Pre-disaster Events and Conditions Contributing to the Crandall Canyon Coal Mine Disaster of August 6, 2007

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Statement of
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Good morning Mr. Chairman and other distinguished members of the Committee. My name is Robert Ferriter. I am the Director of the Mine Safety and Health Program at the Colorado School of Mines in Golden, Colorado. I very much appreciate the opportunity to address the Committee today to present my views on the events and conditions which led to the disaster at the Crandall Canyon Mine, and the actions of both the operator and the Mine Safety and Health Administration (MSHA) during the failed rescue attempt. Based on my observations of the recent disaster, my experience as a mining engineer, an MSHA employee (27 years) and supervisor (17 years), and frequent evaluator of underground mining practice in the Utah coal fields, I believe there is much that needs to be done to improve safety and workplace conditions in western underground coal mines to protect our nation's most valuable resource --- the ***miner***.

To offer my views in an orderly fashion, I will briefly revisit the Crandall Canyon disaster in chronological order, adding pertinent geologic information, explanation, historical safe mining practices, and applicable MSHA safety regulations and contributing events which framed the disastrous event of August 6, 2007.

A. First Reports.

a) Earthquakes. On the morning of August 6, 2007, the company reported to the news media that a seismic event, or earthquake, caused a major underground mine collapse at the Crandall Canyon Mine located in Carbon County near Huntington, Utah. These reports were immediately challenged by various mining experts who had studied the coal mine bump phenomena in the Wasatch Plateau and Book Cliff coal fields in east-central Utah. By Tuesday, August 7, 2007, the very next day, seismologists and the U.S. Geological Survey's National Earthquake Center in Golden, Colorado established that the August 6, 2007 event recorded on various seismographs throughout the west was indeed an implosion, or mine collapse located at the Crandall Canyon Mine. There is no debate among professionals that this was a mining-induced seismic event (coal mine bump).

b) Coal Mine Bumps. Coal mine bumps have presented serious mining problems in the United States throughout the 20^{th} century to the present day. Fatalities and injuries have resulted when these destructive events occurred at the working face of the mine. Persistent bump problems have caused numerous fatalities and serious injuries, the abandonment of large coal reserves, and premature mine closure and loss of coal reserves. Bumps are characterized as releases of energy associated with unstable yielding that occurs with progressive mining. An unstable release of energy occurs when the coal and rock is not able to absorb the excess energy released by the surrounding rock during the yielding process. Holland (BuMines Bulletin 535, 1954) defined a bump as a sudden and explosive-like failure of a single pillar, part of a pillar, or several pillars with varying degrees of violence accompanied by a very loud noise.

Through the years, a variety of techniques were proposed and implemented to mitigate bumps. Mining history is rich with examples of innovative proposals that, at best, temporarily alleviated this complex problem. From the 1930's to the present, NIOSH (former USBM) has conducted fundamental research on the geologic environments and failure mechanisms responsible for coal mine bumps and on methods to control them.

During the 1930's, USBM research indicated that both geology and mining practice (geometry and sequence) play key functions in bump occurrence. Strong, stiff roof and floor strata not prone to failing or heaving were cited as contributing factors when combined with deep overburden. Various poor mining practices that tended to concentrate stresses near the working face were identified and discouraged. Although such qualitative geologic descriptions and design rules-of-thumb have persisted through the years, the need to better quantify bump-prone conditions remains.

Mine operators take little comfort in generalities when they have experienced a bump and must determine if another is imminent. Specific questions about the influence of individual factors and the interaction among factors arise but are often difficult to answer owing to the limited experience at a given mine. Often, many parameters change simultaneously, i.e. strength and stiffness of roof and floor, proximity of strong lithologic units in a coal bed, depth of overburden, mine geometry, and mining rate. (Above discussion referenced from – Occurance and Remediation of Coal Mine Bumps, by Iannacchione and Zelanko, 1995.)

