and researchers aren’t sure why.

The risk of developing black lung plays out over a period years, and it doesn’t pose the immediate risk that a piece of bad roof does. Nonetheless, it can kill you, and significantly reduce your quality of life when you retire. While you can tell when you’re in a dusty environment, you can’t actually see the particles that make it into your lungs and cause the most damage. What controls do you have in place to prevent or mitigate the risk of developing black lung?

PREVENTIVE	**MITIGATING**
Water sprays (maintained with correct pressure)	Regular doctor visits – catch it in early stages
Proper ventilation (curtain within 10 feet)	Administrative controls (job assignments for miners with diagnosed black lung)
PPE – filter face masks	
No working in return air during mining	
CPDMs (let you know when you’re working in too much dust, reposition, put on a respirator)	

It is easy to put your own health on the back burner as you worry about providing about your family, but your family needs you (and wants you) for many years to come.

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Friday, July 28, 2017

Watch your hands

If we examine reportable injuries at <mine name> Mine since November 2017, 35% have been hand injuries. These tend not to be life threatening injuries, but they impact your ability to work (and enjoy your life, do things around your house) significantly. We are reliant on our hands for so many jobs, and they are complex parts of our bodies in terms of ligaments, bones, and muscles. There are 27 bones in the human hand and some of the densest bundles of nerves in the body. What are some preventive and mitigating controls that address the risk of hand injury?

PREVENTIVE	**MITIGATING**
Proper use of hand tools	Metacarpal gloves
Avoid wearing rings	First aid
Keep hands away from pinch points	
Handle materials properly	

Think about your last near miss with your own hand…it probably wasn't that long ago. What can you do to address the risk that you encountered?

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Saturday, July 29, 2017

Maintenance Work - explosions and ignitions

When we think of explosions and ignitions we tend to think of gassy mines or catastrophic explosions like Upper Big Branch and Sago. It is critical to take gas checks during the mining cycle in the face. But, if we look at recent fatalities involving explosion or ignition they often occur during major maintenance projects. Exactly one year ago today, a miner with 40 years of experience was killed while welding in a shaft when methane ignited and he was in direct line of the ignition force. What controls do you in place to prevent ignition and explosion.

PREVENTIVE	**MITIGATING**
Proper gas checks (during maintenance work and in faces)	Availability of firefighting materials (rock dust, water, extinguisher)
Proper firebossing (gas hazards)	First aid
Mining plan accounts for gas wells in area	Rock dusting
Maintenance and inspection of ox-acetylene tanks (especially regulators)	
Proper handling of ox-acetylene tanks	
Water sprays (cool bits)	

Remember to use your spotter frequently and make sure it is properly calibrated

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Monday, July 31, 2017

Stay out of the Red Zone, Get in the Blue Zone

Did you know there are areas in the world called “Blue Zones”? Okinawa, Japan, and Sardinia, Italy are two examples. In these places people live for an exceptionally long time. Researchers attribute it to their lifestyles. We talk often about red zones and proximity detection. Rather than just staying out of the red zone, do your best today to think about all the risks you are encountering and get into the “Blue Zone” – the safest possible place.

For example:

As you move into a cross cut to get out of the way of a piece of equipment, are you also under the best roof? Look out for brows and move to the center of the entry.

Can you think of other examples of “blue zones”?

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, August 1, 2017

Think like a kid – protect your back

Have you ever watched how toddlers lift things…maybe you have a child or grandchild that age? They have near perfect posture, and they instinctively know to lift with their knees – otherwise they will fall over! Think about this as you are lifting and handling materials today – are you protecting your back and watching how you position your body? In what situations is your back at the most risk? Ask for examples…

- *Lifting and handling supplies*
- *Exiting cabs*
- *Hanging cables*
- *Tugging cables*
- *Moving roofbolts*
- *Pulling top*

How do you control this risk to your back?

Good posture (when there is enough height)

Lift with knees (when enough height)

Get help (especially for cable hanging and heavy loads)

Don't twist and wrench your body – make two (or three moves) If you have to.

Exercise and take care of yourself away from work.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, August 2, 2017

Don’t slip, trip, or fall

About 21% of the non-fatal injuries in mining each year are caused by slip, trip, and fall. Mining isn’t the only industry with this problem. OSHA estimates that they also account for a large percentage of other industrial accidents.

What are the controls in place to mitigate or prevent injury associated with the risk of slip, trip, or fall?

PREVENTIVE	**MITIGATING**
Proper foot wear (good fit and intact treads)	PPE
Housekeeping, travelways	Fall protection (for elevated work)
Handrails on some equipment (elevated belt travelways)	First aid
Be cautious exiting equipment cabs	

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Thursday, August 3rd, 2017

Get a good start on the day (or night)

What is one of the first things you do when you arrive at your worksite at the beginning of your shift. Of course, it is preshift examinations, of both your equipment and your work area. What you are doing is assessing risk in a very methodical way. What are the controls you are checking that are in place to keep you safe as you operate equipment? Are they mitigating or preventive controls?

