REPORT of INVESTIGATION

into the

MINE EXPLOSION at the

UPPER BIG BRANCH MINE

APRIL 5, 2010

BOONE / RALEIGH CO., WEST VIRGINIA

WEST VIRGINIA OFFICE of MINERS' HEALTH, SAFETY & TRAINING

FEBRUARY 23, 2012

C.A. PHILLIPS, DIRECTOR

CONTENTS

1 Executive Summary

On April 5, 2010, at approximately 3:02 p.m., an explosion ripped through the underground workings at Performance Coal Company, UBBMC, Montcoal Eagle Mine (UBB), taking the lives of 29 miners and injuring two others.

The explosion began after gas, mostly methane, was ignited by frictional impact as the shearer was cutting sandstone roof or by the rock colliding with steel supports or other rock while falling from the sandstone roof behind the longwall shields. It is deemed more likely that the longwall mining machine (shearer) ignited the methane.

The methane gas apparently was liberated from the mine floor behind the roof-supporting longwall shields, and, as this gas flowed to the return behind the shields, the airflow then became restricted by a recent roof fall across the #7 entry of the #21 Tailgate. This may have allowed combustible gas to accumulate near the location where the shearer was operating. This roof fall would not allow the air current to move directly toward the return at the tailgate corner of the gob, causing it to flow outby to an open crosscut. The shearer shut down just a few feet short of its normal stop position as it mined into the tailgate entry. Approximately 1½ minutes later the methane explosion occurred in the gob behind the longwall shields, spreading quickly to the #21 Tailgate and from there propagated through an extensive area of the mine.

This accumulation of methane was not detected by the required mine examinations or by the required machine-mounted methane monitors. Because the “T-split” is a critical location where ventilation can become blocked and gases can quickly accumulate, additional measures to support the roof at this location are prudent and recommended. More effective monitoring of gases at this location is also advised.

The methane explosion quickly transitioned into a coal dust explosion, which severely damaged ventilation controls, conveyor belts, water lines, electrical systems and numerous items in its path until the fuel was consumed and the explosion extinguished itself outby the track switch at the beginning of North Glory Mains.

A thorough investigation was conducted and the findings documented in this report to the Director of the West Virginia Office of Miners' Health, Safety & Training (WVOMHS&T). Contained in the body of this report is a summary of our findings. Details related to the data developed and the interpretation thereof can be found in the report appendices.

This report is the product of a 20-month investigation which included a thorough underground examination, including the examination of electrical components in the mine, evaluation of the mine geology, comprehensive mapping as part of the joint investigation and supplemental mapping by WVOMHS&T. Interviews were conducted, evidence was collected and evaluated and thousands of documents were examined.

There were certain areas of the mine which were inaccessible for safety reasons, but the remaining areas of the mine comprising a cumulative distance of mine passageways of over 50 miles in length were examined thoroughly and documented extensively in our investigation. The accessible entries and crosscuts were each traversed and examined multiple times in the course of our investigation.

Part of our investigation involved examining the sources of fine coal dust, both float dust from mining sections and conveyor belts, as well as sloughed material from friable coal ribs. We find that fine accumulations that can easily be dispersed into the air by the pressure wave ahead of a propagating flame are of primary concern and deserve increased attention.

The amount of rock dust being maintained on mine surfaces at the time of the explosion was insufficient to stop a coal dust explosion. The region where the dust explosion started does not appear to have had rock dust periodically applied over the fine coal dust. Periodic applications of rock dust over accumulating fine coal dust are necessary to render such dust harmless.

The greatest defense against the hazards of fine coal dust is the proper application of rock dust. The way we currently sample and apply rock dust needs to be modernized, using the latest research knowledge and most appropriate sampling and analyzing methods available. Other strategies to arrest a dust explosion include explosion mitigation barriers, which have important applications in certain conditions. Investigators found evidence that a water barrier just west of #22 Cross-over stopped the explosion from propagating further inby in the #21 Headgate entries. Further research is needed to demonstrate the practical application of water barriers, rock rubble barriers and other explosion-mitigating strategies as supplemental protection with generalized rock dusting to prevent explosion propagations in the future. The data combined in this report will serve as a resource for future research.

2 General Description and Setting

2 General Description and Setting

2.1 Location

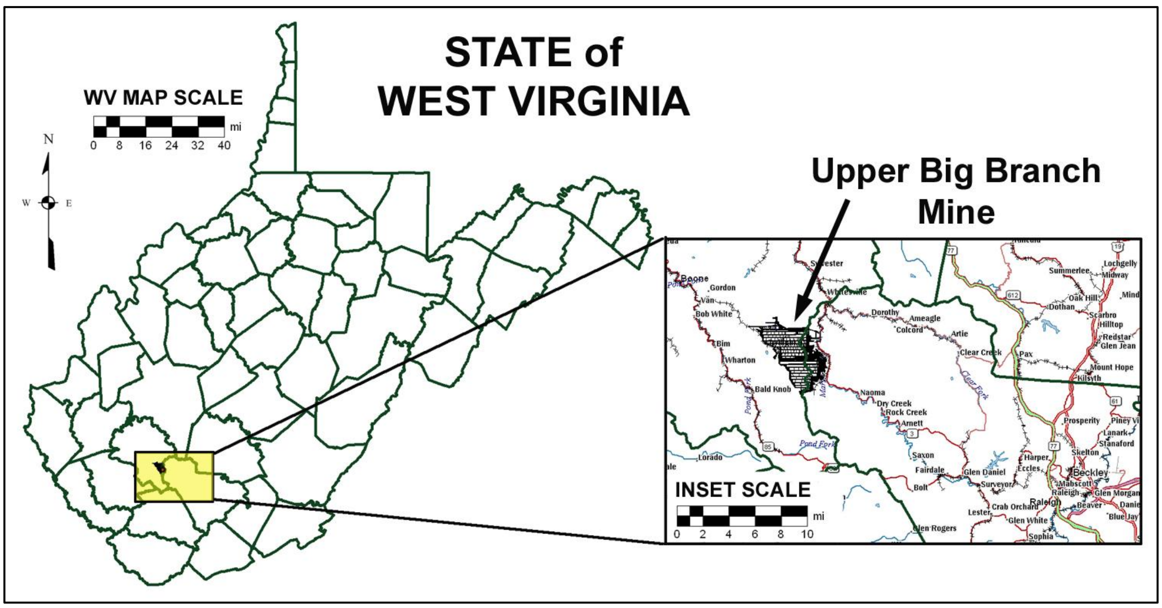


Figure 1. The Upper Big Branch Mine is located in Boone and Raleigh counties in West Virginia.

