Exhibit E

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UNITED STATES
DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION

COAL MINE SAFETY AND HEALTH

REPORT OF INVESTIGATION

Underground Coal Mine

Fatal Underground Coal Burst Accidents
August 6 and 16, 2007

Crandall Canyon Mine
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Huntington, Emery County, Utah
ID No. 42-01715

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PREFACE

This investigation was conducted by the Mine Safety and Health Administration (MSHA) under the authority of The Federal Mine Safety and Health Act of 1977 (Mine Act). The Mine Act requires that authorized representatives of the Secretary of Labor make investigations in coal and other mines for the purpose of obtaining, utilizing, and disseminating information relating to the causes of accidents. The objective of MSHA's accident investigations is to determine the root cause(s) of the accident and to utilize and share this information with the mining community and others for the purpose of preventing similar occurrences. MSHA's accident investigations include determinations of whether violations of the Mine Act or implementing regulations contributed to the accident. In addition to providing critical, potentially life-saving information, the findings of these investigations provide a basis for formulating and evaluating MSHA health and safety standards and policies.

In addition to the traditional accident investigation, the Secretary of Labor also appointed an independent review team. The independent review will consist of a thorough examination of written mine plans (including the mine's approved roof control plan), inspection records, and other documents relevant to the Crandall Canyon Mine and interviews of MSHA employees with personal knowledge of MSHA's inspection responsibilities and enforcement procedures at the mine. This review will provide a comparison of MSHA's actions at the Crandall Canyon Mine with the requirements of the Mine Act (as amended by the Mine Improvement and New Emergency Response Act of 2006), its standards and regulations, and MSHA policies and procedures. The findings of the independent review will result in the development of recommendations to improve MSHA's enforcement program and the agency's oversight of rescue and recovery programs in the aftermath of mine accidents. Copies of this review will be made available to the families of the miners involved in the Crandall Canyon Mine accident, Congress, and the public.

The tragic accidents at the Crandall Canyon Mine in August 2007 occurred when overstressed coal pillars suddenly failed, violently expelling coal from the pillars into the mine openings. Locally referred to in Utah as a "bounce," terminology for this type of event differs regionally, and is also known as an outburst, bump, or burst. Bounces and bumps are broader terms that can include any dull, hollow, or thumping sound produced by movement or fracturing of strata as a result of mining operations. In many cases, vibrations in the strata resulting from such movement can be felt by miners and detected by seismographic instruments. Bounces resulting from intentional caving, where strata in active workings remain intact, are common in deep coal mines and do not pose a threat to miners. However, coal or rock bursts, also known as outbursts[1*], are those bounces specifically characterized by the sudden and violent failure of overstressed rock or coal resulting in the instantaneous release of large amounts of accumulated energy with the ejection of material. When such events occur in active workings, they pose a serious hazard to miners. Federal mine safety standards, therefore, require that the roof, face, and ribs be controlled to protect persons from hazards related to bursts through proper ground support and pillar dimensions. Also, coal or rock outbursts that cause withdrawal of miners or which disrupt regular mining activity for more than one hour are defined as accidents (even if no miners are injured) and must be immediately reported to MSHA, as required by relevant portions of 30 CFR 50. Definitions for these and other terms are provided in Appendix Y. Any references to product manufacturers, distributors, or service providers are intended for factual documentation and do not imply endorsement by MSHA.

[*] References identified by superscript numbers are listed in Appendix Z.

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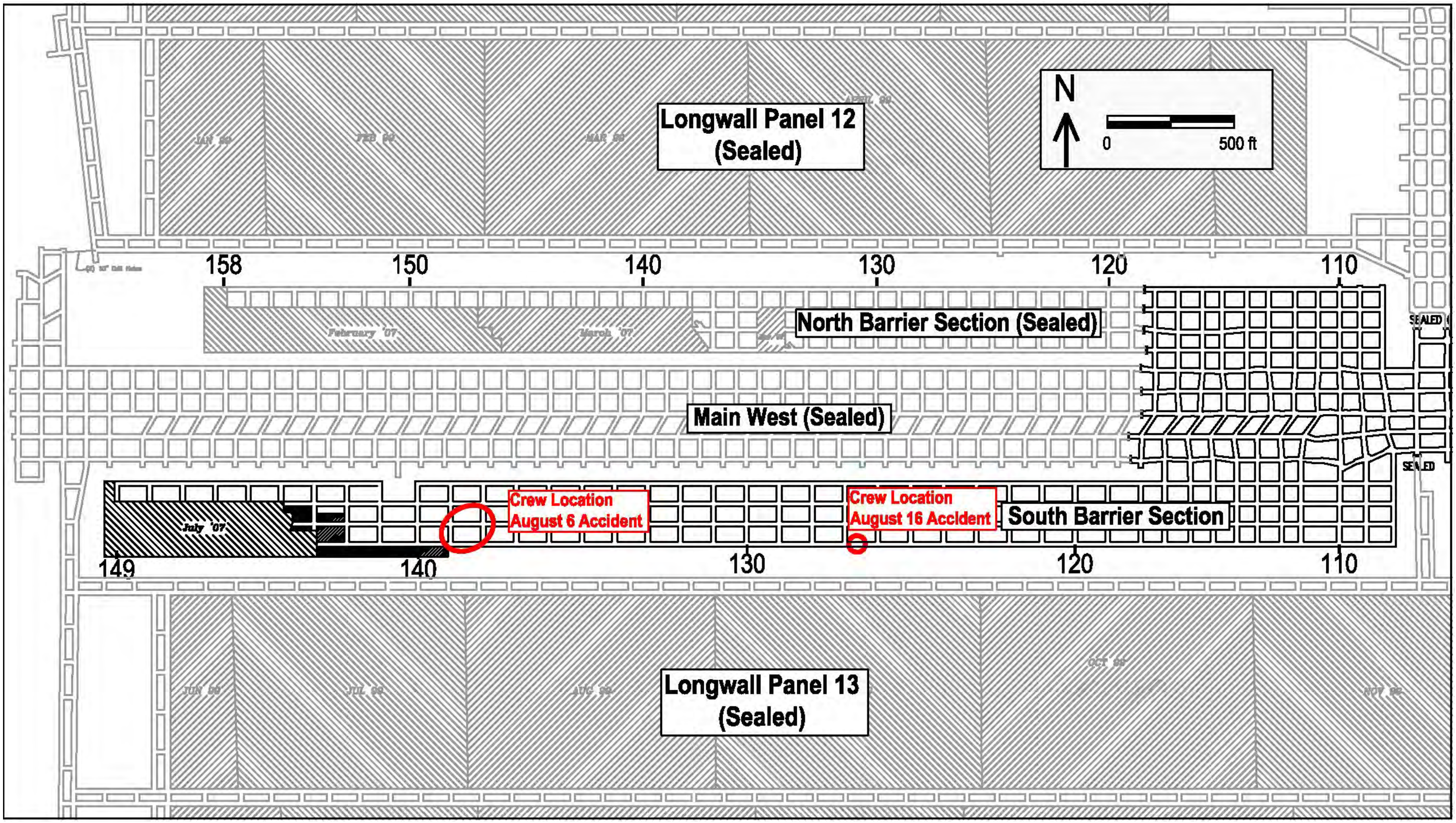


Figure 1 - Map of Accident Sites

EXECUTIVE SUMMARY

The August 6 and 16 Accidents

The Crandall Canyon Mine, in Emery County, Utah, was operated by Genwal Resources Inc (GRI), whose parent company was acquired by a subsidiary of Murray Energy Corporation in August 2006. On August 6, 2007, at 2:48 a.m., a catastrophic coal outburst accident occurred during pillar recovery in the South Barrier section, while the section crew was mining the barrier near crosscut 139. The outburst initiated near the section pillar line (the general area where the miners were working) and propagated toward the mine portal.

Within seconds, overstressed pillars failed throughout the South Barrier section over a distance of approximately ½ mile. Coal was expelled into the mine openings on the section, likely causing fatal injuries to Kerry Allred, Don Erickson, Jose Luis Hernandez, Juan Carlos Payan, Brandon Phillips, and Manuel Sanchez. The barrier pillars to the north and south of the South Barrier section also failed, inundating the section with lethally oxygen-deficient air from the adjacent sealed area(s), which may have contributed to the death of the miners. The resulting magnitude 3.9 seismic event shook the mine office three miles away and destroyed telephone communication to the section.

Federal and local authorities responded to the accident. MSHA issued an order pursuant to section 103(k) of the Mine Act that required GRI to obtain MSHA approval for all plans to recover or restore operations to the affected area. Mine rescue teams were organized, a command center was established, and a rescue effort was initiated. After unsuccessful attempts to reach the miners by crawling over the debris, GRI developed a rescue plan, approved by MSHA, to access the entrapped miners by loading burst debris from the South Barrier section No. 1 entry using a continuous mining machine. These efforts began on August 8 at crosscut 120.

On August 16, 2007, at 6:38 p.m., a coal outburst occurred from the pillar between the No. 1 and No. 2 entries, adjacent to rescue workers as they were completing the installation of ground support behind the continuous mining machine. Coal ejected from the pillar dislodged standing roof supports, steel cables, chain-link fence, and a steel roof support channel, which struck the rescue workers and filled the entry with approximately four feet of debris. Ventilation controls were damaged and heavy dust filled the clean-up area, reducing visibility and impairing breathing. Also, air from inby the clean-up area containing approximately 16% oxygen migrated over the injured rescue workers. Nearby rescue workers immediately started digging out the injured miners and repairing ventilation controls. Two mine employees, Dale Black and Brandon Kimber, and one MSHA inspector, Gary Jensen, received fatal injuries. Six additional rescue workers, including an MSHA inspector, were also injured.

Underground rescue efforts were suspended while a group of independent ground control experts reevaluated conditions and rescue methods, although surface drilling continued. In total, seven boreholes were drilled from the surface to the mine workings. Each successive borehole provided information as to conditions in the affected area and helped to determine the location of the next hole. None of the boreholes identified the location of the entrapped miners. Ultimately, it was learned that the area where the miners were believed to have last been working sustained extensive pillar damage and had levels of oxygen that would not have sustained life.

Explanation of the August 6 Collapse

The August 6 collapse was not a “natural” earthquake, but rather was caused by a flawed mine design. Ultimately, it is most likely the stress level exceeded the strength of a pillar or group of pillars near the pillar line and that local failure initiated a rapid and widespread collapse that propagated outby through the large area of similar sized pillars.

Three separate methods of analysis employed as part of MSHA's investigation confirmed that the mining plan was destined to fail. Results of the first method, Analysis of Retreat Mining Pillar Stability (ARMPS), were well below NIOSH recommendations. The second method, a finite element analysis of the mining plan, indicated a decidedly unsafe, unstable situation in the making even without pillar recovery. Similarly, the third method, boundary element analysis, demonstrated that the area was primed for a massive pillar collapse. Seismic analyses and subsidence information employed in the investigation provided clarification that the collapse was most likely initiated by the mining activity. Information provided by the University of Utah Seismograph Stations (UUSS) and from satellite radar images also helped in defining the nature and extent of the collapse.

The extensive pillar failure and subsequent inundation of the section by oxygen-deficient air occurred because of inadequacies in the mine design, faulty pillar recovery methods, and failure to adequately revise mining plans following coal burst accidents.

GRI's mine design was inadequate and incorporated flawed design recommendations from contractor Agapito Associates, Inc. (AAI). Although AAI had many years of experience at this mine and was familiar with the mine conditions, they conducted engineering analyses that were flawed. These design issues and faulty pillar recovery methods resulted in pillar dimensions that were not compatible with effective ground control to prevent coal bursts under the deep overburden and high abutment loading that existed in the South Barrier section.

AAI's analysis using the engineering model known as "ARMPS" was inappropriately applied. They used an area for back-analysis that experienced poor ground conditions and did not consider the barrier pillar stability factors in any of their analyses. The mine-specific ARMPS design threshold proved to be invalid, as evidenced by March 7 and 10, 2007, coal outburst accidents and other pillar failures. Despite these failures, AAI recommended a pillar design for the South Barrier section that had a lower calculated pillar stability factor than recommended by the National Institute for Occupational Safety and Health (NIOSH) criteria, lower than established by their mine specific criteria, and lower than the failed pillars in the North Barrier section. AAI performed the ARMPS analysis for the South Barrier section, but did not include these results in their reports that were presented to MSHA in support of GRI's plan submittal.

AAI's analysis using the engineering model known as "Lamodel" was flawed. They used an area for back-analysis that was inaccessible and could not be verified for known ground conditions, which resulted in an unreliable calibration and the selection of inappropriate model parameters. These model parameters overestimated pillar strength and underestimated load. AAI modeled pillars with cores that would never fail regardless of the applied load, which was not consistent with realistic mining conditions. They did not consider the indestructible nature of the modeled pillars in their interpretation of the results. Modeled abutment stresses from the adjacent longwall panels were underestimated and inconsistent with observed ground behavior and previous studies at this and nearby mines.

AAI managers did not review input and output files for accuracy and completeness. They also did not review vertical stress and total displacement output at full scale, which would have shown unrealistic results and indicated that corrections were needed to the model. Following the March 10 coal outburst accident, AAI modified the model, but failed to correct the significant model flaws. They did not make further corrections to the model when this analysis result still did not accurately depict known failures that AAI and GRI observed in the North Barrier section.

The mine designs recommended by AAI and implemented by GRI did not provide adequate ground stability to maintain the ventilation system. The designs did not consider the effects of barrier pillar and remnant barrier pillar instability on separation of the working section from the adjacent sealed areas. Failure of the barrier pillars or remnant barrier pillars resulted in inundation of the section by lethally oxygen-deficient air. AAI and GRI also did not consider the effects of ground stability on ventilation controls in the bleeder system. GRI allowed frequent destruction of ventilation controls by ground movement and by air blasts from caving. GRI mined cuts from the barrier pillar in the South Barrier section between crosscuts 139 and 142 intended to be left unmined to protect the bleeder system.

GRI's mining practices, including bottom mining and additional barrier slabbing between crosscuts 139 and 142, reduced the strength of the barrier and increased stress levels in the vicinity of the miners. As pillars were recovered in the South Barrier section, bottom coal (a layer of coal left in the mine floor after initial mining) was mined from cuts made into the production pillars and barrier. The effect of this activity was to reduce the strength of the remnant barrier behind the retreating pillar line. Bottom mining was not addressed in AAI's model to evaluate the mine design or in GRI's approved roof control plan. Similarly, barrier mining was conducted in violation of the approved roof control plan. A portion of the barrier immediately inby the last known location of the miners was mined even though it was required by the roof control plan to be left unmined. Barriers are solid blocks of coal left between two mines or sections of a mine to provide protection. Although neither of these actions is a fundamental cause of the August 6 collapse, they increased the amount of load transferred to pillars at the working face and reduced the strength of the barrier adjacent to it.

The mine operator did not report three coal outbursts that occurred prior to August 6 to MSHA or properly revise its mining plan following these coal bursts. Between late 2006 and February 2007, the 448-foot wide barrier north of Main West was developed by driving four entries parallel to the existing Main West entries. Smaller barriers remained on either side of the new section entries (53 feet wide on the south side and 135 feet wide on the north side). The 135-foot wide barrier that separated the North Barrier section from the adjacent longwall panel gob was insufficient to isolate the workings from substantial abutment loading. Despite the high stress levels associated with deep cover (up to 2,240 feet of overburden) and longwall abutment stress, the section remained stable during development. However, as pillar recovery operations retreated under a steadily increasing depth of overburden, conditions worsened. On March 7, 2007, a non-injury coal outburst accident occurred that knocked miners down, damaged a ventilation control, and caused a delay in mining. These worsening conditions culminated in a March 10, 2007, outburst accident of sufficient magnitude to cause the mining section to be abandoned.

Between March and July 2007, four entries were developed in the barrier south of Main West. Once again, the section was developed without incident but conditions worsened during pillar recovery. On August 3, 2007, another non-injury coal outburst accident occurred as the night shift crew was mining. Coal was thrown into the entries dislodging timbers and burying the continuous mining machine cable. The continuous mining machine operator was struck by coal.

GRI did not notify MSHA of these three coal outburst accidents within 15 minutes as required by 30 CFR 50.10. GRI's failure denied MSHA the opportunity to investigate these accidents and ensure that corrective actions were taken before mining resumed in the affected area. GRI did not submit written reports of these accidents to MSHA or plot coal bursts on a mine map available for inspection by MSHA and miners as required.

These reporting failures were particularly critical because they deprived MSHA of the information it needed to properly assess and approve GRI's mining plans. Under Federal regulations, a mine operator is required to develop and submit to MSHA a "roof control plan" suitable to the prevailing geological conditions and the mining system to be used at the mine. MSHA has an opportunity to review and approve or disapprove the plan. MSHA had specifically separated the operator's proposed mining plans into four separate plans, addressing different stages of the mining process, and had asked the mine operator to communicate any problems encountered so that MSHA could evaluate the safety of the plans as mining progressed. MSHA was only to approve the "retreat mining" phases of the project if favorable conditions were observed during development of the sections. However, the operator failed to make MSHA aware of the extent of the violent conditions encountered during mining and did not make MSHA aware of the severity of the March 10 coal outburst. MSHA approved the operator's plans to conduct retreat mining in the South Barrier, where the fatal accident ultimately occurred, without the benefit of this critical information.

Additionally, GRI continued pillar recovery without adequately revising their mining methods when conditions and accident history indicated that their roof control plan was not suitable for controlling coal bursts. GRI investigations of non-injury coal burst accidents did not result in adequate changes of pillar recovery methods to prevent similar occurrences before continued mining. GRI did not consult with AAI or propose revisions to their roof control plan following the August 3, 2007, coal outburst accident in the South Barrier section, even though pillar conditions were similar to the failed area in the North Barrier section.

Explanation of the August 16 Accident

The August 16 accident occurred because rescue of the entrapped miners required removal of compacted coal debris from an entry affected by the August 6 accident. Entry clean-up reduced confining pressure on the failed pillars and increased the potential for additional bursts. Methods for installing ground control systems required rescue workers to travel near areas with high burst potential. Methods were not available to determine the maximum coal burst intensity that the ground support system would be subjected to. On August 16, the coal burst intensity exceeded the capacity of the support system. No alternatives to these methods were available to rescue the entrapped miners. As a result, only suspension of underground rescue efforts could have prevented this accident.

Prior to the August 16 accident, underground rescue efforts were only likely to have been suspended had definitive information been available to indicate that the entrapped miners could not have survived the accident. Information was not sufficient to fully evaluate conditions on the section prior to this accident. Sufficient resources, including drilling resources, should have been deployed. The rescue attempt imposed greater risks on rescue workers than would be accepted for normal mining. However, the prospect of saving the entrapped miners' lives warranted the heroic efforts of the rescue workers. The greater risks imposed on the rescue workers underscore the high degree of care that must be taken by mine operators to prevent catastrophic pillar failures.

GENERAL INFORMATION

The Crandall Canyon Mine, located near Huntington in Emery County, Utah, was opened into the Hiawatha bituminous coal seam through five drift openings. At the time of the accident, the mine operated with one working section (South Barrier section) and one spare section (3rd North section). The miners, including 63 underground and 4 surface employees, were not represented by a labor organization. Coal was loaded from a continuous mining machine onto shuttle cars and transported to the section loading point, where it was dumped onto a belt and conveyed to the surface. Personnel and materials were transported via diesel-powered, rubber-tired, mobile equipment. An atmospheric monitoring system (AMS) was used for fire detection and monitoring other mine systems, including: electrical power, conveyor belt status, tonnage mined, air quality, and fan operation. An AMS operator was stationed on the surface to monitor and respond to AMS signals and alarms. Two-way voice communication was provided by pager phones installed throughout the underground mine and hardwired to various locations on the surface. A Personal Emergency Device (PED) system was used at the mine to send one-way text messages from the surface to selected miners who wore PED receiver units integrated with their cap lamp battery. To comply with the post-accident tracking requirements of the MINER Act, GRI established five zones from the portal to the South Barrier section for tracking the location of underground personnel (see Appendix C). As miners passed from one zone to another, they reported their location over the pager phone system to the AMS operator who tracked their movements.

Coal was mined seven days per week during two 12-hour shifts. Day shift production crews worked from 7:00 a.m. to 7:00 p.m. and night shift production crews worked from 6:00 p.m. to 6:00 a.m. Maintenance personnel worked 5:00 a.m. to 5:00 p.m. during day shift and 5:00 p.m. to 5:00 a.m. during night shift. One set of day and night shift crews worked Monday through Thursday and another set worked Friday through Monday. Everyone worked on Monday, which was referred to as a "double-up day." Preshift examinations were conducted on established 8-hour intervals beginning at 3:00 a.m., 11:00 a.m., and 7:00 p.m.

The coal resources within the Crandall Canyon Mine mining permit boundary are owned by either the Federal Government or the State of Utah and are leased for mining to GRI. The U.S. Department of the Interior through the Bureau of Land Management (BLM) manages the Federal coal and the Utah School and Institutional Trust Lands Administration manages the State coal. Mining plans for the Federal leases must be approved by BLM and must comply with a Resource Recovery Protection Plan (R2P2) to ensure diligent extraction of all minable coal. The R2P2 is approved by BLM, within the mining capabilities of the operator, to achieve maximum economic recovery of the Federal coal. BLM inspectors monitor compliance with the approved R2P2 through underground inspections. Since the mine is entirely within the Manti-LaSal National Forest, the R2P2 also addresses the impacts of mining on surface lands and water resources that are managed by the United States Forest Service.

The reserve was first opened between 1939 and 1955, when a small area at the portal was mined and then abandoned. Genwal Coal Company Inc rehabilitated the old mine workings and resumed production in 1983 (see Appendix D). Room and pillar mining was utilized and included pillar recovery (often referred to as retreat mining) from panels.

The mine was acquired by Nevada Power in 1989. In 1990, 50% interest was purchased by the Intermountain Power Agency (IPA), a political subdivision of the State of Utah. In 1995, Andalex Resources Inc (ARI), a Delaware corporation operating in Utah, acquired Nevada

Power's 50% ownership of the Crandall Canyon Mine. The other 50% ownership was retained by IPA. ARI operated the mine through its subsidiary Genwal Resources Inc (GRI). Also in 1995, GRI contracted Agapito Associates, Inc. (AAI), a mining consultant group based in Grand Junction, Colorado, to conduct technical studies for longwall mining the remaining reserves. Reports for these studies were finalized in November and December, 1995. The Main West entries, inby crosscut 107, were mined in 1995 with the intention of developing north-south oriented longwall panels from them. However, AAI's fracture orientation report (*Fracture Orientation Study and Implications on Longwall Panel Orientation*) recommended an east-west orientation for longwall panels, so the longwall entries were not developed from the Main West. AAI continued to provide consulting services to GRI, including a study to refine their ground control model for the Crandall Canyon Mine in 1997. In June 1999, a longwall district north of Main West was completed and sealed, leaving a 448-foot wide barrier north of Main West (North Barrier).

A longwall district south of Main West was mined from 1999 to 2003. The Main West entries were separated from these longwall panels by a 438-foot wide minimum dimension barrier (South Barrier). During this period, the Main West entries provided a return air course for the longwall bleeder system through a connection at the western end of these entries. This longwall district was sealed in April 2003, and longwall production moved to the eastern portion of the mine. The Main West was sealed inby crosscut 118 in November 2004 due, in part, to deterioration of roof and coal pillars caused by abutment loads from the adjacent longwall districts. GRI had planned to mine the Main West Barriers inby crosscut 118 by accessing them through Main West. The need to seal the Main West prompted GRI to propose revised mining projections to BLM. Also in 2003, GRI opened the adjacent South Crandall Canyon Mine and the two operations shared surface facilities.

The last longwall panel at the Crandall Canyon Mine was completed in October 2005. Mining was then limited to pillar recovery in the South Mains. Rooms were developed into barrier pillars adjacent to the South Mains, just ahead of the northward retreating pillar line. With this approach, barrier pillars outby the section loading point remained intact.

John T. Boyd Company, mining and geological consultants, conducted a coal reserve estimate for ARI in December 2005 that identified recoverable reserves in the Main West as areas outby the crosscut 118 seals. The map of the reserve estimate illustrated that both barriers would be recovered east of crosscut 118 by mining a series of 3-4 rooms north and south from the original 5-entry Main West, similar to the method used to recover the South Mains. In January 2006, Rothschild Inc. prepared a "Confidential Information Memorandum" for ARI to assist potential transaction parties. This document included a map entitled *"Crandall Canyon Mine Recoverable Reserves As Of January 1, 2006"* that also showed no projected mining in the Main West barriers west of crosscut 118.

Early in 2006, GRI devised a plan to develop and recover the Main West North and South Barriers inby crosscut 118. In April 2006, GRI contacted AAI to evaluate ground control and pillar stability associated with this plan. AAI provided a draft report to GRI (see Appendix F), which concluded that GRI's plan should be *"a workable design and limit geotechnical risk to an acceptable level."*

On August 9, 2006, UtahAmerican Energy Inc. (UEI), a Utah corporation, acquired ARI, including its wholly owned subsidiary GRI. UEI was wholly owned by Murray Energy Corporation, an Ohio corporation. Murray Energy Corporation's stock was wholly owned by

Robert E. Murray. AAI continued to work for GRI, and provided further analyses confirming the viability of GRI's plan to recover the Main West barriers (see Appendix G). Coal production ceased at the South Crandall Canyon Mine at the end of August.

During the last quarter of 2006, pillar recovery in the South Mains was completed and mining of the North Barrier section was initiated. Four entries were developed through the Main West North Barrier beneath overburden ranging from 1,500 to 2,240 feet. AAI visited the section on December 1, 2006, and reported that *"There was no indication of problematic pillar yielding or roof problems that might indicate higher-than-predicted abutment loads"* (see Appendix H). Pillar recovery began in February 2007. The two southern pillars were extracted and the northernmost pillar was left intact to establish a bleeder system.

On March 10, 2007, a non-injury coal outburst accident occurred on the North Barrier section that severely damaged pillars and ventilation controls and caused GRI to abandon the section. Mining equipment was moved to the South Barrier section while coal was produced on a spare section in the 3rd North Mains. The North Barrier section was sealed on March 27, 2007, inby crosscut 118, and GRI commissioned AAI to refine the pillar design for the South Barrier section. In this area, AAI recommended that GRI develop larger pillar dimensions, slab the barrier south of the No. 1 entry, and avoid skipping pillars during recovery under the deepest overburden (see Appendix I).

Four entries were developed through the length of the Main West South Barrier with entry centerlines spaced 80 feet apart and crosscut centerlines every 130 feet (80 x 130-foot centers) beneath overburden ranging from 1,300 to 2,160 feet. A 55-foot wide barrier separated the section from room notches mined off the No. 1 entry of the Main West, and a 121-foot wide barrier separated it from the sealed longwall Panel 13 to the south. The average mining height was approximately 8 feet. During development up to 5 feet of bottom coal was left in the western portion of the section.

Pillar recovery of the South Barrier section began on July 15, 2007, and continued until the August 6, 2007, accident. The approved roof control plan permitted mining up to 40 feet deep cuts into the barrier pillar south of the No. 1 entry during pillar recovery, except in the area between crosscuts 139 and 142 (see Appendix J). This area was to remain unmined to protect the bleeder entry where the section had been narrowed to three entries. Additional production was gained during pillar recovery by ramping down into the bottom coal during cuts from the pillars. Safety precautions for this type of mining were not addressed in the approved roof control plan.

Officials for parties controlling the mine operation at the time of the accidents included:

Robert E. Murray ....President, Murray Energy Corporation
P. Bruce Hill.............................. President and CEO of UEI, ARI, and GRI
Robert D. Moore ....Treasurer of UEI, ARI, and GRI
Michael O. McKown ....Secretary of UEI, ARI, and GRI
Laine Adair .... General Manager of UEI, ARI, and GRI
James Poulson.................................Safety Manager of UEI, ARI, and GRI
Gary Peacock ....Mine Superintendent of GRI
Bodee Allred ....Safety Director of GRI

Table 1 shows recent Non-Fatal Days Lost (NFDL) accident incidence rates for the mine prior to the fatal accidents, and the comparable national rates for mines of similar type and classification. A fatal accident (powered haulage) occurred at the Crandall Canyon Mine in 1997.

Table 1 - Accident Incidence Rates

Calendar Year	NFDL Incidence Rate National/Crandall	Total Incident Rate National/Crandall
2005	5.16/2.46	7.34/4.92
2006	4.83/2.50	6.99/2.50
2007	4.60/3.47*	6.35/3.47*

*2007 values for Crandall Canyon Mine are for January-June.

MSHA completed its last quarterly regular health and safety inspection of Crandall Canyon Mine on July 2, 2007. MSHA started a new inspection on July 5, 2007, which was ongoing at the time of the accidents.

DESCRIPTION OF THE ACCIDENT

August 6 Accident Description

Night shift mechanics Jameson Ward and Tim Harper started their shifts at 5:00 p.m. on August 5, 2007. Ward entered the mine at 5:10 p.m. and drove to the South Barrier section. Harper gathered supplies from the warehouse before entering the mine to set up a new scoop charging station at the junction of Main West and the 3rd North entries. When Ward arrived on the section, he parked his pick-up truck in the No. 1 entry, near the section charging station, and walked to the continuous mining machine in the No. 1 entry to see if they were having any maintenance problems. The day shift production crew was mining the barrier pillar between crosscuts 140 and 141. After 20 minutes, Ward returned to the section charging station and started repairing a scoop.

The night shift production crew entered the mine at 6:00 p.m. and traveled to the South Barrier section. Crew members included: Benny Allred (section foreman), Kerry Allred (shuttle car operator), Brandon Phillips (utility man), Jose Luis Hernandez (shuttle car operator), Manuel Sanchez (continuous mining machine operator), Don Erickson (shuttle car operator/step-up foreman), and Juan Carlos Payan (mobile roof support operator). They arrived on the section at 6:25 p.m. and relieved the day shift crew, which had mined a total of four cuts from the barrier pillar. Larry Powell (maintenance foreman) also arrived on the section at this time and helped Ward repair the scoop at the section charging station. Mining resumed in the barrier pillar after shift change.

At 7:44 p.m., a magnitude 2.2 seismic event originated near the section. Erickson was conducting the preshift examination near the charging station when he and Powell heard a noise that sounded like a large cave inby the pillar line. Erickson went to the face to investigate. He did not report any hazards during the preshift examination.

Gale Anderson (shift foreman), Benny Allred, and Powell were scheduled to attend training the next morning and planned to leave work early. Anderson traveled to the section and met with Erickson about his duties as responsible person and section foreman in their absence. They reviewed mining plans and work assignments. Mining in the barrier pillar was approaching crosscut 139. At this point, breaker posts would need to be set and the conveyor belt and power center would need to be moved outby before pillar recovery between the Nos. 1 and 3 entries could resume. Shortly after 9:00 p.m., Benny Allred gave his notebook and PED light to Erickson. Erickson gave his preshift report to Benny Allred to record in the examination book. Benny Allred asked Ward to help Erickson that night, if needed. Anderson, Benny Allred, and Powell left the section. Before leaving the mine, Anderson and Benny Allred met with outby mine examiners Brent Hardee, Tim Curtis, and Brian Pritt. Anderson provided them with a list of tasks and Benny Allred asked them to retrieve his Self-Contained Self-Rescuer (SCSR) from the section.

At approximately 11:30 p.m., Ward finished repairing the scoop and started helping Phillips move the first aid trailer and rock dusting machine outby. Curtis drove to the section and retrieved Benny Allred's SCSR before helping Hardee and Pritt clean out an area for storing conveyor belt structure at Main West crosscut 18. At 11:43 p.m., Richard Maxwell (material man) arrived at the mine and started making repairs to his diesel-powered supply tractor. Maxwell drove the tractor into the mine at 1:33 a.m., August 6, 2007, to check supplies on the section.

By 2:00 a.m., Ward and other section crew members had started setting breaker posts inby crosscut 139. Harper had finished work on the 3rd North charging station, but his truck would not start and he called Ward for assistance. Ward checked with Erickson to see if he could leave the section to help Harper. Erickson agreed, but told Ward that he needed to finish setting the breaker posts before leaving.

Hardee, Curtis, and Pritt completed cleaning the area at Main West crosscut 18 and drove their pick-up trucks outside, exiting the mine at 2:09 a.m. While on the surface, they unloaded material gathered from the work site. Pritt and Curtis reentered the Crandall Canyon Mine in a pick-up truck at 2:21 a.m., as Hardee prepared to conduct preshift examinations in the South Crandall Canyon Mine.

At approximately 2:30 a.m., Maxwell arrived at crosscut 133 of the South Barrier section and checked section supplies. No supplies were needed. He turned his tractor around and started driving back outby. At 2:36 a.m., Hardee entered the South Crandall Canyon Mine to conduct examinations. By 2:45 a.m., Ward had finished setting breaker posts. He called Harper to tell him he was on his way and left the section.

At 2:48 a.m., as the section crew continued mining the barrier pillar near crosscut 139, a catastrophic coal outburst accident initiated near the pillar line in the South Barrier section and, within seconds, pillar failures propagated outby to approximately crosscut 119. Coal was violently expelled into the entries where Kerry Allred, Don Erickson, Jose Luis Hernandez, Juan Carlos Payan, Brandon Phillips, and Manuel Sanchez were working. All approaches to the section were blocked, entrapping the six miners. The barrier pillars to the north and south of the South Barrier section also failed, inundating the entrapped miners' work area with lethally oxygen-deficient air from the adjacent sealed area(s).

The resulting magnitude 3.9 mining-induced seismic event shook the mine office, located on the surface three miles from the section, where it was felt by Leland Lobato and Mark Toomer, atmospheric monitoring system (AMS) operators. AMS alarms reported communication failure from sensors throughout the South Barrier section and the Nos. 6 and 7 conveyor belts stopped. Air displaced by the ground failure rushed outby in a dust cloud that destroyed or damaged stoppings from the accident site outby to crosscut 93 and the overcasts at crosscut 90 and 91. The resulting short circuit to the ventilation system reduced fan pressure by 1 inch water gauge (w.g.).

Ward had just exited the South Barrier section entries and was driving through Main West crosscut 109 when he was struck by the air blast, causing his truck to slide sideways (refer to Figure 2 for location of miners). Realizing that ventilation was disrupted, he got out of his vehicle to assess the situation. After confirming that the nearest two stoppings were destroyed, he drove to a phone at Main West crosscut 103.

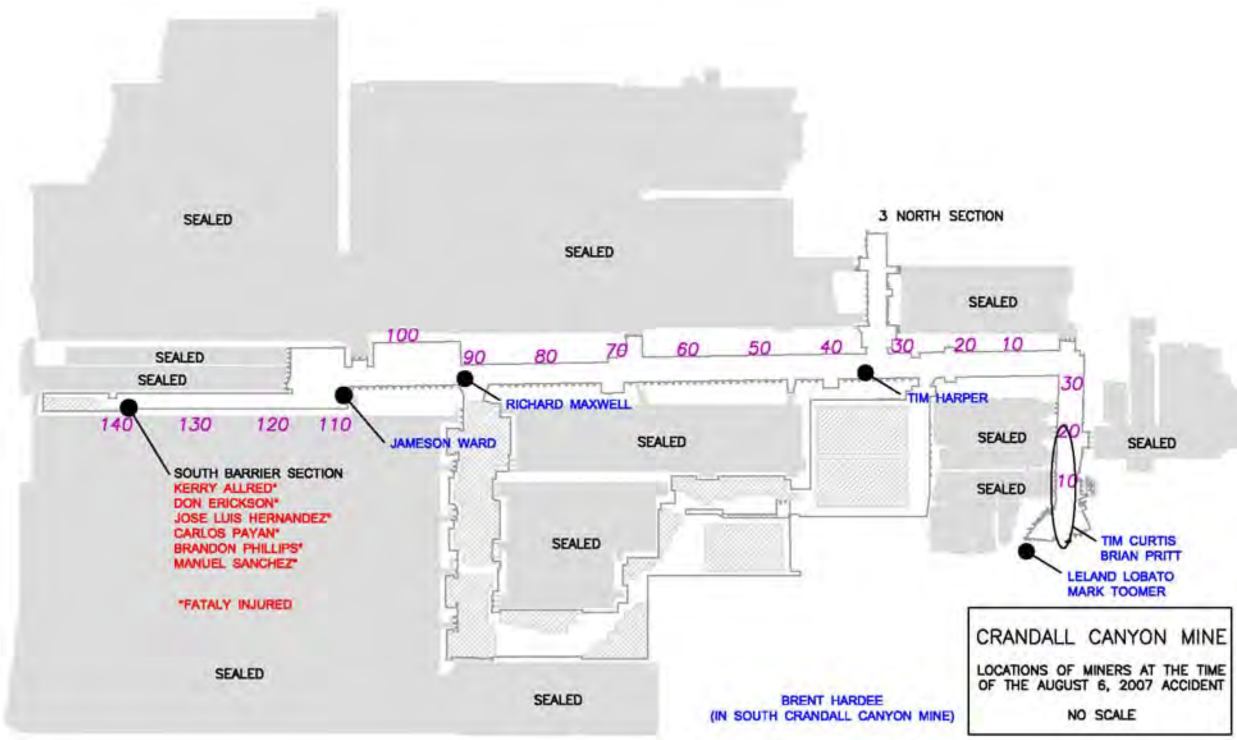


Figure 2 - Location of Miners during August 6 Accident

Maxwell was driving outby from the section at Main West crosscut 91 when his supply tractor was hit by the air blast. He was pelted in the open vehicle by dust and pieces of foam sealant from the destroyed ventilation controls. He continued driving outby to crosscut 85. After the dust cleared, he turned around and started driving inby.

Harper was waiting for Ward at Main West crosscut 35 when he heard a large rumble, which roared past him, high up in the mine roof. A large gust of air followed, blowing two nearby metal airlock doors open and closed. He was peppered with small rocks and his right eardrum was injured. Thinking that the event was a large roof fall close to his location, Harper went to a nearby phone and called Lobato, who was trying to contact the section. Lobato told Harper that the section had lost power, Nos. 6 and 7 belts were down, the water gauge on the fan changed, and the building he was in outside shook hard.

Pritt and Curtis were driving toward the mine entrance and did not feel the effects of the pillar failure. Hardee also did not feel the event from his location in the South Crandall Canyon Mine.

When Ward reached the phone at crosscut 103, he called Harper and they discussed their observations. Harper asked Ward to pick him up so they could travel to the section and find out what had happened. As Ward continued driving outby, Harper called Lobato and told him to contact Erickson and let him know that they were headed his way. Lobato sent a message to the PED light Erickson had been given, instructing him to call the AMS operator. As Ward reached crosscut 88, he passed Maxwell, who had stopped at a phone to call Lobato. Lobato told Maxwell that he thought an earthquake had occurred. Maxwell told Lobato to start calling the section. Lobato continued attempting to contact miners in the working section, without success. Maxwell drove inby crosscut 93, where he saw damaged stoppings and turned around and started driving outby.

Pritt and Curtis were unaware of the collapse when they exited the mine at 2:53 a.m. Pritt dropped Curtis off to start examining the No. 1 conveyor belt. Pritt drove his pick-up truck back into the mine to begin his preshift examination of the No. 2 conveyor belt. When he reached the Main West entries, at 3:01 a.m., Pritt received a PED message instructing him to call the AMS operator. He went to a nearby phone at Main West crosscut 4 and called Lobato, who briefed him on the situation. Pritt told Lobato to send a PED message to Erickson and let them know that he was on his way to the section. Pritt asked Lobato to contact Curtis and have him continue walking the belts inby until Pritt found out what was going on. Pritt also spoke to Harper, just before Ward arrived at crosscut 35. Ward picked up Harper and they sped toward the section, as Pritt started driving inby from crosscut 4. Lobato sent PED messages to Curtis, Hardee, and Erickson.

Ward and Harper encountered thick dust inby crosscut 96, where they saw destroyed stoppings. At approximately 3:12 a.m., they stopped just inby crosscut 113 where a large piece of coal blocked the roadway. Harper walked to a phone near crosscut 112 and called Lobato. Harper instructed him to call Gary Peacock (mine superintendent) and tell him that there was a cave-in, that all the stoppings were blown out inby crosscut 96, and that they were going to try to advance into the section. Meanwhile, Pritt met Maxwell near crosscut 88. Maxwell parked his supply tractor and got into Pritt's truck. They called Lobato and instructed him to notify Peacock that something had happened. Lobato telephoned Peacock at his home. Pritt and Maxwell continued driving toward the section as Ward and Harper explored inby crosscut 113.

Pritt and Maxwell arrived near crosscut 112, called Lobato, and confirmed that the phone worked. Pritt tried to contact the section and received no response. Maxwell returned to his supply tractor to gather materials for reestablishing ventilation.

While exploring inby crosscut 113, Ward and Harper heard loud, deep rumbling from continued movement of the surrounding strata and observed sloughing of the ribs and mine roof. Debris in the travelway and poor visibility hindered their travel. They returned to the phone where they met Pritt. Pritt convinced Ward that they needed to wait for mine rescue apparatuses before attempting to advance inby. Pritt called Toomer and asked him to bring in as many mine rescue breathing apparatuses as he could find. During this call, the AMS operators relayed Pritt’s information to Peacock by telephone. Pritt also told Peacock that they lost communications with the section and that stoppings were down.

Hardee finished his preshift examination of the South Crandall Canyon Mine and drove to the foremen’s room, located inside the Crandall Canyon Mine, at 3:22 a.m. As he prepared to record his examination results, Hardee overheard Pritt requesting breathing apparatuses. Hardee joined the conversation and volunteered to get the apparatuses. At 3:25 a.m., Hardee drove his pick-up truck to the mine office building and ran upstairs to the AMS office, where Lobato was on the phone with Peacock. Hardee briefly spoke with Peacock to tell him he was going into the mine.

Peacock told Hardee that an overcast at crosscut 91 was damaged, and he wanted him to check that out before he went any farther inby. Curtis had completed the preshift examination of the No. 1 conveyor belt and called the AMS operator in response to several PED messages. Hardee answered, informed Curtis of the accident, and arranged to pick him up at Main West crosscut 4.

Hardee located four mine rescue apparatuses (Dräger BG174 A, 4-hour units) and two Dräger 30-minute fire-fighting units in the mine office building and loaded them into his pick-up truck, along with materials to repair ventilation controls. He entered the mine at 3:36 a.m. and drove to Main West crosscut 4, where he picked up Curtis, and then continued driving inby toward the section.

Peacock started notifying other mine officials at 3:30 a.m. Peacock first called Bodee Allred and told him to get the mine rescue team headed to the mine and to contact MSHA, in that order. At 3:37 a.m., Allred called Jeff Palmer and Hubert Wilson (mine rescue team members) and told them to start calling other team members. Allred called the MSHA toll-free number for immediately reportable accidents at 3:43 a.m. He reported that there was a bounce, they had an unintentional cave while pillaring in the mine, and they lost ventilation. Allred also indicated that they could not see past crosscut 92 and they did not know if stoppings were knocked out. At 3:51 a.m., the MSHA toll-free phone operator notified William Denning (MSHA District 9 staff assistant) in Denver, Colorado, who initiated MSHA's response.

The seismic event associated with the accident was detected by the University of Utah Seismograph Stations (UUSS) network. Several minutes later Dr. Walter Arabasz (Director of UUSS) was paged by an automated system. The page indicated that a local magnitude 4.0 event had been detected. Protocol for events larger than 3.5 magnitude required some personnel to go to the network operations center and issue a press release. A check of the automated posting on the UUSS website indicated that the event was in central Utah. Dr. James Pechmann (University of Utah seismologist) was also paged by the system. Working from his home computer, Dr. Pechmann quickly reviewed the data. He then proceeded to the network operations center.

At the network operations center, Dr. Arabasz met Dr. Pechmann and Relu Burlacu (seismic network manager). Notifications were made to parties on a prescribed list. UUSS decided to notify the Carbon and Emery County Sheriffs' Offices because it was believed they might receive calls from the public. Dr. Arabasz told the Sheriffs' Offices that, from the general character of the seismic event, it might be a mining-related event. Neither Sheriff's Office had received any reports or information on the event. The notification phone call was made to the Emery County Sheriff's Office at 3:47 a.m. Five minutes later, Toomer called the Emery County Sheriff's Office and reported, *"We had a big cave in up here, and we're probably going to need an ambulance. We're not for sure, yet, because we haven't heard from anybody in the section."* An ambulance and an Emery County Sheriff's Officer were then dispatched to the mine.

The Carbon County Sheriff's Office called UUSS back at approximately 4:00 a.m. and reported that there had been a collapse at the Crandall Canyon Mine. Dr. Arabasz called the Emery County Sheriff's Office back to inquire if the mine operator had publicly confirmed a collapse. Based on this conversation, Dr. Arabasz determined that they had not. Operating under the belief that it was more appropriate for the mine operator to release the details of the collapse, between 4:10 and 4:20 a.m., UUSS called the Associated Press and relayed only the location, magnitude, and time of the event.

Meanwhile, Pritt, Ward, and Harper waited near crosscut 113 for Hardee and Curtis to deliver mine rescue apparatuses. Hardee and Curtis stopped at crosscut 91, where they confirmed that the overcasts were damaged. They determined that a nearby regulator was intact, which would limit the short-circuit of air caused by the damaged overcasts. As they continued driving inby, light dust was still suspended in the air from crosscut 93 to 109. Inby crosscut 109, dust limited visibility to one crosscut. Shortly before 4:00 a.m., Hardee and Curtis met Pritt, Ward, and Harper and they started exploring the No. 1 entry together. Near crosscut 115, Curtis detected between 19.0 and 19.5% oxygen. All five miners retreated to their vehicles to obtain breathing apparatuses to cope with the dusty atmosphere. However, the four, 4-hour mine rescue apparatuses brought in by Hardee were outdated and unusable. Only the two 30-minute, fire-fighting units were ready for use.

Since Curtis and Pritt were trained members of the fire brigade, they wore the 30-minute fire-fighting units while resuming exploration in the No. 1 entry. Harper and Ward donned their SCSRs and followed Curtis and Pritt. Hardee did not don any type of unit. He trailed behind the group and eventually turned back to reestablish ventilation. As the group advanced, they encountered increased depths of coal and destroyed stoppings covered with debris. After advancing a few crosscuts, the roof started working and they retreated to crosscut 113. A few minutes later, they resumed exploration in the No. 1 entry and advanced to approximately crosscut 123. After encountering oxygen levels of 16% and adverse roof conditions, they returned to crosscut 113 and developed a plan to explore the No. 3 entry.

Pritt, Ward, Curtis, and Harper then traveled in the No. 2 entry, before crossing the belt into the No. 3 entry. They soon encountered very unstable ground conditions and retreated outby. As they crossed back over the belt, Pritt tried to communicate with the entrapped miners by beating on the waterline, but there was no response. When they returned to the phone near crosscut 112, they called and briefed Peacock, who had arrived at the mine.

Pritt and Harper remained at the phone while Curtis, Hardee, and Ward traveled outby to reestablish ventilation. Curtis and Hardee assessed damage as they walked the belt entry toward each other from crosscuts 93 and 103, respectively, while Ward drove outside to obtain ventilation materials. Maxwell was already on the surface, loading his supply tractor with ventilation materials.

By 4:20 a.m., other mine officials and emergency vehicles, including an ambulance and an Emery County Sheriff's Officer, began arriving at the mine. Denning informed William Taylor (MSHA supervisory coal mine inspector) of the accident. Taylor called Barry Grosely (MSHA Coal mine inspector) and assigned him to travel to the mine, issue a 103(k) order, and call Taylor at the MSHA Price Field Office with an update. Taylor traveled to the field office and gathered equipment needed to respond to the accident.

At 4:30 a.m., Curtis and Hardee completed their assessment of ventilation controls in the belt entry and traveled to the phone near the No. 5 conveyor belt drive to report their findings. All of the metal stoppings and some of the block stoppings inby crosscut 93 were damaged or destroyed. Hardee stopped the No. 5 conveyor belt and requested that the remaining conveyor belts be shut off from the surface. Hardee and Curtis started working outby, beginning repairs while awaiting additional supplies from the surface. Ward exited the mine at 4:36 a.m. and loaded his truck with polyurethane foam spray packs. Six minutes later, Maxwell reentered the mine with his supply tractor loaded with ventilation materials, followed by Ward.

At 4:41 a.m., Grosely called the mine and issued an order pursuant to section 103(k) of the Mine Act that prohibited all activity in the section until MSHA determined that it was safe to resume normal mining operations in the affected area. The order also required the mine operator to obtain prior approval from an authorized representative for all plans to recover or restore operations to the affected area. Five minutes later, a magnitude 2.1 seismic event occurred near the South Barrier section, followed by two smaller events within the next two minutes.

Underground Rescue Efforts

Underground rescue efforts were initiated on the morning of August 6. These efforts included exploring approaches to the South Barrier section, restoring ventilation, cleaning up the rubble in approaches to the South Barrier section, and breaching the No. 1 seal in Main West. Grosely, the first MSHA employee on site, arrived at 5:44 am. Thereafter, MSHA evaluated the mine operator's specific rescue plans and approved them under the 103(k) order. GRI's command center was established on the second floor of the warehouse building as required in their Emergency Response Plan. The MSHA Mine Emergency Operations (MEO) mobile command center vehicle arrived from Price, Utah, at 10:15 a.m. It was parked near the entrance to the mine portal access road, adjacent to GRI's command center. MSHA and GRI jointly coordinated the rescue efforts from these locations. Efforts also were made to locate the entrapped miners with seismic equipment and by drilling boreholes.

Allyn Davis (MSHA District 9 manager) arrived on the afternoon of August 6 and assumed control of MSHA's onsite responsibilities. Richard Stickler (Assistant Secretary of Labor) and Kevin Stricklin (Administrator for Coal Mine Safety and Health) arrived during the afternoon of August 7. Three MSHA Technical Support roof control specialists worked onsite during the rescue and advised MSHA decision-makers on roof control issues. They consulted with other Technical Support employees and outside experts. Details of the rescue efforts are explained in the following sections of this report.

Attempts to Explore South Barrier Section and Main West Sealed Area

The operator developed a plan to remove debris from the South Barrier No. 4 entry and to use mine rescue teams to search for an access route to the entrapped miners. Under this plan, mine rescue teams would explore all approaches to the South Barrier section. If no route to the section could be found, the operator intended to breach the Main West No. 1 seal. Mine rescue teams would explore for a route through the Main West entries to a point adjacent to the entrapped miners, where they could drill or mine through the remaining barrier pillar into the working section. The operator presented this plan to MSHA and, at 6:00 a.m. on August 6, Grosely modified the 103(k) order to "*permit the necessary personnel to travel underground to make repairs to damaged ventilation devices, work on installing a belt tailpiece and feeder breaker at crosscut 120 in the number two entry, clean and advance in the No. 4 entry towards crosscut 124 and to open the number one seal in the Old Main West entries inby crosscut 118 and use mine rescue teams to explore within established mine rescue procedures. Ventilation will be established as necessary for the operation of necessary mining equipment. Additional equipment and materials will be moved underground as deemed necessary for current recovery operations.*"

At 6:40 a.m., fourteen members of the UEI mine rescue teams entered the mine to explore approaches to the section (see Figure 3). Eighteen other miners remained in the mine to repair ventilation controls, set up the feeder/breaker, belt tailpiece, and begin the clean-up work. All other miners were evacuated from the mine. At 7:40 a.m., Taylor debriefed Harper, Ward, and

Pritt. Ward told Taylor that the crew was mining off the No. 1 entry at crosscut 139 into the barrier before he left the section.

After 8:00 a.m., mine rescue team members from Energy West Mining Company also entered the mine. Grosely, Randy Gunderson (MSHA coal mine inspector), and a group of miners, including mine rescue team members, explored approaches to the South Barrier section by traveling back and forth between the Nos. 1 and 4 entries in an attempt to find a route to the entrapped miners. Entries and crosscuts were largely filled with debris, while intersections were less filled. They advanced to crosscut 126 where they encountered debris within inches of the roof and oxygen below 16%. A decision was made to retreat.

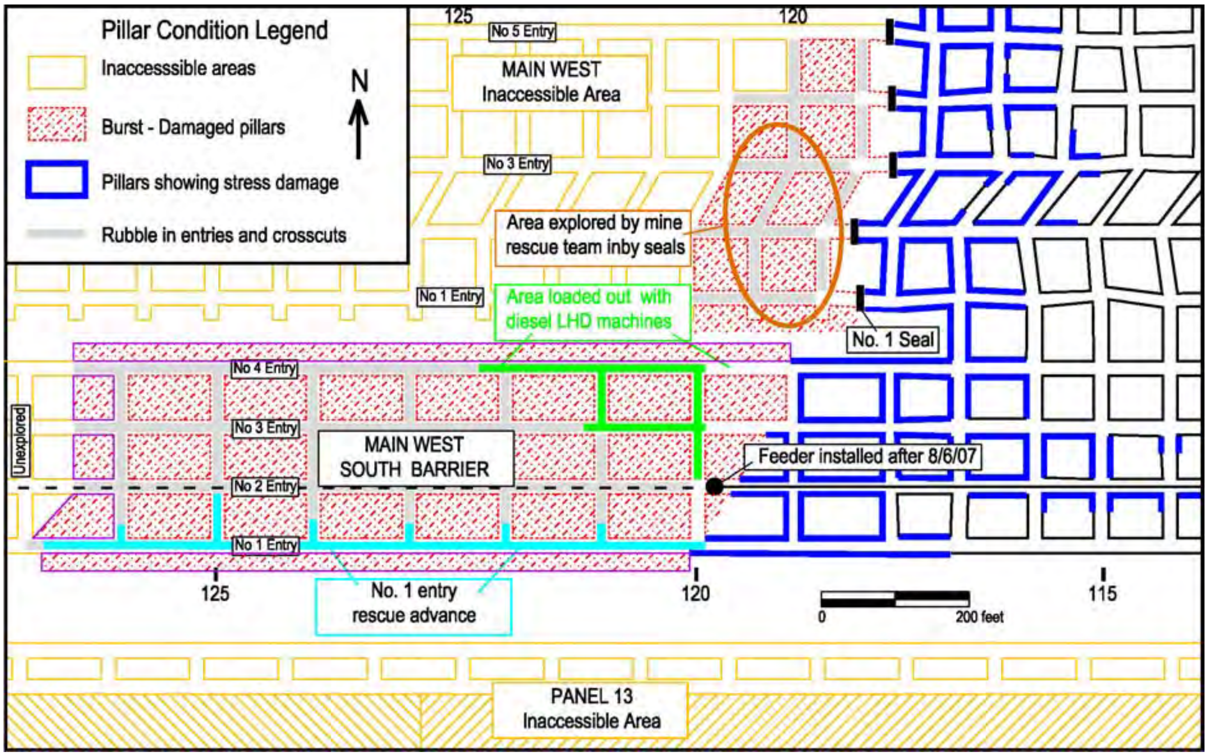


Figure 3 - South Barrier Section Rescue Area Showing Ground Conditions and Rescue Attempts.

Rescuers attempted to provide breathable air to the entrapped miners by utilizing the fresh water pipeline along the conveyor belt. The water was shut off and the pipeline was drained as much as possible by opening fire valves. A PED message stating *"OPEN VALVE ON H2O 4 AIR"* was sent to the cap lamp Erickson was wearing. Erickson was the only entrapped crew member wearing a PED device. A compressor was set up between crosscuts 109 and 110 in the No. 2 entry. The compressor was attached to the water line and started. A second PED message stating *"PUMPING AIR THRU WATERLINE"* was sent at 11:04 a.m.

By noon, the mine rescue teams had established a fresh air base (FAB) one crosscut outby the No. 1 seal and began the arduous work of breaching the seal. At 1:55 p.m., the teams reported to the command center that a 3 x 3-foot area of material, 8 inches deep into the seal, had been removed. By 2:50 p.m., a small opening through the seal had been made and by 3:20 p.m., a 2 x 2-foot hole was completed through the seal.

Brad Allen (MSHA coal mine inspector/Mine Emergency Unit (MEU) member) and five mine rescue team members entered the sealed area and began exploration at 4:42 p.m. The irrespirable atmosphere behind the seal contained 6.0% to 6.8% oxygen, 62 parts-per-million (ppm) carbon monoxide, and no methane. The team advanced in the Nos. 1, 2, and 3 entries to near crosscut 121 where they encountered impassable roof falls. They attempted to advance into the No. 4 entry but the roof had deteriorated and it was unsafe to travel. During the exploration, the ground was working and bounces were occurring. Because of these unstable conditions and the fact that travel routes were impassable in Nos. 1, 2, 3, and 4 entries, the team retreated to the FAB.

After evaluating the information from the team's exploration, the command center requested that they attempt to advance into the No. 5 entry. At 5:02 p.m., as the team prepared to reenter the sealed area, a fall or burst in the sealed area (registering as a magnitude 2.6 seismic event) forced low oxygen through the breached seal and over the FAB. All personnel located in the FAB quickly evacuated to a safe area outby. The team returned to the seal and covered the opening with curtain to limit air leakage. Due to the poor conditions encountered behind the seals, all attempts to explore the sealed area were suspended and mine rescue team members were withdrawn from the mine.

While the exploration was continuing, the UUSS issued the following press release at 3:40 p.m. explaining that further analysis had revised the location and magnitude of the seismic event:

> *The preliminary location and magnitude of today's earthquake are consistent with the shock being a type of earthquake that is induced by underground coal mining. The general region of the earthquake's epicenter is an area that has experienced a high level of mining-induced earthquake activity for many decades. The largest of past mining-induced earthquakes had magnitudes in the 3.5 to 4.2 range, which encompasses the size of today's earthquake (3.9). On the basis of present evidence, however, the possibility that today's shock was a natural earthquake cannot be ruled out. The broad region of central Utah experiences normal tectonic earthquakes in addition to mining-induced earthquakes. For example, in 1988 a magnitude 5.2 earthquake occurred 40 km southeast of today's earthquake.*
>
> *Seismologists have not conclusively determined how the earthquake of August 6 might be related to the occurrence of a collapse at the nearby Crandall Canyon coal mine that, as of midday August 6, had left six miners unaccounted for. The epicenter of the seismic event is close to the mine. We do not have an authoritative report of the time at which the collapse occurred. If the collapse occurred nearly simultaneously with the earthquake, we would consider it likely that the earthquake is the seismic signature of the collapse. At this point, more information-- both from the mine and from more seismological analyses--will be needed to piece together cause and effect relations for today's M3.9 earthquake.*

<u>Rescue Efforts in South Barrier Section Nos. 3 and 4 Entries</u>

Soon after exploratory efforts indicated that entries were impassible, GRI developed a plan to use mining equipment to reestablish a route to the missing miners. Fallen roof rock encountered in the No. 1 entry precluded using that entry initially because a roof bolting machine was not immediately available. The No. 2 entry contained section belt structure that would have hindered the recovery process. At that time, conditions in Nos. 3 and 4 entries were most conducive for the underground rescue effort. The recovery plan was implemented in No. 4 entry.

The South Barrier section loading equipment was inby the blocked entries. Therefore, two load-haul-dump (LHD) diesel powered loaders were borrowed from a nearby mine to move the material. Additional equipment was moved to the rescue site from other areas of the mine, including an electrical power transformer, a radio remote controlled continuous mining machine, and a feeder breaker.

The removal of material from the entries began during the afternoon of August 6, 2007. Initially material was cleared for installation of a feeder breaker in No. 2 entry outby crosscut 120. Rubble was also cleared from crosscut 120, between Nos. 1 and 4 entries. The two LHDs were used to remove material in the No. 3 entry to crosscut 121, in crosscut 121 between the Nos. 3 and 4 entries, and in the No. 4 entry inby crosscut 121. The rubble was loaded and dumped outby in accessible areas near crosscuts 116, 117, and 118. Entries were cleared by taking a single LHD bucket width down the center of the entry. Coal was left along both rib lines. Timbers were set for support in crosscut 120 between the Nos. 3 and 4 entries. The crosscut was not traveled after timbers were set. The day shift crew was relieved at approximately 7:00 p.m. and clean-up work continued into the night shift. The feeder breaker and belt were being installed but were not operational as the diesel loaders were used to remove debris.

On August 7, 2007, a burst occurred in the clean-up area. UUSS registered a magnitude 2.8 seismic event at 1:13 a.m., which coincided with the approximate time of the burst. Ron Paletta (MSHA coal mine inspector) was standing near the feeder breaker with Benny Allred and Gale Anderson. The burst knocked Paletta to the ground and again damaged or destroyed ventilation controls to crosscut 93. The burst put a large amount of dust into suspension throughout the area and limited visibility to only a few feet. There were no injuries associated with this event. However, the burst partially refilled approximately 300 feet of entry that had been cleared (see Figure 4). Neither LHD was in the area refilled by burst material. One LHD was loading loose coal near the feeder between the Nos. 2 and 3 entries and the other LHD was outby the feeder in the No. 3 entry. All miners were withdrawn to crosscut 109 and accounted for.

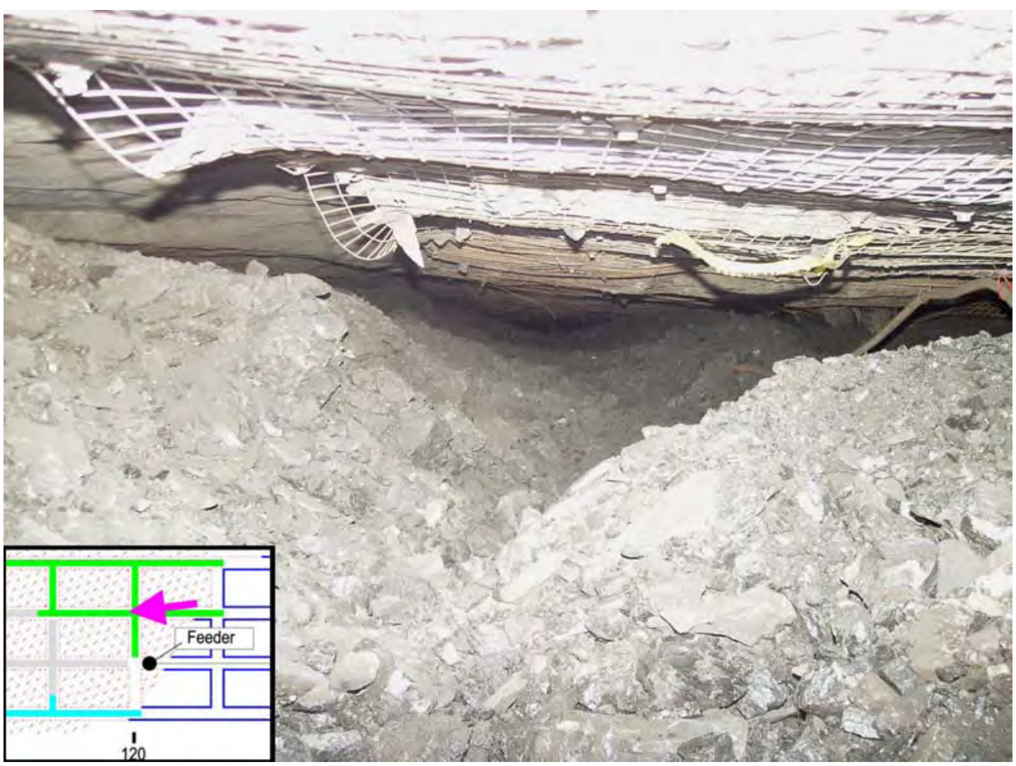


Figure 4 - View of No. 3 Entry after August 7 Burst
Entry cleaned by diesel loaders refilled with rubble (view indicated by arrow in index map insert).

Rescue Efforts in South Barrier Section No. 1 Entry

Laine Adair, Gary Peacock, and Josh Fielder (section foreman) traveled underground to crosscut 120, evaluated the effects of the August 7 burst, and developed a new plan that was subsequently approved by MSHA. The new plan relocated the rescue operation from the No. 4 entry to the No. 1 entry (see Figure 3). The No. 1 entry was adjacent to the 121-foot wide barrier and appeared to be in the best condition. In addition to the 18 miners already assigned to work in the area, 12 miners were assigned to complete work outby crosscut 109 in preparation for advancing in the No. 1 entry.

Before clean-up in the No. 1 entry was initiated, MSHA deployed a small portable seismic detection system consisting of several sensors and a receiver/recorder. The portable system was transported from its storage location in Pittsburgh, Pennsylvania, taken underground on August 7, 2007, and deployed in the No. 1 entry at crosscut 121. This system was designed to locate people over short distances, up to approximately 200 feet. The sensors were placed on roof bolts and on the mine floor and monitored for 30 minutes. No signals from miners were detected. The unit was then moved to the No. 2 entry at crosscut 120, where sensors were attached to the section water supply pipe. After pounding on the pipe, the system was monitored for 30 minutes. No response was detected. The portable system was not used again.

Preparation for Rescue Effort in No. 1 Entry

On August 8, 2007, the 103(k) order was modified to allow recovery operations to continue in accordance with approved site specific plans. The initial site specific plan used for cleaning and advancing in the No. 1 entry of the South Barrier section was also approved on August 8, 2007. This was the base plan throughout the remaining rescue effort, with revisions or addendums approved as needed. This approach eliminated the need to modify the 103(k) order each time there was a change in work procedures or method of cleaning up, without compromising the MSHA approval process. Once the plan was agreed upon by the company and MSHA, it was ready for implementation.

In the initial plan, electrical power to the clean-up area was supplied through a power center located in crosscut 119 between the No. 1 and No. 2 entries. The coal was to be loaded with a continuous mining machine. Shuttle cars or scoops would transport the material to the feeder located in the No. 2 entry between crosscuts 119 and 120 and the material would be carried out of the mine by conveyor belts.

The plan stipulated that the ventilation system would utilize the No. 1 entry for intake with the No. 2 entry being the belt haulage entry and the Nos. 3 and 4 entries would be utilized as the return air course. Ventilation to the area would be established by constructing ventilation controls at the following locations:

- Between No. 1 and No. 2 entries at crosscuts 90-119.
- Between No. 2 and No. 3 entries at crosscuts 90-119.
- In No. 2 entry between crosscut 120 and 121 (belt entry isolation curtain).
- Between No. 1 and No. 2 entries from crosscut 121 to 137 as recovery work advanced in the No. 1 entry.

The clean-up work did not begin immediately in the No. 1 entry. All of the ventilation controls that had been damaged or destroyed by the August 7 burst were rebuilt before loading was started. Stopping repairs were completed on August 8, at 1:55 a.m. The continuous mining machine was moved to the No. 1 entry inby crosscut 120 and the electrical power center was relocated to crosscut 119 between the No. 1 and No. 2 entries. A fresh air base was established at crosscut 119. A pager phone was connected between the clean-up area and the FAB. A person was stationed at the FAB at all times to maintain communication with the clean-up area and the command center on the surface.

The approved site specific plan also addressed the roof support system to be installed in the clean-up area. As clean-up advanced in the No. 1 entry, additional roof and rib control measures were implemented. The roof support portion of the plan required:

> *(A) As cleanup progresses roof support will be installed on 2.5' centers using rock props* [sic] *or 8"x8" square sets on both sides of the entry. The square sets will be capped with Jack Pots for active support.*
>
> *(B) Screen mesh will be installed between the rib and the entry to confine rib roll and protect employees and roadway.*
>
> *(C) As each crosscut is completed 5/8" cable will be wrapped around these props to secure them from pushing out.*

Since 6 x 8-inch hard wood timbers were stronger and more immediately available than the 8 x 8-inch pine square sets specified in the plan, Item A was modified to include them at 1:05 p.m. on August 8, as follows:

> *(A) As cleanup progresses roof support will be installed on 2.5' centers using rock props* [sic] *or 8"x8"pine square sets or, 6X8 hard wood with 8" dimension perpendicular to the rib, on both sides of the entry. The square sets and the 6X8 hard wood will be capped with Jack Pots for active support.*

In addition to the items required for equipment setup, the initial plan listed several special precautions:

> *(A) The continuous miner operator will be protected by a 4'x8' sheet of ½" thick Lexan secured at top and bottom. Conveyer belting may be used in place of Lexan until Lexan arrives.*
>
> *(B) All unnecessary persons will be kept outby the fresh air base located at x-cut 119.*
>
> *(C) Life Line will be maintained in the entry up to the continuous miner operator location. Additional reflective tape will be added to life line.*
>
> *(D) If mining conditions change significantly, mining will stop and the plan will be re-evaluated before mining resumes.*
>
> *(E) Additional SCSRs will be stored at the fresh air base at x-cut 119; so that every person inby x-cut 115 will have access to two SCSRs.*

The roof had deteriorated between the No. 1 and No. 2 entries at crosscut 120. This area extended from the No. 1 entry to the location of the feeder breaker in No. 2 entry and required additional roof bolting before the area could be safely traveled. Thus additional mining equipment, including a twin boom roof-bolting machine, had to be moved into the area.

As specified in the plan, pressurized roof-to-floor standing supports were installed along pillar ribs for protection from pillar bursts. On August 8, 6 x 8-inch hardwood wood posts were installed on both sides of the No. 1 entry beginning at crosscut 118, narrowing the roadway to 14 feet. These posts were capped with Jackpots to actively preload each support between the roof and floor (see Figure 5). The wood posts were installed in the No. 1 entry to midway between crosscut 119 and 120 until RocProps (telescoping steel supports expanded with high pressure water) were available. Thereafter, RocProps were used exclusively as roof-to-floor support (see Figure 6). After the supports were installed, chain-link fence was installed between the rib and the row of supports to confine dislodged coal and to protect miners and the roadway. Additionally, 5/8-inch steel cables were wrapped around the RocProps to secure them from being dislodged.

Figure 5 - Hardwood Posts Installed with Jackpots in No. 1 Entry

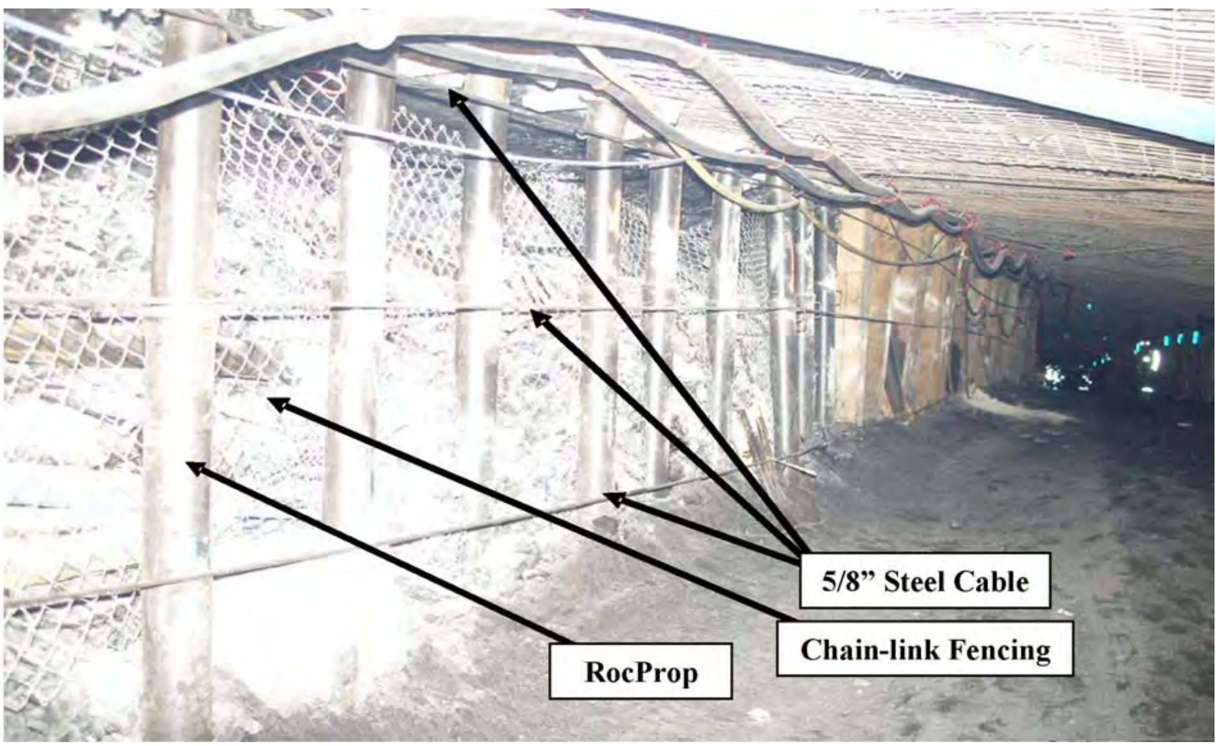


Figure 6 - RocProps, Cables, and Chain-link Fencing Installed in the No. 1 Entry

On the evening of August 8, the underground RocProp installation was completed to the continuous mining machine located just inby crosscut 120 in the No. 1 entry. Just prior to beginning the clean-up efforts, company officials accompanied by MSHA inspectors brought news media personnel into the mine. The news media crew was in the clean-up area for a short period of time filming the rescue efforts.

Material Clean-Up from the No. 1 Entry

Clean-up work began at approximately 6:00 p.m. on August 8, 2007, in the No. 1 entry and advanced as rescue workers developed efficient means to remove coal, install standing support, address damaged roof supports, and advance ventilation and cables. Initially, material was hauled by electric shuttle cars. After clean-up in the No. 1 entry had advanced inby crosscut 122, diesel Ramcars arrived from another mine and were used to transport material to the feeder.

On August 10, 2007, an addendum to the approved plan was implemented. The addendum addressed three concerns:

- No one, including equipment operators, was allowed inby the support (props or timbers). If the continuous mining machine was not advancing, personnel may be allowed to work inby the RocProps and timbers as long as the roof is supported to perform maintenance of the equipment, limited support work, removal of debris from the rubble, etc.
- The maximum clean-up distance was not to exceed the inby end of the shuttle car operator's cab. The shuttle car operators cab shall not extend beyond the last row of RocProps and/or timbers.
- The rock dust was to be applied in conjunction with the installation of roof support to the furthermost extent of those supports.

Also, on August 10, MSHA approved a plan for two people, one from MSHA and one representing UEI, to explore the No. 1 entry inby the continuous mining machine. At 12:43 p.m., Barry Grosely and Gary Peacock left the FAB and crawled over the rubble inby the continuous mining machine at crosscut 123 in the No. 1 entry. Radios were provided for communication with outby rescue workers during the exploration and the team carried multi-gas detectors. Since neither carried a mine rescue-breathing apparatus during this excursion, they were to retreat immediately if the oxygen content fell below 19.5% or the carbon monoxide level elevated to 50 PPM. If bumping or bouncing occurred, they were to retreat to a supported area immediately. The two-man team advanced to near crosscut 124 where they lost communication and retreated outby. Another attempt was made in the No. 4 entry by Bodee Allred and Peter Saint (MSHA coal mine inspector and MEU member). Saint was able to crawl to near crosscut 126 where the entry was impassable and they retreated. Air quality readings taken at the deepest point of advance indicated 20.9% oxygen. These were the last attempts to explore in advance of the clean-up operation.

As loading advanced inby crosscut 123, rescuers observed that part of the barrier south of the No. 1 entry had moved northward as a result of the initial August 6 ground failure. The barrier rib had shifted northward as a unit, as much as 10 feet. In some areas the displaced barrier slid along the immediate roof and tore loose the original roof mesh (see Figure 7). In other areas, the immediate roof was carried northward and damaged the original installed roof bolts (Figure 8).

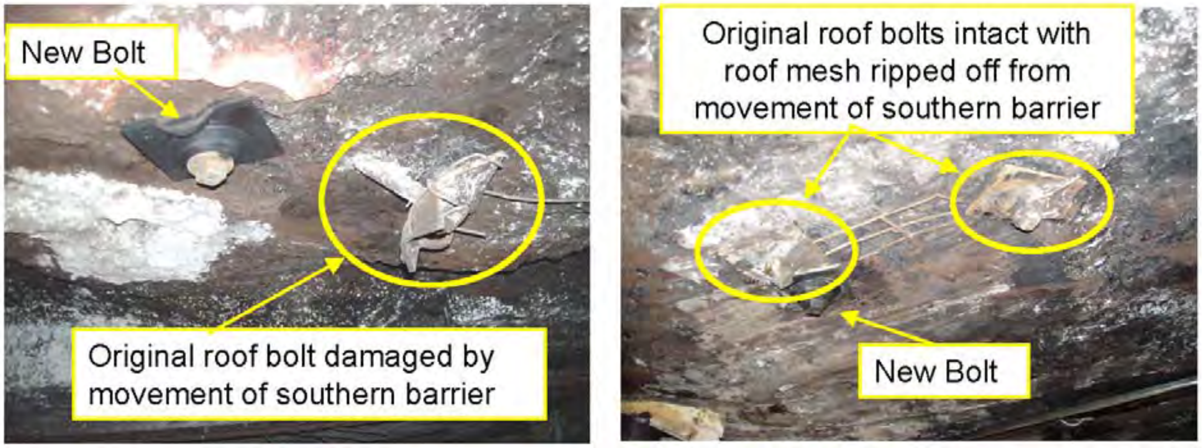


Figure 7- Damaged Roof Bolts and Torn Mesh after August 6 Accident Resulting from Northward Movement of Southern Barrier

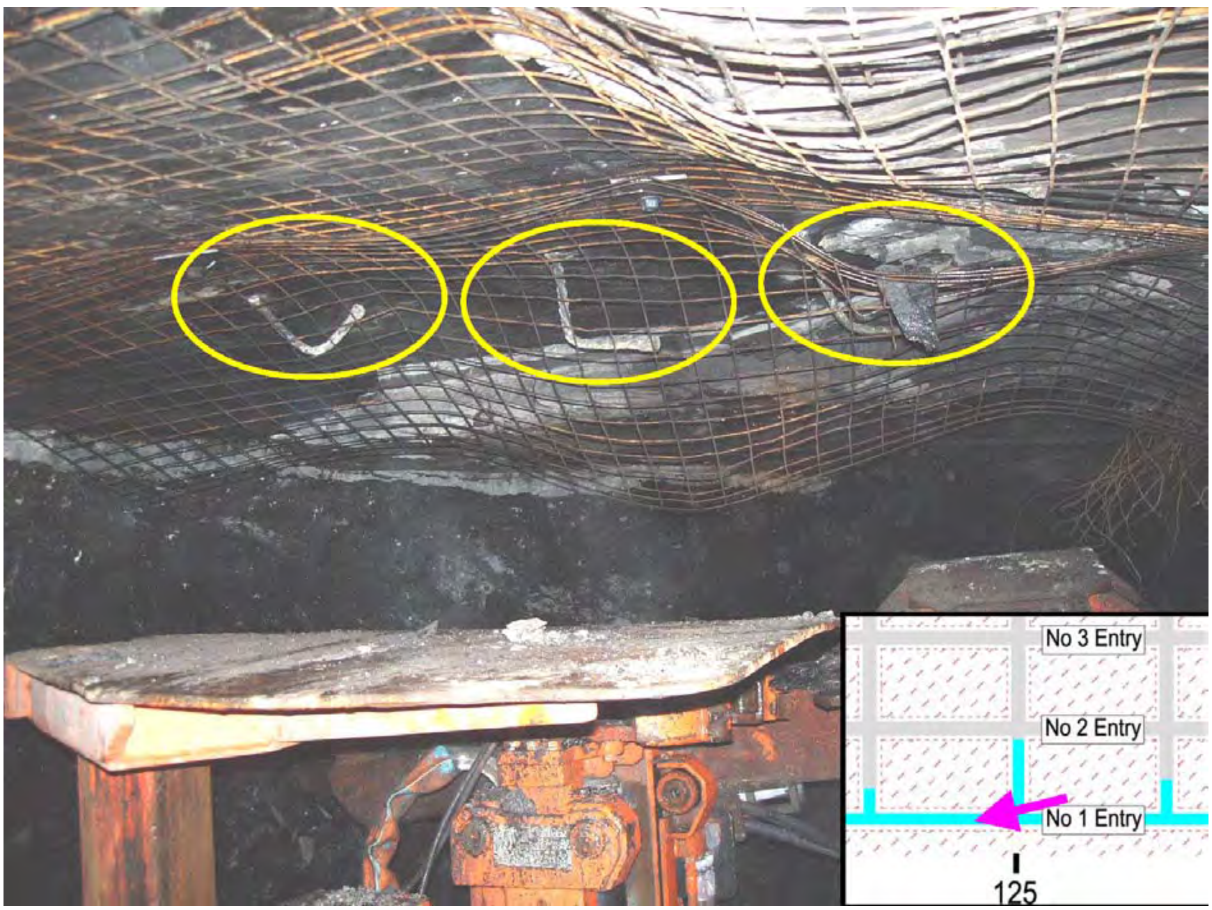


Figure 8 - Damaged Roof Bolts in No. 1 Entry after August 6 Accident Resulting from Northward Movement of Southern Barrier. Mesh shown was installed during rescue operations, over damaged original roof bolts. Camera view is indicated by arrow in index map insert.

The procedures for advancing in the No. 1 entry were again modified on August 11, 2007. The additional requirements were focused on limiting the exposure of the workers and strengthening the support system. Under this revision, workers were not allowed in the clean-up area unless they were designated by the foreman. The clean-up distance that could be advanced before the support system had to be installed also was restricted. The advancement of the continuous mining machine was limited to the distance it took to set three sets of RocProps. There was a stipulation that this distance could be increased if conditions improved. However, both MSHA and UEI had to agree on the increased distance prior to implementation. To limit the exposure of workers inby supports, the RocProps were required to be set one at a time.

Another modification required three steel cables to be installed outside the RocProps instead of the one cable previously required. The cables were to be installed at the top, middle, and bottom of the supports. Each steel cable would wrap around a RocProp and be fastened to itself in 40-foot increments. Each cable was required to be connected to a separate RocProp and terminated using three clamps.

Additional ventilation requirements were also stipulated in this modification. Permanent ventilation controls were to replace the temporary controls inby crosscut 120. A handheld detector was to be placed in the No. 3 entry on the return side of the door at crosscut 120 until an atmospheric monitoring system oxygen sensor could be installed. Also, all shuttle car operators were required to have an extra SCSR in the operator's compartment at all times.

On August 11, 2007, Peacock reported that ground stress had migrated eastward and affected pillars outby the Main West seals. MSHA examined the area and mapped these ground conditions in the Main West entries and the North and South Barrier workings outby crosscut 119. Pillar damage was noted up to three crosscuts outby the seals, to near crosscut 115 (see Figure 3). The damaged ribs were sloughed due to abutment stress from the area to the west. At that time, it appeared that the ground stress had stabilized and was no longer progressing eastward. Clean-up in the No. 1 entry had advanced near crosscut 124.

On August 12, roof deterioration was observed near crosscut 115 in the No. 1 entry. Steel channels were installed for additional support in this area (see Figure 9). The channels were supported on both ends with hardwood posts. At the time, clean-up in the No. 1 entry had advanced just inby crosscut 124. The No. 1 entry was packed with rubble the full width and height of the original mined opening. The continuous mining machine was loading from a rubble pile that resembled an unmined coal face (see Figure 10 and Figure 11). Observations of RocProps tilted from vertical prompted MSHA to install a measurement point to monitor horizontal movement between crosscuts 123 and 124.

Figure 9 - Steel Channels Installed in No. 1 Entry to Support Deteriorated Roof

Figure 10 - No. 1 Entry Packed with Coal Rubble Inby Crosscut 124

Figure 11 - Continuous Mining Machine in Loading Area Inby Crosscut 124

A revised plan for loading loose material in No. 1 entry was approved on August 13, 2007. This was the last addendum to the rescue and recovery plan, which stipulated the following:

1. *After miner loads ram car with loose material, the continuous miner operator will back the miner to the location where rock props* [sic] *need to be set. The exact location will be determined by the length of the hose needed to set the pressure on the rock prop.*
2. *Immediately after the ram car is 25 feet outby the location of the 6 men and heading to the feeder, up to 6 men who are in the closest x-cut to the end of the prop line that provides a minimum of 5 feet of clearance behind the rock props will begin setting support.*
3. *The support setters shall wear reflective vests so they can be easily seen by any approaching individual. Reflective vests are on order.*
4. *A miner will be stationed at least 100 feet, but not more than 200 feet outby the support setters to be assigned to signal any approaching piece of equipment that the support setters are in the entry. If the designated signal person sees the rock prop setters in the entry, he will stop the approaching equipment at least 100 feet short of the support setters.*
5. *As the ram car approaches the continuous miner, the support setters will move back into the x-cut.*
6. *This process will apply for any work associated with rock props, any square sets, j-bar, chain link fence, ventilation controls or wire rope or any support work.*
7. *Ram cars loaded with rock props* [sic] *or any other roof support material will not return to the outby area from the continuous miner without a load of coal.*
8. *If a ram car is taking material to the continuous miner, the car should be loaded while another car is at the miner. The car should be staged in number one entry just out-by the x-cut 120.*

Item 1 refers to the continuous mining machine being used as the hydraulic power source for the water pump for installing the RocProps. However, a scoop or roof bolting machine also was used as a power source for the RocProp water pump. Items 3, 4, and 5 were procedures to cope with the close clearance between the mobile equipment and the installed RocProps.

At approximately 6:30 p.m. on August 13, MSHA mine rescue personnel using breathing apparatuses installed 3/8-inch plastic tubing to the Main West seals. This allowed air samples to be taken remotely in fresh air at crosscut 120 near the feeder. Clean-up in the No. 1 entry had advanced to the vicinity of crosscut 125 at the time the air sample tubes were installed.

On August 14, a slight widening of roof joints was observed outby the FAB in the No. 1 entry between crosscuts 115 and 117. RocProps were installed along the pillar ribs through this area to reinforce the roof in the entry. Clean-up in the No. 1 entry had advanced to midway between crosscuts 125 and 126.

On August 15 at 2:26 a.m., a burst initiated from the right pillar rib in the clean-up area of the No. 1 entry inby the RocProps where the continuous mining machine was working. The burst threw coal across the mining machine and registered as a 1.2 magnitude seismic event. The machine was working 107 feet inby crosscut 125. It was reported as a significant event with ventilation controls damaged at crosscut 125. No injuries occurred; however, the mining machine cutter motors required repair work as a result of the burst. By 4:00 a.m. the mining machine was repaired and clean-up work resumed in the No. 1 entry. Later that day, reports of rock noise emanating from locations outby crosscut 119 prompted MSHA to install convergence monitoring stations. Ten roof-to-floor convergence stations were installed at crosscuts 111, 113, 115, 117, and 119 in the No. 2 and No. 4 entries and sixteen monitoring locations were established on RocProps inby crosscut 116 in the No. 1 entry.

August 16 Accident Description

On the morning of August 16, 2007, the No. 1 entry of the South Barrier section had been cleared to just inby crosscut 126. At 6:25 a.m., Brandon Kimber (foreman), Dale Black (foreman), Lester Day (continuous mining machine helper), Phil Gordon (Ramcar operator), and Steve Wilson (Ramcar operator) were the first five miners on the day shift crew to arrive on the section. They were joined by Casey Metcalf (support crew) at 6:51 a.m. and Randy Bouldin (Ramcar operator), Carl Gressman (support crew), Mitch Horton (support crew), and Brandy Fillingim (outby man) at 7:16 a.m. MSHA coal mine inspectors, Donald Durrant, Peter Saint, and Rodney Adamson arrived on the section approximately 15 minutes later. Durrant monitored activities in the clean-up area, Saint manned the FAB at crosscut 119, and Adamson monitored air quantity and quality outby.

Two MSHA supervisory mining engineers, Joseph Cybulski and Joseph Zelanko, from the Pittsburgh Safety and Health Technology Center's Roof Control Division (RCD) accompanied Durrant, Saint, and Adamson to the section that morning. The purpose of their visit was to evaluate ground conditions in the work area and to measure the convergence stations they had installed on August 15. Cybulski and Zelanko observed conditions between crosscuts 111 and 120 in the Nos. 2 and 4 entries and between crosscut 111 and the clean-up face in No. 1 entry. None of the stations displayed any significant convergence and ground conditions had not changed. They left the section and arrived outside at 10:10 a.m.

The day shift crew began the shift by installing roof supports in the clean-up area of the No. 1 entry. The roof bolting machine hydraulics powered the water pump that was used to pressurize the RocProps. The continuous mining machine was trammed inby and the clean-up and support cycle continued in the No. 1 entry.

The rescue efforts were interrupted at 10:04 a.m. when a burst occurred in the coal pillar between the No. 1 and No. 2 entries. The burst, which registered as a magnitude 1.5 seismic event, displaced approximately 4 feet of the pillar rib inby the RocProps, filling the entry on the right side of the continuous mining machine to a depth of approximately 2.5 feet. No injuries were sustained and no RocProps were dislodged by burst coal. The crew backed the continuous mining machine outby, cleared the debris, and continued the clean-up cycle.

At 1:16 p.m., the crew was joined by Jeff Tripp, a supervisor from the Century Mine in Ohio, operated by American Energy Corporation, a subsidiary of Murray Energy Corporation. This was Tripp's first day working at the Crandall Canyon Mine.

At 1:30 p.m., Cybulski and Zelanko returned to the section to take a second set of measurements at the convergence stations. The measurements were being taken to establish the historical trend and baseline for the convergence data. Again, measurements and observations were made in the Nos. 1, 2, and 4 entries. No significant changes were noted.

At 2:58 p.m., MSHA coal mine inspectors, Gary Jensen, Frank Markosek, and Scott Johnson arrived at the clean-up area to relieve Durrant, Saint, and Adamson for their 8-hour regular shift rotation. Jensen and Johnson were members of MSHA's MEU. Cybulski and Zelanko returned to the surface with Durrant, Saint, and Adamson.

By the end of day shift, the crew had advanced the clean-up efforts in the No. 1 entry close to crosscut 127. After the last Ramcar was loaded, Jensen informed the crew that they needed to set RocProps. Jensen also recommended that steel channels be installed across the last two rows of RocProps. As Wilson drove the loaded Ramcar to the feeder, crew members entered the clean-up area to install supports. Gordon unloaded his Ramcar at the feeder, changed out with Wilson, and parked in crosscut 125. Bouldin parked his Ramcar near crosscut 126 and walked to the clean-up area to help install ground supports. Brandy Fillingim, who had been working outby, came to the clean-up area at the end of the shift and assisted the crew. Fillingim, Bouldin, and Horton installed RocProps and steel channels on the right side of the entry, while Black, Day, and Kimber set them on the left side. Gressman was operating the control valve on the pump used to pressurize the RocProps. Metcalf and Tripp were tightening the steel cables on the left side. Jensen and Markosek were near the tail of the continuous mining machine, monitoring the activities. Johnson was outby the clean-up area, taking air measurements at the Panel 13 seal at crosscut 107.

At 6:38 p.m., as the crew completed installing ground support in the clean-up area, the coal pillar between the No. 1 and No. 2 entries burst. Coal was thrown violently across the No. 1 entry during the magnitude 1.9 seismic event. The burst created a void up to 20 feet deep into the pillar at the roof line (see Figure 12 and Figure 13, view indicated by arrow). The dislodged coal threw eight RocProps, steel cables, chain-link fence, and a steel channel toward the left side of the entry, striking the rescue workers and filling the entry with approximately four feet of debris (see Figure 14). Heavy dust filled the clean-up area, reduced visibility, and impaired breathing. Oxygen deficient air from the inby area migrated over the miners. The dust and oxygen deficiency were slow to clear due to damaged ventilation controls.

