# Major Hazard Risk Assessment Applied to Pillar Recovery Operations

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## ABSTRACT

Recent fatal injuries occurring during pillar retreat coal mining call for better identification of the hazards and recognition of risks. Ground control hazards associated with room-and-pillar retreat mining tend to intensify with depth, requiring extra precautions in the form of additional controls. In many locations these activities are further complicated by local complexities often associated with unique or novel circumstances, such as over-mining or under-mining.

One technique recently studied by NIOSH, Major Hazard Risk Assessment (MHRA), may help mine operators to mitigate the risks associated with pillar recovery operations. The approach was trialed at two underground coal mines in southern West Virginia that are currently practicing pillar recovery. The first step in the MHRA process involved reviewing the segments or parts of the pillar extraction mining system and identifying associated hazards and threats to the operation. Some of the high risk hazards at these two sites included:

- Rock fall during pillar extraction covers equipment and injury occurs during recovery operations,
- Rock fall above the roof bolt horizon, potentially injuring workers and/or requiring recovery action,
- Rib fall under deep cover, potentially injuring workers, and;
- Strata instabilities associated with subsidence of the interburden due to simultaneously mining two seams in close vertical proximity to one another.

The mines' risk assessment teams then considered each threat individually in order to systematically identify potential unwanted events. The top unwanted events were examined individually using structured risk analysis tools. The output from the process includes a list of priority existing controls for monitoring and auditing, and a second list of potential new controls. These controls consisted of:

- Examples of best practices,
- Enhanced communication,
- Implementing standard operating procedures (SOP),
- Protocols for emergency response actions,
- Effective layouts,
- Efficient monitoring, and;
- Successful audits.

This paper documents the process as it unfolded at the two mines, and analyzes the strengths and weaknesses of the MHRA technique as it applies to pillar recovery operations.

This work was part of a larger NIOSH research project. NIOSH was responsible for: 1) facilitating the risk assessment process known as Major Hazard Risk Assessment (MHRA), 2) documenting the risk assessment process, and 3) providing mine management with a written draft summary of the risk assessment process. The results of the risk assessment represent the thoughts and opinions of the individual risk assessment teams and should in no way be construed as an endorsement of the risk assessment output by NIOSH or the University of Pittsburgh.

## INTRODUCTION

Recent fatal injuries occurring during pillar retreat coal mining call for a better identification of the hazards and a recognition of the associated risks. Ground control hazards associated with room-and-pillar retreat mining tend to intensify with depth, requiring extra precautions in the form of additional controls. In many locations, these activities are further complicated by local complexities often associated with unique or novel circumstances, such as over-mining or under-mining. In this study, two sites were chosen where pillar recovery at depth was occurring.

## SITE CHARACTERISTICS OF MINE A

Mine A has been active for over 30 years and most of the virgin coal has been mined using the longwall method. In 2006, operations shifted to mining the remaining isolated pockets of coal, not minable by the longwall method. Some of these pockets consist of large barrier pillars adjacent to the mines' main entry system. The barrier pillar studied in this paper is located in the southern portion of the mine along the main entry system that travels from south to north. The barrier pillar is approximately 480-ft wide and several thousand feet long (Figure 1a). Overburden ranges from greater than 400 ft over the northern end of the barrier to greater than 1,200 ft over the southern end (Figure 1b). Lastly, a coalbed lays approximately 190 ft above the study panel and is partially mined (Figure 1c).

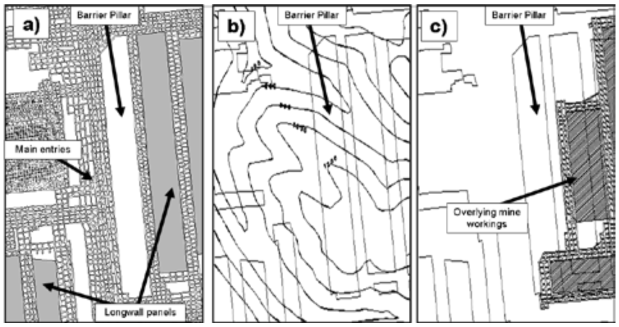


**Figure 1. a) View of study barrier pillar, b) overburden above study area, and c) location of overlying mine workings.**

## SITE CHARACTERISTICS OF MINE B

Mine B often extracts coal under ridge tops where the overburden is sometimes greater than 1,000 ft (Figure 2). To date, the coal has been mined using the room-and-pillar method. Rooms are typically 19- to 20-ft wide and pillar centers range from 70 to 90 ft. The mining height is approximately 6 ft. Recently the mine began to use full extraction mining methods concentrated in production panels located adjacent to its main entry systems (Figure 2). Underground conditions are further complicated by multiple-seam mining. The study mine is the lowest minable coalbed within the geologic section. Above it there are a significant number of mineable coalbeds. Approximately 80 ft and 160 ft above the study mine lay a dozen mining operations, most abandoned. The diverse arrangements of rooms, pillars, and gob (areas where the coal pillars have been extracted) have added to the already complex pillar loading conditions.