Performance Coal Company's UBBMC Montcoal Eagle mine (UBB) is located in Montcoal, just off West Virginia Route 3 in Raleigh County. UBB is 46 miles from the capital city of Charleston, 34 miles from Beckley and 45 miles from Oak Hill. The nearest emergency service agency is located in Whitesville, West Virginia, six miles from UBB. The North Portal of UBB is located at latitude N 37° 55' 2.04" and longitude W 81° 33' 8.10".

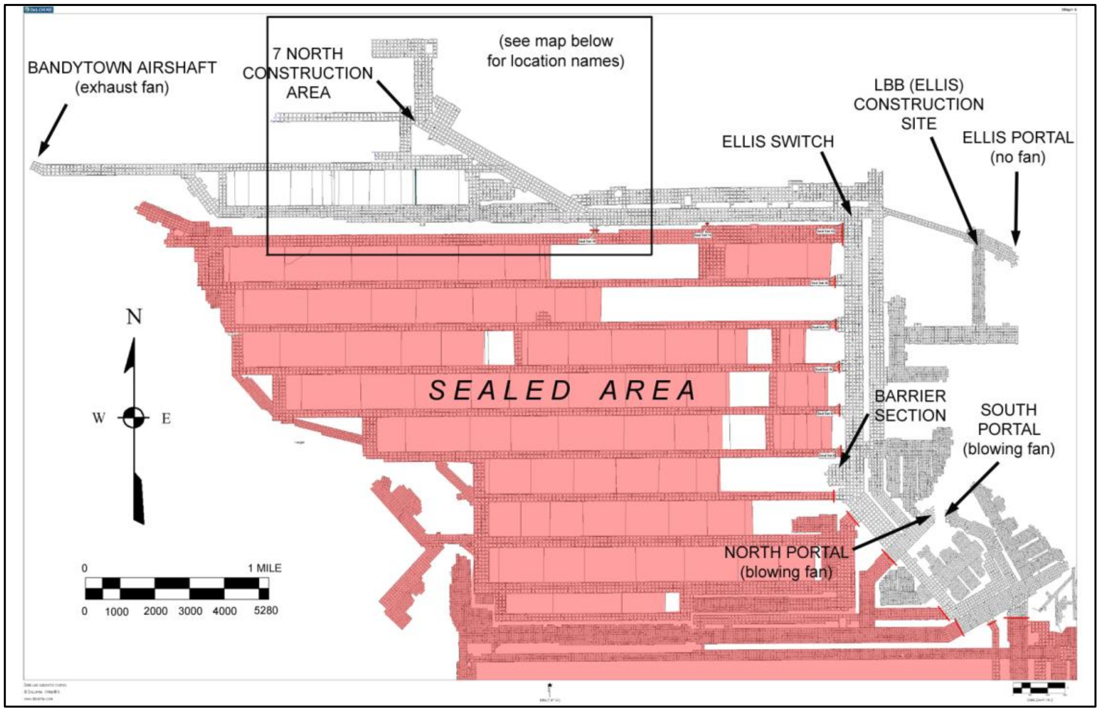


Figure 2. Map showing location of portals and fans. See inset map, below for additional information.

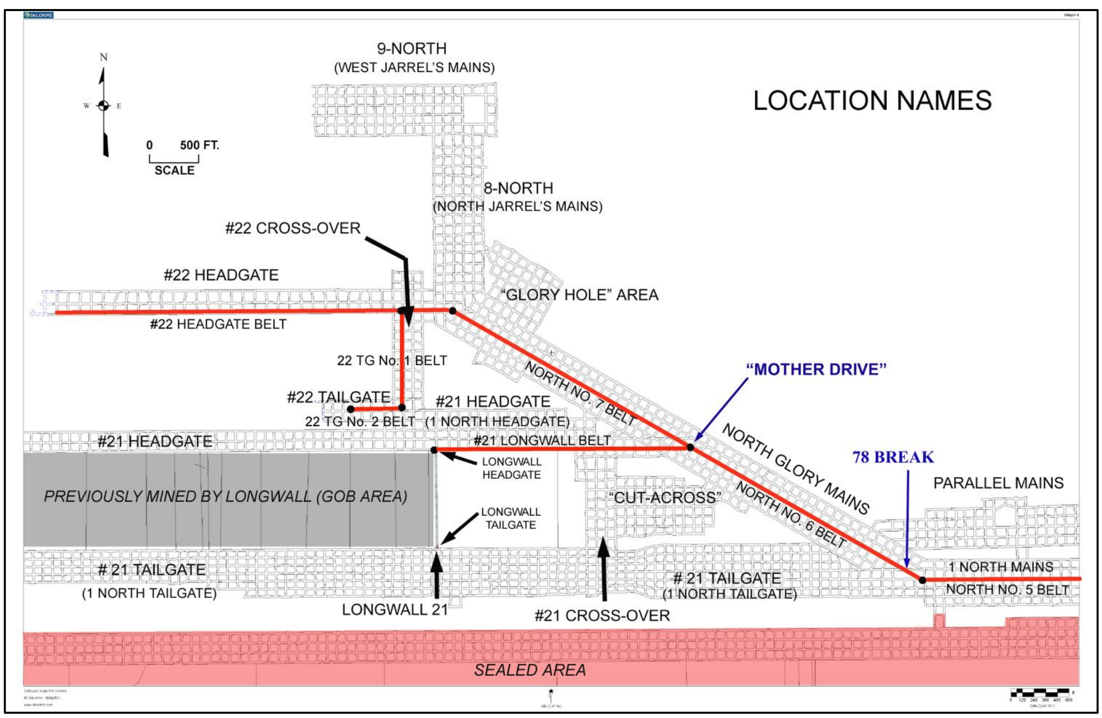


Figure 3. Map showing the names of selected locations and headings referred to in this report.