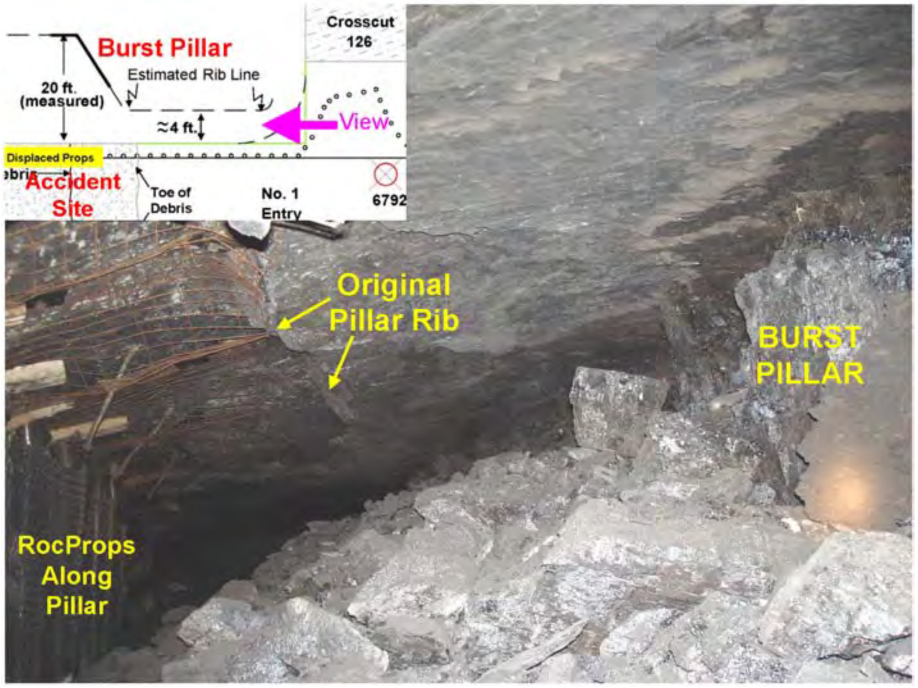


Figure 12 – Damage to Outby Portion of Pillar on Right Side of No. 1 Entry (Outby August 16 Accident Site)

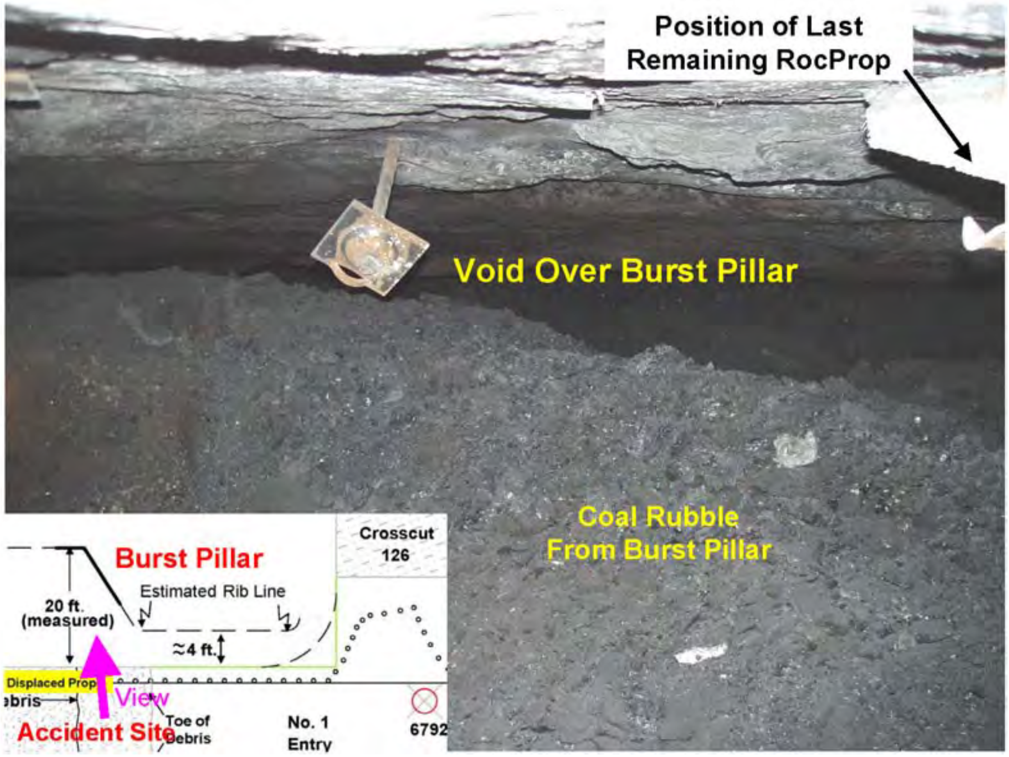


Figure 13 - 20-foot Deep Void over Pillar on Right Side of No. 1 Entry following August 16 Accident

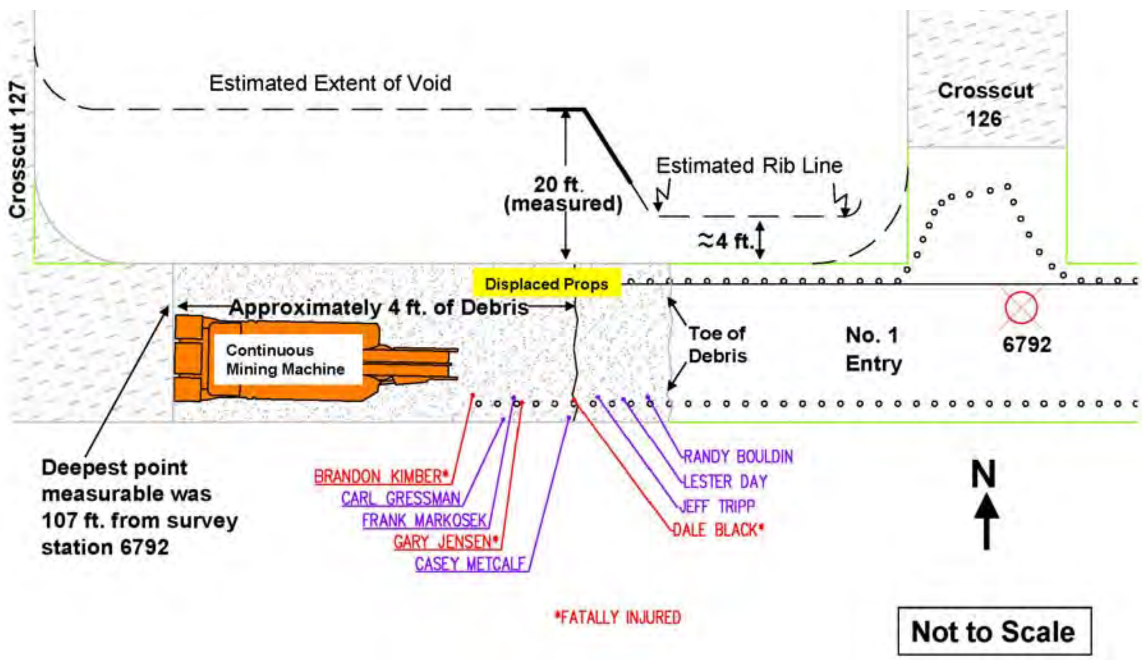


Figure 14 - August 16, 2007, Coal Burst Effects and Location of Injured Miners

Bouldin, Horton, and Fillingim had just walked out of the clean-up area when the burst occurred behind them. Bouldin was knocked down by the thrown material and injured his back. He was able to stand, but had difficulty seeing and breathing in the heavy dust. Fillingim and Horton were not injured. Fillingim was near the edge of the dust cloud and continued out of the clean-up area, unaware of the severity of the accident. Bouldin and Horton were disoriented in the dust and could hear injured miners shouting for help. Bouldin told Horton to go to the phone and get help. Bouldin returned inby to assist the injured miners.

MSHA coal mine inspector Scott Johnson heard the burst from crosscut 110 while walking toward the clean-up area. Protocol for the rescue efforts established that communication between the clean-up crew and outby workers would occur following a bounce or burst. When miners working near crosscut 113 informed Johnson that they had not heard from the clean-up area, he hurried to the fresh air base phone at crosscut 119.

Gordon had just gotten out of his Ramcar and was standing near a pager phone in crosscut 125 when the burst occurred, knocking out the stopping next to him. He looked toward the clean-up area and observed Fillingim walking out of a large cloud of dust. Wilson, located at the feeder, felt a bounce and paged the crew. As Gordon answered Wilson's page, Horton ran out of the clean-up area and told Gordon that the crew was covered up. Wilson asked[†], "*Everything...Is everybody all right in the face, Phil?*" Gordon replied, "*Hey, we need some help in here, now.*" "*Okay, what do you need?*" asked Wilson. Gordon answered, "*Get some vehicles up here.*" Wilson replied, "*Vehicles, right now.*" Gordon continued, "*Hey, get some help up here and get some people.*"

As Bouldin reentered the clean-up area, he could hear Day's muffled voice calling for help. Bouldin asked Day where he was. Day replied that Bouldin was standing on him. Bouldin looked down and saw part of Day's shoulder exposed through the rubble and his head buried beneath large pieces of coal. Bouldin uncovered Day and helped him to his feet before leaving the clean-up area to catch his breath. Day attempted to help the other injured miners even though he felt blood running down over his shoulders and realized that his head had been injured. Day found Tripp buried in coal from the waist down and told him that he was going to get help. After catching his breath, Bouldin resumed his attempts to dig out the injured miners who were partially covered by debris from the burst.

Gordon told Fillingim to call outside and get help. He then entered the clean-up area to assess the condition of the injured rescue workers. Fillingim and Horton called the AMS operator, requesting "*We need help in here now, in the face. We need everybody you can get in here now…We need stretchers, we need bridles, we need everything...Hurry!*" Gordon found Jensen partially covered in coal, but responsive. Metcalf was conscious and lying against the left rib entangled in chain-link fencing. Black was covered in material up to his waist. Markosek and Gressman were severely injured, but alert. Kimber was located farther inby. Gordon checked Black and Kimber for vital signs, but none were detected.

MSHA personnel stationed in the mobile command center vehicle were Bob Cornett (assistant district manager), Danny Frey (MSHA supervisory coal mine inspector), and Dewayne Brown (MSHA coal mine inspector trainee). Brown was manning the pager phone and maintaining the command center log. Brown reported the call for help to Cornett, who assigned Frey and Brown to remain in the vehicle to monitor communications and maintain the log. Cornett also assigned C.W. Moore (MSHA mining engineer) to the Emergency Medical Services (EMS) staging area to get the names and condition of everybody that they brought out, which he was to report to Frey. Cornett then joined Adair in the command center.

[†] Audio files of actual voice communications via the pager phone system were digitally recorded on August 16, 2007. Quoted conversations of pager phone communications were obtained from these recordings for this report.

The night shift crew members were traveling toward the clean-up area when the accident occurred. Benny Allred, Chris Armstrong, Ronnie Gutierrez, Richard Hansen, Natalio Lema, Ignazio Manzo, Dallen McFarlane, and Juan Zarate were walking toward the loading point when they heard the burst and realized that airflow had been disrupted. Gale Anderson, Dave Blake, Jeff Beckett, Keith Norris, and Jason Bell arrived at the fresh air base just behind Allred's group. Anderson told Benny Allred's group to install curtains from the loading point at crosscut 120 to the accident area. Anderson and the remaining night shift crew members continued inby to the accident site and began helping the injured miners. Tim Harper, Ryan Mann, and Jameson Ward were waiting by the phone at crosscut 89 when they overheard Fillingim's call to the AMS operator. Harper asked the AMS operator, "*What's going on?*" AMS replied, "*I don't know, he just told me we need everything in the face.*" Harper told the AMS operator that they were at crosscut 89 and they were going to the face.

Johnson arrived at the fresh air base and instructed miners to get the six stretchers stored there ready. He also told the miners to load the stretchers into a truck and transport them to the clean-up area. Johnson then ran to the accident site.

Mine management had just finished a meeting to discuss progress and work plans for continued rescue work in the No. 1 entry. Bodee Allred, Adair, Peacock, and several other managers exited the meeting into the hallway near the AMS room. Allred overheard the AMS operator talking to Harper. Allred picked up a phone in his office, which was located adjacent to the AMS room, and called the fresh air base. Mike Elwood answered the phone at crosscut 123 and Bodee Allred asked, "*Hey, what's going on in there?*" Elwood replied, "*We had a bump. I don't know exactly what went on...we called up to see how everybody was doing, they called for trucks...so we're going, we are on our way up to the face, now, to see what's happening.*" Allred asked if they needed EMS. Elwood replied: "*I would, just to be on the safe side. I don't know what we got.*" During this conversation, Bodee Allred motioned for Adair and informed him of the accident. Adair immediately turned to Peacock and a few other managers and told them that they had a big bounce and to get in the mine. Allred handed the phone to Adair and left the office to go underground.

As Elwood briefed Adair, Bouldin was having difficulty breathing and went to the phone at crosscut 125 to call for brattice. Bouldin interrupted, *"Can anybody outby bring some rag? Bring some brattice!"* Adair announced, *"They want brattice and rag, take it in there…get moving, anybody outby in the mine, head toward the face."* Bouldin left the phone and returned to the accident site where he was joined by night shift crew members, who began digging out the injured miners and providing first aid treatment.

At 6:45 p.m., Adair attempted to resume contact with the accident site as Jeff Palmer and Bodee Allred drove quickly up the portal road to enter the mine. They slowed down to speak to a person at the portal before continuing into the mine, just as communication with the accident site resumed. *"You guys okay up there?"* someone asked. *"No, there's a bad accident, about eight people…"* The person at the portal called the AMS operator and reported, *"I got Jeff and Bodee heading into the face,"* talking over the miner still speaking from accident site. The miner at the accident site continued, *"…we need lots of shovels, and pick, we need bridles…to hook on the miner…we can't get them unburied." "Okay, we'll bring all we got, bud." "All right, try, hurry fast."* Some of the information from the miner at the accident site was inaudible due to the interruption for post accident tracking of personnel movements through the mine. Adair ordered over the pager phone system, *"This is Laine Adair. I want everybody off this line that's not necessary."*

At 6:48 p.m., Adair paged the accident site. Gordon finished assessing the miners' injuries and answered the phone, *"Hey this is Phil, we're on the face. Who have I got?"* Adair replied, *"This is Laine, what do you need, buddy?"* Palmer and Bodee Allred interrupted to report that they were entering Zone 2 (see Appendix C). Gordon requested, *"Everybody off the phone but Laine."* Adair again ordered everybody off the phone. Gordon, speaking short of breath, continued, *"I think there's five or six…Dale Black and Brandon Kimber, is all that I can tell right now, are fatalities…We got to have air, from the tail piece in, because we have no air up in there, okay?"* Gordon also requested first aid supplies and a medical team.

Johnson entered the clean-up area and detected 16% oxygen. Dust suspended in the air still limited visibility to approximately 20 feet. He informed the workers recovering the injured miners of the low oxygen but they did not want to leave the area. Johnson returned outby to crosscut 125 and instructed miners arriving at the accident site to install brattice in the clean-up area. Johnson paged the command center and reported, *"They're running short on air."* Adair replied, "*Start pushing that air in from the belt line. Check every crosscut. Start taking rag and get that air pushed in.*" Johnson returned to the clean-up area as Benny Allred and his crew continued repairs to the ventilation system.

As Harper, Mann, and Ward traveled toward the accident site, they were stopped by Gutierrez. Gutierrez informed them they needed brattice because the bounce had blown out stoppings. They loaded the material Gutierrez had gathered into Harper's truck and traveled inby. Harper assisted in reestablishing ventilation while Mann and Ward continued inby. They met Day walking out of the clean-up area. Mann had a first-aid trauma kit and bandaged Day's head wounds.

At 6:51 p.m., Peacock, Robert E. Murray, and Jerry Taylor (corporate safety director) entered the mine, followed by several miners in a pick-up truck loaded with stretchers and supplies. Also, an Emery County Sheriff's Officer radioed his office and requested that Huntington EMTs be paged out to respond to the mine. Four ambulances, in addition to the one already stationed at the mine, were dispatched. Three emergency medical transport helicopters were also dispatched to the mine. Ambulances were staged at the entrance to the portal access road, near the MSHA mobile command center vehicle.

At 6:52 p.m., Elwood informed Adair that a temporary stopping had been built in crosscut 125, and airflow to the clean-up area was re-established. Adair expressed a concern for low oxygen coming into the rescue area. He told Elwood to get some detectors in the clean-up area and monitor for low oxygen. Johnson also briefed the command center at 6:54 p.m.

Harper rejoined Mann and Ward. Harper helped Day get a ride outside while Mann and Ward continued inby to assist other victims. As the miners were working to free the injured miners, several factors were slowing their efforts. Not only were rescuers dealing with the quantity of burst material, the roof and rib support that had been installed to protect the workers was now part of the rubble. The electrical cable and water line used to operate the continuous mining machine, along with the line curtain used for ventilation of the clean-up area, were also hindering the recovery of the injured miners (refer to Figure 15).

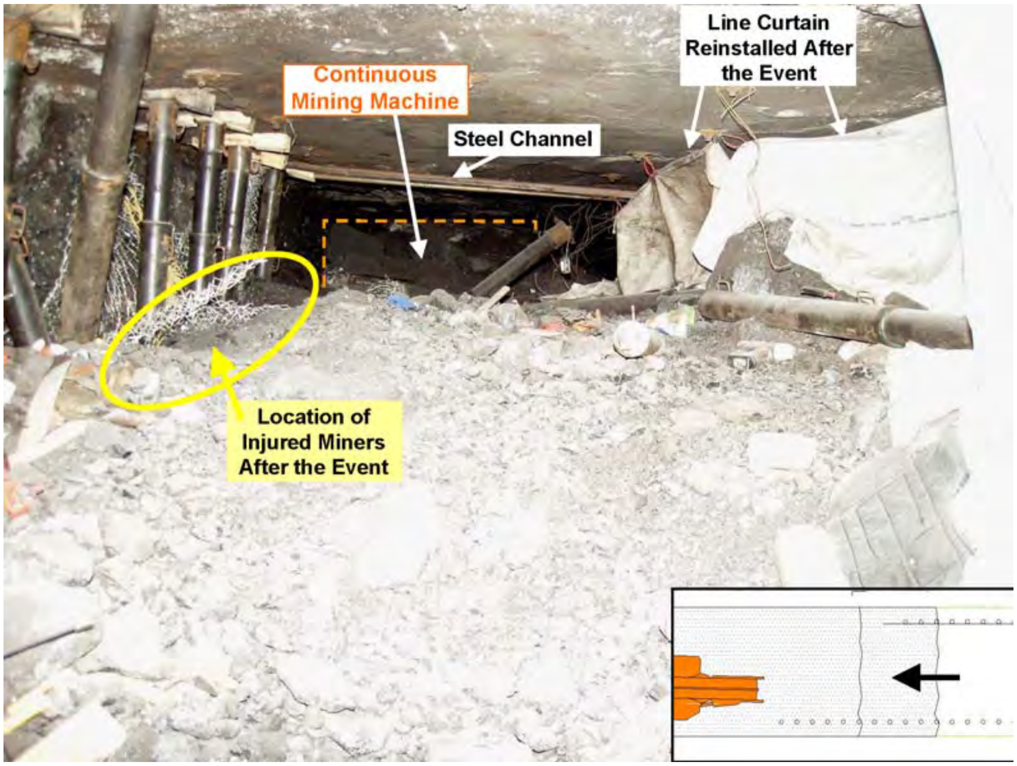


Figure 15 – Clean-up Area Following the Fatal August 16, 2007, Accident
The direction and location of camera view is denoted by black arrow in the insert.

At 6:59 p.m., Bodee Allred arrived at the accident site, where he met rescuers carrying Brandon Kimber to a pick-up truck. Allred helped place Kimber in the truck and started performing cardiopulmonary resuscitation (CPR). Allred continued CPR until reaching the surface at 7:14 p.m. EMT personnel provided medical attention and continued CPR while in route to Castleview Hospital in Price, Utah.

Day arrived at the surface at 7:18 p.m. and was taken to an ambulance where he was assisted by Bodee Allred and attended to by EMT personnel. Markosek was brought out of the mine at 7:27 p.m. and placed in the ambulance with Day, which transported them to Castleview Hospital. Markosek was later airlifted to Utah Valley Regional Medical Center in Provo, Utah. Tripp was brought out of the mine at 7:33 p.m. and transported by ambulance to Castleview Hospital. Gary Jensen was brought out of the mine at 7:40 p.m. and airlifted to Utah Valley Regional Medical Center.

At 8:11 p.m., the last victim, Dale Black, was removed from the accident site. Metcalf and Bouldin exited the mine at 8:13 p.m. and were transported by ambulance to Castleview Hospital. Gressman arrived on the surface at 8:19 p.m. and was airlifted to University Hospital in Salt Lake City, Utah. Black was brought out of the mine at 8:30 p.m.

At 9:17 p.m. the last group of the rescue workers exited the mine. Due to the large number of people assisting in the rescue efforts, it took several minutes and a thorough head count to ensure that everyone was out of the mine. To facilitate this effort, as workers exited the mine they were directed to the shop area. Once everyone was in the shop area, MSHA and the mine operator conducted a debriefing to verify who was in the mine at the time of the accident and to gather specific information about the accident. At 9:55 p.m., mine management verified that everyone was out of the mine. At 11:35 p.m., MSHA modified the 103(k) order and prohibited anyone from traveling inby Main West crosscut 107.

The August 16, 2007, accident resulted in fatal injuries to rescue workers Dale Black and Brandon Kimber and MSHA coal mine inspector Gary Jensen. Randy Bouldin, Lester Day, Carl Gressman, Casey Metcalf, Jeff Tripp, and MSHA coal mine inspector Frank Markosek suffered severe injuries.

Following the August 16 accident, a panel of independent ground control experts was convened at the mine site to reevaluate the rescue effort. Although underground rescue efforts were suspended until the conditions were reevaluated, efforts to locate the miners from the surface continued.

Surface Rescue Efforts

Attempt to Locate Miners - Boreholes

Seven boreholes were drilled from the surface to the mine workings to locate the entrapped miners and assess conditions in the affected area. Mine coordinates for each borehole were determined from the mine map. These mine coordinates were then transferred and translated as surface coordinates and located on the surface using global positioning satellite surveying. If miners were located after a borehole intersected the mine, the hole could be used to communicate and provide fresh air and sustenance until they were rescued. The first three boreholes were drilled as the underground rescue efforts were ongoing. The next four boreholes were completed after the accident on August 16, 2007.

The mine operator contracted the services of two companies to drill the boreholes into the mine. A road, 1.7 miles in length, and a drill pad were constructed with bulldozers while the drill rigs were being transported to the mine. These roads and drill pads were constructed in mountainous terrain (see Figure 16). Surface locations for the boreholes were surveyed by a contractor for the mine operator. The first borehole was started on August 7, 2007, at 7:30 p.m. and the last borehole was completed at 4:30 a.m., August 30, 2007.

Figure 16 - Mountainous Terrain where Roads and Drill Pads were Constructed

Borehole No. 1 was drilled using a small rotary core drill fitted with a full hole, polycrystalline diamond bit. This drill rig was transported by helicopter from another mine to the drill pad for Borehole No. 1 at 4:30 p.m. on August 7, 2007 (see Figure 17). The diameter of Borehole No. 1 was approximately 3 inches for the first 450 feet and 2.4 inches from 450 feet to its full depth of 1,871 feet. This drill did not have any directional control capability.

Figure 17 - Heliportable Drill Rig

The other six boreholes (Nos. 2–7) were drilled with a larger drill rig that was driven to each drill pad location (see Figure 18). This drill rig arrived at the site at approximately 3:00 a.m. on August 8, 2007, and started drilling Borehole No. 2 at approximately 1:20 p.m. that day. The first 20 feet of all six boreholes were drilled 14.75-inch in diameter with a hammer bit and cased with 10.75-inch steel pipe. The remaining lengths of the boreholes were drilled 8.75-inch in diameter with a tri-cone bit. Borehole No. 2 was cased from 20 feet down to the top of the coal seam with 7.0-inch outside diameter by 6.375-inch inside diameter steel pipe. Boreholes Nos. 3-7 were uncased beyond 20 feet in depth. The larger drill rig utilized directional control and boreholes intersected the mine within a few feet of their intended locations. Figure 19 illustrates the locations of these boreholes relative to the mine workings. Figure 20 illustrates the location of these boreholes on the surface. Table 2 summarizes the borehole parameters and locations.

Figure 18 - Drill Rig at Borehole No. 4

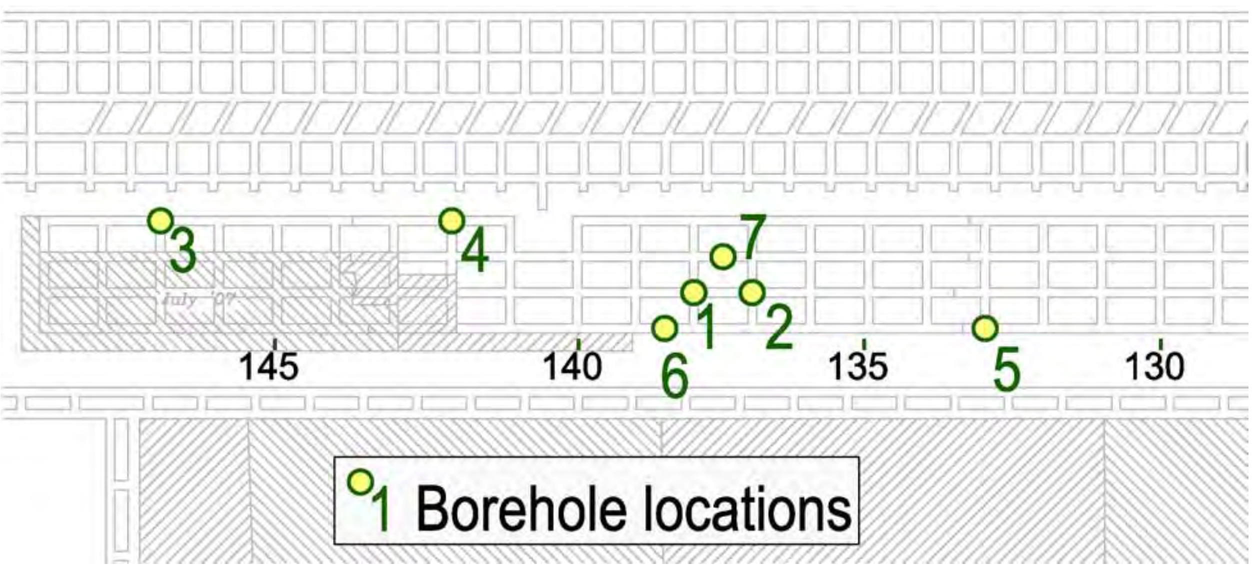


Figure 19 - Borehole Locations Intersecting Underground Workings

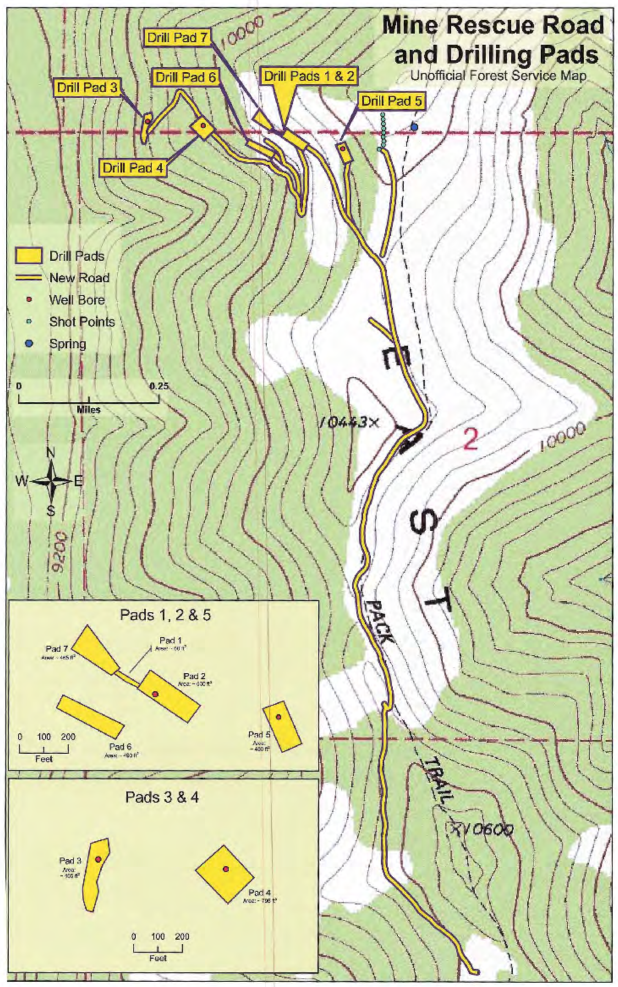


Figure 20 - Surface Location of Boreholes

Table 2 - Summary of Borehole Size, Depth, Drill Rate, Location, Voids, and O_2 Concentration

Borehole No.	Dia. (In)	Depth to Mine (Ft)	Drill Time (Hrs)	Drill Rate (Ft/Hr)	Mine Intersection Time/Date	Mine Intersection Location	Void (Ft)	Initial O_2 Date
1	2.4	1871	50.5	37.0	9:58 pm Aug 9	Crosscut 138, Entry 2	5.5	8.17% August 10
2*	8.75	1886	59.6	31.6	12:57 am Aug 11	Crosscut 137, Entry 2	5.7	Borehole used for air injection
3*	8.75	1414	36.0	39.3	10:11 am Aug 15	Crosscut 147, Entry 4	8.0	16.88% August 16
4*#	8.75	1587	41.5	38.2	9:16 am Aug 18	Crosscut 142, Entry 4	4.0	11.97% August 18
5	8.75	2039	58.3	35.0	8:30 am Aug 22	Crosscut 133, Entry 1	0.5	Borehole blocked
6	8.75	1783	48.0	37.1	4:02 pm Aug 25	Crosscut 138.5, Entry 1	0.0	Borehole blocked
7	8.75	1865	48.3	38.6	4:15 am Aug 30	Crosscut 137.5, Entry 3	2.7	Borehole blocked

* Air was injected into these boreholes with a compressor
# Robot was lowered into mine through this borehole
Note: Borehole Depth to Mine = Depth reported to BLM by GRI

When a borehole intersected the mine opening, attempts were made to contact the entrapped miners by striking the drill steel. MSHA and company personnel would listen for a response by placing a microphone or a person's ear against the drill steel. MSHA's seismic location system was also monitored. The drill steel was then lowered into the mine opening in two-foot increments with pounding and listening taking place at each increment for about ten minutes. This procedure would continue until the drill steel met solid resistance. There were no responses to these activities at any of the boreholes.

The drill operators were able to determine when the boreholes intersected the mine opening by observation of the hydraulic weight indicator gauge. The value on this gauge increased abruptly when the mine opening was intersected. The mine void distance was determined for each borehole by measuring the distance that the drill steel was lowered, after it intersected the mine opening, until it met solid resistance.

Air quality was measured in Borehole No. 1 by drawing an air sample from the drill steel. The air quality was determined in Borehole Nos. 2–7 when the holes were exhausting by collecting air samples near the collar of the hole. The results of air sample analyses from the boreholes are shown in Table 3.

A microphone and camera were lowered into the 8.75-inch boreholes. The camera was equipped with lights and could be rotated 360 degrees. Once evaluations at Borehole No. 2 were completed, a compressor was used to pump fresh air into the mine. The process was repeated at Borehole Nos. 3 and 4.

Description of Boreholes

Borehole No. 1 was started at 7:30 p.m. on August 7, 2007, while preparations were underway to begin the underground rescue in No. 1 entry. The underground rescue efforts had advanced to just inby crosscut 122 in the No. 1 entry when this borehole intersected the mine at 9:58 p.m. on August 9. The mine void was 5.5 feet high at this location. A camera was not lowered into this borehole because of the small diameter. The initial air samples collected at this hole, at 12:00 a.m. on August 10, 2007, contained 20.73% oxygen. However, it was discovered that the holes in the bit were clogged and that this initial sample did not represent the air quality in the mine. After the bit was flushed with water, another air sample taken at 1:45 a.m. on August 10 contained 8.17% oxygen. Since the penetration location was not known at that time, it could not be determined whether the low oxygen concentration was associated with the South Barrier section or a sealed area of the mine. Therefore, a borehole survey was conducted on August 10. The survey determined that the borehole had intersected the mine level at crosscut 138 in the No. 2 entry 85 feet south of its intended location. The large deviation was due to the lack of directional control with this rig and it was only by chance that the hole intersected the mine opening.

The location for Borehole No. 2 was in the belt entry in the intersection outby the section feeder. Drilling of this borehole started at 1:20 p.m. on August 8, 2007. The borehole intersected the mine at crosscut 137 in the No. 2 entry at 12:57 a.m. on August 11, 2007. This was the projected mine location for this borehole. The underground rescue efforts had advanced to between crosscuts 123 and 124 in the No. 1 entry when this borehole intersected the mine. The mine void was 5.7 feet at this location. A camera that was lowered into this borehole revealed that the intersection was mostly open but the entries and crosscuts leading into the intersection were almost completely filled with rubble. The belt was embedded in rubble inby and outby the intersection.

Table 3 - Analysis Results of Air Samples Taken at Boreholes

Borehole Number	Date	Time	H ppm	O_2 %	N %	CH_4 %	CO ppm	CO_2 %	$C2H_2$ ppm	$C2H_4$ ppm	$C2H_6$ ppm	Ar %
#1 BH (2")	08/10/07	0:00	8	20.73	78.12	NDA	12	0.22	NDA	NDA	NDA	0.93
#1 BH (2")	08/10/07	0:10	7	20.76	78.10	NDA	10	0.21	NDA	NDA	NDA	0.93
#1 BH (2")	08/10/07	1:45	116	8.17	90.33	0.01	186	0.53	NDA	NDA	NDA	0.93
#1 BH (2")	08/10/07	1:55	126	8.20	90.29	0.02	180	0.53	NDA	NDA	NDA	0.93
#1 BH (2")	08/10/07	16:00	85	7.70	90.79	NDA	142	0.55	NDA	NDA	NDA	0.93
#1 BH (2")	08/10/07	16:04	88	7.61	90.86	NDA	146	0.56	NDA	NDA	NDA	0.93
#1 BH (2")	08/10/07	16:07	78	7.58	90.90	NDA	140	0.56	NDA	NDA	NDA	0.93
#1 BH (2")	08/10/07	21:57	79	7.46	91.00	NDA	141	0.58	NDA	NDA	NDA	0.93
#1 BH (2")	08/13/07	11:30	43	16.67	82.08	NDA	37	0.30	NDA	NDA	NDA	0.93
#1 BH (2")	08/14/07	15:00	51	16.31	82.39	NDA	42	0.35	NDA	NDA	NDA	0.93
#1 BH (2")	08/14/07	19:00	54	15.48	83.13	NDA	40	0.44	NDA	NDA	NDA	0.93
#1 BH (2")	08/14/07	23:00	43	16.68	82.02	NDA	32	0.36	NDA	NDA	NDA	0.93
#1 BH (2")	08/15/07	3:00	52	16.17	82.49	NDA	35	0.41	NDA	NDA	NDA	0.93
#1 BH (2")	08/15/07	7:00	55	15.93	82.70	NDA	38	0.43	NDA	NDA	NDA	0.93
#1 BH (2")	08/15/07	11:00	65	14.73	83.87	NDA	41	0.45	NDA	NDA	NDA	0.93
#1 BH (2")	08/15/07	15:00	29	14.16	84.46	NDA	43	0.43	NDA	NDA	NDA	0.93
#1 BH (2")	08/15/07	17:00	38	11.65	86.90	0.01	42	0.51	NDA	NDA	NDA	0.93
#1 BH (2")	08/15/07	18:45	33	9.50	88.98	0.01	42	0.58	NDA	NDA	NDA	0.93
#1 BH (2")	08/15/07	23:00	8	9.25	89.24	0.02	41	0.56	NDA	NDA	6	0.93
#1 BH (2")	08/16/07	3:00	90	7.63	90.78	0.03	42	0.62	NDA	NDA	10	0.93
#1 BH (2")	08/16/07	7:00	62	7.60	90.82	0.02	43	0.62	NDA	NDA	9	0.93
#1 BH (2")	08/16/07	11:00	66	8.14	90.29	0.02	42	0.61	NDA	NDA	10	0.93
#1 BH (2")	08/16/07	15:00	7	7.49	90.94	0.03	39	0.60	NDA	NDA	10	0.93
#1 BH (2")	08/16/07	19:00	11	7.85	90.61	0.03	41	0.58	NDA	NDA	20	0.93
#1 BH (2")	08/16/07	23:00	9	8.01	90.47	0.03	39	0.56	NDA	NDA	20	0.93
#1 BH (2")	08/17/07	3:00	8	9.26	89.27	0.02	34	0.51	NDA	NDA	20	0.93
#1 BH (2")	08/17/07	7:00	9	7.14	91.30	0.03	38	0.59	NDA	NDA	20	0.93
#1 BH (2")	08/17/07	11:00	9	7.12	91.31	0.03	36	0.59	NDA	NDA	20	0.93
#1 BH (2")	08/17/07	15:00	4	7.14	91.28	0.04	35	0.60	NDA	NDA	20	0.93
#1 BH (2")	08/17/07	19:00	8	7.88	90.56	0.04	32	0.59	NDA	NDA	30	0.93
#1 BH (2")	08/17/07	23:00	12	7.60	90.82	0.04	32	0.60	NDA	NDA	30	0.93
#1 BH (2")	08/18/07	3:00	11	7.58	90.84	0.04	32	0.61	NDA	NDA	30	0.93
#1 BH (2")	08/18/07	7:00	7	9.43	89.05	0.03	29	0.55	NDA	NDA	20	0.93
#1 BH (2")	08/18/07	15:00	9	9.41	89.00	0.04	32	0.62	NDA	NDA	30	0.93
#1 BH (2")	08/18/07	21:45	14	11.91	86.59	0.03	28	0.53	NDA	NDA	20	0.93
#1 BH (2")	08/18/07	23:00	19	10.92	87.52	0.03	31	0.60	NDA	NDA	30	0.93
#1 BH (2")	08/19/07	3:00	13	10.41	88.01	0.03	33	0.61	NDA	NDA	30	0.93
#1 BH (2")	08/19/07	7:00	20	11.39	87.04	0.03	31	0.60	NDA	NDA	30	0.93
#1 BH (2")	08/19/07	11:00	44	13.97	84.50	0.03	32	0.57	NDA	NDA	20	0.93
#1 BH (2")	08/19/07	15:00	43	13.98	84.48	0.03	32	0.57	NDA	NDA	20	0.93
#1 BH (2")	08/19/07	16:00	33	14.25	84.28	0.02	52	0.50	NDA	NDA	20	0.93
#1 BH (2")	08/19/07	20:00	20	15.03	83.51	0.02	29	0.50	NDA	NDA	20	0.93
#1 BH (2")	08/19/07	23:00	20	14.27	84.22	0.03	32	0.54	NDA	NDA	20	0.93
#1 BH (2")	08/20/07	2:00	25	14.43	84.02	0.03	31	0.58	NDA	NDA	20	0.93
#1 BH (2")	08/20/07	6:00	16	14.18	84.32	0.02	32	0.54	NDA	NDA	20	0.93
#1 BH (2")	08/20/07	9:42	15	15.25	83.35	0.02	33	0.45	NDA	NDA	20	0.93
#1 BH (2")	08/20/07	12:00?	12	14.64	83.95	0.02	32	0.45	NDA	NDA	10	0.93
#1 BH (2")	08/20/07	16:35	NDA	20.95	77.99	NDA	3	0.13	NDA	NDA	NDA	0.93
#1 BH (1")	08/21/07	4:00	15	14.03	84.46	0.02	38	0.55	NDA	NDA	20	0.93
#1 BH (1")	08/21/07	5:00?	15	13.95	84.60	0.02	35	0.49	NDA	NDA	20	0.93
#1 BH (1")	08/21/07	11:42	10	15.04	83.53	0.02	36	0.47	NDA	NDA	10	0.93
#2 BH (8")	08/20/07	13:45	17	14.27	84.27	0.02	35	0.51	NDA	NDA	20	0.93
#2 BH (8")	08/21/07	7:35	12	14.72	83.83	0.02	37	0.49	NDA	NDA	10	0.93
#3 BH (8")	08/16/07	6:00	2	16.88	81.86	0.02	21	0.30	NDA	NDA	40	0.93
#3 BH (8")	08/19/07	15:15	1	20.95	78.04	NDA	18	0.08	NDA	NDA	NDA	0.93
#3 BH (8")	08/19/07	17:00	NDA	20.71	78.21	NDA	23	0.15	NDA	NDA	6	0.93
#4 BH (8")	08/18/07	19:15	3	11.97	86.52	0.04	31	0.53	NDA	NDA	30	0.93
#4 BH (8")	08/18/07	19:45	2	12.92	85.62	0.03	28	0.49	NDA	NDA	30	0.93
#4 BH (8")	08/19/07	8:55	2	14.84	83.73	0.03	29	0.47	NDA	NDA	20	0.93
#4 BH (8")	08/19/07	9:00	2	14.98	83.60	0.03	29	0.46	NDA	NDA	20	0.93
#4 BH (8")	08/19/07	14:20	2	16.85	81.83	0.02	23	0.37	NDA	NDA	20	0.93
#4 BH (8")	08/19/07	21:00	2	14.97	83.61	0.02	28	0.46	NDA	NDA	20	0.93
#4 BH (8")	08/19/07	23:00	3	16.65	82.01	0.02	27	0.39	NDA	NDA	20	0.93
#4 BH (8")	08/20/07	2:00	3	15.95	82.64	0.02	35	0.45	NDA	NDA	20	0.93
#4 BH (8")	08/20/07	6:00	3	15.84	82.74	0.02	38	0.46	NDA	NDA	20	0.93
#4 BH (8")	08/20/07	9:52	3	15.56	83.03	0.02	41	0.45	NDA	NDA	20	0.93
#4 BH (8")	08/20/07	13:50	3	15.50	83.09	0.02	52	0.46	NDA	NDA	20	0.93
#4 BH (8")	08/20/07	17:40	2	16.72	81.93	0.02	33	0.40	NDA	NDA	20	0.93
#4 BH (8")	08/20/07	19:50	3	16.30	82.33	0.01	37	0.42	NDA	NDA	20	0.93
#4 BH (8")	08/21/07	5:00	3	15.95	82.64	0.02	40	0.46	NDA	NDA	20	0.93
#4 BH (8")	08/21/07	9:07	2	19.71	79.15	NDA	13	0.20	NDA	NDA	NDA	0.93
#4 BH (8")	08/21/07	13:40	2	17.28	81.43	0.01	32	0.35	NDA	NDA	10	0.93
#4 BH (8")	08/21/07	14:00	NDA	19.59	79.23	NDA	12	0.24	NDA	NDA	7	0.93
#4 BH (8")	08/22/07	19:50	3	16.98	81.65	0.01	36	0.42	NDA	NDA	10	0.93
#4 BH (8")	08/23/07	8:00	3	16.25	82.37	0.01	46	0.43	NDA	NDA	10	0.93
#4 BH (8")	08/23/07	9:00	2	16.53	82.11	0.01	44	0.41	NDA	NDA	10	0.93
#4 BH (8")	08/23/07	19:40	1	20.12	78.79	NDA	12	0.15	NDA	NDA	NDA	0.93

On August 11, 2007, MSHA's rescue capsule arrived on mine property from Beckley, West Virginia. The 92-inch high by 21.5-inch diameter, one-man rescue capsule required a larger rig to drill a minimum 30-inch diameter hole into the mine opening to provide clearance for the capsule. The rescue capsule was available for use should signs of life be detected during rescue efforts.

The location chosen for Borehole No. 3 was in the bleeder entry of the South Barrier section. Drilling of this borehole started at 10:12 p.m. on August 13, 2007. The borehole intersected the mine at crosscut 147 in the No. 4 entry at 10:11 a.m. on August 15, 2007. This was the projected mine location for this borehole. The underground rescue efforts had advanced to 120 feet inby crosscut 125 in the No. 1 entry when this borehole intersected the mine. The mine void was the full entry height or approximately 8 feet at this location. After penetrating the mine, the drill steel was struck three times with a hammer. A signal, repeating at 1 to 2 second intervals, was detected by the MSHA seismic location system. These signals were received at only one sub-array location (sub-array four). Dr. Jeffrey Kravitz (MSHA chief of scientific development), reviewed the record and determined that the signals were too strong for that expected from an entrapped miner. These signal recordings prompted the decision to move the proposed location of Borehole No. 4 to a location near the sub-array where the signal was received to determine if the entrapped miners might be in that vicinity.

Underground rescue efforts were suspended indefinitely after the accident on August 16, 2007. Borehole No. 4 was being drilled at this time. Borehole No. 4 was completed and three more boreholes were drilled in an effort to locate the entrapped miners after the underground rescue efforts were suspended. The location for Borehole No. 4 was in the South Barrier section bleeder entry, five crosscuts outby Borehole No. 3. Drilling of this borehole started at 3:45 p.m. on August 16, 2007. Borehole No. 4 intersected the mine at crosscut 142 in the No. 4 entry at 9:16 a.m. on August 18, 2007. This was the projected mine location for this borehole. The mine void was 4 feet at this location. After penetrating the mine, the drill steel was struck with a hammer to signal the miners. No response was heard. A quiet time was established by shutting down all surface operations. A series of explosive charges were set off to signal the miners. First, three 100-pound charges were detonated at 12:16 p.m. At 12:53 p.m., three 50-pound charges were detonated. No response was detected by MSHA's seismic location system.

The location for Borehole No. 5 was in the primary escapeway entry of the South Barrier section. Drilling of this borehole started at 10:15 p.m. on August 19, 2007. The borehole intersected the mine at crosscut 133 in the No. 1 entry at 8:30 a.m. on August 22, 2007. This was the projected mine location for this borehole. The mine void was 0.5 feet at this location. An attempt to lower a camera into this borehole was aborted because the hole was blocked with mud at 511 feet from the surface.

The location chosen for Borehole No. 6 was near the last known area where mining was taking place in the South Barrier section. Drilling of this borehole started at 4:00 p.m. on August 23, 2007. The borehole intersected the mine halfway between crosscuts 138 and 139 in the No. 1 entry at 4:02 p.m. on August 25, 2007. This was the projected mine location for this borehole. No mine void was encountered.

The location chosen for Borehole No. 7 was in the kitchen/transformer area of the South Barrier section. This was near the area in which Borehole No. 1 was intended to intercept the mine. Drilling of this borehole started at 4:00 a.m. on August 28, 2007. The borehole intersected the mine level between crosscuts 137 and 138 in the No. 3 entry at 4:15 a.m. on August 30, 2007.

This was the projected mine location for this borehole. A 7-foot rubble depth and a 2.7-foot void height were encountered. An immediate attempt to lower a camera into this borehole was thwarted because water and mud had blocked the hole approximately 9 feet from the mine level.

A camera-equipped robot was quickly designed and assembled specifically for the Crandall Canyon Mine drilling rescue efforts. The robot was lowered into Borehole No. 3 on August 27, 2007. The robot was lowered into the mine with a winch and tripod arrangement as shown on Figure 21 and Figure 22. The robot was unable to enter the mine because the borehole had partially closed.

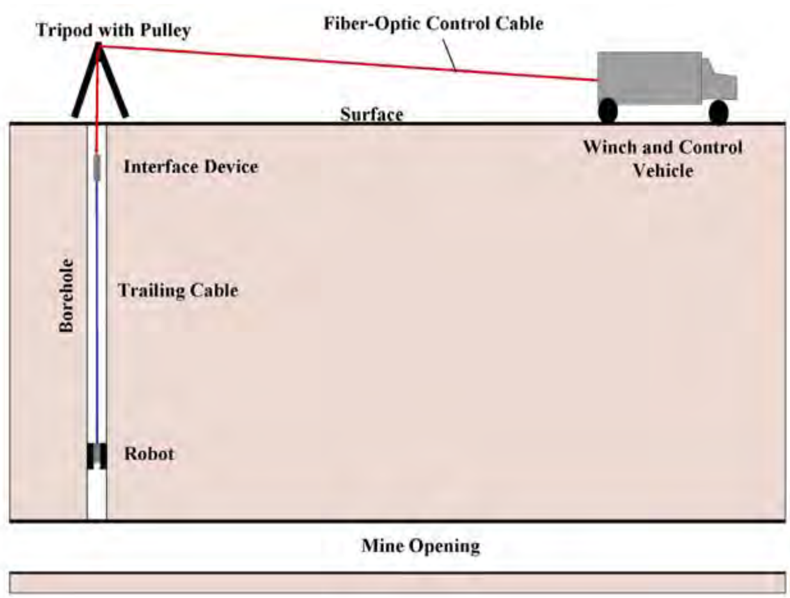


Figure 21 - Arrangement for Lowering Robot into Mine Through a Borehole

Figure 22 - Robot Being Lowered Into Borehole

On August 30, 2007, the robot was lowered into Borehole No. 4 in the same manner as was attempted with Borehole No. 3. However, it was only able to travel a short distance in the mine due to the rubble. While retrieving the robot from Borehole No. 4, it became wedged in the borehole and could not be retrieved.

Attempt to Locate Miners - MSHA's Seismic System

MSHA maintains a truck-mounted seismic location system at the Pittsburgh Safety and Health Technology Center. The system is designed to detect and locate entrapped miners. The truck-mounted system consists of a seismic truck, generator truck, and a supply trailer. The system is unique compared to typical seismic monitoring equipment. The system is tuned specifically to detect the frequencies generated by miners signaling by pounding on the roof.

Kravitz was notified of the accident at 5:58 a.m. MDT on August 6, 2007, and began to ready the system. The system was airlifted from Pittsburgh, Pennsylvania, to Grand Junction, Colorado, and arrived at approximately 4:00 a.m. on August 7, 2007. The two trucks were driven to the mine and arrived at 10:30 a.m. that morning.

The seismic location system utilizes geophone sub-arrays which detect and transmit signals to the seismic truck. Each array consists of several geophones, preamp and telemetry unit with antenna. A line-of-sight path is required from the sub-array antennas to the truck for the telemetry to function. Due to the steep terrain, the seismic location truck was set up to the west of the mine in Joes Valley. This provided a clear line of communication to each sub-array. While the truck was being positioned in Joes Valley, other members of the MEU set up the sub-arrays. The system became operational at approximately 10:30 p.m. on August 7, 2007.

The sub-arrays and drilling operations were both centered over the last known location of the entrapped miners. After the first signals were analyzed, it was apparent that noise from the drilling operations and drill pad preparations would preclude any chance of receiving signals from underground while drilling. System sensitivity had to be decreased during drilling. The sub-arrays were relocated several times to maximize the chance of receiving a signal. A quiet period was established after each borehole intersected the mine. The system sensitivity was maximized at these times and the system was carefully monitored.

Suspension of Rescue Efforts

After the August 16 accident, a group of independent ground control experts was assembled by GRI and MSHA to reevaluate conditions and rescue methods. On August 19, 2007, the seven member panel convened at the mine site. The panel members, listed below, included three NIOSH employees and four consultants.

- Keith A. Heasley, Ph.D., P.E., Professor, West Virginia University
- Hamid Maleki, Ph.D., P.E., President/Principal, Maleki Technologies Inc.
- Christopher Mark, Ph.D., P.E., Mining Engineer, NIOSH Pittsburgh Research Laboratory
- Anthony T. Iannacchione, Ph.D., P.E., Mining Engineer, NIOSH Pittsburgh Research Laboratory
- Reid W. Olsen, Business Manager, Bruno Engineering, P.C.
- Morgan Moon, Engineering Consultant, Morgan Moon Co.
- Peter Swanson, Ph.D., Research Geophysicist, NIOSH Spokane Research Laboratory

The panel was charged with two objectives: evaluate the overall stability of the mine and the underlying and overlying strata in the Main West area, inby crosscut 107; and quantify the risks and recommend potential ground control methods of gaining access to the last known location of the miners. On August 20, 2007, the panel issued a written statement and presented it to representatives of the mine operator and MSHA at the mine site. The panel stated *"that the overwhelming preponderance of data indicates that the entire Main West area remains in a state that is structurally unstable. We are highly concerned that dangerous seismic activity and pillar instability are likely to continue, and that it is not possible to accurately predict the timing or location of these events. No matter how a miner might access the Main West area, seismic activity and pillar instability will pose a significant risk. These risks would be further increased by any excavation of coal in the Main West area."*

The evaluation confirmed what the mine operator and MSHA had surmised from the August 16 accident when underground rescue work was suspended. The panel reinforced the opinion that even with a much stronger support system in place, the process of disturbing the rubble for installation of the next set of supports would endanger those installing the support system. Based on the panel's evaluation it was decided that rescue efforts would be limited to borehole drilling. If miners were located, entering the mine via rescue capsule would be pursued.

Drilling continued until August 30, at which time sufficient information had been obtained to determine that the entrapped miners could not have survived the August 6 accident due to extensive burst damage and low oxygen on the section. As a result of information obtained from the boreholes, the unfavorable conditions encountered underground, and the findings of the expert panel, the families were notified on August 31, 2007, at 5:00 p.m. that all rescue efforts were being suspended. The bodies of Kerry Allred, Don Erickson, Jose Luis Hernandez, Juan Carlos Payan, Brandon Phillips, and Manuel Sanchez remained entombed in the mine.

Mine Closure

The decision to suspend rescue efforts was followed by the mine operator's announcement to cease coal production at the mine. Activities at the mine changed from rescue efforts to the recovery of mining equipment. On September 4, 2007, at 3:55 p.m., the 103(k) order was modified to allow work inby crosscut 90, provided that all entries were continually monitored for oxygen, carbon monoxide, and methane. Travel inby crosscut 107 was prohibited. The order was modified on September 14, 2007, at 2:45 a.m. to prohibit work inby crosscut 50 of the Main West. This modification also required all persons working underground to be provided with multi-gas detectors capable of detecting oxygen, carbon monoxide, and methane.

On September 27, 2007, BLM received a plan from the mine operator requesting approval to grout the boreholes drilled during the rescue attempt. BLM approved the plan the following day. On October 1, 2007, the mine operator submitted a plan to MSHA detailing the grouting of the boreholes on East Mountain and construction of concrete block walls in the mine openings to prevent entrance by unauthorized persons. MSHA acknowledged the plan on October 18, 2007. The borehole abandonment process began on October 12, 2007, and was completed on October 15, 2007. The actual plugging of the boreholes varied from borehole to borehole. Uncased boreholes were extensively blocked. Boreholes were filled from the point of blockage to within 20 feet of the surface with abandonite, a bentonite based grout mixture. The top 20 feet of all boreholes was filled with cement.

INVESTIGATION OF THE ACCIDENT

The MSHA Administrator of Coal Mine Safety and Health appointed a team to investigate the accident at the mine, led by Richard A. Gates, District Manager of Coal District 11. The remainder of the team consisted of personnel from MSHA Coal Districts 2, 3, 6, 11, and Technical Support's Pittsburgh Safety and Health Technology Center. The investigation was conducted jointly with the State of Utah Labor Commission. Sherrie Hayashi, Labor Commissioner served as the state representative. The team received assistance from MSHA personnel in Headquarters, Educational Field Services, and Program Evaluation and Information Resources. The team also received assistance from personnel at The University of Utah, West Virginia University, United States Geological Survey, and Neva Ridge Technologies. The investigation team was announced on August 30, 2007, and arrived at MSHA's Price, Utah, Field Office on September 5, 2007.

Representatives of the miners and GRI participated in the on site investigation. At the mine, the investigative procedures included mapping specific underground areas of the mine including the August 16, 2007, accident scene, and photographing the affected areas. Unstable ground conditions inby crosscut 107 of Main West limited the underground investigation to two underground visits focusing on the August 16 accident scene. However, the team was able to take advantage of in-mine information obtained during the rescue efforts from August 6 through August 16. Pertinent records and documents were obtained and reviewed during the course of the investigation. Information and records were obtained from MSHA District 9 offices, GRI, and AAI.

The investigation team identified people who had knowledge relevant to the accident and conducted 80 interviews. These people included current and former employees of Genwal Resources Inc, UtahAmerican Energy Inc. and other Murray Energy Corporation operations, MSHA, Bureau of Land Management, University of Utah, Agapito Associates, Inc., and Energy West Mining Company. The interviews were conducted at:

- Southeastern Utah Association of Local Governments Building, Price, Utah,
- Residence Inn, Salt Lake City, Utah,
- City Hall Building, Spring City, Utah,
- University of Utah, Salt Lake City, Utah,
- National Mine Health and Safety Academy, Beckley, WV,
- Agapito Associates, Inc., Grand Junction, Colorado,
- Hall & Evans LLC, Denver, Colorado,
- MSHA Approval and Certification Center, Triadelphia, WV.

The interviews with MSHA were voluntary. A number of witnesses declined to give interviews to MSHA, including current and former employees of Murray Energy Corporation operations and AAI.

In addition to this accident investigation and the independent review noted in the Preface, there have been several other governmental investigations and hearings related to the Crandall Canyon Mine accidents. These include those conducted by: the Utah Mine Safety Commission; the Senate Appropriations Subcommittee on Labor, Health and Human Services, Education and Related Agencies; the Senate Committee on Health, Education, Labor, and Pensions; the House Committee on Education and Labor; and the Office of the Inspector General of the U.S. Department of Labor.

DISCUSSION

The Crandall Canyon Mine accident investigation was somewhat unique among MSHA investigations in that (1) it examined two separate but related fatal accidents and (2) it utilized a variety of technical analyses. It was obvious at the most fundamental level that the accidents at Crandall Canyon Mine were precipitated by pillar failures in the South Barrier section. One could envision that the South Barrier was the last substantial block of coal supporting the mountain and, as it was removed, the mountain was simply too heavy for the pillars. Similarly, the August 16, 2007, accident could be attributed to the inability of the installed support system to protect rescuers from an unanticipated pillar burst. However, MSHA's investigation augments these observations with detailed analyses intended to provide sufficient insight to prevent a recurrence.

The following sections provide information pertaining to both accidents. Since these accidents were associated with dynamic pillar failures, detailed technical analyses of ground behavior and mine design are included. In some instances, the results of the analyses are important in explaining what happened. In other instances, it is important to understand the methodologies that were used. Sufficient technical detail has been included to describe the analyses and allow industry practitioners to apply the findings of the investigation to prevent future incidents. Additionally, each major section includes an introduction and summary which provide a general understanding of the issues.

August 6 Accident Discussion

The August 6 accident occurred as a result of the rapid failure of a large number of pillars. Although it was a single catastrophic event, the failure was the culmination of a series of decisions, actions, events, and conditions that were made or occurred over a period of more than 12 years (i.e., from the time the Main West entries in the vicinity of the accident site were developed).

Pillars developed in 1995 in Main West proved to be adequate for development but deteriorated when adjacent longwall panels were mined. These pillars were protected from more extreme longwall abutment loading by large barriers (~450 feet wide) and the system, though damaged, remained stable. Mining through the barriers on both sides of Main West in 2007, however, disrupted the balance.

Between late 2006 and February 2007, the 448-foot wide barrier north of Main West was developed by driving four entries parallel to the existing Main West entries. Smaller barriers remained on either side of the new section entries (53 feet wide on the south side and 135 feet wide on the north side). The 135-foot wide barrier that separated the North Barrier section from the adjacent longwall panel gob was insufficient to isolate the workings from substantial abutment loading. Despite the high stress levels associated with deep cover (up to 2,240 feet of overburden) and longwall abutment stress, the section remained stable during development. However, as pillar recovery operations retreated under a steadily increasing depth of overburden, conditions worsened and culminated in a March 10, 2007, outburst accident of sufficient magnitude to cause the mining section to be abandoned.

Between March and July 2007, four entries were developed in the barrier south of Main West. Pillar dimensions were increased in an effort to mitigate the type of outburst failure that had occurred in the North Barrier section. The longer pillars were about 16% stronger but, at the same time, a narrower barrier pillar (121 feet versus 135 feet in the previous section) exposed the section to higher abutment stress from the adjacent longwall gob. The net effect was that the mining experience in the South Barrier section was quite similar to that in the north. Once again, the section was developed without incident but conditions worsened during pillar recovery and culminated in the catastrophic August 6, 2007, outburst accident.

The August 6 event affected a much broader area than the March 10 outburst accident in the North Barrier section. The primary reason for this was that entry development in both Barrier sections had segmented the original, ~450-feet wide Main West barriers into relatively small pillars; these pillars formed a large area of similarly sized and marginally stable pillars. When the North Barrier section was developed, the overall system (i.e., the North Barrier section, the Main West, and the 53-foot barrier between the two) effectively created a nine-entry system of similarly sized pillars. When the South Barrier section was developed, the system was expanded to a 13-entry system albeit with slightly stronger section pillars. With this large area of similarly sized and marginally stable pillars, once failure initiated at any point in the system, the system was set to fail in domino fashion and on August 6 it did.

GRI relied upon several engineering analyses to validate that their mining plan was sound. However, the results proved to be misleading in some cases because the analyses were wrong and in others they were misinterpreted. Three separate methods of analysis employed as part of MSHA's investigation confirm that the mining plan was destined to fail. Results of the first method, Analysis of Retreat Mining Pillar Stability (ARMPS), are well below NIOSH recommendations. The second method, a finite element analysis of the mining plan, indicates a decidedly unsafe, unstable situation in the making even without pillar recovery. Similarly, the third method, boundary element analysis, demonstrated that the area was primed for a massive pillar collapse (see Appendix K).

All three analysis methods show that the area was destined to fail. However, additional analyses were required to understand how and why it failed. Boundary element models provided insight to the strata mechanics associated with the failure. These results demonstrate that if material properties and loading conditions are exactly uniform throughout the Main West area, then some stimulus such as a gradual weakening of the coal over time or joint slip in the overburden may have triggered the event. On the other hand, if the properties and loading conditions are not uniform (a reasonable geologic assumption), the event may have been triggered by pillar recovery in the active mining section. The boundary element modeling only identified possible triggers, and by itself could not distinguish the most likely trigger. However, seismic analyses and subsidence information employed in the investigation provide further clarification that the collapse was most likely initiated by the mining activity.

Analyses of the seismic event associated with the August 6 collapse indicate that it originated from a point near the last row of recovered pillars, just inby the last known location of the entrapped miners. Soon after the collapse, an initial location of the event was calculated automatically and posted on UUSS and USGS web sites. This calculation process provides expedient information of value to seismologists but it and other routine location procedures lack the precision required for this investigation. In the months following the accident, UUSS employed a variety of advanced seismological methods to improve source location accuracy and to determine other characteristics of the collapse. UUSS determined that the magnitude 3.9 event lasted only seconds, calculated that the mine opening decreased in height by approximately one foot over an area of 50 acres, and noted that movement likely occurred along a north-south oriented vertical plane on the west end of the collapse area. UUSS's description of strata displacements is very consistent with other observations and analyses conducted during the investigation.

Satellite radar images were used to determine surface displacements over the Crandall Canyon Mine. A comparison of images acquired shortly before and after the accident revealed the development of a large surface depression over the accident site. Vertical movements greater than ¾ inches were observed on the surface over an area approximately 1 mile (east-to-west) by ¾ miles (north-to-south). A maximum displacement of nearly 12 inches was observed over the 121-foot wide barrier pillar about 500 feet outby the last known location of the entrapped miners. Borehole No. 5 penetrated the mine workings near the point of maximum displacement and confirmed that the void space in an intersection was only 0.5 feet.

Traditional surface elevation surveys between 1999 and 2004 show that strata overlying about half of the longwall panel south of the working section had not completely subsided and was cantilevered from the Main West South Barrier. Both traditional and satellite surveys conducted after the accident demonstrate that the surface over the panel and the barrier displaced downward as much as 12 inches. Furthermore, the satellite analysis indicates that the strata movement that occurred was much more abrupt at the southern and western edges of the depression (as evidenced by the steeper subsidence contours). The abrupt displacement on the western side is consistent with UUSS's theory that some movement may have occurred on a steeply dipping (near vertical), north-south oriented plane. The abrupt displacement on the southern edge is consistent with substantial failure of the 121-foot wide barrier and an associated downward movement of cantilevered strata over the adjacent longwall gob. The volume of cantilevered strata likely provided the additional loading necessary to initiate the collapse event from the working section.

Pillar recovery operations by their nature create a zone of high stress in adjacent workings. As pillars are removed, the weight of overburden that they once supported must then be carried by neighboring pillars. Abutment loads can be diminished if or when sufficient roof caving and compaction occurs in the gob to allow the weight of overburden to be transmitted into the floor where the pillars were removed; due to the limited dimensions of the South Barrier pillar recovery area, however, it is unlikely that gob compaction had occurred there. Abutment loads were present from the active retreat line and the adjacent longwall gob. Also, overburden depth (and the associated stress level) was increasing as pillar recovery progressed outby. Ultimately, it is most likely that the stress level exceeded the strength of a pillar or group of pillars near the pillar line and that failure initiated a rapid and widespread collapse that propagated outby through the large area of similarly sized pillars.

As pillars were recovered in the South Barrier section, bottom coal was mined from cuts made into the production pillars and barrier. The effect of this activity was to reduce the strength of the remnant barrier behind the retreating pillar line. Bottom mining was not addressed in AAI's model to evaluate the mine design or in GRI's approved roof control plan. Similarly, barrier mining was conducted in violation of the approved roof control plan. A portion of the barrier immediately inby the last know location of the miners was mined even though it had been specified to be left unmined. Although neither of these actions is a fundamental cause of the August 6 collapse, they increased the amount of load transferred to pillars at the working face and reduced the strength of the barrier adjacent to it.

The following sections of this report provide details that support the observations and conclusions of the investigation of the August 6 accident. Included are discussions of: the geology and mining methods at the mine; the relevant ground control history of the mine; the various analyses that were used to determine the nature and extent of the failure; a critique of the previous analyses that provided the basis for the implemented mining plan; and other safety issues (e.g., mine ventilation, emergency response, and training) pertaining to the August 6 accident.

Background for Ground Control Analysis

Since both accidents at Crandall Canyon Mine were essentially ground control failures, factors such as geology, mining dimensions, ground support, and mining method have direct or indirect relevance to the accident or implications regarding conditions encountered afterward. An overview of each of these subjects is provided below.

General Mine Geology

The Crandall Canyon Mine is located in the Wasatch Plateau coal field, within the Hiawatha coal seam. The Hiawatha coal seam typically ranges from 5 to 13 feet thick in the Crandall Canyon Mine reserve. Mining had been undertaken primarily where the coal seam height exceeded 7.5 feet. The Hiawatha coal seam is at the base of the Blackhawk formation (Upper Cretaceous age). Corehole and geophysical data indicate that the overburden above the Hiawatha seam consists of 49% to 68% sandstone. The immediate mine roof typically consists of 0 to 2 feet of interbedded siltstone, shale, and sandstone overlain by bedded sandstone. The Star Point Sandstone, which consists of massive sandstone beds interbedded with shale, lies beneath the Hiawatha seam. A general stratigraphic column for the mine is shown in Figure 23.

The mine portal is at approximately 7,900 feet above sea level in the eastward trending Crandall Canyon. Overburden ranges from less than 100 feet at the mine portal to 2,300 feet under the higher ridges due to the steep mountainous terrain. The Blackhawk formation overlying the Hiawatha coal seam consists of approximately 650 feet of interbedded sandstone and siltstone with an occasional coal seam. The Blind Canyon coal seam lies 55 to 100 feet above the Hiawatha coal seam. Within the Crandall Canyon Mine reserve, the Blind Canyon seam is typically less than 3 feet thick and is not mined. Overlying the Blackhawk formation is the approximately 250-foot thick, cliff forming, Castlegate Sandstone consisting predominantly of sandstone interbedded with shale and siltstone. Alternating sandstone, siltstone, and shale of the Price River and North Horn formations exist above the Castlegate Sandstone.

Geologic structure in the area consists of faults, joints, and igneous dikes. The most significant geologic structure is the north-south oriented Joes Valley Fault system that delineates the western perimeter of the mine reserve (see Appendix D). In the overlying Castlegate Sandstone and Price River formation, the joint orientation trends north to N20ºE. In the southwest and southern portion of the reserve an igneous dike system oriented at approximately N80ºW exists near the southern reserve boundary.

Within the mine property, the coal seam gradually dips at 2.5º to 4º in all directions from a high region in the northwest area (intersection of 2nd North Main and longwall Panel 7 development entries). In the eastern portion of the mine, the face coal cleat (dominant cleat) trends N65ºW. Within the central and western portion of the mine, the face coal cleat mostly trends N40ºE. Sandstone immediate roof and sandstone channel scours of the coal seam have been encountered in some areas.

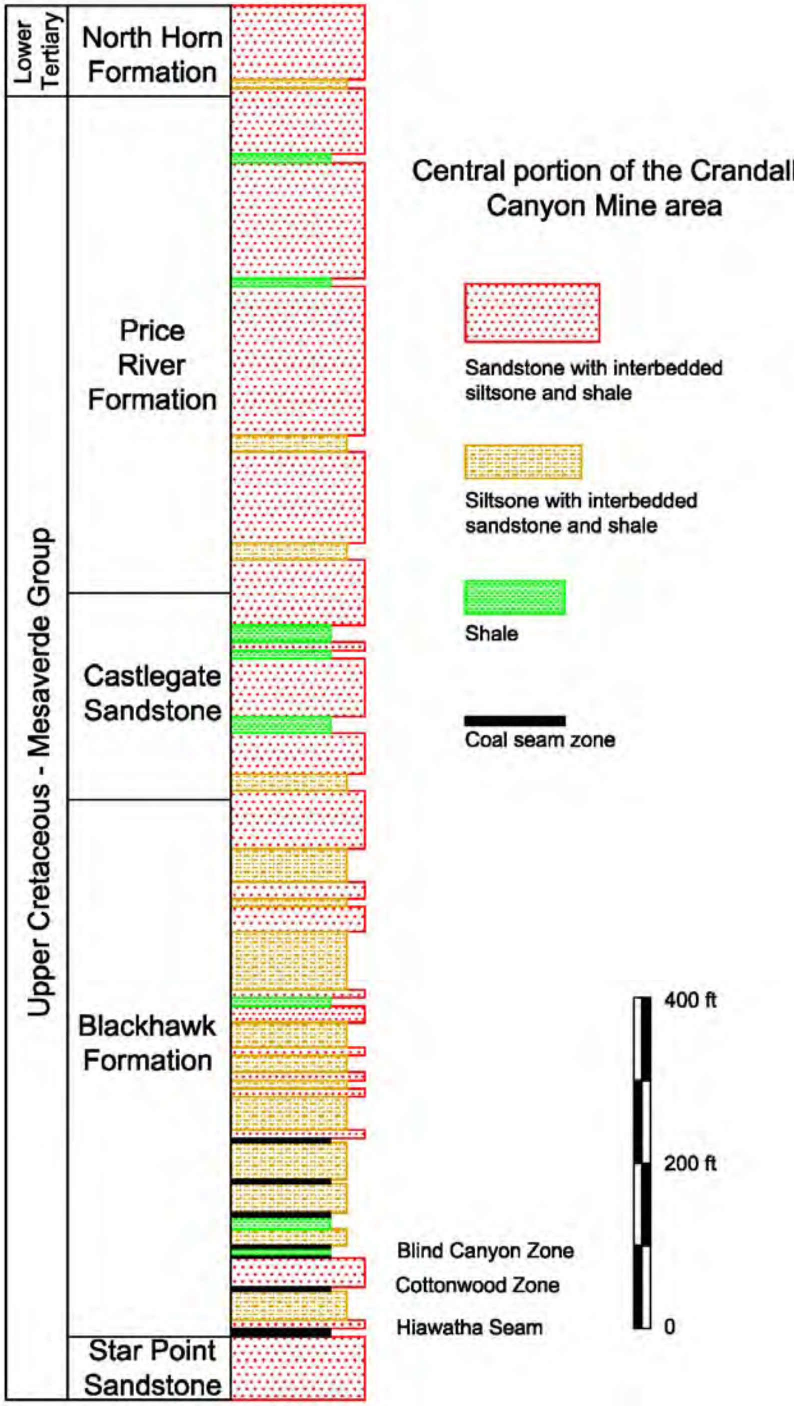


Figure 23 - General Stratigraphic Column for Crandall Canyon Mine

Mining Horizon and Mining Width

The mining height throughout most of the Crandall Canyon Mine was maintained at 7.5 to 8 feet. When the Hiawatha coal seam was less than 8-foot thick, the mined opening had rock roof and floor. However, coal seam thickness often exceeded the mining height. In these areas, coal was left unmined in either the floor or roof. Most of the North and South Barrier sections were developed in the upper portion of the seam; the Main West entries were developed in the lower portion of the seam.

For the mining of the North Barrier section, the roof control plan initially specified that no roof coal would be left in place. While mining in the North Barrier, on January 18, 2007, the plan was modified to allow roof coal to be left in place in areas of weak immediate roof. The plan specified that the minimum bolt length would be 6-foot in the roof coal areas. Prior experience had shown that roof coal would help support weak roof rock. However, the roof coal did not remain intact during retreat mining in the North Barrier section. Therefore, South Barrier section entries and crosscuts were mined to the overlying rock.

While recovering pillars in the North and South Barrier sections, coal left in the floor during development (bottom coal) was being mined. After the upper portion of a cut had been made, the bottom coal would be mined. The continuous mining machine would ramp down into the bottom coal (up to 5 feet in the western portion of the South Barrier section), starting at the edge of the pillar and continuing to the end of the cut. The mining of bottom coal was not addressed in the approved roof control plan.

Areas of Main West developed with continuous haulage were mined an average of approximately 20 to 21 feet wide (based on measurements from 1991 era mining east of crosscut 107). In the newer development, entries and crosscuts were mined 18 feet wide, although the approved roof control plan permitted a maximum mining width of 20 feet. Throughout the mine, pillars showed an hour glass rib profile (see Figure 24). Consequently, mining widths measured at mid pillar often were wider than the original excavated width. The hour glass rib profile was evident when overburden exceeded approximately 1,100 feet and was more pronounced as the depth increased. For example, measurements made during the accident investigation beneath 1,500 feet of cover indicated that older entries, which averaged 20.6 feet on development, had hour glassed to 24.7 feet. Similarly, recently mined 18.5-foot wide openings had hour glassed to an average of 22.4 feet.

Figure 24 - Hour Glass Shape of Stressed Pillars

Primary and Supplemental Roof Support

Prior to 1997, the primary roof support typically consisted of ¾-inch diameter, 5-foot long, fully grouted roof bolts. Five bolts were installed per row, spaced 4 feet apart within a row and 4 to 5 feet between rows. In 1997, the primary support practice transitioned to six roof bolts per row with 3- to 4-foot bolt-to-bolt spacing within the row and wire mesh was installed with the primary roof bolts. Since 1997, six roof bolts per row and wire mesh were used for development and rehabilitation. Wire mesh consisted of welded wire panels 17 feet wide with 4 x 4-inch grids. In mid-2005, the mine adopted a 0.914-inch diameter x 5-foot fully grouted bolt as the primary roof bolt for development mining and rehabilitation roof bolting. For the mining of the North and South Barrier sections, the roof control plan specified six bolts per row with a maximum distance of five feet between rows.

Wood posts, wood cribs, Cans (steel cylinders filled with light-weight concrete), and cable bolts were used for supplemental support. Prior to 2004, wood posts were used as the only supplemental support during pillar recovery. However, beginning in early 2004, four 800-ton capacity Mobile Roof Support (MRS) units were used in conjunction with breaker posts for pillar recovery.

Accidents Related to Ground Control Failures

Standardized form reports must be completed by an operator and sent to MSHA within ten working days of each accident, occupational injury, or occupational illness that occurs at a mine, as required by 30 CFR 50.20. The term "accident" includes the following non-injury ground control related events, as defined in 30 CFR 50.2 (h):

- An unplanned roof fall at or above the anchorage zone in active workings where roof bolts are in use;
- An unplanned roof or rib fall in active workings that impairs ventilation or impedes passage;
- A coal or rock outburst that causes withdrawal of miners or which disrupts regular mining activity for more than one hour.

Data from the standardized form reports are collected and maintained by MSHA. Mine operators also must maintain a map on which roof falls, rib falls, and coal or rock bursts are plotted. MSHA uses all of this information when reviewing roof control plans for adequacy pursuant to 30 CFR 75.223 (d). In addition to submission of standardized form reports, 30 CFR 50.10 requires operators to immediately contact MSHA following an "accident" (as defined, in part, above) at the toll-free number, 1–800–746–1553. MSHA procedures for responding to accidents reported to the toll-free number ensure that the appropriate MSHA manager is rapidly engaged in the decision-making process for initiating accident investigations and for determining that the operator has taken appropriate action to protect miners and prevent a similar occurrence in the future.

Since 1984, GRI submitted form reports for 23 ground control related injuries, 4 non-injury accidents where a longwall tailgate travelway passage was impeded by ground failures, and 8 non-injury roof falls. However, only two of these roof falls were plotted on the mine's roof fall map required by 30 CFR 75.223(b). Prior to 2007, 8 injuries related to coal bursts and bounces were reported. Seven of the eight events occurred during pillar recovery and longwall mining. A 2-entry yield pillar longwall gate configuration was introduced for the deeper longwall Panels 8 to 18 to minimize burst potential and roof instability in the vicinity of the longwall face. Bounces sometimes occurred when the longwall panels retreated to a distance equal to the face length (panel width) or when longwall mining was being conducted under the deeper overburden. Records and interview statements show some bounces and bursts were severe enough to cause reportable injuries. Accident records and interview statements indicate five injuries from bursts and bounces occurred while longwall mining. Accident records also indicate that a miner was injured during pillar recovery from a coal burst in December 1993 and another was injured from a rib fall (reported as a bounce) in January 1994. Both accidents occurred during pillar recovery in the 7th Left Panel off 1st North.

Room and Pillar Retreat Coal Mining Overview

At the time of the August 6 accident, pillars were being recovered on the South Barrier section. Pillar recovery is undertaken at approximately 30% of the 638 underground coal mines in the United States. Approximately 5% of the 638 underground coal mines project pillar recovery in overburden exceeding 1,250 feet. In pillar recovery operations, a series of pillars are first developed using a continuous mining machine and the associated mining equipment. Subsequently, the same equipment is used to remove the pillars. The process generally involves retreating from the deepest point of advance by taking sequential cuts from pillars with the continuous mining machine (typically radio remote controlled) as illustrated in Figure 25. Adjoining pillars are sequentially mined, one pillar row at a time. The regions where the coal pillars are removed are allowed to cave. The border between the remaining pillars being recovered and the area where the roof is expected to break is known as the pillar line. The immediate work area is protected by the intact surrounding pillars and supplemental support systems. The Crandall Canyon Mine used pillar recovery early in its history (until 1995) and restarted pillar recovery in early 2004 (see Appendix D).

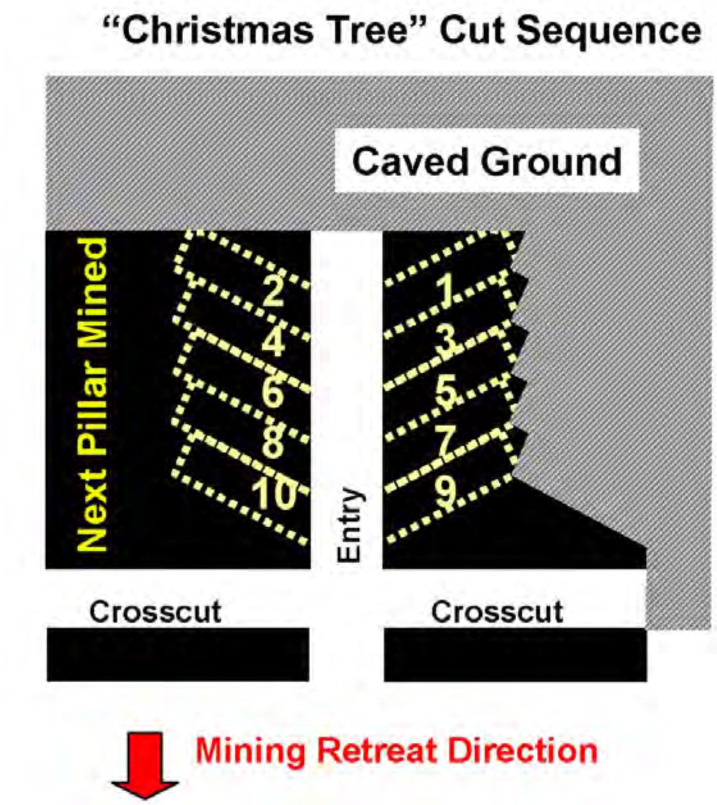


Figure 25 - Example of a Pillar Recovery Cut Sequence

Nature and Extent of Failure

The August 6, 2007, outburst accident was a rapid, catastrophic failure of pillars in a large area of the mine. Rescue attempts in the South Barrier section entries and in the sealed portion of the Main West entries provided direct observations of the nature and outby extent of the failure. Boreholes from the surface provided insight on the inby side. These observations were substantiated by survey and satellite borne radar subsidence data, and seismological records.

Seismological analyses indicate that the 3.9 magnitude event associated with the August 6 failure was characteristic of a collapse event and not a naturally occurring earthquake. The mine collapse resulted in a surface depression up to 12 inches. The greatest vertical movements (and corresponding pillar damage at seam level) were located east of the last known location of the entrapped miners. However, pillar damage of varying degrees extended over a much broader area. The most accurate measure of the initiation time of the August 6 accident was 2:48:40 a.m. (MDT). This time was determined from the seismological analysis and confirmed using records from the atmospheric monitoring system in operation at the mine at the time of the accident.

Underground Observations

Within minutes of the accident, mine workers attempted to reach the South Barrier section to assist their coworkers. These initial efforts and additional attempts in the following days demonstrated that bursting had damaged pillars as far outby as crosscut 119, approximately ½ mile outby the entrapped miners. Debris from the outburst blocked access to all South Barrier entries inby crosscut 126 (see Figure 26). Attempts to reach the miners by breaching a seal and entering the Main West entries revealed poor ground conditions there as well. Inby the seals at Main West crosscut 118, the ground was working and bounces were occurring. Pillar deterioration (rib sloughage) had narrowed walkways to no more than 2 to 3 feet. Roof bolts were showing signs of excessive loading.

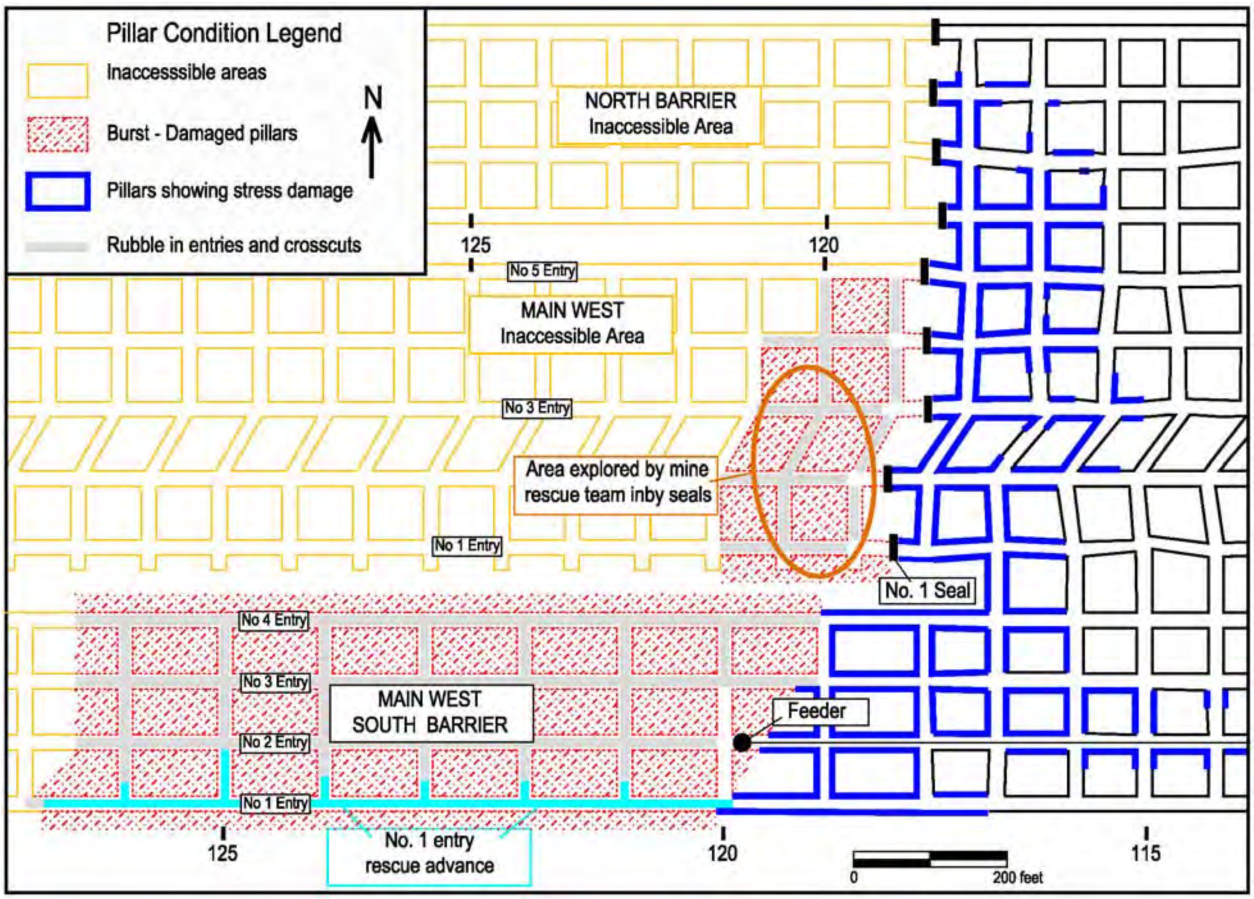


Figure 26 - Extent of Pillar Rib Damage Outby Crosscut 119

On August 11, 2007, ground conditions were mapped in the Main West entries and the North and South Barrier workings outby crosscut 119. Pillar damage was noted up to three crosscuts outby the seals (see Figure 26). The damaged ribs did not appear to be the result of bursting. Rather, the damage appeared to be associated with abutment stress transferred from inby the seals. Figure 27 and Figure 28 illustrate the difference between damaged and undamaged pillar rib conditions. Figure 27 shows normal Main West pillar rib conditions and Figure 28 shows recent pillar rib sloughage from abutment stress.

Figure 27 - Normal Main West Pillar Rib Conditions

Figure 28 - Main West Pillar Rib Condition showing Recent Sloughage from Abutment Stress

Borehole Observations
Conditions determined by the boreholes and visual observations from borehole cameras set the western boundary of the collapse between Borehole Nos. 3 and 4. Borehole No. 4 and others to the east of that location indicated that the mine openings contained rubble. Boreholes in the entries were filled or nearly filled with rubble while boreholes in the intersections contained less rubble. Figure 29 depicts the borehole locations.

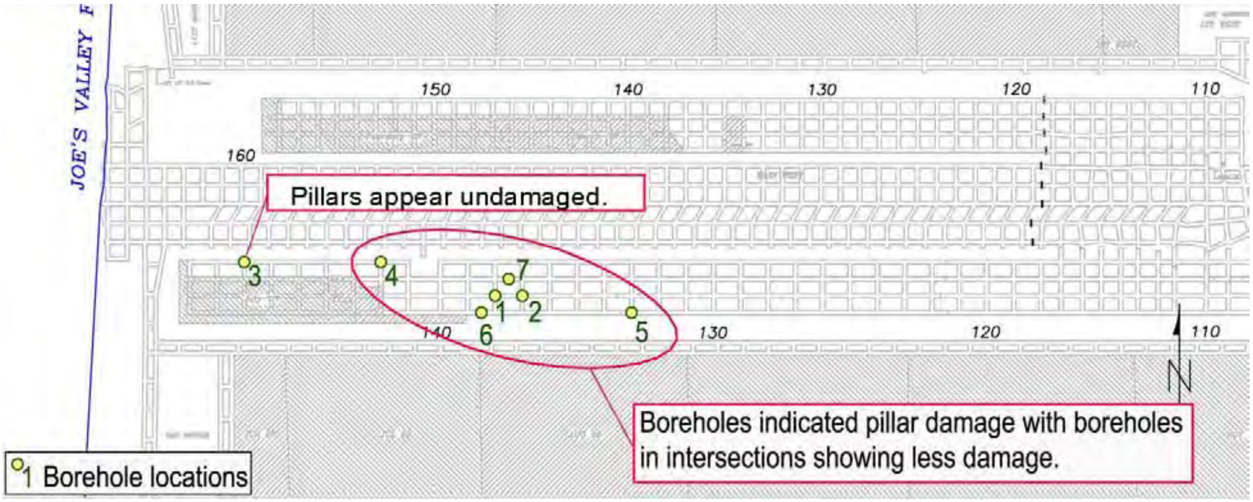


Figure 29 - Borehole Locations and Conditions Observed

Surface Subsidence Determined from GPS Surveys
Surface subsidence had been monitored over the Main West and the adjacent longwall panels since 1999. Longwall subsidence data and characteristics are described in Appendix L. Initially, a baseline survey was done to establish monuments along a north-south line south of crosscut 133 in the Main West (crosscut 129 in the South Barrier). Follow-up surveys were done annually from 2000 to 2004. Aerial photogrammetric surveys were conducted in 2005 and 2006. The aerial survey data lacked the accuracy required to supplement the land surveys.

On August 17, 2007, the subsidence monitoring line was resurveyed over a portion of the South Barrier section and longwall Panels 13 to 14. The GPS survey was conducted along the line of existing surface monuments to provide an updated profile of subsidence. Some of the monuments that previously had been used to monitor subsidence were dislodged. Although the data are incomplete, the profile indicates that a substantial downward movement (approximately1 foot) occurred over the South Barrier between July 30, 2004, and August 17, 2007 (see Figure 30). However, some of the deviation noted in this and earlier time periods may reflect accuracy limitations of the GPS surveys (±0.2 feet).

The longwall subsidence behavior observed in Figure 30 is somewhat typical of the Wasatch Plateau. In this region, strong, thick strata in the overburden control caving characteristics and are responsible for the high abutment stresses and long abutment stress transfer distances discussed in the ground control analysis portion of this report. Subsidence data collected elsewhere in the region indicates that the amount or extent of cantilevered strata at panel boundaries varies. Data presented in Figure 30 indicate that subsidence adjacent to the South Barrier section was incomplete over more than half the width of Panel 13. The figure also demonstrates that additional subsidence over the panel and the adjacent barrier was observed between 2004 and 2007. To determine how much of the recorded movement during the 3-year period was associated with the August accidents, Interferometric Synthetic Aperture Radar (InSAR) analyses were conducted.