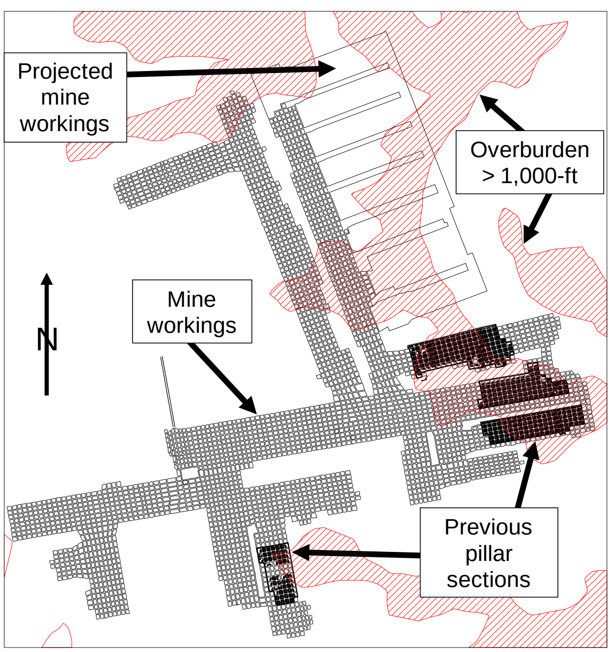


**Figure 2. Site characteristics of Mine B: current and projected mine workings, previous pillar sections, and overburden greater than 1,000 ft.**

## RISK ASSESSMENT OBJECTIVES

The ground control issues associated with retreat mining deep cover coal warrant the study of additional means to prevent worker injuries. One approach that has gained some favor in other mining countries (Anon, 1997; Iannacchione et al., 2008) is Major Hazard Risk Assessment (MHRA). In this approach, mining operations focus on hazards that can cause significant risk to the mine and its workers. To investigate the mine's hazards, the risk assessment team identifies potential hazards and ranks these hazards by their likelihood of occurrence and consequence to safe operations of the mine. The risk assessment team provides a list of priority existing controls for monitoring and auditing, as well as a list of potential new controls to further reduce related risks.

## RISK ASSESSMENT TEAM

The risk assessment teams at both study sites were made up of persons employed at the mines (Table 1).

**Table 1. Composition of risk assessment teams at Mine A and B.**

| Mine A | Mine B |
|---|---|
| Mine Superintendent | Owner |
| Chief Mine Engineer | General Manager |
| Mine Engineer | Mine Superintendent |
| Safety Department | Mine Foreman |
| MRS Operator | Day Shift Foreman |
| | Safety Manager |
| | Mine Superintendent from a another mine |
| *NIOSH contributions, Facilitator and Ground Control Expert* | |

## THE MHRA PROCESS

To accomplish the risk assessment objectives stated above, a process known as Major Hazard Risk Assessment (MHRA) was undertaken at both study sites. The MHRA process was developed by Dr. J. Joy (Joy, 2004 and Joy, 2006) at the University of Queensland's Minerals Industry Safety and Health Centre (MISHC). MHRA consists of multiple steps that culminate in an inventory of existing prevention controls and recovery measures and an Action Plan for evaluating new ideas developed by the risk assessment team. For a more detailed description of the MHRA process, consult NIOSH IC 9508 (Iannacchione, et al., 2008). This paper describes the steps used in this study to accomplish the project objectives.

### Step 1 - Parts of the Pillar Retreat Process

Before any controls are identified, the risk assessment team must thoroughly understand the process they are going to evaluate. In this study, the parts of the pillar retreat process are attained by analyzing all associated procedures, methods, and actions. Typically, pillar retreat systems have four distinct activities: engineering / approval, construction, development mining, and retreat mining. Each of these activities could be evaluated with the MHRA process. For complex operations like pillar recovery, identifying all the important parts and/or actions can require from a few hours to more than a day of the risk assessment team's time. This study focused on two of these activities: development and retreat mining. The discussion below only represents a summary of the most significant actions for each study site.

Mine A Process Summary

Numerous actions are involved in developing rooms and crosscuts within a large barrier pillar. Typically rooms are 18 ft wide but can be as wide as 20 ft. Two distinct layouts were proposed: a 5-entry development and a 6-entry development. The 5-entry layout begins development mining from the south end of the barrier pillar where an overlying mine has previously been developed. Pillars will be mined on 90 by 90-ft centers with the exception of one-row of pillars on the west side of the development where 65 by 90-ft centers will be used (Figure 3). Pillars in the 5-entry development area are not to be extracted because of mining in the overlying coalbed (coal-gob interface). The 6-entry development is proposed to have 105 by 65-ft centers (Figure 3). This layout will be used for the remainder of the barrier pillar. At the north end of the barrier pillar, several entries are to punch out into the adjacent sub-mains. The barrier pillar, when developed, will contain two, much smaller, remnant barrier pillars (Figure 3). On the east side, the new barrier pillar width ranges from 76 to 90 ft. On the west side, the barrier width ranges from 59 to 62 ft along the 6-entry development and 62 to 73 ft along the 5-entry development.