2.2 Geology and Mining Conditions

The Eagle seam is a premium metallurgical "mid-vol" coal of Middle Carboniferous age and is stratigraphically a part of the Kanawha Formation of the Pottsville Group (see **Appendix 2.2-1**). The roof rock at UBB is typically sandstone, but occasionally is shale. The sandstone is gray, medium fine grained and composed mostly of quartz grains (67%). Near the longwall face the first few inches of the immediate roof are sometimes a hard, brown sandstone which contains the sulfide mineral pyrite and/or marcasite,[1] but in small amounts (less than 3.5%; see **Appendix 2.2-2**).

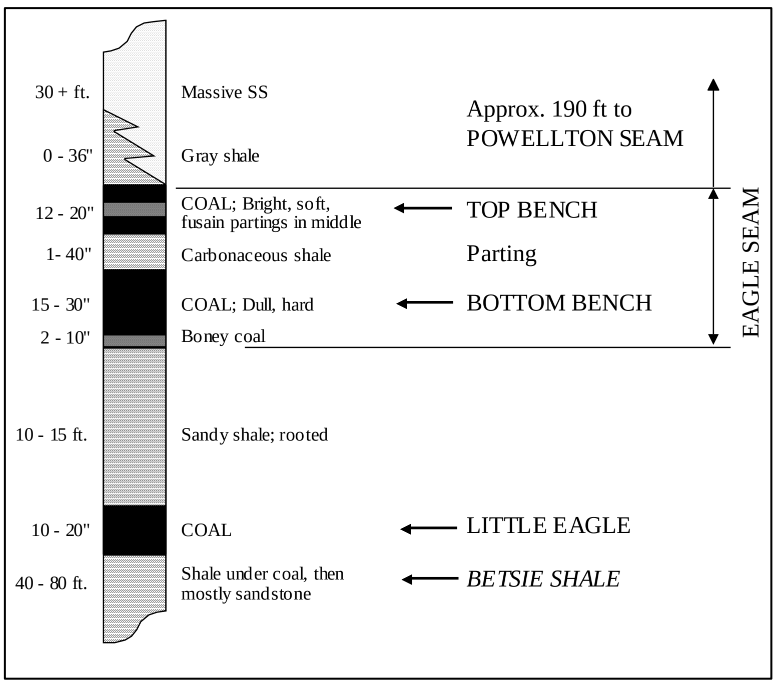


Figure 4. Generalized stratigraphic section showing the seam mined at UBB (Eagle seam), its immediate roof rock (typically sandstone, occasionally shale), and the location of the underlying leader seam (Little Eagle seam), and Betsie Shale.

[1] Pyrite and marcasite are chemically the same (FeS), but have different crystalline structures.

Marcasite was used by Paleolithic and some Native Americans for striking fires,[2] but it is unknown if the amounts present in the sandstone give it enhanced sparking characteristics. The brown sandstone contains half the quartz and twice the amount of albite (a feldspar mineral) as does the gray sandstone.

Seams immediately above the Eagle seam

The first mineable seam above the Eagle seam is the Powellton seam, which lies approximately 180 feet overhead and is actively being mined (see **Appendix 2.2-1**). Overall, the mine roof at UBB is massive, medium grained sandstone that is generally competent. Local areas of bad top occur where roof rock changes from sandstone and are also due to localized accumulations of plant fossils in the sandstone, which create bedding separations that produce occasional drop-outs.

The immediate 1 to 2 feet of the mine floor is typically sandy shale, weakened somewhat by fossil root structures. Typically the floor is softer than the roof, so when additional mining height is desired it is the floor rock that is taken. Floor rock had been mined at the tailgate during development, and was also being mined by the shearer. Below the immediate floor is sandy shale and sandstone.

Strata immediately below the Eagle seam

Approximately 10 to 15 feet below the Eagle seam is the Little Eagle seam, which is typically 10 to 20 inches thick and free of rock partings. Below the Little Eagle is the *Betsie Shale,* which has a thickness of 100 to 250 feet; core logs show that the top half is not shale but sandstone. The Betsie could be a source and reservoir for the accumulation of local pockets of natural gas, but additional research is needed (see **Appendix 2.2-1**).

[2] New York State Museum Bulletin 511, 2009, Chapter 8, Algonquian and Iroquois Uses of Plants and Other Materials to Make Fire

Characteristics of the Eagle seam

The Eagle seam has a Top Bench of 12 to 20 inches of coal that is vitreous, fractured and friable. The center 4 to 6 inches of this bench contain approximately 1.5 inches of distinctive "mother coal" [3] that occurs sometimes as a single layer, but more typically as 3 to 6 thin, silvery and sooty partings. This "fusain" crumbles easily to fine dust, much of which readily passes through a 200 mesh sieve, and, despite its low volatile content, it is comparable in explosibility to Pittsburgh seam float dust (see **Appendix 8.2-1**).

A shale parting separates the (Eagle) Top Bench from the Bottom Bench. Its thickness varies between 1 and 40 inches, sometimes erratically over distances of a few dozen feet.

The (Eagle) Bottom Bench is a hard and splinty coal and varies between 15 to 30 inches in thickness, with an additional 2 to 10 inches of boney coal (very hard) at the very bottom.