PREVENTIVE	**MITIGATING**
Proximity detection	Emergency stop/panic switches
Cable handlers and reels	Fire suppression
ATRS	
Audible warnings (bells or horns)	
Visible warnings (lights)/reflectors at the 2nd to last row of bolts	
Relatively clean equipment (no combustible buildup)	
Brakes	
Proper function of water sprays	

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Friday, August 4th, 2017

Fall of roof - keep your eyes up

On February 20, 2015, a 29-year-old roof bolter helper with 3 years and 48 weeks of mining experience was killed when a piece of rock approximately 3 feet wide, 11½ feet long, and 3 to 16 inches thick fell and pinned him against the top of the drill canopy of a roof bolting machine. The roof bolting machine was positioned to install the next row of permanent supports when the accident occurred. We all know that roofbolters are at the front line when it comes to roof control. Make sure you communicate with them regularly about conditions. When crawling and duckwalking it can be especially hard to keep your eyes up on the roof you are traveling under, but make a point to observe the roof you're under, as well as the guy next to you. What are the controls you have in place to manage the risk of losing control of the roof?

PREVENTIVE	**MITIGATING**
Visual examination	PPE
Good communication of conditions to others	First Aid
Test holes	Additional support after fall
Bolts (cable and 4'), pizza pans	
Cribs and timbers	
Sound and pull top	
ATRS	
Mining shorter cuts	
Reflectors (visual warning at 2nd to last row of bolts)	

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Saturday, August 5th, 2017

Cutting coal is not a quiet business

One in every four miners has a hearing problem, and by the time miners reach retirement age, 4 of every 5 have hearing loss. The danger of damaging our hearing underground is not nearly as clear and present as the risk of a roof fall, or even the long term risk of developing black lung. However, the loss of one of your senses, such as your hearing can severely impair your quality of life, and miners are exposed to substantial noise over the course of a work day. How can you minimize the risk of noise induced hearing loss?

PREVENTIVE	MITIGATING
Hearing protection (in some cases double – plugs and earmuffs), inserted properly. Remember pull your ear up with the opposite hand to put a plug in.	Hearing aid
Equipment modifications (ensure lids aren't rattling, bit isolators, changes to cutting head)	
Monitoring to identify problem areas and noise levels for improvement	
Stay away from noisy areas as possible (for example, don't chat at the feeder-breaker when operating)	

Source: NIOSH Mining Topic: Hearing Loss Prevention Overview. https://www.cdc.gov/niosh/mining/topics/HearingLossPreventionOverview.html

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Monday, August 7h, 2017

Keep your eye on cables

Trailing cables are everywhere we look in the active area of an underground coal mine. In the past ten year several fatalities have occurred related to energized trailing cables. In 2012, an electrician was killed while replacing a cable reel on a shuttle care when he contacted the energized conductors in the cable. In 2008, an electrician was killed after cutting into an energized cable. In 2004 and electrician was splicing a cable during a power outage (the cable was not locked and tagged), and the power was reenergized during his work. The risk when working around electrical hazards is losing control of the electricity. How can we mitigate this risk?

PREVENTIVE	**MITIGATING**
Lock out/tag out procedures (see it with your own eyes and use your own lock)	Use proper PPE when working around power centers – rubber mats, high voltage gloves
Examine cables for wear and splices that need to be repaired	First aid
Verify proper grounding	Ensure that miners engaged in electrical work stay as dry as possible (electrician gets the waders!)
Ensure that catheads/cables are properly labeled.	
Communicate with others when conducting electrical work as to what you are doing.	

Source: MSHA Fatalgrams

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, August 8th, 2017

Thinking about risk – look up

Almost 18% of reportable injuries at <mine name> Mine since November 2014 have been related to fall of roof. Hanging brows and cutter ribs are especially common here, and roof is even more subject to change due to the humidity and water we encounter in the summer. Think about the risk of losing roof control in the area you most often work. How are you constantly assessing that risk?

- Visual inspection (like what?) – cutter roof, brows, cracks, “mushrooming bolts”, missing bolts
- Other visual warnings – reflectors or danger tape
- Noise – roof noise, such as popping and cracking
- Sounding – what are you listening for when you sound top
- Talking to miner operators, roof bolters and foreman about conditions
- Checking test holes

When you do encounter risk related to roof control, you should think of the controls you can immediately put in place (pull top, danger it off, install a timber), and controls you may need to coordinate with others (additional bolting, build a crib, cut down a brow).

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, August 9th, 2017

Mind on Controls – catch some zzz's

Most of you are thinking all the time about the controls you have in place to manage the risk associated with your jobs, most of the time you are consciously keeping your mind on how to accomplish your work safety. This kind of thinking even becomes unconscious after some years. However, even the most seasoned miner can lose focus, which can have unintended consequences.