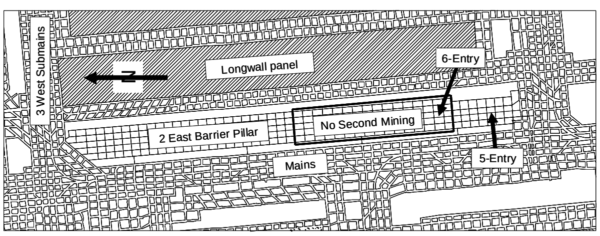


**Figure 3. Detailed layout map of the Barrier Pillar, Mine A.**

Retreat mining will commence after the entire barrier pillar has been developed. Two rows of pillars are left to protect the bleeders at the north end of the barrier pillar. Cable handling issues require that the section be mined from right to left. Blowing ventilation with check curtains are used to force the fresh air to the heading where the mining machine and Mobile Roof Supports (MRS) are positioned (i.e. Room No. 1, Figure 4).

Prior to extracting the first pillar, a star cable bolt pattern is installed in every intersection, starting 4 rows outby the sub-mains. Two rows of breaker posts are installed, 4 in-a-row, just inby the pillar to be mined. Due to the right handed nature of the power cable and connectors, the first cut into a pillar is always taken to the left (Figure 5), allowing the miner operator to be positioned next to solid coal. Mine management determines the depth of the lift and marks each cut position on the coal block and provides the depth information to the miner operator. The miner operator uses markings on the continuous mining machine to measure depth of the cut. Eight breaker posts (Position A, Figure 5) are installed after mining is completed inby. Two cribs may be used in lieu of

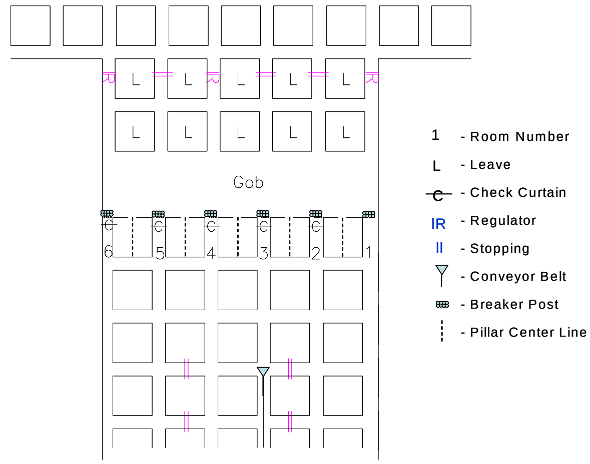


**Figure 4. Initial pillar extraction layout at the north end of the barrier pillar near the Sub-main.**

breaker posts. The MRS units are installed in locations B (Figure 5) prior to mining lift No. 1. MRS units are moved to location C (Figure 5) prior to mining lift Nos. 3 and 4 and are advanced in like manner for each subsequent lift. Thin fenders of coal are sometimes left between lifts. The miner operator has the option to mine these fenders on the way out of the lift. Some operators use these fenders as an early warning device to determine high rates of roof-to-floor convergence. After all lifts are taken, the miner is moved to the next heading to the left of its original position and the process is repeated.

Mine B Process Summary

Mine B is in the process of developing production panels to the east of a main entry development (Figure 6). Each panel is developed to its full length and connected into the bleeder entries at its inby end. After the panels are developed, full extraction pillar mining begins at the inby end of the panel and continues outby until it reaches the main entry developments.

Initially, contract surveyors identify pillar centers and set spads. Headings are advanced in a three cut sequence. Crosscuts are turned in two ways: 1 one turn from the No. 4 entry and 2 two turns from the No. 3 and No. 5 headings. These entries have slightly wider diagonals because of the rounded pillar corners to accommodate the turning continuous miner. The primary roof support consists of 5-ft, fully-grouted bolts. Typically, the sum of the intersection diagonals is 58 to 60 ft. If the intersection diagonals exceed 62 ft, 4 cribs are set per intersection. If the intersection diagonals exceed 64 ft, 8 cribs are set per intersection. All developments will be stopped 200 ft from the known locations of old workings. A blowing mine ventilation system is used as a means of creating positive pressure in the working sections. At the face, an exhausting face ventilation system is used.