The (Eagle) Top Bench is the softest material in the seam section so that when the pillars take weight it fractures readily and spalls out, leaving cavities and ledges. These ledges can catch and accumulate dust from air currents and from progressive spalling. The shale parting that separates the two benches is soft when its thickness is 6 inches or less and is firm when its thickness exceeds about 16 inches. The (Eagle) Bottom Bench is a very hard coal and generally stands firm, as does the floor and roof, so that the weakest strata generally is the Top Bench of the Eagle seam; however, "floor heave" occurs in a variety of places. The depth of cover is generally greater than 800 feet throughout the study area. *Floor heave* is the term applied to fractures in the floor that have opened up and exhibit vertical displacements of usually 1 foot or less but occasionally as much as 3 feet. They tend to be most prevalent where mine entries are aligned N-S or E-W.

[3] Fusinite and semi-fusinite also, commonly referred to as fusain.

Local fractures and gas accumulations

Structurally, the dominant roof fractures are natural extension fractures trending along approximately N 25° W. This is similar to the mine floor, which overall has a dominant fracture trend of approximately N 20° W. The coal face cleat is equivalent to the rock extension fractures but is on a different orientation of approximately N 80° E. Fracture systems of joints and cleats are likely the dominant way that gases from below migrate upward.

The floor strata (which include the Little Eagle underclay, the Little Eagle seam and the interburden between the Little Eagle and the Eagle seam) may serve as a cap, preventing the natural upward migration of gases from the Betsie Shale or lower source beds. Equilibrium between gas pressure and confinement pressures are sometimes disrupted by mining, allowing localized gas to enter the mining spaces via the natural fracture system.

For more information about the geology, see **Appendix 2.2-1**.

2.3 Method of Mining

The following types of equipment and mining methods were used at UBB in the production of coal and other support activities at the time of the explosion on April 5, 2010.

The development sections worked two production shifts a day, mining coal at least five days a week, and sometimes six days a week, with a maintenance shift on the midnight or "owl" shift. The longwall normally produced coal seven days a week with three crews rotating the production schedule. The longwall maintenance and support crews on the midnight shift did not rotate. Starting times varied for production and non-production crews.

The mine was ventilated with three fans. Two blowing fans, one located at the North Portal and the other located at the South Portal. The third fan, located west of the #21 Headgate Longwall at Bandytown was an exhausting fan.

The production units on the advancing room and pillar sections consisted of Joy 12CM and 14CM remote control continuous mining machines. The roof was supported with Fletcher RRII and CDRII-13 dual boom roof bolting machines. The coal was transported to the conveyor belts with Joy 10SC shuttle cars. Fairchild and Long Airdox battery operated scoops were used to assist in the cleanup of the working faces, to move supplies on the sections and support other activities throughout the mine. A few battery powered A. L. Lee forklifts also were used to assist in the movement and transportation of mining supplies in outby areas of the mine.

The two longwall development sections, #22 Tailgate and #22 Headgate, utilized two continuous miners, three shuttle cars and two dual-head roof bolting machines on three entry sections. These two longwall development sections were using sweep ventilation, and mined the section using the "walking style" method of mining. The walking style of mining allowed the extra face equipment to be repositioned for mining while the other equipment was producing coal. These two sections and the longwall section transported the coal by conveyor belts out the Ellis Portal.

The other room and pillar section located in the north side of the mine was the Barrier section, located between the partially mined #16 and #17 Headgate Longwall panels. This seven entry section also utilized two continuous miners, two dual head roof bolting machines and three shuttle cars for production purposes. Air in this section was swept from right to left. The coal from the Barrier section was transported by belt out the East Mains or Silo Portal.

The longwall also located in the north side of the mine, was mining the #21 Headgate panel in an up dip direction, retreating west to east, at the time of the explosion. The longwall had retreated approximately 5,400 feet as of April 5, 2010. The longwall face setup consisted of a Joy 7LS shearer, Joy Shields and stage loader unit. The longwall air was intaking down the face and returning out towards the Bandytown fan located west of the longwall face.

The Portal section, located in the south side of the mine, also used two continuous mining machines, two dual head roof bolting machines and three shuttle cars in the production of coal. This section, however, was the only one that ventilated with "split or fishtail ventilation." This section was not working the day of the explosion and had been "Idle" in the fireboss books since March 29, 2010. Plans were underway to relocate this section.

The #22 Headgate section working faces were the deepest workings, measuring approximately 4.25 miles from the Ellis Portal; the #21 Longwall face was approximately 3.5 miles from the Ellis Portal.

The mine utilized rail haulage from the North, South and Ellis portals to transport workers and supplies into the mine using Brookville battery powered motors and mantrips. Conveyor belts were used to transport the coal from underground. UBB utilized a complex belt system to carry the coal from the Ellis and East Mains or Silo portals. The conveyor belt that exited the Ellis Portal went across West Virginia Route 3 and back underground through other mines to the Marfork Preparation Plant, located southwest of UBB. The conveyor belt that exited the East Mains or Silo Portal also traveled across West Virginia Route 3 and tied in with the same belt system that ends at the Marfork Preparation Plant.

2.4 Ventilation and Methane Drainage

Mine ventilation is the most important of the defenses to prevent mine explosions and respirable dust diseases. Three fans were installed on the surface; two were installed at drift openings blowing air into the mine and the third was an exhaust fan. Most of the air exhausting from the mine was via a 16-foot diameter airshaft near Bandytown. This fan was assisted by blowing fans at the North and South portals (see **Figure 5**). These three fans moved a large quantity of air, about 1,013,900 cubic feet per minute (cfm), of air was reported to be returning to the surface after having ventilated the underground areas. Ventilation is essential to dilute and remove noxious gases, methane and respirable dust.