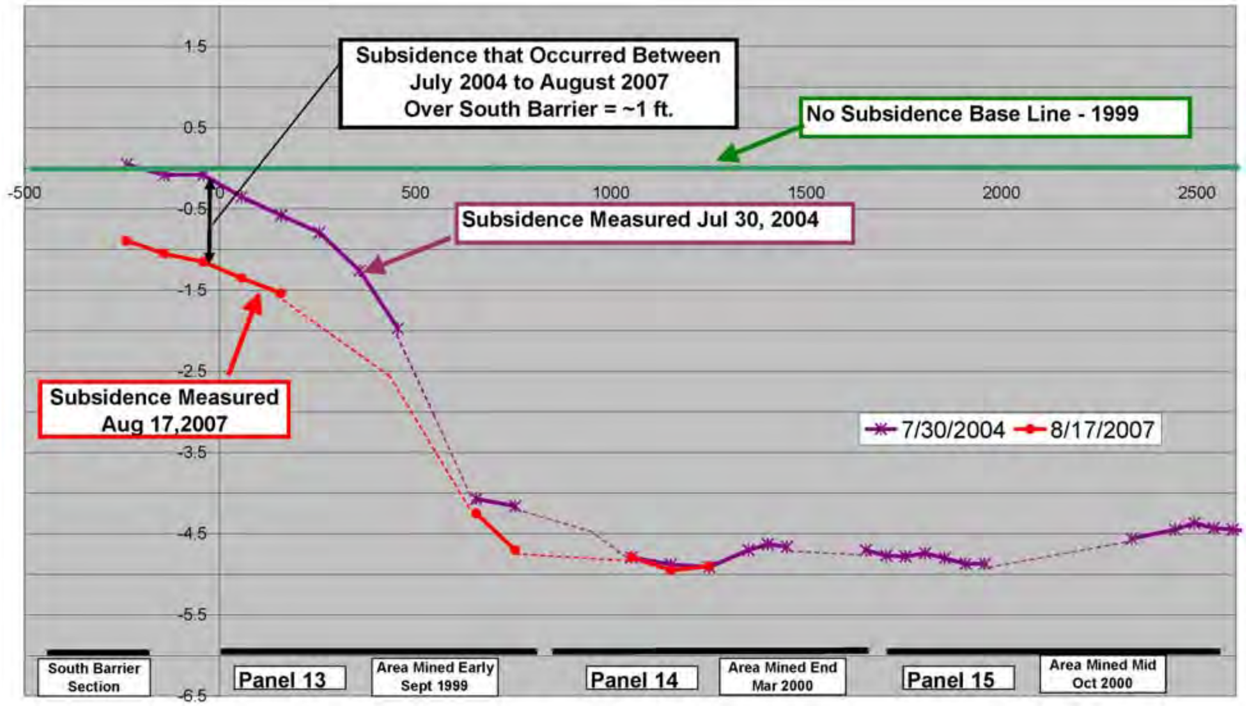


Figure 30 - Subsidence Profiles over Panels 13 to 15
Measurements from 2004 and 2007, vertical scale exaggerated

Surface Subsidence Determined from InSAR Analyses

Interferometric Synthetic Aperture Radar (InSAR) analyses provide precise surface deformation measurements using satellite radar images. The process compares satellite images taken over a study area at different times to determine surface changes (see Appendix L). Although this technique is relatively new to the U.S. coal industry, it has been used extensively to study ground movement, including that due to earthquakes, groundwater loss, and volcanic activity.

Analyses of the Crandall Canyon Mine initially were conducted by the Radar Project of Land Sciences at the U.S. Geological Survey's Earth Resources Observation and Science Center in Vancouver, Washington (USGS). Several time intervals were evaluated to assess surface deformation before and after the August accidents. InSAR subsidence analyses for four time intervals between: June and September 2006, December 2006 and June 2007, June and September 2007, and September and October 2007 were evaluated. Three of the four intervals displayed no significant subsidence. However, comparison of satellite images acquired on June 8, 2007, and September 8, 2007 (a relatively short span of time within which the August accidents occurred) revealed the development of a large subsidence depression over the accident site.

Neva Ridge Technologies (Neva Ridge) in Boulder, Colorado, subsequently was contracted to provide an independent InSAR analysis. The Neva Ridge report (see Appendix M) confirmed the lateral extent and vertical displacements determined by USGS. Maximum vertical displacement at the center of the depression was 12 inches (30 centimeters). Vertical subsidence from the Neva Ridge study is shown on Figure 31. Calculations, based on coal density (in situ and post mining) and mining geometry (pillar and entry volumes) demonstrate that surface subsidence of this magnitude is consistent with extensive coal pillar bursts and substantial filling of entries. A discussion of the two studies is included in Appendix L.

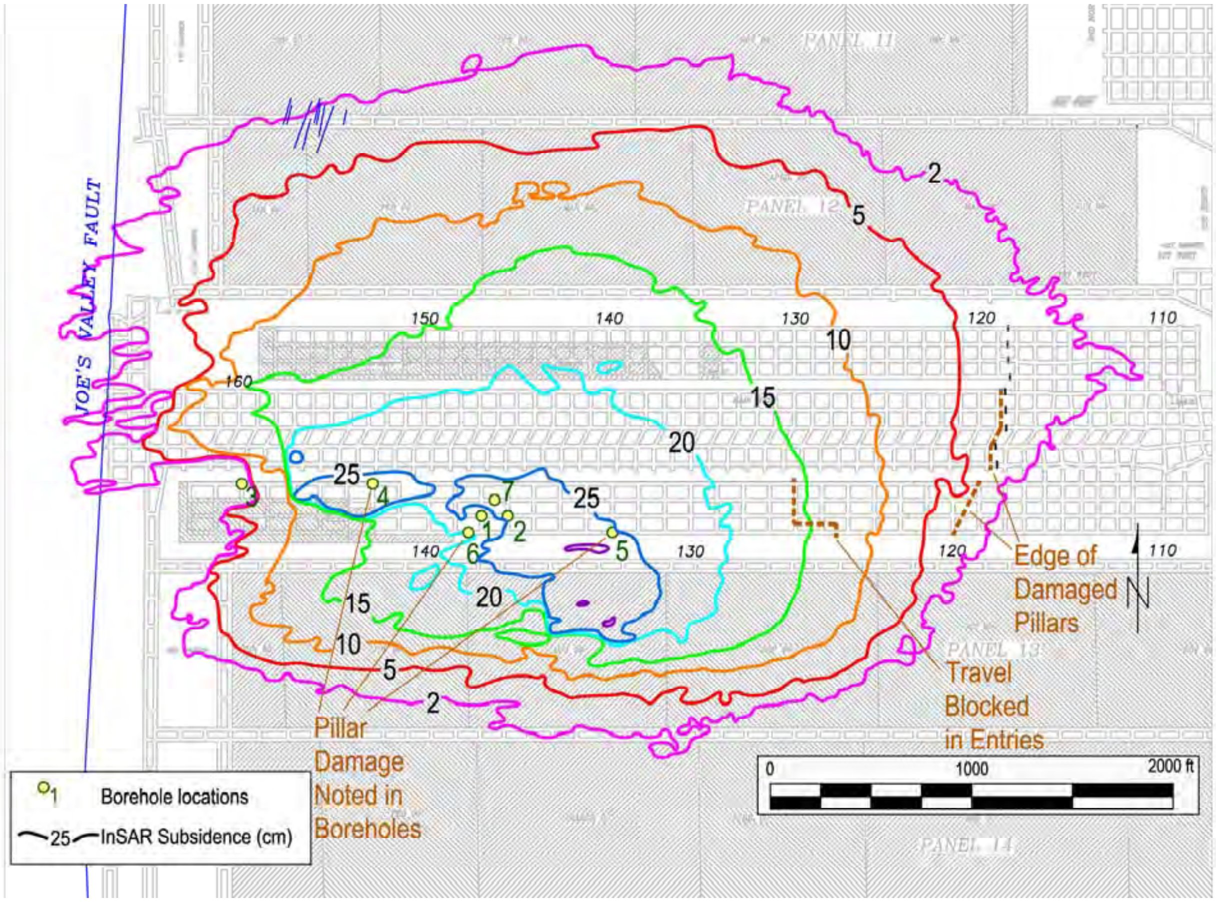


Figure 31 - Surface Deformation from Neva Ridge InSAR Analyses (June to Sept. 2007)

MSHA made visual surveys of the ground surface above Main West before the InSAR data was available. These surveys were conducted from a helicopter and on foot. Mining related surface deformation was not visible. However, a maximum of 12 inches (30 cm) of vertical subsidence over such a broad area may not form visible slips or cracks. Soil slumps were noted but could not be associated with the August accidents.

The InSAR analysis generally confirms the magnitude of subsidence determined in the GPS survey and further constrains the time in which the subsidence occurred. The analysis also provides insight to the lateral extent of the collapse zone. As illustrated in Figure 31, the surface area affected by the collapse extends approximately 1 mile east-to-west and ¾ miles north-to-south. At seam level, subsidence principles suggest that the extent of the collapse would be less laterally but greater vertically than the surface expression implies.

The depth of burst coal in the No. 1 entry of the South Barrier section increased from crosscut 120 until it blocked access to all entries at approximately crosscut 126. Above crosscut 119, the InSAR analysis indicates there was almost 2 inches (5 cm) of vertical subsidence; above crosscut 126, the subsidence was approximately 6 inches (15 cm). The 15 cm subsidence contour encompasses all of the area above the South Barrier section from crosscuts 126 to 142. If the 15 cm contour is used as an indication of pillar damage severe enough to block all travel, then the surface subsidence indicates that the entire working section was severely damaged. The region of Main West between the longwall panels that subsided vertically 6 inches (15 cm) or more was approximately 69 acres in area, centered near crosscut 135.

The area of greatest subsidence, and therefore the greatest damage at seam level, was centered on the 121-foot wide barrier between the South Barrier section and longwall Panel 13. A maximum displacement of nearly 12 inches was observed over the barrier pillar about 500 feet outby the last known location of the entrapped miners. Borehole No. 5 penetrated the mine workings near the point of maximum displacement and confirmed that the damage was severe there as demonstrated by the observation that the void space in that intersection was only 0.5 feet.

It is noteworthy that the maximum surface displacement occurred near crosscut 135, a location nearly equidistant from the ridge top (deepest overburden at ~crosscut 129) and the pillar line (crosscut 142). This observation implies that either the coal pillars were weaker at this point or the stress levels were higher than would be anticipated (i.e., if stress magnitude was based on overburden and abutment load transfer from the active pillar line). However, additional observations of both InSAR and GPS survey data suggest that stress rather than coal strength controlled the location of the failure.

Traditional surface elevation surveys between 1999 and 2004 show that strata overlying about half of the longwall panel south of the working section had not completely subsided and was cantilevered from the Main West South Barrier. Both traditional and satellite surveys conducted after the accident demonstrate that the surface over the panel and the barrier displaced downward as much as 12 inches. Furthermore, the satellite analysis indicates that the strata movement that occurred was much more abrupt at the southern and western edges of the depression (as evidenced by the steeper subsidence contours). The abrupt displacement on the southern edge is consistent with substantial failure of the 121-foot wide barrier and an associated downward movement of cantilevered strata over the adjacent longwall gob. The volume of cantilevered strata likely provided the additional loading necessary to initiate the collapse event from the working section. The abrupt displacement on the western side is consistent with seismological analyses that indicate that some movement may have occurred on a steeply dipping (near vertical), north-south oriented plane.

Seismology

The seismic event created by the August 6 collapse was detected by a regional network of seismographs maintained by the University of Utah. The preliminary location of the seismic event near the Joes Valley fault apparently led to speculation by some that the event was a naturally occurring earthquake. However, additional analyses of the event by both the University of Utah[2], and the University of California at Berkeley and Lawrence Livermore National Laboratories[3], determined that the seismic event was the result of the mine collapse.

Months after the August accidents, the University of Utah Seismograph Stations (UUSS) reevaluated event locations using a “double difference” location method. This methodology can only be used after subsequent events with known locations are available. At Crandall Canyon Mine, the method used the known location of the August 16 accident to improve location accuracy. The revised location indicated that the August 6 accident originated near the No. 3 entry of the South Barrier section between crosscuts 143 and 144.

Analyses of events recorded after the initial August 6 event provided additional insight to strata behavior and the nature of the mine collapse. For example, seismologic records demonstrated that activity persisted for more than 1-½ days after the initial failure. The UUSS reported this in an August 9, 2007, 5:00 p.m. (MDT) press release:

Twelve seismic events were recorded by the University's seismic network in the first 38 [sic] *hours following, and in the vicinity of, the large event of August 6. These smaller events range in magnitude from less than 1.0 to 2.2. A shock of magnitude 2.1 occurred about 17 hours after the main event (at 8:05 PM MDT, August 6); another of magnitude 2.2 occurred about five hours later (at 01:13 AM, August 7). These shocks are interpreted to reflect settling of the rockmass following a cavity collapse.*

The seismic record in this time period is consistent with underground observations of noise emanating from the strata as the initial rescue efforts were underway.

Refined double difference locations of seismic events for the period of August 6 to August 27, 2007, are shown in Figure 32. These refined locations were unavailable until three months after all rescue efforts had been suspended. The August 6 event is indicated by the red circle and the twelve events that occurred within 37 hours afterward are represented as tan circles; the radius of each circle corresponds to the relative magnitude of the events. Activity during the first 37 hours after the accident was predominantly located on the outby side of the collapse area. Conversely, seismic activity for the time period August 8-27 (shown as blue and magenta circles) was concentrated on the inby side of the collapse area. Very few events were located near the north and south boundaries of the collapse area.

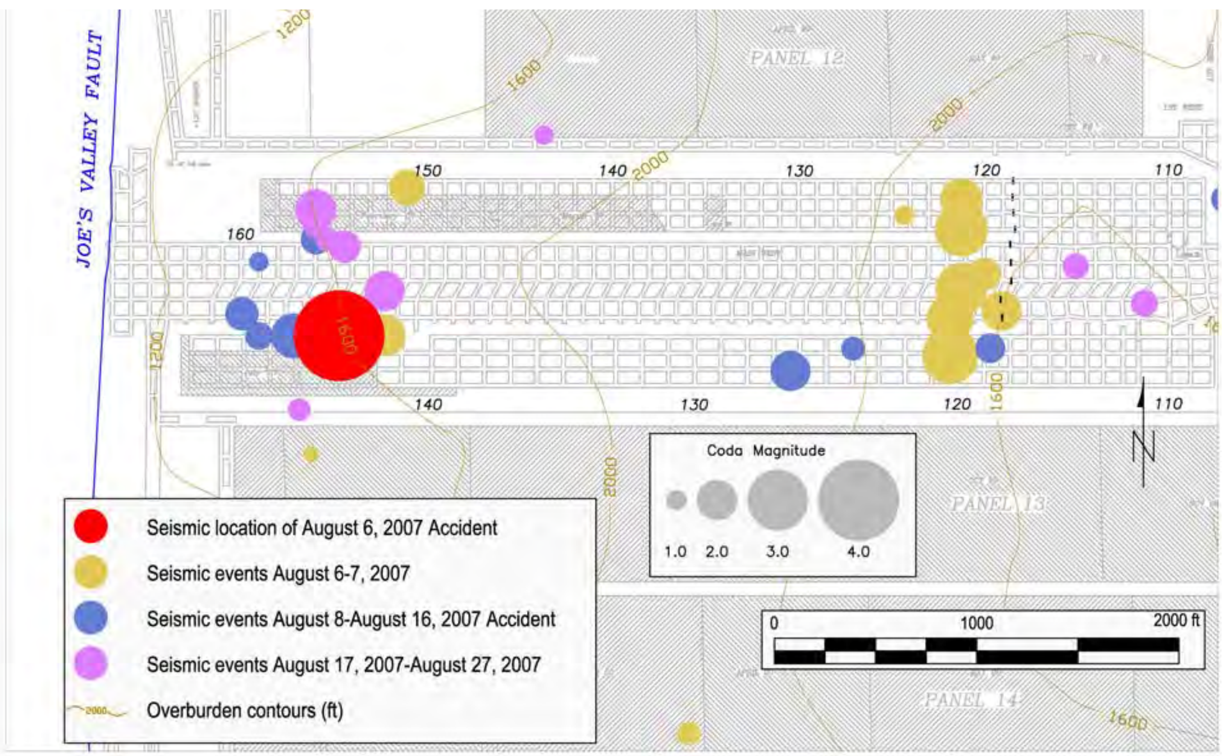


Figure 32 – Double Difference Locations of Seismic Events, August 6-27, 2007

Seismologic analyses indicated that the August 6, 2007, event was dominantly a collapse mechanism but the waveforms also included a smaller shear component. A likely explanation was shear displacement along a vertical plane with movement downward on the east side. The plane would have a strike of approximately 150 degrees azimuth. This conclusion is substantiated by InSAR analyses which show a more abrupt displacement on the western side of the collapse area than on the eastern side. Steeper subsidence in this region could be consistent with movement on a steeply dipping, north-south oriented plane between the North and South

Barrier section gobs. Extensive near-vertical joints are a prominent geologic feature of the strata at Crandall Canyon Mine.

Analyses also indicated that a collapse area of 50 acres moving downward approximately 1 foot represents a plausible model to quantitatively account for 80% of the seismic moment (i.e., the total energy) release associated with the event. Pechmann[2] explains that *"Although this model is by no means unique, it serves to illustrate one possibility that is consistent with both the seismological data and the underground observations."* A more detailed discussion of the seismicity of the Crandall Canyon Mine is provided in Appendix N.

Time of the Accident
Seismological data and mine-specific atmospheric monitoring records provided a very precise time of occurrence. The origin time of the seismic event was determined to be 2:48:40 a.m. (MDT). Seismic monitoring systems incorporate very accurate clocks to ensure that events detected by networks across the world can be correlated with one another.

An atmospheric monitoring system (AMS) was operating in the mine. The system consisted of computers, sensors, and a network to gather and record data on carbon monoxide (CO), fan pressure, tonnage mined, and conveyor belt status. At the time of the accident, a series of communication failures occurred on the system. The failures began at the CO sensor on the South Barrier section alarm box and progressed to other sensors outby. The computer-generated, printed alarms for the initial failures showed a time of 2:51:31 a.m. However, the time display on the AMS computer that generated the printed alarms was not accurate.

To determine an accurate time for the event, the AMS clock was synchronized with the time base at UUSS by telephone. This was done on several occasions to account for any drift in the monitoring system clock. Based on the AMS data, the corrected time of the communication failure report was calculated to be 2:48:53 a.m. The 13-second difference between the 2:48:40 a.m. seismic event and the corrected AMS communication failure time can be explained largely by the methodology used by the AMS system to report a loss of communication and by the accuracy of the time correction.

AMS alerts and alarms typically occur some time after the actual corresponding event, depending on the size and configuration of the system. The AMS system scans all sensors on the system. When a communications failure occurs, repeated attempts are made to communicate with the sensor before a failure is reported by the computer. The number of attempts can be set by the user. The time to report a communication failure depends on the time it takes for the system to cycle through the sensors and the number of attempts the system is set to make. It appears that data was being collected for the "CO Main West Section Alarm Box" sensor at an interval of 2 to 3 seconds before the accident. Because sensors were removed from the system after the accident, the pre-accident interval could not be determined during the investigation. Also, the number of attempts to reestablish communication for that sensor is unknown but was reported by the manufacturer to be typically 3 to 5. The accuracy of the time correction was estimated at plus or minus five seconds. Together, the time lag to report the communication failure and the uncertainty of the time display can explain the difference between the seismically determined time of event and the AMS communication failure. The most accurate measure of the initiation time of the August 6 accident was 2:48:40 a.m. (MDT), as established by the seismic data.

Summary - Nature and Extent of Failure

The nature and extent of the collapse were estimated by combining all of the underground and borehole observations, surface subsidence, and seismic evidence previously described. Seismological analyses indicate that the 3.9 Richter event associated with the August 6 failure was characteristic of a collapse event and not a naturally occurring earthquake. Analyses also indicate that it originated from a point near the last row of recovered pillars, just inby the last known location of the entrapped miners. The collapse occurred at 2:48:40 a.m. (MDT) and it lasted only several seconds. This time was determined from the seismological analysis and was consistent with corrected times from the atmospheric monitoring system in operation at the mine at the time of the accident.

Surface subsidence data (GPS surveys and InSAR analyses) indicate that a surface depression up to 12 inches deep formed over the Main West between June 8 and September 8, 2007. Vertical movements greater than ¾ inches were observed on the surface over an area approximately 1 mile (east-to-west) by ¾ miles (north-to-south). A maximum displacement of nearly 12 inches was observed over the 121-foot wide barrier pillar about 500 feet outby the last known location of the entrapped miners. Borehole No. 5 penetrated the mine workings near the point of maximum displacement and confirmed that the void space in an intersection was only 0.5 feet.

Although the displacements observed in the InSAR analyses could have occurred at any time between June 8 and September 8, several observations suggest that much of the movement was associated with the August 6 accident. First, it is noteworthy that negligible amounts of displacement were noted in analyses of time periods before June and after September. Second, seismic activity detected in the aftermath of the event is located on the east and west margins of the surface depressions. Finally, seismologists estimate that a relatively large volume of strata (e.g., 50 acres of ground moving downward approximately 1 foot over the Main West) must have been involved to account for measured seismic moment (i.e., total energy) of the event.

The satellite analysis indicates that the strata movement was much more abrupt at the southern and western edges of the depression (as evidenced by the steeper subsidence contours). The abrupt displacement on the western side is consistent with UUSS's theory that some movement may have occurred on a steeply dipping (near vertical), north-south oriented plane. The abrupt displacement on the southern edge is consistent with substantial failure of the 121-foot wide barrier and an associated downward movement of cantilevered strata over the adjacent longwall gob. The volume of cantilevered strata likely provided additional loading on the South Barrier section.

Figure 33 superimposes a variety of data used to determine the extent of the collapse, including: the seismic data from the time of the August 6 accident to August 27, 2007, the borehole locations, the InSAR subsidence contours, and the likely extent of damaged pillars. The eastern boundary of the pillar failures was based on the underground observations and InSAR subsidence data and is consistent with residual seismic activity. The western edge of the pillar failures was based on the borehole observations and InSAR subsidence data and is consistent with the seismic location of the accident and the additional seismicity later in August 2007.

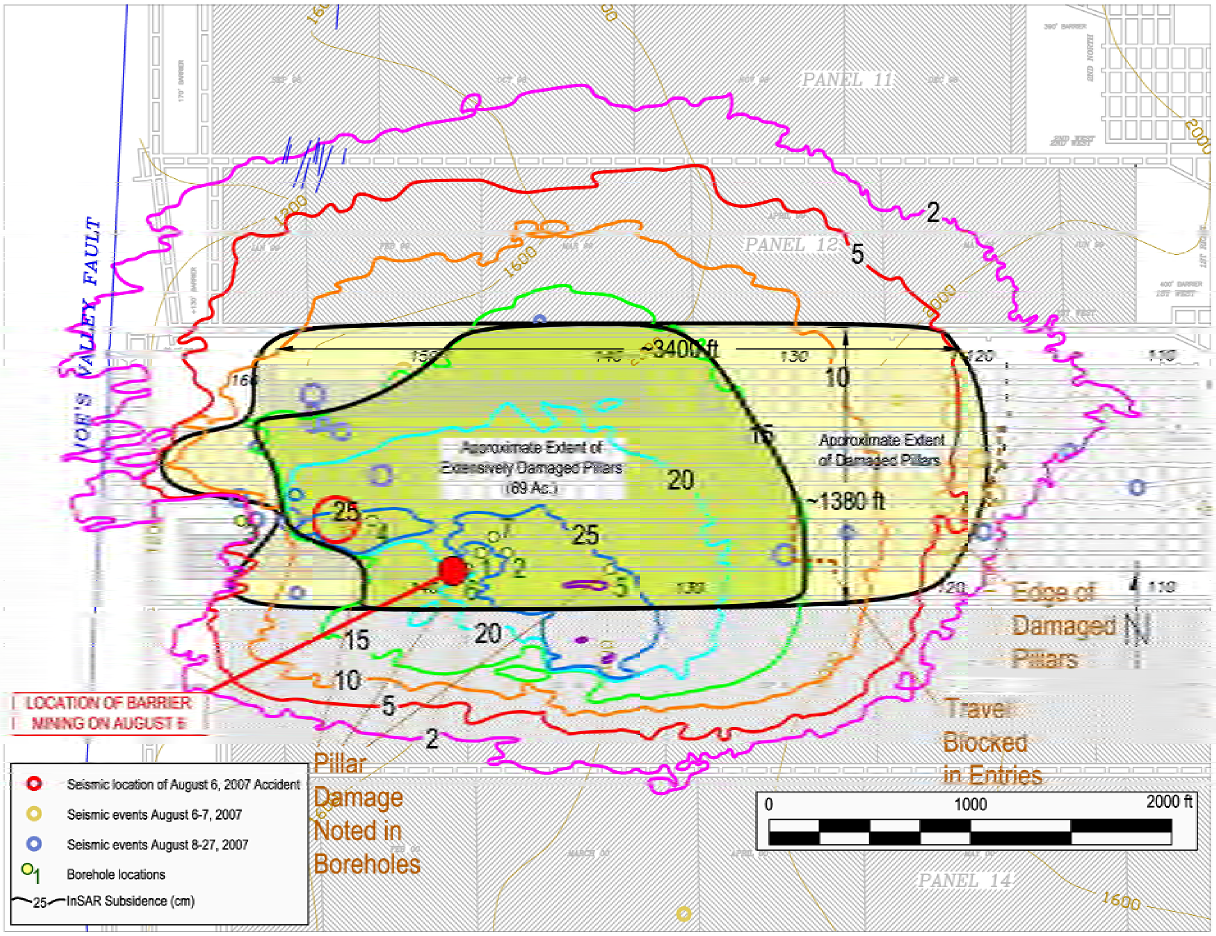


Figure 33 - Combined Data and Likely Extent of Collapse

The extent coincides approximately with the 5 cm vertical subsidence line. The 5 cm line falls between Borehole Nos. 3 and 4. The area indicating extensively damaged pillars was based on conditions observed near crosscut 126 where the damage was more severe and the entries were impassable. The boundary of the area follows the 15 cm subsidence contour and encompasses Boreholes Nos. 1, 2, 4, 5, 6, and 7, all of which showed damage.

Main West Ground Control History

The history of ground conditions in Main West provides a basis for the engineering back-analyses discussed in a later section of this report. Back-analysis is a process in which known failures or successes are evaluated to determine the relationship of engineering parameters to outcomes. For example, the mining scenario associated with the March 10, 2007, outburst accident in the North Barrier section provides insight to the conditions conducive to bursting at Crandall Canyon Mine. Furthermore, the history demonstrates GRI's failure to report outburst accidents. The following sections detail the sequence of events and associated ground control implications that culminated in the August 6 accident.

Main West Development

The Main West entries adjacent to the August 6, 2007, accident site were developed in 1995. This development included five entries and crosscuts on 90 x 92-foot centers. These workings were mined using a mobile bridge continuous haulage system. Pillar corners were rounded and entries were mined to 20 feet or wider (particularly the middle entry, which contained the conveyor belt system). The mining height was established at 8 feet by mining to the bottom of the seam and leaving roof coal in the immediate roof. The entries were stable for several years after development, prior to adjacent longwall mining.

Longwall Panel Extraction

Longwall panels were mined parallel to the Main West entries between 1997 and 2003. Six panels were mined north of Main West (Panels 7 to 12) and six were mined to the south (Panels 13 to 18). Barrier pillars measuring approximately 450 feet wide were established between Main West and the adjacent longwall Panels 12 and 13 (see Figure 34).

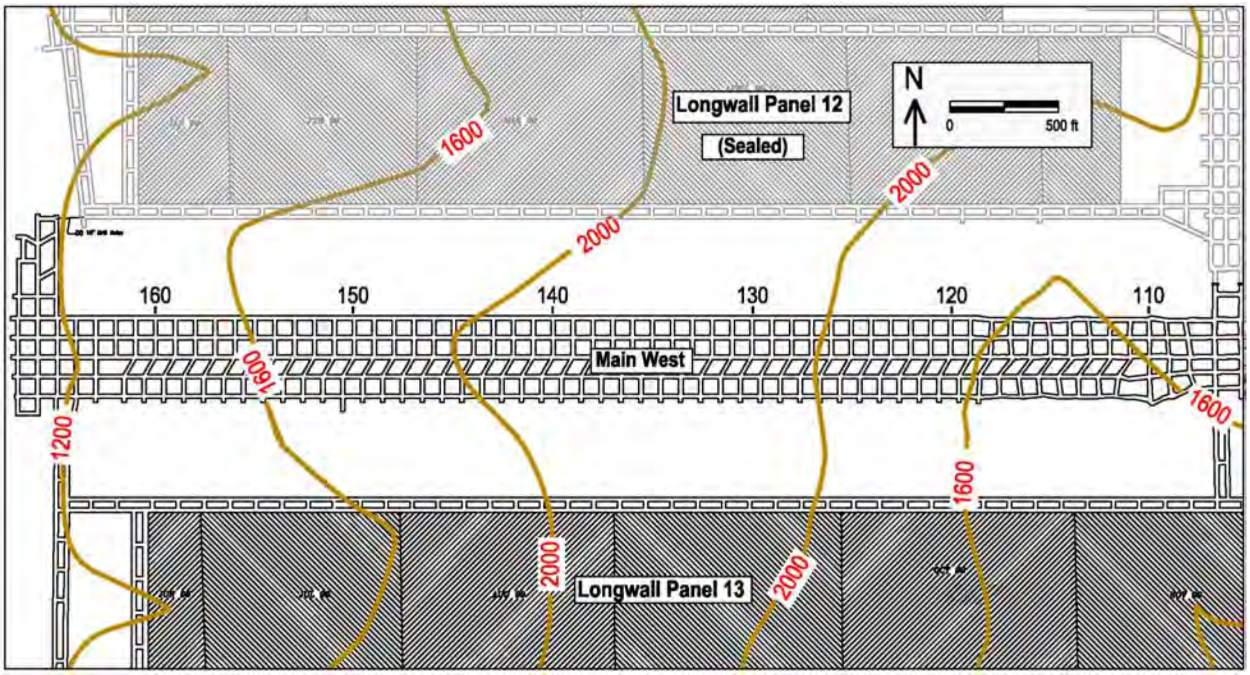


Figure 34 – Initial Main West Barrier Pillars after Panel 13 Mining showing Overburden

In retreat mining operations (longwall or pillar recovery), barrier pillars are used to protect workings from abutment loading associated with panel extraction and to separate active workings from worked out areas. As a block of coal is mined, the immediate roof above the block falls into the void created by mining. At shallow depths and with suitably wide panels, the roof failure can propagate to the surface and allow much of the weight of the overburden to be transmitted directly to the mine floor in the caved area. A portion of the overburden usually cantilevers over the void near the edges (see Figure 35). These cantilevered strata create load on the void boundaries in excess of the typical overburden load that would be carried.

In deep overburden and/or in narrow extraction areas, failure may not propagate to the surface. Instead, strata near the excavation can fail and fall into the void while higher strata may simply sag onto the fallen lower layers. The strength and stiffness of rock layers in the mine roof generally dictate the degree to which the uncaved layers sag and transfer load into the broken material (gob). If the rock layers are strong and thick, load can be transferred across the void created by mining in much the same way that an arch bridge rests on abutments at either of its ends. This abutment stress is usually highest near the excavation and lessens with distance away from the caved area.

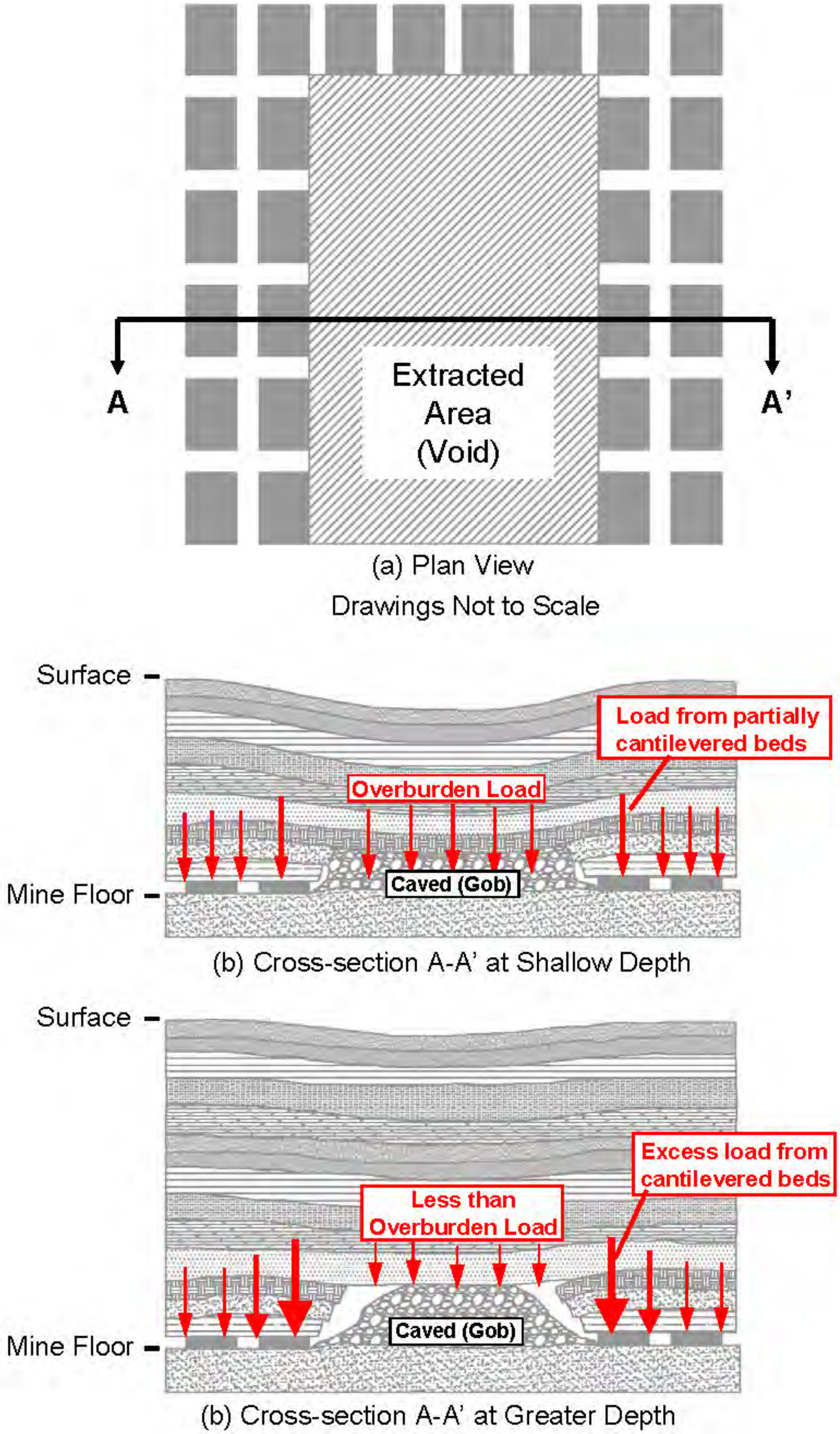


Figure 35 - Abutment Stress due to Cantilevered Strata from Mining

In the Main West entries, some influence of abutment stress was observed when each of the adjacent longwall Panels 12 and 13 were extracted in 1999. Abutment stresses associated with these longwall panels caused pillar rib sloughage and roof deterioration. A similar observation was noted earlier as longwall panels were mined to within about 400 feet of the 2nd North Mains. These observations imply that the Main West barriers and entry pillars were subjected to abutment stress and effects of this stress were evident at distances beyond 450 feet (the approximate width of the original barriers).

Abutment stress from Panels 12 and 13 caused damage in Main West that required additional roof support to maintain stability. The area with the most roof deterioration and pillar sloughing appeared to be the region beneath more than 1,800 feet of overburden, which was approximately between crosscuts 123 and 150. In this region, roadways were timbered-off, roof coal was falling from around roof bolts, and pillars showed significant rib sloughing. It was noted that roof coal deterioration was most apparent in the middle No. 3 entry followed in severity by the No. 2 and No. 4 entries. Efforts focused on maintaining the No. 1 entry near the south barrier and No. 4 entry nearer the north barrier as intake and return air courses. As longwall mining progressed southward, the Main West entries required continued maintenance particularly to keep the stopping line intact.

After March 2003, longwall mining south of Main West was completed and the worked out longwall district was sealed. The Main West entries were no longer needed as part of the longwall ventilation circuit. However, the area was not sealed at that time because GRI anticipated the possibility of recovering the Main West pillars. Later, GRI decided to forgo pillar recovery of the Main West workings inby crosscut 118 and sealed the area in November 2004. In a letter to the BLM dated November 10, 2004, GRI claimed that it *"decided to construct the seals for the following reasons:*

1. *The abutment loads from the longwall districts to the north and south of Main West in this area have caused the roof and coal pillars to deteriorate to a point that a substantial economic investment would be required to rehabilitate the area. This investment would likely exceed the economic value of any recovered coal.*
2. *The majority of the coal resource left in place is in cover greater than 1,500 ft. MSHA currently will not approve pillar extraction in areas where the cover exceeds 1,500 ft.*
3. *The amount of air necessary to keep this area ventilated is making it difficult to get ventilation to those active areas of the mine where the ventilation is required."*

The referenced ventilation problems included the recurrent need to perform maintenance on stoppings in the Main West entries due to continued ground deterioration. In justification of sealing the area, a BLM inspector also noted pillar failure and several large roof falls.

Sealing the Main West had ground control implications. First, the seals prevented access for evaluation of ground conditions west of crosscut 118. Further deterioration of pillars that could lead to additional stress transfer to the adjacent barriers could not be observed. Second, the seals prevented the barriers from being extracted in the manner that had been used in the South Mains. In the South Mains, barriers adjacent to worked out longwall panels were recovered using a "rooming out" technique. Barriers on either side of the South Mains were developed sequentially as illustrated in Figure 36. This method helped maintain the integrity of the barrier outby the working section since the barrier width was reduced only near the retreating pillar line. A similar plan could not be used in the sealed Main West without extensive rehabilitation to the existing Main West entries and crosscuts.

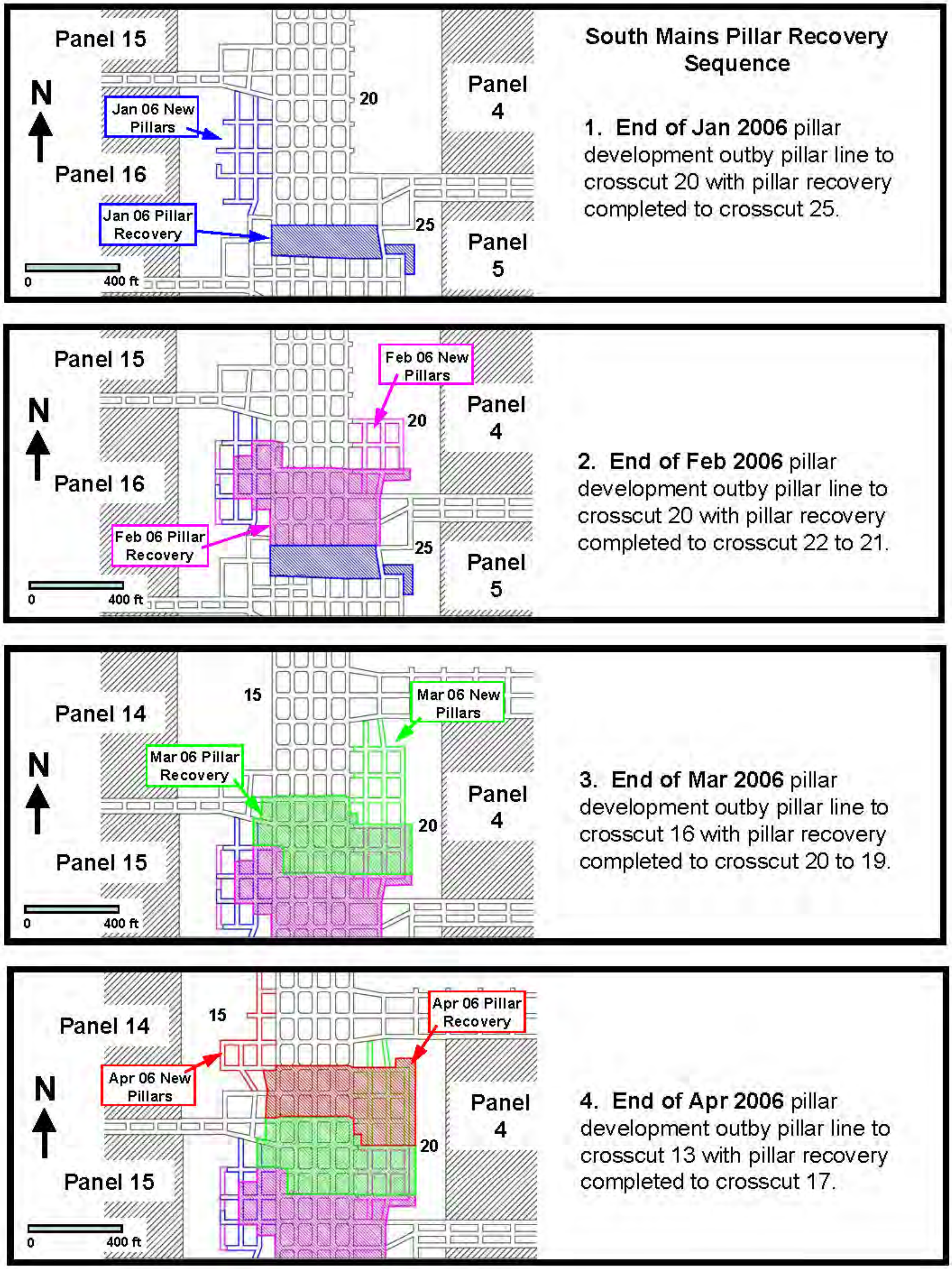


Figure 36 – South Mains "Rooming Out" Pillar Recovery Sequence

North Barrier Section Development
In contrast to the sequential development and recovery plan used in the South Mains, four entries were driven on 80 x 92-foot centers through the Main West North Barrier prior to retreat. The original 448-foot barrier width was reduced during development to 135 feet between the section and Panel 12 to the north and to 53 feet between the section and the sealed Main West to the south (see Figure 37). One implication of this approach was that the load bearing capacity of these barriers (i.e., their ability to support front and side abutment loading during pillar recovery) was reduced. Another was that entries used to access the working faces were subjected to abutment loading during development.

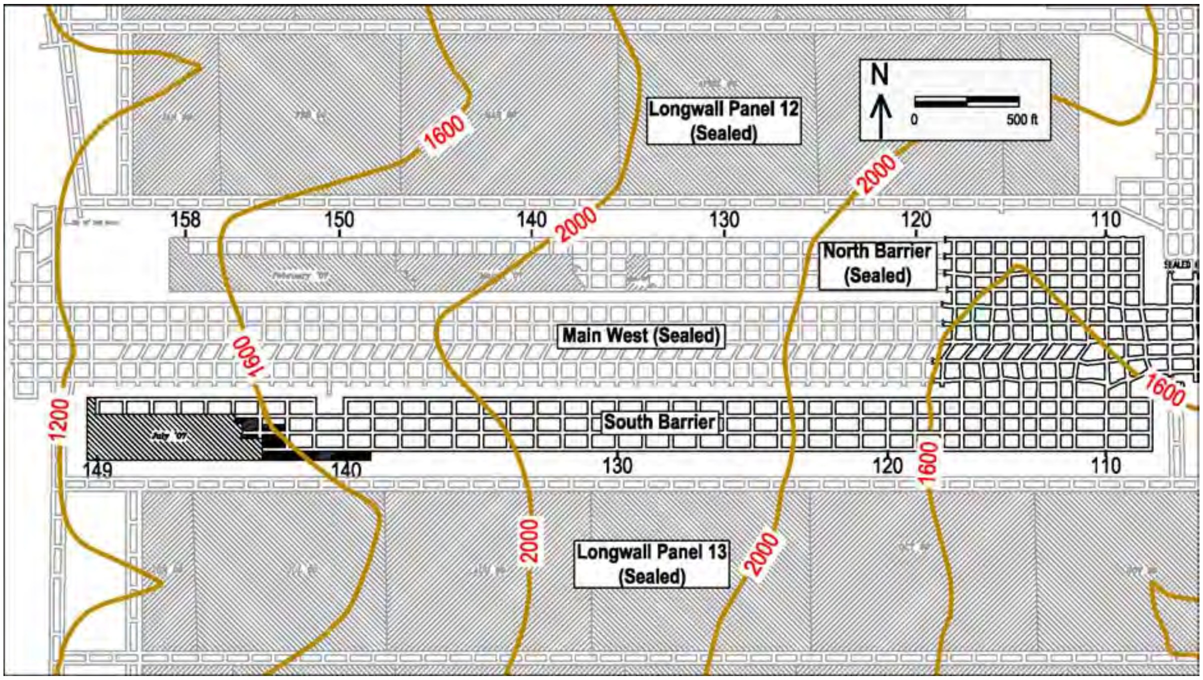


Figure 37 - North Barrier Section Mining showing Overburden

Development of the North Barrier section began in late 2006 and had advanced to crosscut 123 when Agapito Associates, Inc. (AAI) personnel visited the section on December 1, 2006 (see Appendix H). Overburden depth at this location was about 1,900 feet. Based on their observations, AAI reported that *"There was no indication of problematic pillar yielding or roof problems that might indicate higher-than-predicted abutment loads."*

MSHA District 9 Roof Control personnel visited the developing North Barrier section on January 9, 2007. At that time, the section had advanced to about crosscut 141, situated beneath 2,000 feet of overburden, past the deepest overburden (2,240 feet) at crosscut 132. Billy Owens (District 9 roof control group supervisor) and Peter Del Duca (inspector trainee) observed pillar hour glassing outby the face and were present during the failure of the rib in a crosscut. Owens stated that "*about 200 to 300 feet out from the mining face, the --- one of the pillars sloughed, and I mean, it was almost a whole crosscut, probably 6 to 12 inches thick, the rib just set down. But it didn't throw coal out into the walkway. It didn't expel any particles that would strike anyone. It just laid down --- sloped down and laid down against the rib.*" Owens stated further, "*I considered that to be the pillar yielding in the controlled manner that it should.*"

All parties (GRI, AAI, and MSHA District 9) placed a great deal of emphasis on the nature of the observed pillar yielding during the development phase of mining (i.e., that it was nonviolent).

For example, Laine Adair stated in an interview with the investigation team that "*the main things that we were really looking at that was of most interest to Billy* [Owens] *and to me and to Agapito on our other visits was how the coal was yielding as these pillars yielded? Was it in a nonviolent fashion?"* Nonviolent yielding of the coal ribs was perceived as an indication that the mine design was effective. However, a rib failure of this extent in an area where persons work or travel is not indicative of effective rib control to protect persons from related hazards.

Similar ground conditions were noted after MSHA's January 9 visit. Gary Peacock reported in a memo to Adair that "*We advanced the section 14 xc's from 137 to 151 in January. Even though the amount of cover has gone from 2,200' to 1,500', we are still seeing a considerable amount of rib sloughage. It does create some problems, but is no worse than we would expect to see mining in the barrier like we are.*" Bounces were occurring outby the face areas resulting in rib sloughage. The resulting rib sloughage was greatest from crosscut 135 to 142 which was the area of greatest overburden. There was some minor floor heave in this region that did not require grading.

Development proceeded in the North Barrier more than 4,600 feet (measured from crosscut 108) to crosscut 158. Water began flowing from the floor and roof near crosscut 145 to 146. Section development was stopped at crosscut 158, five crosscuts short of the projected extent, due to excessive water inflow. This was the same water zone that had been encountered in the north side of Main West in 1995.

North Barrier Section Pillar Recovery

Pillar recovery operations were initiated in the North Barrier section on February 16, 2007. Two of the three pillars in each row were extracted while the third pillar between the Nos. 3 and 4 entries was not mined to provide a bleeder entry. The section was retreated from west to east. MRS units were used in-lieu-of turn posts near the continuous mining machine during pillar mining. MRS units and wooden posts were used for breaker rows.

Initially, the roof did not cave immediately as pillars were removed, resulting in higher stress in the pillars being mined. Some miners and mine management felt that the section was too narrow to promote good caving. On February 21, 2007, after removing four rows of pillars, eight stoppings were blown out by caving within the pillared area. The next day, foremen reported that hard bounces were occurring and that caving remained close to the pillar line.

BLM inspector Stephen Falk visited the section on February 27, 2007. In the associated Inspection Report, finalized on July 12, 2007, Falk noted: "*So far, the crews have pulled 18 pillars or 9 rows. Currently they are pulling the pillars between crosscut 149 and 150. I have been concerned about pulling pillars in this environment with mining a narrow block with little coal barriers to mined out blocks on both sides. Fortunately, the beginning depth on the west end toward the Joe's Valley Fault is somewhat shallow starting at 1300 feet. So far no inordinate pillar stresses have been noted, though things should get interesting soon. The face is under 1600 feet of cover now and will increase to over 2000 feet by crosscut 139. The working face looks ok and coal is good. There is some cap rock in the roof that is not holding up during mining*." Foremen also reported "*good bounces*" occurring that day.

Beginning on February 28, 2007, in the vicinity of pillar Nos. 23 and 24 at 1,880 feet of overburden, foremen regularly reported problems with the immediate roof, bounces, blown out stoppings, and associated production delays. The roof coal and soft rock above it broke into small pieces that fell onto the wire mesh and caused it to sag down between the roof bolts.

Larger stumps were left unmined in the pillars to avoid the sagging wire mesh. On March 3, a Murray Energy Corporation employee emailed a copy of Crandall Canyon Mine's production report for the night shift ending March 1, 2007, to Jerry Taylor (Corporate Safety Director): "*Fyi…this is at least the third time they have noted walls blown out by caves on the pillar section. Must be pretty violent. You see they had to pull the* [continuous mining machine] *out and had stone between the* [continuous mining machine] *and the MRS supports.*"

Stoppings were blown out during both shifts on Sunday, March 4. The next day, Bruce Hill (president and CEO of UEI, ARI, and GRI) reported to Murray: "*The mine should continue to perform well for the next three months as we pull pillars. The one potential obstacle remains the depth of cover. We are now approaching 2,000 feet of cover. MSHA has never allowed pillar recovery at this depth. I was in the mine on Sunday and while the pillars were bumping and thundering, the conditions remain good.*" Also on March 5, foremen reported "*ran steady until around 3:00 PM, had a couple hard bounces that knocked top coal loose in #2.*" Eight-foot bolts were installed in the affected area, delaying production for eight hours.

A coal burst occurred during the night shift beginning March 6 and ending March 7, 2007. A lump of coal ejected during the burst struck a miner in the face. An entry in the shift foremen's report noted, "*Bouncing real hard on occasion. Smacked little Carlos* [Payan] *up aside of the haid* [sic] *with a pretty good chunk.*" Payan received a small cut on the side of his head, which required first aid treatment only, and he continued working in his normal duties.

A non-injury coal outburst accident during the following day shift on March 7 knocked miners down and damaged a stopping. The shift foreman's report described the event as: "*Had 1 real hard bounce, blowed ribs down in 2-3 crosscut & beltline…*" The production report showed a delay in mining of 70 minutes after the event. MSHA was not immediately notified of the March 7 coal outburst accident as required by 30 CFR 50.10. GRI did not file an accident report with MSHA as required by 30 CFR 50.20.

On March 8, a coal burst tripped a breaker on an MRS unit, requiring the crew to set timbers prior to resetting the breaker. This event caused a 30-minute production delay.

On March 9, 2007, in an attempt to alleviate the poor ground conditions, GRI stopped pillar recovery between crosscuts 137 and 138 and resumed mining between crosscuts 134 and 135. However, the following morning, foremen reported that the section was "*still bouncing pretty hard*." Hill also reported to Murray: *"The mine is experiencing heavy bouncing and rib sloughage. We moved the section back two crosscuts to provide a barrier."* Although Hill characterized the decision to skip several rows as providing *"a barrier,"* the move was not made in consideration of specific concerns about abutment stress. Peacock made the decision to *"get to where we hadn't left any of the top coal and where the initial roof was good."* Mining resumed in an area of greater overburden.

The concept of skipping pillar rows was consistent with AAI's recommendations at that time. In an August 9, 2006, email report to Adair from Leo Gilbride (AAI principal) the report stated: "*The plan affords the contingency to leave occasional pillars for protection during retreat if conditions warrant, thus providing additional control of the geotechnical risk"* (refer to Appendix G). AAI cautioned against this practice after the March 2007 outburst accidents.

March 10, 2007, Coal Outburst

At 5:22 p.m. on March 10, 2007, a non-injury coal outburst accident occurred on the working section while mining the first cut of the southernmost pillar from the No. 1 entry between crosscuts 133 and 134. The associated seismic event registered magnitude 2.3. The outburst threw coal into entries and crosscuts between 131 and 139 and suspended dust in the air for 5 to 10 minutes, obstructing vision. Most of the damage was in the Nos. 3 and 4 entries and rendered the bleeder entry unsafe for travel. Coal expelled from the ribs was up to four feet deep in some entries and crosscuts. A scoop was blocked by coal debris in the No. 3 entry between crosscuts 133 and 134.

During the following shift, crew members cleaned coal from the entries and crosscuts with the continuous mining machine. They also set timbers, retrieved the scoop, and repaired stoppings. Peacock was notified of the burst at approximately 10:00 p.m. and he traveled to the mine later that night to observe conditions on the section. On March 11, Peacock noted in an email to Adair and Hill that *"conditions in the pillar section have deteriorated to the point that I don't think it is safe to mine in there any longer. We are pulling the equipment out and setting up to mine south. The bad conditions consist of some huge bounces and the stopping line is no longer intact back in the bleeder entry. It is not safe to have people in there repairing the stoppings. I talked to Dave Hibbs this morning, he is looking into the possibility of not needing a new MSHA plan to mine south until we go past the seals. I realize pulling out early could change the way MSHA views the plan on the south side. I also realize we have used all the tricks we know of to pull these pillars and I no longer feel comfortable we can do it without unacceptable risk."* Mining was temporarily moved to the 3rd North spare section while the South Barrier section was prepared for mining.

MSHA was not immediately notified of the March 10 coal outburst accident as required by 30 CFR 50.10. Later, on March 12, GRI contacted MSHA District 9 personnel by telephone. In a documented call to Owens, Adair indicated that the section was pulling out due to damage to the bleeder entry. Later that day, GRI left a phone message with William Reitze (District 9 ventilation group supervisor) stating that it was not safe to travel to the approved bleeder measurement point location (MPL) due to a bounce but that there were no plans to immediately seal the area. On March 13, GRI contacted Reitze by telephone and requested to replace damaged permanent ventilation controls adjacent to the bleeder entry with curtains. Reitze denied the request. GRI then proposed a possible relocation of the MPL. When this request was also denied (because ventilation of the worked out area could not be adequately evaluated from the proposed location), the mine operator requested approval to seal the area. During a regular inspection, Randy Gunderson (MSHA coal mine inspector) was informed by GRI that mining had ceased because *"the country got rough."* He did not travel to the damaged area. These communications with MSHA minimized the extent of the adverse conditions and failed to accurately portray the degree of the damage.

Records indicate BLM personnel were also notified of the March 10 event on March 12. As noted earlier, some of the Crandall Canyon coal reserves were leased from the Federal government and managed by BLM. BLM has a mandate to manage these coal resources to maximize economic recovery whenever possible. GRI had to obtain BLM's approval to leave behind coal that would otherwise be mined.

BLM inspector Stephen Falk visited the North Barrier section on March 15. He noted damage on a map filed with his inspection report. He verbally approved GRI's request to cease mining in the North Barrier, to seal the area at crosscut 118, and to mine the one entry of the Main West

South Barrier on the BLM coal lease. A written approval from BLM to GRI dated August 27, 2007, confirmed the verbal approval. The written approval indicated that GRI reported adverse ground conditions with damaging bounces as justification to BLM for leaving the rest of the pillars in the North Barrier section.

At the request of Adair, AAI personnel observed conditions in the section on March 16, 2007. The site visit was documented by photographs and a map showing pillar, entry, and crosscut conditions from crosscut 131 to 145. Figure 38 and Figure 39 illustrate a damaged stopping and conditions in the No. 4 entry from a collection of photos taken on March 16, 2007 (see Appendix O to view additional pictures). AAI's notes and photographs confirmed Falk's representation of conditions on the section in his report. The North Barrier section was sealed on March 27, 2007.

Figure 38 – Stopping Damaged during March 2007 Coal Outburst Accident on North Barrier Section

Figure 39 –Damage in No. 4 Entry after the March 2007 Coal Outburst Accident on North Barrier Section

GRI contracted AAI to refine the pillar design for the South Barrier section based on the conditions encountered during the mining of the North Barrier section. AAI evaluated ground conditions resulting from the coal outburst accident, analyzed the proposed South Barrier mining, and made recommendations for mining the Main West South Barrier (see Appendix I).

South Barrier Section Development

In an effort to mitigate the potential for a failure similar to the one that occurred in the North Barrier section, two changes were implemented during development of the South Barrier section and a third was implemented during pillar recovery:

- entries were mined to the rock in the roof (as opposed to leaving roof coal),
- crosscut spacing was increased from 92 to 130 feet, and
- the width of the caved area was increased by slabbing the barrier between the No. 1 entry and the adjacent longwall Panel 13.

After the March 10, 2007, coal outburst accident, AAI made recommendations for mining in the South Barrier that included a precaution that "*Skipping pillars should be avoided in the south barrier, particularly under the deepest cover*." Bagging of roof coal had contributed to the operator's decision to skip pillars in the North Barrier section. By mining to the rock, the operator effectively eliminated the potential for a recurrence of this type of roof control problem and the resulting need to skip pillars.

In the South Barrier section, pillar length was increased by 38 feet (from 92 to 130-foot center-to-center – see Figure 40). AAI indicated that this change "*increases the size and strength of the pillars' confined cores, which helps to isolate bumps to the face and reduce the risk of larger bumps overrunning crews in outby locations*."

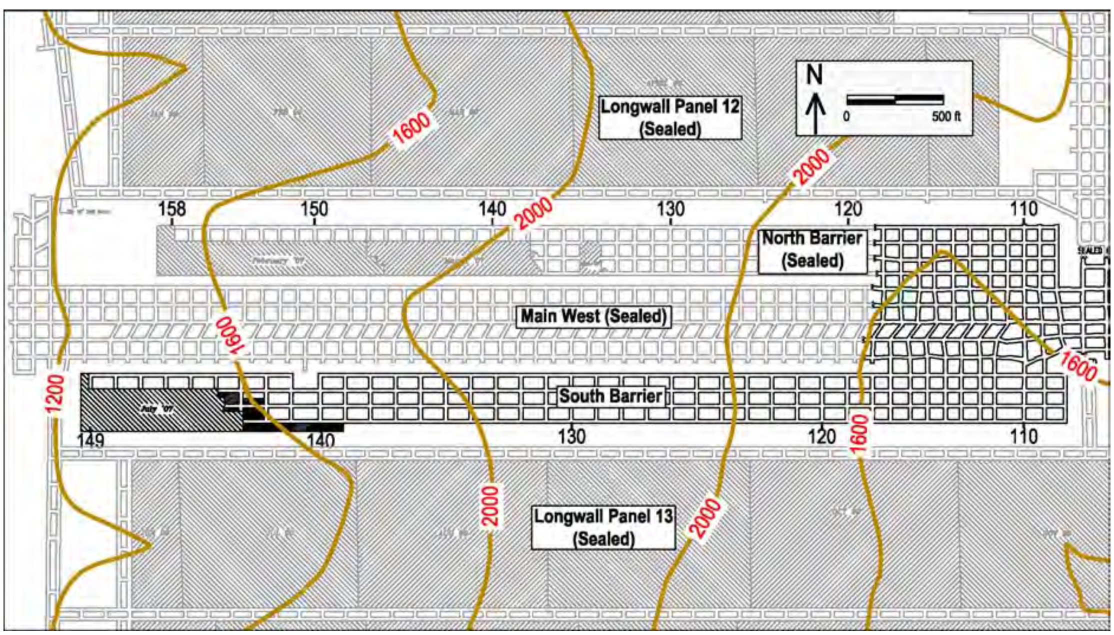


Figure 40 - South Barrier Section Mining showing Overburden

Development of the South Barrier section began on March 28, 2007. By late April 2007, four entries were being driven on 80 x 130-foot centers from crosscut 118 through the length of the Main West South Barrier. The original 438-foot barrier width was reduced during development to 121 feet between the section and Panel 13 to the south and to 55 feet between the section and the Main West No. 1 entry room notches to the north. A sump had been mined southward from the Main West No. 1 entry at crosscut 150. The South Barrier section No. 4 entry was not mined through between crosscuts 140 and 141 to ensure that a minimum 50-foot barrier remained between the section and the sump. The entries and crosscuts were mined eight feet high and 18 feet wide. No coal was being left against the roof. Loose rock was also being mined from the roof. Coal was left in the floor where coal seam thickness exceeded 8 feet. The section was typically dry with one wet area at crosscut 140.

During development mining, roof and rib conditions were better than in the North Barrier. Mine management attributed the improvement to the larger pillars. Owens and Jensen visited the section on May 22, 2007. Owens determined that pillars were yielding closer to the face (which he interpreted as being favorable) and that pillars outby appeared to be more stable than in the North Barrier. Despite these improvements, reports indicated that bounces occurred and the ribs showed significant signs of hour glassing and sloughage. The South Barrier section was mined to crosscut 149, its projected limit, with development completed on July 15, 2007.

South Barrier Section Pillar Recovery

Pillar recovery began in the South Barrier section on July 15, 2007. The section was retreated from west to east. Pillars between the No. 1 and 3 entries were extracted and the barrier to the south was slabbed to a depth up to 40 feet. Pillars between No. 3 and 4 entries on the north side of the section were not mined. These pillars remained in place to protect the No. 4 entry which served as a bleeder. MRS units were used during pillar recovery and bottom mining was taking place in pillar cuts and in barrier cuts (slabbing) south of the No. 1 entry. Barrier slabbing was intended to facilitate better caving inby the pillar line by creating a wider span. Better caving, in turn, was intended to reduce abutment stress transferred to the pillar line.

Grosely was conducting an inspection in the South Barrier section on July 17 and 18, 2007. Removal of the first pillar was taking place during his inspection. He did not hear any bounces and the pillars on the section looked stable. He observed some floor heave in the belt entry. This was the last time MSHA was on the section before the August 6 accident.

The cut sequence when mining a row of pillars is shown in Figure 41. Half of the No. 1 pillar and the barrier to the south were mined simultaneously, right and left, from the No. 1 entry (Sequence A). The remainder of the No. 1 pillar and the No. 2 pillar were then mined as they had been in the North Barrier section (Sequences B, C, D, E, F, and G).

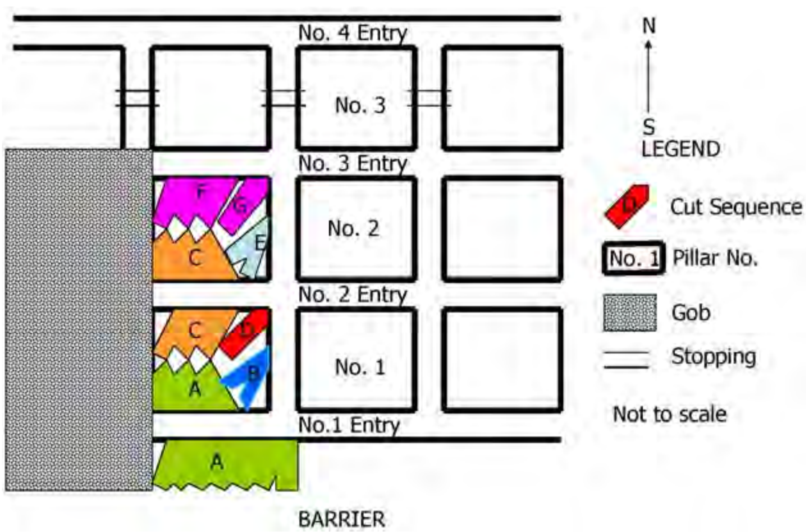


Figure 41 - South Barrier Section Pillar Recovery Cut Sequence

During pillar recovery, eight pillars and the barrier between crosscuts 139 and 142 (where the South Barrier section was reduced to three entries) were designated to remain unmined. This unmined area was intended to protect the bleeder entry from abutment stresses associated with the eventual caved areas to the west and east.

The first large intentional cave within the pillared area of the South Barrier section occurred July 21, 2007, after recovery of two rows of pillars. The caving roof caused an air blast that blew out five stoppings, and delayed production for nearly three hours. As the South Barrier section retreated toward deeper overburden, rib failures and floor heave became more frequent. On July 30, 2007, a bounce occurred at the working face, which broke a torque shaft on the continuous mining machine. Two days later, an intentional cave inby the pillar line damaged stoppings and disrupted production for approximately two hours.

On August 3, 2007, at 4:39 a.m., a non-injury coal outburst accident occurred at the face as the night shift crew mined the first cut to the north of No. 2 entry from the pillar between crosscuts 142 and 143. Coal was thrown into the entries along the entire length of the pillar, dislodging timbers and burying the continuous mining machine cable. The continuous mining machine operator was struck by coal. He was not injured, but the lower half of his body was covered with material. A stopping was damaged and a separation was observed between the mine roof and the damaged pillar. The crew retrieved the continuous mining machine, removed debris, and replaced some of the dislodged timbers before leaving the section at 6:00 a.m. When the day shift crew arrived on the section at 8:35 a.m., they repaired the damaged stopping and finished cleaning roadways and resetting timbers in the No. 2 entry. The accident was not immediately reported to MSHA as required.

Coal production resumed at 10:35 a.m., as the day shift crew mined the remaining cuts from either side of the No. 2 entry inby crosscut 142. Adverse ground conditions in the No. 3 entry prevented mining the north half of the damaged pillar (cut F and G as shown on Figure 41). Crew members (including the section foreman) discussed the possibility that management would decide to pull out of the South Barrier section due to similarities between the outburst accident that morning and the events in the North Barrier. The section was visited by mine management, who discussed the conditions with the section foreman. After this discussion, the section foreman informed the crew that they were to begin mining the barrier and skip some pillar rows. The crew moved the continuous mining machine outby crosscut 142 in the No. 1 entry and mined a lift from the barrier pillar. Six cuts were mined from the barrier during the night shift, retreating to near crosscut 141. Mining in the barrier between crosscuts 139 and 142 was prohibited by the approved roof control plan.

On August 4, 2007, the day shift crew moved the section loading point and power center outby to crosscut 138. They also moved the section equipment. The floor had heaved, making the move difficult. The night shift crew routed two MRS unit cables through the No. 1 entry to continue mining in the barrier pillar before leaving the section at 5:30 a.m.

On August 4, 2007, Gary Peacock emailed agenda information to Bruce Hill and Laine Adair for a management meeting scheduled for August 7, 2007. He described conditions in the South Barrier section: "*The conditions have been very good, we are getting a lot of good floor coal and 85%+ of recovery on the pillars. The cave is good and high and staying right with us for the most part.*" In anticipation of the August 7 pillar line location, he also wrote: "*We just started on the row outby the area where the 3 rows were left, this week will be critical to get the maximum out of each pillar to start a good cave without having the weight go over the top of* *us."* Although Peacock characterized conditions as very good, numerous bounces and a non-injury coal outburst accident had occurred as the pillar line approached crosscut 142.

At 7:30 a.m. on August 5, 2007, the day shift crew arrived on the section. Before mining, they graded floor heave to provide clearance for shuttle cars from the loading point at crosscut 138 in the No. 2 entry to the face in the No. 1 entry. At 11:25 a.m., the crew started mining cuts from the barrier pillar between crosscuts 140 and 141. Production was interrupted from 2:25 p.m. to 3:25 p.m. by an electrical power outage during a lighting storm, after which mining continued until the end of the shift. The night shift crew arrived on the section at 6:25 p.m. and relieved the day shift crew, which had mined a total of four cuts from the barrier pillar. The night shift continued mining the barrier until the time of the August 6 accident, as detailed in the August 6 Accident Description section of this report. Analysis of conveyor belt scale data and information obtained from miners who were on the section shortly before the accident indicated that the night shift crew was mining in the barrier pillar near crosscut 139 at the time of the August 6 accident.

Summary – Main West Ground Control History

Ground conditions encountered historically in the Main West demonstrate that the mine design was insufficient for pillar recovery in deep overburden. Main West workings were affected by abutment stress as adjacent longwall panels were extracted and these workings deteriorated over time. Subsequent development mining in the barriers on either side of Main West encountered high stress levels, particularly under the deepest overburden. During pillar recovery in both the North and South Barrier sections, increased stress levels contributed to increasingly difficult ground conditions that culminated in coal outburst accidents.

Historical ground conditions in Main West also provide a basis for engineering back-analyses of strata behavior. As indicated earlier, back-analysis is a process in which known failures or successes are evaluated to determine the relationship of engineering parameters to outcomes. Longwall abutment stress transfer was observed in the Main West more than 450 feet away from the mined-out panels. Of particular significance for stability analysis is the mining scenario associated with the March 10 non-injury coal outburst accident in the North Barrier section. This event demonstrated that 60-foot wide coal pillars at the Crandall Canyon Mine were prone to bursting under high stress attributed to deep cover and abutment stress.

Analysis of Collapse

Mine design is somewhat unique in comparison to other engineering structural design projects. In other disciplines, designers choose among a variety of materials with different mechanical or aesthetic properties. Often the materials are man-made (e.g., steel or concrete) with precisely controlled properties and known behavior. In contrast, mine design is limited by the properties of the coal or ore that is extracted and the host rock surrounding it. Usually, these geologic materials contain weaknesses (e.g., bedding planes or joints) and other inherent variations that complicate design because properties (and often applied loads) cannot be precisely determined or controlled. As a result, most if not all engineering analyses of geologic structures incorporate various generalizations, simplifications, and assumptions. Furthermore, uncertainties in material properties and applied loads necessitate designs that err on the side of safety.

A variety of analyses are available to assess ground stability in mine design. The basis for the analyses can be empirical (e.g., based on statistical treatment of case histories), analytical (i.e., based on fundamental principles of mathematics and/or mechanics), or numerical (i.e., based on an iterative mathematic process to find an approximate solution controlled by a complex interaction of variables). Various analyses rely on different input parameters or different representations of the same parameter. For example, pillar stability analyses may rely on empirically derived coal strengths or they may be determined from laboratory tests or mine-specific back-analysis. Despite these differences, when used properly, each analysis can provide valid and valuable insight to mine design.

As part of the Crandall Canyon Mine accident investigation, three approaches and computer programs were used to evaluate ground behavior in general and pillar response in particular:

- Analysis of Retreat Mining Pillar Stability (ARMPS[15]) calculations,
- Finite Element Method (UT2[4]) modeling, and
- Boundary Element Method (LaModel[5]) modeling.

In these analyses, the pillar dimensions and extraction widths were determined from mine maps. The overburden was determined by translating and rotating the USGS topographic map into the mine area based on state plane coordinates and corresponding mine local coordinates. The USGS topographic contours were digitized and then used with the digital mine top-of-coal contours to calculate the overburden for the mine area. The resulting overburden map was similar to the overburden contours on the Crandall Canyon Mine map. However, the map generated for the investigation contained more overburden contour detail.

The following sections provide detailed discussions of each analysis. It is important to note that input values (e.g., coal strength) vary between methods but each is valid for the type of analysis in which it is used. Similarly, thresholds used to interpret safety or stability factors are not directly comparable between methods. Although the three approaches differ substantially from one another, all three indicate that a widespread catastrophic pillar failure was central to the events at the Crandall Canyon Mine. ARMPS analyses revealed that stability factors (relative measures of stability) were below NIOSH's recommended minimums and also below the mine's historical experience. Finite element analyses indicated strong potential for a rapid catastrophic failure of the North and South Barrier sections and the Main West pillars between them. Similarly, boundary element analyses confirmed that the Main West was vulnerable to wide-spread failure; these results also provided insight to the factors that contributed to the overall collapse and potential means of triggering the event.

Safety/Stability Factors

Engineering analyses often evaluate the reliability of a design by calculating a factor that relates the strength of a design to its loading condition. The three programs used in this investigation (ARMPS, UT2, and LaModel) use different methods to calculate a measure of stability. Consequently, values or criteria from one type of analysis must not be related or compared directly to values from another type of analysis.

ARMPS. The ARMPS program calculates a stability factor (StF) which has the following relationship:

$$StF = \frac{Pillar\ Load\ Bearing\ Capacity\ \ from\ the\ Mark\ Bienawski\ Equation}{Pillar\ Load\ \ from\ geometric\ configuration\ and\ \ field\ data}$$

In the literature, the ARMPS stability factor is expressed with the term: "SF." To avoid confusion with the factors calculated in UT2 and LaModel, ARMPS stability factor in this report is designated as "StF." Based on a mining database of successful and unsuccessful case histories, recommended StF design criteria were developed. ARMPS design criteria are empirically derived and should not be used with factors derived from UT2 and LaModel which have a different calculation basis.

UT2. In the UT2 analyses, a safety factor (SF) from material modeled as linear elastic can be determined by the following relationship:

$$SF = \frac{Strength}{Stress} \quad \text{or} \quad \frac{Load\ Carrying\ Capability\ at\ Elastic\ Limit}{Applied\ Load}$$

The SF values in the UT2 analysis follow the typical engineering safety factor relationship where material strength is divided by applied stress.

LaModel. In the LaModel analysis a safety factor (SF) from material modeled as strain-softening or elastic-plastic can be determined for a particular element by the following relationship:

$$SF = \frac{Peak\ Strain}{Applied\ Strain}$$

The LaModel SF is a strain-based (deformation-based) safety factor. Traditionally, safety factors are calculated on a stress basis. For LaModel analyses using nonlinear materials, strain-based safety factors are more appropriate.

Analysis of Retreat Mining Pillar Stability (ARMPS)

Pillar stability was evaluated using the ARMPS program developed by Christopher Mark and others at the National Institute for Occupational Safety and Health (NIOSH) Pittsburgh Research Laboratory (a former US Bureau of Mines research center). This program is considered an empirical approach because it is based on a statistical analysis of case histories. More than 250 case histories (including successful and unsuccessful experiences) have been documented and used to develop the ARMPS database of stability factors (StF). StF's are similar to safety factors (SF) in that they are calculated as the ratio of strength to stress (or load carrying capacity to applied load). StF's in ARMPS, however, are computed specifically for pillars using two basic assumptions. First, pillar strength is computed using an empirical pillar strength formula (the Mark-Bieniawski equation). Second, pillar load is estimated using geometric relationships and stress distribution criteria developed from field data.

ARMPS can be used to provide a first approximation of the pillar sizes required to prevent pillar failure during retreat mining. It also provides a framework for evaluating the relative stability of workings in an operating mine. For example, ARMPS stability factors can be calculated for both successful and unsuccessful areas at a given mine site. This approach, referred to as "back-analysis," can be used to establish a minimum StF that has been shown to provide adequate ground conditions. This minimum then can be used as a threshold for design in subsequent areas as changes occur in the depth of cover, coal mining height, or pillar layout.

Site-specific criteria used in lieu of NIOSH's recommendations should be developed cautiously using multiple case histories with known conditions at a given mine. Back-analysis is most appropriate for mines that have a proven track record of retreat mining. In these cases, proper examinations of individual mine data may demonstrate that stability factors above or below NIOSH's recommended values are warranted. Proper examination would entail an analysis of the broad experience at a mine site rather than a focus on isolated case(s) that represent the extreme.

The ARMPS software calculates stability factors using 15 user-provided input parameters:

1. Entry Height
2. Entry Width
3. Number of Entries
4. Entry Spacings
5. Crosscut Spacing
6. Crosscut Angle
7. Depth of Cover
8. Extent of Active Gob
9. Barrier Pillar Width
10. Depth of a slab cut
11. Loading Condition
12. In Situ Coal Strength
13. Unit Weight of the Overburden
14. Breadth of the Active Mining Zone (AMZ)
15. Abutment Angle

Parameters 1 to 10 are dimensions of individual mine openings and the overall mining section that must be established by the user (see Figure 42). Item 11 is associated with the sequence in which panels of pillars are recovered and is defined in the ARMPS help files. Parameters 12 and 13 are properties of the coal seam and rock comprising the overburden; defaults values are provided in the software and should be used if the user plans to utilize NIOSH recommended StF's. The last two parameters are program specific values that establish the geometry used to estimate abutment loading of pillars. Again, defaults values are provided in the software and should be used if the user plans to utilize NIOSH recommended StF's.

Input parameters for each of the case histories in the NIOSH database were used to compute StF's for both successful and unsuccessful cases. The unsuccessful cases included pillar squeezes, massive pillar collapses (usually accompanied by air blasts) and coal bursts. According to NIOSH, pillar squeezes account for approximately two-thirds of the failures in the database. In addition, there were 14 sudden collapses and 17 bursts.

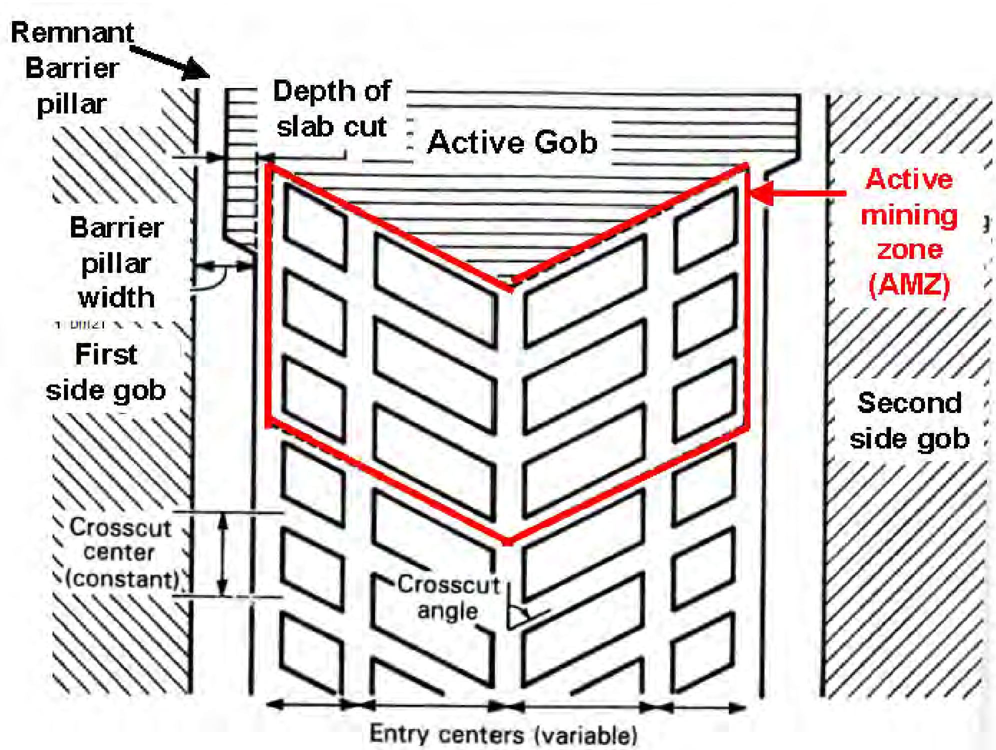


Figure 42 - Illustration of ARMPS Input Related to Panel Geometry (after Chase et al.[15])

ARMPS StF's, depth of cover, and outcomes (successful or unsuccessful) comprising the NIOSH database are illustrated in Figure 43. At depths below 650 feet, NIOSH noted that 88% of the failures occurred when the ARMPS stability factor was less than 1.5. In contrast, the ARMPS stability factor was greater than 1.5 in 78% of the successes.[6] They concluded that an ARMPS StF of 1.5 or greater is appropriate at these depths. At depths greater than 650 feet, Chase et al. (2002)[7] noted that StF's less than 1.5 can be employed successfully. The solid line drawn across Figure 43 represents minimum StF's recommended by NIOSH for various depths of overburden. However, NIOSH's analyses also noted that the use of large barrier pillars at depths greater than 1,000 feet substantially increased the likelihood of success. NIOSH incorporated this factor into their recommendations.

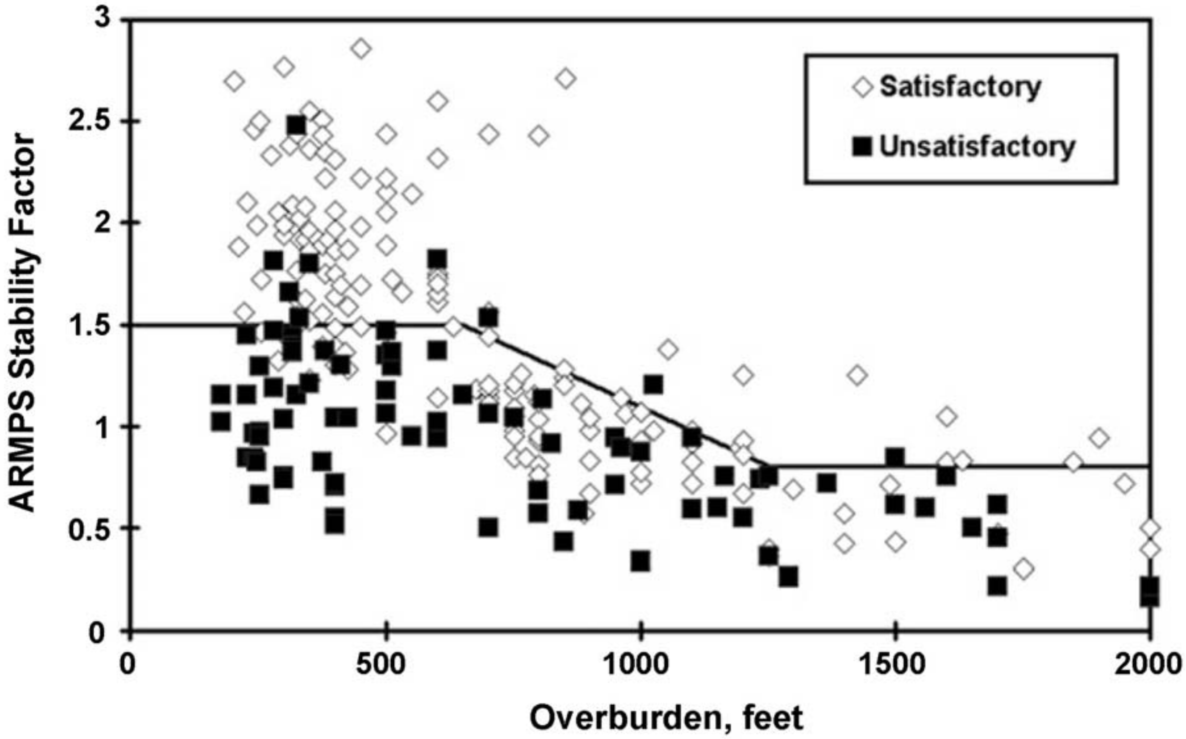


Figure 43 - ARMPS Case History Data Base (Chase et al.[7])

In addition to calculating StF's for "production" pillars that are recovered (PStF), ARMPS also determines stability factors for barrier pillars (BPStF) that separate pillar recovery sections from adjacent pillared workings (see Figure 42). Only one failure (out of 12 cases) in the NIOSH deep cover database occurred when the PStF was greater than 0.8 and the BPStF was greater than 2.0. Conversely, 30 case histories had a PStF less than 0.8 and a BPStF less than 2.0 and 60% of these cases were failed designs. Based on these data, NIOSH recommended the criteria shown in Table 4:

Table 4 - NIOSH Pillar Design Considerations

ARMPS Stability Factor	Overburden (H)	Weak and Intermediate Roof Strength	Strong Roof
Pillar (PStF)	650' ≤ H ≤ 1,250' 1,250' ≤ H ≤ 2,000'	1.5 – (H- 650) / 1,000 0.9	1.4 – (H-650) / 1,000 0.8
Barrier Pillar (BPStF)	H › 1,000'	≥ 2.0	≥ 1.5 (Non-bump prone ground) ≥ 2.0 (Bump prone ground)

(see Appendix Y for definition of bump prone ground)

The ARMPS stability factor for a given mining configuration represents the average value for pillars in an area near the pillar line, the active mining zone (AMZ – see Figure 42), rather than for individual pillars. NIOSH explains the rationale in a Help file in the ARMPS software:

> *ARMPS calculates the Stability Factor for the entire AMZ, rather than stability factors for individual pillars, because experience has shown that the pillars within the AMZ typically behave as a system. If an individual pillar is overloaded, it will normally transfer its excess load to adjacent pillars. If those pillars are adequately sized, the process ends there.*

With regard to barrier pillar stability (BPStF), the program calculates stability factors for barrier pillars on either side of the pillar line. Furthermore, since barrier dimensions can change due to barrier slabbing (see Figure 42), the program provides BPStF's for locations outby (BPStF) and inby the pillar line (remnant BPStF).

Pillar Recovery Analyses at Crandall Canyon Mine. Pillar recovery operations at Crandall Canyon Mine were back-analyzed for the accident investigation using ARMPS. It is not possible to characterize the effectiveness of these operations in every instance (i.e., the conditions encountered during panel development and extraction are not fully known). Nonetheless, ARMPS stability factors for pillars and barriers provide a relative measure of the designs used in various areas of the mine. Back-analyses were performed in four pillar recovery areas: 1st North Left block panels (continuous haulage panels between 1st North and 1st Right), the South Mains, the North Barrier section, and the South Barrier section. These analyses were conducted at specific locations of interest within each area (e.g. under high overburden or locations with known ground conditions).

For each ARMPS analysis, input values related to mining geometry (e.g. number of entries, pillar dimensions, or overburden) were determined from mine maps. An 8-foot mining height and 20-foot entry width was assumed in all cases. Similarly, ARMPS default values for coal strength (900 psi), unit weight of overburden (162 lb/ft^3), abutment angle of gob (21º), and extent of the active mining zone were used in all cases.

The use of default values in the analyses allows the output to be compared directly with stability factors in the NIOSH database where the default values also were employed.[7] This approach provides a relative comparison of mining scenarios at Crandall Canyon Mine and direct consideration of NIOSH's minimum recommended stability factors.

1st North Left Block Panels Pillar Recovery. In early 1992, continuous haulage panel development began to the west of the 1st North main entries. Nine panels were developed and extracted in sequence from north to south (see Appendix D). The continuous haulage panels were developed in a 5-entry configuration with 60º angle crosscuts. The typical panel was driven with five entries on 74-, 56-, 82- and 82-foot centers (spacing measured perpendicular to the center belt entry) and crosscuts on 80-foot centers. Multiple mining units were used and, as a result, development and extraction of a panel to the south lagged slightly behind the development and extraction of a panel positioned to the north.

Overburden increased from east to west in the 1st North panels and approached 1,800 feet near 1st Right. ARMPS analyses were done for four panels, 6th to 9th Left, under the deeper cover (Figure 44). Results of the ARMPS analyses are included in Table 5.

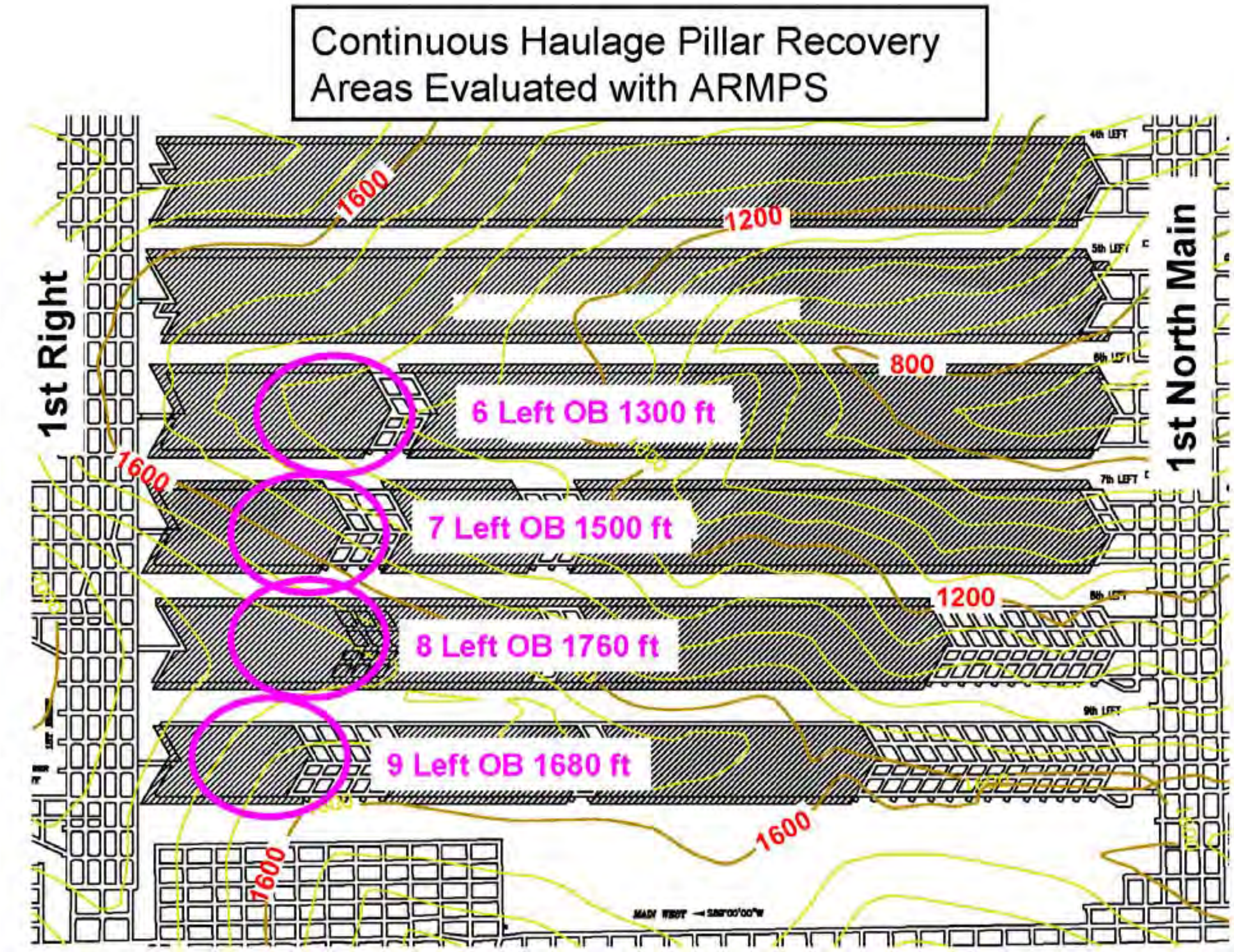


Figure 44 - 1st North Mains Left Panel ARMPS Calculation Areas

Table 5 - Pillar Stability Factors for Continuous Haulage Panel Back-Analysis

Panel	Overburden, ft	Development with Side Gob		Retreat with Side and Active Gob	
		BPStF	PStF	BPStF	PStF
6th Left	1300	2.11	0.88	1.72	0.48
7th Left	1500	1.99	0.76	1.64	0.42
8th Left	1760	1.79	0.64	1.52	0.36
9th Left	1680	1.87	0.67	1.80	0.46
Average	1560	1.94	0.74	1.67	0.43

The four red squares in Figure 45 represent ARMPS stability factors associated with the 1st North continuous haulage system panels. Although no catastrophic failures were reported, pillar recovery was not trouble-free. Accident records indicate that two injuries resulted from bounces (one of which was a coal burst) during pillar recovery in late 1993 and early 1994 in the 7th Left continuous haulage panel. Also, pillars were abandoned in each panel to alleviate some form of difficult ground condition. Roof coal had been left during development of these panels and this practice may have contributed to the difficulties. Regardless of the reason for leaving the pillars, these unmined zones indicate that pillar recovery was not entirely successful.