B. Geologic Conditions Which Cause Bumps.

a) Strong Roof and Floor Strata. Strong floor strata immediately below the coal seam and strong roof strata within 30 to 50 feet of the seam have long been recognized as major contributors to coal bumps (Holland and Thomas, 1954; Iannacchione and DeMarco, 1992; Peparakis, 1958). In fact, the confinement offered to the coal seam by these stronger, stiffer strata appears necessary to generate levels of stored energy sufficient to cause bumps within and immediate to the coal seam structure (Babcock, 1984).

b) Sandstone Channels in Immediate Roof. Sandstone channels are stress-concentrating structures that are directly related to bumping along longwall panels nationwide. The massive nature of many of these units appears to be the major factor affecting bump initiation immediate to these features.

c) Strong Coal Seams. While it has been shown that most U.S. coals can be made to bump under the right combination of confinement and loading conditions (Babcock, 1984), it is worthwhile to mention the seam characteristics in some Western operations that appear to influence bumps. The two most prominent contributors are (1) randomly changing coal cleating, and (2) the presence of strong rock splits in the mid-to-upper portion of the seam. While it is not necessary for these conditions to be present for bumps to occur, they have been linked to some of the worst bump conditions documented in Western mining.

d) Fault and Shear Zone Structures. Investigations of fault and shear zone structures in the central Utah coalfields point to basic concerns: (1) the effect of significant changes in the stress field in the vicinity of these discontinuities, and (2) the loading potential of isolated blocks of strata above the seam. Whether strike-slip movement along fault structures is responsible for dynamic load changes has yet to be more thoroughly determined (Boler, 1994), but changes in loading conditions have been noted as major contributors to bumping when mining approaches a discontinuity (Iannacchione and DeMarco, 1992; Peparakis, 1958).

e) My personal experience in dealing with coal mine bump problems in the Utah coal fields have indicated that one should always anticipate bumping when mining deeper than about 1,200 feet, and develop the mining plan accordingly.

C. Mining Techniques to Reduce Bump Occurrences.

a) Mine Design. To mitigate the frequency of gate road pillar bumps, over the years mine operators in the Wasatch-Book Cliffs coalfields have implemented the use of two-entry, yielding-pillar gate road configurations. (Gateroads are the entries which are developed to access the coal extraction area of a longwall panel. Mine crews, supplies, ventilation air and extracted coal are moved through these entries.) This approach attempts to soften the ground around the gateroad system, thereby restricting bump-inducing stresses to deep within the confines of the adjacent panel abutment. In general, the approach has been very successful when employed correctly. Problems arise, however, where pillar sizes are too small or too large. These improperly sized pillars are termed “critical pillars” and their use can result in the most extreme hazard possible.

b) Destressing. Coal, or in some instances roof and/or floor rock, is intentionally fractured and made to fail. As a result, high stress accumulations can not occur in the fractured part of the mine structure. Unfortunately, destressing can occasionally trigger a bump in another section of the mine.

c) Volley Firing. Destressing by volley firing has successfully reduced the number of bumps in several Western coal mines. In this method, explosives are used to fracture the coal face to a certain depth before mining. The method is used prior to face advance or entry development to advance the high stress zone away from the working face.

d) Hydraulic Fracturing. This method involves the injection of fluid under pressure to cause material failure by creating fractures or fracture systems. Hydraulic fracturing is most effective in the roof and coal seam ahead of the longwall face.

e) Recent Publications.

*Special Publication 01-9*5, U.S. Bureau of Mines (BOM)(Function transferred to NIOSH).
Papers presented at a BOM technology transfer seminar describes the causes of violent material failure in U.S. mines, measurement techniques for monitoring events that result in violent failure, and mitigation techniques for controlling failure. The BOM looked at 16 mines – both coal and hard rock – and analyzed 172 bumps or mining-induced seismic events. The BOM publication describes new monitoring and analysis techniques developed as tools for assessing violent failure; and seismic methods for determining source locations, calculating energy release, and determining source mechanisms are described. USBM studies identified the advantages using both yielding and stable pillars for coal bump control. A computer program has been developed as an aid for selecting room-and-pillar layouts. Additional available references include:

Deep Cover Pillar Extraction in the U.S. Coal Fields (see NIOSH Web Site).