We've all had to function on little to no sleep at one time or another, and we know if slows us down physically, and makes us sluggish. Did you also know that your brain simply doesn't function well when you have had little sleep? This means that all the brain processes you use to assess risk and keep yourself and your buddy safe just don't work as well. In the long term, lack of sleep can also leave you more susceptible to heart disease and stroke.

Try to make your sleep a priority, which can be especially hard for shift workers as life goes on around you. It will make you sharper, healthier, and safer. Your brain will be better able to assess risk and remember all the controls in place to manage it.

Source: http://www.bbc.com/news/health-40036667

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Thursday, August 10, 2017

Positive Communication on the Surface

<mine name> has excellent proximity detection controls in place, particularly in the face. One place where you may be at higher risk is on the surface, especially at shift change. The surface site is fairly crowded, and you may have dozers, mantrips, scoops, haul trucks, and 4-wheel road vehicles moving at once. Not all of these are equipped with proximity detection. What are some of the preventive and mitigating controls you have in place for this scenario?

PREVENTIVE	MITIGATING
Verbal indication you are starting equipment and moving equipment (e.g., "starting up", honking horn, ringing bell)	First aid
Reflective uniforms and material on hats	Proper pre-shift - brakes
Positive communication – ensure others see you either verbally or by radio, and they know what you are doing, make affirmative eye contact.	
Proper pre-shift on equipment (brakes, emergency brakes, lights, etc.)	
Lights on equipment	

Get the shift off to a good start.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Friday, August 11, 2017

The importance of pre-op checks

Everyone here is responsible for pre-operational checks of equipment every shift. These checks are critical to preventing and mitigating consequences associated with different risks. What are some of the risks that you are addressing with preoperational checks?

1. Risk of injury due to moving equipment (you are ensuring that lighting, bells, brakes, etc. are working)
2. Risk of struck by injury (parts are intact, etc) – for instance, if a shuttle car cable comes off the reel, someone could be struck by it.
3. Risk of injury to the operator due to failure of a major part (wheel, for instance)
4. Risk of fire – all fire control equipment (e.g., fire extinguishers, water sprays are in date, look undamaged, and functioning properly)

Today as you do your pre-operational checks remember how important they are for your safety as well as the safety of your coworkers.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Saturday, August 12, 2017

Remember rescuers

When was the last time you took a good look at the rescuer on your belt? The equipment on our belts takes a beating every day, and rescuers should be examined every day to ensure they will function properly if needed. It takes very little time – how do you properly examine your rescuer?

Indicator, seals, no obvious visible damage.

What kind of a control is a rescuer? <u>Mitigating</u> – you don it after control of the underground atmosphere is lost.

Do you remember where the caches are on your escape route? Take some time to look at the map and remind yourself.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Monday, August 14, 2017

Summer roof

We all know that during the summer, the humid and wet conditions in the mine can make the roof less stable. As summer comes to an end, don't become complacent about the roof. If we look at the 17 reportable accidents at this mine since 2014, 3 of them are classified as roof related. It should come as no surprise that they occurred in June, August, and September. So, don't forget to look up, watch the brows, and do the same for your coworkers. What are the **preventive** controls in place to keep you from being injuring by fall of roof?

- Bolts
- Test holes
- Visual inspection, sounding, pulling loose rock
- Supplemental support – jacks, cribs, timbers
- ATRS for bolter operators
- Visual warning at the 2nd to last row of bolts

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, August 15, 2017

Working around conveyor belts

Conveyor belts are the most efficient way to move material out of the mine, but we must be particularly careful working around them, because being pulled into one can result in devastating injuring or fatality. What controls are in place to prevent you from being injured around conveyor belts?

- Avoid walking on the off side when possible
- Blouse your pants/cuff sleeves, avoid loose fitting clothing
- Good housekeeping around belts (e.g., shovel up loose rock, etc. to avoid slip, trip, fall)
- Ensure foot wear is in good condition and fits well to avoid slip, trip, fall around belts
- Do not rest your hand on belt structure
- Ensure emergency stop buttons are functional, and know their locations
- When conducting maintenance work on belts ensure that proper lock out/tag out procedures are followed.
- Only cross belt at designated points

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, August 16, 2017

Risk Management Every Day

Most miners are constantly assessing and managing risk – it's the way you've been trained. You might, however, be doing it unconsciously – not really thinking about it. As you start your shift today, consider one of the immediate risks you will encounter – what are the causes, and consequences?

Remember, causes are the reason control is lost in the first place and consequences are generally the same – the worst consequences, of course are injury and loss of life.

Let's consider a pedestrian struck by moving equipment, since that is a risk every person working on the property faces.

What are the causes of such an accident?

- Equipment operator does not see pedestrian
- Pedestrian does not see equipment operator
- Equipment appears unexpectedly (in an unusual place, from behind a fly pad, coming around a corner)

What are the controls in place to prevent these accidents?