Retreat mining commences at the completion of development mining. Star cable bolt patterns are installed in all intersection except when massive sandstone is present. The depth of the mining cuts is controlled by markings on the continuous miner. The section is mined left to right. The Foreman marks all cuts, fenders, and stumps with strips of red spray paint on the roof and rib of the pillar. Typically a strip of thick coal is left in the center of the

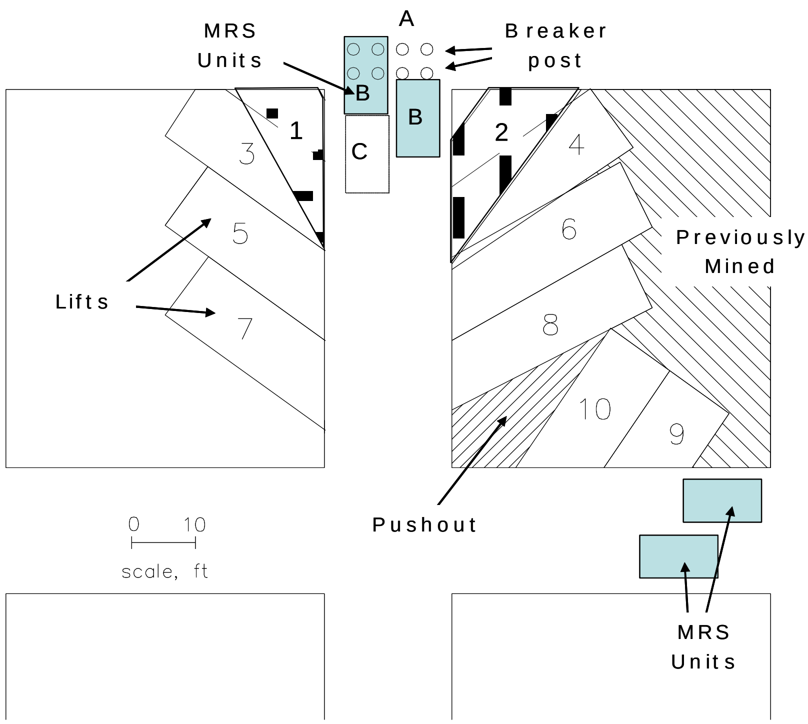


**Figure 5. Deep cut full extraction pillar recovery plan for twinning large coal blocks using two pairs of MRS.**

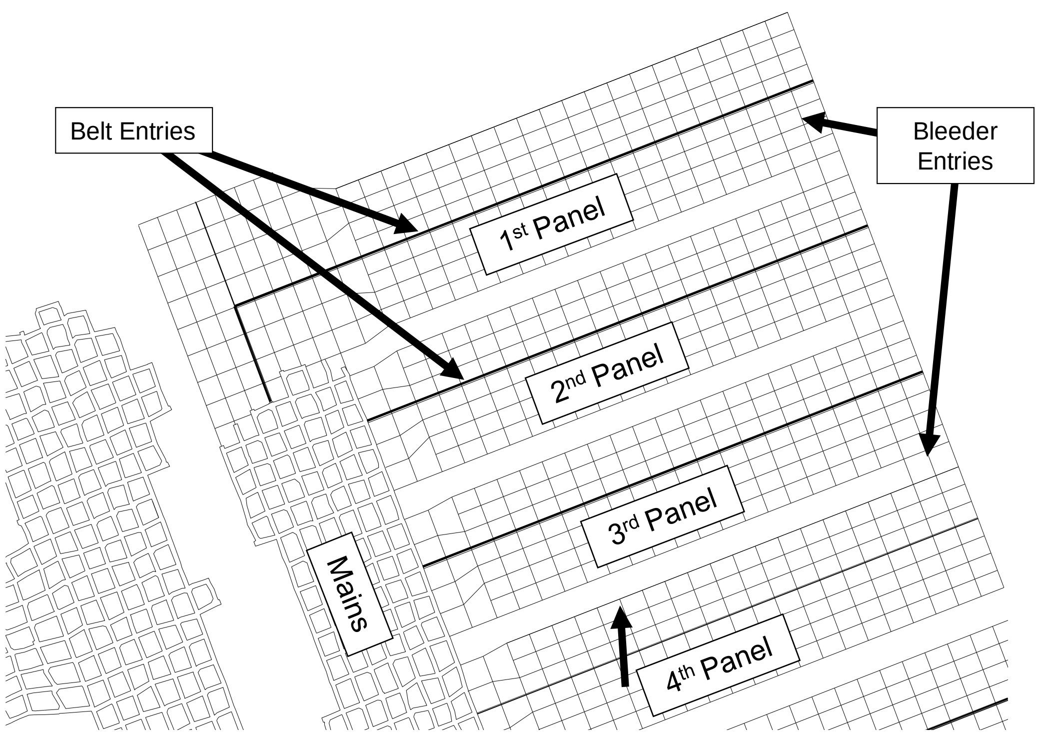


**Figure 6. Detailed view of the projected production panels where pillar recovery will occur.**

pillar. The final cuts are taken from the crosscut, outlining a final stump with minimum cut-to-corner distances of 8 ft. Eight breaker posts are set, 4 per row, prior to mining. The MRSs are set within the breaker post array and flush with the pillar edge (Figure 7). The breaker posts are set within the entries of all outby blocks prior to moving to the next pillar row. A 2-ft-thick fender is left between pillar extraction cuts to keep small rocks off the continuous miner. Only one MRS is depressurized at a time and leapfrogs past the adjacent pressurized MRS. When backing out of a section, the MRS is depressurized and moved to a position half way back from the tip of the set MRS and re-pressurized. Three coal haulage cars (buggies) are used to quickly remove the coal from the continuous miner, minimizing the miner's time in the cuts.