Preventing Massive Pillar Collapses in Coal Mines (see NIOSH Web Site).

f) Modeling Programs

NIOSH (former BOM) has developed three computer-based technologies for use by the mining industry to evaluate proposed mine designs. The programs are called LAMODEL, ALPS and ARMPS. These technologies were developed, documented, and have been distributed freely as engineering design tools to assist both longwall and room-and-pillar coal operators in their daily decision making process. The tools are particularly useful during 1) the planning stage (pillar design and layout), and 2) retreat mining, as an early warning of potential impending failure.

g) Physical Property Testing

NIOSH (formerly BOM) created a comprehensive data base that includes more than 4,000 compressive strength test results from more than 60 coal seams. These data were compared with 100 case studies of in-mine pillar performance from the Analysis of Retreat Mining Pillar Stability (ARMPS) data base.

There is also evidence showing why laboratory strength does not always correlate with pillar strength. The data showed clearly that the "size effect" observed in laboratory testing is related to coal structure. Laboratory tests do not account for large-scale discontinuities, such as roof and floor interfaces, which apparently have more effect on pillar strength than a small-scale laboratory mining structure.

D. Evaluation of Mining Plan

a) Pre-pillar mining configuration. Prior to the practice of retreat mining in the Crandall Canyon Mine, previous mine development by Andalex Mining Co. had left a five-entry primary ventilation, belt conveyor, and services conduit known as Mains West. This primary access to the mine was protected on both the north and south sides by a massive "barrier pillar" of solid coal approximately 500-ft-wide. Longwall extraction panels had been extracted both to the north and south of Mains West barrier pillars. Apparently, this configuration was stable, as no indication of bumping or roof falls were recorded in the area of planned retreat pillar mining. In several areas, both the North and South barrier pillars lie beneath approximately 1,700 to 2,200 feet of massive sandstone and various sedimentary strata.

In the pre-pillar mining configuration, both barrier pillars are subjected to loading and stress buildup from: 1) the adjacent longwall gob areas, 2) naturally occurring overburden above the coal seam (1,700 to 2,200 ft), and 3) loading created by the planned cave in-by the extracted pillars. Therefore, the pillars to be extracted are subjected to the combined loading from these three separate sources, which create high stress levels in the pillars and increase the probability of bumping. The geologic environment in the mining area is known to be conducive to the occurrence of coal mine bumps. In spite of these known conditions, the complete removal of all the weight bearing pillars was planned.

b) Mining of North barrier pillar. As the North barrier pillar was mined and the coal pillars removed, a cave developed in-by the pillar line. Apparently, bumping problems occurred about x-cut 137 and two rows of pillars were left to alleviate the bumping. However, weight transfer overrode these pillars and major bumping occurred when the three pillars at x-cuts 133 thru 135 were mined. This forced abandonment of coal extraction in the North barrier pillar near the end of March 2007 and movement of the extraction process to the South barrier. One should note that the overburden in both mining areas is 1,700 plus feet in thickness indicating that very high static ground pressures existed in both mining areas.

c) Mining of South barrier. Pillar extraction was initiated in the South barrier sometime in May 2007. Extraction pillars were increased in size from 80-ft by 92-ft to 80-ft by 129-ft. This increase was intended to isolate bumps to the face area and reduce the risk of larger bumps over-running the crews in out-by locations. The South barrier was also slabbed to a depth of about 40 feet to improve caving conditions and reduce concentrated loads at the face. (To slab in mining means to remove additional coal from the barrier pillar, thereby reducing the effective width of the barrier.) Again, it is noted that the geologic environment in the North and South barrier pillars is similar. Minor changes to the pillar sizes were made to reduce bumping at the face; however, basically a similar mining plan was in effect. Considering the similarities in geologic conditions, the similar pillar extraction plans with only minor modification, the history of bumping in the immediate mining area, and the development of an active cave in-by pillar extraction mining, one could reasonably anticipate the occurrence of additional coal mine bumps. The risk was quite clear.

MSHA accident files do not document any reported bumps in the South barrier area during the months of May, June and July, 2007. However, my experience tells me that bumping to some degree most likely occurred, even though it is not documented.