- Reflective clothing
- Equipment lighting
- Proximity detection
- Bells/horns
- Preshift checks to ensure these controls are functional
- Proper positioning around equipment
- Care to avoid slips, trips, and falls around equipment

Think about your job consciously this way today, and, most of all, be safe.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Thursday, August 17, 2017

Risk of Fire

Fire hazards are particularly high risk, because they have the potential to rapidly endanger every single person in the mine. Have you considered where the risk of fire is highest? For example, around cutting/welding, belt drives, outside on mobile equipment, ignition potential where coal and rock are being cut.

What controls are in place to prevent and mitigate risk associated with fire?

Preventive	**Mitigating**
Housekeeping, hose off equipment, avoid build up of combustible material	Escapeway routes and training
Regular checks for methane	Firefighting materials – do you know where they are
Good bits, regular inspection of bits	Proper cutting/welding procedure (gas check, rock dust, and fire extinguisher)
Calibration of methane detectors	Fire suppression systems
Maintenance of the ventilation system according to plan (no short circuiting, stoppings out, ensure adequate air in cutting face, etc.)	SCSRs and SCSR caches
	CO monitoring
	Training in the use of firefighting materials
	Refuge alternatives

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Friday, August 18, 2017

Protect your hands

Between 2010 and 2016 MSHA data show over 5500 hand injuries at mines. Almost half of these injuries occurred during use of non-powered hand tools are handling of supplies and materials. In fact, it isn't just mining that sees a high number of hand injuries – they are responsible for about 10% of emergency room trips. 35% of reportable injuries at <mine name> have been to hands and they all could be attributed to handling of materials or use of non-powered hand tools. What controls are in place to prevent the risk of injury to your hands when handling materials or using non-powered handtools?

What controls are in place to prevent and mitigate risk associated with fire?

Preventive	**Mitigating**
Metacarpal gloves	First aid (can you respond to an amputated finger, or profusely bleeding hand or wrist?)
Avoid wearing jewelry on your hands	
Use non-powered hand tools correctly (for example, choose the right tool for the job, and cut away from yourself)	
Handle material using correct procedures, (for example, don't lift loads that are two heavy alone, get help if needed, watch for pinch points)	

Sources:

MSHA Safety Alert (Hand Injury Accidents) (2016.) https://arlweb.msha.gov/Alerts/2016-hand-injury.pdf

De Jong, et al. (2014.) The Incidence of Acute Traumatic Tendon Injuries in the Hand and Wrist: A 10-Year Population-based Study. Clinics in Orthopedic Surgery. https://synapse.koreamed.org/search.php?where=aview&id=10.4055/cios.2014.6.2.196&code=0157CIOS&vmode=FULL

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Saturday, August 19, 2017

The risk of stored energy

Stored energy poses a significant risk for struck by and caught between injuries. What is meant by stored energy? This could be a scoop bucket that is up in the air (there is energy stored in the hydraulic system, sudden release could drop the bucket); A continuous miner cable and water line that is hung across an entry with insufficient or damaged hangers (failure of the hangers could result in sudden release of the load).

Last summer (2016) a 34 year old miner with seven years of experience was fatally injured when a front end loader fell on him. He and another miner had used the hydraulic pressure to push down the bucket and raise the middle of the loader. They then crawled under it, and the hydraulic pressure unexpectedly released, bringing the loader down on both of them.

It is critical that you consider stored energy during regular work (like unloading supplies from a scoop) and especially during maintenance work. What controls are in place to prevent these types of accidents?

What controls are in place to prevent and mitigate risk associated with fire?

Preventive	**Mitigating**
PPE (gloves, hard hat, metatarsal boots)	First aid
Cribbing or otherwise blocking any equipment that you are required to be inside or under	
Hanging and securing cables adequately	
Staying away from steel cables under tension	
Parking equipment with hydraulically operated pieces in the lowest position (for example, miner ripper head on the ground, scoop bucket on the ground)	

Name a few maintenance jobs that require you to block or crib equipment? Take your time today to carefully assess a job before getting started.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Monday, August 21, 2017

Common Injuries: slip, trip, or fall

Slips, trips and falls are common injuries in the coal mines. The floor is often slick or has rubble on it, maneuvering around can be awkward, due to low roof, poor lighting, or a load you are carrying. These injuries also range from minor to quite severe, and can impact any part of the body. They are regularly a leading cause of accidents in Virginia mines. What are the preventive controls in place to address your risk?

Preventive	**Mitigating**
Housekeeping (clear walkways)	First aid
Lighting (equipment, hat, fixed, even rock dust helps with visibility)	
Maintain 3 points of contact when descending ladders, steps and stairs	
Use care when entering, exiting equipment cabs	
Use fall protection when working in high and suspended locations	
Proper tread and fit for boots	

Sources:

Slips, Trips, and Falls Hazard Alert. (2011).
https://arlweb.msha.gov/alliances/formed/NSSGA/SlipsTripsFalls112012.pdf

DMME (2012). Slips, trips, and falls
https://www.dmme.virginia.gov/DMM/PDF/TRAINING/REFRESHER/FallsTopics/AR-Slips,TripsandfallsI.pdf

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, August 22, 2017

Ventilation keeps you safe and healthy

Roof control and ventilation are two of the most critical mine wide controls. Consider your ventilation system here at <mine name>, do you feel that you understand it, do you know who to talk to if you have questions or concerns? What are some of the risks and specific controls that the ventilation system addresses?