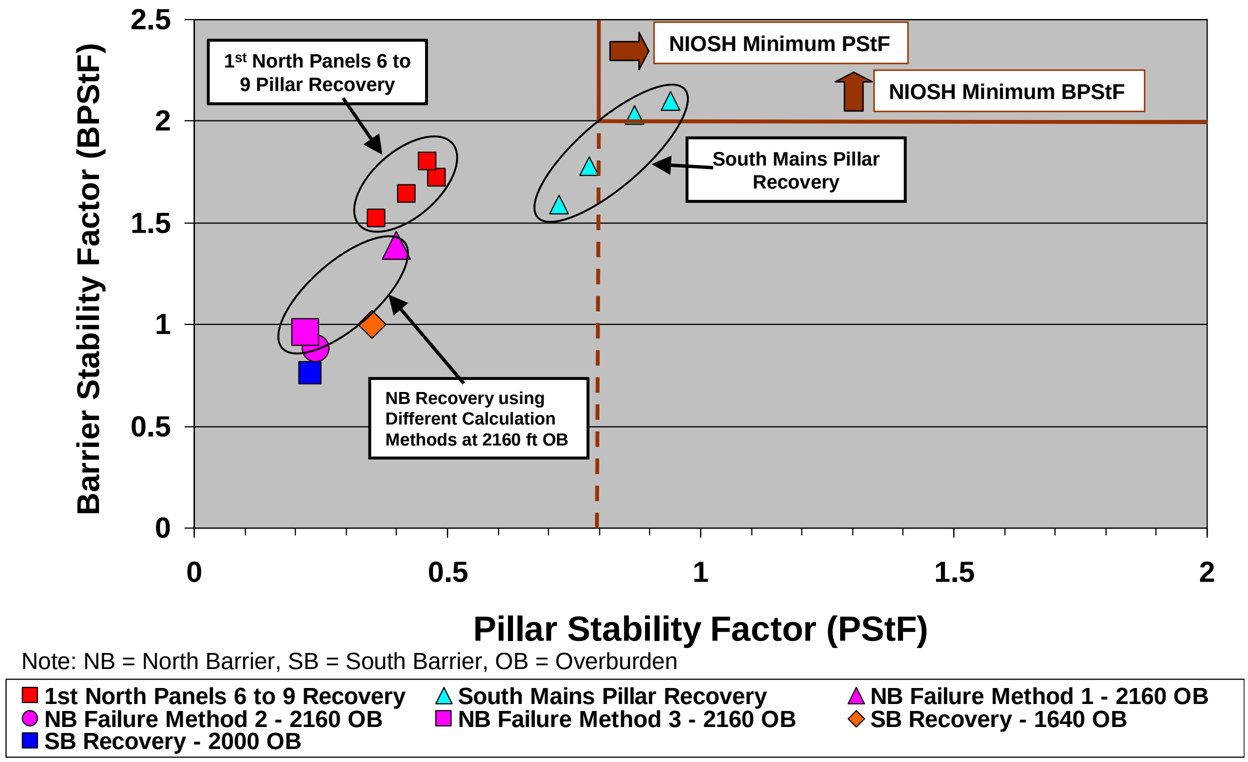


Figure 45 - ARMPS Stability Factors at Crandall Canyon Mine

South Mains Pillar Recovery. The South Mains pillaring process involved mining a series of 3-4 rooms east and/or west from the original 5-entry main, typically 3 crosscuts deep into the adjacent longwall barrier pillars (see Figure 36). The newly formed pillars were typically the same dimensions as the original South Mains pillars (approximately 80 x 112-foot centers). The new pillars and the original South Mains pillars were then extracted. This process was repeated along the length of the South Mains, where overburden ranged from 700 to 1,520 feet.

Four areas with relatively high overburden and minimal barrier width to the longwall gobs were selected for back-analysis using ARMPS. The areas were between longwall Panels 6 and 18, Panels 5 and 16, Panels 4 and 15, and Panels 3 and 13 (see Figure 46). At each of these locations, the maximum extraction area and minimum barrier widths were applied in the analysis to subject pillars and barriers surrounding the developing gob to the highest degree of loading. This approach was used to define the lower limit of the historical pillar stability factors associated with pillar recovery in the South Mains. Results of the ARMPS analyses are included in Table 6.

The light blue triangles in Figure 45 represent stability factors associated with pillar recovery in the South Mains. Two of the cases satisfied the NIOSH criteria for minimum stability factors. Although no catastrophic failures were reported, miners described “heavy” conditions on the pillar line indicative of high stress and pillar bounces were reported. These conditions led the operator to adopt a pillar recovery sequence in which pillars were extracted exclusively in one direction rather than alternating the direction between successive rows. Reportedly, less “thumping” was experienced on the pillar line when the pillars were extracted exclusively from west-to-east. Also, interview statements and documents indicate pillar “bouncing” occurred during pillar extraction in the South Mains. Two rows of pillars beneath a ridge near the center of South Mains (1520 feet of overburden) were not extracted.

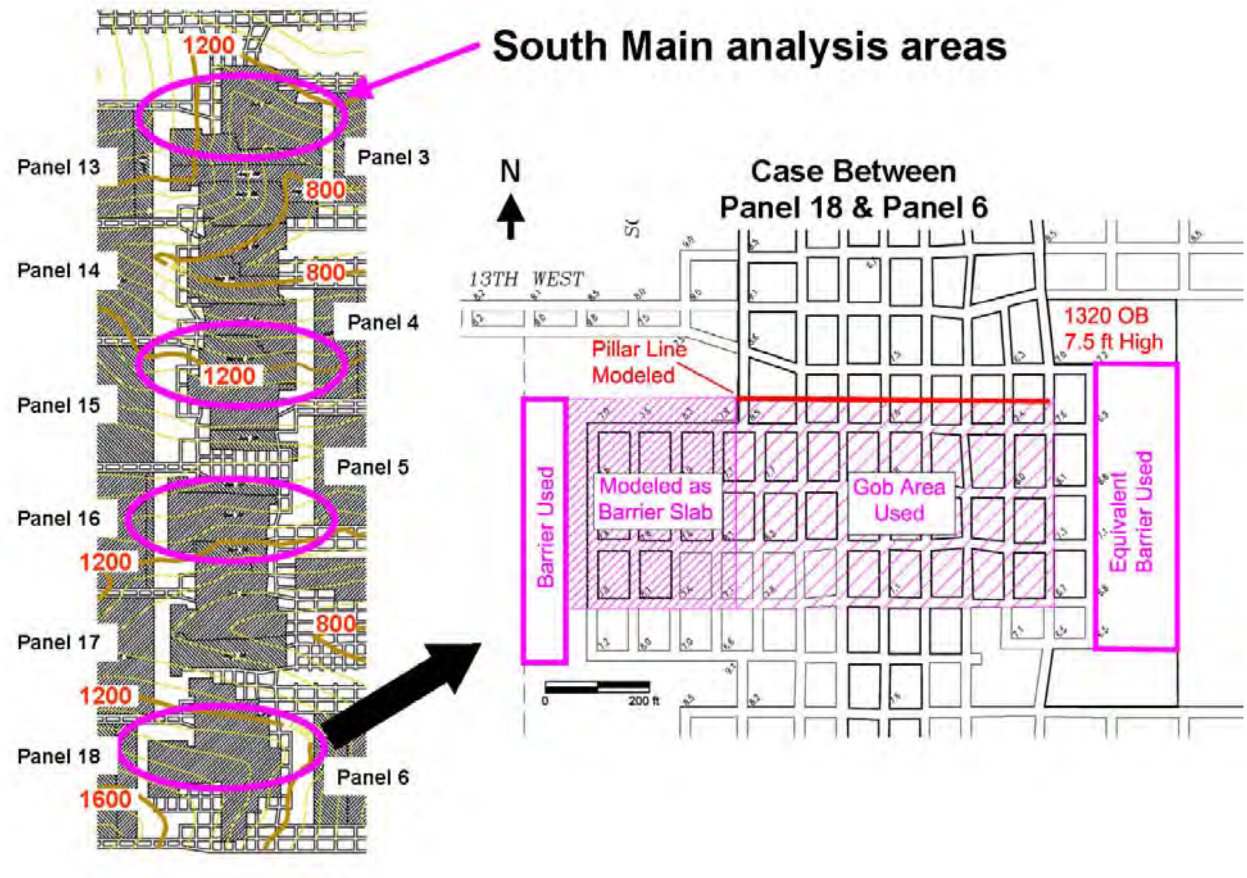


Figure 46 - South Mains ARMPS Calculation Areas

Table 6 - Pillar Stability Factors for South Mains Back-Analysis for Areas with Side and Active Gobs

Area Mined	**Over-burden (ft)**	**Development with Side Gob**			**Retreat with Side and Active Gob**			
		Original West BPStF	**Original East BPStF**	**PStF**	**BPStF, West Barrier**	**BPStF, East Barrier**	**Minimum BPStF**	**PStF**
Between Panels 6 and 18	1330	7.35	2.12	1.53	5.36	2.10	2.10	0.94
Between Panels 5 and 16	1300	7.00	7.03	1.43	1.59	2.02	1.59	0.72
Between Panels 4 and 15	1200	7.84	7.81	1.55	2.28	2.03	2.03	0.87
Between Panels 3 and 13	1130	8.64	12.55	1.72	5. 65	1.78	1.78	0.78
Average	**1240**	**7.71**	**7.38**	**1.56**			**1.88**	**0.83**

North Barrier Section. Recovery mining in the North Barrier section extracted the two southern pillars leaving the northernmost pillar intact for a bleeder system. Prior to December 2007, the ARMPS software did not have the capability to model bleeder system geometry directly. At least three alternatives could be considered for determining stability factors in this scenario.

1. Assume that the bleeder pillar is not developed. Using this approach, the section is modeled as a three entry system and the overall width of the barrier is the sum of the actual barrier width plus the bleeder pillar width.
2. Assume that the entire pillar row is mined. In this model, the load bearing capacity of the bleeder pillar is not considered.
3. Assume a greater barrier width than the actual dimension. In this approach, the load bearing capacity of the bleeder pillar is determined and a recalculated barrier dimension is used. The barrier dimension is chosen such that its load bearing capacity represents the combined strength of the actual barrier pillar and the bleeder pillar (see Appendix P).

Each of these approaches uses a different assumed geometry (Figure 47) and provides a different result. The first method generates the highest PStF and the second and third methods generate lower and similar PStF values. Consequently, when compared to NIOSH pillar design criteria from the NIOSH database or pillar design from mine site back-analysis, the first method is more likely to overstate stability than the second or third method. The inappropriateness of Method 1 is evident in the fact that StF's calculated for a retreating section using this method are actually greater than StF's calculated for development using actual pillar and barrier dimensions (see Table 7). When comparing the design to NIOSH or mine site specific design criteria, the second and third methods offer the safest approach.

Table 7 - Pillar Stability Factors for North Barrier Section

Calculation Method	Overburden at Failure (ft)	Development with Side Gob		Retreat with Side and Active Gob	
		BPStF, North Barrier	PStF	BPStF, North Barrier	PStF
1 (215-foot barrier)	2160	0.91	0.35	1.39	0.40
2 (135-foot barrier)	2160			0.88	0.24
3 (147-foot barrier)	2160			0.96	0.22

Since overburden at the location where the March 10, 2007, non-injury coal outburst accident occurred was 2,160 feet, that value was used in the back-analysis for pillar recovery to establish a minimum stability factor threshold for future pillar design. Results of the ARMPS analyses using all three assumptions for incorporating a bleeder pillar are included in Table 7.

The magenta colored shapes in Figure 45 represent ARMPS stability factors for the North Barrier section determined using the three methodologies discussed earlier. They are grouped together in an oval to signify that all three correspond to the same mining scenario. Regardless of the methodology used, both the pillar stability factor and barrier pillar stability factor fall below the NIOSH recommended values for bump-prone and non-bump-prone ground. The low stability factors indicate that poor ground conditions and/or section failure would be anticipated during pillar recovery.

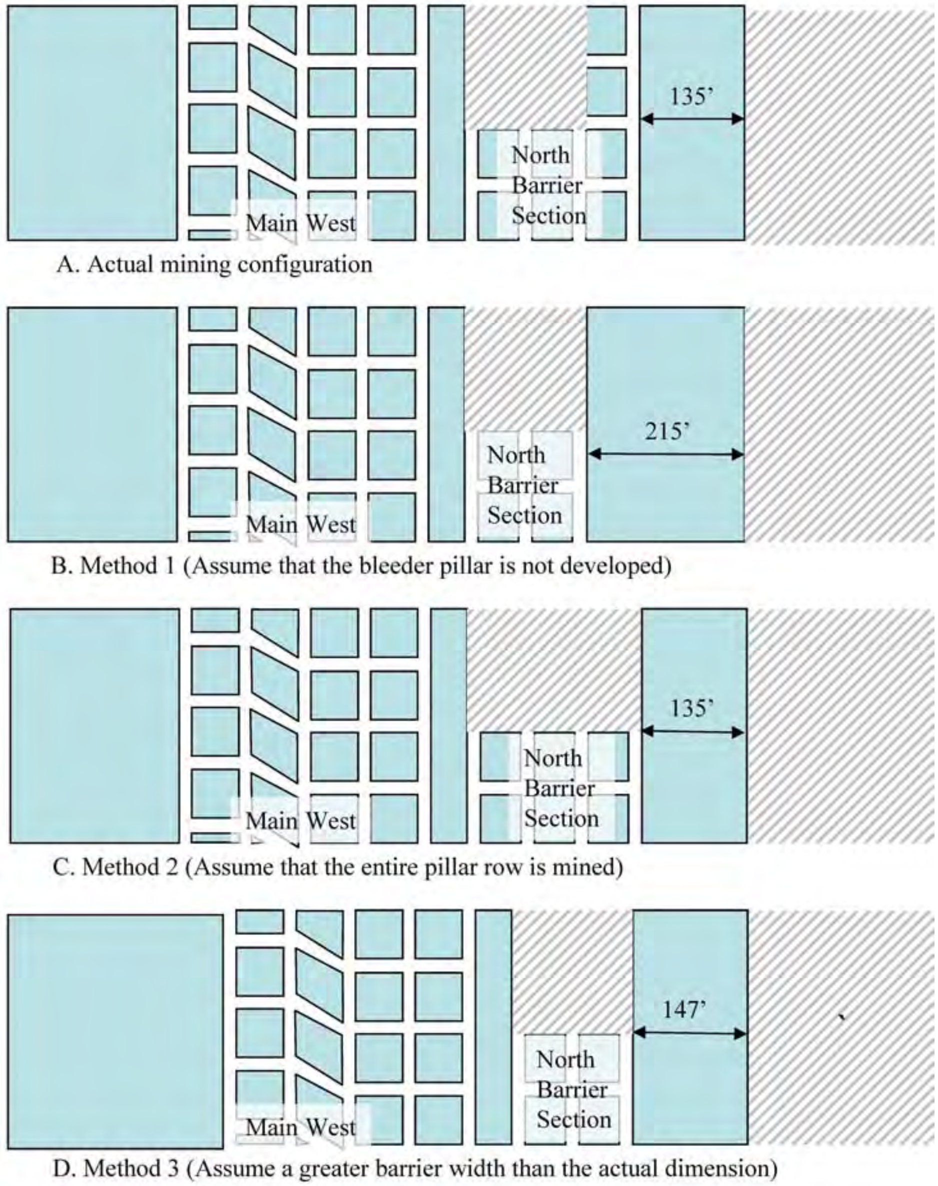


Figure 47 - Methods of Incorporating a Bleeder Pillar in ARMPS Analyses

South Barrier Section. Approximately 25% of the South Barrier section was developed in overburden exceeding 2,000 feet. Thus, analyses to assess the overall section design were based on that overburden depth. These calculated pillar stability values are summarized in Table 8. The table also includes PStF and BPStF values for 1,640 feet of overburden. This is the maximum cover that the retreating pillar line encountered in the South Barrier section prior to the August 6 accident.

Table 8 - Pillar Stability Factors for South Barrier Section

Method	Overburden (ft)	Development with Side Gob		Retreat with Side and Active Gob	
		BPStF South Barrier	PStF	BPStF South Barrier	PStF
N/A	2000	0.91	0.46	0.76	0.23
N/A	1640	1.18	0.73	1.00	0.35

The blue square and orange diamond in Figure 45 correspond to these two pillar recovery scenarios. Since the bleeder pillar in this section was not adjacent to the barrier along the Panel 13 gob, the ARMPS software could consider the South Barrier width directly (i.e., without making adjustments like those for the North Barrier). Had the pillar line retreated to a point beneath the deepest cover, the PStF and BPStF would have been nearly the same or less than those associated with the March burst in the North Barrier (substantially lower than values determined using the method with the highest risk, Method 1, and lower than the NIOSH recommended values). Although longer pillars were employed in the South Barrier section, the thinner barrier towards Panel 13 and the slab cut into the barrier during pillar recovery result in larger calculated abutment loads and lower StF's. As before, the low stability factors indicate that poor ground conditions and/or failure would be anticipated.

Effects of Barrier Pillar Recovery on Main West Entries. ARMPS analyses typically are used to assess the stability of a single pillar recovery panel. Other approaches such as finite element and boundary element modeling are better suited to evaluate a catastrophic pillar collapse like the one that occurred at Crandall Canyon Mine on August 6, 2007. However, if the effects of longwall mining north and south of the section are neglected entirely, ARMPS provides a simplified way of evaluating the overall stability of the Main West pillar system.

The Main West can be represented as a developed section (no pillar recovery) bounded on either side by the North and South Barrier Section workings, as illustrated in Figure 48. On development, the Main West PStF is 0.86 (near borderline with respect to NIOSH recommendations) for the maximum Main West overburden of 2,160 feet. As the North Barrier is recovered, the PStF drops to 0.70, below the recommended level, and even further to 0.66 with extraction in the South Barrier. In fact, the actual StF's are likely much lower given the age of the workings (i.e., pillar degradation over time) and the influence of the adjacent longwall workings.

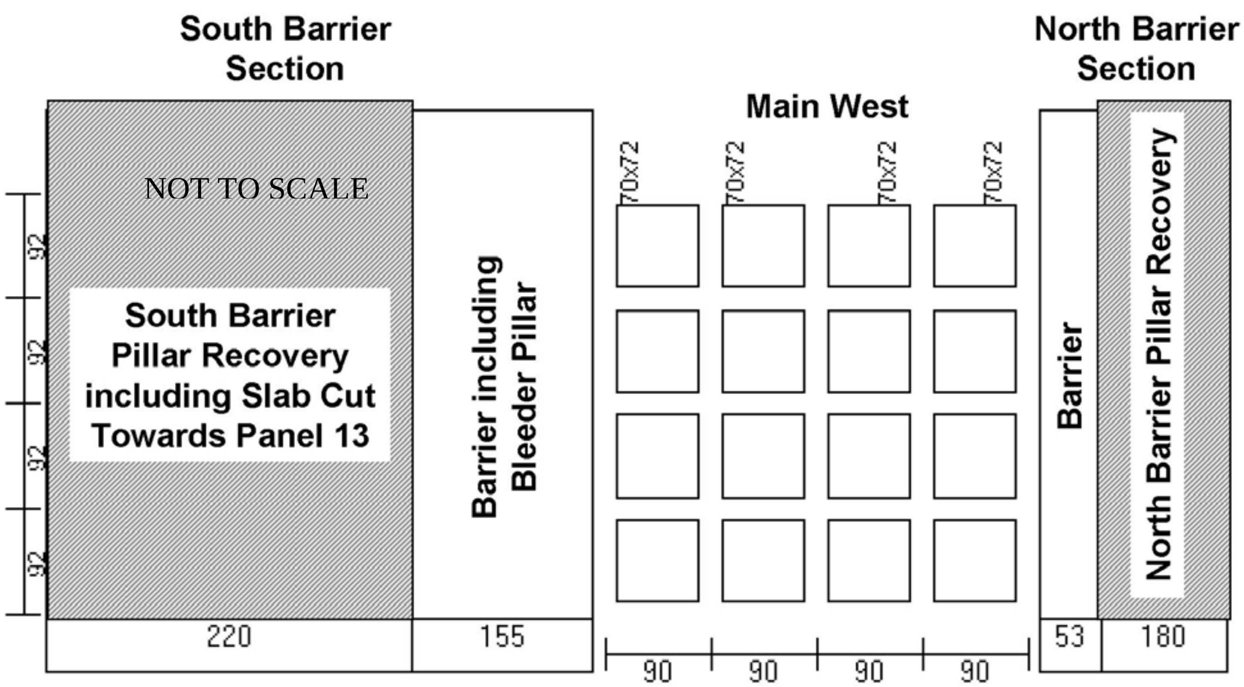


Figure 48 - ARMPS Layout for Simplified Main West Analysis

Summary. ARMPS stability factors for Crandall Canyon Mine pillar recovery scenarios are illustrated in Figure 45. In this figure the vertical and horizontal solid color lines represent NIOSH recommended minimum stability factors (0.8 PStF and 2.0 BPStF). The recommended NIOSH values (0.8 PStF and 2.0 BPStF) are for overburden deeper than 1,250 feet with strong roof and bump prone ground. ARMPS stability factors that are above or below NIOSH recommended values do not ensure success or failure. However, when stability factors are maintained above the thresholds for both production and barrier pillars, experience (reflected in case studies in the NIOSH database) has demonstrated likelihood for success.

With the exception of portions of the South Mains pillar recovery areas, stability factors at the mine were below NIOSH recommendations and, as would be expected, various ground control problems were experienced. The low stability factors in the North and South Barrier sections, as well as in the adjacent Main West entries, show a high potential for ground failure. The following finite element and boundary element analyses show similar results.

Finite Element Analysis

Dr. William Pariseau, Professor of Mining Engineering at the University of Utah, performed an analysis of mining in the Main West barriers at Crandall Canyon Mine using the finite element method (FEM). FEM analyses have been used widely in the field of civil and aerospace engineering and in a variety of geomechanics applications as well. In FEM analysis, the area to be studied is represented by a grid of discrete areas or elements. Properties and loadings are assigned to each element. A system of equations is constructed and solved to determine the stress, strain, and displacement of each element. Computer programs are utilized to prepare and calculate results and to display the model output. To model Crandall Canyon Mine, Dr. Pariseau elected to use a 2-dimensional FEM program, UT2[4], which he had previously developed. The objective of this study was to develop a better understanding of the strata mechanics associated with the August 6, 2007, accident at the Crandall Canyon Mine.

A complete review of Dr. Pariseau's FEM analysis is beyond the scope of this report. However, a report that he prepared is included in its entirety as Appendix Q. His report describes the study methodology and results in detail.

In the FEM analysis, rock above and below the coal seam and the seam itself were modeled as linear elastic materials. The term linear elastic implies that the materials deform at a constant rate to an increasing or decreasing load. Generally, rock response to initial loading is considered elastic. However, at elevated load levels beyond the elastic limit of a given rock type, fracture and material flow lead to irreversible deformation or "yielding." Although an elastic FEM analysis does not consider rock failure and yielding explicitly, the models can provide insight to ground stability by evaluating safety factors. Safety factors (SF) can be defined as follows:

$$SF = \frac{Strength}{Stress} \quad \text{or} \quad \frac{Load\ Carrying\ Capability\ at\ Elastic\ Limit}{Applied\ Load}$$

When the load applied to a model element is greater than that element's load carrying capability, the SF is less than 1.0 and is considered to have failed. In reality, yielding and failure prevent applied loads from exceeding load bearing capacity and, therefore, SF cannot be less than 1.0. However, in an elastic model *computed* SF's may be less than 1.0 and the distribution of these lower values provides a measure of the degree of failure likely in a given mining scenario.

Elastic-plastic elements can be used in FEM analysis to model yielding behavior. However, post failure behavior of rock materials is difficult to resolve and the analyses are complex and time consuming. Generally, the effect of yielding in an elastic-plastic analysis is to “spread the load” in a model. Element yielding essentially creates a limit above which additional loading can no longer occur and excess loads must be transferred to adjacent elements. In contrast, an elastic model provides an optimistic analysis of stability since stress may exceed strength. Thus, if an unsafe condition is inferred from the results of an elastic analysis, then it is likely that any actual instability will be even more widespread.

In the Crandall Canyon Mine analysis, a model was prepared to examine stresses and displacements in mine strata in a two-dimensional cross-section through the Main West workings. The cross-section measured 6,480 feet in an approximately north-south orientation and extended 2,609 feet vertically. These dimensions encompassed worked-out longwall panels north and south of Main West and overburden above the Hiawatha seam and 1,000 feet below the seam. The Hiawatha seam was modeled as an 8-foot thick unit.

An overburden thickness of 1,601 feet was used in the FEM analysis to correspond with the length of a borehole that was used to characterize the stratigraphy of Crandall Canyon Mine. In the FEM analysis, beds of similar rock type are represented as layers with specific material properties. These properties usually are developed from laboratory tests on rock samples obtained from coreholes. Using fundamental principles of engineering mechanics, the FEM computes stresses and strains induced in the rock mass by excavation.

In the Crandall Canyon Mine model, calculations were performed for four stages of excavation: (1) excavation of the Main West entries, (2) excavation of longwall panels on either side of the Main West entries, (3) excavation of entries in the north barrier pillar, and (4) excavation of entries in the south barrier pillar. At each mining stage, stresses and strains were computed to illustrate the effects of mining.

Main West Mining. Model results in the first stage of excavation, Main West development, suggest that the roof, floor, and pillars would be stable. Pillar safety factors are greater than 2.2 (i.e., strength is more than double the applied stress). Safety factors are even greater in the roof and floor due to the greater strength of the shale and sandstone materials.

Longwall Mining. Model results in the second mining stage, longwall panel extraction, indicate that some areas have reached the elastic limit while others are well below (see Figure 49). For example, 25% of the barrier pillar separating the Main West from the longwall panels has yielded in this stage of mining. Although the remainder of the barrier adjacent to the Main West has not yielded, it is highly stressed. The gray elements in Figure 49 indicate mine openings in the Hiawatha seam and the black elements represent element safety factors less than 1.0.

Dr. Pariseau stated that:

> *“Safety and stability of an entry surrounded by an extensive zone of yielding would surely be threatened. A pillar with all elements stressed beyond the elastic limit would also be of great concern.”*

Although yielding is isolated to the longwall side of the barrier opposite Main West, longwall mining has had a significant effect on stress levels in the Main West pillars. The highest SF in the Main West pillars is 1.34 which is substantially less than the values on development. Roof and floor SF’s are in the 4 to 5 range suggesting that they continue to be stable.

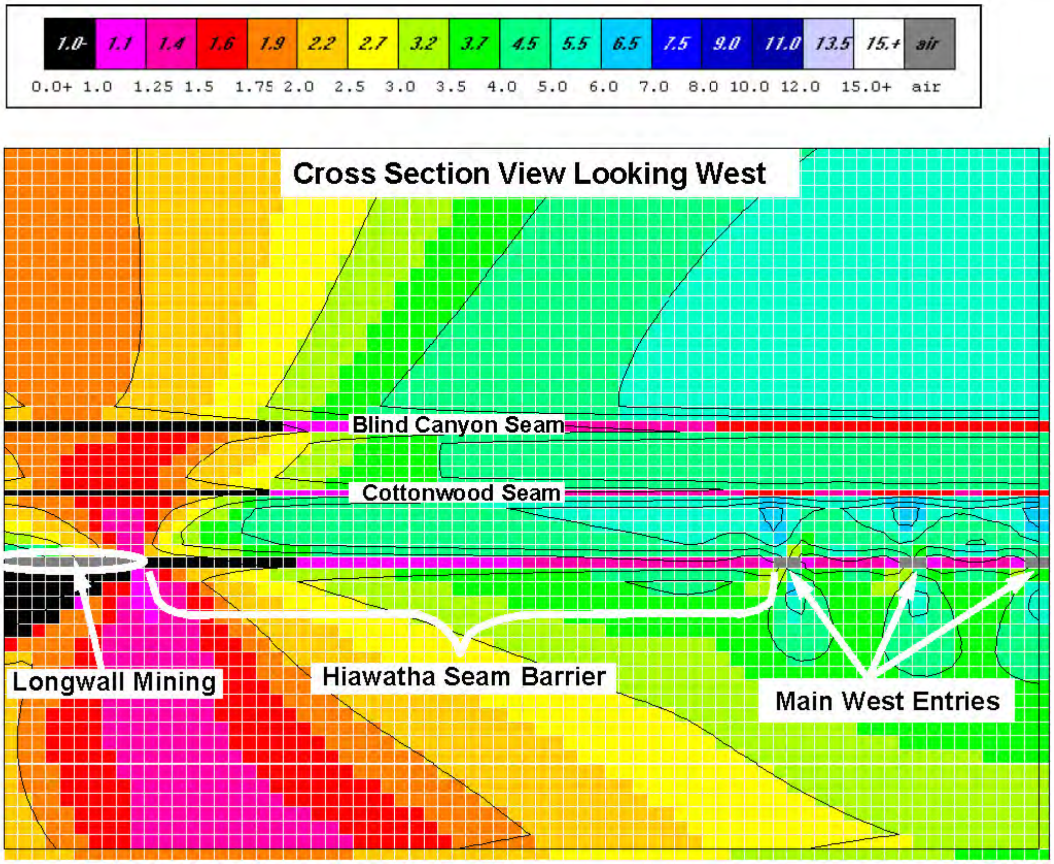


Figure 49 - Element Safety Factors about a Barrier Pillar after Longwall Mining

North Barrier Section Development. Model results from the third stage of excavation, development in the North Barrier, indicate that most elements in the north side barrier pillar are now at yield (note the black elements on the right side of Figure 50 at seam level). Rib elements in pillars adjacent to the Main West entries are also at yield. The outside entry of Main West shows ribs yielding in the pillar between it and the new north side barrier pillar entry. The south outside entry ribs show yielding extending 10 feet into the ribs and the highest safety factor in any pillar element in Figure 50 is 1.2.

South Barrier Section Development. The fourth and last stage of analysis is entry development in the South Barrier. The distribution of element safety factors at this stage is shown in Figure 51. Almost all elements in the south side barrier pillar are now at yield and all pillar elements across the mining horizon are close to yield. Again, since purely elastic behavior leads to an underestimate of the extent of yielding, it is likely that yielding would spread further and affect portions of the pillars that have not yielded in the elastic model.

Peak vertical stress in the barrier pillars exceeds 38,400 psi, over 9 times the unconfined compressive strength of the coal. Horizontal stress exceeds 7,300 psi. Even so, this high confining pressure is insufficient to prevent yielding. The lowest vertical pillar stress is about 6,000 psi, almost half again greater than the unconfined compressive strength of the coal; the lowest horizontal pillar stress is about 1,500 psi. Any release of horizontal confinement would likely result in rapid destruction of pillars. Additionally, entries nearest to the mined panels are showing reduced roof and floor safety factors. Overlying coal seams are also yielding or are very close to yielding over portions of the barrier pillars, as seen in Figure 51. These model results are indicative of unstable conditions.

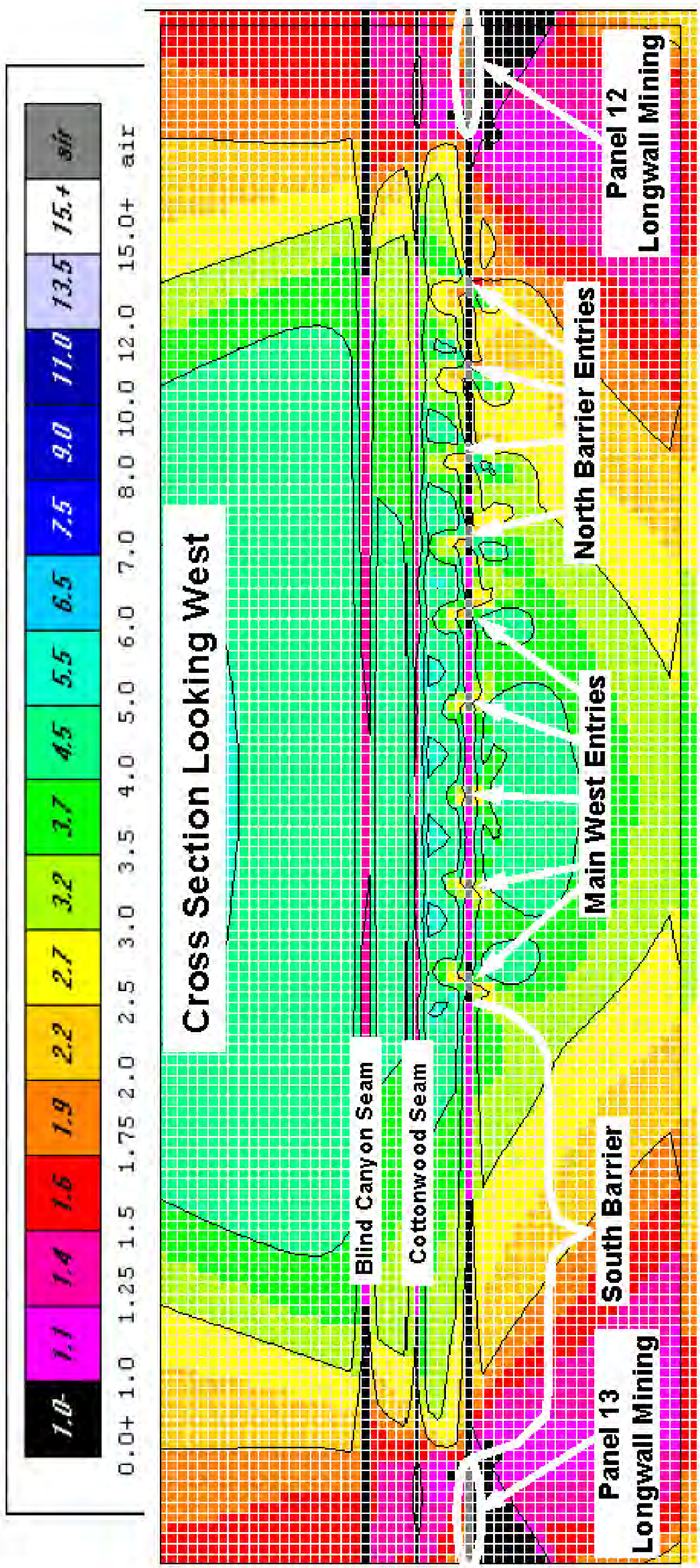


Figure 50 - Element Safety Factor Distribution after North Barrier Section Development

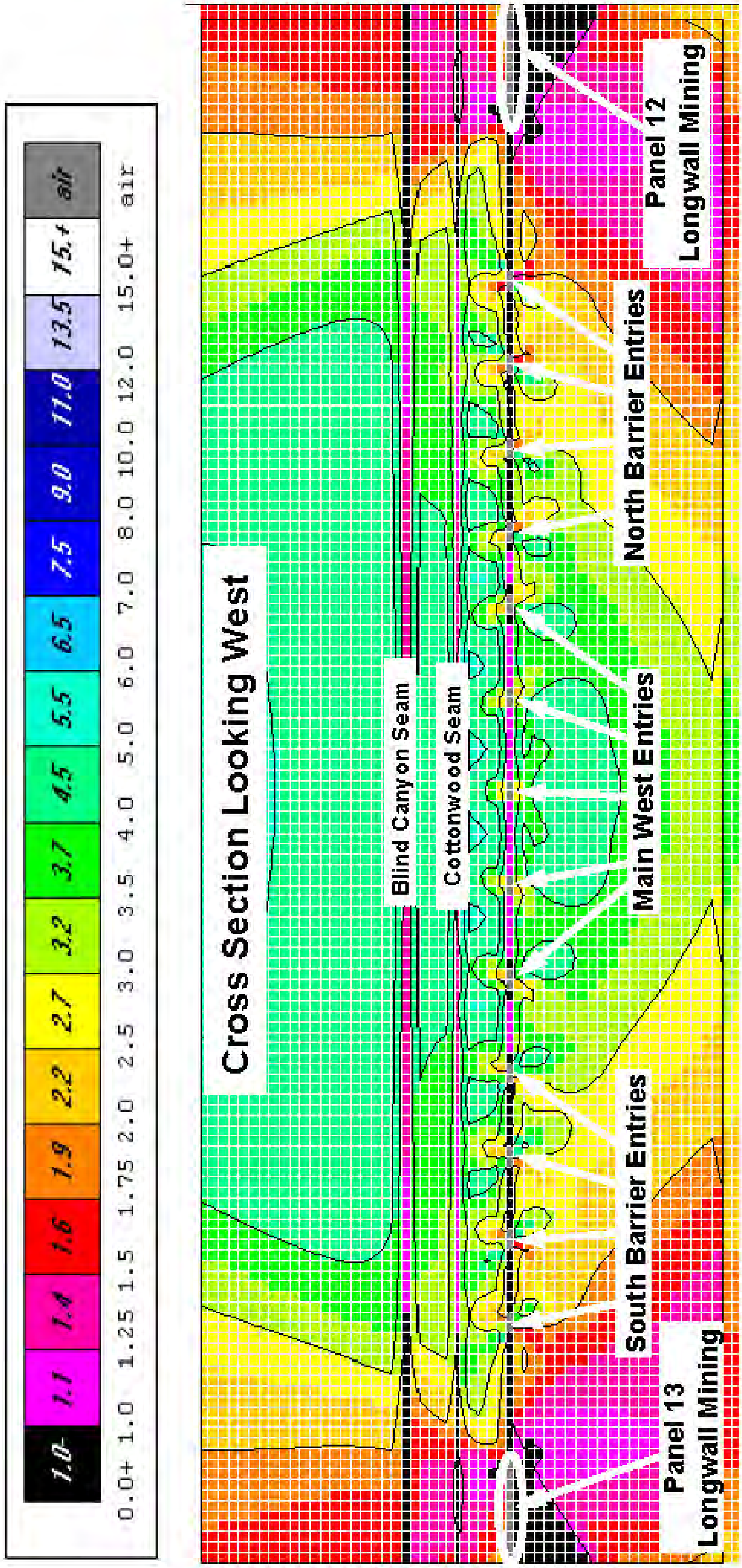


Figure 51 - Element Safety Factor Distribution after South Barrier Section Development

Conclusions of Finite Element Analysis. Dr. Pariseau's FEM analysis of barrier pillar mining at Crandall Canyon Mine *"indicates a decidedly unsafe, unstable situation in the making."* It is noteworthy that the analyses used *"optimistic"* input values and assumptions that would tend to make the mine workings appear to be more stable as opposed to less. For example:

- Models assumed overburden depth of about 1,600 feet even though the actual overburden exceeded 2,000 feet in some locations.
- The 2-D analysis did not account for crosscuts that would increase the actual pillar stress.
- The analysis did not account for pillar recovery that would further increase pillar stress.
- Elastic material properties were used that limited stress transfer normally associated with yielding behavior.
- Laboratory strength values were used in the analysis even though rock masses tend to be weaker.

Despite the use of these *"optimistic"* input values and assumptions, the results indicate a potential for rapid destruction of the pillars with expulsion of the broken coal into the adjacent entries.

Boundary Element Analysis

The boundary element method using the displacement-discontinuity calculation is well suited to modeling thin, tabular deposits like coal seams (see Appendix R). In contrast to the two-dimensional finite element model discussed in the previous section, BEM programs provide a quasi three-dimensional analysis capability. As illustrated in Figure 52, entries and pillars in a coal seam can be represented as a plane of elements bounded by a rock mass. Stress changes and displacements associated with mining activity can be evaluated by comparing successive models in which elements are altered to correspond with the changing mine geometry.

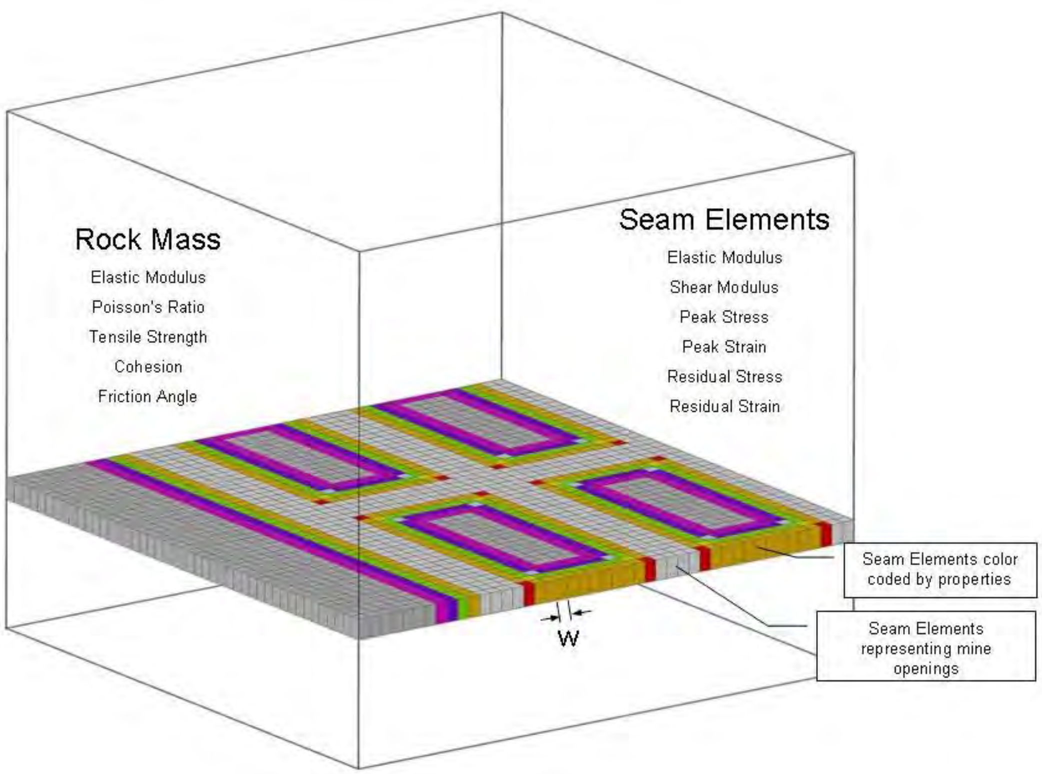


Figure 52 - Illustration of Boundary Element Model Components

Like all numerical methods, BEM results are always dependent on the input values. In particular, properties that define the behavior of the coal seam, the gob, and the rock mass surrounding the seam are critical (see Figure 52). Furthermore, numerical models can only be considered to be reliable after they are adjusted (i.e., calibrated) so that they duplicate observed field behavior.

Crandall Canyon Mine Back-Analysis. Dr. Keith Heasley, Professor of Mining Engineering at West Virginia University, performed an analysis of mining in the Main West area using the boundary element method. Dr. Heasley used LaModel, a BEM program which he had previously developed. One objective of this work was to use the best available information to back-analyze the August 6, 2007, pillar failure in order to better understand the geometric and geomechanical factors that contributed to the collapse. Another objective was to perform a parametric analysis of pertinent input parameters to assess the sensitivity of the LaModel results to the input values.

A complete review of Dr. Heasley's BEM analysis is beyond the scope of this report. However, a report that he prepared is included in its entirety as Appendix S. His report describes the study methodology and results in detail.

LaModel Calibration Process. In the LaModel analyses, rock above and below the coal seam were modeled as frictionless layers of linear elastic materials. However, elements representing the coal were modeled using strain softening material properties. Strain softening properties simulate the failure process by defining an elastic threshold beyond which an element's load bearing capacity decreases; in effect, at some predetermined peak load, the element yields and with further deformation, load bearing capacity generally decreases. Elements near an opening may actually shed load as a result of the yielding process. Elements further from openings yield at progressively higher peak loads and at some point may sustain the peak load with further deformation (i.e., plastic behavior).

Numerical analyses that incorporate strain-softening or elastic-plastic behavior provide a means of assessing element failure and any associated stress redistribution. However, in geologic materials, these properties are not easily defined. Furthermore, the modeled behavior of pillars comprised of groups of these elements, is affected by other model parameters (e.g., rock mass and gob properties). The selection of appropriate material properties relies primarily on the model "calibration" process.

Model calibration is an iterative process in which the analyst compares simulated results with known actual conditions (or in some instances, proven analytical solutions) to verify that model output is reasonable. The process, also referred to as "back-analysis," essentially demonstrates that the model is capable of duplicating known historical outcomes before it is used to evaluate future scenarios.

Dr. Heasley's report provides an overview of calibration as it pertains specifically to the LaModel program. The most critical factors with regard to accurately calculating stresses and loads, and, therefore, pillar stability and safety factors, are:

- The Rock Mass Stiffness
- The Gob Stiffness
- The Coal Strength

Each of these factors may comprise more than one input parameter (e.g., rock mass stiffness is defined by a lamination thickness and a rock mass modulus). Furthermore, a change in one factor often influences another. For this reason, model calibration is most efficient when it follows a systematic process and relies as much as possible on the best available information which may be measured, observed, or empirically or numerically derived. However, in calibrating the model, the user also needs to consider that the mathematics in LaModel are only a simplified approximation of the true mechanical response of the overburden. Because of the mathematical simplifications built into the program, the input parameters may need to be appropriately adjusted to account for the program limitations.

Model Development. The major effort of the back-analysis was directed toward selecting the critical rock mass, gob and coal properties to provide the best LaModel simulation of documented events at Crandall Canyon Mine. Initially, the mine and overburden geometries of the Main West area of the mine were developed into LaModel mine and overburden grids. Then, the rock mass stiffness was selected to obtain an abutment load distribution (i.e., extent) consistent with empirical averages and local experience. Next, the gob behavior was evaluated to provide reasonable abutment and gob loading magnitudes. For the coal properties, the peak strength was primarily determined from back analyzing the March 10 outburst accident in the North Barrier section, and the strain-softening behavior was optimized from the back-analysis of the August 6, 2007, event. Throughout this process, a number of particular locations, situations, and conditions were used as distinct calibration points. Detailed discussions of this process are provided in Appendix S.

Models were evaluated to select optimum input values for matching the observed mine behavior and to assess the sensitivity of the model results to the input values. These analyses provided a broad understanding of factors that affected ground conditions at Crandall Canyon Mine and culminated in the development of a model that simulates:

- the March 2007 bursts,
- the South Barrier section development, and
- the August 6 collapse.

In this model, mine workings were represented in a grid of 10 x 10-foot elements that measured 570 elements wide by 390 elements high. A separate grid was developed to incorporate the influence of topography in the model. Lamination thickness was set at 500 feet, the final modulus of the north gob was set at 250,000 psi, and the final modulus of the southern gob was set at 200,000 psi. The coal strength in the North and South Barrier sections was set at 1,300 psi and coal strength in the Main West was set at 1,400 psi. For the strain softening coal behavior, the residual stress was set with a 30% reduction from the peak stress. The safety factors presented were adjusted so that the peak pillar strength in the North Barrier pillars corresponded to a safety factor of 1.0. This same adjustment was made to all pillar safety factor plots shown. The model grid boundaries and calculated in situ overburden stress (i.e., stress levels due to overburden alone and without any influence of mining) are illustrated in Figure 53.

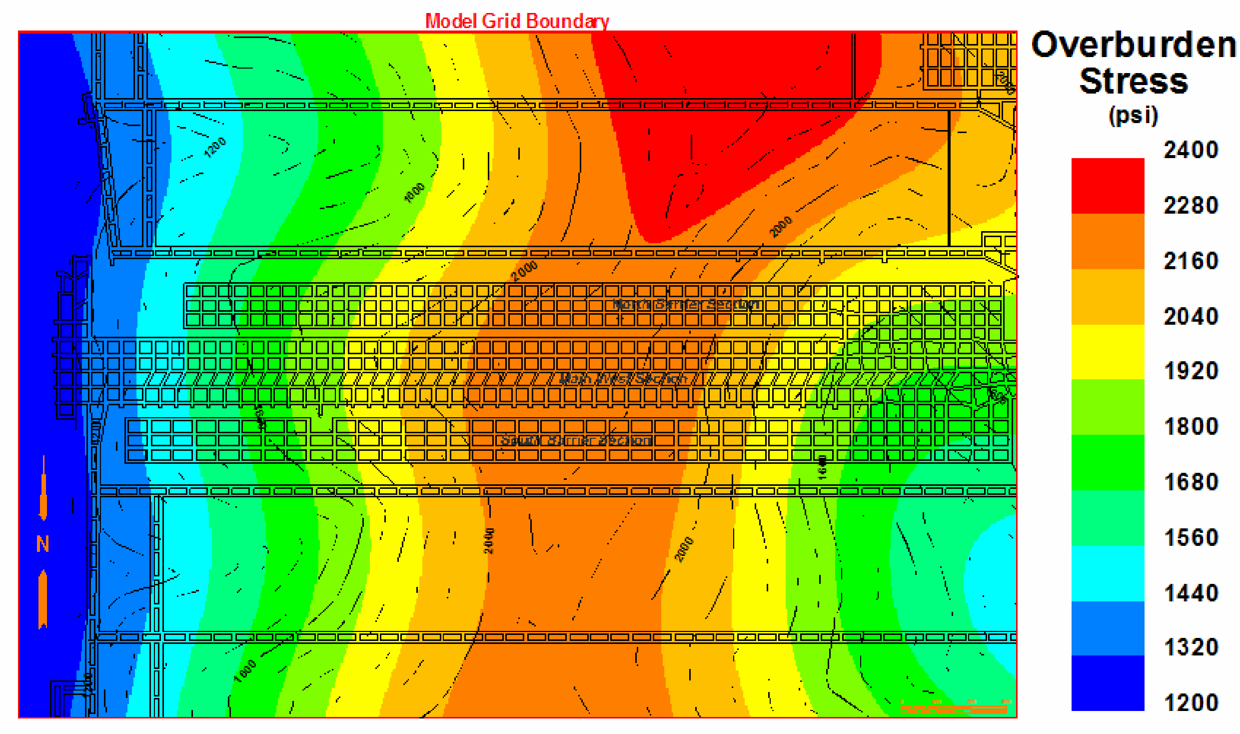


Figure 53 - LaModel Grid Boundaries and Overburden Stress

LaModel Results. The results from the optimum calibrated model for Crandall Canyon Mine are shown in Figure 54 and Figure 55. In these figures, “cooler” colors (green and blue) correspond to safety factors greater than 1.0. “Hotter” colors (yellow, orange, and red) correspond to safety factors less than 1.0 and, therefore, represent pillar failure. It is important to note that LaModel does not calculate any of the details of the coal or overburden failure mechanics. Since the program does not have any dynamic capabilities, it cannot distinguish between a gentle controlled pillar failure and a violent pillar burst. However, coal that bursts must be at, or very near, its ultimate strength at the time of the burst; therefore, it is reasonable in bump prone ground to associate the point of coal failure in LaModel simulations with coal bursts.

In Figure 54A, model results correlate reasonably well with conditions observed after the March 2007 bursts. For example, failure in the North Barrier section correlates well with observed damage. In this illustration, only one pillar appears to have failed in the Main West at the time of the burst. Figure 54B shows the development and retreat to crosscut 142 of the South Barrier section. In this illustration, safety factors for pillars in the South Barrier section remain above 1.0, although 42 pillars have failed in the Main West. Figure 55 demonstrates the catastrophic pillar failure propagation consistent with the August 6 collapse. In this simulation, 106 additional pillars fail in the Main West and 59 pillars fail in the South Barrier section. The failed area extends from crosscut 123 in the South Barrier section inby to crosscut 146 in the bleeder area. This optimum model simulates most of the critical observations of ground behavior at the Crandall Canyon Mine reasonably well.

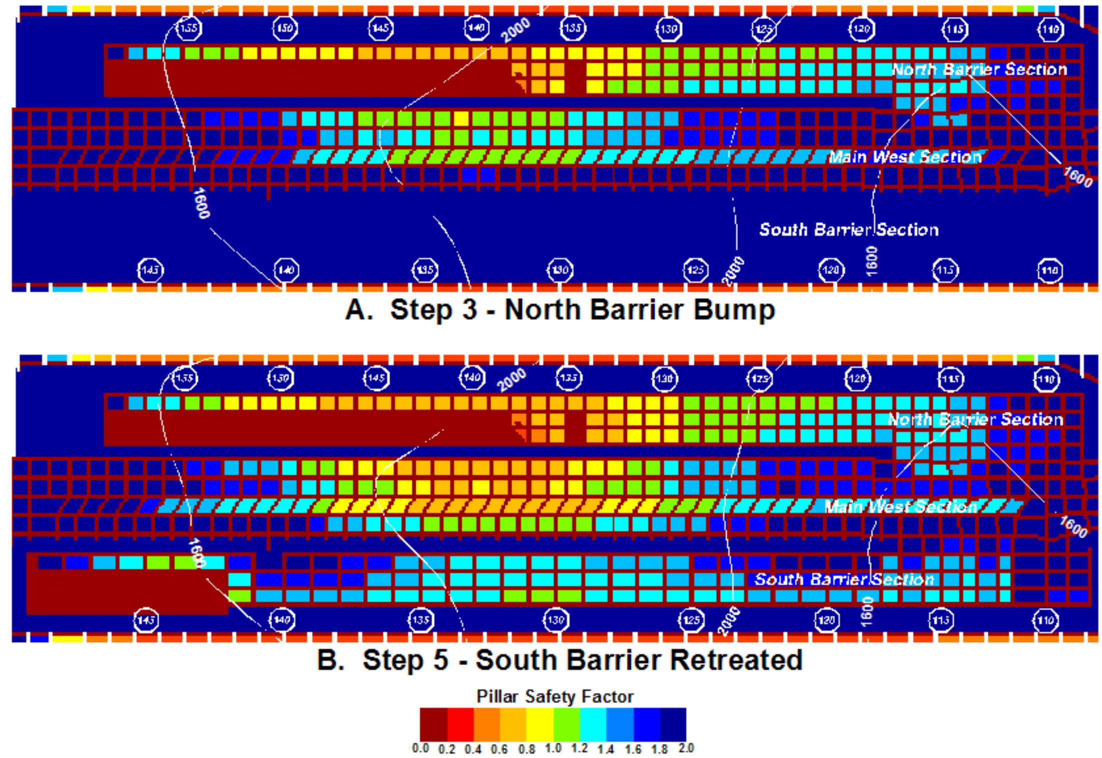


Figure 54 - Optimum Model Before and After South Barrier Section Mining

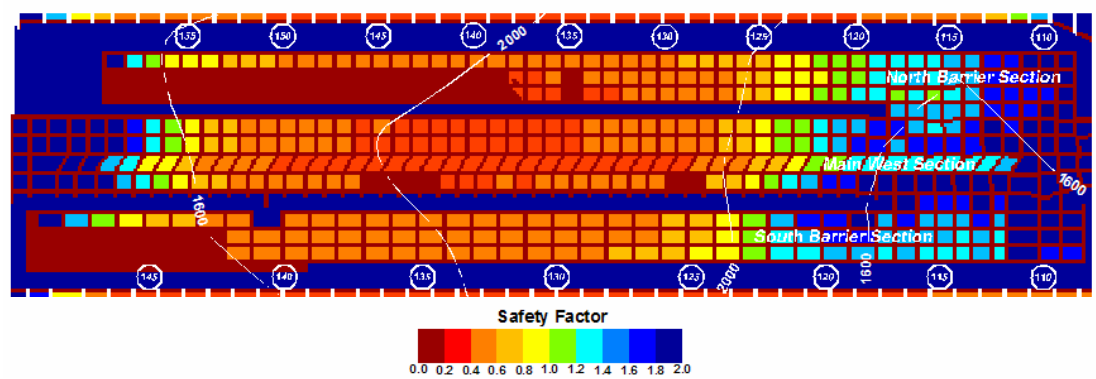


Figure 55 - Optimum Model after August 6 Failure

In all of these models, once the coal strength was calibrated to the March 10, 2007, North Barrier section outburst, results indicate that the pillars in the Main West were also close to failure. Once the South Barrier was subsequently developed, the model showed that it was very likely for the entire Main West and South Barrier entries to collapse upon the South Barrier development, or just a small perturbation was needed to initiate the collapse.

Modeling demonstrates that several actions could have triggered the collapse. Results demonstrate that if material properties and loading conditions are exactly uniform throughout the Main West area, then some stimulus is required to trigger the event with the mine configuration present on August 6. In the simulation depicted in Figure 55, for example, six pillars within the sealed area in Main West were simulated as having been mined and replaced with gob material to act as a triggering mechanism. This action simulates the possibility that isolated pillar failures (e.g., due to degradation over time and in the presence of abutment stress) initiated a collapse which swept through the Main West pillars and down through the South Barrier section.

Similarly, a sudden change in stresses due to slip along a joint in the roof within the collapse area could have been a factor in triggering the collapse. Model results also indicate that if the properties and loading conditions are not uniform (a reasonable geologic assumption), the event may have been triggered by pillar recovery in the active mining section.

Conclusions. An extensive back-analysis of events at Crandall Canyon Mine using the LaModel program suggests that the August 6 collapse resulted from the failure of a large area of similar size pillars. Pillars in the North Barrier section and Main West are nearly the same size and strength. Also, the barrier pillars between the Main West and the North and South Barrier sections have a comparable strength (within 15%) to the pillars in the Main West and barrier sections. The pillars in the South Barrier section were stronger than the pillars in the North Barrier section and Main West, but only by about 16%. Once a failure initiated, the surrounding similar strength pillars were likely to fail in domino fashion.

An imminent failure situation was created when pillars adequately sized for development mining were subjected to additional stress associated with retreat mining (longwall and pillar recovery). Development pillar safety factors below 1.4 indicate that high overburden (approximately 2,200 feet) caused considerable development stress on the pillars in the middle of the Main West, North Barrier, and South Barrier sections. Abutment stresses associated with longwall mining north and south of the Main West contributed to even lower safety factors. Overall, the area was primed for collapse because equal size pillars in a large area were already near failure.

Boundary element modeling alone cannot distinguish between the factors or combination of factors that may have triggered the August 6 collapse. If conditions are assumed to be exactly uniform throughout the Main West area, modeling suggests that some stimulus such as pillar degradation in the sealed area or joint slip in the collapse area was required to trigger the collapse. However, the modeling also demonstrates that if material properties or loading conditions are not uniform, then the active mining may have triggered the collapse.

Initially, Dr. Heasley modeled the Main West using coal and gob with identical properties. However, with this approach, he noted that the pillars in the Main West seemed to fail too soon (or too easy) while the pillars in the South Barrier section seemed to resist failure. Results were determined to be more consistent with known conditions when coal properties and applied load (adjusted through changes in gob property) were not uniform in the model.

Boundary Element Analyses of GRI Mining

Separate boundary element analyses were conducted by MSHA as part of the accident investigation in order to gauge the effects of three separate actions taken by GRI in the South Barrier:

- The barrier between crosscut 139 and 142 was mined even though this activity was prohibited by the approved roof control plan.
- Bottom coal was mined from pillars and the barrier even though this activity was not addressed in the approved roof control plan.
- The widths of the barrier pillars north and south of the South Barrier section were inconsistent with the widths evaluated by AAI.

Each of these actions had implications on ground stability during the development and recovery of pillars in the South Barrier section. BEM models were used to assess the degree to which GRI's actions may have contributed to the August 6 accident. Dr. Heasley's calibrated model was used as the basis for each analysis but some modifications were required to generate data for comparison (e.g., grids were changed to reflect conditions with and without barrier mining). Modifications required for the three analyses are discussed individually in the following sections.

Effect of Barrier Mining. Dr. Heasley's boundary element model was developed using the best available information to back-analyze the August 6, 2007, accident. In this model, the barrier pillar south of the No. 1 entry was considered to have been mined by taking 40-foot deep cuts between crosscuts 139 and 142. The accident investigation team modified Dr. Heasley's model by incorporating an additional model step. This step simulated a condition in which the barrier was not mined in this area and provided a basis for comparison of model results (i.e., with and without barrier mining).

The impact of barrier mining was evaluated by observing the distribution of vertical stress in the vicinity of the August 6 mining location. Vertical stresses were determined for the section before and after mining the barrier (see Figure 56). As discussed in the Main West Ground Control History section of this report, eight pillars and the adjacent barrier between crosscuts 139 and 142 were to remain unmined to protect the bleeder entry where it jogged around a sump in the Main West workings. The pillars were not mined but the barrier to the south was mined. Model results indicate that stress levels increased substantially in the pillars adjacent to the sump and were highest in the remnant barrier near the location where the South Barrier section crew was working at the time of the August 6 accident. These stress levels are similar in magnitude to those in the remnant barrier pillar inby crosscut 142 before barrier mining.

Stress redistribution associated with barrier mining occurred over a relatively broad area but diminished with distance from the extracted area. Vertical stress changes throughout the model can be determined by subtracting model results in the grid representing an intact barrier (Figure 56, top) from those in the grid that includes barrier mining (Figure 56, bottom). Negative values reflect stress decreases that result from either element removal (i.e., simulated mining) or yielding. Positive values represent stress increases.

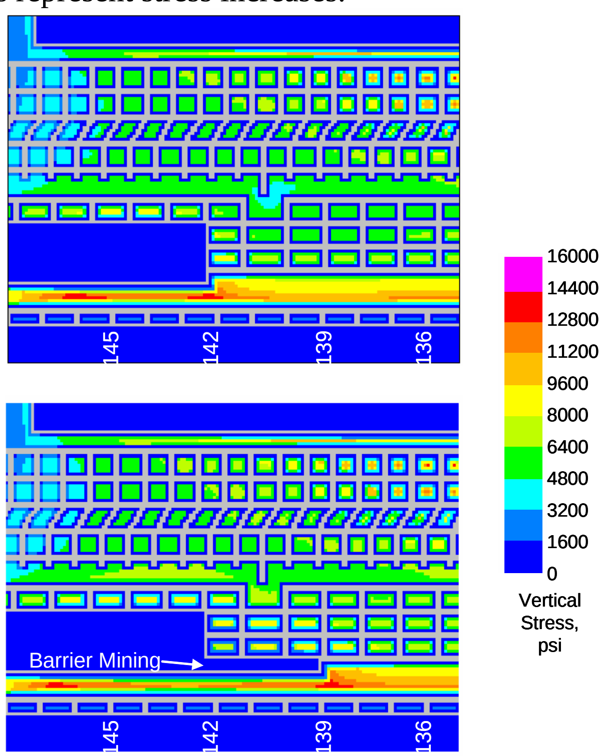


Figure 56 - Distribution of Vertical Stress in the South Barrier Section

The magnitude and distribution of increased vertical stress in the vicinity of the Main West sump are illustrated in Figure 57. Model results indicate that the highest increases (over 4,000 psi) occurred in the remnant barrier and adjacent pillars and decreased substantially within a relatively short distance. Stress increased in the Main West and outby in the South Barrier. However, it is important to note that the vertical stress scale in Figure 57 has been expanded in the interval from 0 to 500 psi to provide more detail in this range. Modeled stress increase was less than 200 psi within five crosscuts (~500 feet) of crosscut 139. Also, it should be noted that these values represent increases in individual elements rather than in average pillar stress.

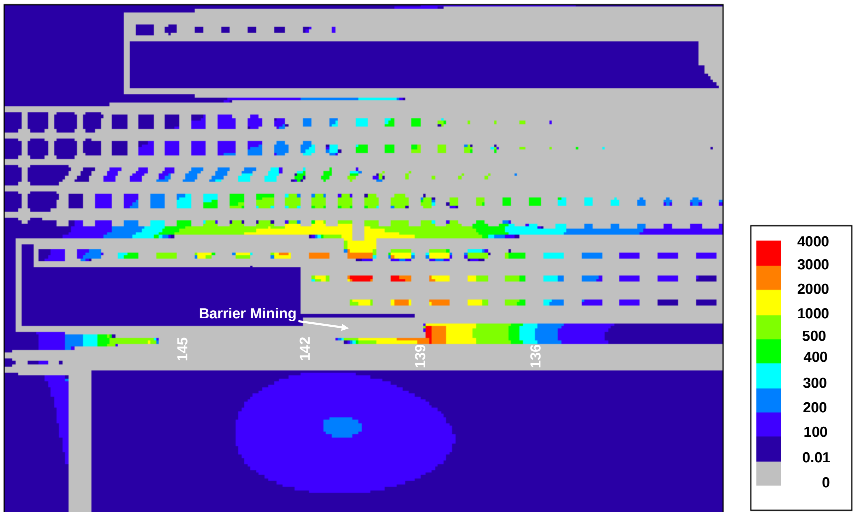


Figure 57 - Vertical Stress Increases due to Barrier Mining

As illustrated in Figure 58, average pillar stress decreased in the pillars immediately adjacent to the barrier mining. However, pillar yielding that caused these decreases contributed to load transfer and increased stress levels in adjacent pillars. Stress increases were largest in the vicinity of the bleeder entry. For example, model results indicate that vertical stress increased by 24% in a portion of the barrier adjacent to the Main West sump. The approved roof control plan excluded mining the barrier between crosscut 139 and 142 explicitly to protect the bleeder entry in this area. Model results indicate that mining in this area likely jeopardized the stability of the bleeder system inby crosscut 139. This activity also increased stress levels in the remnant barrier and pillars near the location where the South Barrier section crew was working at the time of the August 6 accident.

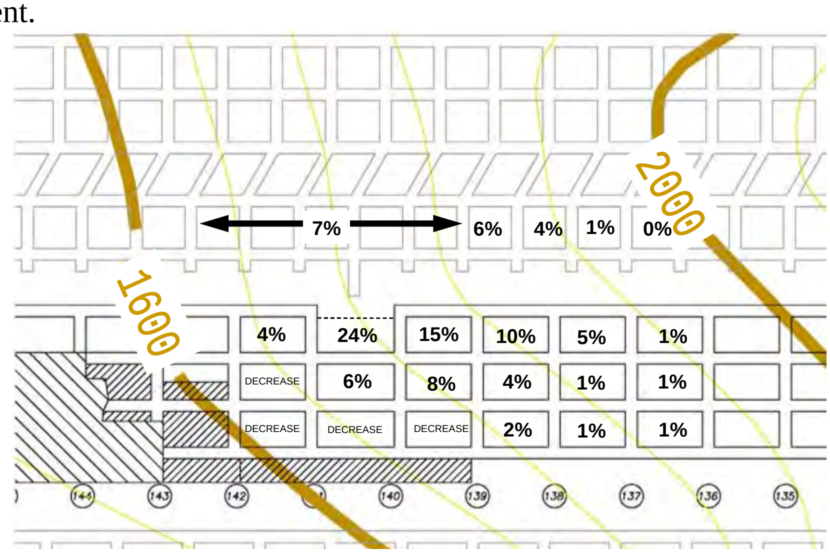


Figure 58 - Effect of Barrier Mining on Average Pillar Stress

Steps were added to Dr. Heasley's model to simulate the planned pillar recovery outby crosscut 139 (with the barrier intact between crosscuts 139 and 142). Pillar safety factors associated with pillar extraction in the rows between crosscuts 139 and 136 are shown in Figure 59. These results indicate that even if the barrier had not been mined between crosscuts 139 and 142, pillars in the South Barrier section likely would have failed if pillar mining continued in the next several pillar rows. After one row of pillars is recovered, pillar SF's are still above 1.0 as indicated by the blue and green colors in Figure 59A. When the next row of pillars is recovered (Figure 59B), failure occurs near the pillar line (yellow and orange) and with recovery of the third row, failure propagates outby over a broad area as indicated by the red and orange colors in Figure 59C.

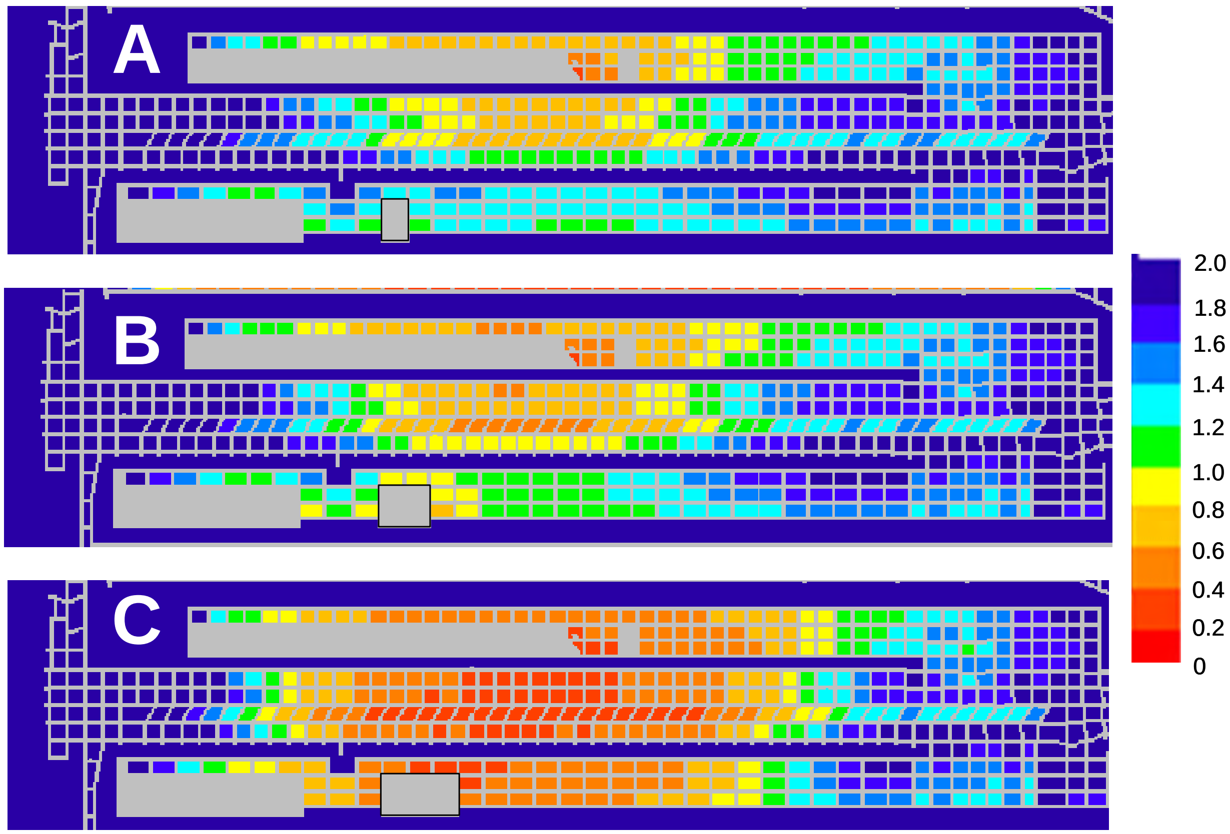


Figure 59 - Pillar Safety Factors for Pillar Recovery Outby Crosscut 139

Effect of Bottom Mining. Dr. Heasley's boundary element model was also modified to evaluate the effects of bottom mining during pillar recovery inby crosscut 139 in the South Barrier section. Bottom mining refers to the recovery of coal that remains in the floor after development mining particularly in thick seams. In the western area of the South Barrier section, up to 5 feet or more of bottom coal remained after development. The continuous mining machine ramped into the floor to remove this coal as pillars and barriers were recovered, even though this had not been considered by AAI in the mine design. Bottom coal was not removed from the entries and crosscuts, except when grading heaved bottom to maintain clearance for mining equipment.

Bottom mining creates taller pillars, which are generally weaker than shorter pillars of the same length and width. In the South Barrier section, the affected areas were the remnant pillars and the 80-foot wide remnant barrier labeled A and B, respectively, in Figure 60. Bottom mining in the pillars affected pillar stability as mining proceeded within each row. However, once a row was completed, this effect was negated as the roof was intended to collapse after mining was completed.

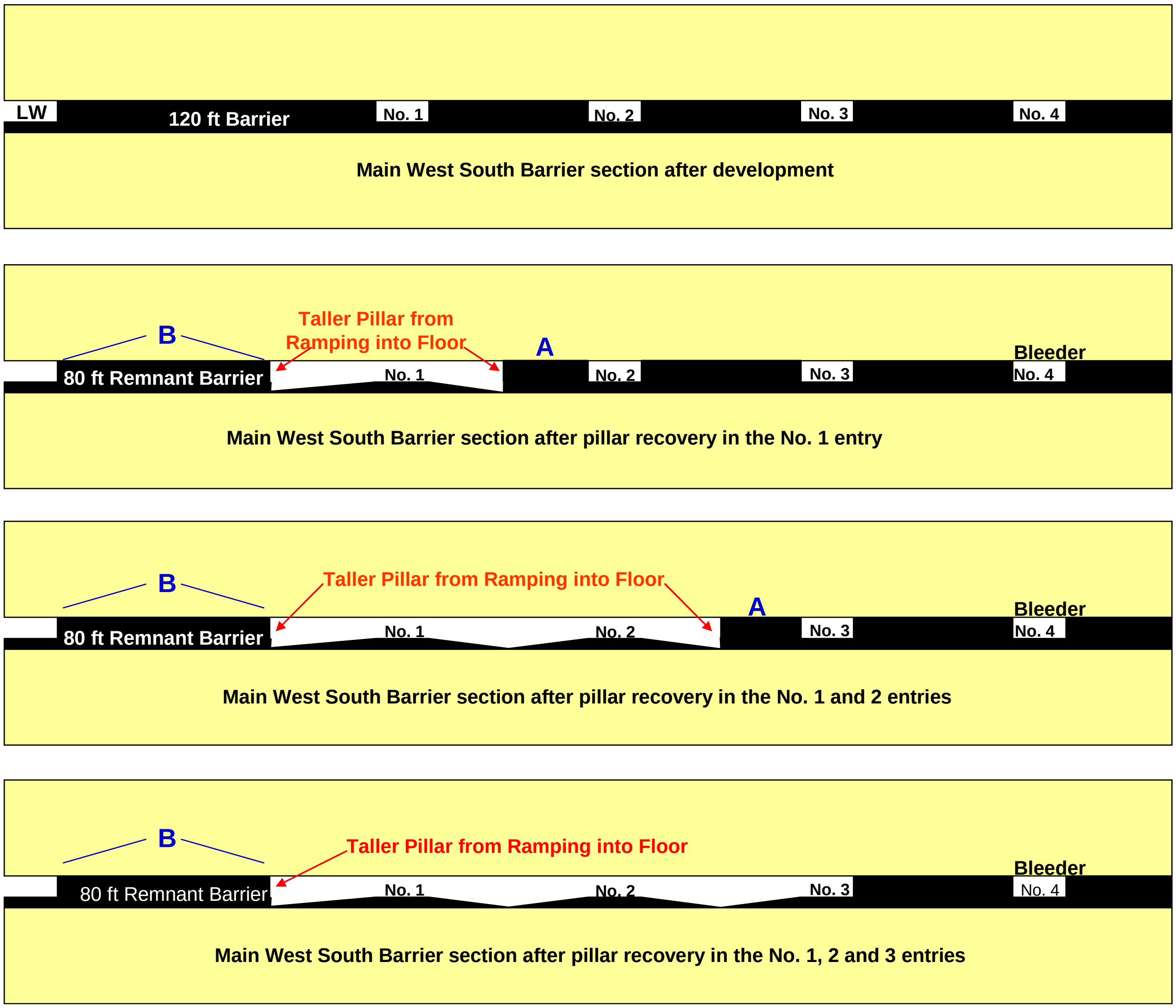


Figure 60 - Cross-Section through South Barrier Section during Pillar Recovery

As illustrated in Figure 61, the partial pillar between No. 1 and No. 2 entry separates the mining crew from the caved area. The stability of the work area relies largely on the stability of the partial pillar, particularly as mining progresses outby to the intersection. Bottom mining on the gob side of this pillar increases the pillar height and effectively reduces its strength. A similar situation occurs when mining moves to the No. 3 entry. Thus, bottom mining can impact local stability even though the pillars are intentionally being reduced in size and the roof is expected to collapse. Also, bottom mining adjacent to the remnant barrier weakened the remnant barrier inby the pillar line and contributed to overall instability of the section as it retreated.

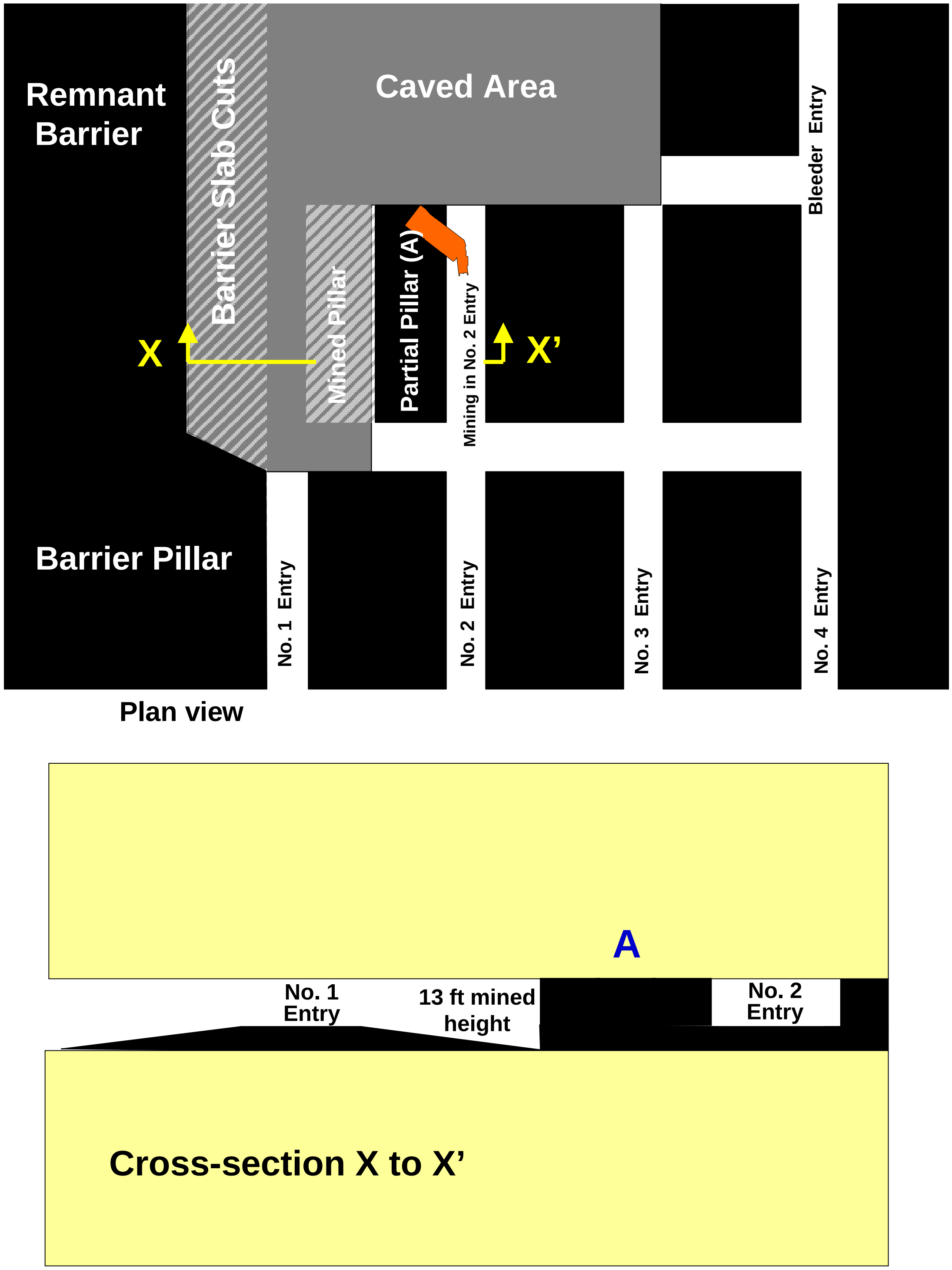


Figure 61 - Effect of Bottom Mining on Pillar Geometry
(e.g. inby crosscut 142)

Dr. Heasley’s model was modified to evaluate the impact of bottom mining. As illustrated in Figure 62, one half of the remnant barrier was modeled using coal properties developed for a mining height of 8 feet, while the other half used a weaker coal strength and lower stiffness based on a mining height of 13 feet. Simulations with and without bottom mining were compared to measure the relative impact of the activity.

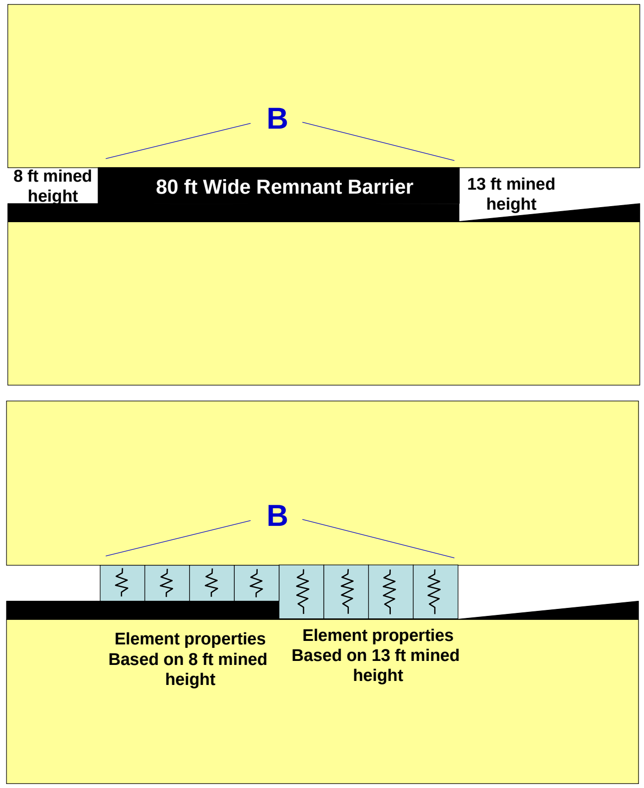


Figure 62 - Model Representation of Bottom Mining in the Remnant Barrier

The impact of bottom mining in the barrier was evaluated by assessing vertical stress levels and element safety factors in the vicinity of the August 6 mining location. The distributions of vertical stress with and without bottom mining are presented in Figure 63.

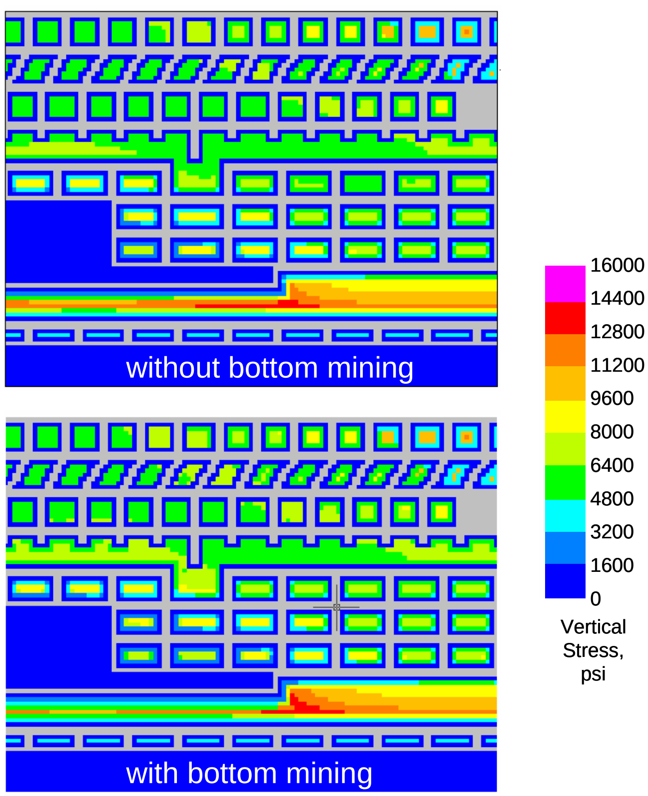


Figure 63 - Distribution of Vertical Stress in the South Barrier Section

Although there are subtle differences over a broad area, the primary impact of bottom mining is seen in the remnant barrier. The core of the 80-foot wide remnant barrier has a higher peak and residual strength (Figure 63 top) when bottom mining is not conducted. With bottom mining, load that otherwise may have been supported by the barrier is redistributed to other elements. Stress redistribution was examined by subtracting model results in the two model grids shown in Figure 63. Negative values reflect stress decreases that result from lower element strength and/or yielding. Positive values represent stress increases. Since no additional mining was simulated, decreases between the models demonstrate the stress redistribution between elements. In effect, Figure 64 shows where stress increased and decreased as a result of bottom mining.

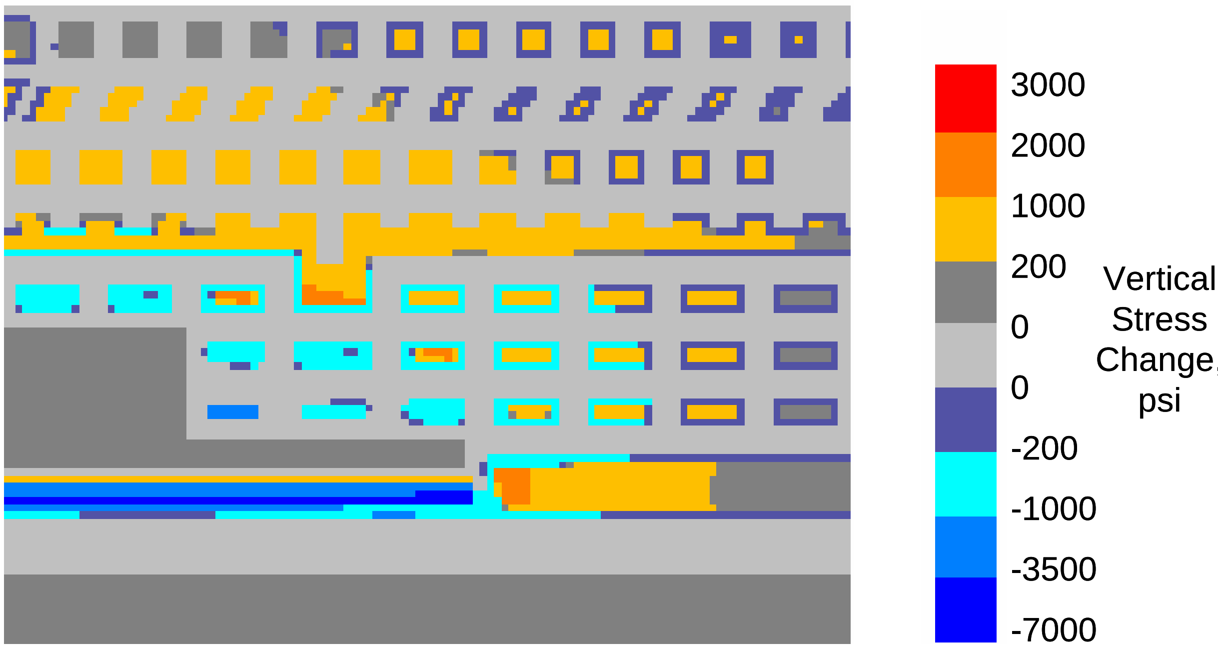


Figure 64 - Differences in Vertical Stress due to Bottom Mining

The element safety factors from the model results indicate that the remnant barrier would have failed even if the bottom coal had not been mined (Figure 65). Element stability factors below 1.0 in Figure 65 indicate that the peak strength of elements was exceeded across the entire width of the barrier even though the modeled mining height was 8 feet. The primary effect of bottom mining inby the pillar line was to weaken an already undersized remnant barrier. Bottom mining in the barrier cuts between crosscuts 139 and 142 weakened the barrier near the last known location of the miners and, consequently, contributed to increased stress levels.

Variation in Barrier Width from Design to Implementation. The South Barrier section was developed with four entries on 80-foot centers and crosscuts on 130-foot centers. AAI had evaluated this pillar system using both ARMPS and LaModel. However, their analyses considered system stability with a 55-foot wide barrier north of the section and a 135-foot wide barrier to the south. When the South Barrier section was developed, barrier widths were actually 75 feet (55 feet minimum from the Main West notches) and 121 feet, respectively. Dr. Heasley's calibrated Crandall Canyon Mine model was modified and rerun to consider the effects of varying barrier widths. Since the model uses 10-foot wide elements, the "as designed" barriers were represented as being 60 and 140 feet wide to the north and south, respectively. The "as mined" model used 80 and 120-foot wide barriers to the north and south, respectively. With the exception of these grid modifications, the two models were identical to one another.

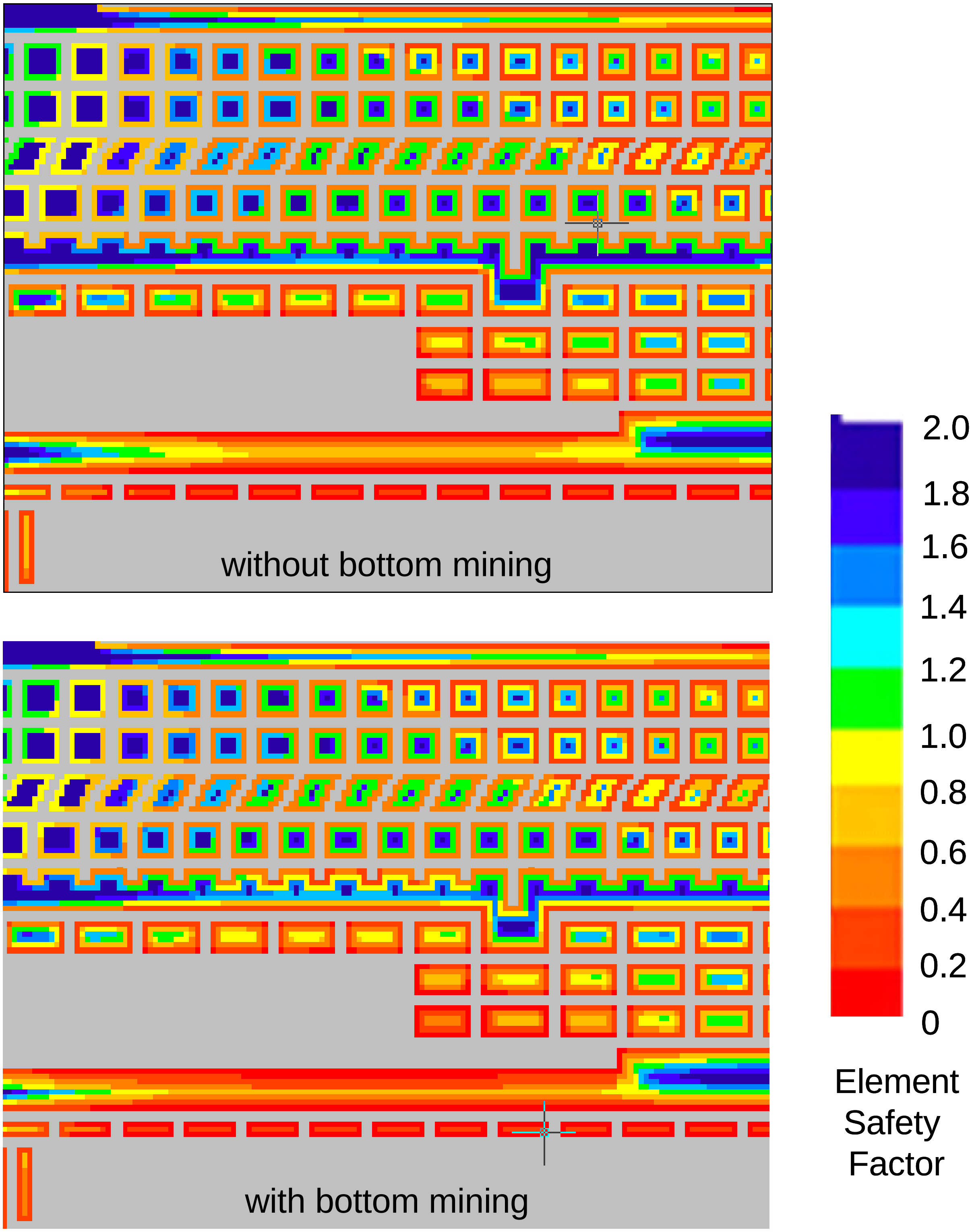


Figure 65 - Element Safety Factors

Figure 66 illustrates pillar safety factors calculated for the Main West region as it was actually developed and recovered prior to the August 6 accident. These model results are consistent with Dr. Heasley's results that show some pillar failure in the sealed portion of Main West but stable pillars in the section after development and after the pillar recovery prior to the August 6 accident. Although broad pillar failure can be triggered by one of several mechanisms, the model demonstrates a general reluctance for the Main West failure to propagate south past the

75-foot wide barrier pillar (modeled as 80 feet wide) and into the South Barrier Section. In contrast, when the north side barrier width is reduced to 55 feet (modeled as 60 feet), Main West pillar failure propagates southward into the section during development mining.