Interviews with miners who worked in the South barrier pillar area will either confirm or contradict my opinion. Miner interviews should also be conducted to validate if visual signs of excessive pillar loading and stress buildup (pillar "hour-glassing", floor heave, unstable roof, abnormal breaking of pillars, roof and/or floor) were observed. These are all common visual expressions of stress build-up which should be evaluated by competent technical personnel.

d) Post-Seismic Event Observations

Two observations of interest are readily apparent from the August 6, 2007 MSHA web-site postings and seismic event records: 1) the reported elapsed time of seismic event is approximately four (4) minutes. Based on my experience in similar investigations, this means that the event was initiated in one or more pillars (probably in the active pillar extraction area) at some location in the mine, and that not all pillars bumped at the same time. Rather, after the initial pillar(s) disintegrated, a weight transfer occurred, overloading adjacent pillar(s), which then disintegrated and transferred their load to successive pillar(s), in effect creating a domino effect, or "cascading pillar failure." This would account for the extraordinarily long run of the bump; and 2) all the pillars that failed appeared to be located under approximately 1,700 feet or more of overburden. In my opinion, this indicates that all pillars under 1,700 feet or more of cover were subjected to combined loads (as previously explained) which created stress levels somewhat under the failure level for the pillar. As the "domino effect" of the failure mechanism occurred, the weight transfer from the failed pillars to the adjacent pillar(s) increased the stress level of the receiving pillar(s) to the failure level, etc. Pillar(s) under less than 1,700 ft of cover had lower initial stress levels and, therefore, were able to accept the weight transfer without reaching unacceptable (failure) stress levels.

E. Continuing Erosion of Coal Mine Bump Expertise in the West.

a) Wilberg Mine Disaster (1984)

Although not caused by a bump, the Wilberg Mine disaster (mine fire in December, 1984) focused significant attention on the geologic environs of the Utah coal deposits, their depths, bump occurrence, and the stability of deep (2,000 ft) underground coal mine entries.

In the Wilberg disaster, 27 miners lost their lives due to carbon monoxide poisoning. An underground compressor overheated, igniting and setting fire to the surrounding coal bed which burned for nearly one year before it could be extinguished. The miners underground at the time were trapped, unable to escape and died from poisonous gases.

The mine used the two-entry retreat longwall mining method for removing coal. Access to the longwall panels was by what is known as the two-entry longwall gateroad access system. This system requires MSHA approval of an operator initiated 101 (c) Petition for Modification to use two-entry gateroads rather than three entries (one for intake air, one for return air, and one for the conveyor belt to remove coal from the longwall face). With only two-entries, the conveyor belt must be placed in either an intake or a return entry. Either case is a violation of current MSHA regulations, mandating approval of a 101 (c) Petition to use only two access entries.

b) MSHA's Two-Entry Longwall Task Force (1985)

Immediately following the Wilberg mine disaster, the United Mine Workers of America (UMWA) began criticizing the use of the two-entry longwall mining system. The basis for their criticism was that with only two entries available for escape, the Wilberg miners were trapped, and that only three-entry longwall gateroad systems should be allowed by MSHA. Stung by this criticism and lacking any technical study to rebut the UMWA's charges, MSHA, in partnership with the U.S. Bureau of Mines, convened its Two-Entry Longwall Task Force to study all aspects of the Two-Entry system including, but not limited to: ground control, ventilation, fire prevention, electrical, dust control, escapeways, etc. The resulting report overwhelmingly endorsed the two-entry system because of its proven ability to reduce the occurrence of devastating coal mine bumps in western deep coal mines. The report, however, recognized the reduction in escapeways from face areas of the mines, and compensated for this reduction by recommending numerous safeguards, in addition to those required by MSHA regulations. The two-entry longwall gateroad system is now commonly used by Utah mine operators developing longwall extraction panels under more than 1,000 feet of overburden.

c) Elimination of U.S. Bureau of Mines (1995)

In 1995, the Secretary of Interior disbanded the U.S. Bureau of Mines. All research centers were closed with the exception of the Spokane Research Center and the Pittsburgh Research Center. The effect on western coal mines was significant with the closing of the Denver Research Center and the termination of much of the research effort focused on coal mine bump prevention and multi-seam mining in western coal mines. Although a few new modeling programs have been written in the intervening years, significant new research efforts in bump prevention have not been undertaken.

d) Closing of MSHA's Denver Safety and Health Technology Center and transfer of all positions to eastern centers.