Ignition (air for dilution of gas and dust, sprays, and sharp bits with intact lugs)
Explosion (same as ignition plus rock dust)
Dust (air for dilution, sprays)

How are you (specifically) responsible for maintaining this system?

- Checking water pressure and sprays
- Applying rock dust
- Maintaining controls (stoppings/brattices, line curtain, advancing curtain during mining)
- Taking regular gas checks
- Reporting problems (like a stopping out)
- Checking and changing bits
- Maintaining equipment (lugs, permissibility, etc.)
- Maintaining sensors

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, August 23, 2017

Lessons learned: risk of roof fall

In April of this year a section foreman in West Virginia died of injuries sustained 2 weeks prior by a falling rock in an active section. The rock fell out from between the bolts and was about 3 feet by 2 feet by 4 inches. This isn't a very big rock – we've probably all pulled a rock this size or watched one fall nearby. We should all remember that it does not take a large rock to kill or seriously injure a miner. It's especially important at <mine name> to keep an eye on brows and cutter ribs. What controls do we have in place to address the risk of loss of roof control AFTER an entry or area has already been bolted?

Preventive	**Mitigating**
Observe and sound the roof, pull loose rock from a safe location	First aid
Position yourself away from ribs and brows when possible	PPE (hard hat)
Cut down brows that pose a hazard	
Examine entries for rib cutters and install supplemental support as necessary (cribs, timbers, jacks)	
Check test holes, especially if you notice a change in roof conditions	
Spot bolt/install cable bolts as necessary	

Most of all, keep your eyes on the top and remind your coworkers to do the same.

Sources:

MSHA (2017). Fatalgrams. https://arlweb.msha.gov/fatals/coal/2017/fatalgrams/FAB-c05.asp

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Thursday, August 24, 2017

Moving Equipment - Levels of Protection

When it comes to moving equipment there are several levels of protection, the first, and probably most effective, being proximity detection. The other two levels rely on your own senses – sight and sound for *preventative* control. What are the visual controls? And what are the sound controls?

Visual

Reflective material on clothing/hats

Blinking lights on hats

Lights on equipment (also indicate direction)

Eye contact and light signals with operators (did they see you?!)

Sound

Bells and horns

Verbal communication by radio or otherwise

Engine, tramming noise

Which controls do you think are most effective?

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Friday, August 25, 2017

Electrical Safety

Since 1990, there have been at least 75 fatal and 1,850 non-fatal accidents in the mining industry which were classified by MSHA as "Electrical." Many of these could have been prevented if the circuits would have been locked, grounded, and tagged prior to any maintenance work being performed.

What controls are in place to prevent loss of control of electricity during maintenance work?

Preventive	Mitigating
Lock out/tag out procedures	PPE (rubber soled boots, gloves)
Communication with everyone working around tagged out equipment	First aid
	Rubber mats at electrical installations
	Grounded circuits

- Don't forget to take these simple steps prior to performing any electrical work:
- Determine the location of the disconnecting means for the circuit to be worked on.
- Carefully de-energize the circuit.
- Each employee working on the circuit should place his/her own lock and tag on the disconnecting device.
- The circuit to be worked on should be tested for voltage to ensure no electricity is present.
- Ground all the phase conductors to the equipment grounding conductor with a jumper.

Source: MSHA's Accident Prevention Program, Miner's Tip:
https://arlweb.msha.gov/Accident_Prevention/Tips/eleclock.htm#.WW8dZ4grJeU

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Saturday, August 26, 2017

Working around conveyor belts

In 2014, there were a rash of accidents around conveyor belts in metal/non-metal operations. Several of these accidents resulted in traumatic amputation of arms and fingers in the field and one in a fatality. Perhaps, because we work in such tight spaces here at <mine name> we automatically take additional care around conveyor belts, but it still pays to consider the risk a conveyor belt poses and the controls we have in place to prevent and mitigate injury. What are the controls we have in place for working around belts?

- Avoid walking on the off side when possible
- Blouse your pants/cuff sleeves, avoid loose fitting clothing
- Good housekeeping around belts (e.g., shovel up loose rock, etc. to avoid slip, trip, fall)
- Ensure foot wear is in good condition and fits well to avoid slip, trip, fall around belts
- Do not rest your hand on belt structure
- Ensure emergency stop buttons are functional, and know their locations
- When conducting maintenance work on belts ensure that proper lock out/tag out procedures are followed.
- Only cross belt at designated points
- Ensure proper guarding is in place

NEVER attempt to perform work on a running belt.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Monday, August 28, 2017

Roof conditions

According to MSHA data, since 2013, roof and rib falls or coal bursts led to the deaths of five continuous mining machine operators, and injured 83 other operators. What are the preventive controls you have in place to prevent fall of roof or rib, especially in the face?