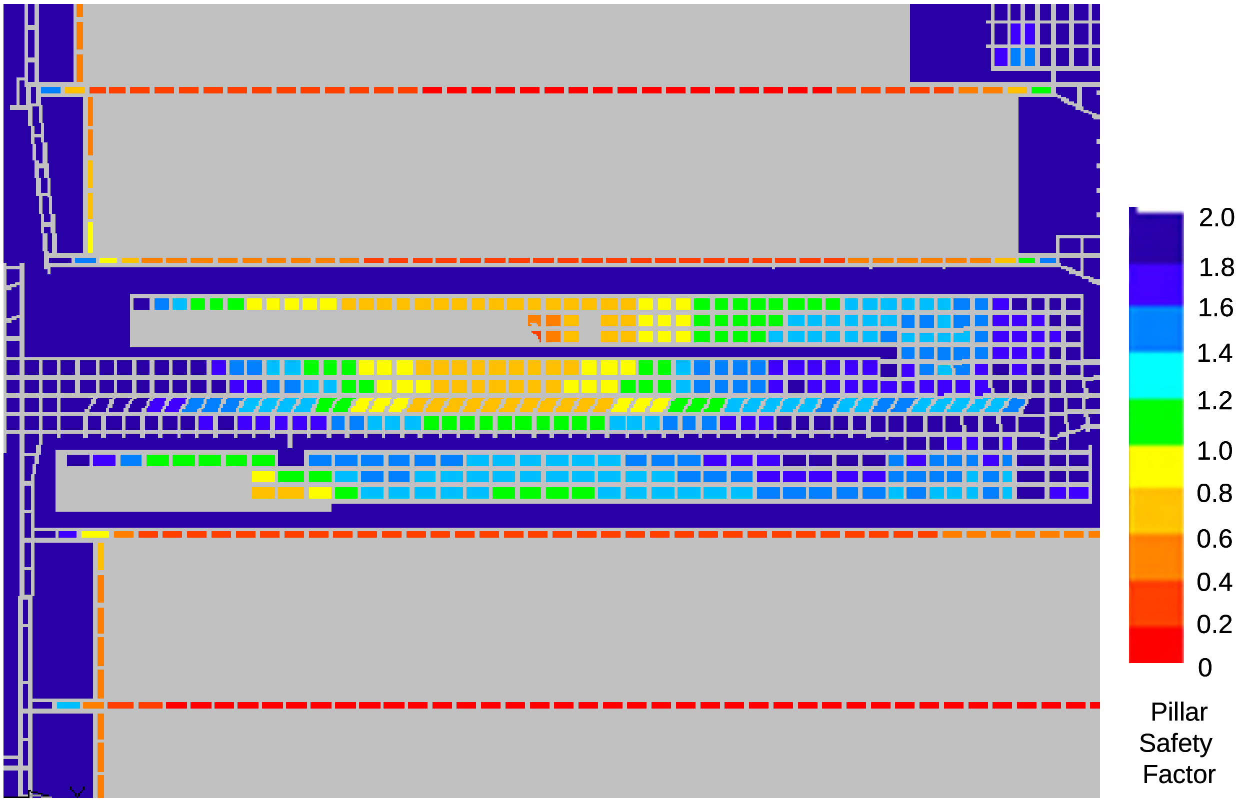


Figure 66 – Pillar Safety Factors Modeled with a 120-foot Southern Barrier

Figure 67 illustrates pillar safety factors for three model steps that represent development mining in the South Barrier section modeled with a 60-foot north side and a 140-foot south side barrier. In Figure 67A, pillars in the South Barrier section are stable as indicated by the blue colors. In Figure 67B, one additional crosscut has been developed. The South Barrier section remains stable but several additional pillar failures are noted in the Main West. In Figure 67C, another crosscut has been developed and failure is widespread throughout the South Barrier section as noted by the yellow and orange colors. A wider barrier south of the section (137-foot versus the 121-foot actually mined) may have decreased the likelihood of failure from Panel 13 longwall extraction abutment stress. However, model results suggest that pillar failure may have occurred in the section during development as a result of the corresponding reduction of barrier width to the north (55 feet initially planned versus 75 feet as mined measured outside the Main West notches).

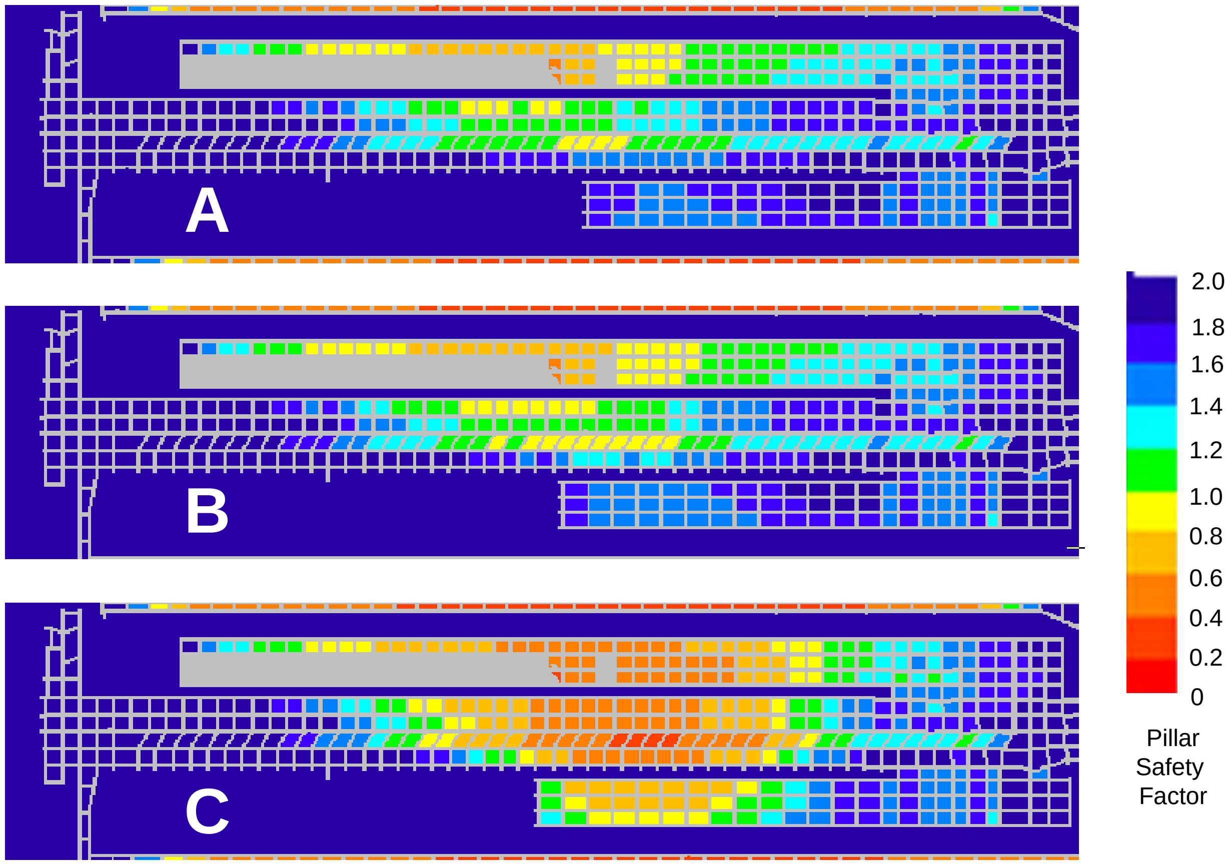


Figure 67 – Pillar Safety Factors Modeled with a 140-foot Southern Barrier for Development Mining

Skipping Pillars during South Barrier Retreat. After the March 10 non-injury coal outburst accident in the North Barrier section, AAI and the mine operator concluded that the method of mining in that area had contributed to the event. Pillar recovery had been discontinued at crosscut 137 and resumed outby between crosscuts 134 and 135 (i.e., pillars were "skipped"). When the March 10 accident occurred, several pillars had been removed outby crosscut 135 but good caving conditions had not been established. Hanging, cantilevered strata inby the new pillar line were thought to have caused additional loading on the surrounding pillars. Thus, AAI and GRI attributed the event in part to the operator's decision to reestablish the pillar line under deep cover and in the abutment zone of the original pillar line and, to a lesser extent, the abutment load from the Panel 12 longwall gob to the north. As a result, AAI cautioned against skipping pillars in the South Barrier.

Although the mine operator skipped pillars between crosscuts 139 and 142 in the South Barrier section, this decision did not contribute to the August 6 accident. The North Barrier section burst experience raised concerns with abutment stress as a pillar line was reestablished. However, the South Barrier section scenario is distinctly different and similar stress conditions were not present for several reasons:

- First, on August 6, a new pillar line had not yet been created. Mining was limited to the barrier pillar south of the No.1 entry; no pillars had been recovered. Thus, the amount of potentially cantilevered strata created by the barrier cuts and available to generate additional abutment load was minimal.

- Second, the August 6 mining location was about 400 feet outby the last South Barrier pillar line. At this distance, abutment stress from the active gob would also be minimal.
- Finally, overburden was 1,760 feet versus more than 2,000 feet in the area affected by the North Barrier outburst accident. AAI recommended against skipping pillars "*particularly under the deepest cover*." In February 2008, AAI indicated that *"the deepest cover"* could apply to the ridge crest over the area (2,000 to 2,200 feet) or may be interpreted more broadly (e.g., 1,800 to 1,900 ft). AAI stated that GRI did not seek clarification of this term.

The skipped pillars between crosscuts 139 and 142 in the South Barrier section did not cause or compound the pillar collapse that occurred on August 6. Conversely, these pillars likely reduced the severity of the event in the vicinity of the working section.

Summary - Analyses of Collapse

Three types of analyses were conducted to evaluate ground behavior at Crandall Canyon Mine. Although the approaches are substantially different, the results and conclusions are similar.

- ARMPS stability factors below NIOSH's recommended minimums do not necessarily ensure failure. However, stability factors for the North Barrier section were below recommended values and lower than any previous experience at the mine. GRI abandoned the North Barrier section due to difficult ground conditions and bursts, yet they employed a design with still lower stability factors in the South Barrier section.
- ARMPS is not directly capable of evaluating the exact geometry of the entire area affected by the August 6 collapse. However, if the effects of longwall mining are neglected entirely, ARMPS provides insight to overall Main West stability. This approach demonstrates that the Main West pillar stability is below NIOSH recommendations even without the additional influence of longwall abutment stress.
- Despite the use of optimistic input values (e.g., consideration of development mining only), FEM model results indicate the strong potential for a rapid catastrophic failure of the North and South Barrier sections and the Main West pillars between them.
- BEM analyses confirm that the Main West was vulnerable to wide-spread failure because a large area of pillars was developed with marginal safety factors and similar strength barrier pillars. Analyses indicate that one or more events or conditions may have been the trigger which actually initiated the pillar failure. However, model results are more consistent with known conditions at the accident site when coal properties and applied load (adjusted through changes in gob property) are not uniform in the model.

All of the analyses conducted as part of this accident investigation indicate that the mining plan employed to extract barriers on either side of the Main West was inadequate to maintain stability during pillar recovery. The design created a large area of similar sized and marginally stable pillars. When one pillar or group of pillars failed, the rest were destined to fail in domino fashion.

Seismic analyses and subsidence information developed in the accident investigation indicate that the collapse initiated near the South Barrier section pillar line and the greatest surface displacements were located 500 feet outby the last known location of the miners. These observations suggest that loading conditions were more extreme near the working face and provide further clarification that the collapse was most likely initiated by the mining activity.

Critique of Mine Design

The engineering analyses discussed in the previous sections demonstrate that the August 6, 2007, accident was caused by the rapid collapse of a large area of pillars. Overburden in excess of 2,000 feet and abutment stresses from adjacent mined-out longwall panels and active pillar recovery combined to create a high stress environment that the pillar system was incapable of supporting. Initially both GRI and MSHA recognized the potential for high stress. Although recent pillar recovery operations had been conducted in the South Mains without the assistance of a ground control consultant, GRI retained these services for the design of the North and South Barrier sections. Similarly, previous pillar recovery operations had been conducted at the mine under the existing roof control plan without the benefit of site-specific provisions. For the North and South Barrier sections, MSHA required such site-specific plans for both development and pillar recovery.

GRI implemented and MSHA approved a mine design based largely on the results of engineering analyses performed by AAI. These analyses used two of the approaches discussed in the previous section of this report, ARMPS and LaModel. AAI generated an overburden map for these analyses, which was determined to be accurate by comparing it to the overburden map independently generated by the MSHA accident investigation team. AAI's analyses concluded that proposed pillars should function adequately for short-term mining in the North Barrier. After this design failed, AAI modified the design. Their further analyses indicated that pillar dimensions proposed for South Barrier mining would "*provide a reliable level of protection against problematic bumping for retreat mining under cover reaching 2,200 feet*." However, pillar recovery operations had retreated beneath overburden of only about 1,640 feet at crosscut 142 (barrier slabbing to 1,760 feet at crosscut 139) when the August 6 collapse occurred.

While mining in the South Barrier section, GRI deviated from the design analyzed by AAI and the approved roof control plan (e.g., GRI mined bottom coal, varied the barrier pillar dimensions, and mined the barrier between crosscuts 139 and 142). These actions affected barrier pillar strength and pillar stress levels in the vicinity of the last known location of the miners. They were also part of the active pillar recovery operations the cumulative effect of which was the August 6 collapse. However, the Main West and adjacent North and South Barrier sections were primed for a catastrophic pillar failure independent of these activities because the mine design created a large area of equal size and marginally stable (near unity safety factors) pillars. This failure mechanism was not apparent in the results of some of the AAI analyses conducted prior to the accident because overly optimistic design assumptions and/or inappropriate input parameters or procedures were used. Other analyses were done properly but results indicative of failure were either misinterpreted or were not acted upon.

Previous Ground Control Studies at Crandall Canyon Mine

Prior to mining in the North and South Barrier sections, GRI contracted AAI to evaluate ground conditions and entry stability associated with GRI's plan for room and pillar mining in the barriers. AAI's proposal for this work indicated that "*Concern exists for potentially high stress conditions caused by a combination of deep cover and side-abutment loads from the adjacent longwall gobs, and, to a lesser extent, load transferred onto the barriers by time dependent pillar convergence in Main West.*" To evaluate these concerns, AAI elected to use a numerical model to assess vertical stress, convergence, and pillar yielding (see Appendix F).

GRI had used AAI's services on several occasions prior to the analysis of Main West. AAI had developed numerical models of ground behavior at Crandall Canyon Mine prior to 1996. These models were used to make preliminary evaluations of pillar design configurations, even though at that time model accuracy could not be verified.

Between June 1995 and January 1996, Neil & Associates (NAA) conducted field studies in the 6th Right yield-abutment longwall pillars at the mine. Subsequently, GRI contracted AAI to refine the model for Crandall Canyon Mine using the now available field data. AAI's calibration to the 6th Right data in 1997 improved their confidence in accurately representing ground behavior at the mine.

AAI developed the calibrated model of Crandall Canyon Mine ground behavior using a boundary element computer code called EXPAREA (see Appendix R). This software and the calibrated model were used in 2000 to evaluate the effect of barrier pillar width on future bleeder entry stability. The mine location modeled in this study (bleeder entries west of Panel 15) was less than 2,500 feet from the Main West South Barrier and several aspects of the study (e.g. evaluations of abutment load distribution) were relevant to the subsequent Main West South Barrier study (see Appendix E).

Barrier Pillar Design

In coal mining, the term barrier pillar refers to a block of coal left in place to isolate or protect mine structures from potentially harmful interactions. For example, barriers could be required to isolate workings in adjacent properties from one another or to separate active and abandoned workings within the same mine. In these contexts, barriers function primarily to prevent an influx of impounded water or gasses. However, in retreat mining applications (both pillar recovery and longwall), barrier pillars typically are used to protect mine workings from high vertical stress concentrations near the boundaries of extracted areas often referred to as gobs.

A variety of rules of thumb, mathematical formulas, and design methods have been developed to establish minimum widths of barrier pillars. A USBM publication[8] summarizes nine of these approaches and provides an overview of performance evaluation techniques that can be used to optimize barriers. Each of the nine formulas is included in Table 9 even though some of them were developed especially for water impoundment. The formula names indicated by bold font are applicable to barriers used in longwall and pillar recovery operations.

Table 9 also includes a minimum barrier width corresponding to each barrier design equation. Input parameters used to generate these results are pertinent to the Crandall Canyon Mine accident site. For example, an 8-foot mining height, 2,160 feet maximum overburden, and 800-foot panel width were used. A maximum convergence value of 3.7 inches was used in the Holland Convergence Method. Using the six bolded equations in Table 9, these parameters generate minimum barrier pillar widths ranging from 202 to 384 feet.

AAI had considered four of these equations in a 2000 project which evaluated the effects of barrier pillar widths on future bleeder entry stability for Panel 15, south of Main West (see Appendix E). Results of AAI's analyses in that study are illustrated in Figure 68[‡]. AAI stated that this figure "*gives a summary of recommended barrier pillar widths by various empirical*

[‡] Calculated values in Table 9 and Figure 68 are dissimilar because input values (e.g. mined height and overburden depth) vary between the two scenarios.

methods. The design widths shown here might be helpful as an additional source on which to base decisions. For a depth of 1000 ft, all the methods support a barrier pillar of 260 ft or less. At 1500 ft of cover, three of four methods suggest a barrier pillar of less than 260 ft." AAI refers to this work as an "*additional source*" since it was presented as confirmation of the conclusions drawn from numerical models.

Table 9 - Barrier Pillar Design Formulas

	Name	Formula	Barrier Width (ft) under 2,160 ft overburden
1	Dunn's Rule	$W = \frac{(D-180)}{20} + 15$	114
2	Old English Barrier Pillar Law	$W = \frac{(H \times T)}{100} + 5T$	212
3	**Pennsylvania Mine Inspector's Formula**	$W = 20 + 4T + 0.1D$	**268**
4	Ash and Eaton Impoundment Formula	$W = 50 + 0.426D$	970
5	**Pressure Arch Method**	$W \rangle A = 3\left(\frac{D}{20} + 20\right)$	**384**
6	**British Coal Rule of Thumb**	$W = \left(\frac{D}{10}\right) + 45$	**261**
7	**North American Method**	$W = \frac{(D \times P)}{7000 - D}$	**357**
8	**Holland Rule of Thumb**	$W = \frac{D}{22.2} + 105$	**202**
9	**Holland Convergence Method**	$W = \frac{5(\log 50.8C)}{(E \log e)} + 15$	**290**

where:
W = barrier pillar width, ft
D = depth of mining (or height of hydrostatic head in #3 above), ft
H = hydrostatic head or depth below drainage (ft)
T = coal seam thickness (ft)
A = minimum width of the maximum pressure arch, ft
P = width of adjacent panel, ft
C = estimated convergence on high-stress side of barrier pillar, in
E = coefficient of extraction adjacent to barrier (E = 0.09 for complete caving)

AAI used numerical models in their 2006 studies of Main West barrier development and pillar recovery. Despite the relatively close proximity and similar study objectives, results of the 2000 and 2006 model studies differ substantially. These numerical analyses will be discussed in detail in a later section of this report. The 2006 results also conflict with output from the empirical formulas in Table 9. Unlike, the 2000 study, AAI did not use barrier pillar formulas to confirm the 2006 model results. One of a series of written questions posed to AAI during the accident investigation addressed the use of barrier pillar equations:

> *AAI designed barriers for longwall panels at Crandall Canyon and it appears that several methods were used to estimate barrier widths (North American method, Holland Rule of Thumb, Holland Convergence method, PA Mine Inspectors formula). How were these formulas considered when evaluating mining in the existing barriers or why were they not considered?*

AAI responded, "*These methods are limited to cover less than 2,000 ft.*"

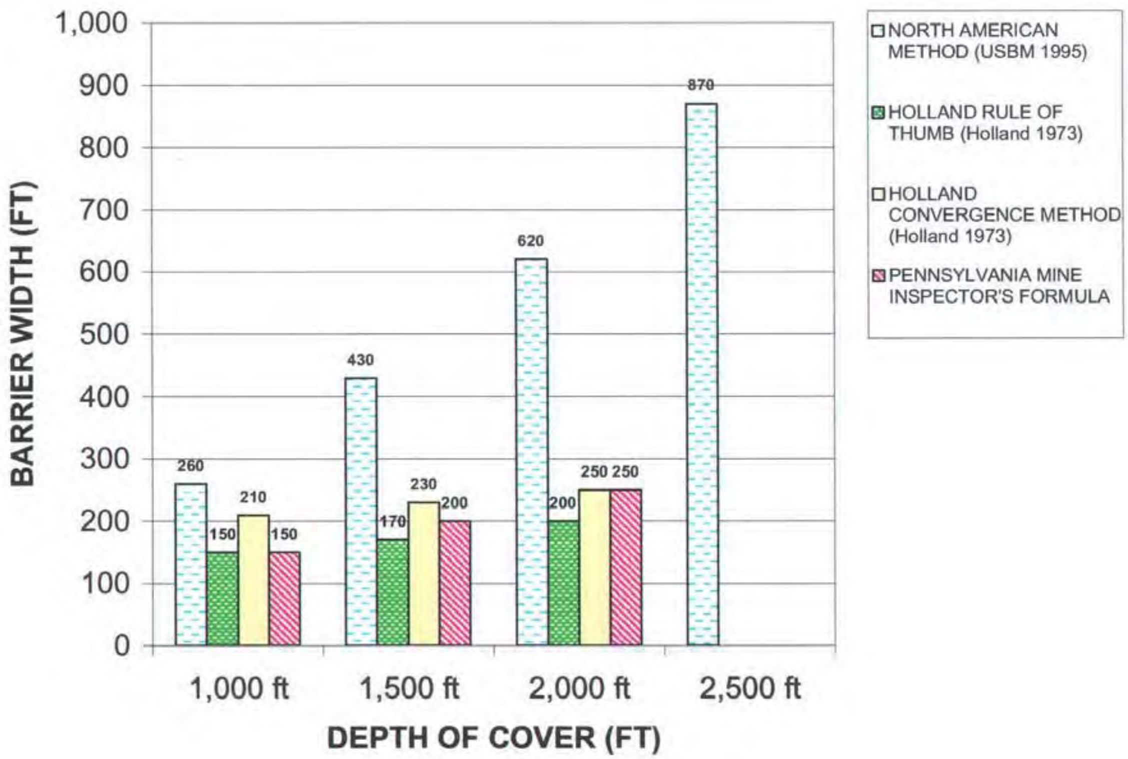


Figure 68 - Barrier Pillar Sizes from Empirical Methods
Figure 4 in AAI's May 5, 2000, Report

As indicated in Figure 68, AAI had previously used the North American method to determine barrier width in overburden depths up to 2,500 feet. This method is the only one of the four that accounts for the width of the adjacent panel in determining the barrier width. AAI's results in Figure 68 were based on using two longwall panel widths (~1,560 feet) and, even at lower depths of cover, this method recommends wider barrier widths than the other three methods. This is a reasonable assumption, given the caving characteristics of strata in the Wasatch Plateau (i.e., maximum subsidence may not be achieved with the extraction of a single panel – see Appendix L). However, if one panel width is used (~800 feet), the calculated barrier widths are much more consistent with the other methods (i.e., 130 feet wide at 1,000 feet of overburden, 210 feet wide at 1,500 feet of overburden, 310 feet wide at 2,000 feet of overburden, and 430 feet wide at 2,500 feet of overburden). As indicated in Table 9, the recommended barrier width using this approach is 357 feet for 2,160 feet of overburden (the depth at which pillar recovery was abandoned in the North Barrier section). Although this approach generates a narrower barrier width than what AAI had calculated in 2000, the recommended width is still nearly three times larger than the 130-foot width determined through numerical modeling in AAI's 2006 studies.

Also, the 130-foot dimension is approximately half the width that the barrier design equations would recommend for a depth of 2,000 feet. This is significant since about 25% of the Main West North and South Barriers have overburden exceeding 2,000 feet. Whereas the numerical model results for barrier design in the May 2000 study were consistent with empirical design equations, the 2006 results were not.

AAI did not consider the empirical equations in 2006 because they considered them less relevant to the North and South Barrier mining scenarios. Similarly, they discounted the relevance of the May 2000 study since it addressed barriers to protect a two-entry bleeder system (i.e., to limit the effects of longwall mining-induced stresses) rather than a pillar recovery section. However, a comparison to either of these results would have indicated that AAI's 2006 model results were flawed. AAI's report on the 2000 barrier design project concludes that "*To minimize any potential for stress overloading resulting from panel mining, or to minimize maintenance and to provide long term stability (greater than three years), a barrier pillar of 400 ft would be required*." Regardless of the relevance of the scenario, this conclusion contradicts the 2006 conclusion that "*For the current geometry, stress levels taper to near pre-mining (in situ) stress levels approximately 100 ft into the barrier, indicating that the proposed 130-ft-wide barrier will limit exposure of the planned entries and pillars to most of the abutment*."

Abutment stresses are transferred from extracted areas to adjacent workings (see Figure 35). The stresses are highest near pillared areas (referred to as "gob") and diminish with distance. Rules of thumb used to estimate abutment stress transfer distance are discussed in Appendix T. However, longer transfer distances have been observed in some mines in the Wasatch Plateau. In a paper titled "*Long load transfer distances at the Deer Creek Mine*," Goodrich et al.[9] wrote:

> *Load transfer distances at the Deer Creek mine (including other mines in the Wasatch and Book Cliff Coal Fields) have been generally greater than predicted using empirical design methods (Koehler & Tadolini 1995[8], Abel 1988[10], Barrientos & Parker 1974[11]). The long load transfer distances observed in the case of the 5th and 4th West panels is believed to be due to the strong and stiff sandstone/siltstone strata in the overburden, including the Upper Blackhawk strata and the Castlegate Sandstone."*

Similar long abutment stress transfer distances are implicit in a discussion of barrier sizing in a paper titled "*Interpanel Barriers for Deep Western U.S. Longwall Mining*[12]." Although numerical models described in the paper address a longwall mining scenario, they demonstrate that wide barriers (e.g., 390 feet wide at depths of 2,600 feet) are required between panels to minimize abutment stress override. Cantilevered or overhanging strata are typically associated with high abutment stresses. The authors state that "*Overhanging is likely in the Wasatch Plateau-Book Cliffs coal fields given the abundance of massive overburden strata, such as the Castlegate Sandstone*."

The authors or coauthors of each of the aforementioned papers were employees of AAI when the papers were written. Since the Upper Blackhawk and Castlegate sandstone units (see Figure 23) discussed in these papers are present at Crandall Canyon Mine, AAI's institutional knowledge should have indicated that the short abutment load transfer distance from the model results was not accurate. Similarly, since interpanel barriers are used at another UEI mine in the area, GRI also had pertinent institutional knowledge.

Agapito Associates, Inc. Analyses
AAI used LaModel to analyze room and pillar workings in the North Barrier section. The initial analyses focused on development mining in the area and calibration of the model to historical conditions in the 1st North pillar panels, which were developed in a herringbone pattern and retreated using a continuous haulage system. Results of this work were reported in a July 20, 2006, draft letter report to Laine Adair (see Appendix F). AAI concluded that the section design should function adequately for short-term mining in the barriers. Model results indicated that side-abutment stress from the adjacent longwall would be limited in extent (about 130 feet) and, thus, stress conditions would be controlled by the depth of cover and not by abutment loads.

AAI subsequently was contracted to do additional LaModel analyses to evaluate pillar recovery in the North Barrier section. These results were reported in an email dated August 9, 2006, from Leo Gilbride to Laine Adair (see Appendix G). In this instance, ARMPS was used to supplement the LaModel analysis. AAI reported that "*Conclusions from LAMODEL corroborate the ARMPS results, principally that convergence can be adequately controlled with the proposed mine plan and that ground conditions should be generally good on retreat in the barriers, even under the deepest cover (2,200 ft).*"

AAI concluded that the ground conditions they observed on December 1, 2006, agreed with their analytical predictions (i.e., LaModel results). However, the predictions themselves were inaccurate and misleading. Both the LaModel and ARMPS analyses used either inappropriate input values or an overly optimistic design approach that negatively affected the reliability of the results, as discussed below.

Boundary Element Modeling. The July 20, 2006, report prepared by AAI describes the procedures used to develop a numerical model for mining in the North Barrier section. The report also includes two tables that list input parameters that were used in the final, "calibrated" model. The first table lists coal material properties developed using equations included in the report. The second table lists additional parameters that reportedly were "*based principally on previous modeling studies for the Crandall Canyon Mine.*" However, examination of the actual LaModel input files demonstrates that many of the input parameters were much different than those shown in the report and were not consistent with those used in previous Crandall Canyon Mine models.

Coal Properties. AAI used both strain softening and elastic coal properties in their Crandall Canyon Mine models. Strain softening implies that an element of coal will carry increasing loads up to a peak value before it then fails. At failure, the element loses strength and, subsequently, it is only able to carry a lesser, "residual," load. The methodology for using strain softening properties described in AAI's July 20 report is very similar to that used by MSHA Technical Support (see Appendix U). The methodology assumes that elements farther away from an entry will fail at progressively higher peak loads and also maintain higher residual loads. This approach is based largely on the premise that coal strength increases with lateral confinement and lateral confinement increases with distance from the pillar edge.

Traditionally, the effect of confinement on pillar strength has been incorporated into BEM models by representing an individual pillar as a series of concentric rings (Figure 69A). Letter codes are used to represent various material properties and the codes are deployed such that material strength increases toward the pillar center. In reality, pillar corners experience less confinement and, consequently, have lower peak strengths. The LaModel preprocessing program, LamPre, offers a utility to calculate coal properties to account for the weakening at pillar corners and another to deploy them (automatic yield zone application) as illustrated in Figure 69B. The preprocessor provides a user-friendly interface to facilitate the construction of model grids; letter codes (material properties) can be arranged manually in any configuration. The automatic yield zone application available in LamPre provides a convenient means of distributing codes as illustrated in Figure 69B. However, the material properties assigned to the letter codes must be determined specifically for this configuration (i.e., they must be calculated to represent side and corner elements).

AAI correctly calculated coal properties as indicated in their report using the methodology described in Appendix F. The results of these calculations are listed in Table 10. Each of the eight sets of values listed in Table 10 corresponds to coal strengths at successively deeper distances into the pillar on 5-foot intervals. The values were then entered manually into the LaModel preprocessor program, LamPre. These values are consistent with a model constructed as shown in Figure 69A. AAI entered the material properties manually and then used the automatic yield zone application to deploy them as shown in Figure 69B. As a result, the distribution of lettered elements used to represent the material properties was incorrect.

Table 10 - Coal Properties Calculated by AAI

LAMODEL input element classification	Distance into pillar, ft	Avg strength of each element, psi	Peak Strain	Residual Strength, psi	Residual Strain
I	2.5	2059	0.004	425	0.017
H	7.5	3845	0.008	1746	0.032
G	12.5	5631	0.012	3206	0.047
F	17.5	7417	0.016	4785	0.062
E	22.5	9203	0.019	6459	0.077
D	27.5	10989	0.023	8209	0.092
C	32.5	12775	0.027	10025	0.107
B	37.5	14562	0.031	11896	0.122

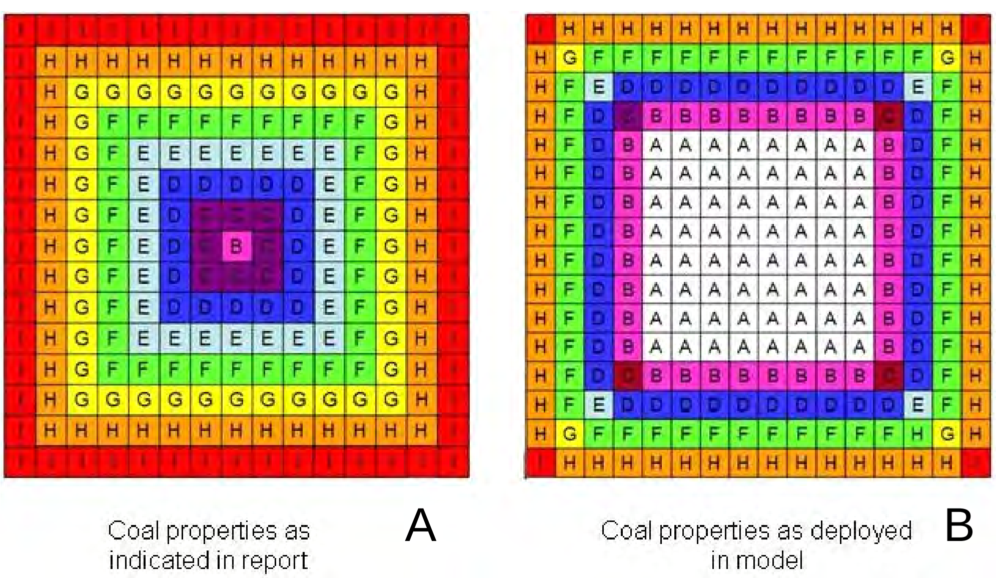


Figure 69 – Plan View of Pillars showing Coal Property Elements as Indicated in AAI Report vs. Those Actually Deployed in AAI Modeling

The significance of this error was that modeled pillars up to 40 feet wide appear to be much stronger than they actually are (approximately 60% greater peak strength and 160% greater residual strength). Furthermore, pillars over 40 feet wide contain elastic elements with no limit on their load carrying capability. Elastic elements are infinitely strong.

Elastic elements are used routinely in boundary element models. However, Karabin and Evanto pointed out in a 1999 publication[13], "*Known or potentially yielding pillars should not contain linear-elastic elements which could erroneously affect the stress transfer to adjacent areas*." The implication of using elastic elements in the Crandall Canyon Mine model was that the cores of modeled pillars in the North and South Barrier sections and in the sealed portion of the Main West entries would never fail regardless of the applied load. Elastic conditions (unlimited strength) is inconsistent with the known conditions discussed in AAI's May 3, 2006, project proposal for the Main West Barrier mining study, which stated that *"time-dependent pillar convergence existed in the sealed portion of the Main West."* The model, as constructed with the associated rock mass and gob properties, was incapable of demonstrating pillar failure, subsequent yielding, and stress transfer (domino failure) over a broad area.

Rock Mass Properties. One significant difference between EXPAREA, the program originally used to develop a calibrated Crandall Canyon Mine model, (see Appendix R) and LaModel relates to the representation of the rock above and below the seam (rock mass). In EXPAREA and most other boundary element models, the rock mass is comprised of a single (homogeneous elastic) unit of material. In LaModel, the rock mass is represented as a stack of layers piled atop one another. The layered formulation used in LaModel provides an additional parameter that can be adjusted to allow more flexible and realistic strata behavior. Rock mass behavior in this model is controlled by both the assigned material properties and layer thickness.

In selecting parameters for the laminated rock mass in LaModel, AAI evaluated two lamination thicknesses (25 and 50 feet). AAI concluded there was no difference between the two values and the smaller value was selected.

In his doctoral thesis, Dr. Heasley included equations that could be used to estimate properties that would equate the laminated strata behavior with the homogeneous rock mass used in other boundary element programs (see Appendix V). Equating the parameters used in the calibrated EXPAREA model to LaModel suggests that a 115-foot thickness would have been more appropriate than the 25-foot value that AAI used. The implication of using thin laminations is that the roof tends to sag readily into the mine openings and load the edges of the pillars. Conversely, the rock mass is less apt to span across openings or failing pillars and transfer loads over a longer distance.

Gob Properties. The last of the three critical components of a boundary element model is the gob. Gob properties are extremely important in these models because they influence the amount of abutment load transferred from a gob area to adjacent structures. However, there are few established guidelines for selecting them. In the absence of field data, modelers often rely on a fundamental understanding of the influence of gob parameters and various rules of thumb based on personal experience.

With regard to gob modulus (an input parameter), Michael Hardy (AAI Principal) stated in an interview with the investigation team that "*it's very important because it controls the load transfer through the gob…we tweak that a lot to try and get the right load transfer through the gob. And this is a very important parameter. It's a very difficult parameter because we have* *very little feedback from the field that says this is the stress on the gob. It's the biggest --- quite possibly the biggest parameter that's used in interpreting load transfer from a gob into the barrier pillars and surrounding area*." The EXPAREA model that AAI had previously calibrated to Crandall Canyon Mine conditions used a bilinear gob model. Although a bilinear gob model is available for use in LaModel, AAI elected to use the default material, strain-hardening gob, instead.

The LaModel preprocessor, LamPre, includes a utility to assist users in selecting a final gob modulus for the strain-hardening gob element. As written in the program Help file, this utility "*is intended to simplify the task of determining gob material properties and to allow the user to obtain fairly accurate gob properties in the initial model run*." Typically, the user inputs the width of the gob area and the estimated peak stress on the gob, and the utility returns a final gob modulus which provides a starting point for calibration.

The parameters that AAI used in the LamPre gob property utility are not available since these data are not retained in the LaModel input files. Furthermore, given the number of variables that can affect the utility's output, it is impossible to replicate the process. However, it appears that the effects of thin lamination thickness and perhaps a very wide gob resulted in a very low final gob modulus value.

The effects of a very low gob modulus are readily apparent in the LaModel convergence results. In models of the North and South Barrier sections that used this value, LaModel convergence results actually exceeded the height of the mined openings over broad areas of the model. The modeled entry height was 8 feet but maximum convergence in some of the models exceeded 20 feet, which is physically impossible. Although the excessive convergence values are evident in the LaModel postprocessor, LamPost, they are not evident in illustrations provided in AAI's reports due to the manner in which the output data were scaled.

Scale Selection for Illustration. Each of the reports that AAI prepared for GRI included numerous illustrations. Typically, color figures were provided to illustrate the distribution of vertical stress, convergence, and yield condition in plan view. The July 20, 2006, report (Appendix F), for example, included 21 colored plan view figures, two cross-section views, and one mine map. All of the vertical stress figures included a key that ranged from 0 to 10,000 psi. However, one of the cross-section figures shows that peak stresses in excess of 30,000 psi occur near the barrier rib adjacent to the longwall gob. Thus, a more appropriate label for the key in the plan view figure would indicate that the highest color range includes all vertical stress levels greater than 9,000 psi.

It is common practice to scale numerical model results to highlight particular points or ranges of interest. For example, even though safety factors may range from near 0 to 6 in a given (hypothetical) model, it may be beneficial to illustrate the range between 0 and 2. Since safety factors below one indicate failure, this range would show the most critical areas. Similarly, AAI focused on a range of convergence from 0 to 2 inches because they associated 2 inches of convergence with difficult roof conditions. Although this scale highlighted a range of interest, another implication was that the scale masked unreasonably high levels of convergence that were present elsewhere in the model. The range used in the vertical stress plan views had a similar effect. Vertical stress levels in these plots appeared to be reasonable even though peak values in some of the models actually exceeded 90,000 psi.

Model Calibration. In the initial proposal to model Main West Barrier mining, AAI indicated that two previous pillar recovery areas would be used for calibration purposes. One area was South Mains, which was recovered between August 2005 and October 2006. The second was the 1st North panels that were recovered between February 1992 and August 1994. Ultimately, however, AAI opted to calibrate the model based only on the 1st North Left Panels.

In a paper titled "*Experience with the Boundary Element Method of Numerical Modeling as a Tool to Resolve Complex Ground Control Problems*" Karabin and Evanto[14] outlined a procedure for creating and using effective boundary element models. Their recommended simulation process flow chart is illustrated in Figure 70. The first four steps of the flow chart in Figure 70 represent the model calibration portion of the simulation process. The authors emphasize that underground observations are an essential first step in any modeling effort. They recommend that several areas be evaluated and they describe a system of mapping that can be used to quantify various observed ground conditions for later use in model validation. The authors stress that verifying model accuracy (i.e., validation) is the most critical step in the entire simulation process. If model results do not correlate reasonably well with observed conditions, the calibration process must continue (i.e., material properties must be adjusted).

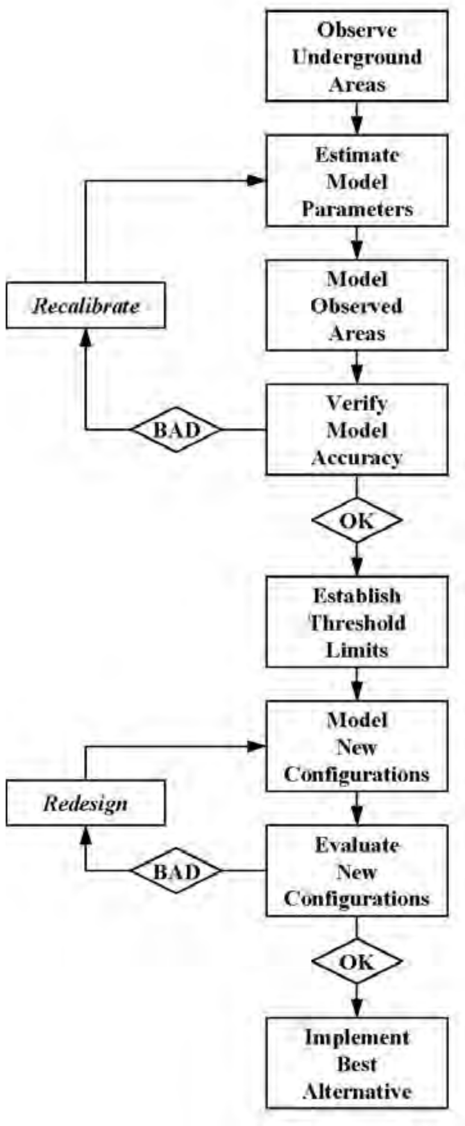


Figure 70 - Simulation Process Flow Chart

AAI's LaModel model was calibrated to Crandall Canyon Mine ground conditions by adjusting input parameters until model results were consistent with mining conditions reported to have existed in the 1st North Left panels. AAI personnel could not make underground observations in these inaccessible panels, but relied instead on descriptions of the ground conditions provided by GRI.

AAI claimed that they calibrated the LaModel program using three criteria: vertical stress, convergence, and yielding condition. Lamination thicknesses and coal strength were varied to gauge the sensitivity of model results, reportedly to calibrate to all three input criteria. In their written response to the accident investigation team, AAI indicated that this activity resulted in a calibrated model that simultaneously fit all three criteria. However, interview statements of the AAI engineer that did the modeling reveal that the calibration process relied exclusively on an evaluation of pillar yield condition. Coal strength was adjusted until pillars in the first pillar row of the 1st North, 9th Left Panel (immediately north of Main West crosscut 99) yielded during panel retreat while the outby rows did not (Figure 71).

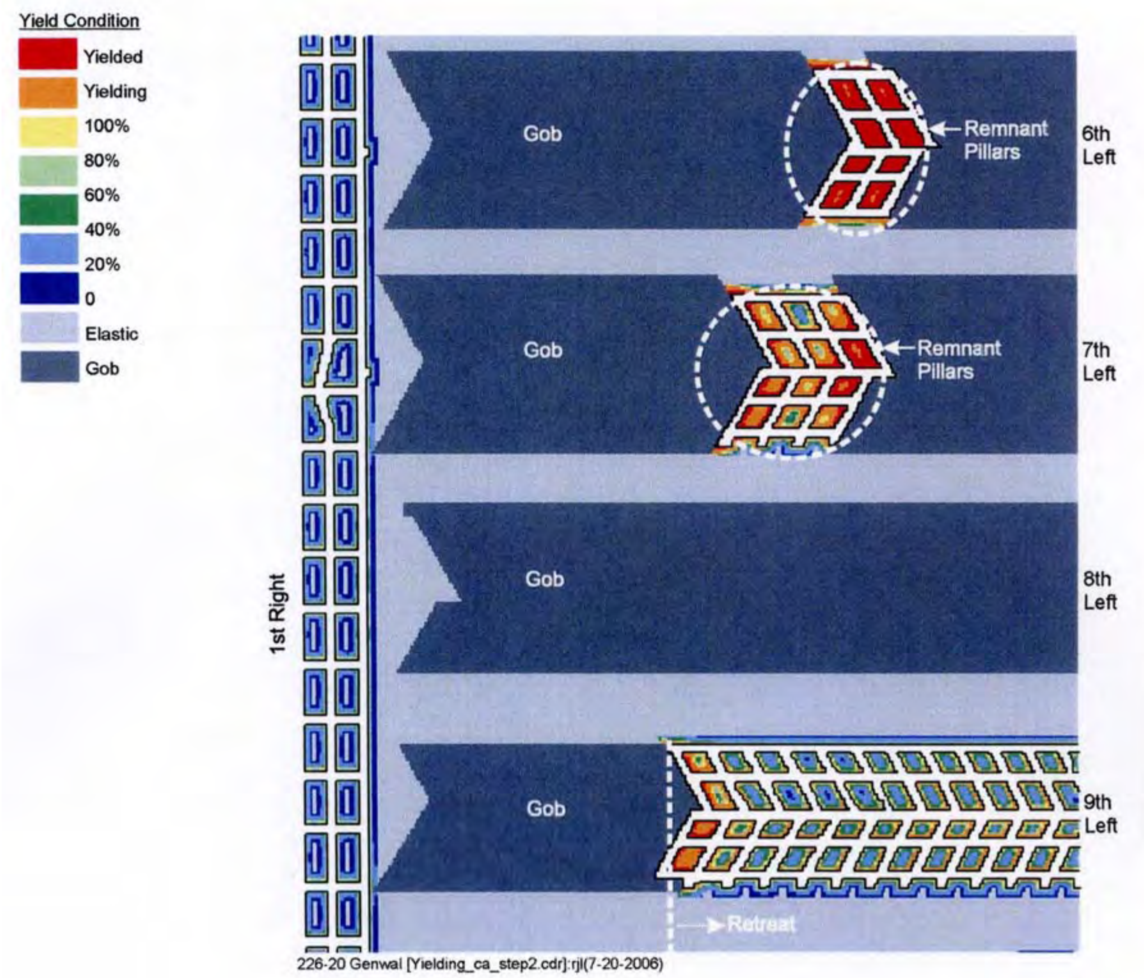


Figure 71 - Modeled Yield Condition - Partial Retreat in 9th Left Panel

While mining the 9th Left panel, difficult roof conditions were encountered (i.e., "peeling top coal") on the pillar line. AAI noted that 2.0 inches or more of convergence was associated with the yielded pillar row in their "calibrated" model. Thus, 2.0 inches of convergence was considered a site-specific indicator of potential roof and rib instability for subsequent predictive models.

AAI also interpreted abutment stress transfer from their model of the completed 9th Left Panel. As illustrated in Figure 72, AAI's model included mining that was done north of the Main West entries. This northward extension of Main West (labeled "Area A" in Figure 72) was developed intermittently between 2003 and 2005 and approached to within about 145 feet of the 9th Left Panel. AAI interpreted model results to show *"no significant side abutment stress override across the barrier on the main pillars, consistent with actual conditions."* Since this interpretation appears in a report section titled "1st North Left Panels Back-Analysis," it appears to be intended to support the validity of AAI's model. However, the interpretation actually does little to verify that abutment stress transfer in AAI's model is reasonable.

Underground observations made by the accident investigation team (in Area A, Figure 72) confirmed that there were no significant effects of abutment stress transfer from the adjacent 9th Left Panel. However, this observation does not validate AAI's model results. Given the geometry, substantial abutment stress effects would not be anticipated to occur in Area A. The center of this area is bounded by unrecovered pillars in the 9th Left Panel. One end of the area is bounded by solid coal and the other by a barrier and unmined pillars of the 1st Right Mains. A more appropriate method of validating model behavior is to correlate model results with stress damage (e.g., roof or rib deterioration) rather than a lack of damage.

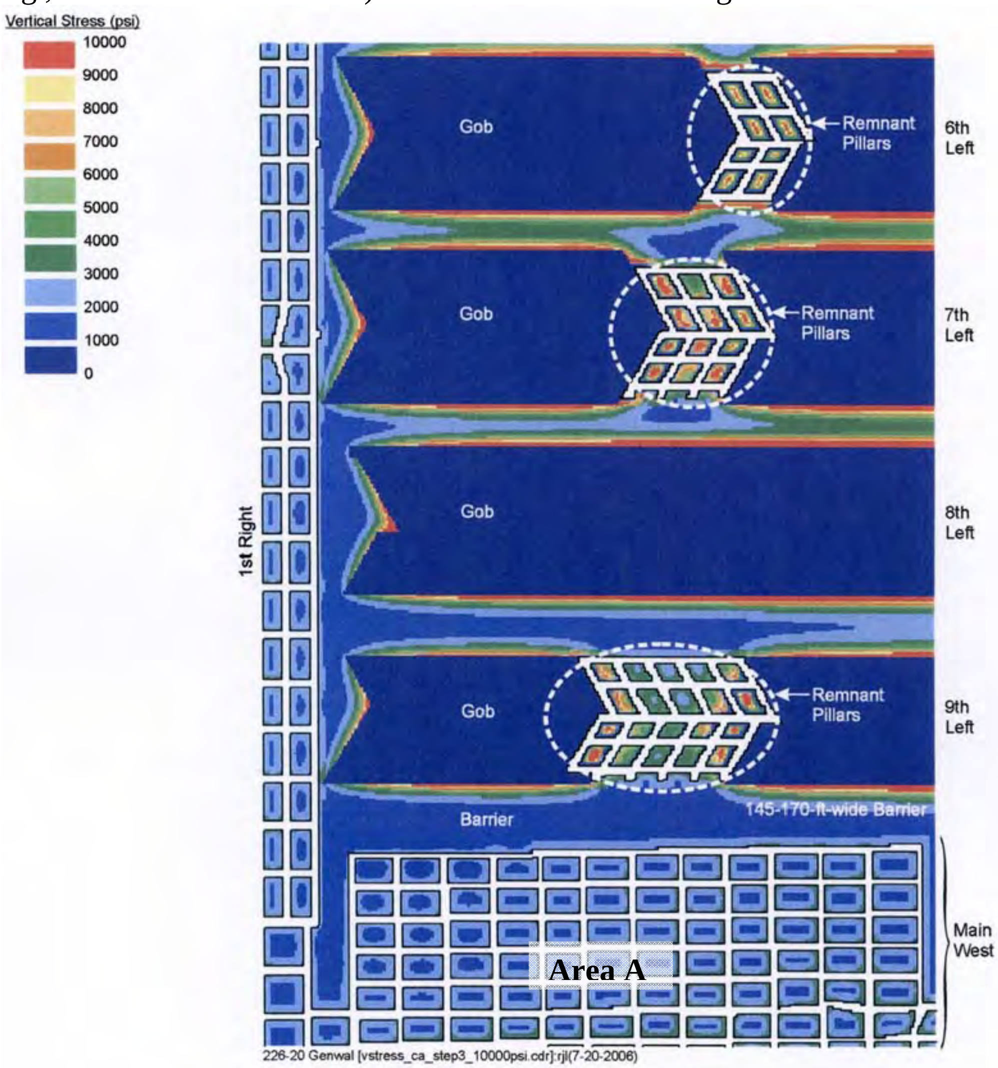


Figure 72 - Modeled Vertical Stress – Retreat Completed in 9th Left Panel

After the initial calibration process based on 1st North Panels, AAI had two opportunities to verify that model results were consistent with actual observed conditions at the mine. The first opportunity was in December 2006 when AAI personnel visited the site specifically to view ground conditions under deep cover. At that time, AAI viewed conditions as being "*consistent with analytical predictions*." Mining had not advanced into the deepest overburden at the time of the site visit. No modifications were made to the Crandall Canyon Mine model as a result of AAI's December 1, 2006, visit.

The second opportunity was after the March 10 pillar burst. AAI was notified by GRI of the event and Hardy and Gilbride traveled to the site on March 16. When asked "*What conclusions did AAI personnel draw from the conditions observed on the North Barrier section regarding the adequacy of the design process (e.g,. models) that had been used?*," AAI responded that "*The bump occurrence in the North Barrier was limited to six or seven pillars and did not extend outby. The observation of this condition seemed to be consistent with the modeling results, i.e. bump occurred only around the edges of the pillars. Based on the observations in the North Barrier, further analysis was completed using the established models and a change in the plan for mining the South Barrier was recommended to reduce bump risk.*"

Photographs, sketches, and interview statements of others indicate that the area affected by the burst was not limited to six or seven pillars and did extend outby. BLM's Falk noted, for example, that "*Entry ways outby two breaks from the face had extensive rib coal thrown into the entry way. Stress overrides outby the face were very concerning.*" AAI's field notes also suggest that the damage was more widespread (see Figure 73). The remnants of damaged pillars are sketched inside the original pillar boundaries as indicated by the orange lines in the figure. Photographs taken in this area during AAI's March 16 visit are included in Appendix O.

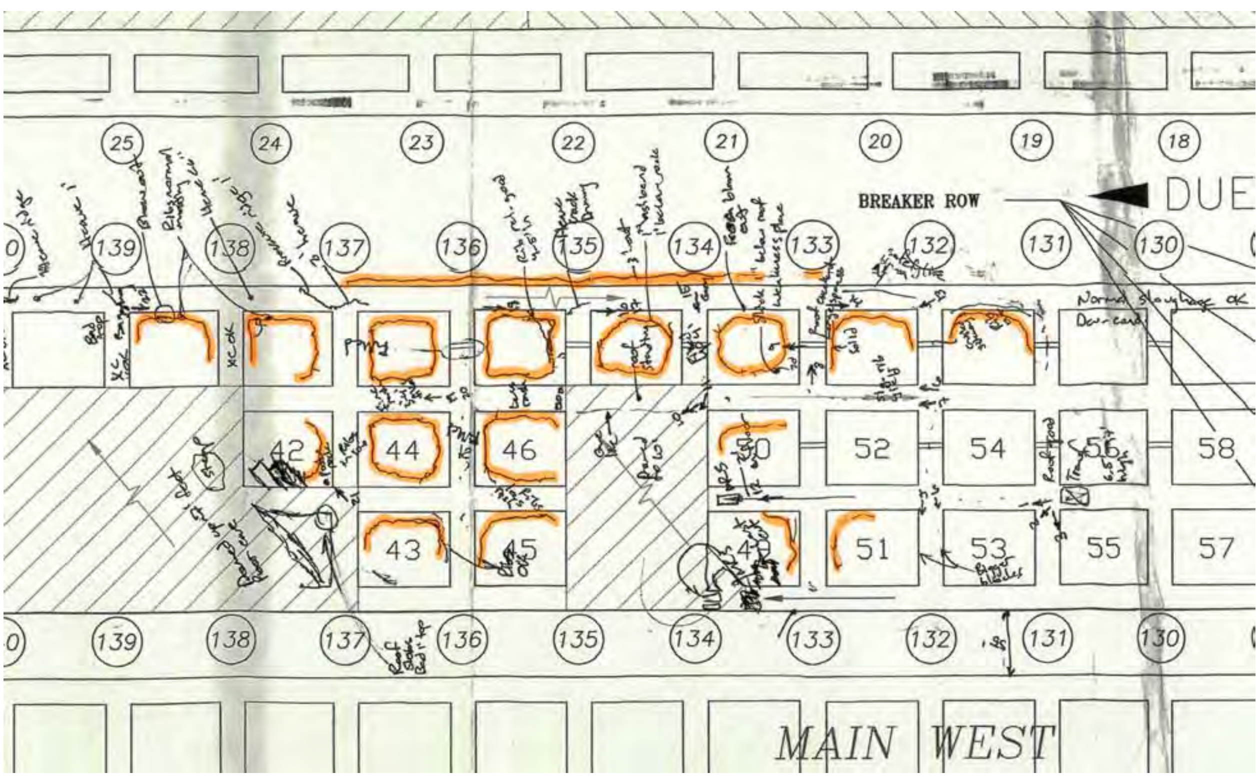


Figure 73 - Notes Made by AAI on March 16, 2007
(orange lines added for emphasis)

AAI attributed the March burst to a lagging cave inby crosscut 138 and the start-up cave between crosscuts 134 and 135 based on their onsite observations. The model grid was changed to reflect this condition. Open entries (as opposed to gob material) were used to represent the areas between crosscuts 134 to 135 and 138 to 139. However, this change had a negligible effect on the model results. Since the gob modulus used in both models was very low, the amount of load transmitted to the gob (rather than transferred to adjacent pillars) was small in either case. Models run by the accident investigation team indicated that peak stress in the gob only increased by approximately 7 psi when the lagging cave was replaced with AAI's low gob modulus.

Models that AAI developed after the March bursts indicated that high stresses were concentrated in the area between these two partially caved or un-caved gobs (see Figure 74). A comparison of Figure 73 and Figure 74 indicates that, even with the lagging cave incorporated into the model, high vertical stresses do not coincide with the extent of damage observed in the mine. Modeled vertical stresses in pillars between crosscuts 136 and 137 appear to be quite similar to stress levels in pillars outby crosscut 133. Furthermore, the pillars outby 133 appear to be largely unaffected by stress transfer from either the longwall gob to the north or the un-caved pillared area between crosscuts 135 and 134. AAI postulated that a dynamic failure (a localized burst) of these pillars could have propagated to pillars over a much wider area.

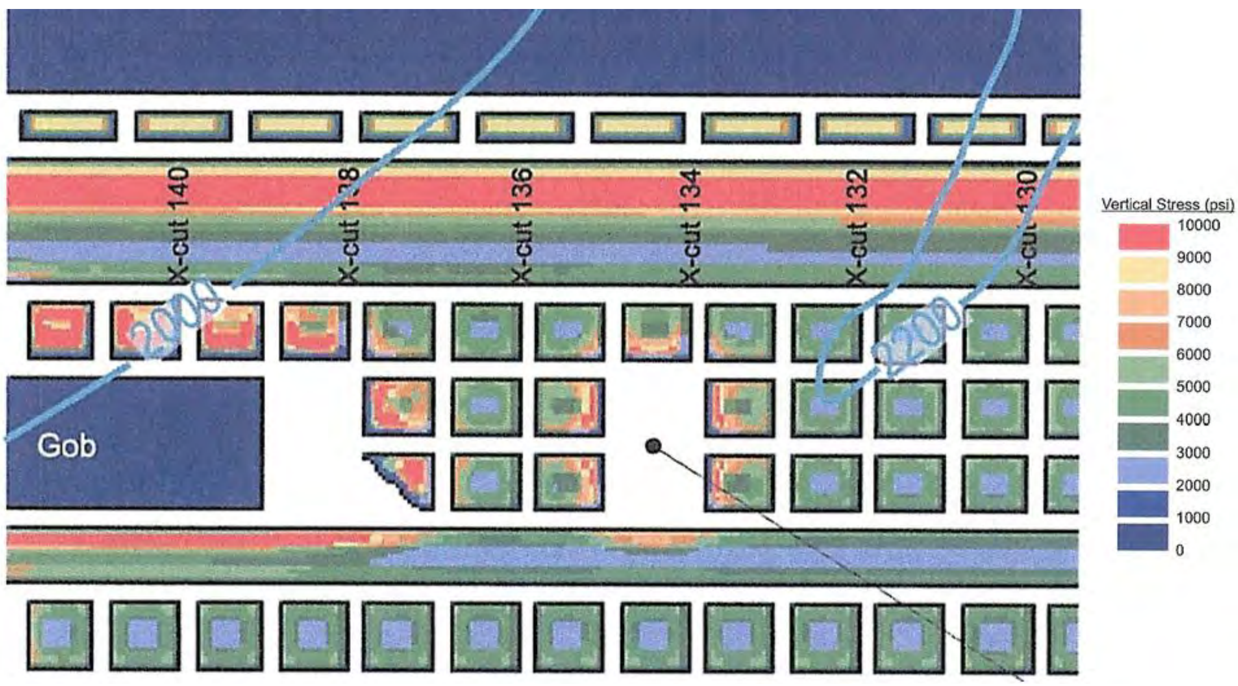


Figure 74 - AAI Model Results of Vertical Stress in March 2007 Burst Area

The changes that AAI made to their numerical model after the March bursts did not constitute a recalibration of the model to the observed ground conditions. Had the disparity between field conditions and model results prompted a careful examination of model input and model recalibration, a properly constructed model would have shown that the South Barrier section mine design was destined to fail. The following section illustrates the output that can be derived by a properly constructed model using AAI's reported parameters.

BEM Using AAI Model Constructed as Reported. LaModel analyses were conducted with coal properties distributed as outlined in the text of AAI's July 20 report (Appendix F). Results indicate that pillars in the North and South Barrier sections would have failed over a relatively broad area (Figure 75). In this figure, red and yellow represent elements with a safety factor less than 1 (i.e., the element is considered to have failed).

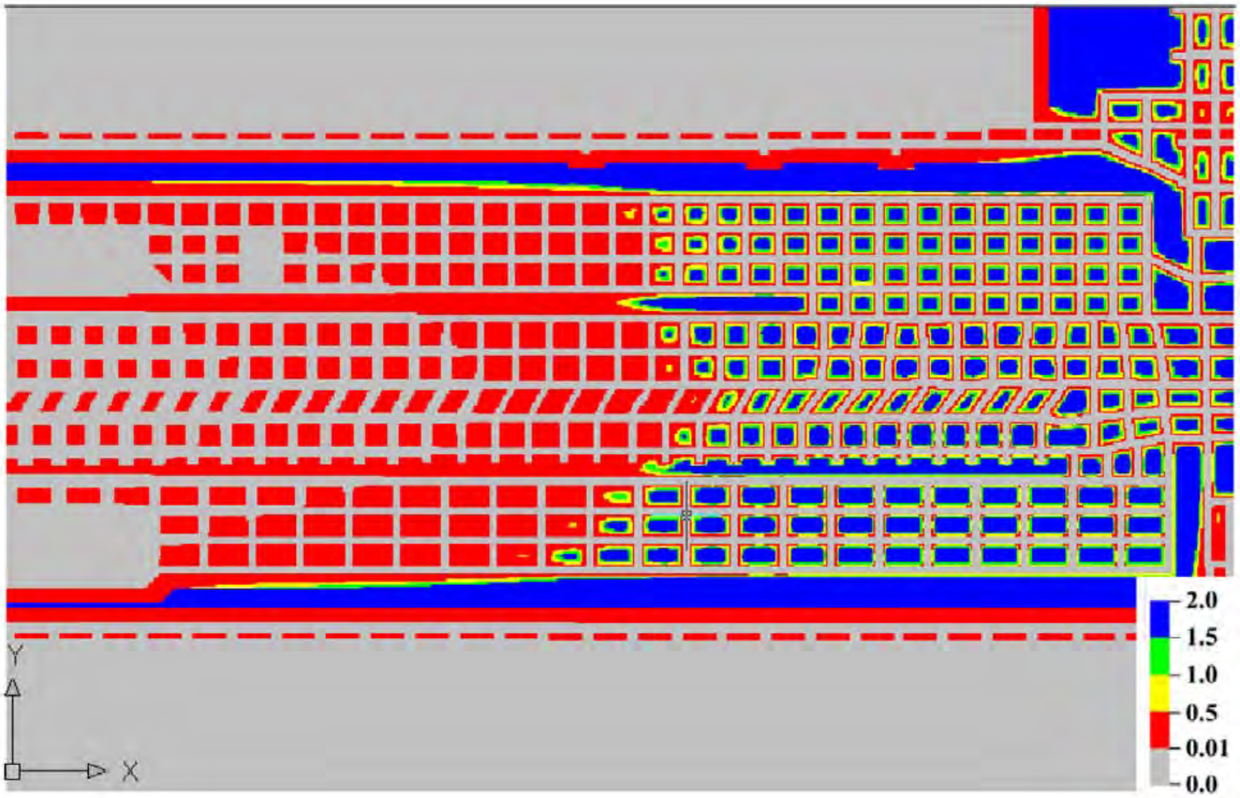


Figure 75 - Element Safety Factors with Coal Properties Distributed as Indicated in AAI Report

Figure 76 illustrates element safety factors from a simulation in which AAI's model was further modified to reflect gob properties and lamination thicknesses more consistent with their calibrated EXPAREA model. In this case, a bilinear gob model was used rather than strain hardening and lamination thickness was increased to 115 feet rather than 25 feet. The greater thickness was established using an equation provided by Heasley[5]. Also, rather than modeling a single scenario as AAI had, mining in the North and South Barriers was modeled as three steps: (A) North Barrier pillar recovery to crosscut 133, (B) South Barrier development and (C) South Barrier pillar recovery to about crosscut 131. Results of these model steps are illustrated in Figure 76. Both models (Figure 75 and Figure 76) show widespread pillar failure.

Element safety factors based on the modified model show pillar failure near the site of the March 10 outburst accident (Figure 76 A). Pillar rib elements fail under the deepest cover but pillars remain stable as the South Barrier is developed (Figure 76 B). However, as pillars are recovered in the South Barrier, failure propagates outby the face and extends into the Main West and North Barrier section workings. Although the model does not match the observed damage as well as Dr. Heasley's model, it is generally consistent with the failures that occurred in March and August 2007 at Crandall Canyon Mine. The modeling results illustrate that a properly constructed and calibrated model will depict that the South Barrier section pillar design is unstable and destined to wide spread failure.

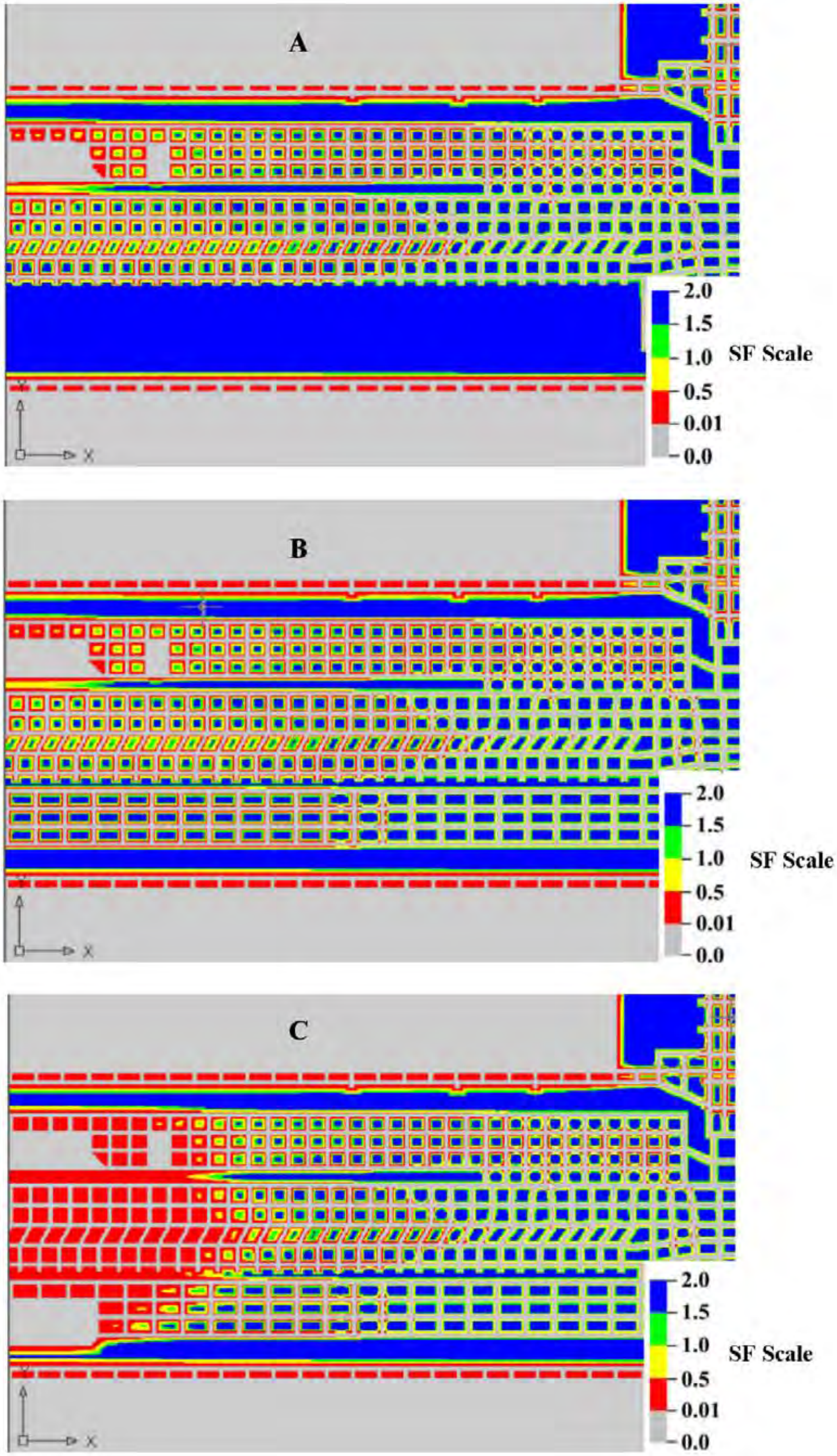


Figure 76 - Element Safety Factors using Modified Coal Strength Property Distribution, Gob Properties, and Lamination Thickness

South Barrier Design. After the March burst, AAI changed their model to reflect a lagging cave but this change had very little impact on model results. The model used to evaluate designs for the South Barrier section was essentially the same as the model used to design the North Barrier section. Proposed design changes including longer crosscut spacing were evaluated. AAI had modeled the effects of longer crosscut spacing early in the Main West Barrier Mining project. Their earlier conclusion was that "*increasing crosscut spacing does not significantly improve conditions*." Increased pillar length (reported as a 20-foot increase, but modeled as a 10-foot increase from 70 to 80 feet) *"only incrementally reduces rib yielding, corresponding to a modest decrease in entry convergence."* In the South Barrier section models, however, pillar length was increased by 37 feet (72 to 109 feet). AAI noted that modeled stresses in the projected South Barrier workings were similar to those experienced at the March burst site when crosscuts of similar length were used (see handwritten notes, Figure 77). However, AAI concluded that the longer crosscut spacing "*increases the size and strength of the pillars' confined cores, which helps to isolate bumps to the face and reduce the risk of larger bumps overrunning crews in outby locations*."

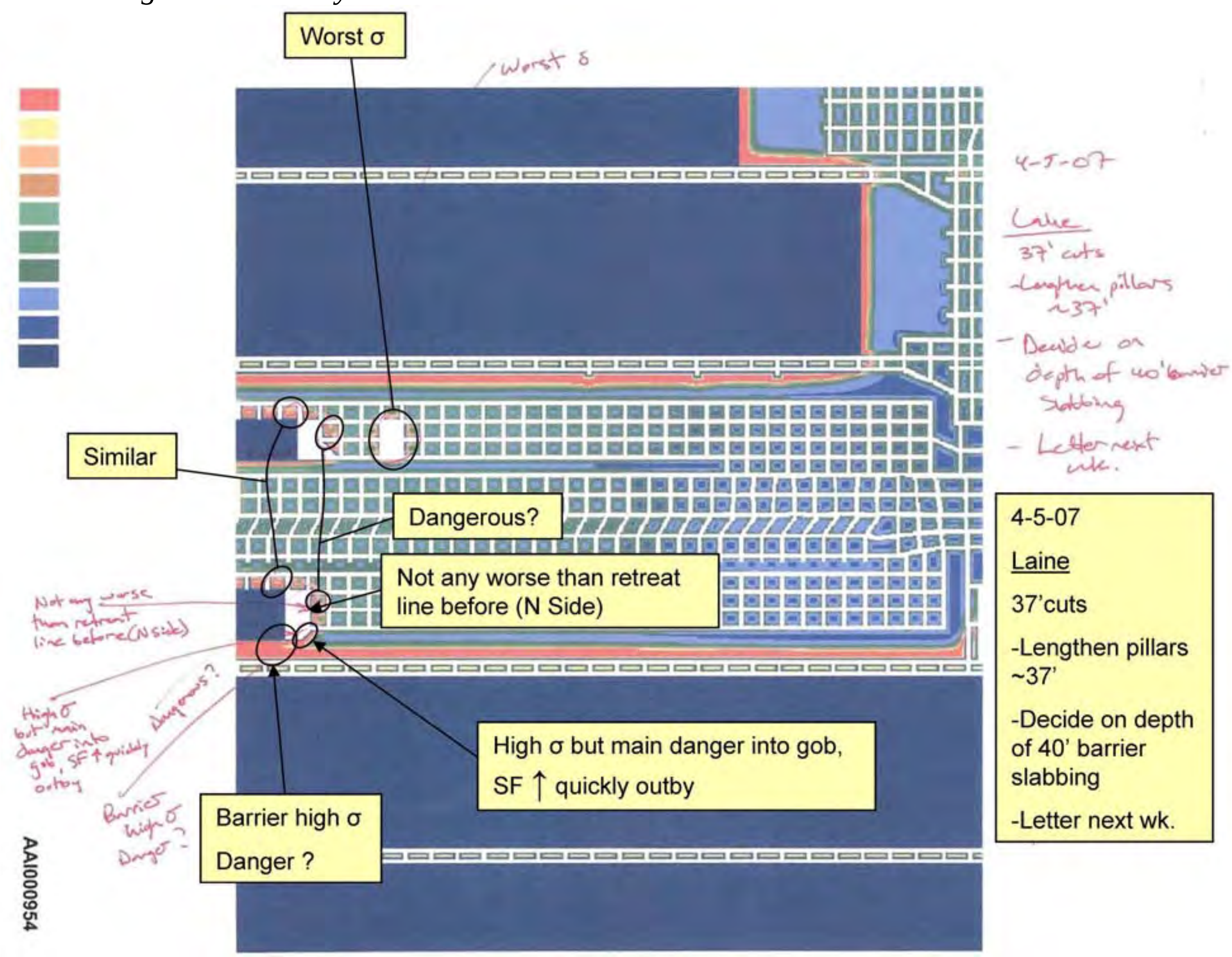


Figure 77 - AAI Notation on Plot of Model Results
Text boxes reflect handwritten notes and were added for clarity.

AAI's model results with two different crosscut spacing distances are shown in Figure 78. The images are similar in the sense that high stresses are concentrated in pillar ribs adjacent to the expanding gob area. With longer pillars, the concentration appears to be reduced in the vicinity of the outby intersection. It is important to note, however, that the models did not evaluate pillar recovery on a cut-by-cut basis. When pillar cuts remove coal from the inby ends, the pillars in the active mining area are reduced in size. Consequently, some of the benefit of longer pillars in the active mining area is diminished as pillar recovery proceeds. The stress concentration will migrate towards the outby intersection as the pillar in the active mining area is reduced. Although the larger (i.e., longer) pillars used in the South Barrier were stronger than those used in the North Barrier, they were not sufficient to ensure the stability of these workings during pillar recovery. Given the aforementioned deficiencies, the models provided no insight into the "*risk of larger bumps overrunning crews in outby locations*."

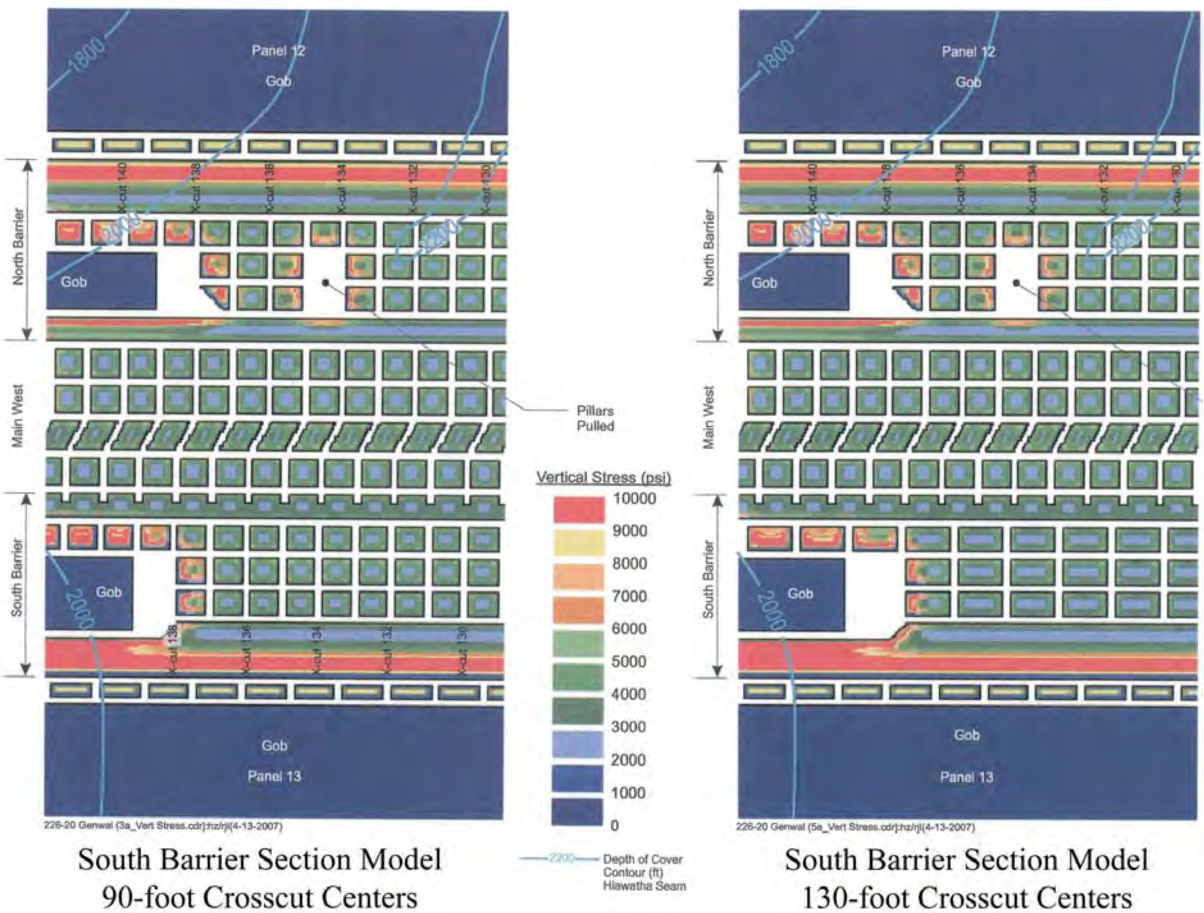


Figure 78 – AAI Modeled Vertical Stress Results Comparing Effects of Crosscut Spacing

ARMPS Analyses. As part of their evaluation of proposed mining in the North Barrier section, AAI performed calculations using NIOSH's Analysis of Retreat Mining Pillar Stability (ARMPS) software. Model procedures and results described in an August 9, 2006, email from Leo Gilbride to Laine Adair provide insight to these analyses. The available information demonstrates that much of AAI's ARMPS analysis was consistent with NIOSH's recommended use of the program. However, several assumptions led to overstated estimates of stability. In addition, calculations indicating extremely low pillar stability factors for the South Barrier analysis were either misinterpreted or not acted upon.

ARMPS Input. AAI calculated stability factors (StF's) for the 1st North Panels and for the North Barrier section. The calculations were performed using default values available in ARMPS. For example, the analyses relied on default values for in situ coal strength (900 psi), unit weight of overburden (162 lb/ft^3), abutment angle of gob (21º) and extent of the active mining zone (AMZ). Using these values and the geometries illustrated in Figure 79, AAI determined that the minimum pillar stability factor (PStF) in the 1st North Panels was 0.37.

Minimum PStF in the North Barrier section was 0.53 at 2,000 feet of overburden. These values (0.37 and 0.53) are generally consistent with the PStF values discussed earlier in Table 5 and Table 7 (Method 1 – 215-foot barrier). However, it is important to note that Method 1 overstates the benefit of leaving a row of bleeder pillars. More conservative estimates of PStF at 2,000 feet of overburden, obtained using Methods 2 and 3, are 0.29 and 0.27, respectively.

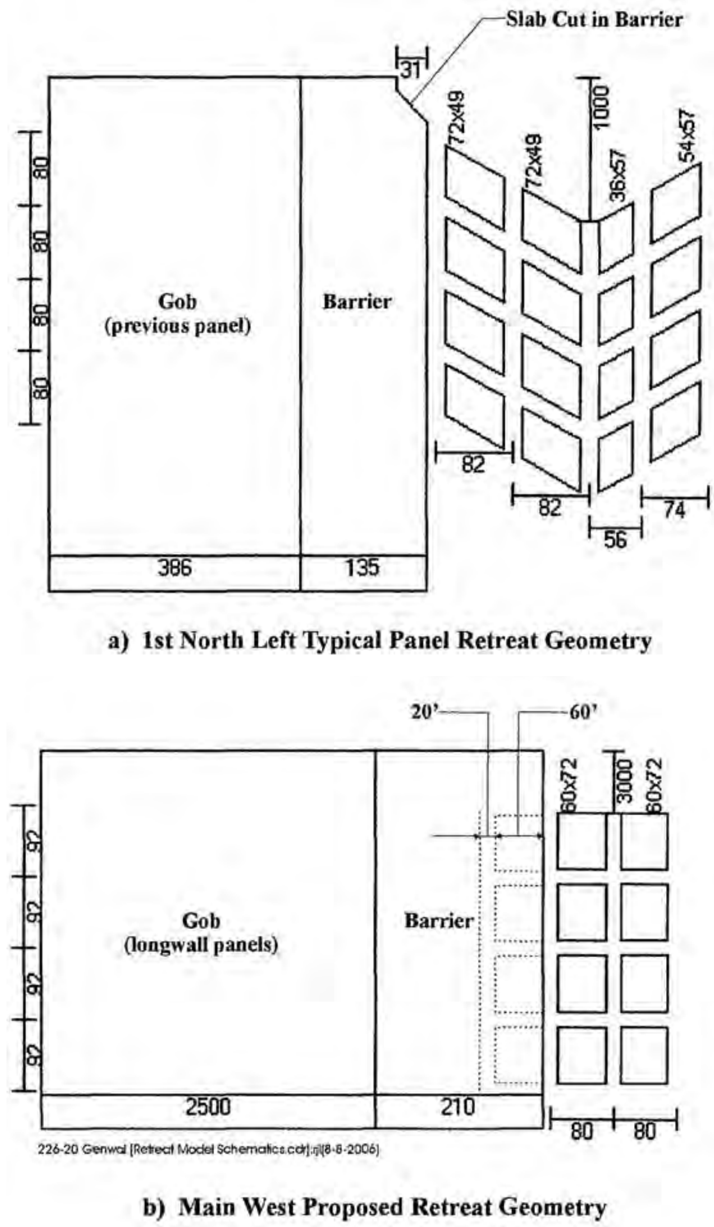


Figure 79 - ARMPS Analysis Geometries used by AAI

Back-Analysis. NIOSH provides the following guidance for developing site-specific criteria in one of the resource files[15] provided in the ARMPS Help file:

> *"ARMPS appears to provide good first approximations of the pillar sizes required to prevent pillar failure during retreat mining. In an operating mine, past experience can be incorporated directly into ARMPS. ARMPS stability factors can be back-calculated for both successful and unsuccessful areas. Once a minimum ARMPS stability factor has been shown to provide adequate ground conditions, that minimum should be maintained in subsequent areas as changes*

occur in the depth of cover, coal thickness, or pillar layout. In this manner, ARMPS can be calibrated using site-specific experience."

Back-analysis is considered an acceptable practice for mines with a proven track record of retreat mining experience. However, site-specific criteria used in lieu of NIOSH's recommendations should be developed cautiously using multiple case histories with known conditions at a given mine. In these cases, proper examinations of individual mine data may demonstrate that stability factors above or below NIOSH's recommended values are warranted. Proper examination must entail an analysis of the broad experience at a mine site rather than a focus on isolated case(s) that represent the extreme.

AAI used default input parameters (including 900 psi coal strength) in their ARMPS analyses. Therefore, the resulting stability factors could be compared directly to those comprising the NIOSH database. AAI considered the database and observed that:

"The ARMPS database shows that industry experience is mixed for mines reporting similar SFs (0.16 to 1.05) at comparable depths (1,500 to 2,000 ft). Of these cases, slightly more than half were successful, while the remainder encountered ground control problems."

This observation is accurate. Eleven of 21 cases at depths greater than 1500 feet were deemed to be satisfactory designs. Difficult ground conditions were attributed to the remaining ten. Similarly, five of ten cases with PStF's less than 0.53 (i.e., the PStF value they determined for the proposed North Barrier section) were satisfactory and the other five experienced difficulties (see Figure 80). It is noteworthy that in all of the "failed" cases, NIOSH indicated some degree of pillar "bumping" was involved.

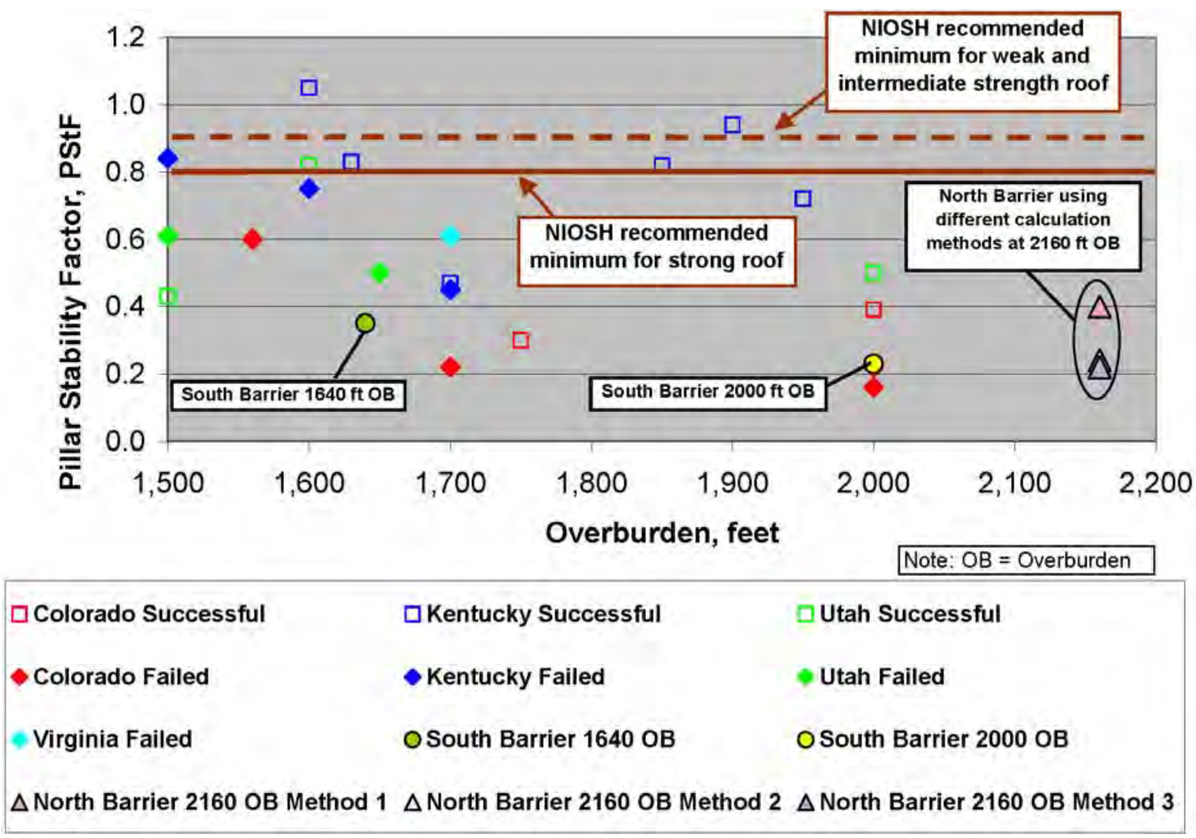


Figure 80 - Pillar Stability Factors from NIOSH ARMPS Database for Depths Over 1,500'
NOTE: NIOSH ARMPS Database only contains case histories at or below 2,000' overburden.

AAI recognized that the North Barrier section pillar stability factors they had calculated were below the NIOSH recommended minimum. AAI reasoned that since the 1st North Left block panels had been mined successfully with a PStF of 0.37, the North Barrier section with a PStF of 0.53 should be acceptable:

> *"At GENWAL* [Crandall Canyon Mine] *good success has been achieved at SFs below 0.90. Retreat conditions in the 1st North Left block were generally successful with a SF of 0.37, suggesting that a SF of about 0.40 is a reasonable lower limit for retreat mining at GENWAL…The lowest SF for the proposed retreat sequence in Main West barriers is 0.53 under the deepest cover, which is approximately 43% higher than the "satisfactory" SF of 0.37 for the 1st North Left block. Implications are that the proposed retreat sequence in Main West will be successful in terms of ground control, even under the deepest cover (2,200 ft)."*

However, AAI's back-analysis was flawed in several ways. First, the panels in 1st North Panels were considered to be satisfactory designs despite the fact that pillar rows were skipped in each of the last four panels near the deepest cover. This assumption was made even though AAI, and GRI personnel who provided information to AAI, did not have personal experience with mining in these areas. Mine personnel related problems associated with roof coal and AAI considered this from the standpoint that similar problems would not be anticipated in the North and South Barrier sections:

> *"…occasional problems with peeling top coal were encountered in the 1st North Left block. This required skipping pillars on retreat in some locations. Top coal is currently mined to minimize this risk and is not expected to be a problem in Main West."*

It is highly speculative to conclude that additional problems would not have been encountered had the top coal been mined in these areas. Furthermore, reports indicate that ground control problems were not limited to spalling top coal. Two injuries caused by ground failures (a burst and a rib roll associated with a bounce) were reported during pillar recovery in the 1st North 7 Left panel.

Second, AAI's analysis considered GRI's pillar recovery experience in the 1st North Left Block panels but did not consider recovery work in the South Mains. GRI had much more recent experience and first hand knowledge of ground conditions during pillar recovery in this area since mining was not completed until October 2006. Although the South Mains pillars and barriers were recovered in a different manner than the Main West Barriers, back-analysis would have demonstrated that PStF's in the North and South Barrier sections were far lower than those associated with difficult conditions in the South Mains. Rather than anticipating ground conditions better than those encountered in the 1st North Left Block panels, GRI and AAI should have expected conditions worse than those encountered in the deepest cover in the South Mains.

Third, AAI's analysis did not consider barrier pillar stability factors. In formulating their recommendations for stability factors in deep cover mining operations, NIOSH noted that the use of large barrier pillars in conjunction with reasonably sized pillars substantially increased the likelihood of successful pillar recovery in overburden greater than 1,000 feet. Minimum BPStF's for panels in 1st North and for recovery in the South Mains were 1.52 and 1.59, respectively. The back-analysis showed that pillar recovery at Crandall Canyon Mine historically had been conducted with barrier pillar stability factors (BPStF) exceeding 1.5, as shown in Figure 81. The minimum BPStF calculated for the North Barrier section varies from 0.98 to 1.54. Method 1, representing the effect of combining the bleeder pillar and barrier pillar in ARMPS (i.e., assume the pillar is not developed) yielded the 1.54 BPStF value that is consistent with BPStF's in the historical previously mined areas. However, Method 1 overstates the benefit of leaving bleeder pillars. Methods 2 and 3, which offer more realistic approaches, both show that BPStF in the North Barrier design is well below those calculated for past Crandall Canyon Mine pillar recovery areas.

Finally, after the March 10 outburst accident, AAI again used ARMPS to evaluate several potential pillar designs for use in the South Barrier section. The analyses included a design similar to the one that was actually implemented. The ARMPS pillar stability factor for this design is 0.26 and the barrier pillar stability factor is 0.87 (yellow square in Figure 81). There are no indications that these values were included in any written report or email to GRI. AAI's StF's were based on a barrier width of 137 feet between the section and the worked out longwall Panel 13. When it was actually developed, the barrier width was reduced to 121 feet. For this scenario, the pillar and barrier pillar stability factors are 0.23 and 0.76, respectively. The South Barrier section PStF's are below AAI's mine-specific stability threshold of 0.4 and below the values associated with the March 10 outburst accident. Also, Figure 80 illustrates that the PStF values for the implemented South Barrier section pillar design at 2,000 feet of overburden are below all successful cases in the data base and equivalent to two failed cases. None of these ARMPS results were presented in the April 2007 AAI report for the South Barrier section design that MSHA considered in the plan approval process (see Appendix I).