Arguably the most significant negative impact on western coal mine bump remediation occurred when MSHA closed its Denver Safety and Health Technology Center. With the transfer of approximately all 50 technical positions to West Virginia and Pennsylvania when the closure was announced, the western mining community lost easy access to technical experts in ventilation, ground and roof control, bump prevention, industrial hygiene, hoisting, and practically all technical disciplines found in western coal mining. Of the 50 employees at the Denver Center, only approximately four (4) employees elected to transfer to West Virginia and Pennsylvania. Included in loss of technical expertise was a small group of six (6) highly qualified mining engineers and geologists who had been engaged in western coal mine bump evaluation for 15 to 20 years. This group regularly reviewed roof control plans for MSHA's Coal Mine District 9, ran computer simulations, and investigated bump occurrences and roof falls in western mines. Unfortunately, with the closure of the Denver Technology Center, all but one member of the group left MSHA. In my opinion, if this group or a similarly qualified group had reviewed the Crandall Canyon roof control plan, the disaster would not have occurred.

e) Summation – Are Western miners less valuable than Eastern miners?

Ever since the Wilberg Mine Disaster in 1984, and the resulting Two-Entry Task Force Study, MSHA has known that western deep mines are highly susceptible to explosive-like disintegration of coal pillars. Apparently MSHA's technical capability to analyze roof control plans for conditions and mining practices which would encourage bump occurrence has deteriorated to an unacceptable level. Does MSHA have any plans to reinvigorate its western technical expertise? With western coal mines reaching deeper into the earth for their resources (3,000 feet below the surface) (the shallow, easy to mine resources have already been mined), more hazardous mining conditions will be encountered. Western miners are as valuable as Eastern miners and deserve the same protections under the law. As Crandall Canyon has demonstrated, these protections are not being provided by MSHA.

F. The Rescue Effort

1) Initial Response. Initial public briefings were always conducted by Murray Energy Company. MSHA was noticeably in the background giving some comments later in the briefings. The message conveyed to the public was "its Robert Murray's mine, he's in charge and can do whatever he thinks is right." MSHA was not the primary communicator the first couple of days, allowing for a poor public image.

2) Reporters and T.V. Crews Filming Underground. Five reporters, including CNN, were allowed underground while the rescue was taking place. While the videos were informational, the video and photos did not in any way aid the rescue effort. In fact, another bump occurred while the reporters were underground. If one of the crew had been injured, MSHA would have had another disaster to deal with. Other non-involved mines in the Price, Utah area probably would have allowed visits for informational purposes if asked by MSHA.

3) Safety of Rescue Crews. Anyone involved with mine rescue work knows that the safety of the rescuers is of primary importance. It must be assumed that the victims may be fatalities. To risk rescuers for bodies is unacceptable. Even though Assistant Secretary Stickler stated that the rescue crews had installed steel sets every 2.5 feet, this protection proved inadequate, emphasizing the explosive-like force of a coal mine bump. A more appropriate protective device would have been pre-fabricated tunnel liners (large U-shaped steel sections) which construction crews work under when tunneling through unstable soil or rock.

MSHA standard 75.202 Protection from falls of roof, face and ribs states: *(a) The roof, face and ribs of areas where persons work or travel shall be supported or otherwise controlled to protect persons from hazards related to falls of the roof, face or ribs and coal or rock bursts.*

G. U.S. Bureau of Land Management Reports

The following excerpts from Bureau of Land Management (BLM) Inspection Reports document mining conditions in the West Mains as described by the BLM inspector. Generally the statements of the inspector describe deteriorating conditions, bumping, roof falls, etc, as mining of both the North and South barrier pillars progressed. Typically the BLM inspector was Steve Falk and the company representative was mining engineer Tom Hurst unless otherwise noted.

1. Inspection Report of November 4, 2004:

Andalex mining engineer John Lewis

Conditions were deteriorating (west portion of the West Mains) and access through the area near impossible.

The barrier planned on both sides looked like it was designed to only hold up for only a short while. The north entry was taking weight and extra roof supports and re-bolting had to be done. Now the situation is even worse.