**Step 3 - Risk Ranking Potential Unwanted Events**

Once the pillar retreat mining segments or parts and the associated hazards are identified, the team is ready to apply the risk assessment methods. This step has the risk assessment team develop a list of potential unwanted events. A risk ranking is then performed using a broad-brush risk assessment tool, such as the Workplace Risk Assessment and Control (WRAC) or the Preliminary Hazard Analysis (PHA), to identify the unwanted events that presented that greatest risk.

Mine A's Most Significant Potential Unwanted Events

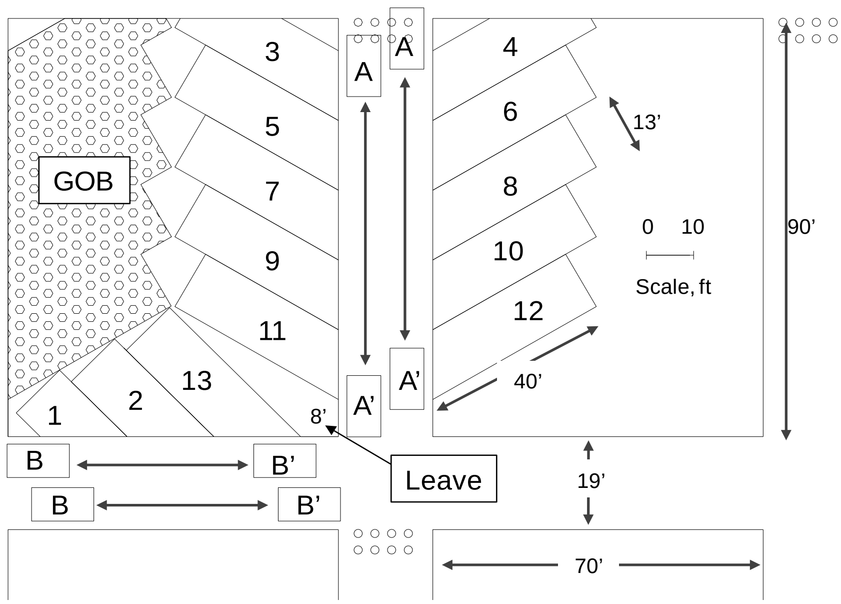


**Figure 7. Cut sequence used to fully extract 90 by 70-ft pillars. Note the location of the 8 by 8-ft final stump.**

**Step 2 - A Comprehensive List of Hazards**

Due to time constraints, the teams decided to limit their consideration of hazards to those associated with ground control and not to consider ventilation issues such as fires and explosions. The risk assessment teams identified the big energies as stresses, pressure, gravity, gas, and water. They also recognized eight associated hazards (Table 2).

**Table 2. List of general ground control hazards associated with pillar retreat mining.**

| Energy | Hazards | |
|---|---|---|
| *Stresses* | Bumps | Pillar instability |
| *Pressure* | Air blast from gob caving event | Support failure |
| *Gravity* | Roof falls | Rib instabilities |
| *Gas and Water* | CO, CO2, CH4 from adjacent gob | Water from overlying abandoned mine |

Mine A identified 25 potential unwanted events (Table 3). Risk numbers (R) were assigned using risk matrix technique and ranged in value from 2 to 25 (Anon., 1997). The lower the number, the greater the risk to the mining operation. The risk rankings are grouped into five categories: very low (VL), low (L), medium (M), high (H), and very high (VH). There are three potential unwanted events that are in the high and very high risk categories (# 7, #16, and #22, Table 3).

Mine B's Most Significant Potential Unwanted Events

Mine B identified 12 potential unwanted events (Table 4). Risk numbers ranged from 4 to 20. There are three potential unwanted events that are in the high risk category (#1, #4, and #12, Table 4).

**Step 4 - Determine All Existing Prevention Controls and Recovery Measures**

For each of the potential unwanted events listed as high above, the risk assessment team uses some risk analysis tool to identify existing prevention controls and recovery measures. In this study, the Bow-Tie Method (BTM) was used. The following are a summary of each mine's key prevention controls and recovery