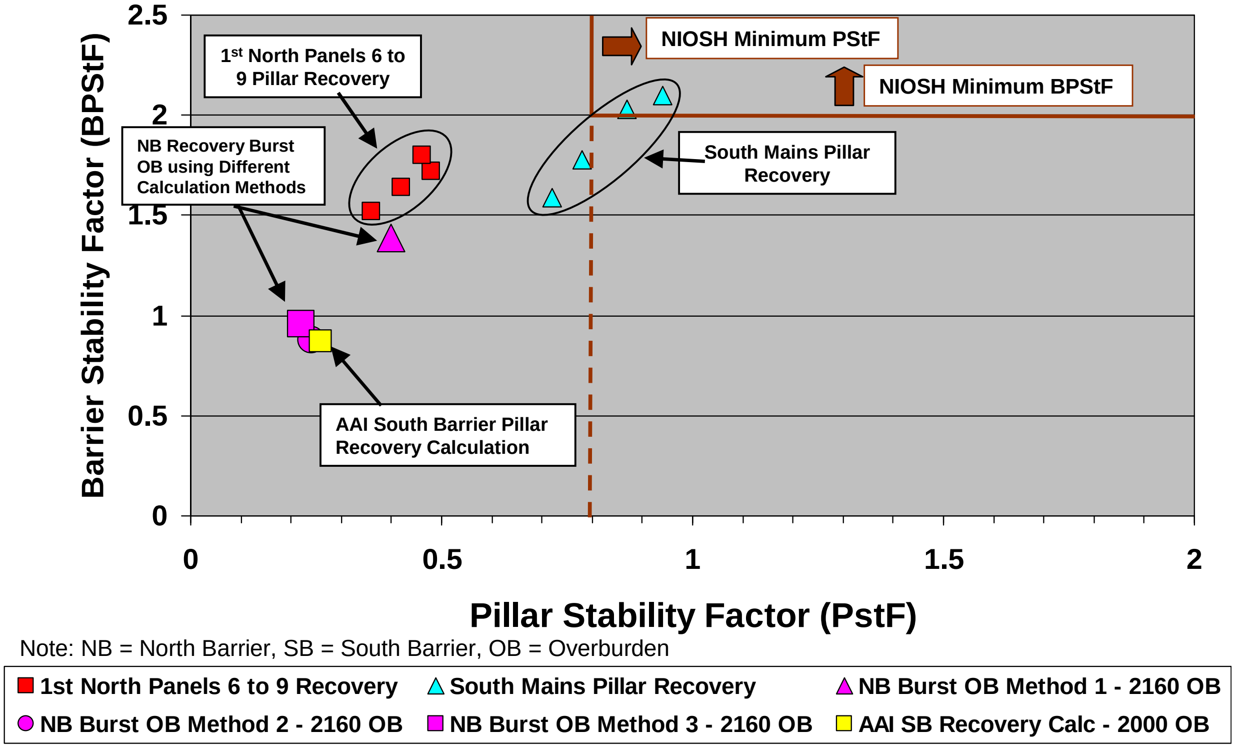


Figure 81 – Crandall Canyon Mine ARMPS Stability Factors showing AAI South Barrier Calculations

Roof Control Plan

Section 30 CFR 75.220(a)(1) requires each mine operator to develop and follow a roof control plan, approved by the district manager, that is suitable to the prevailing geological conditions and the mining system to be used at the mine. After reviewing the plan, the mine operator is notified in writing of the approval or denial of the proposed roof control plan or proposed revision. At the time of the August 2007 accidents, the relevant portions of the approved roof control plan consisted of the following:

- A base plan approved July 3, 2002.
- Added pages 21 through 94 concerning pillar recovery, approved September 5, 2003.
- A site-specific plan for extraction of pillars in South Barrier section, dated May 16, 2007, and approved June 15, 2007.

Several previous site specific roof control plans had been approved for mining the North and South Barrier sections. At the time of the August accidents, these plans had been terminated because mining had been completed in the affected areas:

- A site-specific plan for development of North Barrier section, dated November 11, 2006, and approved November 21, 2006.
- A site-specific plan for leaving roof coal during development of North Barrier section, dated January 10, 2007, and approved January 18, 2007.
- A site specific plan for pillar recovery in North Barrier section, dated December 20, 2006, and approved February 2, 2007.
- A site-specific plan for development of South Barrier section, dated February 20, 2007, and approved March 8, 2007.

On July 20, 2006, a draft report of a geotechnical analysis for developing the North and South Barrier sections was sent from Gilbride to Adair (see Appendix F). The report concluded "*that the proposed Main West 4-entry layout with 60-ft by 72-ft (rib-to-rib) pillars should function adequately for short-term mining in the barriers (i.e., less than 1 year duty*)". AAI conducted another geotechnical analysis, dated August 9, 2006, for recovering the pillars in the North and South Barrier sections. The report for this analysis stated that "*ground conditions should be generally good on retreat in the barriers, even under the deepest cover (2,200 feet)*". On September 8, 2006, GRI provided these reports to MSHA District 9 to justify approval of their proposed plans to mine the North and South Barrier sections. As part of the plan review of the AAI ARMPS analysis, MSHA District 9 conducted a back-analysis of the 1st North 9th Left Panel. The MSHA analysis determined that the pillar stability factor (PStF) should exceed 0.42 for the proposed North and South Barrier recovery plans. No assessment was made for the required barrier pillar stability factor (BPStF). The MSHA ARMPS analysis is described in Appendix W.

MSHA's review of the August 9, 2006, AAI analysis for pillar recovery in the North and South Barrier sections raised several questions. On November 21, 2006, MSHA sent a letter to GRI stating that the pillar recovery plan could not be approved and listed the following deficiencies:

1. *In situ coal strength was estimated at 1640 psi. An explanation of how this strength was determined should be included. Typical coal strength values are much lower.*
2. *The elastic modulus of coal was estimated at 500 ksi. An explanation of how this modulus was determined should be included. If experimental analysis of test samples*

was conducted, an explanation of the number of samples, the size of samples, and the testing method employed should be included in the submittal.

3. *The mine geometry employed in the computer model differs from the physical map geometry. This observation applies to the ARMPS model geometry employed in the analysis of the historical section and the projected sections.*
4. *The LAMODEL analysis shows, that during pillaring, surrounding pillars exhibit yielding zones. This could indicate a violent outburst since the in-situ coal strength is stated as 1640 psi.*
5. *A stability factor of 0.37 was determined by analyzing the pillars of 1st North 9th Left Panel. The analysis of this area was employed to determine the minimum stability factor for favorable retreat mining. This stability factor appears to be determined from where mining ceased due to poor ground control conditions. Therefore, a higher stability factor should be employed that ensures an adequate factor of safety.*

There was no written response from GRI to MSHA's letter. However, Billy Owens discussed these inconsistencies with GRI in December 2006. Owens recalled that GRI provided the following explanations to address the deficiencies:

1. Studies indicate that coal strengths for the Hiawatha seam range from 1,800 to 4,000 psi and, therefore, the operator felt that the 1,640 psi coal strength was appropriate.

2. AAI had instrumented the coal Hiawatha coal seam and determined that the elastic modulus of 500 ksi was typical.

3. The ARMPS program is not designed to simulate a section that is recovering pillars but leaving an unmined pillar to establish a bleeder. AAI's model incorporated the bleeder pillar as part of the barrier pillar. Also, the geometry that AAI used was from actual survey data provided by the operator.

4. As long as the core was not overstressed, there was no bounce potential.

5. The minimum stability factor of 0.40 was used, which was above the 0.37 threshold determined by back-analysis in 1st North.

Based on this information, Owens agreed with AAI's analysis. However, approval of the North and South Barrier section recovery plans would only be granted if favorable conditions were observed during development.

North Barrier Section - Development Plan. GRI submitted a roof control plan for developing through the North Barrier section, dated November 11, 2006, which was approved by MSHA on November 21, 2006. The plan showed development of four entries through the barrier. The plan specified a minimum of 80 x 90-foot centers, which could vary depending upon conditions encountered. The plan required a minimum 130-foot barrier to the north. The width was not specified for the barrier to the south.

Density of the primary roof support during development of the North Barrier section was six bolts per row with a maximum distance of five feet between rows. This bolting pattern had been used routinely for many years even though it had not been specified previously in the roof control plan. The entries and crosscuts were to be mined a maximum of 20 feet wide. No roof coal was to be left in this area.

Owens and Peter Del Duca visited the developing North Barrier section on January 9, 2007, to assess and investigate the conditions for the pillar recovery plan, dated December 20, 2006. At that time, the section had advanced past the deepest overburden to about crosscut 141 which was beneath approximately 2,000 feet of overburden. This inspection was purposely scheduled so that conditions could be observed under the deepest cover prior to approval of the pillar recovery plan. Owens considered pillar yielding that he observed to be acceptable. However, weak roof rock was falling out during mining. He discussed with GRI the possibility of leaving roof coal to prevent this. Prior experience had shown that roof coal would help support the weak rock. The plan was revised on January 18, 2007, to permit leaving roof coal. Where roof coal was left, the minimum length of bolt was required to be six feet.

Owens also observed that there was a need for roof-to-floor support in the crosscut between the Nos. 3 and 4 entries. Since the No. 4 entry was the future bleeder entry after pillar recovery started, he informed GRI that additional roof support would be needed in this crosscut for approval of the submitted pillar recovery plan. GRI submitted a revised pillar recovery plan that required a double row of timbers in the crosscuts adjacent to the bleeder entry.

North Barrier Section - Pillar Recovery Plan. Based on information furnished by GRI, AAI's ground control analysis, and visual observations during development, the pillar recovery plan for the North Barrier section (dated December 20, 2006) was approved on February 2, 2007. The plan showed the sequence of removing pillars from west to east and specified where coal was not permitted to be mined. The rows of pillars were to be extracted from south to north. Pillars between the Nos. 3 and 4 entries were not mined to establish a bleeder entry. Barrier mining was not permitted. A double row of roof-to-floor support, on four-foot maximum centers, was required to be installed outby the pillar line at the entrance to the crosscuts in the No. 4 entry.

MSHA personnel did not visit the North Barrier section during pillar recovery. Coal outburst accidents occurred on this section on March 7 and 10. GRI did not immediately contact MSHA at once without delay and within 15 minutes at the toll-free number, 1-800-746-1553, following both of these accidents as required by 30 CFR 50.10. On March 12, 2007, GRI contacted MSHA District 9 personnel by telephone to request approval to move the bleeder measurement point location outby. The proposed location was in the No. 4 entry, adjacent to the pillar line, because the bleeder entry had been damaged by the coal outburst accident. An MSHA inspection was not conducted in the area affected by the accident. MSHA denied the request because the bleeder could not be properly evaluated at the proposed measurement point location. The section was abandoned and sealed.

South Barrier Section - Development Plan. On March 8, 2007, prior to the accident that stopped pillar recovery in the North Barrier section, a plan for developing the South Barrier section (dated February 20, 2007) was approved. The plan allowed development of four entries through the barrier. The plan specified a minimum of 80-foot entry centers and 90-foot crosscut centers, which could vary depending upon conditions. A 55-foot barrier was required to the north. No width was specified for the barrier to the south.

Density of the primary roof support during development of the South Barrier section was six bolts per row with a maximum distance of five feet between rows. The entries and crosscuts would be mined a maximum of 20 feet wide. Roof coal could be left in areas where weak immediate roof was encountered.

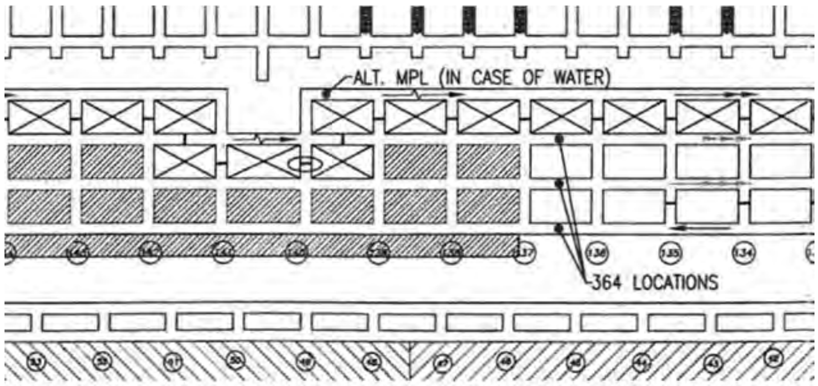
At the end of March 2007, development mining began in the South Barrier section under the approved roof control plan. The North Barrier coal outburst accidents had prompted the operator to have AAI reevaluate mining of the South Barrier section. While AAI was performing their analysis, mining was conducted in relatively shallow overburden in the vicinity of crosscuts 108 to 115. Although AAI considered designs based on 35 feet (measured from the Main West notches) and 137 feet wide barriers, mining in this area established the barrier widths at 55 and 121 feet. AAI completed their analysis as mining progressed to crosscut 118. AAI's recommendations for pillar recovery were: to increase pillar centers from 80 x 92 feet to 80 x 129 feet, to recover the pillars as completely as is safe, to slab the south side barrier, and to avoid skipping pillars under the deepest cover (refer to Appendix I). Based on these recommendations, development mining to the west of crosscut 118 was established on 80 x 130-foot centers.

South Barrier Section - Pillar Recovery Plan. On May 16, 2007, GRI submitted site-specific amendments to the roof control and ventilation plans to permit pillar recovery of the South Barrier section. They also provided MSHA with a copy of the AAI report for pillar recovery in the South Barrier section. Maps included with both proposed plans were consistent in showing that no pillars would be recovered immediately adjacent to the bleeder entry. In the three-entry portion of the section between crosscuts 139 and 142, both proposed plans showed slab cuts from the barrier pillar south of the No. 1 entry, as well as recovery from those pillars between the No. 1 and No. 2 entries.

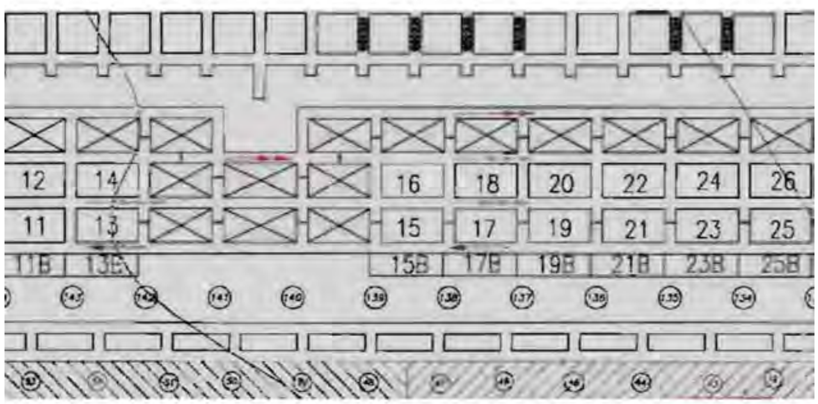
On May 22, 2007, Owens and Gary Jensen visited the South Barrier section to observe conditions and evaluate the adequacy of the proposed roof control plan amendment. Owens determined that pillars were yielding closer to the face and that pillars outby appeared to be more stable than he had observed during his visit to the North Barrier section. He interpreted these observations to be favorable. However, he expressed concern that any pillar recovery in the area between crosscuts 139 to 142 could jeopardize bleeder stability and suggested that no pillar recovery be conducted in this area. The following day, GRI submitted a revised roof control plan for recovering the South Barrier section. The revised plan showed that no pillars would be recovered between crosscuts 139 and 142, and no slab cuts would be mined from the barrier pillar south of the No. 1 entry. The proposed ventilation plan for recovering the South Barrier section was not revised, resulting in differences between the maps in the proposed plans (see Figure 82). However, the ventilation plan addendum did contain a provision stating: *"This plan is for the ventilation for the pillar recovery of the developed area of the south barrier block…The pillar recovery proposed by this plan will be done in accordance with the approved Roof Control Plan."* Accordingly, the pillar recovery sequence was not shown on the map included with the site-specific ventilation plan, giving preference to relevant portions of the roof control plan. The ventilation plan for South Barrier pillar recovery was approved on June 1, 2007.

The revised roof control plan for pillar recovery of the South Barrier section was approved on June 15, 2007 (see Appendix J). Measurements from the scaled map included with this roof control plan addendum indicated that the pillars were to be mined on 80 x 130-foot centers. The plan also showed the sequence of removing pillars from west to east and specified where coal was to be left unmined. The rows of pillars were to be extracted from south to north. To protect the No. 4 bleeder entry, the northern-most pillars were not recovered.

A 55-foot barrier between the South Barrier section No. 4 entry and the sealed Main West notches was also required to be left unmined. The roof control plan permitted a maximum 40-foot cut from the last row of roof bolts into the barrier south of the No. 1 entry. A double row of roof-to-floor support (timbers) was also required to be installed at the entrance to crosscuts in the No. 4 entry for additional bleeder protection. These timbers were required to be set a maximum of four feet apart with a minimum of four per row.



Portion of mine map from ventilation plan approved June 1, 2007 showing pillar and barrier mining from crosscuts 139 to 142 allowed.



Portion of mine map from roof control plan approved June 15, 2007 showing pillar and barrier mining from crosscuts 139 to 142 not permittted.

Figure 82 - Comparison of South Barrier Roof Control and Ventilation Plans

Mine management was made aware of the approved roof control plan requirements by the UEI engineering staff, who routinely provided the mine with 1":100' scaled section maps of projected mining. This map (referred to as a “mark up map”) was posted in the records room and additional copies were provided to section foremen. Section foremen placed temporary notations on the posted mark up map showing mining progress at the end of each shift. Periodically, engineers would exchange new mark up maps for older copies, from which they would incorporate the temporary notations into the up-to-date map of the entire mine.

The initial South Barrier section mark up map showed the pillar recovery sequence from crosscut 149 to crosscut 142. On July 31, 2007, as pillar recovery approached crosscut 143, Gary Peacock emailed David Hibbs (manager of engineering), *“We need an updated mark up map at Crandall showing the pillars that will be left in the area were there is only 3 entries.”* Hibbs replied, *“Gary, I feel we need to leave all rows in the area of 3 entries and also delete the barrier. Do you have any thoughts?”* Peacock answered, *“I think we should take the barrier.”* Hibbs responded to Peacock: *“Gary, This is the drawing in approved Roof Control Plan for that* *area."* Hibbs attached a copy of the pillar extraction map from the approved roof control plan and included Shane Vasten (surveyor) in his email response to Peacock. Later that evening, Vasten emailed Peacock and Hibbs: *"Gary, Here is a mark up map for you to look at based on the latest approvals forwarded to me from Dave. If you have any questions/concerns, get with Mr. Hibbs. Ace and I will be there tomorrow doing month end. I will check with you then to see if any changes need to be made. I will also plot more maps for you then. I just wanted to send you this one so you can be looking it over."* Between crosscuts 142 and 139, the attached mark up map (see Figure 83) correctly showed that no pillars were to be recovered and the barrier was to remain unmined south of the No. 1 entry (as indicated by the standard symbol X in the pillars) in accordance with the approved roof control plan. Interview statements, belt scale records, shift foremen's reports, and production records revealed that the barrier south of the No. 1 entry between crosscuts 139 and 142 was, nonetheless, mined.

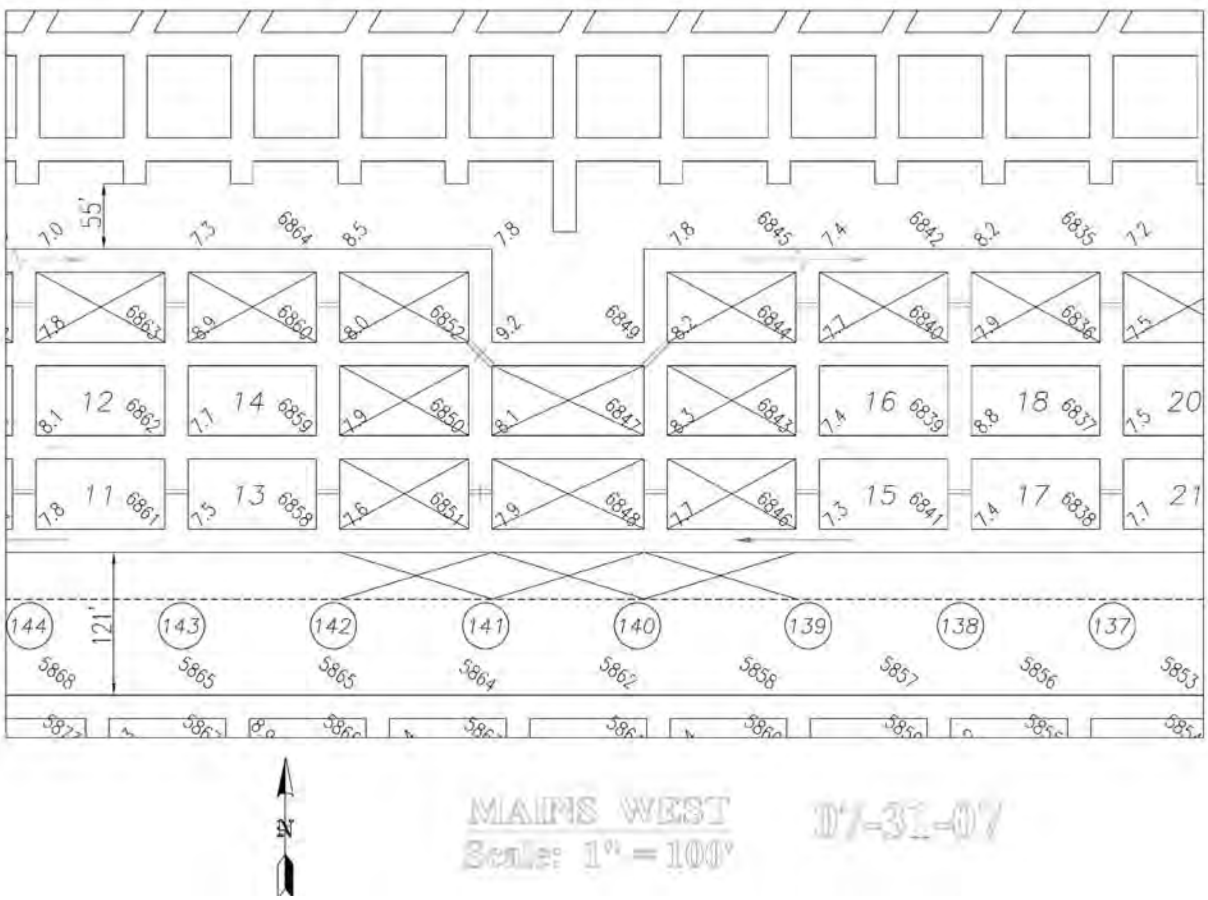


Figure 83 - Mark Up Map Provided to Mine Management on July 31, 2007

Roof control plans as required by 30 CFR 220(a) (1) must be developed and followed by the mine operator and be suitable for the prevailing geologic conditions and the mining system to be used at the mine. MSHA approved site specific roof control plans for pillar recovery in the North and South Barrier sections by considering observed mining conditions and AAI's analyses of mine stability provided to MSHA by GRI. Although no adverse conditions were observed when MSHA roof control specialists visited the sections during development mining, adverse conditions were encountered during pillar recovery on both sections, including coal burst accidents on at least three occasions: March 7, March 10, and August 3. Prior to the March 10 and August 6 accidents, miners were struck by coal, ventilation was impaired, regular mining was disrupted, and equipment was damaged, indicating that the roof control plan was not suitable for controlling the roof, face, ribs, or coal bursts. While recovering pillars in the South Barrier section, miners recognized that ground conditions were similar to those that forced abandonment of the North Barrier section. Although these similar conditions indicated that the roof control plan was inadequate, revisions to the plan were not proposed by GRI and mining was allowed to continue until the August 6 accident.

Summary – Critique of Mine Design

ARMPS and LaModel analyses were conducted by AAI to evaluate the stability of mine designs proposed for development and recovery of pillars in the North and South Barrier sections. Although AAI concluded that the designs should function adequately, mining in each area ended in failure. A review of input files, model results, notes, and various types of correspondence indicates that the analyses were flawed and relied on overly optimistic assumptions. Furthermore, the South Barrier section was evaluated using essentially the same models that had proved to be unreliable in the North Barrier section analyses. An AAI ARMPS analysis that showed the design was inadequate was not included in the report that GRI furnished to MSHA.

The roof control plan, developed by GRI using AAI's mine design, was not suitable to the prevailing burst prone ground conditions and the pillar recovery system used in the North and South Barrier sections. Accident experience at the mine included at least three coal outburst accidents in the North and South Barrier sections prior to August 6. The accident on August 3, 2007, showed that conditions on the South Barrier section were similar to those preceding the March 10 accident. Following the August 3 accident, GRI did not propose revisions to the roof control plan when conditions and accident experience indicated the plan was inadequate and not suitable for controlling coal bursts on the South Barrier section. Instead, GRI resumed mining in a manner that did not comply with the approved roof control plan. Continued pillar recovery prior to taking corrective actions following the August 3 accident exposed miners to hazards related to coal bursts.

An analysis of MSHA's roof control plan review process is beyond the scope of this report. MSHA's procedures for determining if mine operators are complying with relevant requirements of 30 CFR and the Mine Act will be addressed in the findings of an independent review team.

Mine Ventilation

Mine Ventilation System

Figure 84 depicts a simplified schematic of the mine ventilation system based on air measurements recorded during the week prior to the accident. The mine was ventilated by exhausting fans. Mine openings consisted of five drift openings. From left to right, the first drift served as the entrance to an underground bath house and provided a small amount of intake air. The second drift served as the main intake and travelway. The third drift contained the belt conveyor. Return air exited the mine through the fourth drift. A stopping was erected in the fifth drift to separate the return air course from the surface.

According to the weekly examination record book, in the week preceding the August 6, 2007, accident, 220,806 cfm of air was entering the mine through the main intake. An air quantity of 252,216 cfm was exiting the mine through the return drift and main fans. The quantity entering the belt haulage entry and the bath house entrance were not recorded in the weekly examination book. A revised ventilation map received on July 2, 2007, indicated that 31,036 cfm of air entered the mine through the belt drift and 5,200 cfm entered through the bathhouse.

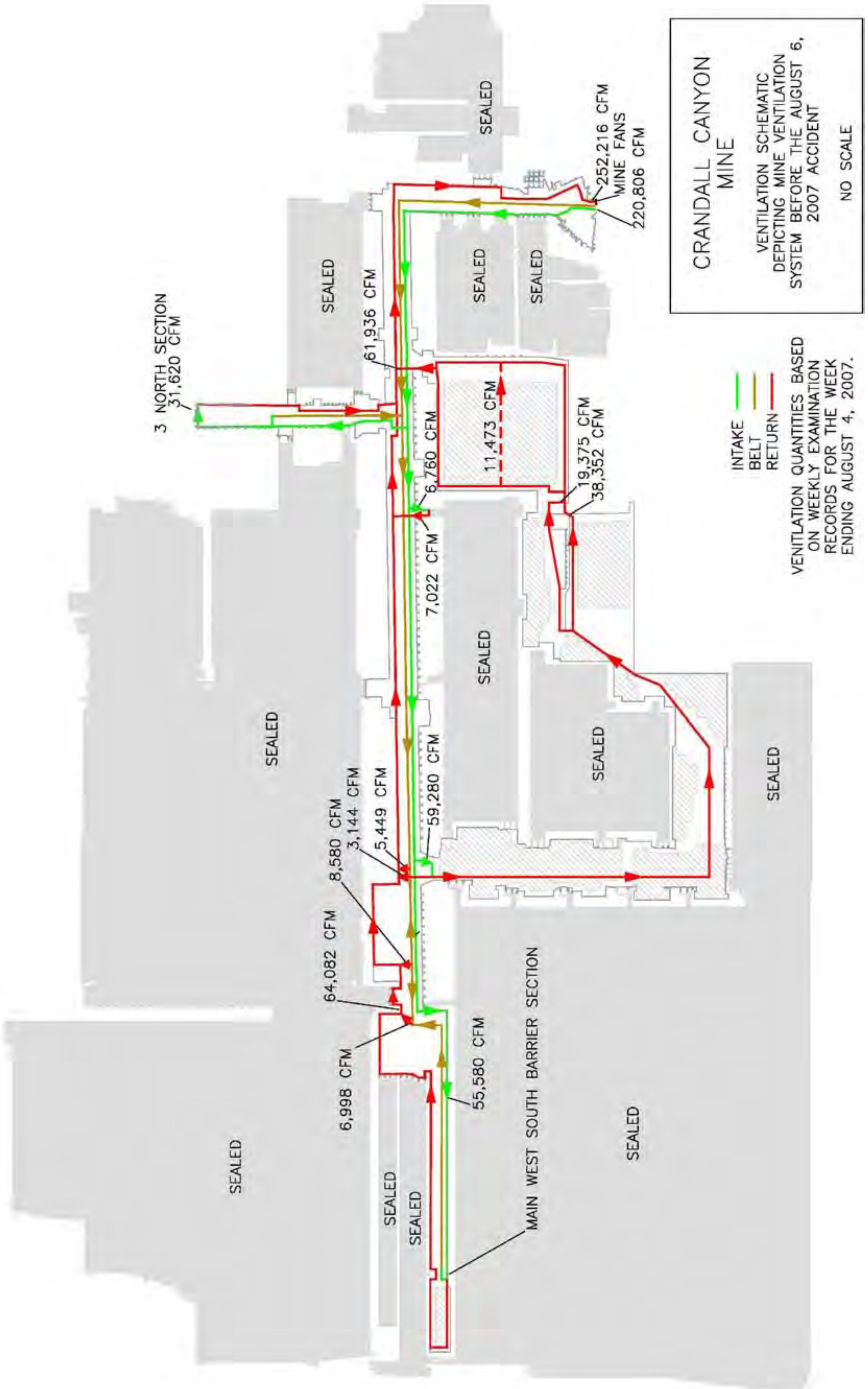


Figure 84 - Ventilation System before August 6 Accident

The main fan installation consisted of four main fans. Two parallel sets of two fans in series were utilized. Documents provided by the operator indicate that an original installation of two fans in parallel had been upgraded by installing additional fans in series resulting in the four fan system. The fan system capacity was stated in the ventilation plan as 300,000 cfm, with 150,000 cfm being provided by each set of fans. The actual operating point of the fan system prior to the accident was 252,216 cfm at a pressure of 6.5 inches of water gauge.

At the time of the accident, the ventilation system consisted of three main air splits: the 3rd North section, the completed South Mains pillar recovery section, and the South Barrier section. Only the South Barrier section was active. A minimum of 15,000 cfm of air was required by the mine ventilation plan at the intake end of the pillar line. Records indicate that 51,340 cfm was provided. A discussion of the ventilation plan is included in Appendix X.

Post-Accident Mine Ventilation

The effect of the August 6, 2007, accident on the mine ventilation system was significant. The initial air blast and burst coal pillars destroyed or damaged stoppings from the accident site outby to crosscut 93 and the overcasts at crosscut 90 and 91. The damage short-circuited ventilation inby that point.

The short circuiting of air affected the main fan pressure. Figure 85 shows the fan pressure recorded by the mine monitoring system for the time period immediately before and after the accident. Also, the daily fan examination record book indicated 6.5 inches of water gauge (w.g.) for fans 1 and 2 and 6.25 inches w.g. for fans 3 and 4 on the previous day. A pressure of 5.25 inches w.g. for fans 1 and 2 and 5.5 inches w.g. for fans 3 and 4 was recorded after the accident. This was an average decrease of 1.0 inches w.g. after the accident.

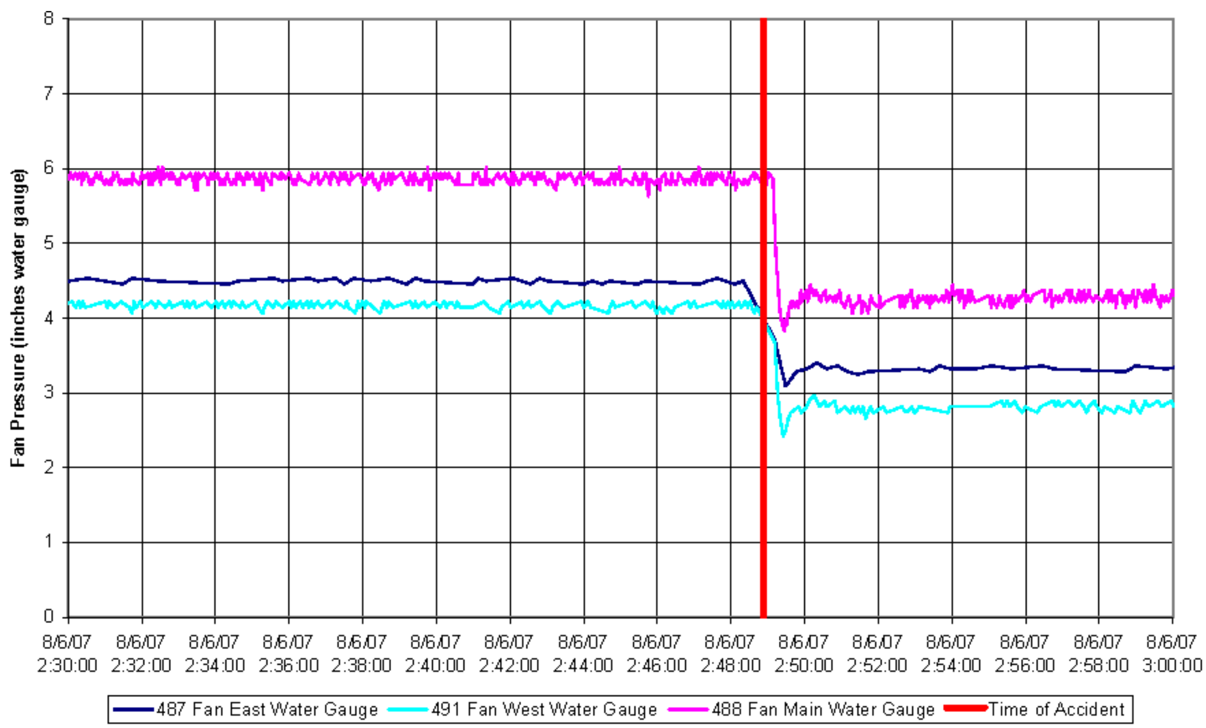


Figure 85 - Fan Pressure at the Time of the August 6 Accident

Curtains were installed in place of the damaged permanent ventilation controls up to the rescue work site in the hours following the August 6 accident. The subsequent burst at 1:13 a.m. on

August 7 damaged many of these temporary ventilation controls. The temporary controls were then replaced with permanent stoppings. These permanent stoppings were completed prior to resuming rescue efforts. Figure 86 shows the locations of stoppings damaged in the August 6 accident and the stopping configuration after the August 16 accident.

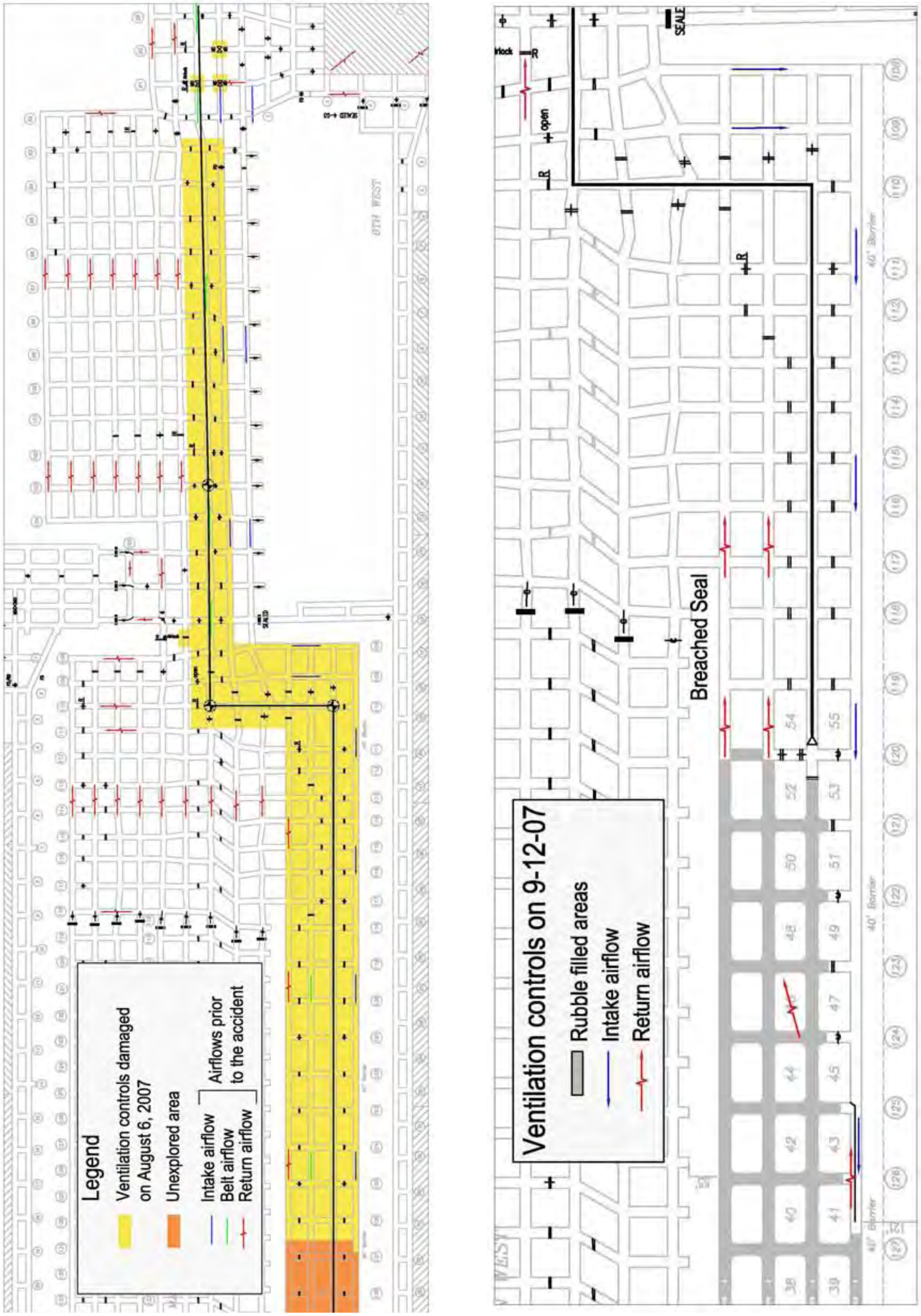


Figure 86 - Ventilation Controls after Accidents

Originally, the South Barrier section No. 3 entry was in common with the belt entry. As ventilation controls were reestablished, the No. 3 entry was utilized as a return air course. Stoppings were erected between the No. 2 and 3 entries. A feeder was set in the No. 2 entry between crosscuts 119 and 120. The stoppings between the intake and belt entries (No. 1 and No. 2) were reestablished up to crosscut 120. Crosscut 120 was left open to serve as the haul road to the feeder. A stopping was built across the No. 2 entry inby crosscut 120. Inby that point, the No. 1 entry served as the intake and the Nos. 2, 3, and 4 entries served as returns.

As material was loaded and the rescue operation advanced, ventilation controls were erected in the crosscuts between the No. 1 and No. 2 entries. The last crosscut outby the clean-up area was left open to serve as a connection to the return air course. Line curtain was used to ventilate to the clean-up area during the rescue operation.

Ventilation in Area of Entrapment

It was unlikely that any ventilation was reaching the working area of the South Barrier section immediately after the August 6 accident. When boreholes were drilled into the South Barrier section, outside air entered the holes due to the negative pressure of the exhausting ventilation system. This indicated that some borehole air could be drawn through the collapse area. Later, air was injected into some holes to provide breathable air to potential survivors. Initially the other holes continued to intake. However, when the injected air volume was increased, air exited from the other boreholes. The air being injected (2,000 to 3,000 cfm) exceeded the air quantity returning to the mine ventilation system. This observation shows that the rubble from the collapse severely restricted air flow to the South Barrier section.

On the morning of August 6, rescuers attempted to pump breathable air to the section from underground. A compressor was used to force air through the fresh water pipeline running along the South Barrier section belt. Since the pipeline was likely damaged by burst material between crosscut 120 and the working section, the air may not have reached the work area.

Air Quality in South Barrier Section Pillar Recovery Area

Before the accident, preshift examination records for the South Barrier section indicated air quality of 20.9% oxygen (O_2), 0% methane (CH_4), and 0 ppm carbon monoxide (CO). After the accident, oxygen deficiency as low as 16% was encountered. Samples from Borehole No. 1 taken at 9:57 p.m. on August 10, 2007, indicated 7.46% O_2, no detectable amount of CH_4, 141 ppm CO, and 0.58% CO_2. Exposure to this atmosphere will result in vomiting, unconsciousness, and death. Higher oxygen concentrations were detected in Borehole Nos. 3 and 4. However, no evidence of the miners was observed in these boreholes. It is likely the entrapped miners were exposed to an atmosphere similar to that observed in Borehole No. 1.

Had the miners survived the initial catastrophic ground failure, oxygen deficiency would have contributed to their deaths. Table 11[16] lists effects of exposure to reduced oxygen. These effects would occur at increased oxygen concentrations at higher altitudes. Figure 87[16] shows the time of useful consciousness versus oxygen concentration. At 7.5% O_2, the time of useful consciousness is just over one minute. The time of useful consciousness is the time after exposure to oxygen deficiency during which a person can effectively take corrective action such as donning an SCSR before impairment or unconsciousness occurs.

Table 11 - Effect Thresholds for Exposure to Reduced Oxygen

% O_2 by Volume	Effect
17	Night Vision Reduced, Increased Breathing Volume, Accelerated Heartbeat
16	Dizziness
15	Impaired Attention, Impaired Judgment, Impaired Coordination, Intermittent Breathing, Rapid Fatigue, Loss of Muscle Control
12	Very Faulty Judgment, Very Poor Muscular Coordination, Loss of Consciousness, Permanent Brain Damage
10	Inability to Move, Nausea, Vomiting
6	Spasmatic Breathing, Convulsive Movements, Death in 5-8 Minutes

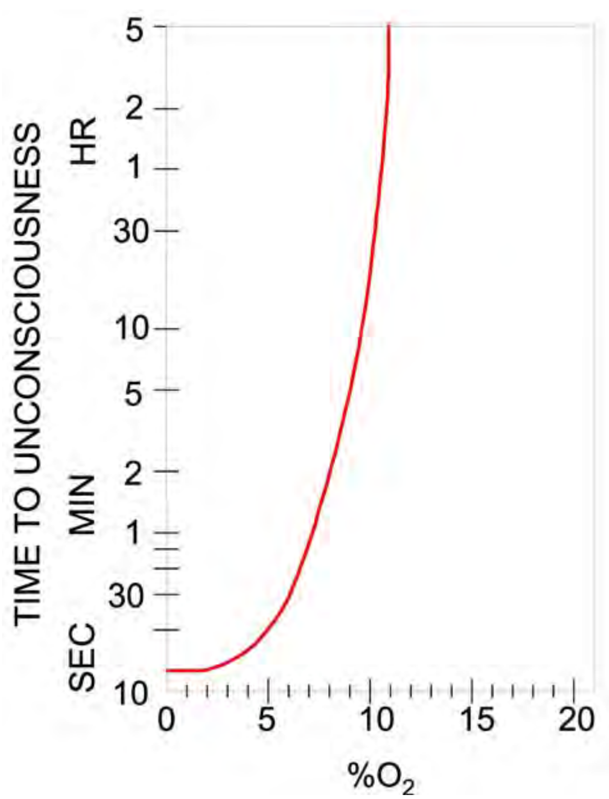


Figure 87 – Approx. Time of Useful Consciousness vs. Oxygen Concentration For Seated Subjects at Sea Level. Adapted from Miller and Mazur[16]

Three sources of the oxygen deficiency detected in the South Barrier section after the accident were considered:

- Release of in situ gasses from the coal seam,
- Oxidation of the coal during the initial catastrophic pillar failure, and
- Breaching of one or both of the barrier pillars to the north and south of the section.

At other mines, low oxygen concentration has been reported to have occurred after coal bursts. However, reports of these accidents also indicated that the oxygen was displaced by a release of methane gas. Several samples taken from boreholes after the August 6 accident contained methane concentrations below 0.1%. The remaining samples contained no detectable amount. No report of oxygen deficiency was recorded for the preshift examination conducted after the March 10, 2007, outburst accident, nor was there any indication of oxygen deficiency from interview statements.

During development of Main West, approximately between crosscuts 73 and 78 and at the mouth of 1st North, gasses were liberated during mining that created a detectable amount of oxygen deficiency. The gasses present were unknown and appeared to be related to a change in the immediate roof confined to that area. The oxygen deficiency was detectable only by placing a detector directly against a freshly exposed coal rib and it did not affect normal mining. This phenomenon was not reported to have been observed in any other part of the mine. The accident site was located approximately one mile west of this area. It is unlikely that the oxygen deficiency resulted from gasses released from the coal at the August 6 accident site. No incidents of oxygen deficiency were reported during the development or pillar recovery of that area or immediately after the March 10, 2007, outburst accident in the North Barrier section.

It is also unlikely the oxygen deficiency was caused by oxidation of coal during the initial catastrophic pillar failure. The oxygen level dropped from 20.9% to approximately 7.5%. Any rapid oxidation would have generated high levels of carbon monoxide (CO) and carbon dioxide (CO_2). Gas analysis of samples collected from boreholes indicated concentrations of approximately 140 ppm CO and 0.6% CO_2. While these concentrations are above normal levels, they cannot account for a 13% drop in oxygen levels. Also, no reports were made of any other products of oxidation or combustion detected by instruments or smell during rescue efforts.

The areas to the north and south of the South Barrier section were both sealed at the time of the accident. Mining had been completed and the areas were sealed for several years. Oxygen deficiency was known to exist behind the seals in these areas, based on samples collected during previous examinations.

During the rescue attempt, the Main West No. 1 seal was breached. Air samples were collected of the atmosphere in the sealed area. Air samples were also collected from the Panel 13 sealed area atmosphere at crosscut 107, the South Barrier section during the rescue attempt, and from boreholes drilled into the inby end of the section. Table 12 shows selected results from gas chromatograph analysis of the air samples.

Table 12 - Results of Air Sample Analysis

Location	Date & Time	H_2 ppm	O_2 %	N_2 %	CH_4 %	CO ppm	CO_2 %	C_2H_2 ppm	C_2H_4 ppm	C_2H_6 ppm	Ar %
Main West Seal 1	08/12/07 20:30	4	7.78	89.46	NDA	152	1.81	NDA	NDA	NDA	0.93
Main West Seal 1	08/14/07 15:00	5	6.14	90.94	0.01	186	1.96	NDA	NDA	NDA	0.93
Main West Inby Seal 1	08/16/07 14:40	5	4.27	92.57	0.01	204	2.19	NDA	NDA	NDA	0.93
Panel 13 xc 107 seal	01/00/00 00:00	NDA	19.45	79.02	NDA	4	0.6	NDA	NDA	NDA	0.93
Panel 13 xc 107 seal	01/00/00 00:00	NDA	19.39	79.07	NDA	5	0.61	NDA	NDA	NDA	0.93
126 xc#4 Entry	08/10/07 14:00	2	20.95	78.02	NDA	7	0.1	NDA	NDA	NDA	0.93
126 xc#4 Entry	08/10/07 15:58	2	20.95	78.02	NDA	8	0.1	NDA	NDA	NDA	0.93
No 2 Entry	08/10/07 19:15	1	20.95	78.04	NDA	6	0.08	NDA	NDA	NDA	0.93
50 feet inby xc 123	08/10/07 19:20	2	20.95	78.03	NDA	10	0.09	NDA	NDA	NDA	0.93
65 feet inby xc 119	08/10/07 19:25	2	20.95	78.04	NDA	8	0.08	NDA	NDA	NDA	0.93
Borehole No. 1	08/10/07 16:04	88	7.61	90.86	NDA	146	0.56	NDA	NDA	NDA	0.93
Borehole No. 1	08/10/07 16:07	78	7.58	90.90	NDA	140	0.56	NDA	NDA	NDA	0.93
Borehole No. 1	08/10/07 21:57	79	7.46	91.00	NDA	141	0.58	NDA	NDA	NDA	0.93
Borehole No.3	08/16/07 06:00	2	16.88	81.86	0.02	21	0.3	NDA	NDA	40	0.93
Borehole No.4	08/18/07 19:15	3	11.97	86.52	0.04	31	0.53	NDA	NDA	30	0.93

NDA = No Detectable Amount

Before and after the August 6 accident, handheld gas detectors were used to monitor gas concentrations in the Panel 13 sealed area to the south and the Main West sealed area to the north. Samples were drawn from pipes installed through seals. Measurements were also made by handheld gas detectors inby the breached seal in Main West during the rescue operation. These concentrations are shown in Table 13.

Table 13 - Handheld Gas Detector Concentrations

Location	Date	O_2	CH_4	CO	Gas Direction
Crosscut 107 Seal (Panel 13)	6/18/2007	1.2	0.0	-	out
Crosscut 107 Seal (Panel 13)	6/19/2007	20.9	0.0	-	in
Crosscut 107 Seal (Panel 13)	6/20/2007	20.9	0.0	-	in
Crosscut 107 Seal (Panel 13)	6/21/2007	1.1	0.0	-	out
Crosscut 107 Seal (Panel 13)	6/27/2007	0.7	0.0	-	out
Crosscut 107 Seal (Panel 13)	7/4/2007	2.6	0.0	-	out
Crosscut 107 Seal (Panel 13)	7/11/2007	0.0	0.0	-	out
Crosscut 107 Seal (Panel 13)	7/18/2007	0.8	0.0	-	out
Crosscut 107 Seal (Panel 13)	7/25/2007	0.4	0.0	-	out
Crosscut 107 Seal (Panel 13)	8/1/2007	0.4	0.0	-	out
Crosscut 107 Seal (Panel 13)	8/8/2007	20.9	0.0	-	in
Crosscut 107 Seal (Panel 13)	8/15/2007	7.0	0.0	-	out
Crosscut 107 Seal (Panel 13)	8/29/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	6/18/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	6/19/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	6/20/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	6/21/2007	10.1	0.0	-	out
Crosscut 118 Center (Main West)	6/27/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	7/4/2007	20.8	0.0	-	in
Crosscut 118 Center (Main West)	7/11/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	7/18/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	7/25/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	8/1/2007	20.9	0.0	-	in
Crosscut 118 Center (Main West)	8/8/2007	20.6	0.0	-	out
Behind #1 Seal (Main West)	8/6/07 13:30	6.8	0.0	57	-
#1 Seal (Main West)	8/6/07 15:15	8.0	-	-	out

Gas concentrations measured at the seals varied due to the pressure differential. This is typical of sealed areas. The change in pressure differential direction is related to normal changes in barometric pressure. All seals leak some amount and during a rise in barometric pressure air will typically leak into the sealed area and samples will indicate higher oxygen content than representative of the atmosphere in the sealed area. When the barometric pressure decreases, the differential will reverse and out-gassing will occur. After enough time, samples will more accurately reflect the atmosphere behind the seal.

The results of bottle sample analyses and handheld detector gas concentrations indicated that the South Barrier section was bounded on both sides by sealed areas with oxygen deficient atmospheres. Leakage of normal air from the active areas into and out of the sealed areas can only increase the oxygen levels. Based on this fact, the most reliable samples were those with the lowest oxygen levels taken while the sealed areas were out-gassing. Oxygen concentrations in the Panel 13 and Main West sealed areas before the accident were near zero percent and four percent, respectively.

The level of oxygen in Borehole No. 1 drilled into the South Barrier section was approximately 7.5%. Earlier samples indicated higher concentrations. This was due to problems with the sample collection (i.e., plugged bit).

The oxygen concentrations from Boreholes Nos. 3 and 4 were approximately 17% and 12%, respectively. These holes were drilled into the bleeder entry at the back of the section. The higher concentration of oxygen indicated that a pocket of less contaminated air existed there. Borehole No. 3 was drilled in that location anticipating that such a pocket of breathable air might exist and provide a refuge for the entrapped miners. Although Borehole Nos. 3 and 4 contained high enough oxygen concentrations to sustain life, video images taken from the boreholes showed no indications that the miners had traveled to this area.

The most likely cause of the oxygen deficiency was a breach in the barriers separating the South Barrier section from the sealed Panel 13 area to the south and the Main West sealed area to the north. This conclusion is based on several factors. First, damage to the southern barrier was observed as a rib displacement of up to 10 feet into the No. 1 entry during the rescue work. Second, InSAR data indicates subsidence occurred over the barriers to the north and south. Third, the rapid convergence that occurred during the August 6 accident that created the air blast felt outby in the South Barrier section would have likely caused a similar flow of air from the sealed areas through the damaged barriers into the South Barrier section work area.

GRI and AAI did not give proper design consideration to implications of a barrier breach inby the working section. AAI's analysis focused on pillar stability at the pillar line. While it was apparent that the need for a ventilation barrier was recognized, the remnant barriers were not designed to be stable inby the pillar line. Interview statements by AAI engineers indicated that no consideration was given to maintaining the integrity of the remnant barrier as a ventilation separation between the gob and the sealed area. They acknowledged that the structural component of the remnant barrier was questionable and that it was not designed to carry the entire load. The stability of the barriers was critical to ensure that the miners were protected from lethally oxygen deficient atmospheres that were present in sealed workings to either side of the section.

Attempt to Locate Miners with Boreholes

A decision to drill boreholes into the mine was made early on August 6. Seven boreholes were drilled from the surface to the mine workings. The goal for drilling the boreholes was to locate the entrapped miners and assess conditions in the affected area. If miners were located, the boreholes could be used to provide communication, fresh air, and sustenance until they were rescued. GRI and MSHA jointly decided the location for each borehole.

Boreholes Drilled Prior to August 16

Three boreholes were completed and a fourth borehole was started prior to the August 16 accident. The location chosen for Borehole No. 1 was near the kitchen/transformer area (crosscut 138 in No. 3 entry) in the South Barrier section. This was the designated location that miners were to gather in the event of an emergency and the location of the pager phone. The drill rig for this borehole did not have directional controls and, as a result, intersected the mine opening at crosscut 138 in the No. 2 entry, which was 85 feet south of its intended location. Although the goal for this borehole was not met, the information obtained from it was useful. This small drill rig was used to drill Borehole No. 1 because it was immediately available and could be transported quickly to the drill site by helicopter. The mine void was 5.5 feet high at this location. The drill rod had a 2.25-inch outside diameter and 1.875-inch inside diameter. The drill rod and bit were left in the hole so that air samples could be taken through the rod's hollow drill stem.

Initial air samples collected from Borehole No. 1, at 12:00 a.m. on August 10, 2007, showed 20.73% oxygen. It was later discovered that the holes in the bit were clogged and the sample did not represent the true air quality in the mine. After the bit was flushed with water, another air sample was collected at 1:45 a.m. which indicated 8.17% oxygen. This concentration of oxygen would cause unconsciousness in about two minutes. Two down-hole cameras were on site. One was a four-inch diameter camera and the other a 2.5-inch diameter. Due to the small borehole diameter of 2.4 inches, neither camera was used.

The projected mine location for Borehole No. 2 was the No. 2 belt entry at crosscut 137, in the intersection outby the section feeder. The location for this borehole was chosen because it could be drilled from the same drill pad as Borehole No. 1 and, therefore, could be started immediately. This hole was one crosscut outby the location of Borehole No. 1. The mine void was determined to be 5.7 feet. Air was entering this borehole from the surface and therefore air quality analysis was not done at that time. Because of its proximity to the Borehole No. 1, the air quality was likely similar at the two locations. A compressor was used to pump fresh air through the borehole after video examination was completed.

On August 12, a camera lowered into Borehole No. 2 showed that the intersection was mostly open. A canvas bag was observed hanging from the mine roof and the intersection was largely free of rubble. This visual evidence reinforced the assumption that the entrapped crew might have made their way into an area where they could survive. It was also thought that open entries might exist inby the blockage at crosscut 126. However, additional observations on August 21 using brighter lighting and computer enhancements on August 22 revealed that while the intersection was open, severe damage was observed in the entries. Boreholes completed after August 16 and InSAR subsidence analyses also indicate that the collapse was more extensive than envisioned when Borehole No. 2 penetrated the mine level. It is now concluded that in areas of pillar collapse, the intersections may have some voids while the adjoining entries and crosscuts were rubble filled. There was little chance for a miner to survive at the Borehole No. 2 location because of the low oxygen content observed in Borehole No.1 and because the entries and crosscuts were partially filled with rubble from the collapse.

Irrespirable air sample results from Borehole No. 1 prompted rescue drilling in an area of the mine where the entrapped miners could have barricaded to survive these conditions. The location chosen for Borehole No. 3 was in the No. 4 bleeder entry of the South Barrier section at crosscut 147 because it was considered a likely location for barricading. Also, the position for this hole was under the area of lower cover (1,400 feet) where collapsed ground was less likely to occur. The full entry height of 8 feet was encountered at this location. A camera lowered into this borehole revealed that the pillars had sloughed but the entries and crosscut were open. Analysis of an initial air sample showed 16.88% oxygen. The air quality and mine condition indicated that a miner could survive at this location, which encouraged further rescue efforts underground and from the surface. Borehole No. 3 also reinforced the concept that open entries existed inby the blockage at crosscut 126. A later attempt to lower a robot into the mine through Borehole No. 3 was unsuccessful because the borehole became blocked.

Boreholes Drilled After August 16

After underground rescue efforts were suspended, the focus turned to searching for the entrapped miners solely by drilling boreholes. If miners were found, a special drill rig, large enough to drill a 30-inch diameter hole, would be acquired to drill a hole of sufficient diameter for the mine rescue capsule.

Borehole No. 4 was being drilled at the time of the August 16 accident. The location for Borehole No. 4 was in the No. 4 bleeder entry, crosscut 142, of the South Barrier section, five crosscuts outby Borehole No. 3. This location was chosen because a pattern of noise was detected by MSHA's seismic location system. Although this noise was considered too strong to be signals from the entrapped miners, to be certain, the borehole was drilled at the location of the noise. After penetrating the mine on August 18, the miners were signaled by striking the drill steel and setting off explosive charges. No response was detected. The mine void was 4 feet at this location. Analysis of the initial air sample showed 11.97% oxygen in the mine. A camera lowered into the borehole revealed that the entries and crosscut were partially filled with rubble. The air quality and mine condition indicated that there would be a very low possibility of survival at this location. Therefore, it was concluded that the noises detected by the MSHA's seismic system were not made by entrapped miners.

On August 30, 2007, a robot was lowered into the mine through Borehole No. 4. The prototype robot lacked vertical clearance and was only able to travel a short distance in the mine. It was unable to explore the area around the borehole. No information useful to the rescue efforts was gained from the robot.

The location for Borehole No. 5 was in the No.1 intake escapeway entry of the South Barrier section at crosscut 133. This location was chosen because it is an area where the entrapped miners could have tried to escape after the accident. The mine void was 0.5 feet at this location. An attempt to lower a camera to the mine level was aborted because the borehole was blocked with mud and water at 511 feet, more than 1,500 feet above the mine level. There would have been no chance of survival at this location because the entry was filled with rubble.

The location chosen for Borehole No. 6 was near the last known area where mining was taking place in the South Barrier section. The borehole intersected the mine in the No. 1 entry between crosscuts 138 and 139. There was no mine void at this location. Based on the material encountered during drilling, these conditions appeared to rescue workers to be similar to the packed rubble encountered near crosscut 124 where the barrier had shifted violently into the No. 1 entry. The material at mine level was so compacted that water flowing down the borehole could not flow into the mine and backed up approximately 100 feet into the borehole. Consequently, when a camera was lowered into the borehole, it encountered mud and water approximately 100 feet from the mine level and could not be lowered any further. There would have been no chance of survival at this location.

The location chosen for Borehole No. 7 was in the kitchen/transformer area of the South Barrier section, No. 3 entry between crosscuts 138 and 139. This was near the area in which Borehole No. 1 was intended to intercept the mine. A 7-foot rubble depth and a 2.7-foot void height were encountered. An attempt to lower a camera into this borehole was stopped because water and mud had blocked the hole approximately 9 feet from the mine level. The material at mine level was so compacted that water flowing down the borehole could not flow into the mine and backed up into the borehole. There would have been no chance of survival at this location because the entry was nearly filled with rubble. After drilling the seventh borehole, a decision was made to discontinue all drilling.

It was feasible to acquire a special drill rig and drill a 30-inch diameter rescue hole. However, the rubble seen through Borehole Nos. 5, 6, and 7 showed that pillar failure was extensive in the South Barrier section from crosscut 139 to where rescue operations began at crosscut 120. Rescue workers lowered into the region with the rescue capsule would be forced to clear material by hand wearing a breathing apparatus and that process could trigger another burst. The strata above the mine were considered to be unstable with a high probability that the hole could collapse. Evidence of the strata instability was demonstrated by the fact that some of the 8-inch boreholes collapsed. Consequently, the rescue capsule option was considered to be too dangerous and constituted an unacceptable risk to rescue personnel.

Decision makers at the accident site relied on limited information available from boreholes to determine conditions in the affected area. Only one rig was used to drill boreholes after Borehole No. 1 intersected the mine. If two directional drill rigs had been used after completion of Borehole No. 1, five boreholes would have been completed before the August 16 accident. If three directional drill rigs had been used, all seven boreholes would have been completed before the August 16 accident. Greater drilling resources would have provided information sooner for evaluating the potential success of continuing rescue efforts. Similarly, if better lighting and camera resolution (e.g., zoom capability) had been available, decision makers would have had more accurate and timely information.

<u>MSHA's Seismic Location Systems</u>

MSHA's seismic location system was deployed and arrived at the mine site 32 hours after the accident. The system was operational within another twelve hours. At the Crandall Canyon Mine, the system was near its operational limit. The depth of the mine near the accident site was 1,760 feet. The greatest depth the system has ever detected a signal was approximately 2,000 feet. This was during a test over an idle mine with ideal conditions.

The activity associated with rescue drilling interfered with the seismic location system. The steep terrain required extensive development of roads and drill pads to support the drilling. The earthwork and the drilling itself generated too much seismic noise to effectively monitor for any signals from the miners. At the sensitivity required to detect miners at that depth, even vehicular and pedestrian traffic interfered with the system. However, due to the fact that the system response to signals is primarily vertical, the underground rescue operations, 2,400 to 1,600 feet away horizontally, were not believed to be interfering with the system.

Because of the priority given to completion of the rescue boreholes, monitoring was essentially limited to the quiet times established after the completion of each borehole. Drilling and surface operations were not stopped to establish additional quiet times. A noise, which was interpreted as not characteristic of miners, was a factor in determining the location of Borehole No. 4. No other signals were detected. Other than the previously mentioned event, the system did not play a role in the rescue.

A portable seismic system was used underground. The range of the system is approximately 200 feet. The trapped miners were over 2,400 feet away. The system was deployed on a water pipe that extended towards the section in an attempt to expand the operational range. No signals were detected.

The extent of the collapse and the atmospheric analyses from boreholes indicated that the miners were likely incapable of signaling. If they survived the collapse, the atmosphere would have rendered the miners unconscious unless they immediately donned their SCSR units and retreated to the breathable air in the bleeder entry near Borehole Nos. 3 and 4. These boreholes did not indicate any evidence of the miners.

Emergency Response Plan

Section 2 of the Mine Improvement and New Emergency Response Act of 2006 (MINER Act) requires underground coal mine operators to have an Emergency Response Plan (ERP), which is to be approved by MSHA. The ERP in effect at the time of the accident was approved on June 13, 2007.

MSHA emphasizes that, in the event of a mine emergency, every effort must be made by miners to evacuate the mine. Barricading should be considered an absolute last resort and should be considered only when evacuation routes have been physically blocked. Lifelines, tethers, SCSRs, and proper training provide essential tools for miners to evacuate through smoke and irrespirable atmospheres.

The operator must periodically update the ERP to reflect: changes in operations in the mine, such as a change in systems of mining or mine layout, and relocation of escapeways; advances in technology; or other relevant considerations. When changes to the ERP are required, MSHA approval must be obtained before the changes are implemented.

Section 2(b)(2)(B)(i) of the MINER Act requires that the ERP shall provide for the evacuation "of all individuals endangered" by an emergency. The individuals covered by this provision do not include properly trained and equipped persons essential to respond to a mine emergency, as permitted in 30 C.F.R. § 75.1501(b).

The ERP established provisions for storage of Self-Rescuers, Lifelines, Post-Accident Communications, Post-Accident Tracking, Training, Post-Accident Logistics, Post-Accident Breathable Air, Local Coordination, and Additional Provisions. The Post-Accident Breathable Air provision of the plan had not been implemented at the time of the accident. It was required to be implemented within 60 days after the June 13, 2007, approval letter.

Notification

The ERP included a list of emergency responders that will be notified following an emergency: MSHA One Call 24/7, Ambulance 911, Police 911, Castleview Hospital, Emery Medical, Poison Control, and MSHA's Price Field Office. The list also included names and phone numbers of company officials, mine rescue teams, and several mine emergency equipment suppliers.

Five miners underground responded to the emergency. Soon after the accident occurred at 2:48 a.m., these men evaluated the mine conditions. They observed that numerous ventilation controls had been blown out and the entries leading into the section were blocked. They called Leland Lobato (AMS operator) at approximately 3:13 a.m., to relay this information and instructed him to notify Gary Peacock (superintendent), of the mine emergency. By this time, the underground miners making the call to the surface were aware that a mine emergency existed. Lobato briefed Peacock with the information that he had received from the men underground. He also told him that 18 minutes had passed since he lost communication with the section. At 3:25 a.m., Hardee was outside in the safety office gathering self contained breathing apparatus units that the men underground had requested. Before traveling underground he had a brief telephone discussion with Peacock, who was at his home, to apprise him of the situation. Peacock then called Bodee Allred (safety director) at 3:30 a.m. and apprised him of the accident. Peacock instructed Allred to mobilize the mine rescue team and to contact MSHA, in that order.

The call lasted five minutes. Allred called the mine rescue teams at 3:36 a.m. and MSHA's toll-free number for immediately reportable accidents at 3:43 a.m. More than 15 minutes had elapsed from the time that persons underground became aware of the emergency and the time that MSHA was notified.

Bodee Allred reported to MSHA's toll-free number operator that there was a bounce, that pillar recovery had been occurring in the mine, that they had an unintentional cave, and that they lost ventilation. He also reported that they did not know if it knocked out stoppings, that visibility was poor, and that miners could not see past crosscut 92. MSHA's toll-free number report form indicated no injuries, no death, no fire, and no one trapped.

Self-Rescuers

The operator provided CSE SR-100, Self-Contained Self-Rescuers (SCSR) for use as required by 30 CFR Part 75 requirements. The ERP defined storage and reliability requirements for the units. At the time of the accident, all SCSR units were located in the areas stipulated in the ERP.

Following the accident, five miners initiated a rescue attempt into the South Barrier section. Two miners used Dräger, 30-minute, self-contained breathing apparatus units (SBAs), two used the CSE SR-100, and one did not don any type of unit. Tim Curtis and Brian Pritt were trained to use the SBAs as members of the mine fire brigade. Tim Harper and Jameson Ward donned the SR-100s to cope with dust in the atmosphere. Harper and Ward stated that the SCSR units activated properly, and performed as expected without incident. Brent Hardee did not don any type of unit. During their attempt to advance into the section, the miners retreated after encountering low levels of oxygen and adverse ground conditions. The lowest oxygen level detected was 16.0%.

Post-Accident Logistics

The command center was located on the second floor of the warehouse building (AMS dispatcher and safety office) as required by the ERP. On August 6, the command center was established and manned by MSHA and GRI personnel to formulate the plans for the rescue operation and to coordinate initial exploration by mine rescue teams. Later, MSHA personnel were principally located in the MSHA mobile command center vehicle immediately adjacent to the warehouse, while the command center in the warehouse building was primarily manned by GRI. Both locations were linked to the underground communication system and to each other. Joint meetings between GRI and MSHA were held twice daily and more often when necessary. New or revised plans were formulated and approved by both groups, which would meet at either location. Separate locations for mine operator and MSHA personnel were not typical for past mine emergency command center operations.

The ERP detailed that the family accommodations will be located in the main shop on mine property. However, this location was not used. On August 6, 2007, the families were accommodated for a short time at the Senior Citizens Center in Huntington, Utah, and relocated later that day to the Canyon View Jr. High School in the same town. On August 18, 2007, family accommodations were established at the Desert Edge Christian Center Chapel, also in Huntington, and remained there until August 31, 2007, when all rescue operations were suspended.

Exceptional security and traffic control was provided by Emery County Sheriff Lamar Guymon and his department at the mine and at family accommodation sites. The Emery County Sheriff's Office also provided and manned a command vehicle that was stationed on State Route 31 at the entrance to the mine access road. Press conferences and accommodations were provided at this location.

The State of Utah also provided support during the rescue efforts. The Governor and his staff met with the family members and assisted with both the media and family briefings. The Department of Public Safety, through the Utah Highway Patrol, assisted the Emery County Sherriff with traffic control. The Division of Homeland Security provided transportation of supplies and equipment. The Department of Natural Resources assisted with media relations with the Director of the Division of Oil, Gas and Mining, John R. Baza, the senior state official on location for most of the rescue effort. The American Red Cross and the Salvation Army also provided assistance at the mine site and to the families during rescue efforts.

Lifelines

Directional lifelines were installed in the primary and secondary escapeways from the working section to the surface. The directional lifelines were marked with reflective material every 25 feet and had directional indicators showing the escape route at intervals no greater than 100 feet. The small end of the directional cone was facing inby. Before the accident, both lifelines had been installed. Lifelines outby the area affected by the accident were intact. At the edge of the collapse area, they extended inby above the rubble or were embedded into the top of the rubble.

Post-Accident Communication

The mine utilized two independent hardwired communication systems that were located in separate entries to provide redundant means of communication between the surface and persons underground. Each independent system consisted of a number of pager phones installed throughout the underground mine and linked to various locations on the surface. On the South Barrier section, one pager phone system was located in the primary escapeway, No. 1 entry, and the other was in the alternate escapeway, No. 4 entry. These two systems were in place before the accident.

Although not an MSHA requirement, a Personal Emergency Device (PED) system was used as an additional means of in-mine communication. The PED is a one-way communication system integrated with the miner’s cap lamp battery. The AMS operator is capable of sending text messages from the surface location to any miner that is carrying a PED unit. The receiving unit was not capable of verifying back to the sender that a message was received nor was it capable of transmitting messages.

The PED system was comprised of a surface computer and an underground computer/transmitter located at crosscut 44. A loop antenna was located in the Nos. 1 and 2 entries of Main West from the transmitter to Main West crosscut 107, to Main North crosscut 25, and back to the transmitter, a distance of approximately 4.8 miles. While the accident on August 6, 2007, damaged ventilation controls as far outby as crosscut 90, it did not appear that the loop antenna was damaged. Text messages were successfully received by rescuers during the initial rescue attempt. Because the PED system was still operational after the accident, it was likely that if the receiving unit Don Erickson was carrying was still operational, messages would have been received by the unit.

During the rescue operation, a two-way voice activated microphone was lowered into accessible boreholes that were open to the mine level. The microphone was turned on each time it was lowered into the mine void. No record was kept of exactly how long a microphone remained in each hole. The microphone was not removed until it was certain that no sounds of life were heard. If a mine pager phone was located anywhere near a borehole and the phone system had survived the accident, the microphone would have picked up any messages broadcast from the pager phones. During the listening time, no pager phone communication was heard. The accident involved all four entries leading into the South Barrier section. Because of the violent nature and magnitude of the burst, it is highly unlikely that this part of the pager phone system remained intact.

Post-Accident Tracking

The mine utilized a dispatcher system (AMS operator) to track miners underground by using a magnetic tracking board and later an electronic spreadsheet. There were five tracking zones from the portal to the South Barrier section. Pager phones were located at all zone intersections, the belt head of each section, belt flight transfer points, and in the bleeder travelway. All zone intersections were marked with placards. The magnetic tracking board was located at the AMS operator's station and when a person called out with their location, the AMS operator moved the magnetic strip with their name to that location on the board. Another magnetic board was located in a room in the underground mine office/bathhouse near the mine portal. This was used as the check-in, check-out board required by 30 CFR 75.1715. Before entering or leaving the mine, each person moved his/her nametag to correspond with their location. Based on company records and interviews obtained during the investigation, the system was effective on August 6. However, problems with the dispatcher system did occur during the August 16 accident, as discussed later in this report.

Local Coordination

A complete list of emergency responders and their phone numbers was included in the ERP. This list included MSHA's 1-800 number, mine management contact information, and mine rescue teams. The list also included contact information for mine emergency suppliers, including: mine drilling services, mining cranes, heavy equipment, nitrogen foam and generators, gas detection/ mine rescue equipment, and ventilation sealing services. Local emergency responders, including airlift providers, were familiar with the mine location, operation, and personnel.

On August 6, 2007, following the accident, Mark Toomer, AMS operator, called the Emery County Emergency Dispatcher at 3:52 a.m., and requested that an ambulance be sent to the mine for a possible mine emergency. The ambulance arrived on mine property at 4:22 a.m. escorted by an officer from the Emery County Sheriff's Office. The ambulance remained at the mine that day but was not needed.

Training

Training was provided in accordance with the ERP. The miners and mine managers who were interviewed were familiar with the ERP requirements and the operator's records documented that the required training was completed.

Post-Accident Breathable Air

The plan described the locations in the mine where post-accident breathable air is to be provided. It also discusses oxygen consumption rates, air supply, purging of the safe haven barricade, chemicals used for scrubbing carbon dioxide, and a map identifying locations of the supplies. The post-accident breathable air provisions were not required until 60 days following approval of the ERP, which was approved on June 13, 2007. At the time of the accident, the post-accident breathable air provisions of the ERP had not been implemented.

On August 9, 2007, the operator ordered two Strata Emergency Air/Barricade Skids, one 32-man unit and one 11-man unit from Strata Safety Products, LLC, of Jasper, Alabama, as documented by a purchase order. Delivery was expected in April 2008.

Additional Provisions

The plan identified additional materials that must be stored on an Emergency Materials Skid and/or trailer and its location. Some of these materials included: a first aid kit, roof jacks or timbers, wedges, tools, brattice material, and foam packs. A complete list was detailed in the approved ERP. The operator provided information showing that the skid was located near crosscut 122 and later moved to crosscut 113.

Family Liaisons

Under Section 7 of the Mine Improvement and New Emergency Response Act of 2006 (MINER Act), the Secretary of Labor established a policy that required the temporary assignment of a Department of Labor official to be a liaison between the Department and the families of victims of mine tragedies involving multiple deaths. It also requires MSHA to be as responsive as possible to requests from the families of mine accident victims for information relating to mine accidents. In addition, it requires that in such accidents, MSHA serve as the primary communicator with the operator, miners' families, the press, and the public.

MSHA personnel were assigned as family liaisons to establish communication with the victims' families. They were: William Denning, District 9 Staff Assistant; Carla Marcum, District 7, Specialist; Robert Gray, District 10, Health Supervisor; and Richard Laufenberg, Metal/Non-Metal Rocky Mountain District, Assistant District Manager. These individuals were specially trained by the National Transportation Safety Board to serve as family liaisons between MSHA and families during mine accidents involving fatal injuries or where miners are unaccounted for. They maintained constant contact with family members and met with them for regular briefings to provide updates and answer questions. These designated family liaisons were assisted by other MSHA personnel in support of the victims' families' needs. Also, the Assistant Secretary of Labor, the Administrator for Coal Mine Safety and Health, and the District 9 District Manager played key roles communicating with the operator, miners' families, the press, and the public.

MSHA's Lead Accident Investigator regularly conducted family briefings in person and by telephone during the weeks and months following the accident. These briefings provided the families an opportunity to follow the progress of the investigation, to ask questions and to contribute any information to the investigation.

Mine Emergency Evacuation and Firefighting Program of Instruction

Section 30 CFR 75.1502 requires each operator of an underground coal mine to adopt and follow a mine emergency evacuation and firefighting program that instructs all miners in the proper procedures they must follow if a mine emergency occurs. MSHA approved the Mine Emergency Evacuation and Firefighting Program of Instruction (Program) on March 16, 2007. This Program must be reviewed with all miners annually and with newly employed miners prior to assignments of work duties in accordance with 30 CFR Part 48.

The Program includes provisions for: fire, explosion, water and gas inundation emergency procedures; location and use of fire-fighting equipment; location of escapeways; exits and routes of travel; evacuation procedures; fire drills; SCSR location, use and storage; AMS fire detection; operation of fire suppression equipment; mine emergency evacuation drills; two-entry response parameters, and mine emergency scenarios. Portions of the approved Program relevant to the August 2007 accidents are discussed in the following sections of this report.

Procedures for Evacuation
The Program stated in part, *"The proper evacuation procedures shall be initiated by the Responsible Person who has current knowledge of assigned locations and expected movement of miners. This Responsible Person shall also be knowledgeable in escapeways, mine communications, mine monitoring systems, mine emergency evacuation, firefighting program of instruction, and all personnel qualified to respond to emergencies."* The Program did not specifically identify the Responsible Person by name or title, but clearly defined their duties and responsibilities. In practice, the shift foreman was typically identified as the Responsible Person for each shift. A nameplate located above the mine check-in/check-out board identified this specific person each shift. If the Responsible Person changed during the shift, all miners were notified before the start of the shift when this change was to occur. The Program did not define the physical location of the Responsible Person during the shift.

The Responsible Person on the night shift, August 5/6, (6:00 p.m. to 6:00 a.m.) was Gale Anderson. Anderson, Benny Allred, and Powell were scheduled to attend training on August 6, and would not have been working their entire scheduled shift. Therefore, Anderson designated Don Erickson to act as the Responsible Person during his absence. Anderson, Benny Allred, and Powell exited the mine around 9:00 p.m. and left the mine property sometime after 10:00 p.m. The program stated, *"the procedure for rapid assembly and transportation of persons necessary to respond to the specific mine emergency, emergency equipment, and rescue apparatus to the scene of the emergency shall be initiated, by the responsible person in charge, who will notify the mine rescue team so that equipment can be assembled"*. Erickson, working in the South Barrier section, was one of the six miners entrapped in the section and, therefore, was not able to respond as the designated Responsible Person.

Leland Lobato (AMS operator) was stationed on the second floor of the shop/office building which was located several hundred yards from the mine opening. His assigned duties included monitoring the AMS and underground mine communication systems, along with documenting the location and movement of miners. On August 6, Lobato was training Mark Toomer as a new AMS operator.

There were five miners underground at the time of the accident in addition to the six miners in the working section. Peacock talked with them from his home through the AMS operator. An evacuation of the mine was not ordered because all miners underground were needed to assess post accident conditions and restore ventilation.

Atmospheric Monitoring System (AMS) Fire Detection
The primary function of the AMS system was fire detection with sensors capable of detecting levels of carbon monoxide. The system also continuously monitored mine electrical power, mine conveyor belts and tonnage, and fan operation. The accident did not involve fire or explosion. Therefore, none of the sensors detected alert or alarm levels of carbon monoxide. A requirement of the system is that it shall automatically provide visual and audible signals at the designated surface location for any interruption of circuit continuity and any electrical malfunction of the system.

The system functioned properly at the time of the August 6 accident. After the accident, the system alarmed and recorded a communication failure for all sensors located from the No. 6 belt drive inby including the working section. The main fan continued operating during the entire event without interruption but the AMS system did record a change in pressure.

Training Plan

The approved Part 48 Training Plan was reviewed to verify that the plan met the requirements of 30 CFR 48.3. The plan included all required subject matter. An addendum to the plan included Mine Emergency Evacuation instructions for the donning and transfer of self-rescue devices.

The training records required by 30 CFR 48.9 were reviewed for all miners employed at the Crandall Canyon Mine at the time of the accident. Based on this review and interviews conducted during the investigation it was determined that training met the requirements of 30 CFR Part 48.

August 16 Accident Discussion

The August 6, 2007, accident rendered all entries to the working section inaccessible and there was no further communication with the crew of six miners working there. Burst coal filled or partially obstructed mine openings, blocking all approaches to the section. The force of the burst damaged roof supports in some locations and the associated air blast damaged stoppings over a broader area.

There is no record[17] of a disaster of this type in the last 50 years of U.S. mining history. The miners were located beneath 1,760 feet of overburden in rugged terrain with difficult access. MSHA's mine rescue capsule, which had proved effective at the Quecreek #1 Mine in 2002, had never been deployed at such depth. The miners also were separated from coworkers underground by approximately 2,400 feet of rubble-filled entries. An underground rescue through this type and extent of failed ground was unprecedented.

While surface drilling efforts were being initiated to locate the entrapped miners, plans were formulated for an underground rescue effort. The underground rescue work involved reestablishing ventilation, clearing a travelway through the failed pillars, and re-supporting the roof as necessary. The degree of ground failure was so extensive that the clean-up effort began at crosscut 120 of the South Barrier section. The repair of ventilation controls began more than one mile from the entrapped miners.

Initial efforts to reach the miners via the No. 4 entry progressed only 300 feet before a burst occurred that refilled much of the path that had been cleared. No one was injured, but the occurrence emphasized the need to provide rescue workers some form of protection against further bursts. The subsequent rescue plan relocated the effort to the No. 1 entry and incorporated several elements to mitigate the burst hazard.

Standing supports were installed on either side of the No. 1 entry. They were placed outby for a distance of several hundred feet before recovery work began and then they were installed behind the clean-up face as it advanced. Initially, wood timbers were used in conjunction with a hydraulic pre-loading device to wedge them between the roof and floor. However, they were only used for a distance of about 200 feet, when another form of hydraulically wedged standing support, RocProps, was employed. As clean-up advanced in the No. 1 entry, a number of changes were implemented to enhance the support system and/or to reduce worker exposure.

Advance rate in the No. 1 entry between August 8 and 12 was somewhat erratic but afterward became relatively consistent at about 65 feet per day. The haul distance between the clean-up face and the belt feeder increased as the clean-up advanced. Also, the amount of debris encountered in the No. 1 entry increased substantially. In some areas between crosscuts, the barrier side rib was observed to have moved up to 10 feet into the entry. The entry was completely filled and had the appearance of a previously unmined face. In some areas, roof bolts had been sheared and/or damaged and hazardous roof conditions were encountered. Despite all these issues, rescue workers managed to find efficient means to overcome the problems they encountered and maintain a steady rate of progress. Although some bounces were noted, the support system was effective in containing coal dislodged from the ribs.

The first surface borehole penetrated the mine workings inby the collapse at 9:58 p.m. on August 9. Information that the mine atmosphere contained only about 8% oxygen was not encouraging. However, the rescue effort continued with the prospect that the miners could have escaped to another area of the mine with a favorable atmosphere or that they may have barricaded safely. Air quality could not be evaluated at Borehole No. 2 when it penetrated the workings at 12:57 a.m. on August 11. However, the presence of a 5½-foot void at mine level (similar to the void at No. 1) provided encouragement that perhaps the burst had not affected the mine openings in the area where the miners had been working.

Between August 10 and 13, the reported location of bounces and bursts was somewhat mixed (i.e., at the clean-up face, outby crosscut 120, away from the No. 1 entry and unknown). However, from August 13 to 16, the reports indicated that the activity was most often associated with areas outby the fresh air base (FAB) at Crosscut 119. Changes in roof conditions also were noted outby the FAB and, in response, additional standing supports were installed and an array of convergence stations was established to monitor ground behavior. Bursts occurred in the clean-up face periodically but were either at the continuous mining machine inby the RocProps or they were contained by the RocProps.

Subsequent analyses of satellite images and information gained from later surface boreholes revealed that the degree of damage encountered in the No. 1 entry would have worsened substantially before the rescuers reached the last known location of the miners. However, this information was not available on August 16. At that time, rescuers were operating under the premise that the worst conditions were likely associated with the overlying ridgeline (i.e., the greatest overburden depth). Calculations at the time were consistent with that premise. It was anticipated that the conditions observed on the outby side of the collapse would correlate to conditions under similar overburden on the inby side. Thus, there was hope that the miners had not been subjected to the effects of bursting coal and could have retreated to a safe area. This hope was bolstered when, at 10:11 a.m. on August 15, Borehole No. 3 penetrated 8 feet high workings that contained 17% oxygen.

At 10:04 a.m. on August 16, a burst occurred in the clean-up area that filled the entry between the continuous mining machine and the pillar rib to a depth of approximately 2½ feet. No one was injured and the event did not displace the support system. The debris was cleared and the clean-up cycle continued. A gradual opening encountered in the recovery face on August 16 was perceived as an indication that a travelable opening might be encountered soon. Efforts were initiated to prepare a mine rescue team to enter the area if that opportunity arose. Neither the burst that occurred at 6:38 p.m. on August 16 nor the associated failure of the support system was anticipated.

Ground Control during Rescue Efforts

Pillar bursting in the South Barrier filled or partially obstructed entries up to 20 crosscuts outby the pillar line. The force of the burst damaged roof supports in some locations and the associated air blast damaged stoppings over a broader area. Thus, the underground rescue work involved reestablishing ventilation, clearing a travelway through the failed pillars, and re-supporting the roof as necessary.

Selection of Entry for Rescue Work

Initial efforts to reach the entrapped miners were focused on clean-up in the Nos. 3 and 4 entries. The August 7 burst forced the rescue effort to be temporarily halted until another plan could be developed. A revised plan was proposed by the mine operator and approved by MSHA the evening of August 7, 2007. This plan relocated the rescue operation from the No. 4 entry to the No. 1 entry (see Figure 3). After the August 7 burst, the Nos. 3 and 4 entries were refilled to a depth of at least 6 ½ feet inby crosscut 120 (see Figure 4) and the roof continued to work (make noise indicative of continued failure) to the north and outby this location. In contrast, coal depth and rock noise were less in the No. 1 entry. Also, recovery in the No. 1 entry allowed rescue work to be conducted in intake air with air returning in the Nos. 2, 3, and 4 entries.

The initial rescue effort in No. 4 entry provided little protection against hazards related to coal bursts. However, the August 7 event heightened the rescuers' awareness of the potential for further ground failure. In response, the operator proposed and MSHA approved a plan to mitigate the hazard. One element of the plan was the support system installed concurrent with advance. This system was intended to protect workers should a burst occur. Additional elements were intended to reduce the likelihood of bursts. For example, precautions were taken to minimize the disturbance of failed pillars. Clean-up was limited to the minimum width necessary to allow the support system to be installed. Clean-up was limited to one entry and crosscuts were occasionally cleared to provide space for personnel or equipment.

Intuitively, the No. 1 entry could have been perceived as a poor choice for the rescue effort. As discussed earlier, abutment stress levels typically are highest near gob areas. Since the No. 1 entry is nearest the mined-out longwall panel 13 south of Main West, it could be assumed that the pillar between Nos. 1 and 2 entries would be the most highly stressed and most burst-prone. However, observed ground conditions were inconsistent with this expectation. Pillar damage on the outby edge of the collapsed area appeared to be more severe near the Main West entries and better near the barrier. In choosing the No. 1 entry, it was noted that the 121-foot wide barrier beside the No. 1 entry had a width-to-height (W/H) ratio of 15. In contrast, the minimum 55-foot wide barrier (measured to the Main West notches) adjacent to No. 4 entry had a W/H ratio of approximately 9. Historically, pillars with W/H ratios in the range of 5 to 10 have been associated with bursts.

As the mine operator prepared to advance in the No. 1 entry, MSHA performed ARMPS and LaModel analyses. These analyses were done to gain insight to the mechanics of the failure and to estimate the extent and severity of poor ground conditions likely to be encountered during the rescue. Both LaModel and ARMPS models showed that pillars throughout the Main West area (including the North and South Barrier sections) may have been involved with the failure that had occurred on August 6. The results were supported by descriptions of bursting in the North Barrier section, pillar damage observed during the August 7 exploration inby the Main West seals at crosscut 118, and reports of substantial floor heave outby the South Barrier section pillar line in the vicinity of crosscuts 138 to 140.

GRI furnished a map to MSHA during the rescue effort on which topography was slightly shifted out of position over the mine workings. This map was used to note the general positions of valleys and ridges during rescue operations. However, this map was not used as a basis for any detailed analysis.

On the basis of engineering analyses and underground observations, MSHA considered on August 9 that the South Barrier failure most likely could be attributed to instability within the large expanse of nearly equal size pillars created by mining in Main West and the adjacent north and south barriers. Progressive pillar failure was thought to have occurred within the Main West pillars inby the seals at crosscut 118 under the deepest overburden along the East Mountain ridge. MSHA surmised that the failure of Main West would have shifted load onto the South Barrier section pillars and that this load could have generated the extensive failure in the South Barrier section. Analyses available at that time indicated that it was possible that the burst originated under the deepest cover of the East Mountain ridge and that the miners, who were located under shallower overburden, may not have been subjected to the extensive pillar burst. However, the potential effects of the air blast on the entrapped miners' location could have been worse than the air blast that propagated outby (eastward).

Information gained from the first three surface boreholes drilled into the mine supported the belief that the inby extent of the burst was limited. These holes penetrated the mine workings between the evening of August 9 and August 15. Each one provided an initial indication that a substantial height of entry was open at mine level. Estimated opening heights ranged between 5.5 and 8 feet. At that time, clean-up in the No. 1 entry progressed under the assumption that total blockage of entries would be limited to the highest overburden between crosscuts 126 to 132 and the effects of the burst inby crosscut 137 may not have been as severe. Holes completed after August 16 indicate that this assumption was overly optimistic. Subsequent analyses of satellite images and information gained from later surface boreholes revealed that the degree of damage encountered in the No. 1 entry would have worsened substantially between Crosscut 132 and the last known location of the miners.

Work Procedures under Operator's Recovery Plan

The rescue effort was a dynamic process. The work procedures and corresponding plan approvals underwent numerous changes to minimize exposure to miners, improve efficiency, and improve the effectiveness of the support system. The number of miners working in the clean-up area was reduced. Work processes were adjusted and refined to efficiently excavate material and install the required ground support. Supports for burst control were reinforced through the installation of additional of steel cables and roof control was maintained by installing additional roof bolts, roof mesh, and steel channel where required.

Timely access to the entrapped miners in the South Barrier section work area required the rehabilitation of debris filled, previously mined entries of the South Barrier section or Main West. There were no alternative routes. To reach the entrapped miners required removing coal debris from entries within damaged pillars. This unavoidable process required removal of compacted coal that reduced the confinement around damaged pillars. Consequently, this led to working in the vicinity of ground with high burst potential.

The most rapid method of advance in the No.1 entry required the implementation of typical coal mining methods using the most available coal mining equipment. No other means of excavation was available to quickly reach the miners. Remote means of excavating the debris filled entry was available through the use of the remote control continuous mining machine. However, during the rescue work in the No. 1 entry, the RocProps and associated chain-link fence and steel cables, which were advanced behind the continuous mining machine, had to be installed manually. This process required working and traveling in close proximity to ground with high burst potential. No methods were available to remotely install the ground control system.

Pillar Burst Support System

After the August 7, 2007, burst in the No. 4 entry, support systems were used to protect rescue workers from additional pillar bursts. Standing supports installed on either side of the No. 1 entry were an integral part of these systems. They were placed outby for a distance of several hundred feet before recovery work began in the No. 1 entry and then installed behind the clean-up face as it advanced.

All forms of standing support used in the U.S. coal mining industry primarily are designed to support the mine roof. The stated capacity of these supports refers to their ability to sustain vertical roof loads rather than lateral loads. The lateral load-carrying capability of the installed supports was unknown as was the force that the supports would be required to resist. It was known, however, that the RocProps could be installed with a substantial preload, the mine workers were familiar with their installation, and they had been used successfully for protection from burst hazards at another mine. Other support systems including arches and steel sets were considered. However, at the time RocProps were chosen to be used in the rescue, planners were unaware of any preferable alternative to RocProps in terms of versatility, availability, worker familiarity, and installation exposure. No other support system capable of withstanding significantly greater lateral loading was available. A NIOSH ground support specialist familiar with the testing and evaluation of underground mining support systems was consulted regarding support systems that could be used in this application. RocProps were also suggested independently by the NIOSH specialist.

The mine operator submitted and MSHA approved a plan to install a support system that included standing supports. Initially, posts (6 x 8-inch hardwood) were used in conjunction with Jackpots, hydraulic preloading devices, to wedge them between the roof and floor. Once inflated with high-pressure water through a non-return valve, the Jackpots provided a preload that improved the wood posts ability to close cracks in the roof and secure any loose rock, reduce the likelihood of ground falls, and provide resistance to lateral loading. Wood posts were only used for a distance of about 200 feet, when another form of hydraulically wedged standing support, RocProps, was employed.