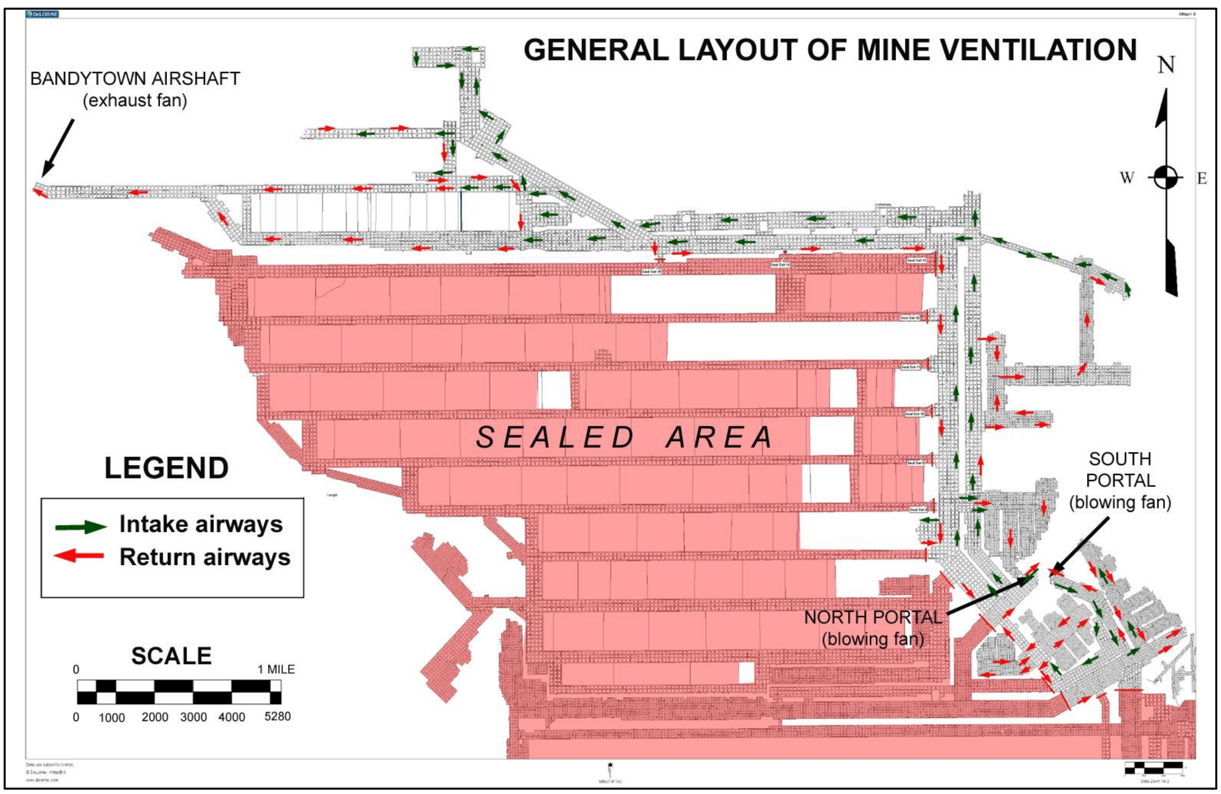


Figure 5. General layout of the ventilation at UBB at the time of the April 5, 2010 explosion.

The air currents are directed as needed to various locations underground, where needed, by concrete block walls (stoppings) strategically placed in mine openings. Three separate air currents are used: intake, belt air and return. Air crossings (overcasts) were used where the various air currents, such as intakes and returns, crossed as they were divided throughout the mine. A system of airlock doors were used to separate one type ventilation current, such as a current dedicated to belt air, and another type, such as the intake.

The Federal Mine Safety and Health Act contains three categories of methane liberation: more than 200,000, over 500,000 and over 1,000,000 cubic feet of methane liberated in a 24-hour period. The UBB mine liberated about 1,067,510 cubic feet of methane per day according to the last available air measurements and air analysis. About 981,000 cubic feet of the methane was reportedly exhausting from the Bandytown fan. Air analysis found 0.182% methane in the air current and about 0.11% carbon dioxide (normal air contains about 0.03% carbon dioxide). Significant amounts of the methane came from the rocks below the Eagle coal seam, as stress fields changed during mining, and probably some came from the roof as it caved. Outbursts of gas occurred from breaks in the mine floor near longwall shields on February 18, 2004, and July 3, 2003.

A large portion of the previous mining had been sealed at the time of the explosion (see **Figure 5**). The active portions of the mine were north and east of that sealed area. Carbon dioxide, methane and air with low oxygen are gases normally found in sealed gobs. Even though the seals are competent, some gases can escape around their perimeters during periods when the barometer trends downward. For that reason, the seals were ventilated by air directed to the return and exhausted at the North and Silo portals. Most of the coal production was from the region ventilated by the Bandytown fan north of the large sealed area. This is the area affected by the explosion, where one longwall section and two continuous miner sections were operating.

2.5 Communication and Tracking System

The communication and tracking system approved and installed at UBB consisted of a Minecom UHF leaky feeder-type communication system that utilized wireless handheld Motorola radios and Pyott-Boone, Model #1981 tracking boss, tag readers. The tag readers are located at specific locations underground. The RF ID Tags, Model #1980, were worn by individual miners and used to track their location while underground. The tracking system was tied in with the Pyott-Boone carbon monoxide mine-wide monitoring system (MineBoss), which was already in use at the mine.

An Emergency Communication and Tracking Plan for UBB was approved on January 22, 2008 (see **Appendix 2.5-1**). Violation #26611 was issued on August 4, 2009, by the WVOMHS&T for not being in compliance with the approved plan. This violation was extended at least five times through March 1, 2010, as work on this system progressed (see **Appendix 2.5-2**).

At the time of the explosion, the tracking system was still not fully operational throughout the entire mine. Work was being done to complete the tracking system and also to eliminate electrical problems (blown fuses) in the system amplifiers. The Tag Reader Tracking System was operational from the surface up to crosscut 102 North Mains (near the mother drive). All other areas of this mine not covered by the operational tag readers were required to be tracked by manual tracking procedures.

The tag reader (station ID 3.5), located at crosscut 76 on the North Mains Track, identified several people that were in the #22 Tailgate Section mantrip at approximately 3:01.53 p.m., minus eight seconds for data transfer, or 3:01.45 p.m. on April 5, 2010.