. . . . (overburden) is about 1500 feet and rises to 2000 feet . . . .

It was apparent from traveling down the intake that the area is taking unacceptable weight.

It is apparent the pressure arches from both side gobs are sitting right down on the main entry pillars.

The situation in Main West is untenable for future pillar recovery.

No mining company in the area has ever pulled pillars in main entries with mined out sides and under 1500 feet of cover.

Genwal's thoughts and plans to try pillar recovery was wishful thinking . . . .

2. Close Out Discussion - 1/24/05:

. . . . the pillars in Main West are failing over time with greater than 1700 feet of cover.

Caves are occurring at intersections by irregular intersection dimensions.

. . . . attempts to split pillars under this depth could not hold the top and prevent pillar outbursts.

Weight on the pillars is substantial and dangerous conditions are present.

Mining any of the coal in the pillars will result in hazardous mining conditions such as pillar bursts and roof falls.

3. Inspection Report of August 1, 2006:

Genwal is continuing to pull pillars from south to north in the South Mains . . . .

Pillar pulling has been pretty good. Depth at this area is less than 1000 feet.

The crew is getting adept at this pillaring as they now had about 2 years experience.

Though Tom Hurst is new, he is not as pessimistic as the ious engineer . . . . prev

4. Inspection Report of December 2006:
The sale of Andalex is complete to Bob Murray's Utah American.

The new 3 entries in the barrier now would leave 130 foot barrier to the north gob.

5. Inspection Report of February 27, 2007 (North barrier pillar):

This section finished driving 4 entries on 92 foot entry centers and 80 foot crosscut centers.

So far no inordinate pillar stresses have been noted, though thing(s) should get interesting soon. The face is under 1600 feet of cover now and will increase to over 2000 feet by crosscut 139.

6. Close Out Discussion - March 05, 2007 (North barrier pillar):

This section is mining coal that was not considered minable in the previous plan .

. . . . BLM is pleased to have them try for coal that was thought unminable but warned them to beware of the depth above the ridge and mining a barrier pillar that has been sitting for a number of years. Pulling pillars will be interesting if even MSHA will OK a ventilation and roof control plan for the section.

7. Inspection Report of March 15, 2007 (North barrier pillar):

. . . . Utah American obtained the property in August 06 . . . .

. . . . water inflows much greater than available pumping facilities. This was at crosscut 158 which was about 400 feet short of the back end of Main West next to Joe's Valley Fault.

The section pulling the two bottom pillars on retreat out this area (between 133 and 132 crosscut) experiencing greater stresses on the pillars.

Pillar bumps were increasing and some damage to the stopping to the north bleeder entry were occurring.

Genwal tried to stop the stress override and left two rows of pillars at 137 to 135 and then started up again . . . .

Hurst reported that a few large bounces occurred on off shift soon after start up of pillar mining which did most of the damage.

Entry ways outby two breaks from the face has extensive rib coal thrown into the entry way.

The bounces had either knocked out or damaged all the stoppings to the north bleeder entry from crosscut 132 inby to crosscut 149.

The weight of the area will only be the same or worse as this is under the ridge top on the surface.

Hurst said the risks are too great that this event will happen again outby should they try pillar pulling again and east.

8. Inspection Report of June 13, 2007 (South barrier pillar):

They moved over to this section from the north barrier block at the end of March when pillar pulling in the north barrier block was halved about half way through due damaging bumps and outby pillar loading.

. . . . back in March when they were having the tough conditions in the North Barrier and asked to leave the rest of the pillars.

After receiving the various reports, it is obvious that mining conditions in the barrier pillars were extremely hazardous, yet the removal of coal pillars from the barrier pillars continued.

H. Recommendations

1) The rescue effort at the Crandall Canyon mine was severely hampered by the inability to both locate the missing miners and determine their physical condition (heartbeat, respiration, etc.). The importance of through-the-earth, two-way communications and tracking was spotlighted, and the development and implementation of the technology clearly needs to be accelerated.