A RocProp is a hydraulic cylinder that also provides an active preload when it is inflated using high pressure water. During the rescue effort, a hose was connected from a high pressure pump to the injection nozzle at the base of the RocProp. A control valve was opened allowing water into the cylinder. The water pressure telescoped the inner tube until the RocProp was against the mine roof and self-supporting. From a safe position, the RocProp was further pressurized until a setting pressure of between 1,100 and 1,200 psi was achieved. The control valve was closed to maintain the required setting pressure and a cone shaped locking ring was hammered into place with a cone-setting tool. The setting tool was positioned around the RocProp and the cone was driven into the flare of the outer tube to complete installation. The pump was powered by tapping into the hydraulic system of the continuous mining machine, shuttle car, roof-bolting machine, or Ramcar by using quick connect/disconnect couplings.

During most of the rescue work in the No. 1 entry, RocProps were a primary component of the support system. They were installed on 2.5-foot centers, typically one at a time, one side of the entry and then the other, until all of the required roof-to-floor supports were set. The spacing between supports on opposite sides of the entry was established at 14 feet. This dimension was considered the minimum that would allow equipment to tram to and from the clean-up face. This limited entry width was maintained in an effort to minimize the disturbance to the burst pillars on either side. Opening height varied in the recovered entry. However, RocProps were available to accommodate various mining heights.

After a series of RocProps was installed, chain-link fencing was installed on the rib side of the RocProps to contain sloughed or burst coal. Periodically, 5/8-inch diameter steel cables were installed on the travelway side of the RocProps to contain the RocProps and fencing in the event of a larger burst event. Three cables were installed on the travelway side of the RocProps at the top, middle, and bottom. Each cable connection or loop was secured with three cable clamps. The cable was wrapped around one RocProp every 40 feet and connected to itself. Each cable was anchored to a separate RocProp (Figure 88). The RocProps and associated chain-link fence and steel cables were advanced behind the continuous mining machine.

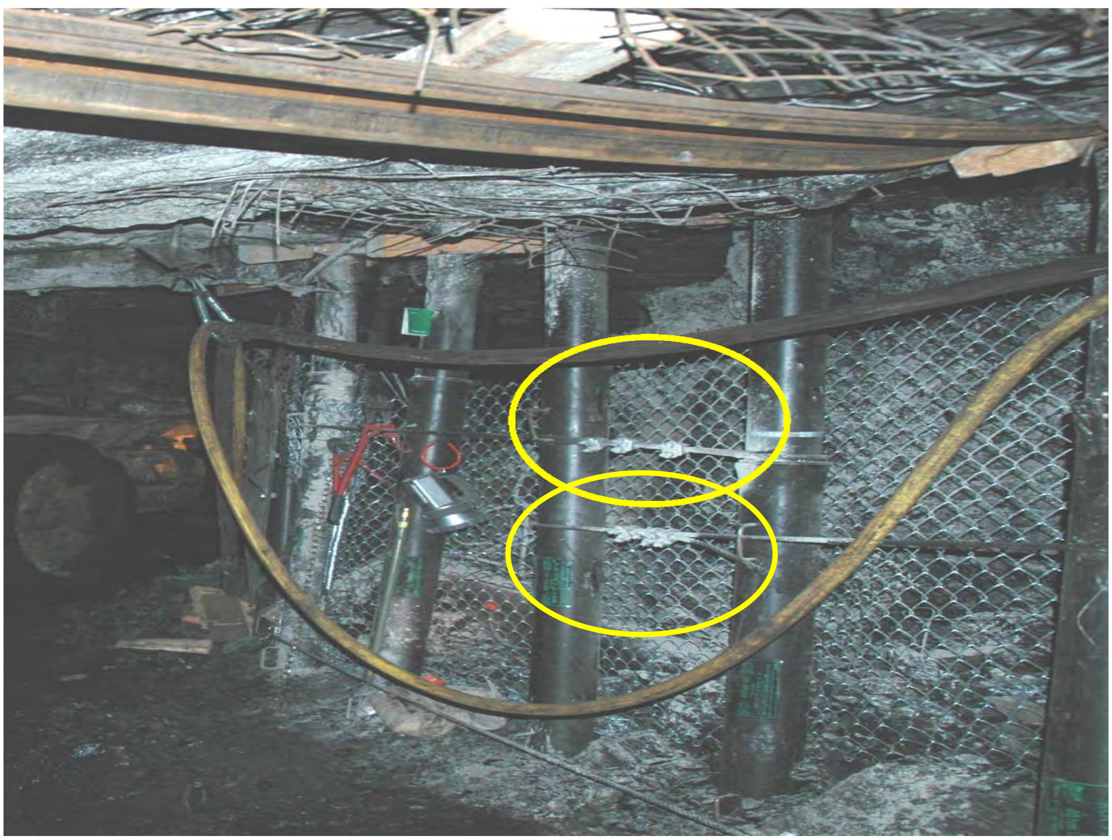


Figure 88 – Steel Cables Connected to RocProps

When damaged roof bolts were encountered or the roof showed signs of fractured conditions, additional roof bolts, wire roof mesh, and/or steel channels were installed. Occasionally, channels spanned the entry and were supported on either end using RocProps or wood posts. They also were installed using fully grouted roof bolts. A twin-boom walk-thru roof-bolting machine was utilized to install the roof bolts, mesh, or channels if it was necessary (Figure 89).

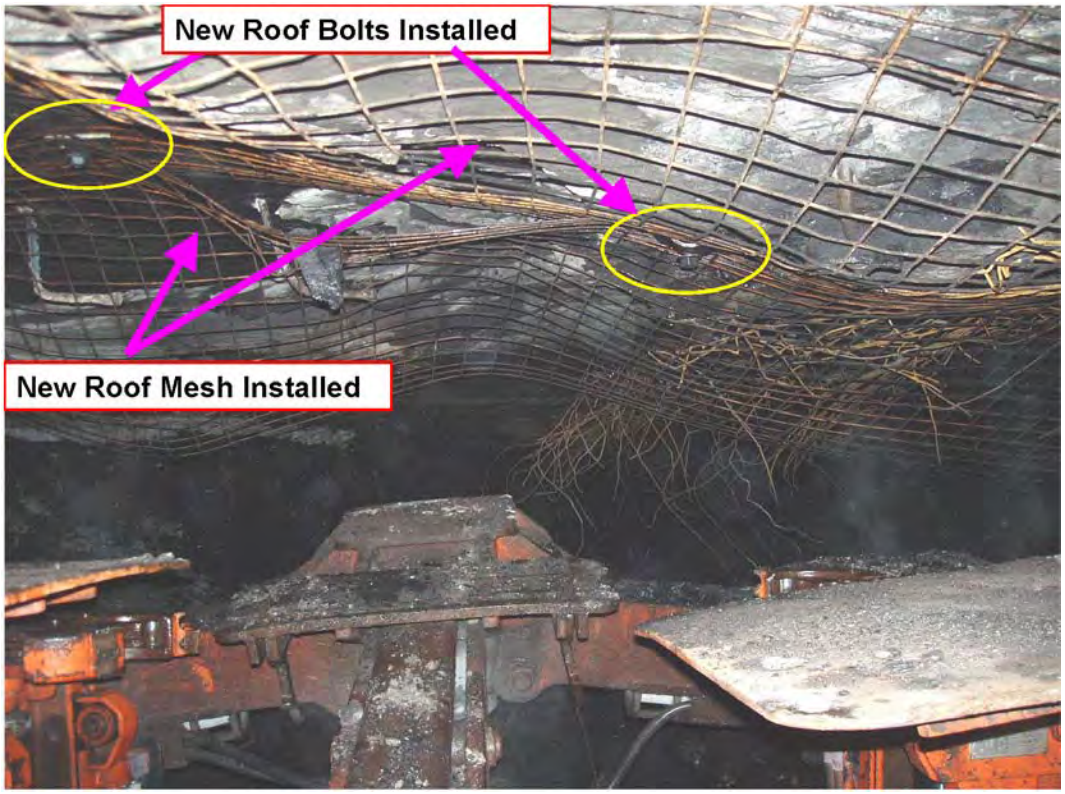


Figure 89 - New Roof Bolts and New Wire Mesh Installed in the No. 1 Entry

As clean-up advanced in the No. 1 entry, a number of changes were implemented to enhance the support system and/or to reduce worker exposure. For example, a 4 x 8-foot sheet of ½-inch thick Lexan[18] was provided near the face to offer protection to rescue workers in the clean-up area. The sheet was secured to the mine roof by chains attached along one edge. The chain was connected to roof bolt plates (Figure 90). The Lexan sheet served as a shield between personnel and the coal pillar rib.

Figure 90 - Sheet of Lexan Suspended from Mine Roof

Seismic Activity Recorded by UUSS during Rescue Efforts

After the August 6 accident, seismic activity continued regularly for approximately 37 hours (see Figure 32). During this period, miners reported a substantial amount of rock noise emanating from the area north and west of the accessible portion of the South Barrier workings. One of these events recorded by UUSS was related to the August 7 coal burst that ended the rescue operation in the No. 4 entry. No further seismic events were recorded until August 13, 2007, when seismic activity was recorded at the inby edge of the collapse area (over 2,000 feet west of the clean-up area). In a presentation before the Utah Mine Safety Commission on November 11, 2007, Dr. Walter Arabasz noted a *"5.8 day gap between August 7 and 13 for events above the threshold for complete detection of magnitude (MC) 1.6."* A general reduction in activity was observed underground during this time period as well.

On August 15, 2007, at 2:26 a.m., a seismic event occurred that was related to a burst in the clean-up area, inby crosscut 125 in the No. 1 entry. Another seismic event was recorded at 10:04 a.m. on August 16, which was related to a burst in the clean-up area, inby crosscut 126 in the No. 1 entry. The next recorded seismic event was related to the August 16 accident at 6:38 p.m.

Bounces and bursts were observed underground throughout the rescue effort. Most of these occurrences were not in the seismologic record due to the reporting threshold of the network. The UUSS seismic network was set to record only events larger than approximately magnitude 1.6. After additional seismic stations were installed between August 9 and 11, 2007, the threshold was reduced to approximately magnitude 1.2. Some smaller events were recorded concurrently with a larger event that had triggered the system.

Initial locations of seismic events lacked sufficient accuracy to be used for decisions affecting rescue efforts. Figure 91 shows the initial locations generated by the UUSS automated system. The red circle depicts the August 6 accident. The blue circle depicts the August 16 accident. The remaining magenta circles depict those events recorded between these accidents. All events plot in regions away from the underground rescue work. The more accurate locations of events shown in Figure 92 were not available until well after the rescue efforts had been suspended. Underground observations were much more representative of actual ground activity.

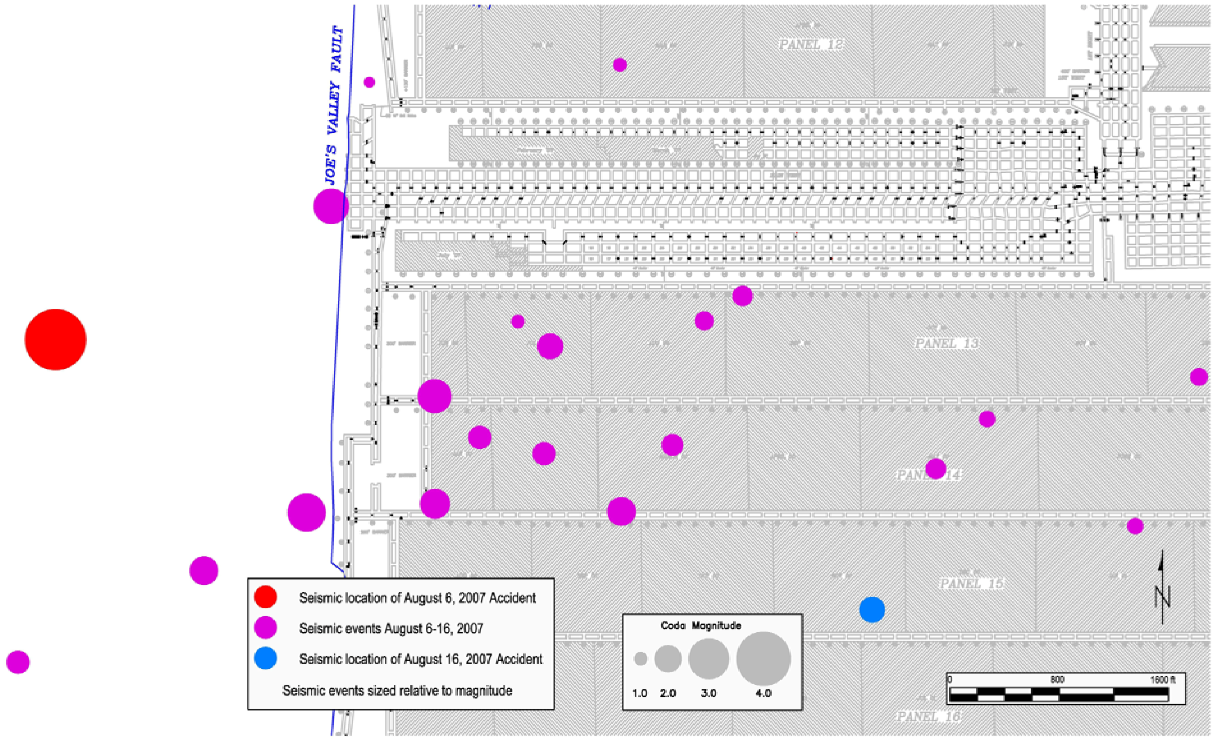


Figure 91 - Initial Location of Seismic Events August 6-16, 2007

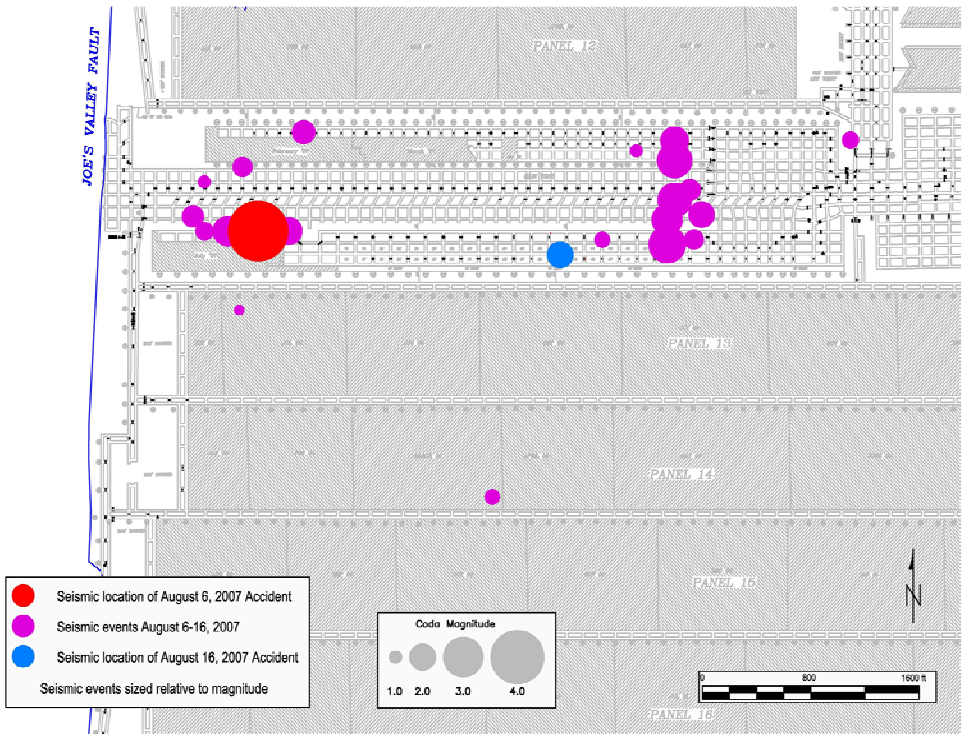


Figure 92 - Double Difference Locations of Seismic Events, August 6-16, 2007 (unavailable until November 2007)

Pillar Bounce and Burst Activity during Rescue in No. 1 Entry

The command center log book noted bounces and bursts from August 6 through August 16. Protocol to qualify an event's significance for reporting purposes, which could range from a noise generated by a mild bounce to a coal burst, was not clearly established. Rescue workers called and reported such events to the command center based on varying individual perceptions of the event's significance. Reporting was also dependent on whether or not the individual was in the vicinity of the event. With these constraints, the recorded bounce and burst activity can only be discussed in general terms.

Forty-one events were reported by underground personnel during rescue work in the No. 1 entry prior to the August 16 accident. All bounce activity, which included bursts, originated from the section pillars to the north of the No. 1 entry. None was associated with the barrier to the south. The majority of these bounces or bursts were outby crosscut 120 (see Figure 93). This area was outby the crosscut leading to the feeder, away from the clean-up operation in the No. 1 entry (see Figure 3). The rescue work area was protected with RocProps or wood posts with Jackpots. Rib deterioration and bursts that occurred outby the clean-up area were contained by the support system.

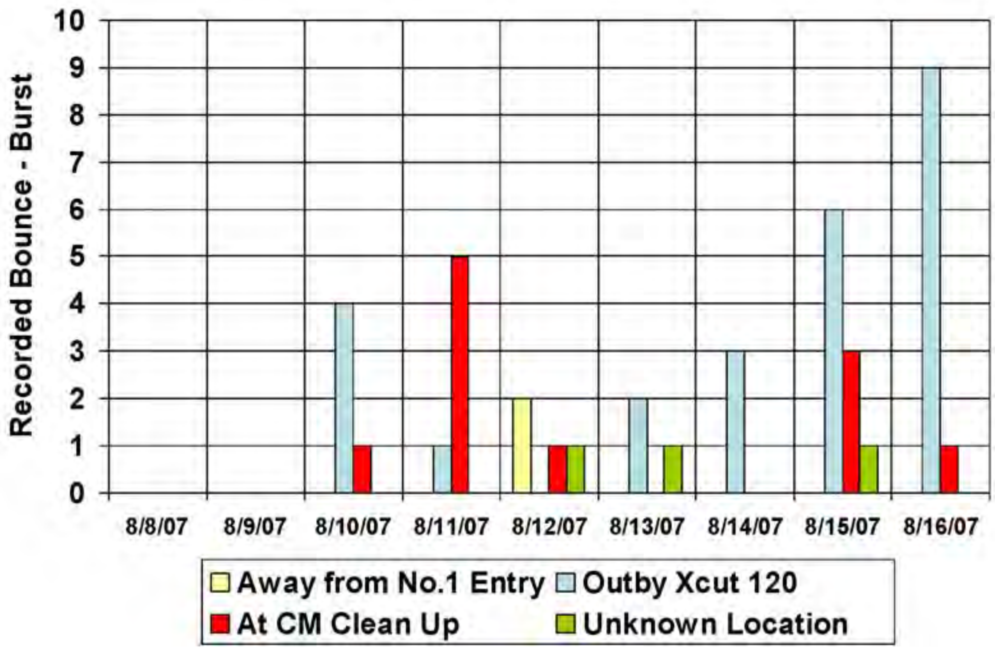


Figure 93 – Bounce or Burst Activity Recorded in Command Center Log Book August 8 to August 16, Prior to August 16 Accident

Prior to the August 16 accident, eleven burst/bounce events were reported to have originated from the north side (right side) section pillars inby crosscut 120 (see Figure 93). These events occurred at the remote-controlled continuous mining machine where the material was being loaded, inby the area of the advancing RocProp system. The approved clean-up plan included procedures that minimized exposure of rescue workers in this area. It was thought that if a significant pillar burst were to occur, it most likely would be in the area where material was being removed. The command center log book noted that events in the clean-up area varied in size with two large pillar bursts in this area recorded prior to the August 16 accident. Prior to August 16, no significant bounces or bursts were recorded within the RocProp support system inby crosscut 120. One burst event was noted outby crosscut 120. Material piled behind the chain-link fencing inby crosscut 120 resulted from unreported bounces or bursts, or from rib sloughage.

The rescue advance in the No. 1 entry achieved a somewhat steady rate of approximately ½ crosscut (65 feet) per day after August 12 as illustrated in Figure 94. No correlation to rescue advance rate in the No. 1 entry and the burst or bounce frequency could be identified.

Figure 94 - No. 1 Entry Rescue Clean-up Progress Plotted by Day

On the evening of August 16, a large burst originated from the north side of the No. 1 entry. The burst dislodged the installed RocProps, steel cables, and chain-link fencing, violently throwing the debris and the support system from one side of the entry to the other. It happened at a time in the rescue work cycle where the maximum number of personnel was in the area. This accident resulted in six injuries and three fatalities.

The August 16 accident confirmed that potential energy remained in the damaged pillars. The level of ground activity in the No. 1 entry from August 8 to 15 did not provide a clear indicator of pillar stability. The lack of ground activity could have indicated either that the pillars were stable or that hazardous unreleased energy remained in the pillar. Likewise, substantial activity could have indicated that the pillars are remaining stable as they release energy, or that a hazardous event is pending. Therefore, analysis of underground observations and frequency of bounce or burst activity (Figure 93) offered little useful guidance on potential for bounces and bursts. Because of the magnitude of the pillar burst and the failure of the roof-to-floor support system, all underground rescue activity was suspended. The 103(k) order was modified requiring all personnel to remain outby crosscut 107 in Main West.

<u>Ground Condition Monitoring</u>

During the rescue operation, underground observations and convergence measurements were used to assess the stability of the areas that rescuers worked in or traveled through in the South Barrier section. These monitoring activities identified areas requiring supplemental support but failed to anticipate the burst that occurred on August 16. Measurements and visual observations did not indicate that failure was imminent and the rescue activity should be suspended.

The burst that occurred on August 7 during the initial clean-up effort in No. 4 entry had demonstrated that additional local bursting could occur as a travelway was reestablished. The event illustrated that, despite their fragmented appearance, pillars within the burst area still were capable of violent failure sufficient to cause injury. Although specific conditions that might be indicative of an impending burst were not known, MSHA and GRI personnel remained alert to any changes in the work environment as the clean-up progressed. MSHA positioned an inspector at the clean-up face at all times to visually monitor conditions and observe work practices. Usually these MSHA personnel were from the Price, Utah, Field Office since these inspectors had knowledge of the mine, regional mining conditions and practices, and burst hazards in general. An MSHA inspector also was stationed each shift at the FAB phone at crosscut 119 and another took air measurements at various locations throughout each shift.

As the clean-up effort advanced between August 8 and 11, the amount of debris encountered in the No. 1 entry increased substantially. In some areas, roof bolts had been sheared and/or damaged and hazardous roof conditions were encountered. The bolt damage in some instances was associated directly with movement of the barrier-side rib. This rib line was observed to have moved horizontally up to 10 feet into the entry. The displaced coal was much different in appearance than ribs encountered to that point. Whereas most burst ribs had a loose, fragmented appearance, the barrier-side rib appeared to be more intact and remained nearly vertical as clean-up progressed. Initially, the competent appearance of the coal raised concerns that it might be more capable of storing strain energy that could be released as a burst event. However, as clean-up continued, bursts were observed to originate from the pillar-side rather than the barrier-side.

On August 11, GRI and MSHA mapped pillar damage east of the Main West seals (see Figure 26). The damaged pillar ribs were sloughed due to abutment stress from failed pillars to the west. Earlier, a substantial amount of rock noise had been noted in this area, but on August 11, it was relatively quiet. Thus, it was determined that the ground stress had stabilized and that pillar failure was no longer progressing eastward. Roof deterioration and slight widening of roof joints was observed in the No. 1 entry outby crosscut 117. Roof-to-floor supports were installed through this area and steel channels were installed where adverse roof conditions were present.

On August 12, observations of RocProps tilted from vertical had prompted the MSHA inspector positioned at the clean-up face to install a measurement point to monitor RocProp horizontal movement. The measurement was taken routinely between RocProps installed on opposite sides of the No. 1 entry between crosscuts 123 and 124. Between August 12 and 13, the horizontal distance between the RocProps decreased by ½ inch across the ~13 ½-foot opening. From August 13 to the last measurement on August 15, no further movement was noted,

Between August 12 and 15, clean-up progressed steadily but there was an increasing number of reports of rock noise emanating from locations outby crosscut 119 and roof cracks were observed between crosscuts 115 and 119. These observations raised concerns that a roof fall could occur outby the rescue workers and that additional pillar failure could be responsible for the changing conditions. MSHA installed 10 roof-to-floor convergence stations (at crosscuts 111, 113, 115, 117, and 119 in the No. 2 and No. 4 entries) to assess ground behavior.

Each convergence station was established between two points on the mine roof and floor. Roof bolt heads were identified at specific locations to serve as measurement points on the roof. Directly beneath each roof bolt, a ⅜-inch diameter hole was drilled to accept a plastic anchor and a ¼-inch diameter screw that served as the measurement point on the floor. Spray paint and survey ribbon were used to identify the monitored locations. Convergence measurements were taken using a telescoping rod, shown in the photograph on the left side of Figure 95. This instrument, manufactured by Sokkia, can extend up to 26 feet and is capable of determining the distance between roof and floor points to within one millimeter.

Figure 95 - Convergence Measurements
Left: Roof-to-floor convergence station. Right: RocProp convergence station.

The convergence stations were monitored to determine the magnitude, rate, and distribution of roof-to-floor closure. Historically, measurements of this type have been useful in monitoring changing and potentially hazardous ground conditions. Initial (baseline) measurements were taken on August 15 and the stations were measured twice on August 16 prior to the accident. Measurements in this time frame indicated that ground conditions were stable; three of ten stations showed closures of 0.04 inches but this amount of displacement is within the precision of the measuring instrument.

Sixteen monitoring locations were established using RocProps in the No. 1 entry. As shown in the photograph on the right side of Figure 95, these monitoring locations were established by painting a line on installed RocProps, 12 inches above the locking ring. Entry convergence could be monitored at these locations simply by measuring the distance between the lock ring and paint line using a tape measure. Although not as exact as a convergence rod, these measurements were intended to provide a convenient method for determining convergence between the mine roof and floor that anyone with a tape measure could perform.

The RocProps designated for measurement stations extended from crosscut 116 to 126 in the travelway to the clean-up area. No convergence stations had been established inby crosscut 126, near the August 16 accident site, because the area had just recently been cleaned and supported before the accident. The RocProp stations were measured twice on August 16, prior to the accident, and indicated stable conditions. No closure was noted at 14 of the 16 measurement points. One RocProp near crosscut 126 showed 1/16-inch of closure and another near crosscut 121 showed 3/16-inch. Subsequent measurements by the accident investigation team on September 10 indicated that additional vertical closure had occurred in eight RocProps. Seven of the eight moved 1/8 inch or less while closure on the RocProp at crosscut 123 measured ½ inch. Two RocProps located farther inby at crosscuts 124 and 125 showed no additional closure.

Ventilation on August 16

During the rescue operation on August 16 the clean-up area was ventilated with line curtain. Oxygen deficiency, as low as 14%, was detected inby the continuous mining machine earlier that day. When the accident occurred, the line curtain was damaged and buried in coal. Multi-gas detectors carried by victims and the rescuers began to alarm. The lowest oxygen concentration was generally observed on the north side of the entry, away from the victims. Repairs to the line curtain began as rescuers continued removing debris to free the injured miners. Ventilation was reestablished in a short time.

An oxygen deficient atmosphere was present in the rubble in advance of the continuous mining machine. The ventilation system had diluted and carried away gasses that had migrated into the workplace. The accident damaged the ventilation system and may have pushed additional oxygen deficient air onto the accident site. During the exploration on the morning of August 6, 16% oxygen was detected in the area explored near crosscut 126. The lowest oxygen concentration reported after the accident on August 16 was 14.7%. The presence of oxygen deficient air and the need to reestablish ventilation diverted resources from the rescue effort for a short time, however, no ill effects were reported from the oxygen deficient air.

Post-Accident Tracking

The mine tracking system was changed on August 11, 2007. The new system eliminated the use of the magnetic tracking board and was replaced with a computer spreadsheet. This system functioned identically to the magnetic board with the exception that it provided a printed copy of each person's underground location every hour. In addition, the check-in, check-out procedure was supplemented by having each person write their name, date, and time they entered and exited the mine in a log located at the portal.

On August 16, 2007, the post-accident tracking system was not maintained so that it could be used to determine the pre-accident location of all underground personnel and was not reliable during the post-accident setting. On the morning of August 16, audio recordings of the pager phone system verified that Dale Black's location was reported to the AMS operator as he traveled between zones toward the clean-up area. However, Black was not entered into the tracking system during this shift. All other miners in the clean-up area were properly tracked.

Immediately following the August 16 accident, the mine pager phone system was needed to coordinate rescue efforts from the command center. Miners attempting to call out as they changed zones interfered with communications between the command center and rescue workers at the accident site. This prompted mine management to temporarily limit use of the phone system. Vehicles transporting injured miners, including cases where CPR were being performed, did not stop to call out zone locations as this would have delayed potentially life-saving treatment. Additionally, some rescue workers rapidly responded to the accident scene without reporting their movements. This caused an increase in time and confusion when accounting for all persons after the mine had been evacuated. However, the tracking system failures did not cause any delays in medical treatment to the injured miners.

Local Coordination

Following the August 16 accident, the response was rapid. Immediately after the accident occurred, a call went out to 911 emergency medical services. Several ambulance services in the area responded, including medical evacuation helicopters. Medical personnel were stationed at the mine portal and began medical treatment as the injured exited the mine. At least one Emergency Medical Technician traveled underground to provide onsite first aid. There were no delays in treatment or transportation of the injured rescue workers.

ROOT CAUSE ANALYSIS

An analysis was conducted to identify the most basic causes of the accidents that were correctable through management controls. Listed below are root causes identified for each accident and their corresponding corrective actions to prevent a recurrence of the accident.

Root Causes of August 6, 2007, Accident

1. *Root Cause*: **GRI and AAI's mine design was not compatible with effective control of coal bursts.** The dimensions of pillars within the active workings, as well as dimensions of the adjoining barrier pillars, did not provide sufficient strength to withstand stresses. AAI's ARMPS analysis of the pillar dimensions was inappropriately applied and their LaModel analysis was faulty. These analyses were not adequately reviewed for correctness and results were not accurately reported.

   Corrective Action: Engineering procedures should ensure analyses are conducted in accordance with established guidelines. Correspondence, input files, and output files should be adequately reviewed for accuracy at each stage of model analysis. Systematic verification of numerical model construction, parameter selection, and model calibration should be conducted to ensure that output represents known conditions. Reports should accurately convey analyses results, provide clear recommendations, and include justifications for any departure from established guidelines. Pillars and mining methods should be designed to maintain ventilation systems, including separation from adjacent sealed areas.

2. *Root Cause*: **GRI did not take adequate steps to prevent recurrences of coal outburst accidents.** Revisions of the roof control plan were not proposed by the operator when conditions at the mine indicated that the plan was not adequate or suitable for controlling the roof, face, ribs or coal bursts. These conditions included roof and rib burst damage, miners being struck by coal, and several coal outburst accidents that were not reported to MSHA as required by 30 CFR 50.10.

   Corrective Action: All coal outburst accidents must be properly reported to MSHA and mapped to accurately portray accident history for determining adequacy of the approved roof control plan. Adequate steps to prevent the recurrence of all coal outburst accidents should be taken before mining is resumed. Revisions to the roof control plan must be proposed when the plan is not suitable for controlling coal bursts.

3. *Root Cause*: **GRI did not follow their approved roof control plan and pillar design parameters.** The barrier south of the No. 1 entry was mined between crosscut 142 and crosscut 139 where pillar recovery was not permitted by the approved roof control plan. Pillars were mined to a greater height by mining of bottom coal and entries were centered differently than modeled.

   Corrective Action: Mine operators must follow their approved roof control plan. Persons analyzing mine designs should be provided with all pertinent aspects of intended mining, and any revisions to such information. Mine operators should consult with analysts before implementing any changes to modeled mining plans.

4. *Root Cause*: **GRI included incorrect information in the roof control plan submitted to MSHA for approval.** GRI submitted roof control plans based on AAI's inaccurate evaluations, which determined that projected mining would be safe and pillar and barrier dimensions were appropriate when in fact they were not.

   Corrective Action: Mine operators should ensure that proposed roof control plans are suitable for prevailing geological conditions and the mining system to be used at the mine. Corrective actions regarding MSHA's roof control plan approval process will be addressed in the findings of an independent review team.

Root Causes of August 16, 2007, Accident

All root causes for the August 6 accident can also be attributed to the August 16 accident; the following are additional root causes unique to the latter. Unlike the August 6 accident, viable alternatives were not available for most causes of the August 16 accident, which imposed greater risks on rescue workers than would be accepted for normal mining. The prospect of saving the entrapped miners' lives warranted the heroic efforts of the rescue workers. The greater risks imposed on the rescue workers underscore the high degree of care that must be taken by mine operators to prevent catastrophic pillar failures as occurred on August 6.

1. *Root Cause:* **Information was not sufficient to determine underground conditions prior to August 16.**

   Corrective Action: Due to the high level of risk inherent to rescue efforts, all resources, including drilling resources, should be deployed to obtain information necessary to determine underground conditions in the shortest possible timeframe. Information is critical to evaluate the potential success of rescue efforts.

2. *Root Cause:* **The method used for reaching the entrapped miners required removal of compacted coal debris, which reduced confinement pressure on the failed pillars.**

   Corrective Action: None. No viable excavation method exists to rescue the entrapped miners.

3. *Root Cause:* **Ground support systems were not capable of controlling maximum potential coal burst intensity.**

   Corrective Action: None. Viable support systems capable of sustaining significantly greater lateral loads are not available. Methods do not exist to determine the maximum coal burst intensity that the ground support system would be subjected to.

4. *Root Cause*: **Installation of ground control systems required rescue workers to travel near areas with high burst potential.**

   Corrective Action: None. No means exists to remotely install the ground control systems.

CONCLUSION

The catastrophic coal outburst accident on August 6, 2007, initiated near the pillar line in the South Barrier section and propagated outby, resulting in a magnitude 3.9 mining related seismic event. Within seconds, pillars failed over a distance of approximately ½-mile, expelling coal into the mine openings. The six miners working on the section likely received fatal injuries from the ejected coal as it violently filled the entries. The barrier pillars to the north and south of the South Barrier section entries also failed, inundating the section with lethally oxygen-deficient air from the adjacent sealed area(s) and may have contributed to the death of the miners. The extensive pillar failure and subsequent inundation of the section by oxygen-deficient air occurred because of inadequacies in the mine design, faulty pillar recovery methods, and failure to adequately revise mining plans following coal burst accidents. The mine design was inadequate because it incorporated recommendations from AAI's flawed LaModel and ARMPS analyses. These design issues and faulty pillar recovery methods resulted in pillar dimensions that were not compatible with effective ground control to prevent coal bursts under the deep overburden and high abutment loading that existed in the South Barrier section.

AAI's ARMPS analysis was inappropriately applied. They used an area for back-analysis that experienced poor ground conditions and did not consider the barrier pillar stability factors in any of their analyses. The mine-specific ARMPS design threshold proved to be invalid, as evidenced by the March 7 and 10, 2007, coal outburst accidents and other pillar failures. GRI did not propose revisions to their roof control plan before resuming mining following the March 7 coal outburst. Despite these accidents, AAI recommended a pillar design for the South Barrier section that had a lower calculated pillar stability factor than the failed pillars in the North Barrier section, lower than recommended by NIOSH criteria, and lower than established by their mine specific criteria. AAI performed the ARMPS analysis for the South Barrier section, but did not include these results in their reports that were presented to MSHA in support of GRI's plan submittal.

AAI's LaModel analysis was flawed. They used an area for back-analysis that was inaccessible and could not be verified for known ground conditions, which resulted in an unreliable calibration and the selection of inappropriate model parameters. These model parameters overestimated pillar strength and underestimated load. AAI modeled pillars with cores that would never fail regardless of the applied load, which was not consistent with realistic mining conditions. They did not consider the indestructible nature of the modeled pillars in their interpretation of the results. Modeled abutment stresses from the adjacent longwall panels were underestimated and inconsistent with observed ground behavior and previous studies at this and nearby mines. AAI managers did not review input and output files for accuracy and completeness. They also did not review vertical stress and total displacement output at full scale, which would have shown unrealistic results and indicated that corrections were needed to the model. Following the March 10 coal outburst accident, AAI modified the model, but failed to correct the significant model flaws. They did not make further corrections to the model when this analysis result still did not accurately depict known failures that AAI and GRI observed in the North Barrier section.

The mine designs recommended by AAI and implemented in part by GRI did not provide adequate ground stability to maintain the ventilation system. The designs did not consider the effects of barrier pillar and remnant barrier pillar instability on separation of the working section from the adjacent sealed areas. Failure of the barrier pillars or remnant barrier pillars resulted in inundation of the section by lethally oxygen-deficient air. AAI and GRI also did not consider the effects of ground stability on ventilation controls in the bleeder system. GRI allowed frequent destruction of ventilation controls by ground movement and by air blasts from caving. GRI mined cuts from the barrier pillar in the South Barrier section between crosscuts 139 and 142 intended to be left unmined to protect the bleeder system.

GRI employed a mine design that exposed miners to hazards related to coal bursts. The large area of similarly sized and marginally stable pillars developed in the Main West and North and South Barrier sections created a system primed for collapse. Pillar recovery in the South Barrier section most likely triggered the pillar collapse. GRI's unapproved mining practices, including bottom mining and additional barrier slabbing between crosscuts 139 and 142, reduced the strength of the barrier and increased stress levels in the vicinity of the miners. GRI failed to have AAI evaluate the design that was actually employed in the South Barrier section. Proper evaluation of either design, as mined or as proposed, would have indicated failure.

GRI continued pillar recovery without adequately revising their mining methods when conditions and accident history indicated that their roof control plan was not suitable for controlling coal bursts. GRI investigations of non-injury coal burst accidents did not result in adequate changes of pillar recovery methods to prevent similar occurrences before continued mining. GRI did not consult with AAI or propose revisions to their roof control plan following the August 3, 2007, coal outburst accident in the South Barrier section, even though pillar conditions were similar to the failed area in the North Barrier section.

GRI did not immediately notify MSHA of previous coal outburst accidents. GRI's failure denied MSHA the opportunity to investigate these accidents and ensure corrective actions were taken before mining resumed in the affected area. GRI did not submit written reports of these accidents to MSHA or plot coal bursts on a mine map available for inspection by MSHA and miners. The lack of proper documentation and reporting of ground conditions and related accidents denied MSHA required information for reviews to determine the suitability of the roof control plan to prevailing geological conditions and mining systems used at the mine.

The fatal August 16, 2007, coal pillar burst accident occurred when the pillar between the No. 1 and No. 2 entries failed adjacent to rescue workers as they completed installing ground support behind the continuous mining machine. Coal ejected from the pillar dislodged RocProps, steel cables, chain-link fence, and a steel roof support channel, which struck the rescue workers and filled the entry with approximately four feet of debris. This accident resulted in the death of two mine employees and one MSHA inspector. Six additional rescue workers, including an MSHA inspector, received nonfatal injuries.

The August 16 accident occurred because access to the entrapped miners required removal of compacted coal debris from an entry affected by the August 6 accident. Entry clean-up reduced confining pressure on the failed pillars and increased the potential for additional bursts. Methods for installing ground control systems required rescue workers to travel near areas with high burst potential. Methods were not available to determine the maximum coal burst intensity that the ground support system would be subjected to. On August 16, the coal burst intensity exceeded the capacity of the support system. No alternatives to these methods were available to rescue the entrapped miners, which imposed greater risks on rescue workers than would be accepted for normal mining. As a result, only suspension of underground rescue efforts could have prevented this accident. Prior to the August 16 accident, this was only likely to occur once definitive information was available to indicate that the entrapped miners could not have survived the accident. However, information provided by the drilling operations was not obtained in time to fully evaluate conditions on the section prior to this accident. The prospect of saving the entrapped miners' lives warranted the heroic efforts of the rescue workers. The greater risks imposed on the rescue workers underscore the high degree of care that must be taken by mine operators to prevent catastrophic pillar failures.

Kevin G. Stricklin Administrator for Coal Mine Safety and Health	7-10-08 Date

ENFORCEMENT ACTIONS

An order was issued to Genwal Resources Inc on the morning of the accident, pursuant to section 103 (k) of the Mine Act. The order required the mine operator to obtain MSHA approval of any plan to rescue the entrapped miners, to recover the affected area of the mine to normal, and to assure the safety of all persons at this operation. The order was modified numerous times to allow the rescue and recovery operations to proceed. Additionally, nine enforcement actions were issued to the mine operator, Genwal Resources Inc, and one to the engineering contractor, Agapito Associates, Inc., for violations identified as contributing to the causes and effects or severity of the accident as follows:

Genwal Resources Inc

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 75.203 (a)
Gravity: S&S, Fatal, Occurred **Negligence:** High
Condition or Practice: During pillar development and recovery in the Main West Barrier sections, pillar dimensions were not compatible with effective control of coal or rock bursts. Pillar stability analysis confirms that the length and width of pillars within the active workings, as well as dimensions of the adjoining barrier pillars, did not provide sufficient strength to withstand stresses during pillar recovery. This also constitutes a violation of 75.202(a).

On August 6, 2007, a sudden and violent failure of the overstressed coal pillars and barrier occurred in the Main West South Barrier working section. This instantaneous release of energy caused the coal ribs to burst, fatally injuring the six man production crew. A second failure of a coal pillar occurred on August 16, 2007, fatally injuring three rescuers and injuring six other rescuers. This constituted an unwarrantable failure to comply with a mandatory standard.

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 75.203 (a)
Gravity: S&S, Fatal, Occurred **Negligence:** High
Condition or Practice: During pillar recovery of the Main West South Barrier section from July 15, 2007, until August 6, 2007, the mining of bottom coal exposed persons to hazards caused by faulty pillar recovery methods. GRI mined up to five feet of additional bottom coal from the barrier and the pillars. This resulted in pillars with heights up to 13 feet, as opposed to the original 8-foot high pillars. This compromised the stability of the pillars. These pillar dimensions were not compatible with effective control of coal or rock bursts.

On August 6, 2007, a sudden and violent failure of the overstressed coal pillars occurred, instantaneously releasing large amounts of accumulated energy that exposed miners on the Main West South Barrier section to hazards related to the coal burst. This constitutes an unwarrantable failure to comply with a mandatory standard.

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 75.223 (a)
Gravity: S&S, Fatal, Occurred **Negligence:** High
Condition or Practice: Revisions of the roof control plan were not proposed by the operator when conditions at the mine indicated that the plan was not adequate or suitable for controlling the roof, face, ribs or coal bursts. These conditions included bounces, which occurred in the Main West North Barrier section that resulted in roof and rib damage, and caused miners to fall onto the mine floor and a reportable coal outburst that occurred on March 7, 2007. The operator's failure to make appropriate changes to its roof control plan contributed to the August

6, 2007 fatal accident. This constitutes an unwarrantable failure to comply with a mandatory standard.

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 75.223 (a)
Gravity: S&S, Fatal, Occurred **Negligence:** High
Condition or Practice: The operator did not propose adequate revisions to the roof control plan when conditions at the mine indicated that the plan was not adequate or suitable for controlling the roof, face, ribs or coal bursts. These conditions included bounces that occurred in the Main West North Barrier section and resulted in roof and rib damage and equipment damage, and a coal outburst, which occurred on March 10, 2007 and caused substantial damage to the section.

The revisions to the roof control plan proposed following the March 10, 2007 coal outburst did not make the plan adequate or suitable for controlling the roof, face, ribs or coal or rock bursts. The operator's failure to make appropriate changes to its roof control plan contributed to the August 6, 2007 fatal accident. This was an unwarrantable failure to comply with a mandatory standard.

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 75.223 (a)
Gravity: S&S, Fatal, Occurred **Negligence:** Reckless Disregard
Condition or Practice: Revisions of the roof control plan were not proposed by the operator when conditions at the mine indicated that the plan was not adequate or suitable for controlling the roof, face, ribs or coal bursts. These conditions included bounces that occurred in the Main West South Barrier section that resulted in roof and rib damage, and caused miners to fall onto the mine floor and a reportable coal outburst that occurred on August 3, 2007. The operator's failure to make appropriate changes to its roof control plan contributed to the August 6, 2007 fatal accident. This constitutes an unwarrantable failure to comply with a mandatory standard.

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 75.220 (a) (1)
Gravity: S&S, Fatal, Occurred **Negligence:** Reckless Disregard
Condition or Practice: 30 CFR 75.220(a) (1) requires that a mine operator develop and follow a roof control plan approved by the District Manager. The mine operator did not follow the approved roof control plan amendment dated June 15, 2007 addressing pillar recovery mining in the Main West South Barrier. The site specific approved plan does not permit mining in any of the barrier to the south of the No. 1 entry between crosscut 142 and crosscut 139. The barrier south of the No. 1 entry was mined in this restricted mining area. This mining worsened the stability of the barrier and pillars in this area and contributed to the fatal accident on August 6. This violation constitutes an unwarrantable failure to comply with a mandatory standard.

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 50.10
Gravity: S&S, Fatal, Occurred **Negligence:** Reckless Disregard
Condition or Practice: The operator did not immediately contact MSHA at once without delay and within 15 minutes at the toll-free number, 1-800-746-1553, once the operator knew that an accident in the Main West North Barrier section occurred on March 7, 2007. A coal outburst threw coal into the mine openings, disrupting regular mining activity for more than one hour. The accident was not reported to MSHA pursuant to this standard. Without proper notification, MSHA had no opportunity to investigate this accident. The failure to report this accident denied MSHA an opportunity to investigate it and learn that the mining methods provided inadequate protections. This failure contributed to the August 6 fatal accident. This violation is an unwarrantable failure to comply with a mandatory standard.

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 50.10
Gravity: S&S, Fatal, Occurred **Negligence:** Reckless Disregard
Condition or Practice: The operator did not immediately contact MSHA at once without delay and within 15 minutes at the toll-free number, 1-800-746-1553, once the operator knew that an accident in the Main West North Barrier section occurred on March 10, 2007. A coal outburst threw coal into the mine openings, disrupting regular mining activity for more than one hour. The accident was not reported to MSHA pursuant to this standard. The failure to report this accident denied MSHA an opportunity to investigate it and learn that the mining methods provided inadequate protections. This failure contributed to the August 6 fatal accident. This violation is an unwarrantable failure to comply with a mandatory standard.

Type of Issuance: 104 (d) (2) Order **Standard Violated:** 30 CFR 50.10
Gravity: S&S, Fatal, Occurred **Negligence:** Reckless Disregard
Condition or Practice: The operator did not immediately contact MSHA at once without delay and within 15 minutes at the toll-free number, 1-800-746-1553, once the operator knew that an accident in the Main West South Barrier section occurred on August 3, 2007. A coal outburst threw coal into the mine openings, disrupting regular mining activity for more than one hour. The accident was not reported to MSHA pursuant to this standard. The failure to report this accident denied MSHA an opportunity to investigate it and learn that the mining methods provided inadequate protections. This failure contributed to the August 6 fatal accident. This violation is an unwarrantable failure to comply with a mandatory standard.

Agapito Associates Inc.

Type of Issuance: 104 (d) (1) Citation **Standard Violated:** 30 CFR 75.203 (a)
Gravity: S&S, Fatal, Occurred **Negligence:** Reckless Disregard
Condition or Practice: During pillar development and recovery in the Main West Barrier sections, pillar dimensions were not compatible with effective control of coal or rock bursts. Pillar stability analysis confirms that the length and width of pillars within the active workings, as well as dimensions of the adjoining barrier pillars, did not provide sufficient strength to withstand stresses during pillar recovery. This also constitutes a violation of 75.202(a).

On August 6, 2007, a sudden and violent failure of the overstressed coal pillars and barrier occurred in the Main West South Barrier section. This instantaneous release of energy caused the coal ribs to burst, fatally injuring the six man production crew. A second failure of a coal pillar occurred on August 16, 2007, fatally injuring three rescuers and injuring six other rescuers.

Contractor, Agapito Associates Inc., (AAI) inaccurately evaluated the conditions and events at the mine when determining if areas were safe for mining. Based on its results, AAI recommended to the operator that mining methods were safe and pillar and barrier dimensions were appropriate when in fact they were not. The negligence of the contractor directly contributed to the death of nine people. This violation is an unwarrantable failure to comply with a mandatory standard.

Appendix A - Persons Participating in the Investigation

Murray Energy Corporation

Jerry M. Taylor .... Corporate Safety Director

UtahAmerican Energy Inc.

P. Bruce Hill... President/CEO
Laine Adair .... General Manager
James A. Poulson .... Safety Manager

Genwal Resources Inc

Gary D. Peacock .... Mine Superintendent
Bodee R. Allred .... Safety Director
Blaine K. Fillmore .... Representative of the Miners

Agapito Associates, Inc.

Michael P. Hardy, Ph.D. .... President, Chairman of the Board

Ware Surveying & Engineering

Cody Ware. .... Professional Licensed Surveyor

Neva Ridge Technologies

David Cohen, Ph.D. .... Vice President of Engineering

State of Utah

Sherrie Hayashi.. Labor Commissioner

University of Utah

Walter J. Arabasz, Ph.D. .... Director of the University of Utah Seismograph Station
James C. Pechmann, Ph.D. .... Associate Professor of Geology and Geophysics
Kristine Pankow, Ph.D. .... Asst. Director of the University of Utah Seismograph Stations
Michael K. McCarter, Ph.D. .... Professor and Chair of Mining Engineering
William G. Pariseau, Ph.D. .... Professor of Mining Engineering

West Virginia University

Keith A. Heasley, Ph.D. .... Professor of Mining Engineering

U. S. Geological Survey, Earth Resources Observation and Science Center

Zhong Lu, Ph.D. .... Scientist, Radar Project of Land Sciences

Bureau of Land Management

James F. Kohler .... Chief, Branch of Solid Minerals
Stephen W. Falk.. Mining Engineer

Mine Safety and Health Administration

Richard A. Gates.. District Manager
Michael Gauna.. Mining Engineer
Thomas A. Morley.. Mining Engineer
Joseph R. O'Donnell Jr. .... Supervisory Coal Mine Inspector
Gary E. Smith.. Supervisory Coal Mine Inspector
Timothy R. Watkins...Assistant District Manager
Chris A. Weaver.. Supervisory Coal Mine Inspector
Joseph C. Zelanko..Supervisory Mining Engineer
Steve Powroznik ....Education Field Services
James I. Pruitt.. Coal Mine Safety & Health Inspector Trainee
Michael E. Turner .... Health and Safety Specialist

Appendix B - Victim Data Sheets

Accident Investigation Data - Victim Information

Event Number: 4 4 7 6 4 3 5

U.S. Department of Labor

Mine Safety and Health Administration

Victim Information: 1

1. Name of Injured/Ill Employee: *Kerry Allred*
2. Sex: *M*
3. Victim's Age: *57*
4. Degree of Injury: *01 Fatal*
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: *08/06/2007* b. Time: *2:48*
6. Date and Time Started: a. Date: *08/05/2007* b. Time: *18:00*
7. Regular Job Title: *050 Shuttle Car Operator*
8. Work Activity when Injured: *099 Unknown*
9. Was this work activity part of regular job? Yes | X | No

10. Experience

	Years	Weeks	Days
a. This Work Activity:	27	40	0
b. Regular Job Title:	18	28	0
c: This Mine:	18	28	0
d. Total Mining:	27	40	0

11. What Directly Inflicted Injury or Illness? *122 Side or Rib*
12. Nature of Injury or Illness: *390 Unknown*
13. Training Deficiencies: Hazard: | | New/Newly-Employed Experienced Miner: | | Annual: | | Task: | |
14. Company of Employment: (If different from production operator) *Operator* Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: | X | First-Aid: | | CPR: | | EMT: | | Medical Professional: | | None: | |
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim: *9999 None (No Union Affiliation)*

Victim Information: 2

1. Name of Injured/Ill Employee: *Don Erickson*
2. Sex: M
3. Victim's Age: *50*
4. Degree of Injury: *01 Fatal*
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: *08/06/2007* b. Time: *2:48*
6. Date and Time Started: a. Date: *08/05/2007* b. Time: *18:00*
7. Regular Job Title: *050 Shuttle Car Operator*
8. Work Activity when Injured: *099 Unknown*
9. Was this work activity part of regular job? Yes | X | No

10. Experience:

	Years	Weeks	Days
a. This Work Activity:	0	32	0
b. Regular Job Title:	0	32	0
c: This Mine:	2	32	0
d. Total Mining:	15	40	0

11. What Directly Inflicted Injury or Illness? *122 Side or Rib*
12. Nature of Injury or Illness: *390 Unknown*
13. Training Deficiencies: Hazard: | | New/Newly-Employed Experienced Miner: | | Annual: | | Task: | |
14. Company of Employment: (If different from production operator) *Operator* Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: | X | First-Aid: | | CPR: | | EMT: | | Medical Professional: | | None: | |
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim: *9999 None (No Union Affiliation)*

Victim Information: 3

1. Name of Injured/Ill Employee: *Juan Carlos Payan*
2. Sex: *M*
3. Victim's Age: *22*
4. Degree of Injury: *01 Fatal*
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: *08/06/2007* b. Time: *2:48*
6. Date and Time Started: a. Date: *08/05/2007* b. Time: *18:00*
7. Regular Job Title: *047 Roof Bolter Operator*
8. Work Activity when Injured: *099 Unknown*
9. Was this work activity part of regular job? Yes | X | No

10. Experience:

	Years	Weeks	Days
a. This Work Activity:	2	40	0
b. Regular Job Title:	2	40	0
c: This Mine:	2	40	0
d. Total Mining:	6	4	0

11. What Directly Inflicted Injury or Illness? *122 Side or Rib*
12. Nature of Injury or Illness: *390 Unknown*
13. Training Deficiencies: Hazard: | | New/Newly-Employed Experienced Miner: | | Annual: | | Task: | |
14. Company of Employment: (If different from production operator) *Operator* Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: | X | First-Aid: | | CPR: | | EMT: | | Medical Professional: | | None: | |
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim: *9999 None (No Union Affiliation)*

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Accident Investigation Data - Victim Information

Event Number: 4 4 7 6 4 3 5

U.S. Department of Labor
Mine Safety and Health Administration

Victim Information: 4

1. Name of Injured/Ill Employee: Jose Luis Hernandez | 2. Sex: M | 3. Victim's Age: 23 | 4. Degree of Injury: 01 Fatal

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: 08/06/2007 b.Time: 2:48

6. Date and Time Started: a. Date: 08/05/2007 b.Time: 18:00

7. Regular Job Title: 050 Shuttle Car Operator

8. Work Activity when Injured: 099 Unknown

9. Was this work activity part of regular job? Yes | X | No

10. Experience

	Years	Weeks	Days
a. This Work Activity:	0	8	0
b. Regular Job Title:	0	8	0
c: This Mine:	0	8	0
d. Total Mining:	5	8	0

11. What Directly Inflicted Injury or Illness? 122 Side or Rib

12. Nature of Injury or Illness: 390 Unknown

13. Training Deficiencies Hazard: | New/Newly-Employed Experienced Miner: | Annual: | Task:

14. Company of Employment: (If different from production operator) Operator

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment
Not Applicable: X | First-Aid: | CPR: | EMT: | Medical Professional: | None:

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim: 9999 None (No Union Affiliation)

Victim Information: 5

1. Name of Injured/Ill Employee: Brandon Phillips | 2. Sex: M | 3. Victim's Age: 24 | 4. Degree of Injury: 01 Fatal

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: 08/06/2007 b.Time: 2:48

6. Date and Time Started: a. Date: 08/05/2007 b.Time: 18:00

7. Regular Job Title: 024 Trainee

8. Work Activity when Injured: 099 Unknown

9. Was this work activity part of regular job? Yes | X | No

10. Experience:

	Years	Weeks	Days
a. This Work Activity:	0	3	0
b. Regular Job Title:	0	3	0
c: This Mine:	0	3	0
d. Total Mining:	0	3	0

11. What Directly Inflicted Injury or Illness? 122 Side or Rib

12. Nature of Injury or Illness: 390 Unknown

13. Training Deficiencies: Hazard: | New/Newly-Employed Experienced Miner: | Annual: | Task:

14. Company of Employment: (If different from production operator) Operator

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment:
Not Applicable: X | First-Aid: | CPR: | EMT: | Medical Professional: | None:

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim: 9999 None (No Union Affiliation)

Victim Information: 6

1. Name of Injured/Ill Employee: Manuel Sanchez | 2. Sex: M | 3. Victim's Age: 42 | 4. Degree of Injury: 01 Fatal

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: 08/06/2007 b.Time: 2:48

6. Date and Time Started: a. Date: 08/05/2007 b.Time: 18:00

7. Regular Job Title: 036 Continuous Mining Machine Operator

8. Work Activity when Injured: 099 Unknown

9. Was this work activity part of regular job? Yes | X | No

10. Experience:

	Years	Weeks	Days
a. This Work Activity:	0	24	0
b. Regular Job Title:	0	24	0
c: This Mine:	5	35	0
d. Total Mining:	15	2	0

11. What Directly Inflicted Injury or Illness? 122 Side or Rib

12. Nature of Injury or Illness: 390 Unknown

13. Training Deficiencies: Hazard: | New/Newly-Employed Experienced Miner: | Annual: | Task:

14. Company of Employment: (If different from production operator) Operator

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment:
Not Applicable: X | First-Aid: | CPR: | EMT: | Medical Professional: | None:

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim: 9999 None (No Union Affiliation)

Accident Investigation Data - Victim Information

Event Number: 4 0 1 1 3 6 1

U.S. Department of Labor

Mine Safety and Health Administration

Victim Information: 1

1. Name of Injured/Ill Employee: *Brandon Kimber*
2. Sex: *M*
3. Victim's Age: *29*
4. Degree of Injury: *01 Fatal*
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: *08/16/2007* b. Time: *20:25*
6. Date and Time Started: a. Date: *08/16/2007* b. Time: *6:00*
7. Regular Job Title: *049 Foreman*
8. Work Activity when Injured: *083 Setting Props*
9. Was this work activity part of regular job? Yes [ ] No [X]
10. Experience

	Years	Weeks	Days
a. This Work Activity:	0	1	2
b. Regular Job Title:	2	37	0
c: This Mine:	2	37	0
d. Total Mining:	3	0	0

11. What Directly Inflicted Injury or Illness? *122 Side or rib*
12. Nature of Injury or Illness: *370 Blunt force trauma to chest/Asphyxia*
13. Training Deficiencies: Hazard: [ ] New/Newly-Employed Experienced Miner: [ ] Annual: [ ] Task: [ ]
14. Company of Employment: (If different from production operator) *Operator* Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: [ ] First-Aid: [ ] CPR: [X] EMT: [X] Medical Professional: [ ] None: [ ]
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim: *9999 None (No Union Affiliation)*

Victim Information: 2

1. Name of Injured/Ill Employee: *Dale R. Black*
2. Sex: *M*
3. Victim's Age: *49*
4. Degree of Injury: *01 Fatal*
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: *08/16/2007* b. Time: *18:51*
6. Date and Time Started: a. Date: *08/16/2007* b. Time: *6:00*
7. Regular Job Title: *049 Foreman*
8. Work Activity when Injured: *083 Setting Props*
9. Was this work activity part of regular job? Yes [ ] No [X]
10. Experience:

	Years	Weeks	Days
a. This Work Activity:	0	1	2
b. Regular Job Title:	23	21	6
c: This Mine:	23	21	6
d. Total Mining:	23	21	6

11. What Directly Inflicted Injury or Illness? *122 Side or Rib*
12. Nature of Injury or Illness: *370 Blunt Trauma to Head/Multiple Skull Frac*
13. Training Deficiencies: Hazard: [ ] New/Newly-Employed Experienced Miner: [ ] Annual: [ ] Task: [ ]
14. Company of Employment: (If different from production operator) *Operator* Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: [ ] First-Aid: [ ] CPR: [ ] EMT: [X] Medical Professional: [ ] None: [ ]
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim:

Victim Information: 3

1. Name of Injured/Ill Employee: *Gary L. Jensen*
2. Sex: *M*
3. Victim's Age: *53*
4. Degree of Injury: *01 Fatal*
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death: a. Date: *08/16/2007* b. Time: *21:50*
6. Date and Time Started: a. Date: *08/16/2007* b. Time: *14:00*
7. Regular Job Title: *095 MSHA Inspector*
8. Work Activity when Injured: *083 Setting Props*
9. Was this work activity part of regular job? Yes [ ] No [X]
10. Experience:

	Years	Weeks	Days
a. This Work Activity:	0	1	2
b. Regular Job Title:	35	0	0
c: This Mine:	0	0	0
d. Total Mining:	35	0	0

11. What Directly Inflicted Injury or Illness? *122 Side or Rib*
12. Nature of Injury or Illness: *370 Blunt Force Injury*
13. Training Deficiencies: Hazard: [ ] New/Newly-Employed Experienced Miner: [ ] Annual: [ ] Task: [ ]
14. Company of Employment: (If different from production operator) *Mine Safety and Health Administration* Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: [ ] First-Aid: [ ] CPR: [ ] EMT: [X] Medical Professional: [ ] None: [ ]
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim:

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Accident Investigation Data - Victim Information

Event Number: 4 0 1 1 3 6 1

U.S. Department of Labor

Mine Safety and Health Administration

Victim Information: 7

1. Name of Injured/Ill Employee: *Carl J. Gressmen* | 2. Sex: *M* | 3. Victim's Age: *37* | 4. Degree of Injury: *03 Days away from work only*

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death:

6. Date and Time Started: a. Date: *08/16/2007* b. Time: *6:00*

7. Regular Job Title: *001 Beltman*

8. Work Activity when Injured: *083 Setting Props*

9. Was this work activity part of regular job? Yes [ ] No [X]

10. Experience	Years	Weeks	Days
a. This Work Activity:	0	1	2
b. Regular Job Title:	0	1	4
c. This Mine:	0	1	4
d. Total Mining:	3	0	0

11. What Directly Inflicted Injury or Illness? *122 Side or Rib*

12. Nature of Injury or Illness: *370 Multiple Injuries*

13. Training Deficiencies: Hazard: [ ] New/Newly-Employed Experienced Miner: [ ] Annual: [ ] Task: [ ]

14. Company of Employment: (If different from production operator) *Operator*

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment: Not Applicable: [ ] First-Aid: [ ] CPR: [ ] EMT: [X] Medical Professional: [ ] None: [ ]

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim: *9999 None (No Union Affiliation)*

Victim Information: 8

1. Name of Injured/Ill Employee: *Casey T. Metcalf* | 2. Sex: *M* | 3. Victim's Age: *22* | 4. Degree of Injury: *03 Days away from work only*

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death:

6. Date and Time Started: a. Date: *08/16/2007* b. Time: *6:00*

7. Regular Job Title: *012 Roof Bolter*

8. Work Activity when Injured: *083 Setting Props*

9. Was this work activity part of regular job? Yes [ ] No [X]

10. Experience	Years	Weeks	Days
a. This Work Activity:	0	1	2
b. Regular Job Title:	0	1	4
c. This Mine:	0	1	4
d. Total Mining:	1	21	2

11. What Directly Inflicted Injury or Illness? *122 Side or Rib*

12. Nature of Injury or Illness: *370 Multiple Injuries*

13. Training Deficiencies: Hazard: [ ] New/Newly-Employed Experienced Miner: [ ] Annual: [ ] Task: [ ]

14. Company of Employment: (If different from production operator) *Operator*

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment: Not Applicable: [ ] First-Aid: [ ] CPR: [ ] EMT: [X] Medical Professional: [ ] None: [ ]

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim: *9999 None (No Union Affiliation)*

Victim Information: 9

1. Name of Injured/Ill Employee: *Lester A. Day* | 2. Sex: *M* | 3. Victim's Age: *49* | 4. Degree of Injury: *03 Days away from work only*

5. Date(MM/DD/YY) and Time(24 Hr.) Of Death:

6. Date and Time Started: a. Date: *08/16/2007* b. Time: *6:00*

7. Regular Job Title: *001 Beltman*

8. Work Activity when Injured: *083 Setting Props*

9. Was this work activity part of regular job? Yes [ ] No [X]

10. Experience	Years	Weeks	Days
a. This Work Activity:	0	1	2
b. Regular Job Title:	2	24	0
c. This Mine:	2	24	0
d. Total Mining:	14	0	0

11. What Directly Inflicted Injury or Illness? *122 Side or Rib*

12. Nature of Injury or Illness: *370 Multiple Injuries*

13. Training Deficiencies: Hazard: [ ] New/Newly-Employed Experienced Miner: [ ] Annual: [ ] Task: [ ]

14. Company of Employment: (If different from production operator) *Operator*

Independent Contractor ID: (if applicable)

15. On-site Emergency Medical Treatment: Not Applicable: [ ] First-Aid: [ ] CPR: [ ] EMT: [X] Medical Professional: [ ] None: [ ]

16. Part 50 Document Control Number: (form 7000-1)

17. Union Affiliation of Victim: *9999 None (No Union Affiliation)*

MSHA Form 7000-50b, Mar 2008 Printed 07/07/2008 1:30:10 PM

Accident Investigation Data - Victim Information

Event Number: 4 0 1 1 3 6 1

U.S. Department of Labor
Mine Safety and Health Administration

Victim Information: 4

1. Name of Injured/Ill Employee: Jeff Tripp
2. Sex: M
3. Victim's Age: 40
4. Degree of Injury: 03 Days away from work only
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death:
6. Date and Time Started: a. Date: 08/16/2007 b.Time: 12:45
7. Regular Job Title: 049 Foreman
8. Work Activity when Injured: 083 Setting Props
9. Was this work activity part of regular job? Yes | No X

10. Experience

	Years	Weeks	Days
a. This Work Activity:	0	0	1
b. Regular Job Title:	0	0	1
c: This Mine:	0	0	1
d. Total Mining:	10	0	0

11. What Directly Inflicted Injury or Illness? 122 Side or Rib
12. Nature of Injury or Illness: 370 Multiple Injuries
13. Training Deficiencies: Hazard: | New/Newly-Employed Experienced Miner: | Annual: | Task:
14. Company of Employment: (If different from production operator) Operator
Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: | First-Aid: | CPR: | EMT: X | Medical Professional: | None:
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim: 9999 None (No Union Affiliation)

Victim Information: 5

1. Name of Injured/Ill Employee: Frank E. Markosek
2. Sex: M
3. Victim's Age: 57
4. Degree of Injury: 03 Days away from work only
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death:
6. Date and Time Started: a. Date: 08/16/2007 b.Time: 14:00
7. Regular Job Title: 095 MSHA Inspector
8. Work Activity when Injured: 083 Setting Props
9. Was this work activity part of regular job? Yes | No X

10. Experience:

	Years	Weeks	Days
a. This Work Activity:	0	1	2
b. Regular Job Title:	36	0	0
c: This Mine:	0	0	0
d. Total Mining:	36	0	0

11. What Directly Inflicted Injury or Illness? 122 Side or Rib
12. Nature of Injury or Illness: 370 Multiple Injuries
13. Training Deficiencies: Hazard: | New/Newly-Employed Experienced Miner: | Annual: | Task:
14. Company of Employment: (If different from production operator) Mine Safety and Health Administration
Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: | First-Aid: | CPR: | EMT: X | Medical Professional: | None:
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim:

Victim Information: 6

1. Name of Injured/Ill Employee: Joseph R. Bouldin
2. Sex: M
3. Victim's Age: 37
4. Degree of Injury: 03 Days away from work only
5. Date(MM/DD/YY) and Time(24 Hr.) Of Death:
6. Date and Time Started: a. Date: 08/16/2007 b.Time: 6:00
7. Regular Job Title: 050 Shuttle Car Operator
8. Work Activity when Injured: 083 Setting Props
9. Was this work activity part of regular job? Yes | No X

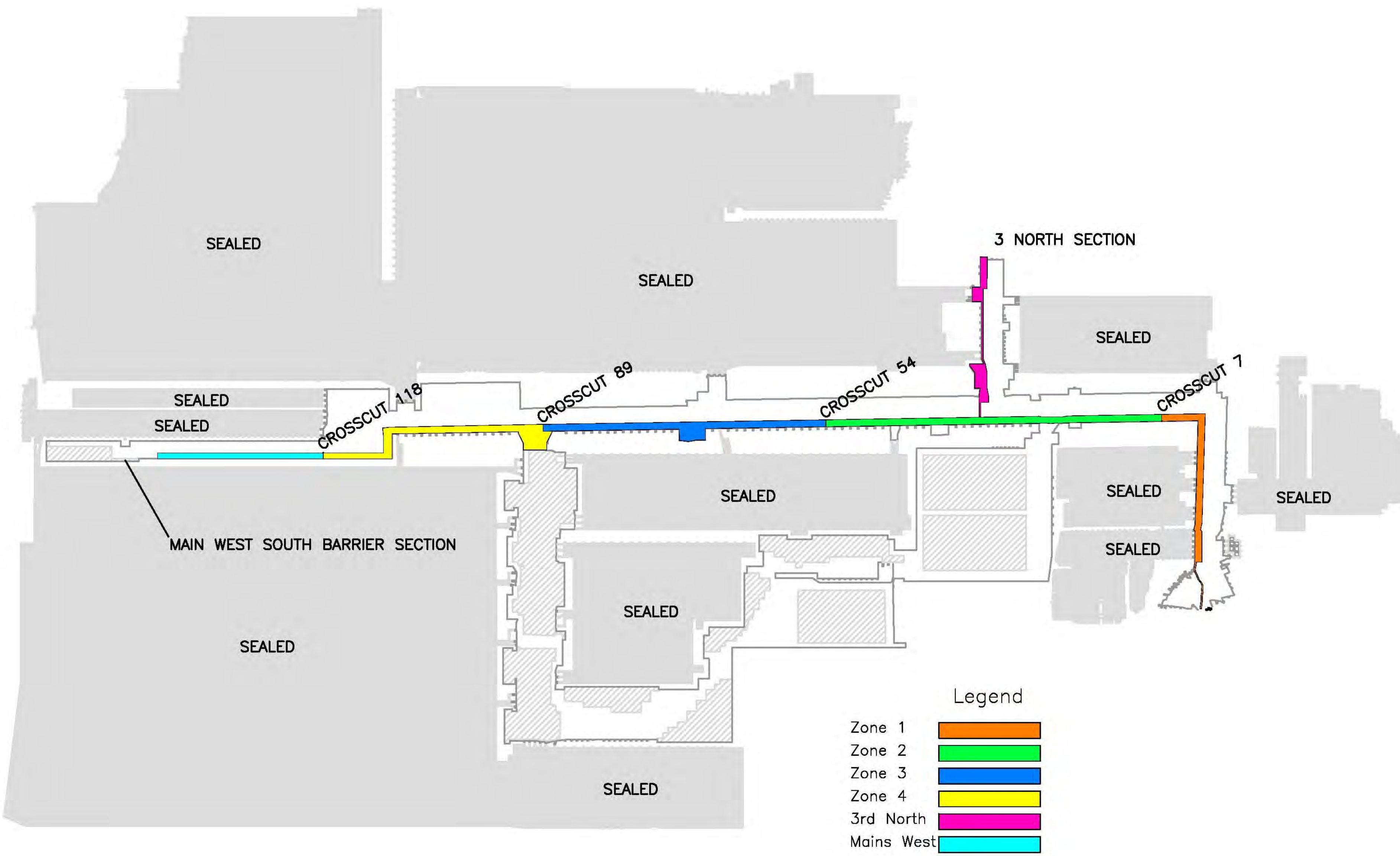
10. Experience:

	Years	Weeks	Days
a. This Work Activity:	0	1	2
b. Regular Job Title:	0	1	4
c: This Mine:	0	1	4
d. Total Mining:	1	7	2

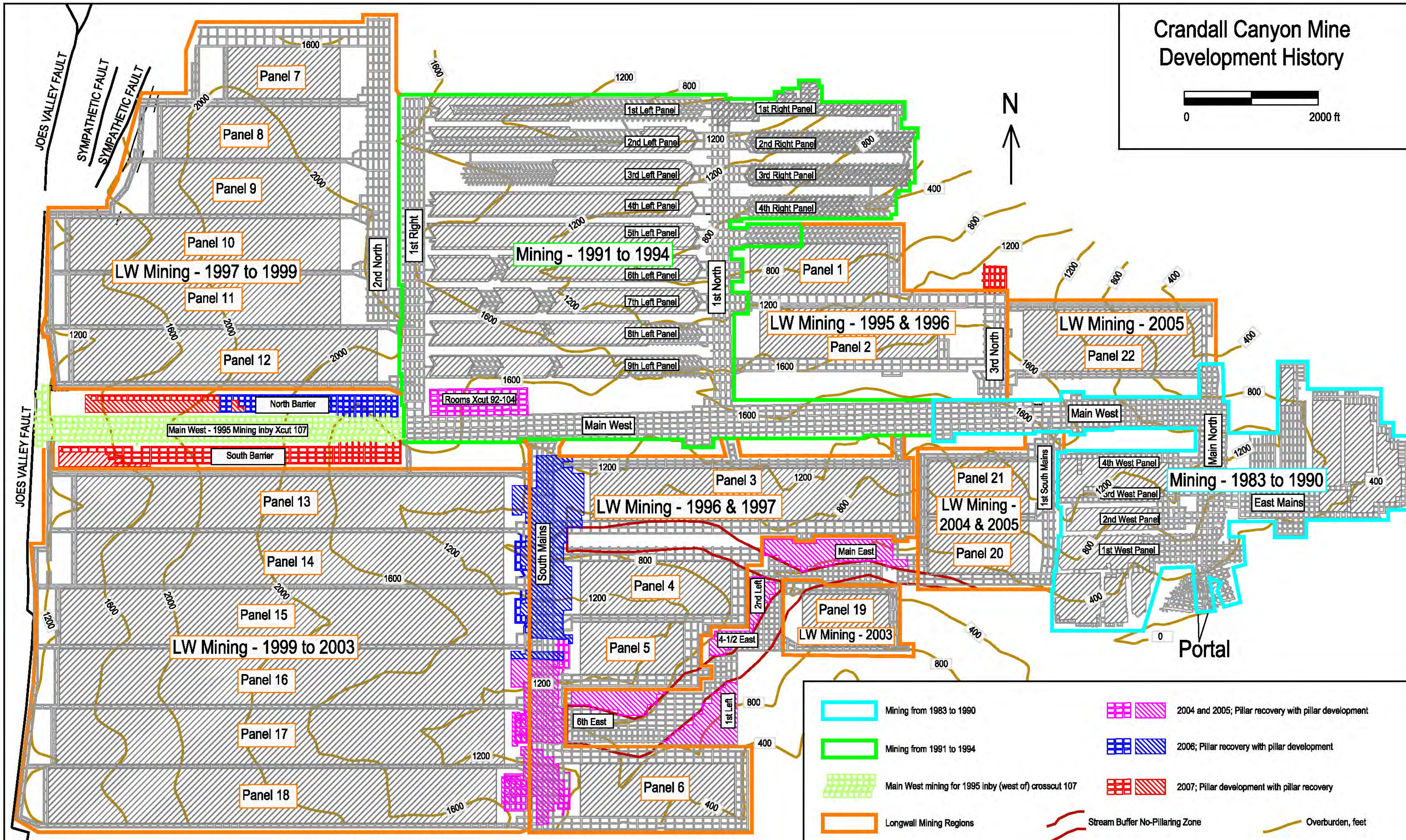
11. What Directly Inflicted Injury or Illness? 122 Side or Rib
12. Nature of Injury or Illness: 370 Multiple Injuries
13. Training Deficiencies: Hazard: | New/Newly-Employed Experienced Miner: | Annual: | Task:
14. Company of Employment: (If different from production operator) Operator
Independent Contractor ID: (if applicable)
15. On-site Emergency Medical Treatment: Not Applicable: | First-Aid: | CPR: | EMT: X | Medical Professional: | None:
16. Part 50 Document Control Number: (form 7000-1)
17. Union Affiliation of Victim: 9999 None (No Union Affiliation)

MSHA Form 7000-50b, Mar 2008 Printed 07/07/2008 1:30:03 PM

Appendix C - Safety Zone Map



Appendix D - Mine Development History Map



AGAPITO ASSOCIATES, INC.
CONSULTING ENGINEERS

May 5, 2000 226-07

Laine Adair
General Manager
GENWAL Resources, Inc.
195 North 100 West
PO Box 1420
Huntington, UT 84528

RE: **Barrier Pillar to Protect Bleeders for Panel 15, South of West Mains**

Dear Laine,

This letter summarizes results of the analysis of the effects of barrier pillar widths on future bleeder entry stability for Panel 15, south of the west mains. Results of computer models can be found in Figures 1, 2, and 3. Empirical barrier design methods have been applied and are summarized in Figure 4 as an additional aid. The study was initiated during my site visit on March 15, 2000. These analyses were completed in April and the results communicated to you during a conference call involving Rex Goodrich, Kyle Free, and myself on April 5, 2000. This letter provides the written backup to support the decision to proceed with barrier pillars of 240-ft width. The analysis presented was performed by Kyle Free.

PURPOSE AND SCOPE OF WORK

The purpose of the study was to provide analytical support for a decision to select the width of the bleeder barrier pillar for Panel 15. Two sizes, 260 and 300 ft, were considered. The analysis evaluates the effects of LW mining-induced stresses on the barrier pillars and bleeder entries. EXPAREA models of the area, including Panels 14, 15, and 16, were created and analyzed to estimate how stresses redistribute eastward from the gob toward the bleeders. The models assume a mining height of 7.3 ft and a variable depth of cover. Rock properties consistent with previous models of the mine were selected. Two mine geometries were modeled:

1. Three LW panels **without** bleeder entries [Figure 1].
2. Three LW panels **with** bleeder entries [Figure 3].

AAI004285

DISCUSSION OF ATTACHMENTS

Figure 1 depicts a scenario in which Panels 14, 15, and 16 are fully extracted and no bleeder entries exist. Plots of vertical stresses and the change in vertical stresses due to LW mining are shown. The vertical stress at 260 ft, 300 ft, and 400 ft from the outer startup entry of Panel 15 are estimated to increase by 16.4%, 15.9%, and 12.1%, respectively, as a result of the longwall mining of Panels 14, 15, and 16. This increase in stress is the average increase along the face length of Panel 15. A cross section plot (A-A') of the vertical stress increase was created to show the rate of decrease in mining-induced

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stresses with distance from the startup entries (Figure 2). If the bleeders were located 260 ft from the starter rooms, at the specific location of section A-A', they would experience a 1.3% increase in stress as compared to if the bleeders were at 300 ft. If the bleeders were at 400 ft from the starter room, the stress change would be 4.9% less than if located at 260 ft from the starter room.

Figure 3 provides modeling results for two cases of a scenario in which bleeder entries have been developed forming a 260-ft barrier pillar to the east of Panel 15. In Case 1 only the development of the LW panels is complete, and in Case 2 the panels have been fully extracted. The average pillar stress of the yield pillar annotated in Figure 3 was estimated to be 1820 psi for Case 1 and 2120 psi for Case 2. This represents a 16.5% stress increase caused by LW mining. (This is very close to the expected stress increase indicated in Figures 1 and 2.)

Figure 4 gives a summary of recommended barrier pillar widths by various empirical methods. The design widths shown here might be helpful as an additional source on which to base decisions. For a depth of 1000 ft, all the methods support a barrier pillar of 260 ft or less. At 1500 ft of cover, three of four methods suggest a barrier pillar of less than 260 ft.

DISCUSSION OF BARRIER PILLAR SIZING

The discussion on barrier pillar sizing in this location must consider the stress redistribution resulting from longwall mining, the geologic variability along the bleeder entries, the expected operational life of the bleeders, and the level of maintenance acceptable to management. The stress redistribution resulting from panel mining is projected to be less than 20% of the pre-existing stress conditions for barrier pillars greater than about 230 ft. This change in stress should not be significant given the depth of cover and pillar sizing in the bleeders. The geologic variability along the bleeders cannot be predicted, but given the proximity of the bleeders to Joe's Valley Fault and the potential to intersect splays or associated sub-faults, some variability in roof conditions resulting from variable geologic conditions can be expected. The expected operational life of the bleeders is less than three years, which is sufficient to complete mining of Panels 15 through 18. There is some possibility that the bleeders may be required to function longer if GENWAL mines the southern leases. If this were a high probability, consideration should be given to a larger barrier pillar and/or a three-entry bleeder. Maintenance of the bleeders is required for barrier pillar size and would be similar if the barrier pillars were 240 ft and up to 300-ft wide. To minimize any potential for stress overloading resulting from panel mining, or to minimize maintenance and to provide long term stability (greater than three years), a barrier pillar of 400 ft would be required.

We appreciate the opportunity to visit your mine and work with you and your staff. If you have any questions, please call Rex or myself.

Yours sincerely,

Michael P. Hardy
Principal

cc: Sam Quigley
MPH/pg

AAI004286

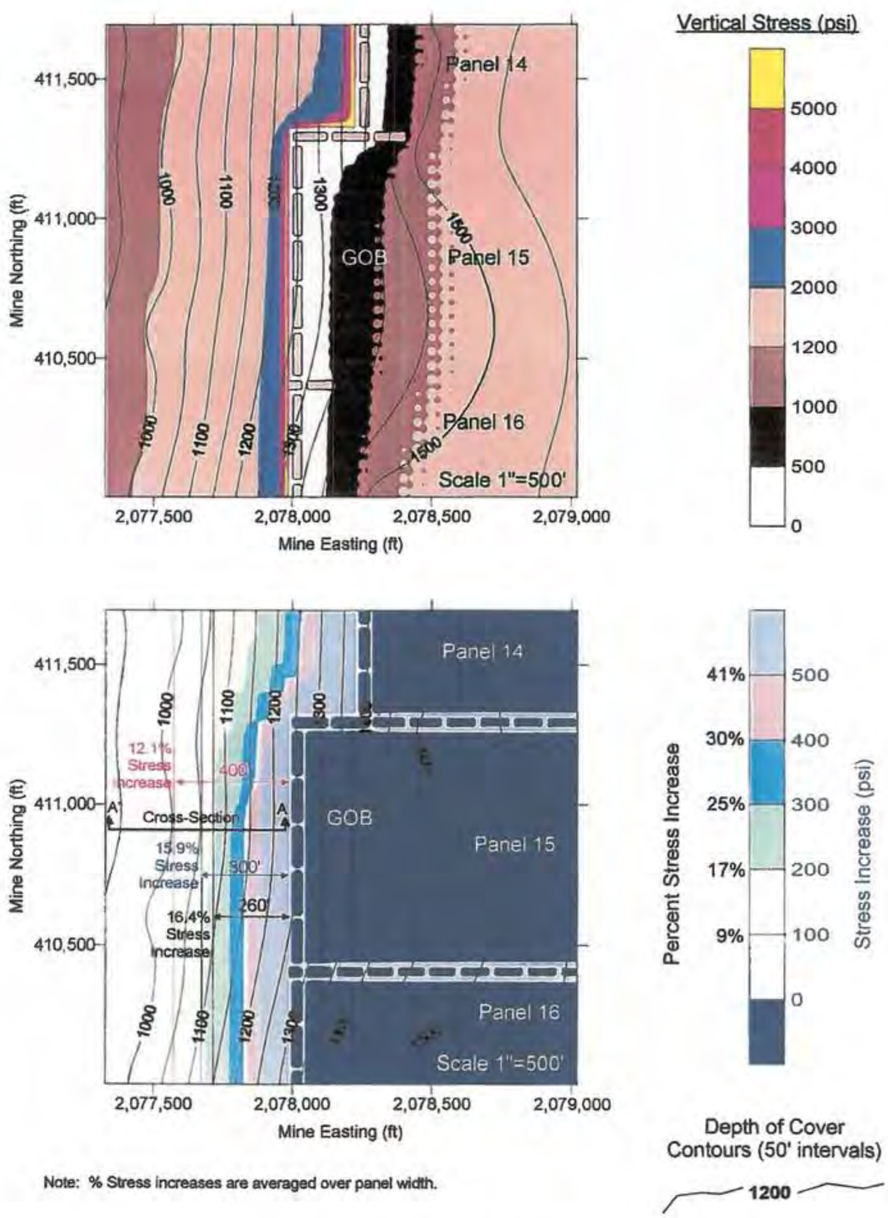

Figure 1. Vertical Stress Distribution in Area of Barrier Pillar, With Mining of Panels 14 Through 16

04-24-00 ; Projects/Genwal/barrierwidth.srf ; ksf

Agapito Associates, Inc. **AAI004287**

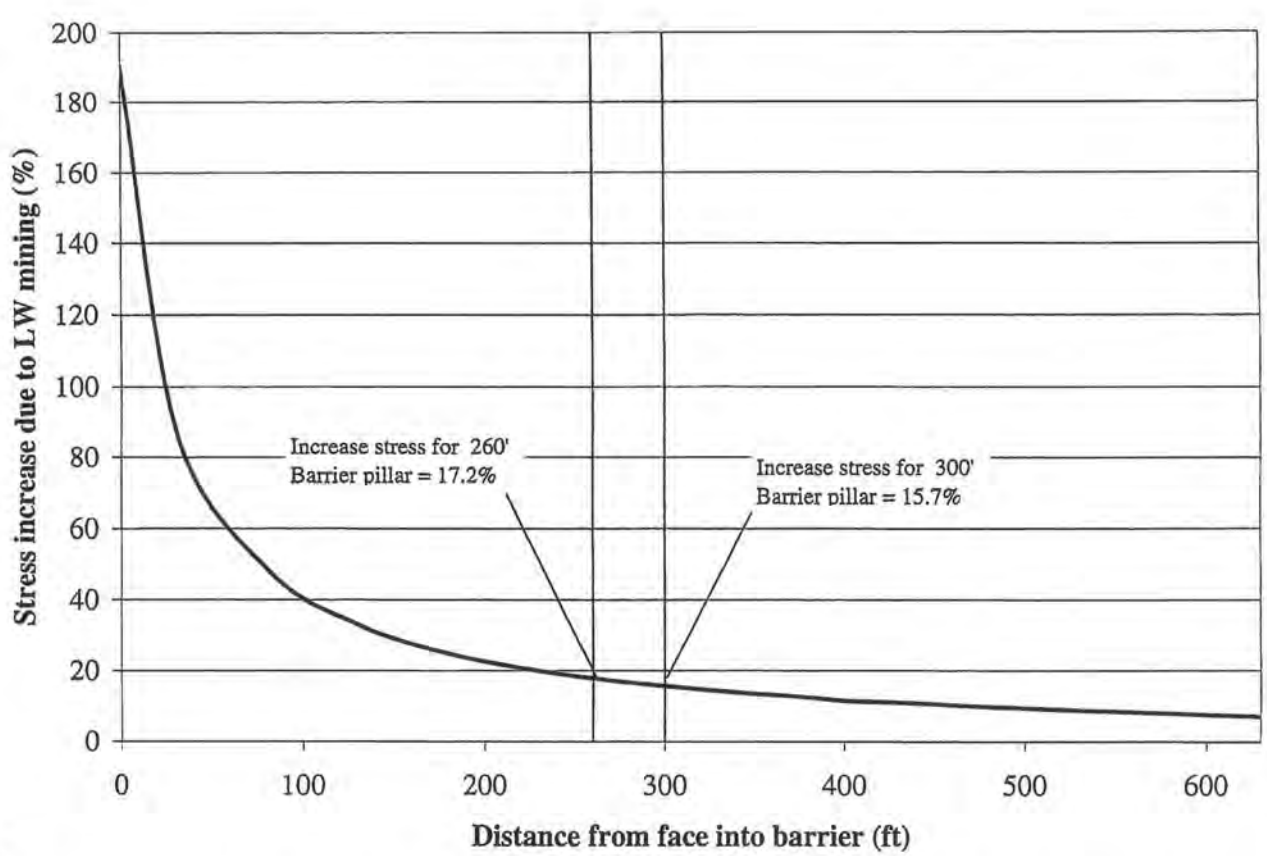

Figure 2. Vertical Stress Change from Starter Room Access Drift as Percent of Pre-existing Vertical Stress

Genwal
Barrier Width Analysis
(226-07)
ksf';Genwal/x-sect.xls;4/24/00

Agapito Associates, Inc.

AAI004288

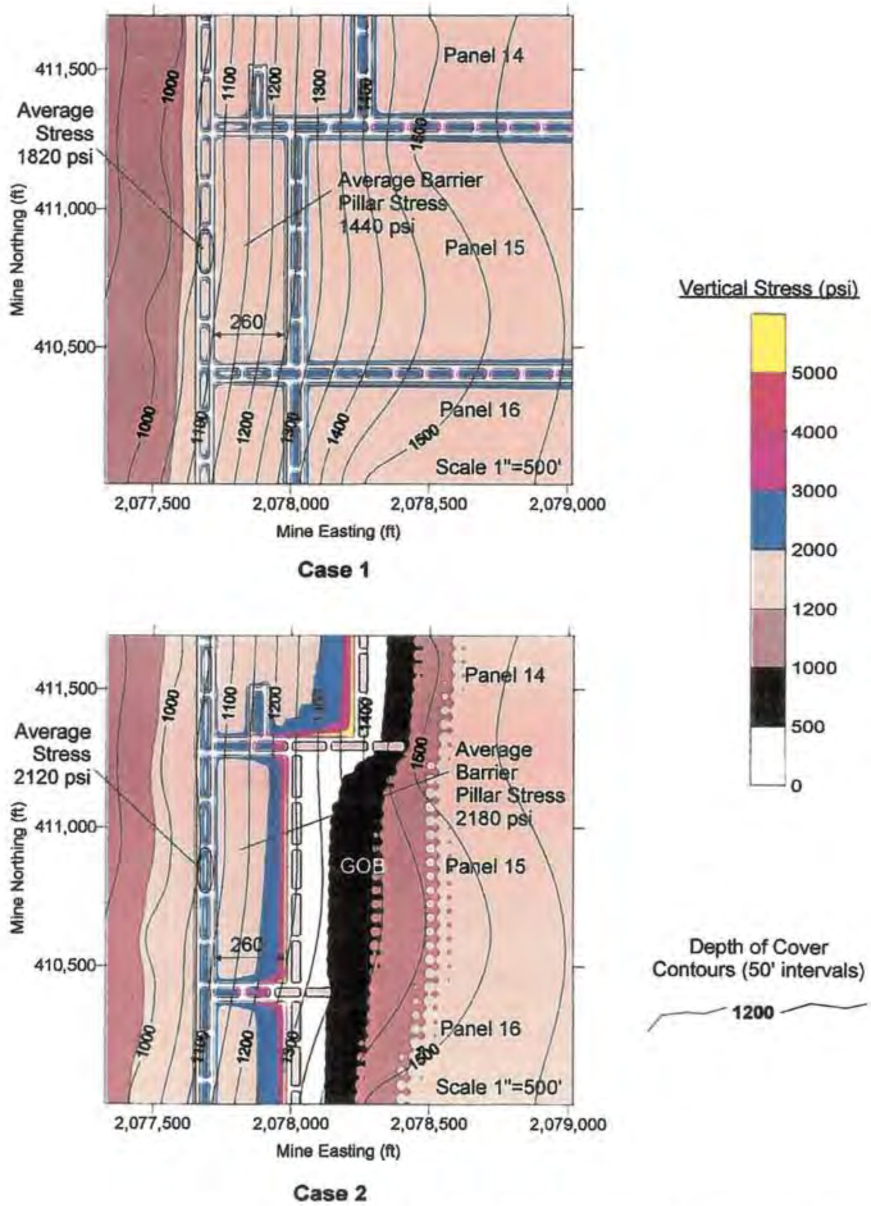

Figure 3. Vertical Stress in Barrier and Bleeder Pillars for 260-ft Barrier Pillar

BARRIER PILLAR DESIGN
Longwall Mining

BARRIER DESIGN	DEPTH OF COVER			
	1,000 ft	1,500 ft	2,000 ft	2,500 ft
MINING PARAMETERS				
Longwall Panel Width (ft)	780.0	780.0	780.0	780.0
Number of Mined Adjacent Longwall Panels (*Prior to arch collapse*)	2	2	2	2
Pillar Height (ft)	7.3	7.3	7.3	7.3
COAL STRENGTH PROPERTIES				
Specimen* Unconfined Compressive Strength (psi)	5,000	5,000	5,000	5,000
CALCULATED BARRIER WIDTHS				
NORTH AMERICAN METHOD (USBM 1995)	260	430	620	870
HOLLAND RULE OF THUMB (Holland 1973)	150	170	200	NA
HOLLAND CONVERGENCE METHOD (Holland 1973)	210	230	250	NA
PENNSYLVANIA MINE INSPECTOR'S FORMULA	150	200	250	NA

* "Specimen" indicates small scale laboratory test results versus rock mass scale values.