At approximately 3:02.18 p.m., the Pyott-Boone system computer, located on the surface, recorded a communication loss from a CO monitor located at crosscut 99 on 6 North Belt as the explosion severed a power cable near that location (see **Section 4.2**). Due to the programming and data transfer speed of the system, the event time may be as much as 108 seconds prior to the recorded time of the alarm, or 3:00.30 p.m.[4] This system was rendered inoperative by the explosion on April 5, 2010 (see **Appendix 2.5-4**).

2.6 Organizational Structure

Performance Coal Company is a West Virginia corporation and a 100% subsidiary of Elk Run Coal Company, which is also a West Virginia corporation. Elk Run Coal Company is a 100% subsidiary of A. T. Massey Coal Company, Inc. which is a Virginia corporation. A. T. Massey Coal Company, Inc. is a 100% subsidiary of the parent Massey Energy Company, a Delaware corporation.

On April 5, 2010, the corporate officers of Performance Coal Company were Mark Clemens, Director; Chris Blanchard, Director/President; Jamie Ferguson, Vice-President; Richard Grinnan, Secretary; Shane Harvey, Assistant Secretary; and Phillip Nichols, Treasurer.

The management structure at UBB consisted of Wayne Persinger as general manager. Everett Hager was superintendent and Terry Moore was the mine foreman on the north side of the mine. Gary May was the superintendent and Rick Foster was the mine foreman of the south side of the mine. Jack Roles was the longwall coordinator.

[4] Time after time drift correction was conducted by WVOMHS&T (see **Appendix 2.5-3**).

3 Operations: Pre-explosion

3 Operations: Pre-explosion

3.1 History and Previous Mining

UBB is located near the community of Montcoal, in the Marsh Fork District of Raleigh County.

"Advance Approval" from the West Virginia Division of Environmental Protection, later known as Department of Environmental Protection (WVDEP), was transferred from Peabody Coal Company to Performance Coal Company on October 7, 1994. The WVOMHS&T issued the Health and Safety permits to Performance Coal Company, Upper Big Branch Mining Company, Montcoal Eagle Mine (UBB) on November 2, 1994. UBB was assigned permit number U-3042-92. There was no underground mining activity on the permit prior to Performance Coal Company acquiring this property.

Production began and within approximately 18 months additional openings had been developed for ventilation, transportation of workers and coal. This was completed with the use of remote control continuous miners, shuttle cars and double head roof bolting machines that utilized the room and pillar method.

Mining of the West Mains and Hazy Mains was developed to set up longwall panels and a bleeder system to ventilate the 10 projected longwall panels in the reserves on the south side of the mine. The longwall panels were developed to allow the retreating face to mine in a west to east direction. The first longwall panel was completed by March 1997. Additional openings for ventilation and transportation of coal and workers were developed as mining advanced. The longwall completed mining 10 panels in the south area of the mine by March 2000. Later that month, the longwall was moved to the north reserves where nine panels were mined. Three of these panels were not totally mined on initial setup. Those three partial panels were mined in 2005 and 2006.

Longwall mining at UBB ceased in July 2006 when the short panel on #16 Headgate was completed. Since there were no other panels developed at UBB, the longwall was moved to the Castle Mine (Logans Fork) of Elk Run Coal Company while additional panels in the north reserves of UBB were being developed. The longwall returned to UBB prematurely in the summer of 2009 due to difficult mining conditions at the Castle Mine. This unexpected development caused some issues with the setup area for the returning longwall. Ventilation and water drainage issues had not been completely resolved prior to the longwall being put back in production at UBB in September 2009.

On April 5, 2010, UBB was operating four production sections in the Eagle seam. The Barrier section was located between the old #16 Headgate and #17 Headgate panels. The longwall was producing on the #21 panel. The #22 Headgate and #22 Tailgate sections were located north of the longwall and were developing a future longwall panel. This longwall panel was behind schedule and would not have been ready when the current panel was completed. As a result, plans were to develop a short panel at the Ellis/LBB Construction site.

Three coal mines are adjacent to UBB in the Eagle seam. On the southwest side is the Peabody Coal Company, Harris No.1 Mine. The abandoned Eagle Energy Inc., No.1 Mine is located on the west side. The third mine, Ellis Eagle Mine of Marfork Coal Company, is located on the east side across West Virginia Route 3. Longwall mining was conducted at these mines.

Production History

The UBB mine produced approximately 13,000 tons of coal in December, 1994. When the longwall went into service in April 1996 coal production increased to just over 3,080,000 tons for the year. This began a period of 10 consecutive years (1996 to 2005) that production exceeded two million tons annually.

The highest production year was 1998 when approximately 5,698,800 tons were produced. From 1994 to 2010 the mine produced approximately 41,400,000 tons of coal.