2) Using a single or very few runs of the LAMODEL structural analysis program, or any computer modeling program, does not properly frame the risk (probability for failure). Rather, varying the values of input parameters over their practical ranges is important. These input parameters should include but not be limited to:

    a. coal strength (unconfined and confined),
    b. peak strain in an element of the model,
    c. coal modulus of elasticity,
    d. Poisson's ratio,
    e. angle of internal friction,
    f. depth of cover, and
    g. progressive mining steps from initial entry development through the completion of retreat mining.

    By doing this, a practical range of stability factors could have been calculated for various scenarios of mining (mining entries and crosscuts in the barrier as well as full or partial retreat of the pillars created in the barrier).

    A consulting firm does only the analyses required in the scope of work issued by the mine operator, who pays for the analyses. If a risk assessment with a sensitivity analysis is not requested by the mine operator, then it will not be done, i.e., it costs more money to run many more analyses (varying parameters). If MSHA would require a more thorough risk-based sensitivity analysis, then the company would be required to do it in order to gain approval of the proposed mining plan. Requiring a sensitivity analysis with varying parameters would frame the level of risk mining in bump-prone mines.

3) MSHA should reevaluate its policy for reviewing and approving roof control plans (mining plans) and require, as a minimum, several computer analyses using a range of input data. NIOSH has developed the Analysis Retreat Mining Pillar System (ARMPS) program by Dr. Chris Mark. This program is readily available, easily run, and is based on 150 case studies. Some updating of the program may be required to include deep-cover pillar design.

4) MSHA should revisit its policies on rescue team safety and Command Center decision making training. The loss of three rescuers, including one Federal inspector during a rescue mission, and six injured rescuers is not acceptable.

5) Clearly, the technical expertise to recognize and remediate bump hazards associated with coal mining within the geologic environs found in the coal-producing areas of Utah and western Colorado has been lost to both industry and MSHA by the abolishment of Federal offices (U.S. Bureau of Mines and MSHA's Denver Safety & Health Technology Center). With the depletion of easily mined, high-grade coal deposits, mine operators are forced to consider mining deeper deposits with the ensuing risk of accentuating coal mine bump problems, or leaving large blocks of coal un-mined (loss of valuable resource). It is recommended that Congress mandate the creation of a small staff of highly qualified engineers and geologists within an existing Federal agency to focus attention on the bumping problem. The office should be easily accessible by western coal mine operators in Utah and Colorado.

6) MSHA, through its Mine Health and Safety Academy and its Educational Field Services Office, should develop new and informative training material on coal mine bumps, geologic environments and hazard recognition for operator and miner use. Availability of this material would enhance the miner's knowledge of hazards and allow early recognition and remediation of hazardous conditions.

7) In the long-term, industry should review current pillar load monitoring technology and determine its acceptability for in-mine use and remote monitoring of pillars in bump prone areas. Systems such as current CO and methane monitoring data recorders which can be continuously read outside the mine are envisioned. This would allow continuous monitoring of pillar stress buildup in active mining areas.

8) MSHA's public image at the Crandall Canyon mine was not impressive. It is obvious that additional training should be provided to Command Center personnel and Public Information Officers. The critical role of objectivity and staying on point in briefing the press and families of victims needs to be emphasized.

9) The cooperation between the Bureau of Land Management and MSHA needs to be reviewed. From the referenced BLM Inspection Reports, BLM noted the effects of the bumps in the North barrier pillar and expressed concern. Although BLM's primary focus is resource recovery, their inspectors appear to be quite knowledgeable of underground hazards, and an early exchange of information

between the two Agencies may have focused MSHA’s attention on the bump problems at the Crandall Canyon mine.

10) As evidenced by both the Sago and Crandall Canyon disasters, the need for training of mine rescue crews (teams) and both operator and MSHA command center personnel remains great. Congress should consider funding the establishment of several mine rescue training centers in mining areas throughout the United States.

11) Accidents involving multiple fatalities should be investigated by a Federal entity independent of the regulatory Department. To protect the validity of the investigation and to ensure impartiality in fact finding, an independent entity needs to conduct these disaster investigations. This will allow an unbiased determination of process errors and misjudgments by all involved parties, and speed any requirements for corrective actions to further improve workplace safety for our nation’s most valuable resource - - the miner.