- Visual observation and sounding, then pulling loose roof and rib
- Cutting down brows as possible
- Installation of roof and rib bolts according to plan (and pizza pans)
- Installation of supplementary support as needed (timbers, cribs, jacks) – how do you know when these are needed? (wide spot in entry, severe cutter rib, etc.) Also, cable bolts as needed.
- Proper use of ATRS when bolting
- Drilling and checking test holes
- Communicating observation of problems to foreman, management and other miners.

In YOUR regular work area this week, what roof conditions have you noted that pose the greatest risk?

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, August 29, 2017

Noise is a major health hazard

One in every four miners has a hearing problem, and by the time miners reach retirement age, 4 of every 5 have hearing loss. The danger of damaging our hearing underground is not nearly as clear and present as the risk of a roof fall, or even the long term risk of developing black lung. However, the loss of one of your senses, such as your hearing can severely impair your quality of life, and miners are exposed to substantial noise over the course of a work day. How can you minimize the risk of noise induced hearing loss?

PREVENTIVE	MITIGATING
Hearing protection (in some cases double – plugs and earmuffs), inserted properly. Remember pull your ear up with the opposite hand to put a plug in.	Hearing aid
Equipment modifications (ensure lids aren't rattling, bit isolators, changes to cutting head)	
Monitoring to identify problem areas and noise levels for improvement	
Stay away from noisy areas as possible (for example, don't chat at the feeder-breaker when operating)	

Source: NIOSH Mining Topic: Hearing Loss Prevention Overview. https://www.cdc.gov/niosh/mining/topics/HearingLossPreventionOverview.html

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, August 30, 2017

Fire Prevention

Fire is one risk that has a number of both preventive (keep it from happening) and mitigating (keep it from causing injury) controls. What are the controls you have in place to <u>prevent</u> fire?

- Good housekeeping (no buildup of combustible material)
- Regular methane checks
- Preoperational inspections
- Proper charging and coupling at power supplies (prevent arcing)
- Water sprays and sharp bits (prevent ignition)
- Proper ventilation

What are the <u>mitigating</u> controls?

- Firefighting and fire suppression equipment
- Isolated escapeways with lifelines and reflectors
- Refuge alternatives
- SCSRs
- Rock dust
- Emergency response plans and designated responsible persons so decisions are made quickly and efficiently

What area do you regularly work in that you feel has the highest risk of fire? Keep these risks in mine today. A fire can very quickly affect the safety of an entire mine and everyone in it.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Thursday, August 31, 2017

Experience Matters

In examining fatal accidents in underground coal for 2017, in 8 of the 9 fatalities, the victims had been working at the mine for less than one year. In some cases, miners simply don't have the experience on the job to actively identify all the risks associated with their occupation, while in others, they don't have the experience with the conditions at that mine. What are some conditions at <mine name> that expose you to specific risks? …and the general controls you have in place to manage those?

Low top – can cause injury when riding in vehicles

- Controls are slow speeds, proceeding cautiously through especially low areas or potholes, hardhats

Cutter roof and loose brows

- Pizza pans, cable bolts, regular bolt patterns, and other supplemental support
- Sound and inspect top, pull loose rock and coal

Tight spaces due to low mining height

- Proximity detection
- High visibility and communication
- Be careful, and watch out for each other, especially those with less experience.
- Visual and audible warning systems for moving equipment

Source: MSHA Quarterly Coal Call:
https://www.msha.gov/sites/default/files/Training_Education/stakeholder-quarterly-training-071817.pdf

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Friday, September 1, 2017

Protect your eyes

About 20,000 eye injuries occur every year in US workplaces. These tend to be three types of injuries:

- Scraping or striking
- Penetration of the eye
- Chemical or thermal burns

What are some of the causes of these injuries, and the controls that are in place to protect your eyes?

Striking or scraping could include using a pry bar that gives way and strikes a person in the face, dust or small pieces or rock or coal blowing into the eye, or a cable or chain that fails in tension and strikes a person in the face.

Penetration of the eye can easily occur when cutting (or sawing) something that gives way and splinters, or due to a flying piece of material (small piece of rock during mining, metal slivers when using a hammer and chisel on equipment).

Finally, *chemical and thermal burns* are fairly obvious. Chemical burns might occur via use of an aerosol (WD40), or other materials used in the mine that rely on chemical reactions like sealant foam. Thermal burns can occur during welding.

The primary control for prevention of risk of eye injury is proper eye protection – safety glasses during normal work. Welding hoods for welding operations.

Can you think of a time when your safety glasses have protected your eyes from serious injury?

Source: Eye Injuries at Work. American Academy of Opthamology (2017.)
https://www.aao.org/eye-health/tips-prevention/injuries-work

NIOSH Eye Safety. https://www.cdc.gov/niosh/topics/eye/default.html

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Saturday, September 2, 2017

Watch your hands

If we examine reportable injuries at <mine name> Mine since November 2017, 35% have been hand injuries. These tend not to be life threatening injuries, but they impact your ability to work (and enjoy your life, do things around your house) significantly. We are reliant on our hands for so many jobs, and they are complex parts of our bodies in terms of ligaments, bones, and muscles. There are 27 bones in the human hand and some of the densest bundles of nerves in the body. What are some preventive and mitigating controls that address the risk of hand injury?