**Table 3. Mine A's completed PHA form showing the risk ranking of the 25 potential unwanted events.**

| # | **Potential Unwanted Event** | **L** | C | R# | RR |
|---|---|---|---|---|---|
| 1 | Floor hooves and delays development mining | 1 | 1 | 25 | VL |
| 2 | Floor hooves and compromises ventilation | 1 | 1 | 25 | VL |
| 3 | Floor hooves catastrophically | 2 | 3 | 17 | L |
| 4 | Floor hooves and blocks travel | 1 | 3 | 20 | L |
| 5 | Rib instability injures miner | 4 | 2 | 14 | M |
| 6 | Rock falls between bolts injuring miner | 4 | 2 | 14 | M |
| 7 | Rock falls from above the roof bolt horizon covers continuous miner requiring recovery actions | 2 | 5 | 7 | H |
| 8 | Large roof fall collapse traps miner | 3.5 | 3 | 11 | M |
| 9 | Large roof fall outby the pillar line injuries miners | 1 | 4 | 16 | L |
| 10 | Poor or delayed roof caving(i.e., cantilevered roof) and causes coal pillar failure | 1 | 3 | 20 | L |
| 11 | Main roof doesn't cave and causes coal pillar failure | 3.5 | 3 | 11 | M |
| 12 | Windblast generated by large caving event injuries miners | 1 | 3 | 20 | L |
| 13 | Barrier pillar fails injuring | 1 | 1 | 25 | VL |
| 14 | Chain pillars in mains fail disrupting transportation throughout the mine | 1 | 1 | 25 | VL |
| 15 | Development pillar fails at face injuring miner | 2 | 4 | 12 | M |
| 16 | Development pillar fails several rows outby disrupting travel | 3 | 4 | 8 | H |
| 17 | Water from overlying mine enters section and damages floor | 5 | 1 | 15 | M |
| 18 | Water from overlying mine inundates section | 1 | 2 | 23 | VL |
| 19 | Barrier pillar gob combines with adjacent longwall panel gob because of pillar collapse allowing gob gas into the face | 1 | 1 | 25 | VL |
| 20 | Differential subsidence in the workings of the new overlying mine is caused by the current mining of the barrier pillar. | 3 | 2 | 18 | VL |
| 21 | Damage to currently barrier pillar from overlying stress caused by multiple seam interactions | 4 | 2 | 14 | M |
| 22 | Active subsidence occurs when overlying mining dynamically interacts with the mining of the barrier pillar | 5 | 4.5 | 2 | VH |
| 23 | Miner injures back from handling heavy materials | 3 | 2 | 18 | L |
| 24 | Continuous miners excavates rib bolts and strikes/injures miner | 1 | 3 | 20 | L |
| 25 | Massive dynamic failure of barrier pillar | 1 | 5 | 11 | M |

L = Likelihood of Occurrence R = Risk number (based on L x C)
C = Consequence of the Event RR = Risk Rank

measures used during pillar retreat mining. These controls and measures represent a potential partial list of Best Practices for other deep cover pillar retreat mining.

Mine A's Existing Prevention Controls and Recovery Measures

The limited time available for the risk assessment exercise did not allow the team to completely address the issue of recovering from the priority unwanted events. However, two of the highest risk potential unwanted events were examined. Table 5 is presented to demonstrate what consequence and recovery measure might be associated with two priority unwanted events. The major point of this activity is to consider: 1) how the mining operation could react to a potential unwanted event while mining the barrier pillar, and 2) identify impediments to this reaction when the potential unwanted event is placed at different locations within the section.

Mine B's Existing Prevention Controls and Recovery Measures

The limited time available for the risk assessment exercise did not allow the team to completely address the issue of recovering from the priority unwanted events. However, one of the highest risk potential unwanted events, roof falls, was examined. Table 6 is presented to demonstrate what prevention controls and recovery measure might be associated with two priority unwanted events.

**Step 5 - Determine New Prevention Controls and Recovery Measures**

One of the most important outcomes of any risk assessment is the identification of potential new controls that might help to mitigate the risk associated with the recognized hazards. The two risk assessment teams at the study mines identified 14 new potential controls and 2 new recovery measures (Table 7). These new ideas were submitted to management in the form of an Action Plan. The

**Table 4. Mine B completed PHA form showing the risk ranking of the 12 potential unwanted events.**

| # | **Potential Unwanted Event** | **L** | C | R# | RR |
|---|---|---|---|---|---|
| 1 | Rock falls on equipment requiring recovery | 2 | 2 | 5 | H |
| 2 | Rock fall on equipment retrieval unit(wire rope damaged) | 4 | 5 | 20 | L |
| 3 | Coal bump injures miner | 4 | 2 | 8 | M |
| 4 | Rib fall injures miner | 2 | 2 | 4 | H |
| 5 | Water inundation associated with a rock fall(water from upper seam) | 4 | 5 | 20 | L |
| 6 | Miner injured while running during a pillar fall | 3 | 4 | 12 | M |
| 7 | Material handling injury from lifting heavy equipment | 4 | 4 | 16 | L |
| 8 | Large roof cave causes gas emission problem interrupting ventilation | 3 | 5 | 15 | M |
| 9 | Large roof cave causes air blast injuring miners | 2 | 4 | 8 | M |
| 10 | Weighting or pressure on pillars cause rock instability | 2 | 4 | 8 | M |
| 11 | Roof support fails injuring miner | 4 | 3 | 12 | M |
| 12 | Rock falls on miner | 2 | 2 | 4 | H |