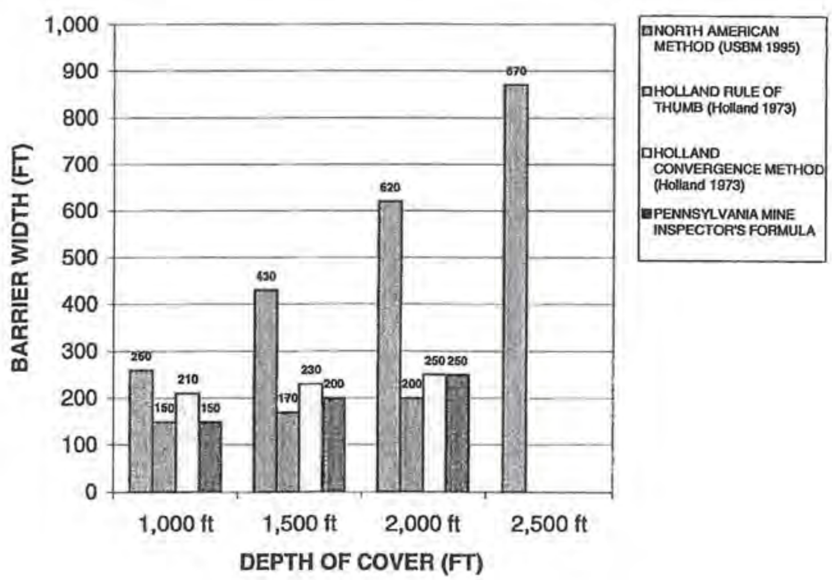

Figure 4. Barrier Pillar Sizes from Empirical Methods

AGAPITO ASSOCIATES, INC.
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July 20, 2006 226-20

Mr. Laine Adair
Andalex Resources, Inc.
195 North 100 West
Huntington, UT 84520

Re: **DRAFT—GENWAL Crandall Canyon Mine Main West Barrier Mining Evaluation**

Dear Laine,

Agapito Associates, Inc. (AAI), has completed the geotechnical analysis of GENWAL Resources, Inc.'s (GENWAL) plan for room-and-pillar mining in the Main West barriers at the Crandall Canyon Mine (Figure 1). Current plans include developing four entries in the barriers north and south of the existing mains in the area west of the 1st Right/2nd North submains under cover ranging from about 1,300 ft to 2,200 ft. Barrier mining is also planned to the east between the 1st Right/2nd North and 1st North submains under generally shallower cover. Figure 1 shows the existing mine in green and planned mining in black. The objective of the analysis was to evaluate the potential for high-stress conditions caused by a combination of deep cover and side-abutment loads from the adjacent longwall gobs, and any load transferred onto the barriers from the existing pillars in Main West. Findings of the analysis and implications for pillar design and ground control are discussed.

CONCLUSIONS

Conclusions are that the proposed Main West 4-entry layout with 60-ft by 72-ft (rib-to-rib) pillars should function adequately for short-term mining in the barriers (i.e., less than 1 year duty). Model results indicate that planned mining in the barriers will avoid the majority of the side-abutment stress transferred from the adjacent longwall panel gobs. Stress conditions are expected to be controlled by the depth of cover and not by abutment loads.

The proposed 60-ft by 72-ft pillars are not intended for long-term performance and, therefore, can accept a reduced design safety margin compared to typical life-of-mine mains pillars. Analytical results indicate that the proposed pillars result in only incrementally more geotechnical risk than associated with the historical pillars in Main West. The historical 70-ft by 72-ft pillars in Main West have performed adequately for many years longer than will be required for mining the barriers. Because rib yielding and roof sag are time-dependent effects, it is probable that mining will be completed in the barriers before rib and roof conditions show advanced deterioration. The modern mining practices of GENWAL, including systematic bolting rapidly after excavation, bolting with 6 bolts per row, tight geometric control, mining with narrow entries (18 ft wide), and mining to rock instead of leaving top coal, should make this a workable design and limit geotechnical risk to an acceptable level. Increasing crosscut spacing is not expected to significantly improve ground control.

ANALYSIS

Ground conditions were simulated using the NIOSH displacement discontinuity code, LAMODEL.[1] The approach involved two stages of modeling, first, simulation of historical mining in the 1st North Left block of room-and-pillar panels and, second, simulation of future conditions in Main West. The historical and future mining areas modeled are highlighted in Figure 1. The models were used to calculate three parameters: (1) in-seam vertical stress, (2) roof-to-floor convergence, and (3) pillar (coal) yielding. These parameters provide the principal quantitative basis for comparing historical and future conditions.

Both models (historical and future mining areas) incorporated the mining geometry, sequence of mining, and variable depth of cover. To provide realistic pillar behavior, a high-resolution model was created using 5-ft-square elements. Coal strength was specified for eight levels of increasing confinement based upon depth into the rib, ranging from 2.5 to 37.5 ft.

In LAMODEL, the "method of slices" is applied to approximate the load bearing capacity of the pillars. This method assumes that the strength of any pillar element is a function of its distance from the nearest pillar rib and element size by:

$$\sigma_v = S_l[0.71 + 1.74(x/h)] \qquad \text{(Eqn. 1)}$$

where
σ_v = Confined coal strength
S_l = In situ rock mass unconfined strength
x = Distance from the nearest pillar rib
h = Pillar height

Peak strain in each element is calculated by:

$$\varepsilon_v = \sigma_v / E \qquad \text{(Eqn. 2)}$$

where
ε_v = Peak strain
E = Coal elastic modulus

Upon yielding, the residual stress and residual strain within a pillar element are calculated by:

[1] Heasley, K.A. (1998), *Numerical Modeling of Coal Mines with a Laminated Displacement-Discontinuity Code*, Ph.D. Thesis, Colorado School of Mines, 187 p.

$$\sigma_r = 0.2254 \times \ln(x) \times \sigma_v \qquad \text{(Eqn. 3)}$$

and

$$\varepsilon_r = 4 \times \varepsilon_v \qquad \text{(Eqn. 4)}$$

where σ_r = Residual stress
ε_r = Residual strain

The in situ unconfined coal strength and elastic modulus are estimated to be 1,640 psi, and 0.5×10^6 psi, respectively, for a 5-square-ft element. An average 8-ft pillar height, representative of actual and planned mining, was used in all models. The eight levels of confined coal strength and corresponding strain for a typical pillar, using Equations 1 through 4, are listed in Table 1.

Table 1. LAMODEL Confined Coal Strength

Confined Coal Distance into Rib (ft)	Confined Strength (psi)	Peak Strain	Residual Strength (psi)	Residual Strain
2.5	2,059	0.004	425	0.017
7.5	3,845	0.008	1,746	0.032
12.5	5,631	0.012	3,206	0.047
17.5	7,417	0.016	4,785	0.062
22.5	9,203	0.019	6,459	0.077
27.5	10,989	0.023	8,209	0.092
32.5	12,775	0.027	10,025	0.107
37.5	14,562	0.031	11,896	0.122

Other model properties are summarized in Table 2 and are based principally on previous modeling studies for the Crandall Canyon Mine.[2,3,4,5]

1st North Left Panels Back-Analysis

The historical mining area is relevant for calibrating the model for predicting future conditions in Main West because of (1) similar geologic conditions to that in Main West,

2 Agapito Associates, Inc. (1995), "Technical Review of Longwall Feasibility," prepared for GENWAL Resources, Inc., November.
3 Agapito Associates, Inc. (2000), "Barrier Pillar to Protect Bleeder for Panel 15, South of West Mains," prepared for GENWAL Resources, Inc., May 5.
4 Agapito Associates, Inc. (1997), "Panel 6th Right Experiment Back Analysis and Model Calibration," prepared for GENWAL Resources, Inc., November 20.
5 Agapito Associates, Inc. (2004), "GENWAL South Crandall Canyon Mine Gateroad Alternatives Geotechnical Study," prepared for GENWAL Resources, Inc., December 17.

Table 2. Input Parameters for LAMODEL

Overburden	
Deformation Modulus of Roof Rock (psi)	2,000,000
Poisson's Ratio of Overburden	0.25
Lamination Thickness of Overburden (ft)	25
Unit Weight of Overburden (pcf)	158
Coal	
Elastic Modulus of Coal (psi)	470,000
Poisson's Ratio of Coal	0.34
Strain Hardening Gob	
Initial Modulus (psi)	100
Final Modulus (psi)	76,000
Final Stress (psi)	4,000
Gob Height Factor	1
Poisson's Ratio of Gob	0.25

(2) significant depth of cover (up to 1,800 ft), and (3) similar mine geometry. The historical model area includes a barrier separating the mains from gob in the 9th Left panel at depths reaching 1,800 ft, which represents the same type of high-stress, side-abutment load transfer onto a barrier mechanism anticipated in Main West.

The 1st North Left model describes an area where room-and-pillar panels were retreated under relatively deep cover during the late 1990s. Ground conditions are reported to have been good during primary mining even with side-abutment loading from adjacent gob. Occasional pillars were left behind during retreat because of locally difficult ground conditions, mainly related to peeling top coal. This was compounded by large center-entry roof spans (reaching 22 to 23 ft) mined to accommodate the continuous haulage system in use at that time. Also, short 5-ft bolts and only 5 bolts per row were used in the panels, which is considered substandard for retreat mining compared to the mine's current practice. Conclusions are that, while retreat mining was overall successful, ground conditions could have been improved by mining the top coal. It is believed that this would have eliminated the need for leaving pillars in some locations.

Main West was recently mined northward into the barrier separating the mains from Panel 9th Left—1st North, leaving a 145-ft to 170-ft-wide barrier at a depth of about 1,600 to 1,800 ft. Ground conditions in the new entries are reported to be very good with no obvious effects of side-abutment load override across the barrier. Good conditions are also attributed to better mining practices than used in the historical panels to the north, including mining the top coal (rock roof), narrower entries (nominally 18-ft wide), and better roof bolting (6 bolts per row).

Modeling results presented in Figures 2 through 10 show vertical stress, coal yielding, and convergence for three stages of mining in Panel 9th Left, (1) when the panel was fully mined on the advance, and after the panel was (2) partly and then (3) fully retreated.

Figures 2, 3, and 4 show vertical stress, yielding, and seam convergence, respectively, during the first stage. Almost all remnant pillars in the north panels are shown to be fully yielded. The stresses in the centers of these pillars exceeded 10,000 psi, resulting in convergence greater than 2.0 inches. Pillars in Panel 9th Left show limited rib yielding. Seam convergence in the panel is computed by the model to be less than 1.6 inches and average vertical stresses within the pillars around 3,000 psi, reflecting an increase of about 800 psi above in situ stress levels.

At the second mining stage, pillars next to the gob at the retreat line are shown to be yielded (Figure 6) and converged more than 2.0 inches (Figure 7) in response to abutment stresses. Based on the experience in the panel with peeling top coal, 2.0 inches of convergence is considered an indicator of potential roof and rib instability in the model.

The third stage of mining in Figures 8, 9, and 10 shows 9th Left fully retreated and Main West mined into the barrier per the current geometry. The results show no significant side-abutment stress override across the barrier on to the mains pillars, consistent with actual conditions. Pillar rib yielding is shown to be minimal and roof convergence less than 1.0 inch in the vicinity of the barrier. This behavior is considered an indicator in the model of good ground conditions.

Main West Barrier Mining Predictive Model

Future mining in the north barrier of Main West was simulated using the same model properties from the back-analysis model. The Main West model was adjusted to include the actual depth of cover which ranges from about 1,600 to 2,200 ft. The area encompassed by the model is considered representative of the range of conditions expected throughout Main West, including planned mining in the barrier south of the mains.

Results of the model are shown in Figures 11 through 19. Mining was simulated in three stages: (1) current conditions before any new mining (Figures 11 through 13), (2) early during planned mining with development part way into the barrier (Figures 14 through 16), and (3) after the barrier is fully mined (Figures 17 through 19). Planned mining includes 18-ft-wide rooms with 60 ft by 72 ft (rib-to-rib) pillars. These dimensions were rounded to 20 ft and 60 ft by 70 ft, respectively, in the model because of the 5-ft element size. Notably, the models show mining into the existing Main West entries. This may or may not be the final design. This is a conservative assumption useful for analyzing the highest pillar loading.

For the current geometry, the model shows side-abutment stresses reaching as high as 30,000 psi in the northern interior of the existing 450-ft-wide barrier. Figure 20 shows two stress profiles (A-A′) through the barrier, one for the current geometry (magenta) and a second with planned mining in the barrier (blue). The location of Profile A-A′ is shown in Figure 14. For the current geometry, stress levels taper to near pre-mining (in situ) stress levels approximately 100 ft into the barrier, indicating that the proposed 130-ft-wide barrier will limit exposure of the planned entries and pillars to most of the abutment. Mining conditions are expected to reflect stress levels normally associated with development mining away from abutment stresses. Stress levels are expected to be controlled by the depth of cover, and not side-abutment stresses. This is consistent with the recent experience mining across the barrier from Panel 9th Left.

The proposed 60-ft by 72-ft (rib-to-rib) mains pillars are predicted to be about 7% weaker on average than the existing 70-ft by 72-ft pillars in Main West. This is based on five widely recognized empirical pillar strength formulas which show anywhere from a 1% to 12% drop in pillar strength with the 10 ft narrower pillar. Pillar strengths predicted by the various methods are summarized in Table 3.

Table 3. Reduction in Pillar Strength Based on Empirical Design Formulas

Empirical Formula	Pillar Design Strength: Existing 70-ft × 72 ft Pillars	Pillar Design Strength: Planned 60-ft × 72-ft Pillars	Existing to Planned Pillar Strength Change	
1,600 ft Deep				
Wilson Method	4,960 psi	4,800 psi	-160 psi	-3%
Abel Method	5,740 psi	5,690 psi	-50 psi	-1%
Bieniawski Method	3,910 psi	3,450 psi	-460 psi	-12%
ALPS-Bieniawski Method	3,410 psi	3,010 psi	-400 psi	-12%
Holland Method	3,060 psi	2,830 psi	-230 psi	-8%
			Average	**-7%**
2,200 ft Deep				
Wilson Method	6,730 psi	6,510 psi	-220 psi	-3%
Abel Method	7,370 psi	7,290 psi	-80 psi	-1%
Bieniawski Method	3,910 psi	3,450 psi	-460 psi	-12%
ALPS-Bieniawski Method	3,410 psi	3,010 psi	-400 psi	-12%
Holland Method	3,060 psi	2,830 psi	-230 psi	-8%
			Average	**-7%**

This reduced strength translates to slightly increased rib yielding (sloughage) and increased roof convergence. Figure 18 shows rib yielding predicted by the model. In the figure, rib yielding is limited to the corners of the existing 70-ft by 72-ft pillars (bottom two rows of pillars). In the proposed smaller pillars (top four rows of pillars), yielding occurs in the skin all the way around the pillar. However, the pillar cores are shown to remain competent in all locations, indicating acceptable pillar performance.

Figure 19 shows predicted roof convergence. Figure 21 compares centerline convergence along an entry in the existing mains (Profile B-B′) with an entry central to the new mining (Profile C-C′). Profile locations are shown in Figure 19. The figures show that the proposed smaller pillars result in up to a 0.15 inch increase in roof convergence in the intersections, or about a 15% increase, compared to historical conditions in Main West. This reflects the increased rib yielding around the smaller pillars.

Based on modeled convergence, ground conditions are expected to be heavier compared to conditions in the mains across from Panel 9th Left, and only slightly heavier than conditions in the existing Main West entries. This suggests there will be an increased reliance on roof support, particularly under the deeper cover (>1,800 ft). However, convergence is far below the 2.0-inch level associated with roof and rib instability established by the back-analysis model.

The existing 70-ft by 72-ft pillars in Main West have performed reliably over the long-term (several years) and are considered a successful design, including under the deepest 2,200-ft cover. Some deterioration has occurred locally in Main West. This is attributed to the same historical mining practices responsible for poor roof conditions in the 1st North panel, namely, leaving variable top coal, mining extra wide entries to accommodate the continuous haulage system, using short bolts, and only bolting with 5 bolts per row. Also, where angled crosscuts were mined, disintegration of the sharp pillar corners produced spans 10 to 20 ft wider than normal. In spite of some localized time-dependent roof falls, the 70-ft by 72-ft pillar design has demonstrated it success for ensuring long-term stability when properly mined. Given the reliability of the existing mains pillars and the results of modeling, the narrower 60-ft by 72-ft pillars are not expected to substantially increase geotechnical risk for short-term mining.

Model results indicate that increasing crosscut spacing does not significantly improve conditions. Figures 22 through 24 show stress, yielding, and convergence for a 60-ft by 80-ft pillar, representing about a 20-ft increase in pillar length (between crosscuts) over the proposed design. The increased length only incrementally reduces rib yielding, corresponding to a modest decrease in entry convergence of about 2% to 4%, as shown by comparison of convergence profiles in Figure 21.

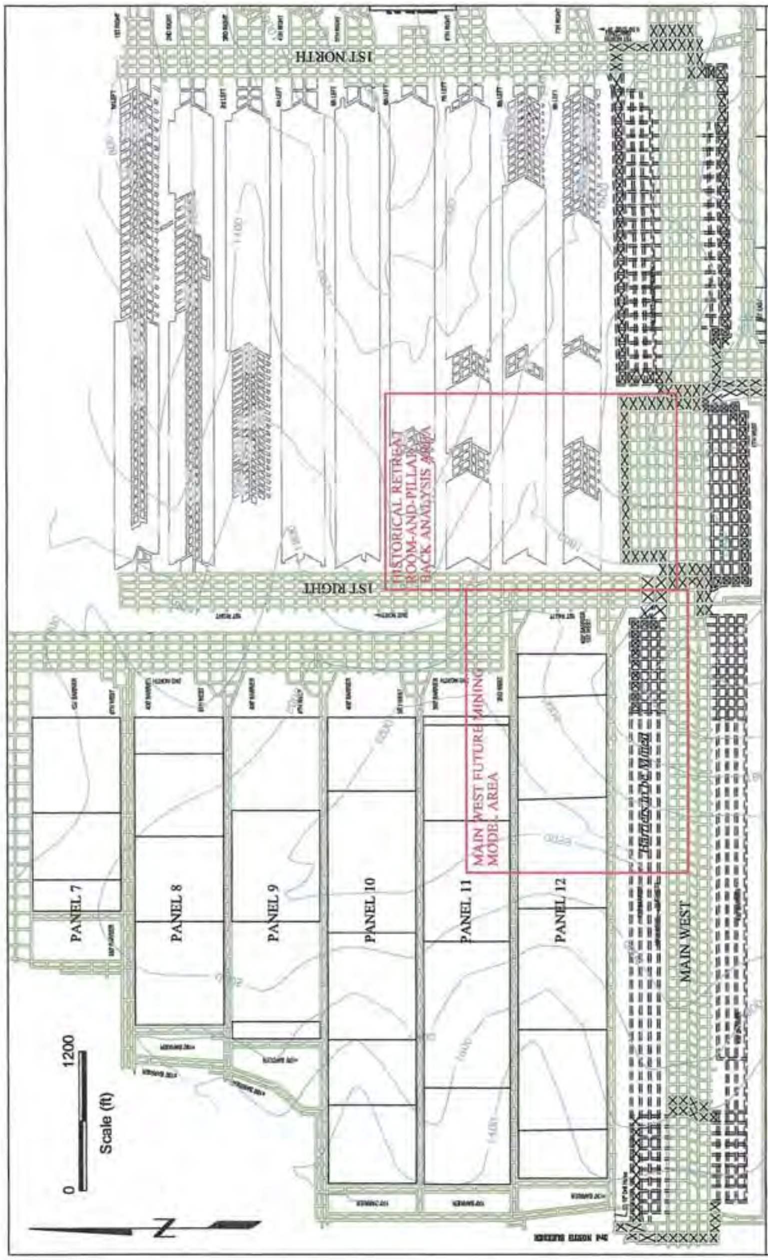
Please contact me to discuss these results, at your convenience, or if you have any questions.

Sincerely,

[signature]

Leo Gilbride
Principal
gilbride@agapito.com

LG/smvf
Attachments(24): Figures 1–24



226-20 Genwal [Genwal_Plan Modeled Area.dwg Layout:AAI_Plan Model]-by/rjl(07-20-2006)

Figure 1. Main West Location Map Showing Existing and Future Mining and Modeled Areas

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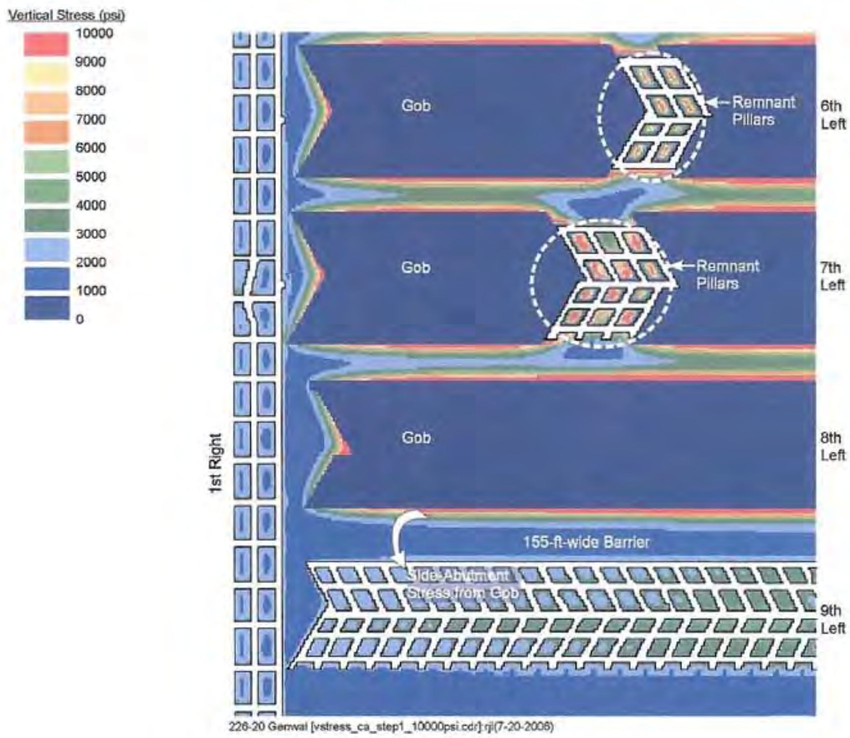

Figure 2. Modeled Vertical Stress—Primary Mining Completed in Panel 9th Left—1st North

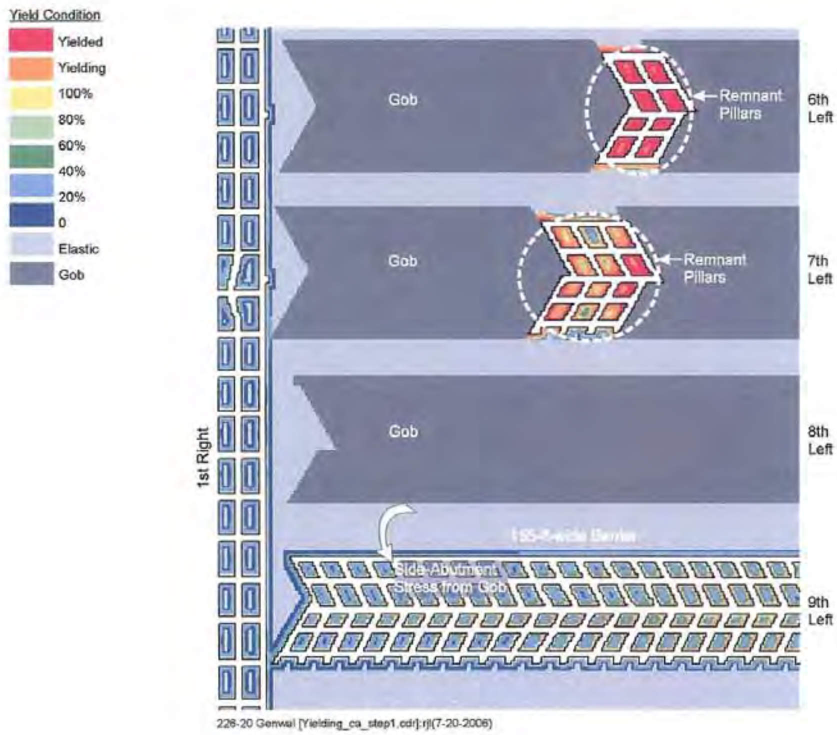

Figure 3. Modeled Coal Yielding—Primary Mining Completed in Panel 9th Left—1st North

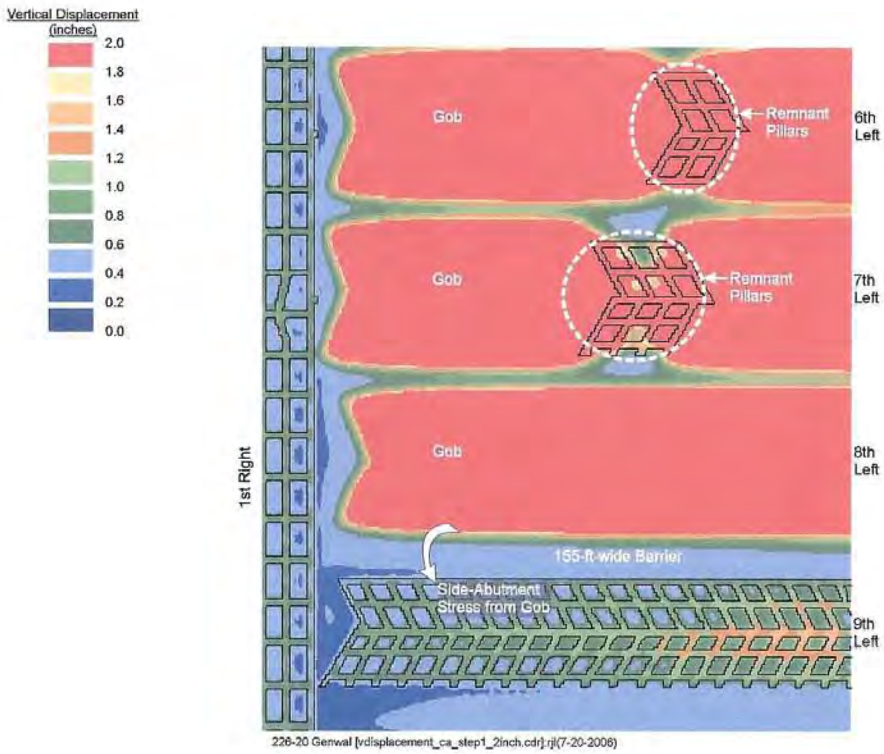

Figure 4. Modeled Roof-to-Floor Convergence—Primary Mining Completed in Panel 9th Left—1st North

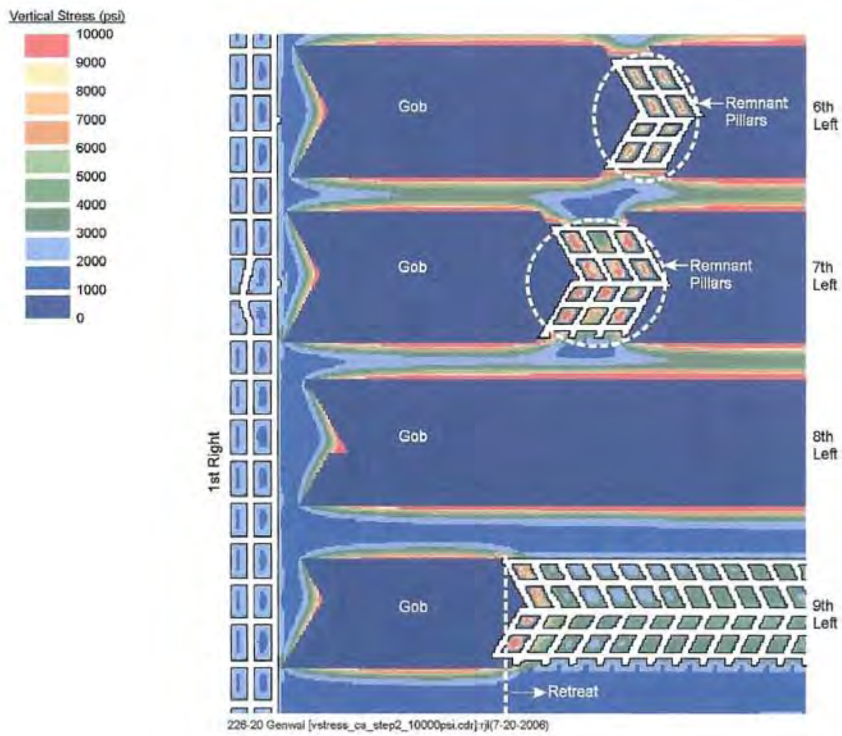

Figure 5. Modeled Vertical Stress—Partial Retreat in Panel 9th Left—1st North

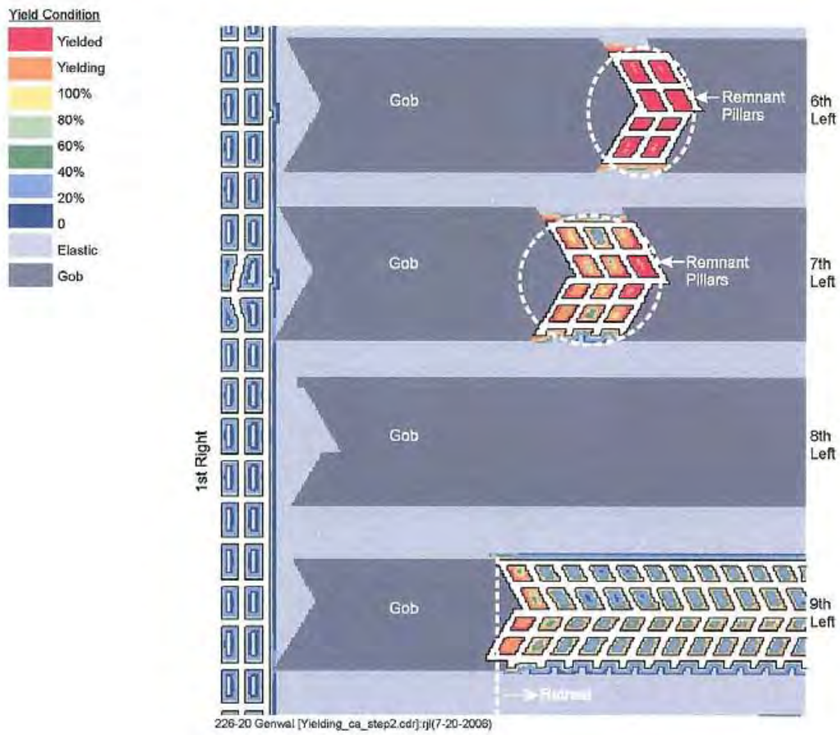

Figure 6. Modeled Coal Yielding—Partial Retreat in Panel 9th Left—1st North

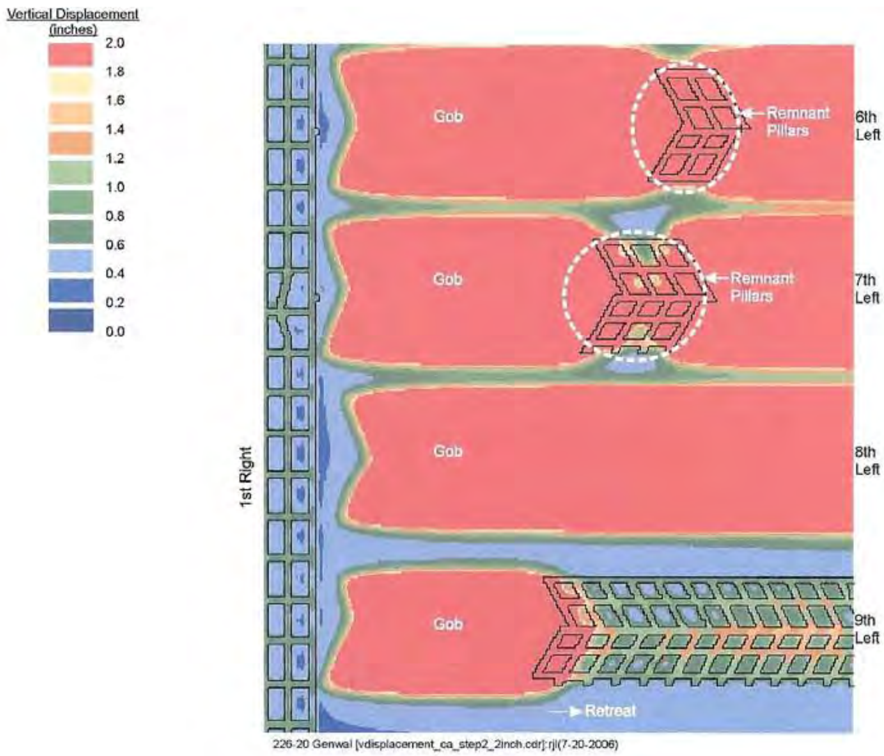

Figure 7. **Modeled Roof-to-Floor Convergence—Partial Retreat in Panel 9th Left—1st North**

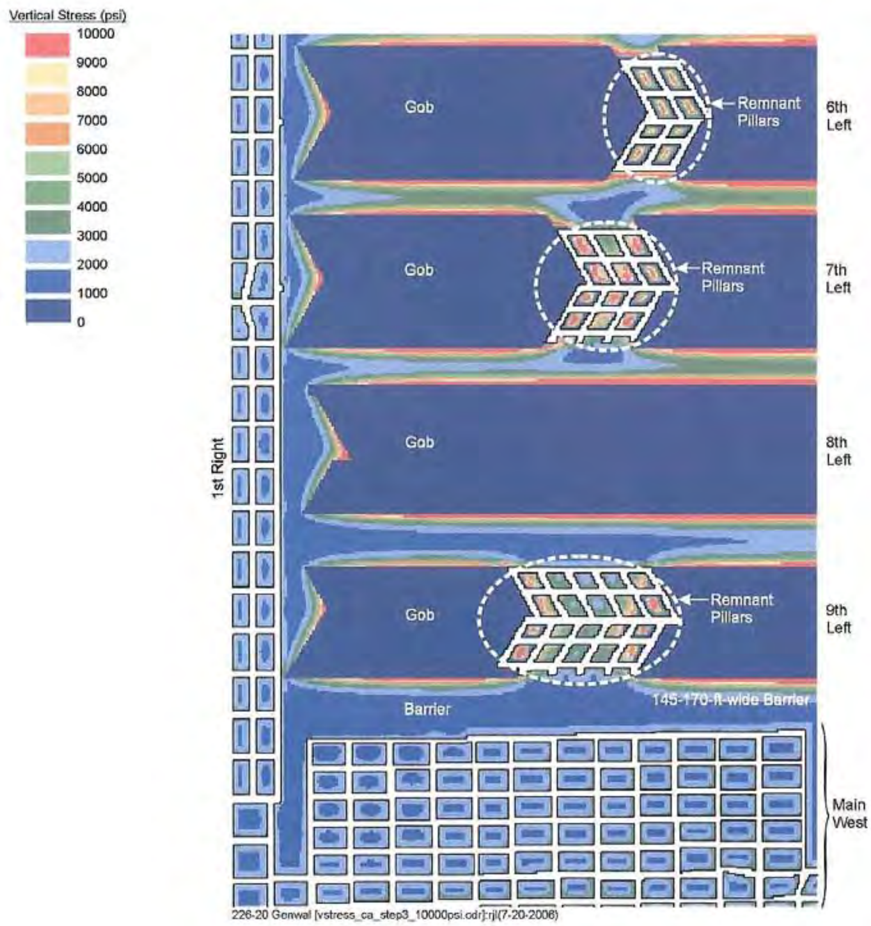

Figure 8. Modeled Vertical Stress—Retreat Completed in Panel 9th Left—1st North

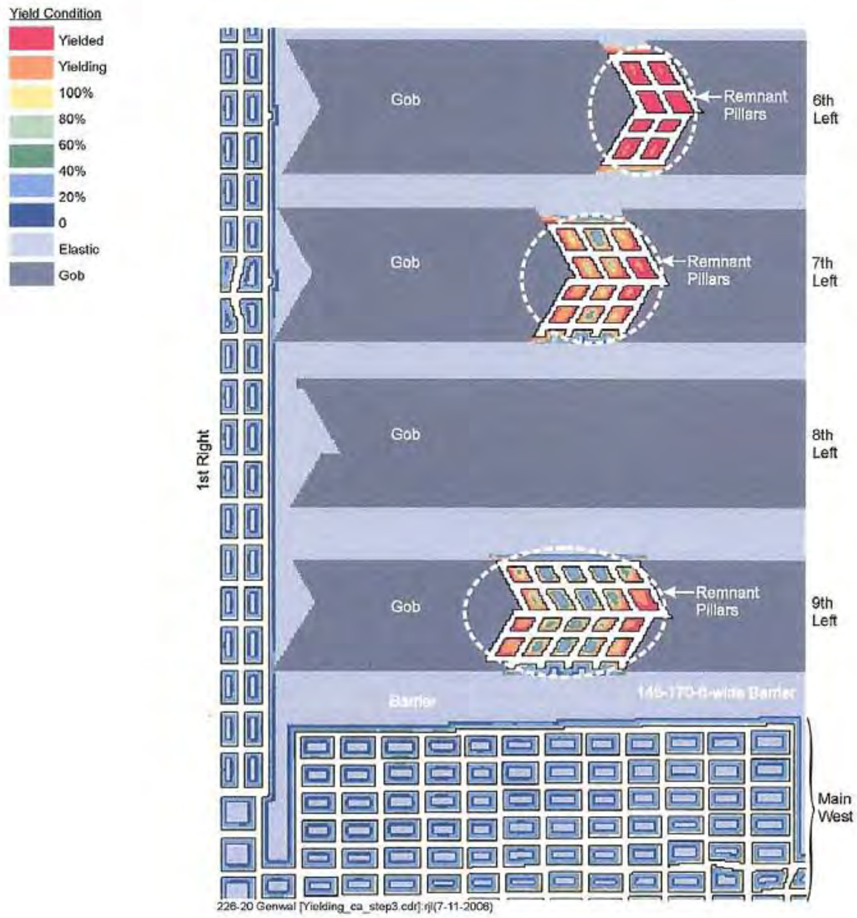

Figure 9. Modeled Coal Yielding—Retreat Completed in Panel 9th Left—1st North

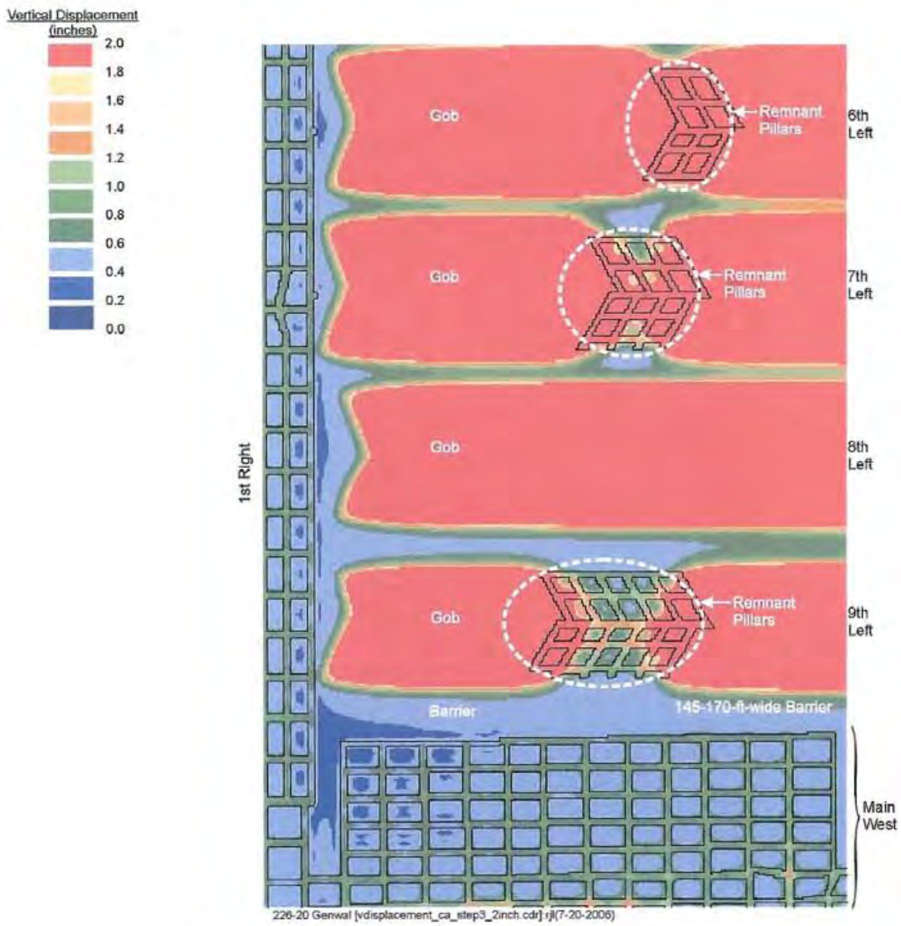

Figure 10. Modeled Roof-to-Floor Convergence—Retreat Completed in Panel 9th Left—1st North

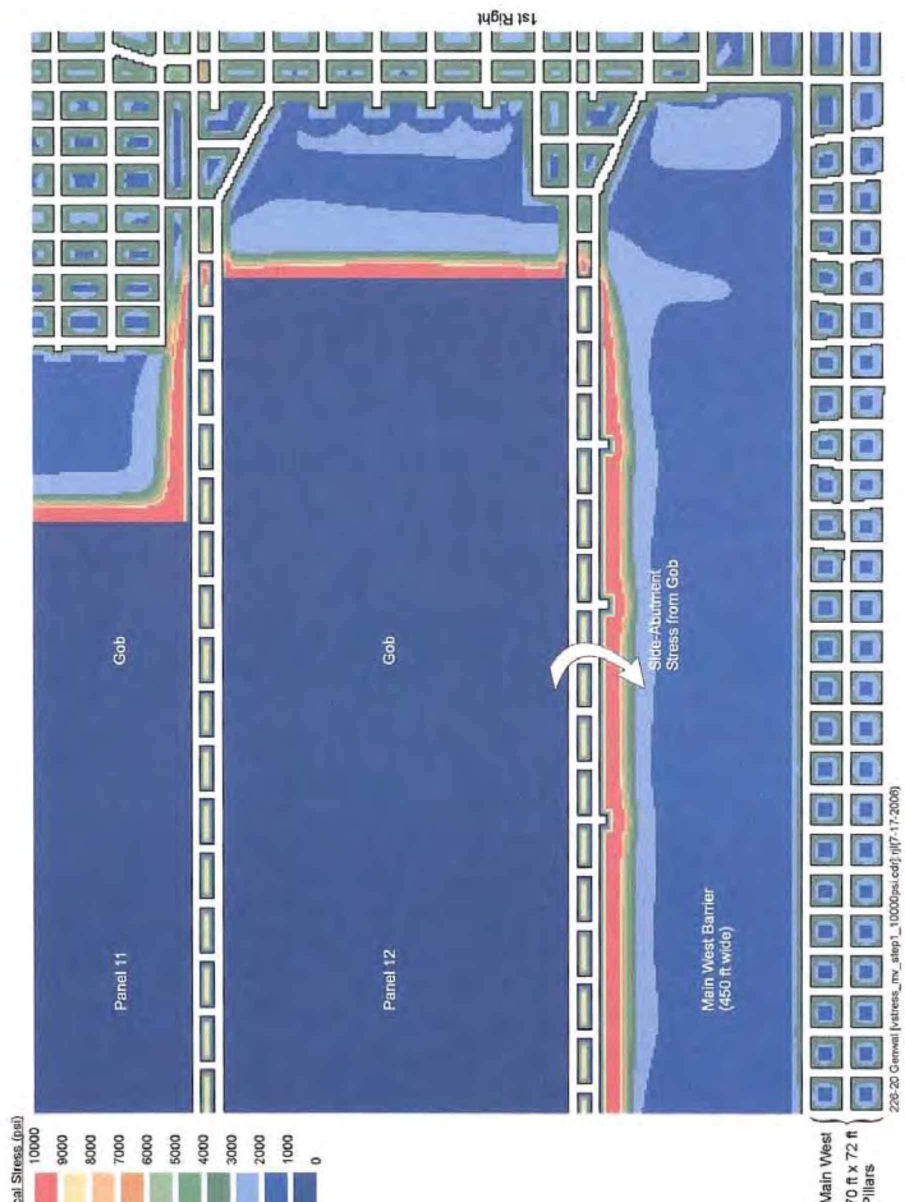

Figure 11. Modeled Vertical Stress—Current Conditions in Main West Barrier

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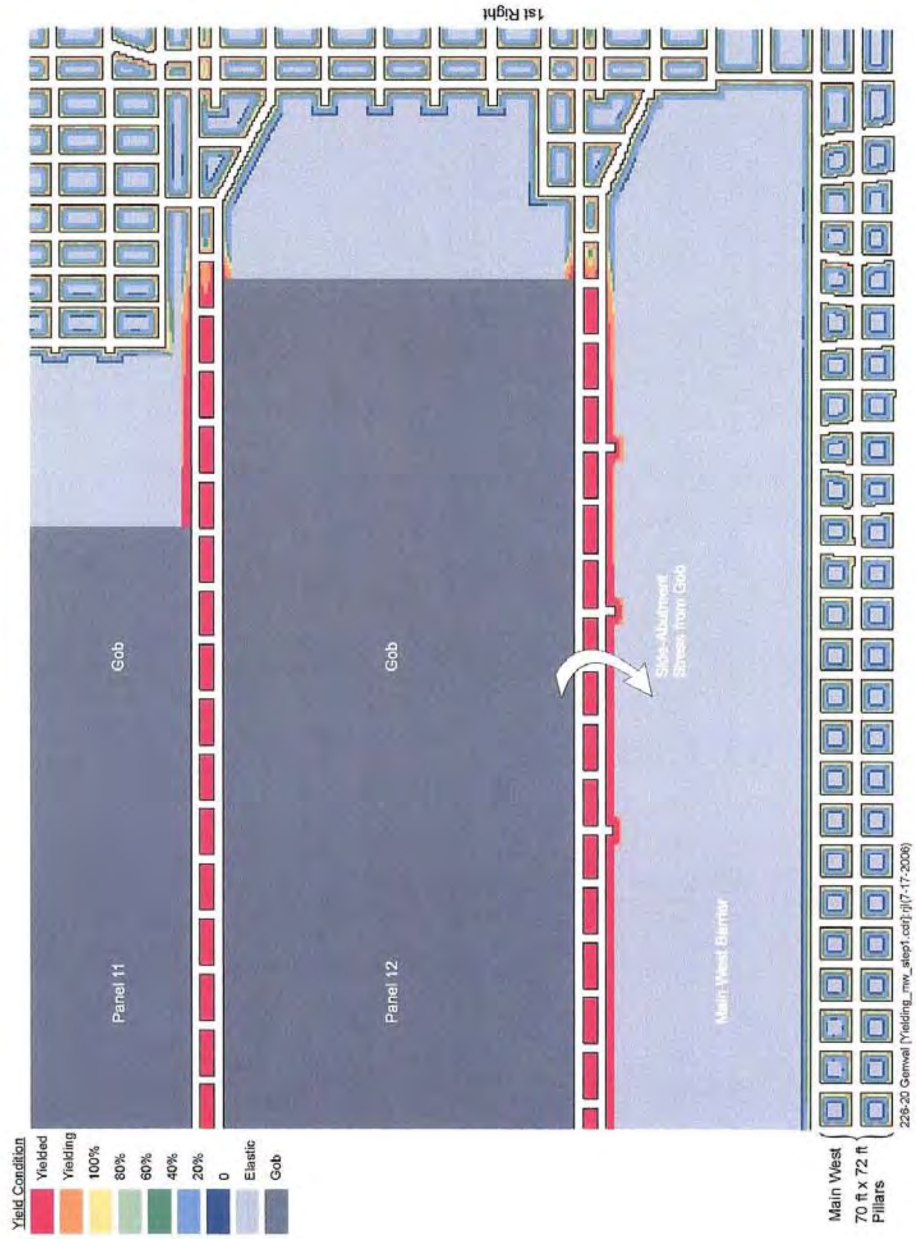

Figure 12. Modeled Coal Yielding—Current Conditions in Main West Barrier

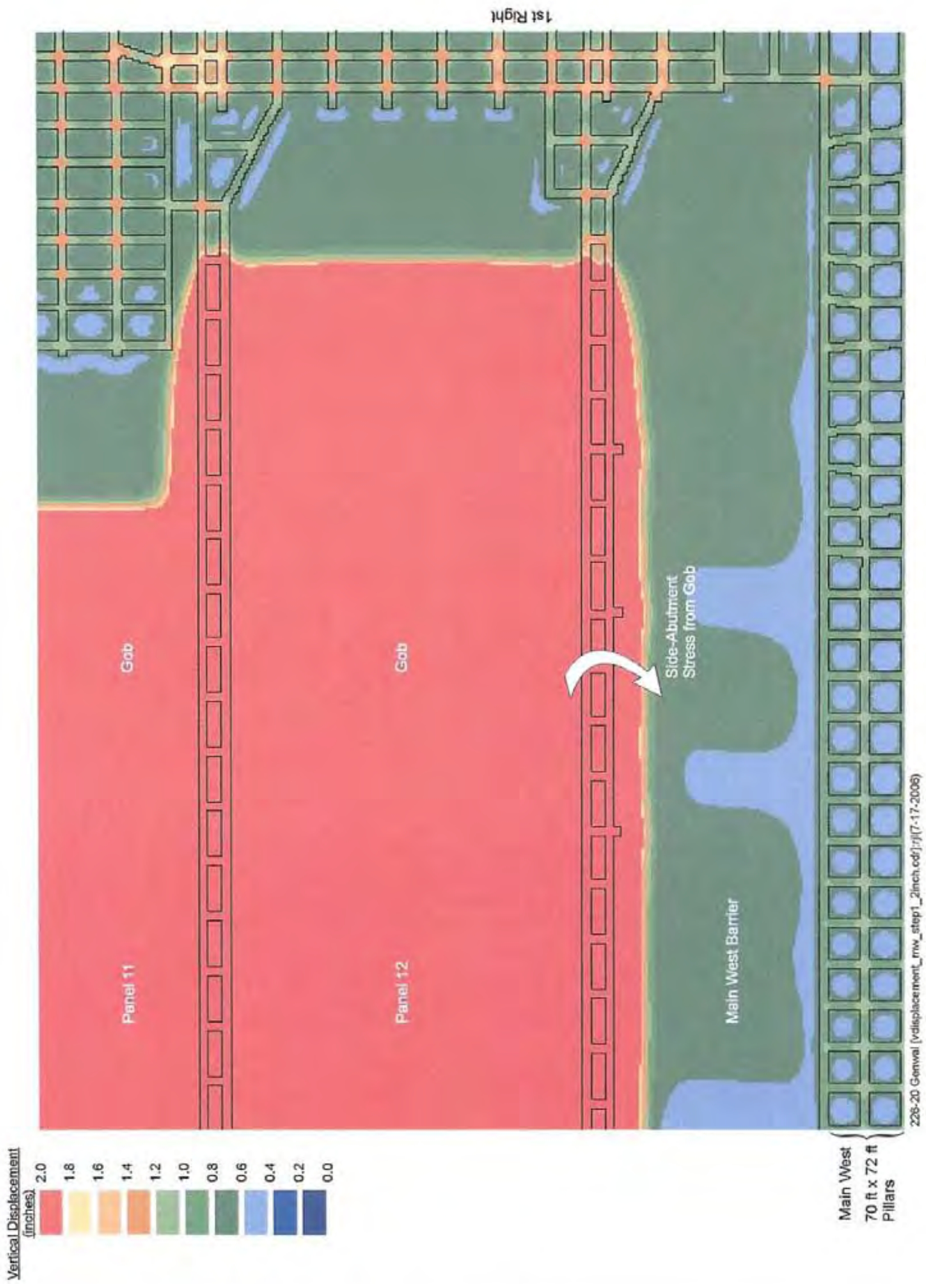

Figure 13. Modeled Roof-to-Floor Convergence—Current Conditions in Main West Barrier

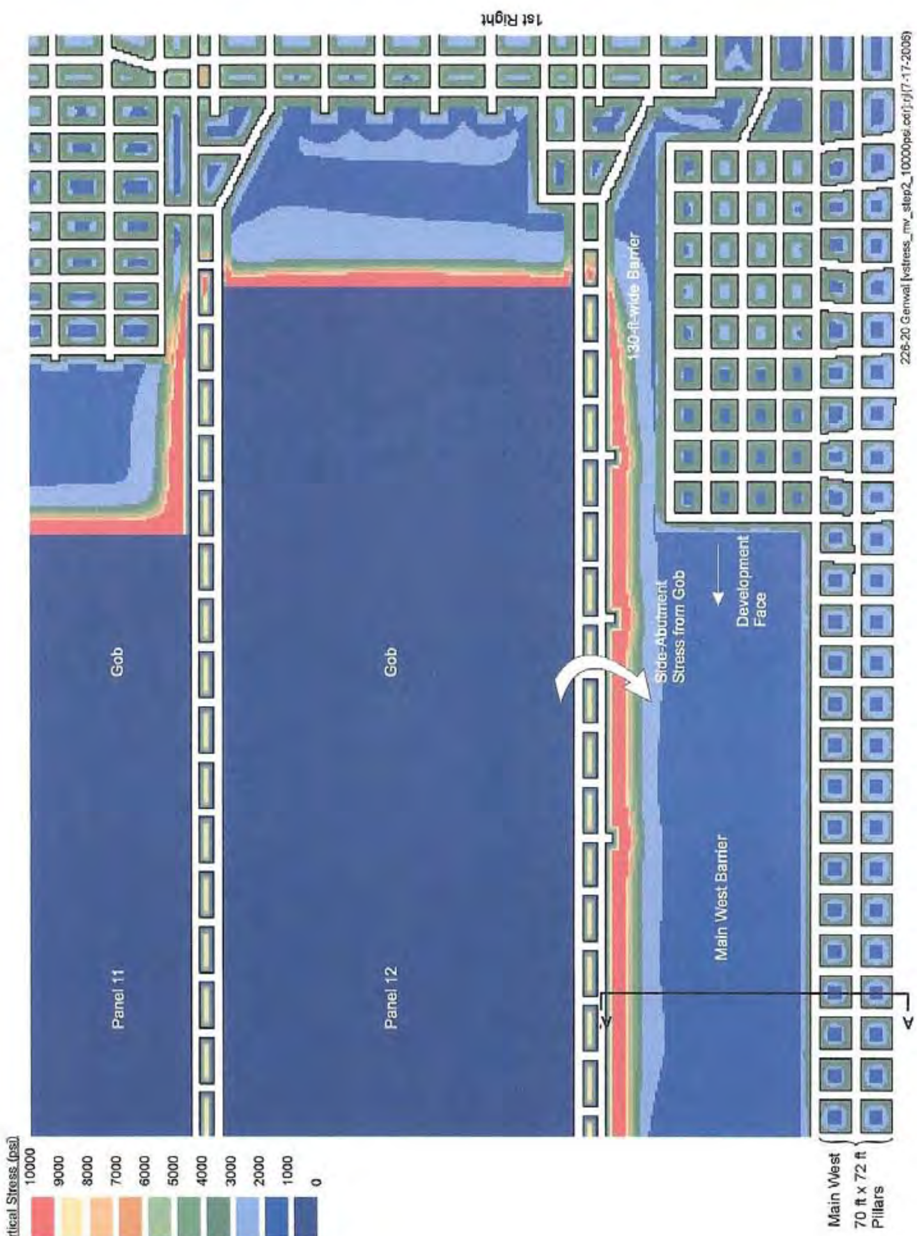

Figure 14. Modeled Vertical Stress—Partial Mining in Main West Barrier

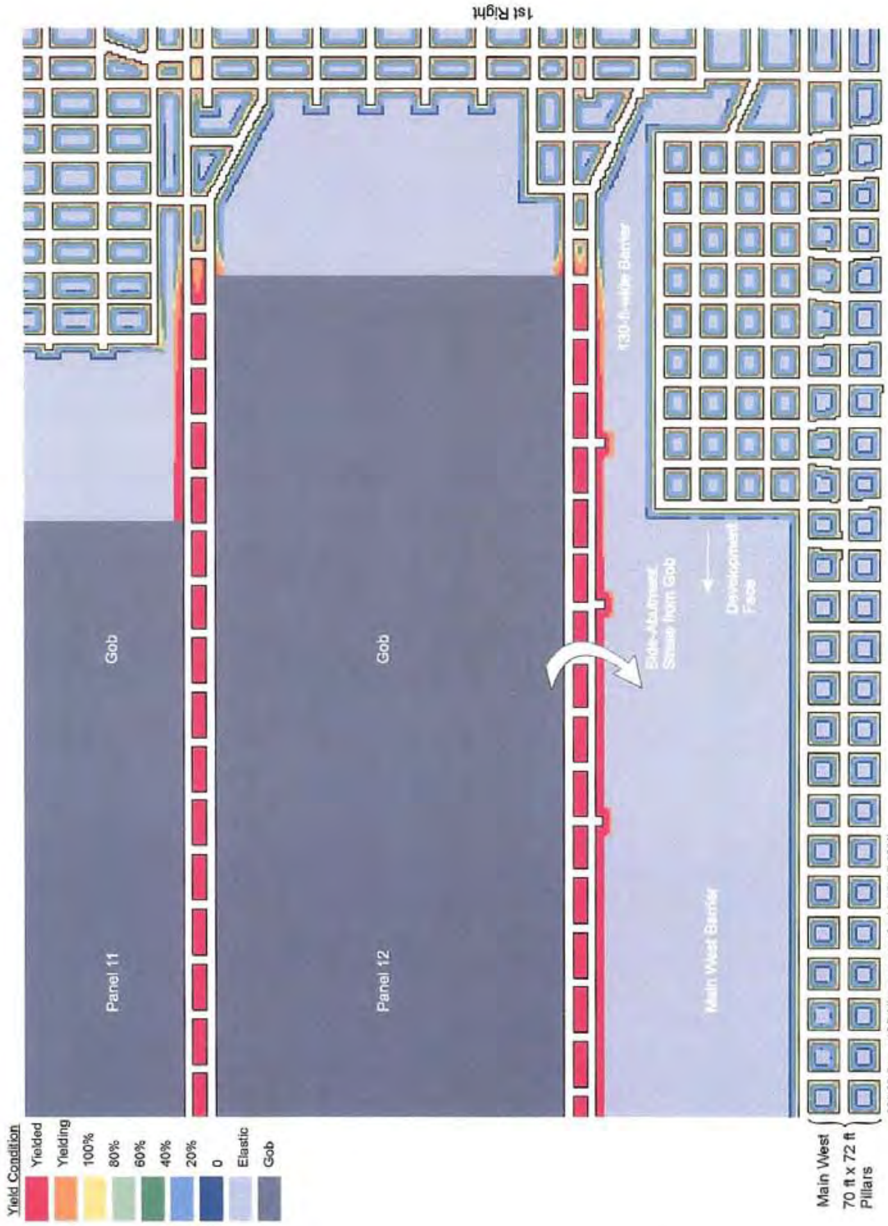

Figure 15. Modeled Coal Yielding—Partial Mining in Main West Barrier

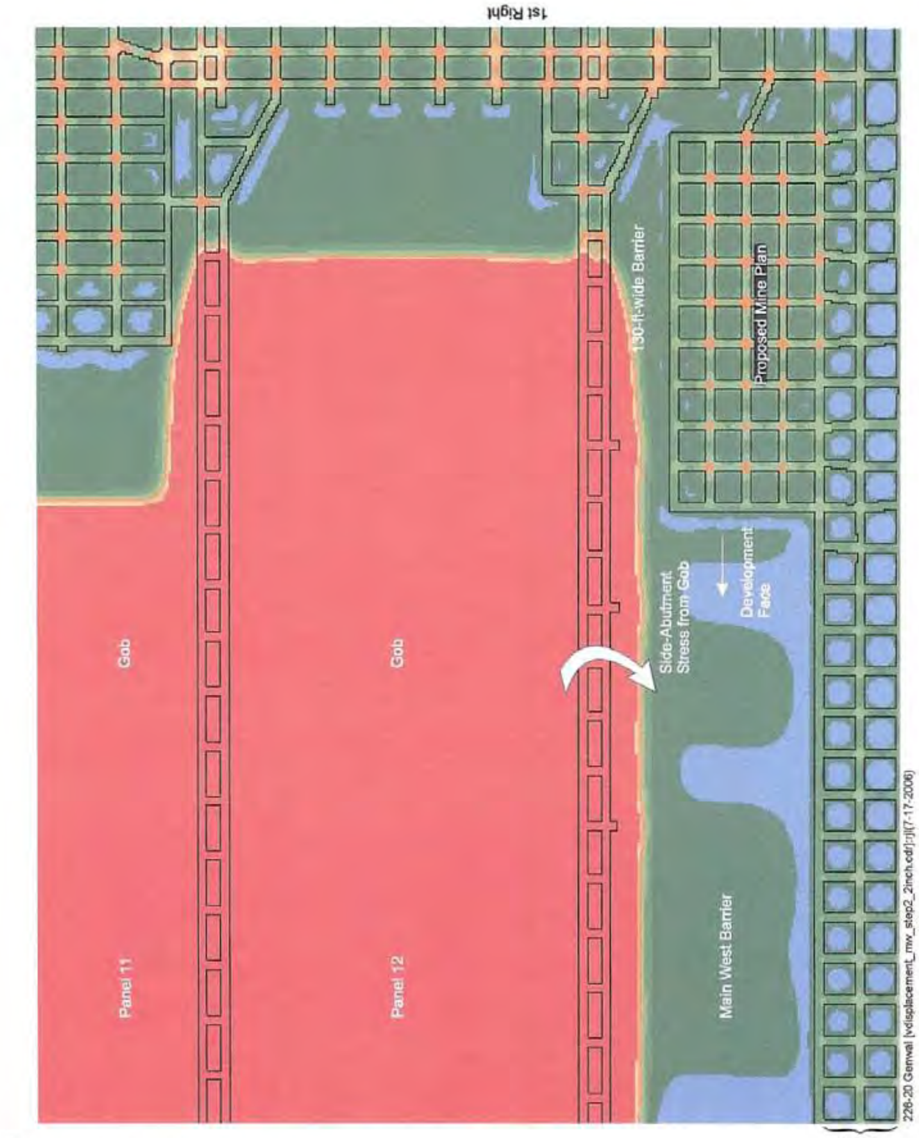

Figure 16. Modeled Roof-to-Floor Convergence—Partial Mining in Main West Barrier

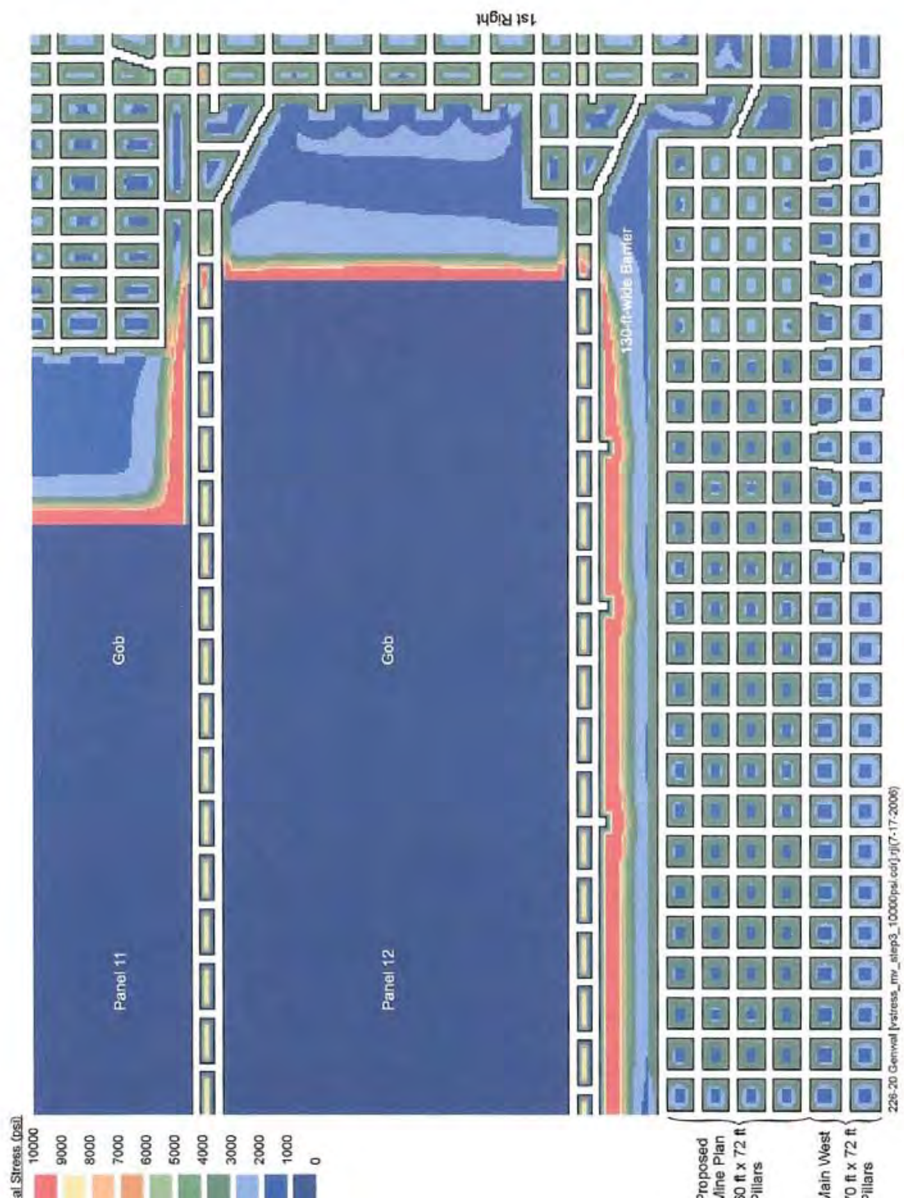

Figure 17. Modeled Vertical Stress—Mining Completed in Main West Barrier

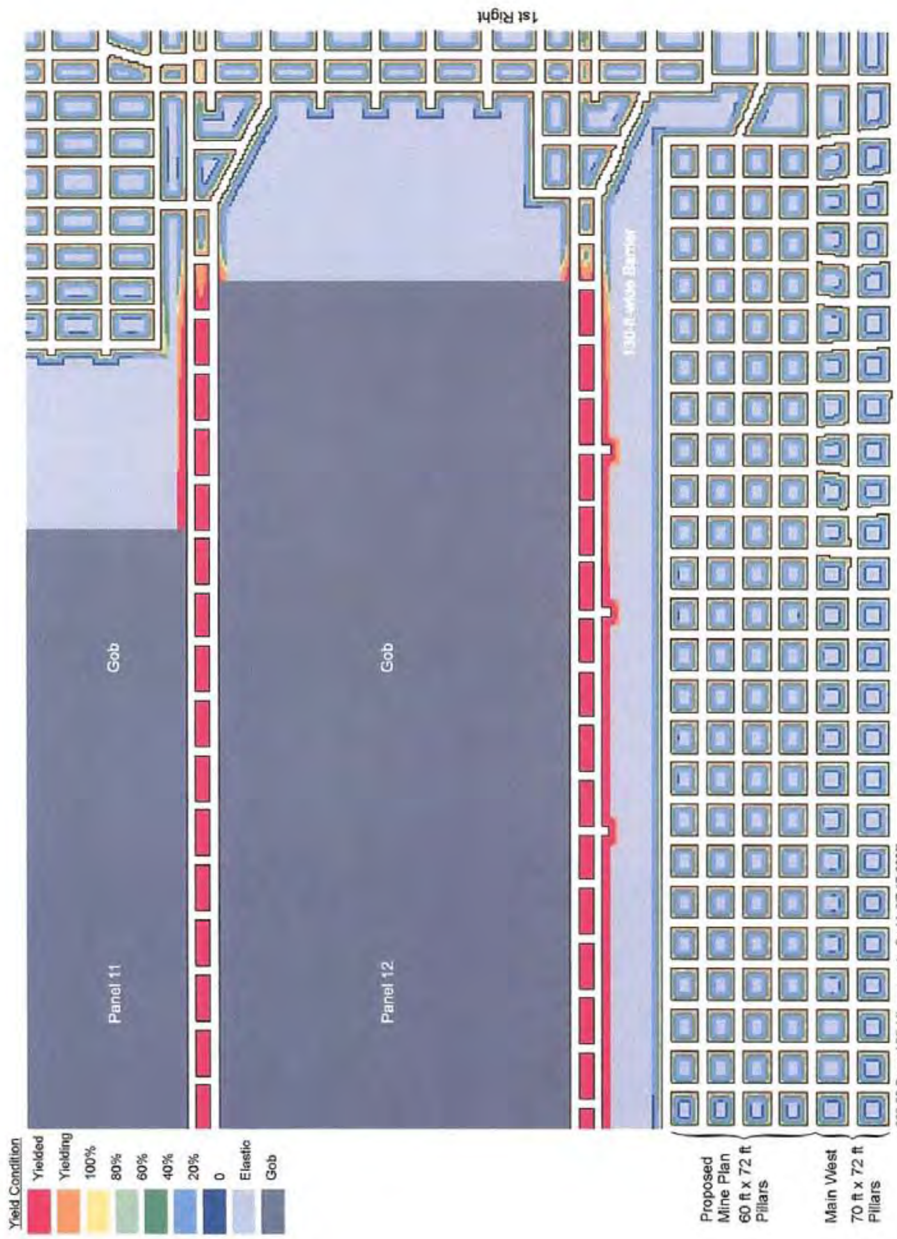

Figure 18. Modeled Coal Yielding—Mining Completed in Main West Barrier

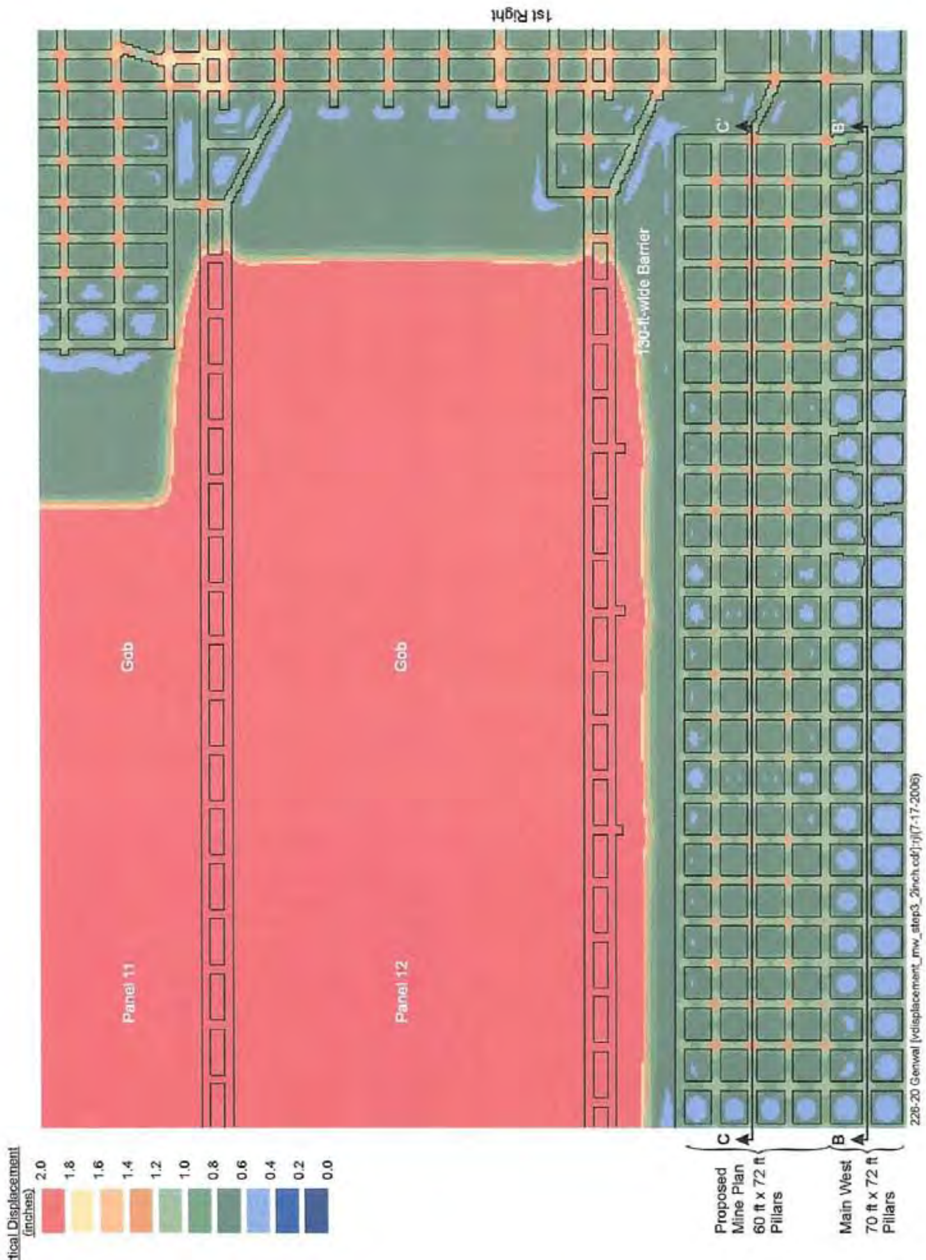

Figure 19. Modeled Roof-to-Floor Convergence—Mining Completed in Main West Barrier

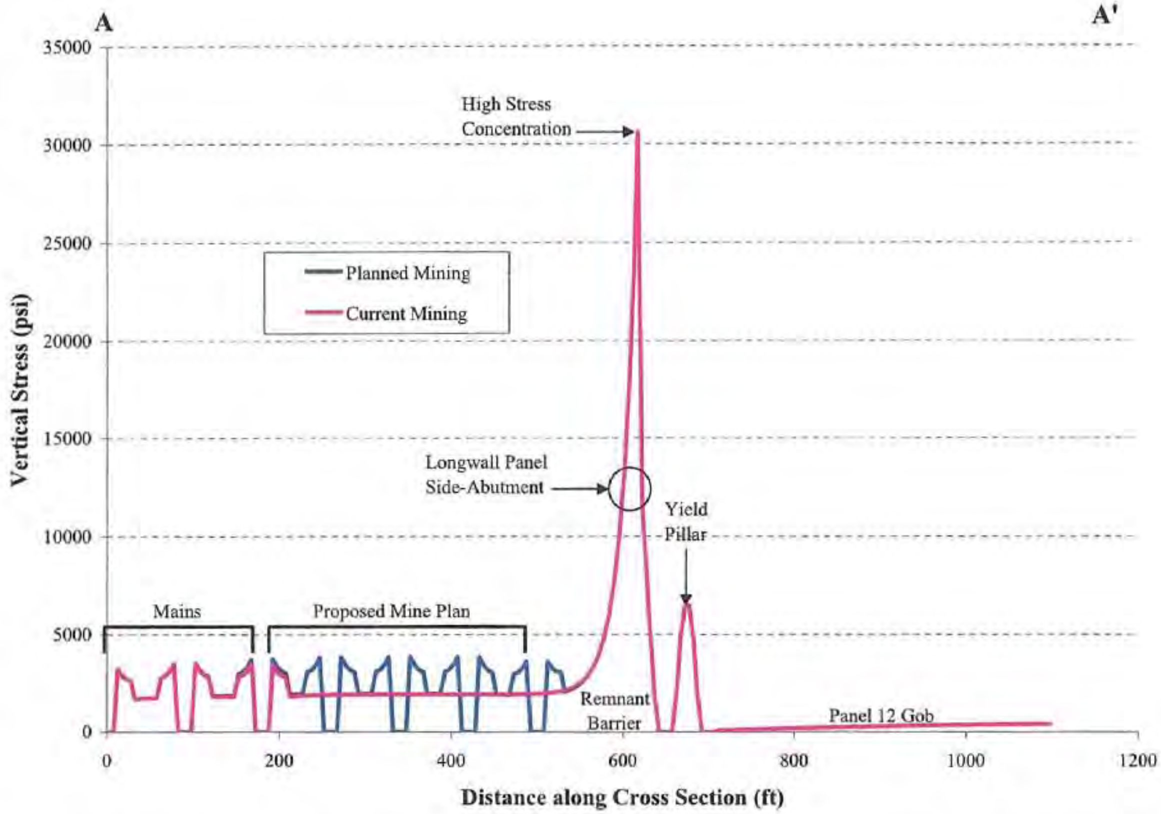

Figure 20. Modeled Vertical Stress Profiles Across Main West Barrier—Profile A-A' *(profile location shown in Figure 14)*

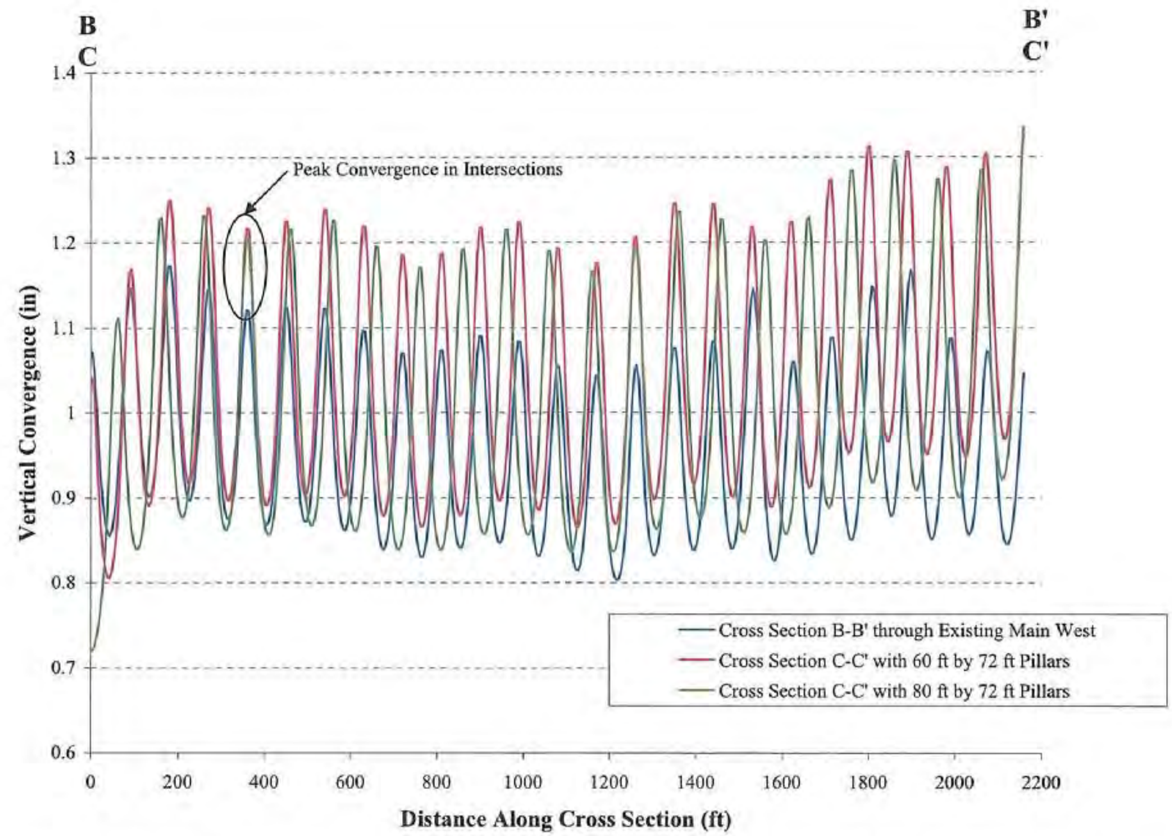

Figure 21. **Modeled Roof-to-Floor Convergence Profiles Along Main West Entries—Profiles B-B′ and C-C′** *(profile locations shown in Figure 19)*

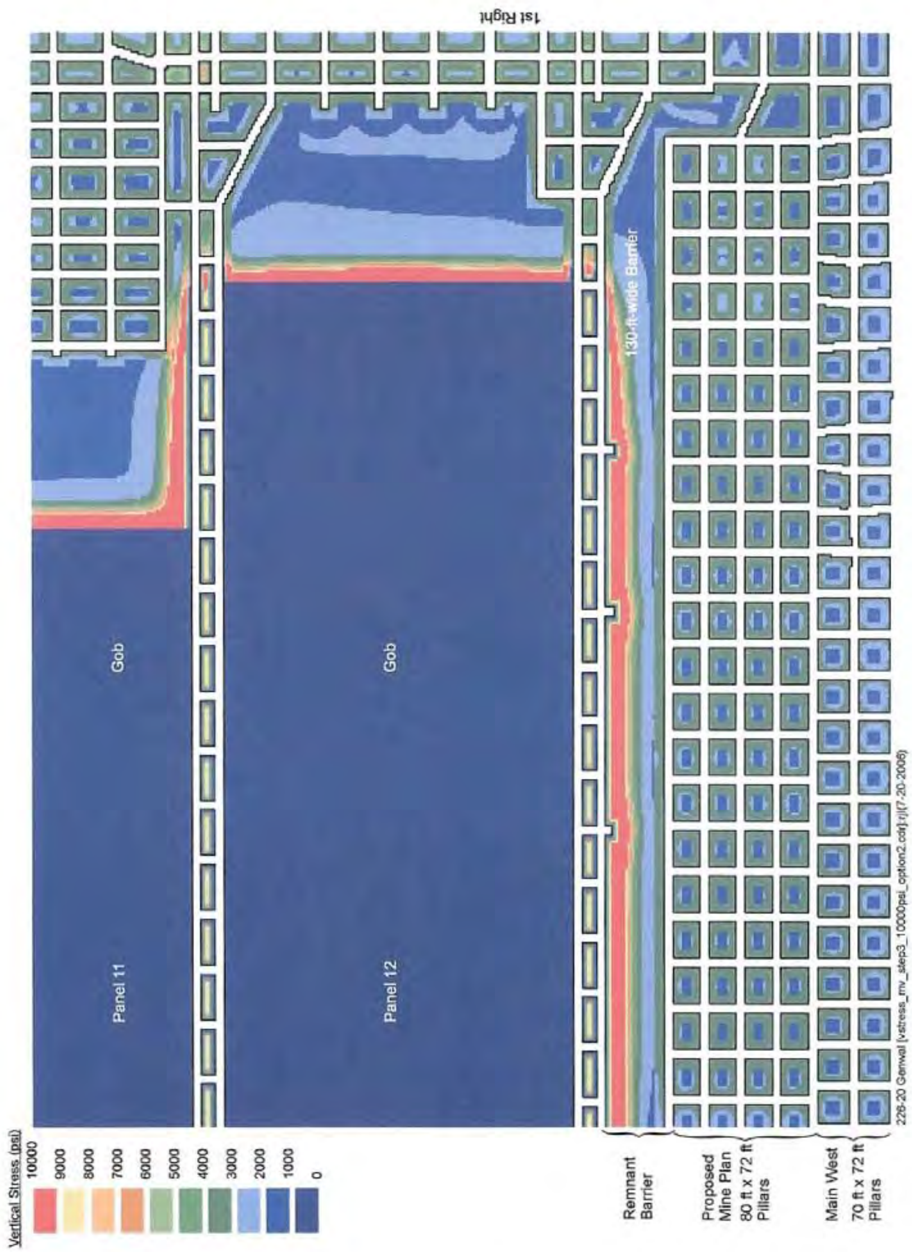

Figure 22. Modeled Vertical Stress—Main West Barrier Mining with 60-ft by 80-ft Pillars

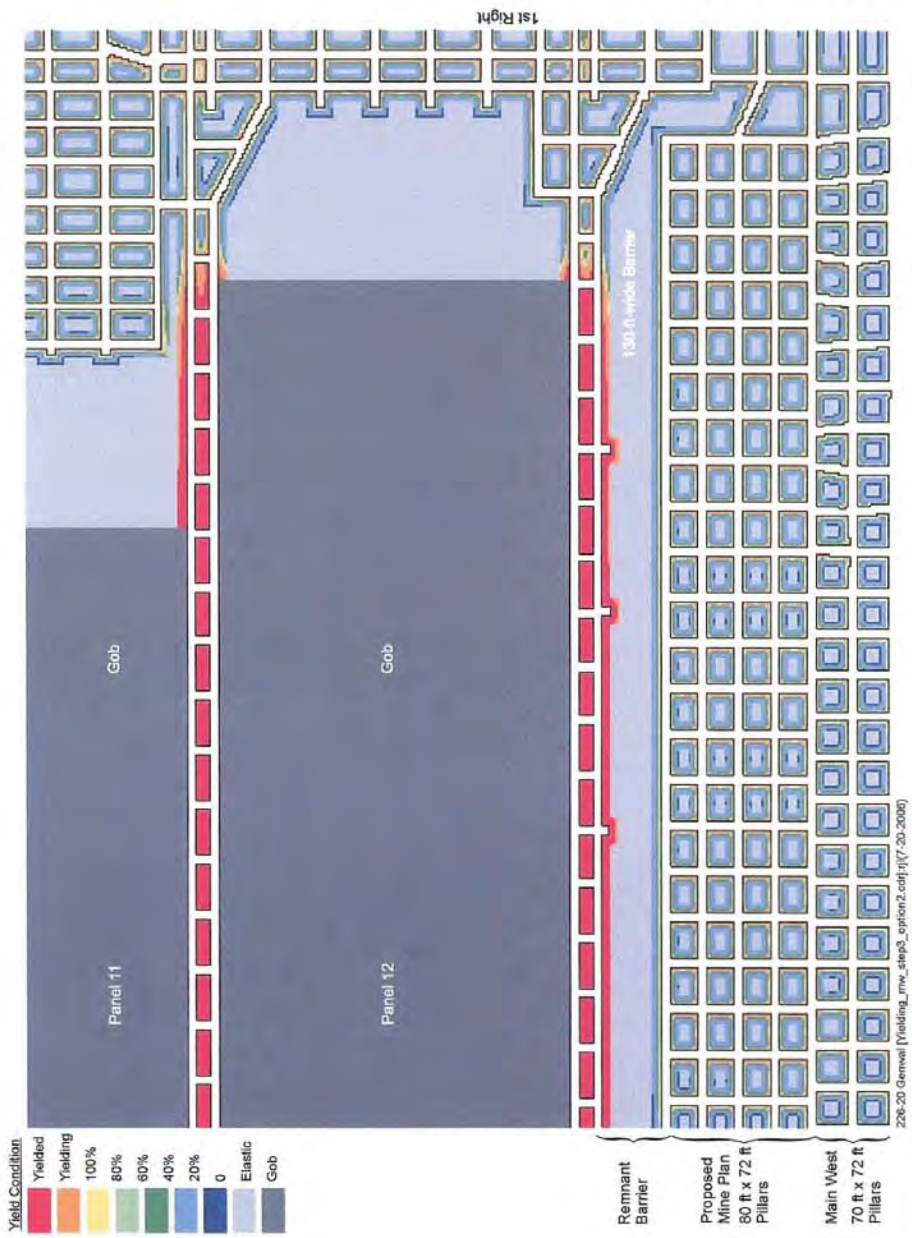

Figure 23. Modeled Coal Yielding—Main West Barrier with 60-ft by 80-ft Pillars

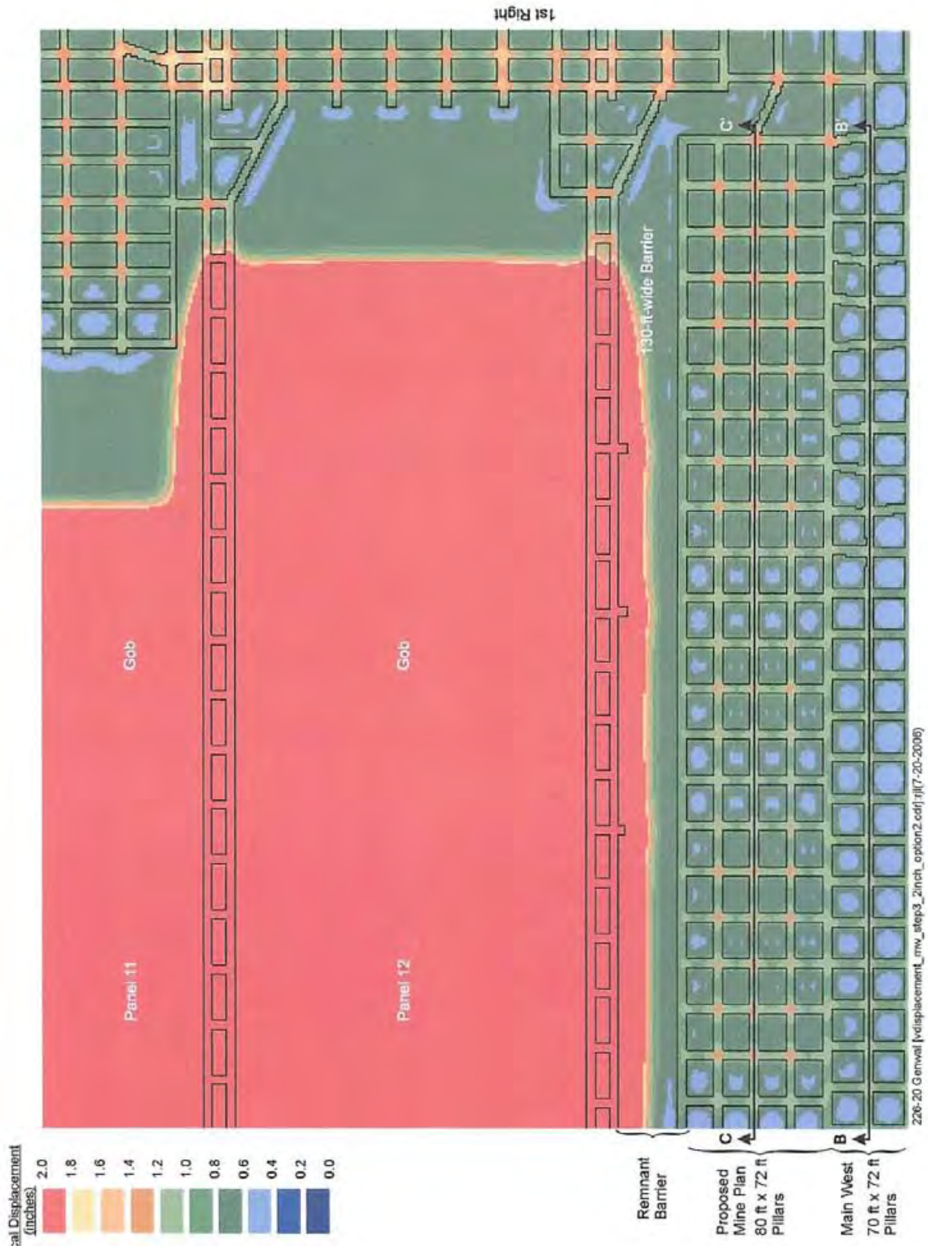

Figure 24. Modeled Roof-to-Floor Convergence—Main West Barrier with 60 ft by 80 ft Pillars