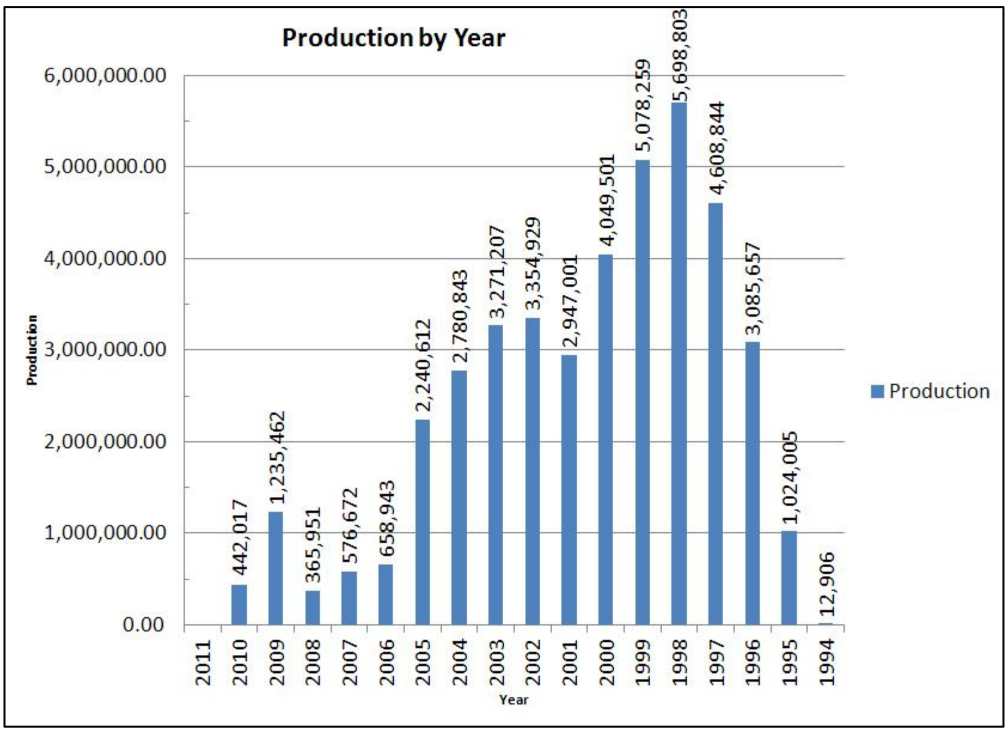


Figure 1. Annual Production records from Upper Big Branch Mine, 1994 to 2010.

After the longwall was moved to the Castle Mine, production dropped to 576,672 tons in 2007 and approximately 365,000 tons in 2008. The longwall returned to UBB in 2009 and began producing in September of that year.

Mining History of the Longwall

When operation of the south portion of UBB began in April 1996 panels were mined until those reserves were depleted. The only reported event dealing with an ignition or gas inundation on a longwall face while mining these reserves occurred on January 4, 1997.

The North Reserves were developed and longwall production began in March 2000. Prior to the April 5, 2010 explosion, there were at least two occasions of large inundations of gas while mining the North Reserves. There were no catastrophic repercussions with either incident. One incident occurred in 2003 and another in 2004.

.

When the longwall section was moved to the overlying castle mine in July 2006 coal was transported through the Castle Mine, down the Glory Hole and then by conveyor belts to the surface of UBB. The Glory Hole was developed from UBB into the Castle Mine which is approximately 180 feet above. Bad mining conditions at the Castle Mine were the catalyst to bring the longwall back to UBB before originally planned.

UBB continued mining operations with continuous miners in the longwall's absence. The #21 Headgate Longwall panel was developed at UBB and the longwall was brought back from the Castle Mine. Longwall production at UBB resumed in September 2009. The #21 Longwall panel was developed approximately 6,700 feet in length with a longwall face approximately 1,000 feet wide. This panel was being mined west to east, with a rise in elevation of approximately 85 feet from the beginning of production until the time of the accident. The depth of cover for the panel being mined was as much as 1,275 feet, and was approximately 1,075 feet at the current face location. Mining had progressed approximately 5,400 feet at the time of the explosion. The Bandytown exhaust fan was located approximately 11,600 feet west of the #21

Longwall face at the time of the explosion. A blowing fan also was utilized at the North Portal to assist in mine ventilation. This panel was the first one to be ventilated by the Bandytown exhaust fan. This fan was installed to ventilate the longwall gob for this and following panels to be mined in this area, and to assist in ventilating the two working sections north of the active longwall section.

Longwall Equipment and Systems

There were 176 Joy twin leg shields that made up the face support. The longwall face was mined by a double drum shearer utilizing bi-directional mining as a regular part of the mining sequence. Coal was transported along the face onto the stage loader by a steel conveyor chain. From there, conveyor belts transported the coal to the surface by way of the Ellis Portal.

The longwall face methane monitor sensor was located at the tail of the longwall under the tail drive motor covers, and the readout for the face monitor was at the headgate control box area. The shearer also had a methane monitor and constant readout on the shearer.