L = Likelihood of Occurrence R = Risk number (based on L x C)
C = Consequence of the Event RR = Risk Rank

**Table 5. Summary of Mine A's existing potential controls and recovery measures.**

<table>
<tr><th></th><th>Dynamic Interaction Caused by Active Subsidence</th><th>Roof Falls above the Roof Bolt Horizon</th></tr>
<tr><td rowspan="4">Existing Prevention Controls</td><td>Appropriate mine plan - The timing between mining the Barrier Pillar and the overlying mine are managed.</td><td>Effective layouts - Pillars are not mined under the overlying old workings or when overburden is greater than 1,200-ft.</td></tr>
<tr><td rowspan="2">Effective mine design - The plan to mine the Barrier Pillar requires the barrier, development and extraction pillars to be sized in accordance with the recommended Stability Factor determined from NIOSH's Analysis of Retreat Mining Pillar Stability, or ARMPS, method. These factors are based on the assumption that the mine is not bump prone. The risk assessment team members were not aware of any past bump incident at the mine.</td><td>Efficient monitoring - Numerous monitoring activities are used including test holes, strobe lights and gages on the MRSs and Geologic Shift Reports.</td></tr>
<tr><td>Safe pillar extraction process - Ground support near the pillar line follows best practice with two sets of MRS Units and intersection cable bolting systems. Several procedural controls are used to keep miners out of the areas with known hazards. Section workers are trained to monitor the MRS and if a unit goes to yield, they are instructed to pull out and reset the unit. Pillar stumps are at least 10 by 10-ft in dimension and are marked to maintain their minimum size.</td></tr>
<tr><td>Stability while mining - In addition to the primary support system used during development mining, the Barrier Pillar has 2 rows of 6 by 8-inch wood posts on 2 to 4-ft spacing to control minor levels of dynamic interaction.</td><td>Successful audits - Workers are trained to be aware of the red and yellow zone markings. The mine's Safety and Health Team audits the performance of section crew to make sure that safety and health policies and procedures are being adhered to.</td></tr>
<tr><td rowspan="5">Recovery Measures</td><td colspan="2">Two entries have standing supports (6 by 8 posts on 2 to 4-ft spacing)</td></tr>
<tr><td colspan="2">Anchors and other hardware for the Miner Retriever are on the section</td></tr>
<tr><td colspan="2">Nitrous oxide for first aid</td></tr>
<tr><td colspan="2">Transportation for quick evacuation</td></tr>
<tr><td colspan="2">Air bags on section for lifting / moving heavy material, i.e. broken rock, etc.</td></tr>
</table>

**Table 6. Summary of Mine B's existing potential controls and recovery measures.**

| | Roof Falls on Miner |
|---|---|
| *Existing Prevention Controls* | Supplemental support in the form of a star bolt pattern is installed in the recovery area |
| | Test holes are drilled at the beginning of each shift and at intervals not to exceed 40-ft thereafter |
| | Test holes are examined to gather additional information on rock characteristics |
| | Workers observe roof conditions |
| | Examinations of working places, i.e. by Foreman and continuous miner operator (20-min intervals) |
| | Measure entry widths to ensure they are approximately 19-ft |
| | Measure cut-widths and marked on the rib and roof |
| | Cuts are made at no more than 45-deg angles from headings and are no more than the width of the miner head. The continuous miner moves straight in and backs straight out |
| | Personnel placement is such that all workers are positioned outby, with the exception of the continuous miner operator, and those required to watch conditions. In particular, the MRS operator watches for continuous miner operator at the outby intersection |
| | The continuous miner pump motor is turned off when setting timber or MRS to increase workers ability to hear rock noise |
| | MRSs are positioned to add stability to the area and pressures are monitored |
| | The continuous miners can reboot quickly (< 1.5-min) after shutdown assisting in quick relocation |
| *Recovery Measures* | Communication at the primary intake and feeder or power center are available for calling out to dispatcher |
| | If workers are injured, contact MSHA immediately, otherwise contact MSHA one hour after a roof fall |
| | Mine B has a SOP for "Clean-Up Procedures for Rock Falls" |
| | There is an EMT on most sections |
| | First response kits are available ($O_2$ bottles, blood pressure, airway, EMT equipment) |
| | Supervisors get 5-hr of extra first aid training |
| | Emergency stretcher on every section |
| | 10-ton lifting Jack and bar on every section |
| | An equipment retrieval unit is located in the surface yard and can be deployed to the section quickly |

ideas presented in Table 7 might also be of value for other deep cover retreat mining operations.

## DISCUSSION: A DEEP COVER RETREAT MINING RISK MANAGEMENT PLAN

A significant advantage of the MHRA technique is the listing of the mine's prevention controls and recovery measures. These lists represent a partial inventory of Best Practices for deep cover retreat mining. The MHRA exercise demonstrates the value of focusing an operation's attention on specific hazards. It also helps to reinforce the existing prevention controls and recovery measures used by the mining operation and brain-storm new ideas that might help to lower the risk.