PREVENTIVE	**MITIGATING**
Proper use of hand tools	Metacarpal gloves
Avoid wearing rings	First aid
Keep hands away from pinch points	
Handle materials properly	

Think about your last near miss with your own hand…it probably wasn't that long ago. What can you do to address the risk that you encountered?

Note to safety meeting leader:

- *Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).*

Monday, September 4, 2017

Proximity Detection

<mine name> has excellent proximity detection controls in place, particularly in the face. One place where you may be at higher risk is on the surface, especially at shift change. The surface site is fairly crowded, and you may have dozers, mantrips, scoops, haul trucks, and 4-wheel road vehicles moving at once. Not all of these are equipped with proximity detection. What are some of the preventive and mitigating controls you have in place for this scenario?

PREVENTIVE	**MITIGATING**
Verbal indication you are starting equipment and moving equipment (e.g., “starting up”, honking horn, ringing bell)	First aid
Reflective uniforms and material on hats	Proper pre-shift - brakes
Positive communication – ensure others see you either verbally or by radio, and they know what you are doing, make affirmative eye contact.	
Proper pre-shift on equipment (brakes, emergency brakes, lights, etc.)	
Lights on equipment	

Get the shift off to a good start.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, September 5, 2017

Electrical Safety

The risk of losing control of electricity in a mine is high and can result in severe injury, even fatality. When we consider power centers, trailing cables, and high voltage cables we are near them all the time. Let's consider the preventive and mitigation controls that protect us from electrocution.

Preventive

- These are the things that allow us to keep electricity under control in the first place:
- Proper cable maintenance – splices are well maintained, cable is regularly inspected for problems
- Cables are hung out of the way of moving equipment
- Power centers are properly maintained including grounding
- Catheads for equipment are regularly inspected, are well plugged in, and appropriately maintained
- Proper lock out/tag out procedures are always used, no matter how long it takes

Mitigating

- Wear proper PPE – High voltage gloves when appropriate, rubber soled boots, use dry rubber mats at power centers
- First aid

Also, electricians and mechanics often work alone or put power in alone. Be cognizant of where they are, communicate regularly, and check on them if you haven't heard from them in a while or have other reasons to be concerned.

Note to safety meeting leader:

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, September 6, 2017

Take care of your back

A back injury can significantly change your quality of life – for the worse. Miners are often moving loads in awkward ways, especially low coal miners. As you to lift, move, carry, or hang something today, consider carefully how you will complete the job safely. What are preventive controls…mitigating controls to reduce your risk of back injury.

PREVENTIVE	MITIGATING
Proper positioning	First aid
Good communication (when lifting with others)	
Keep walkways clear	
Use proper tools	
Use mechanical (such as come-a-longs) and human help as necessary	

There are other preventive controls that we don't talk about as often – your own fitness. Exercise, good posture, proper back strengthening, and stretching can also reduce your risk of injury.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Thursday, September 7, 2017

Mitigating Controls | Mine Emergencies

When we consider mitigating controls, especially in mine wide and critical (serious injury) emergencies we have several major mitigating controls that we spend a great deal of time on:

- Mine Evacuation
- Donning an SCSR (multiple types, and changing them!)
- Providing first aid
- Providing timely and complete details to mine management/responsible person in the event of an emergency

Sometimes all this training becomes something that we no longer carefully consider. In several fires and explosions in the last 15 years there is evidence that miners did not know how to use SCSRS as well as would be expected, and did not have a good grasp of how to get outside on foot. Ask yourself a few questions:

Can I envision exactly how to get from my regular work area out of the mine – both in the primary and secondary? What controls are there to help me?

- Mine map
- Lifeline
- Reflectors

Can I envision how to don and change a rescuer? Imagine each step in sequence as if you had to teach one of your loved ones how to use it.

Do I remember major points of first aid? When was the last time someone in this room had to give first aid?

Could I stay calm and let people know what is going on in an underground emergency? What are some techniques for calming your own panic in an emergency? Take deep breaths (SCSRS can make you feel additional panic if you have one on), remember that you have been trained for this.

Do I know how to deploy our RA? ***What are the steps?*** Under what conditions would I do this?

Finally, don't forget to check in/check out!