A significant limitation of the MHRA technique centers on its inability to determine how well controls are actually applied. For example, the majority of the controls identified by the two risk assessment teams consist of procedures that rely on personnel skills and training. These kinds of controls often require administrative procedures and clear work processes. They have the potential for significant human error and can be only marginally effective in reducing risks. In these cases, regular audits and reviews are needed to provide assurances to mine management that the controls are being applied to some operational standard.

Clearly, the MHRA exercise alone will not assure the risks are mitigated. It is recommended that all the actions defined by the MHRA process be incorporated into some kind of deep cover retreat mining Risk Management Plan (RMP). The RMP should be a component of the mine's overall safety and health management system. It should represent a management process by which hazards are identified and risks are continually and systematically assessed, and either eliminated or controlled, from design through to abandonment of the mining section. In this example, the RMP would be solely focused on the deep cover retreat pillar risks. In practice, all RMP's could be linked to the mines overall RMP for all known major hazards.

A RMP would only be adequate if individuals who have roles relating to the outlined activities have the responsibility and authority to carry out these actions. It is also important to note that mine management has the overall responsibility, implementation, and coordination for the actions described above. As is the case with all safety and health management systems, communications of the plan to relevant parts of the workforce will help to ensure that all personnel with responsibilities under the plan are informed. This requires targeted, regularly scheduled, training. It also requires that the plan be monitored and some kind of audit process will be established.

**Table 7. New ideas lowering the risk associated with the priority unwanted events.**

| Control Type | **New Ideas** |
|---|---|
| Prevention controls | Reinforce MRS proper placement during cut(lift) extraction, i.e., move one MRS at a time |
| | Evaluate personnel placement issues to assure that only necessary personnel enter high risk areas on the pillar line |
| | Section Foreman watches the mining of the final cut from a remote location and sounds an air horn if unstable conditions are observed |
| | Measure intersection diagonals to make sure entry spans are within acceptable standards |
| | Locate dips in the coalbed, i.e., points of highs and lows |
| | Place geologic and rock damage information on maps, i.e., fractures, roof falls, rib damage, intersection spans, etc., and attempt to develop risk maps prior to mining |
| | Study the advantages of installing cable trays on continuous miners, allowing the continuous miner to be re-handed to optimize the position of the miner operator |
| | Integrate information collected from other areas into current pre-retreat/daily safety training, i.e., geologic map, etc. Make training more specific to the panel or section being mined. Post this information in the dinner hole |
| | Each roof bolter collects roof rock type information and engineer puts this information on a mine map |
| | Incorporate personnel placement during pillaring, i.e., where not to be (the 'red-zone' concept) into an SOP |
| | Consider clipping corners of outby pillars to facilitate taking lifts from the crosscut |
| | Formalize the orientation and placement of future mining to control subsidence damage in the future mining of the overlying mine |
| | Investigate using tell-tails for ground stability characterization, i.e., roof fall and squeeze warning |
| | Determine the length of time needed to minimize dynamic interaction from undermining |
| Recovery measures | Investigate air bags on section for lifting / moving heavy material, i.e., broken rock, etc. |
| | Check on MSHA requirements for notification when continuous miner is trapped in a pillar cut |

## SUMMARY AND CONCLUSIONS

This NIOSH sponsored study was undertaken to evaluate the use of the MHRA technique to develop potential improvements in the way pillar retreat mines plan and mine deep cover coal. The MHRA's strength lies in its capacity to systematically evaluate complex mining processes and their associated hazards that present significant consequence to the operation. A list of potential unwanted events is developed and risk ranked. The mining operation's most knowledgeable personnel then focus on identifying a list of all existing prevention controls and recovery measures associated with each high risk potential unwanted event. During this process new ideas are identified and presented to mine management in the form of an Action Plan that should be evaluated further.

Several important facts were observed by the authors as a result of these two MHRA exercises. Mining operations benefit from activities that help them focus on potential unwanted events. Many low probability events, like the ones discussed in this study, rarely happen, but when they do, they can have significant consequences. Discussing all existing prevention controls and recovery measures helps to re-focus the operation, making sure that all the necessary systems are being applied to monitor and audit these most important actions. Because it is difficult to quantify the impact of actions in the reduction of risk, the most proactive RMP continually apply more robust prevention controls. They also apply additional measures that will help them quickly recovery from these events with little consequence to the mining operations and its miners. The MHRA process shows potential in helping to lessen risk associated with deep cover pillar retreat mining operations.

## DISCLAIMER

This work was part of a larger NIOSH research project. NIOSH was responsible for: 1) facilitating the risk assessment process known as Major Hazard Risk Assessment (MHRA), 2) documenting the risk assessment process, and 3) providing mine management with a written draft summary of the risk assessment process. The findings and conclusions in this report have not been formally disseminated by the National Institute for Occupational Safety and Health or the University of Pittsburgh and should not be construed to represent agency determination or policy.

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