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags)

Friday, September 8, 2017

Check your top

During the summer, draw rock can pose a greater risk than during other times of year. There tends to be increased water movement in the roof. Additionally, temperature changes throughout the day can drive loosening of rock. Today, make a point to keep an on what is over year head as well as the person working near you. Sometimes a different vantage point can give you a completely different view of the top – it could save your life, or your buddy's. Describe the controls you have in place for <u>IDENTIFYING</u> bad roof:

- Visual examination
- Test holes
- Sounding
- Roof noise

Keep an especially close eye on cutter roof near the ribs and drawrock near pillar corners. And watch out for the guy working next to you.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Saturday, September 9, 2017

The risk of stored energy

Stored energy poses a significant risk for struck by and caught between injuries. What is meant by stored energy? This could be a scoop bucket that is up in the air (there is energy stored in the hydraulic system, sudden release could drop the bucket); A continuous miner cable and water line that is hung across an entry with insufficient or damaged hangers (failure of the hangers could result in sudden release of the load).

Last summer (2016) a 34 year old miner with seven years of experience was fatally injured when a front end loader fell on him. He and another miner had used the hydraulic pressure to push down the bucket and raise the middle of the loader. They then crawled under it, and the hydraulic pressure unexpectedly released, bringing the loader down on both of them.

It is critical that you consider stored energy during regular work (like unloading supplies from a scoop) and especially during maintenance work. What controls are in place to prevent these types of accidents?

What controls are in place to prevent and mitigate risk associated with fire?

Preventive	**Mitigating**
PPE (gloves, hard hat, metatarsal boots)	First aid
Cribbing or otherwise blocking any equipment that you are required to be inside or under	
Hanging and securing cables adequately	
Staying away from steel cables under tension	
Parking equipment with hydraulically operated pieces in the lowest position (for example, miner ripper head on the ground, scoop bucket on the ground)	

Name a few maintenance jobs that require you to block or crib equipment? Take your time today to carefully assess a job before getting started.

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Monday, September 11, 2017

Electrical Safety

Since 1990, there have been at least 75 fatal and 1,850 non-fatal accidents in the mining industry which were classified by MSHA as "Electrical." Many of these could have been prevented if the circuits would have been locked, grounded, and tagged prior to any maintenance work being performed.

What controls are in place to prevent loss of control of electricity during maintenance work?

Preventive	Mitigating
Lock out/tag out procedures	PPE (rubber soled boots, gloves)
Communication with everyone working around tagged out equipment	First aid
	Rubber mats at electrical installations
	Grounded circuits

- Don't forget to take these simple steps prior to performing any electrical work:
- Determine the location of the disconnecting means for the circuit to be worked on.
- Carefully de-energize the circuit.
- Each employee working on the circuit should place his/her own lock and tag on the disconnecting device.
- The circuit to be worked on should be tested for voltage to ensure no electricity is present.
- Ground all the phase conductors to the equipment, grounding conductor with a jumper.

Source: MSHA's Accident Prevention Program, Miner's Tip:
https://arlweb.msha.gov/Accident_Prevention/Tips/eleclock.htm#.WW8dZ4grJeU

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Tuesday, September 12, 2017

Stay visible and communicate

When we consider the causes of moving equipment accidents they often occur because an equipment operator either could not see another person or did not know their location. In low coal, visibility is further impaired. What are some controls that you have to enhance visibility and communication? These are almost all preventive.

- Reflective stipes on clothes, materials on hats
- Headlights on front of hats – light signals
- Blinking lights on back of hats
- Radio communication
- Mine phones (particularly during emergency)
- Horns/bells – particularly when starting up, approaching blind turns, fly pads
- Eye contact and a verbal confirmation (for example, "I'm walking in front of you")
- Making a plan before a big or unusual job (something like major unplanned belt maintenance) – this is good time to use STAR cards.

As you travel your work area today remind yourself of the importance to visibility and communication:

Am I doing everything I can to be visible to equipment operators?

Am I communicating my position and intentions well?

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).

Wednesday, September 13, 2017

Watch out for Draw Rock

Draw rock is fairly common here at <mine name>. In particular the water present in the mine during summer tends to loosen the roof even more, and the risk is present outby and on the production sections. Further, as we head into fall, conditions in the mine may change and become dryer – these changes can also impact the roof. Be especially attentive to ground conditions as the seasons change, and let your coworkers know what you observe. Especially watch out for cutter rib and draw rock on the corners of a pillar. Often the rib has sloughed out leaving a corner of rock exposed that can be a foot thick and over two feet wide. Clearly, a piece of rock this size can do serious damage and is usually sharp enough to cause serious lacerations.

What controls do you have in place to manage this risk?

PREVENTIVE	**MITIGATING**
Standard Bolting (plus pizza pans)	PPE (hard hat)
Good observation, sounding, pulling loose rock	First aid
Drive and travel center of the entry	
Spot bolting as needed	
Cribs, timbers, jacks	
Cutting down draw rock on the corners if discovered early enough for CM access	

<u>Note to safety meeting leader:</u>

Please deliver as you would normally. If you are comfortable doing so prompt miners to tell you what the preventive controls and mitigating controls are for a particular event. If you think the meeting was especially good or bad or if you have suggestions or feedback please note them in the safety meeting book. Remember, preventive controls keep you from losing control in the first place (like defensive driving); mitigating controls minimize the damage or injury when control is lost (seat belts and airbags).