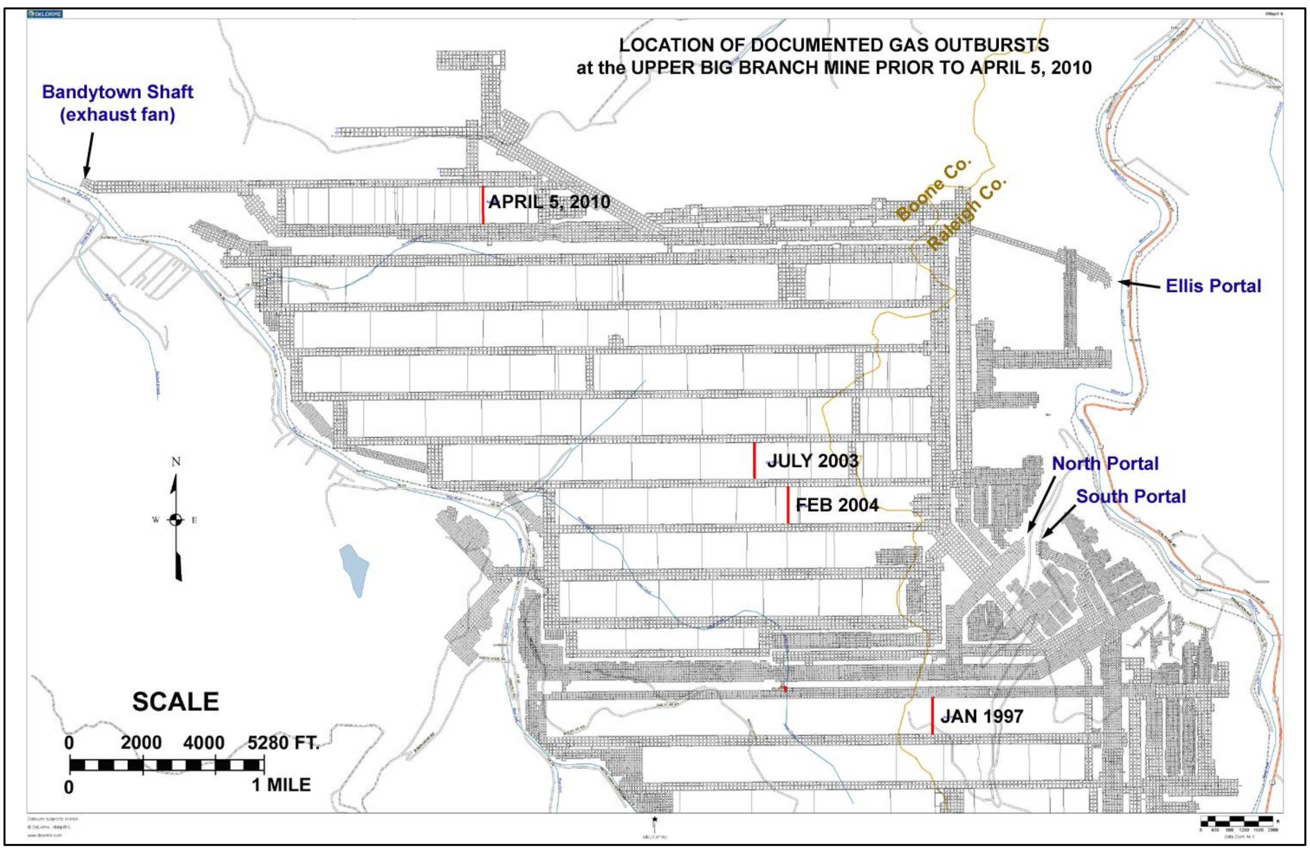
Shield hydraulics was supported by Kamat Pumps with fresh water for the emulsion brought into the mine from two deep freshwater wells. Water for the longwall shearer and other sections of the mine was pumped from the Coal River by way of 150 horsepower pumps, and then stored in large tanks located on the surface above the Silo or East Mains Portal. This water flows underground from the tanks and, after being filtered, is transported underground by means of PVC piping throughout the mine and to the longwall face. Pressure pumps are installed at strategic locations to obtain the water pressures needed to operate the longwall shearer, continuous miners and other water activated systems.

Pressurized water was provided to the shearer by a Sunflo Pump located at the “Mule Train” near the end of the longwall section track.

3.2 Incidents of Prior Gas Inundations

Summary of Incidents

Between 1997 and 2004, there were at least three known gas events associated with longwall mining at UBB. The first event led to a series of methane ignitions. The last two were gas inundations, but no ignitions were involved. The event which occurred January 4, 1997 involved one or more gas ignitions. Testimony from eyewitnesses indicates two or more ignitions occurred at approximately 10:20 a.m., beginning in the gob subsequently entering the #2 West Longwall face.



MAP 1. Location of the April 5, 2010 explosion, and prior gas events in 1997, 2003 and 2004.

January 4, 1997[1] Gas Ignition

The nine-man crew began production on Saturday morning, January 4, 1997, from the tailgate of the longwall where the shearer was left the previous shift. Air measurements taken by the foreman showed that airflows on the working face were in excess of the amounts required. Workers stated that face ventilation seemed good, and face mining conditions seemed better than normal. However, the mine roof was breaking higher up more than usual, and the mine roof fell several times behind the longwall shields that morning.

The crew completed the fourth mining pass of the day by cutting out on the tail of the section at about 10:20 a.m. As the operator was "shearing down" with the tail drum of the shearer, the mine roof fell behind the shields and an ignition occurred in the gob area where the roof had just fallen.

The shield operator had just advanced shields 175 and 176 and he was standing at shield 174 facing the gob and was first to see the ignition. He saw a red glow in the gob that was becoming brighter. He pointed toward the glow, and then started running toward the longwall headgate. He felt heat on his legs and ran 400 to 500 feet to about mid-face before getting out of smoke that resulted from the ignition. Both shearer operators also saw the ignition, and flame singed hair on the tail drum operator's neck and arm. The head drum operator next saw the ignition come from behind the shields and then continue up the face line from the longwall tailgate. These two shearer operators also ran toward the headgate and said "something blew up."

Two workers were changing batteries in the speaker phone near shield 150 when the first ignition occurred. One felt heat from the ignition, but did not see any flash or flame. He thought the shearer power cable had exploded so he called the headgate operator on the speaker phone and had him de-energize the face power. The foreman and another worker went to the tail to check

[1] See **Appendix 3.2-1** (Report of a Methane Gas Ignition, January 4, 1997) for additional information.

the area after making sure everyone was headed out toward the head. The foreman stated he also observed the ignition.

Both of these men detected 0.6% methane at shield 174, and enough carbon monoxide was present to activate the alarm of the foreman's LTX 310 detector. The detector was set to alarm at 50 parts per million (ppm) carbon monoxide. They detected a smell like "old works," but no fire was present. These two men witnessed a second ignition, which appeared like a "yellowish" flash, while they were examining near shield 174. A third event occurred as they were walking past shield 36 toward the longwall headgate. They described this final event as "bucking of the air."

The crew was directed to assure proper ventilation in the headgate entries, and a ventilation curtain was also installed in the first four shields on the face to direct all available air down the longwall face. The foreman started his exam back down the face but stopped when he got to shield 92 where he experienced heat. The men then evacuated the mine.

The immediate roof in the tailgate return aircourse adjacent to shield 176 (the last shield) was unstable and was blocked by a roof fall about 50 feet outby the tailgate of the section near survey station 1266 (see **Appendix 3.2-1** for map). The return air course was being carried as "dangered off" in the fireboss reports for the last several days because of "bad top." It was also determined during the investigation that the back-up curtains in the headgate entries were not installed and being used at the time of the ignition.

The WVOMHS&T investigation determined that adequate airflow was not provided in the longwall section bleeder system sufficient to prevent a dangerous accumulation of methane gas in the gob area. It is believed that the gas was ignited by sparks created when the sandstone mine roof struck the longwall shields after an unusually high roof fall.

Examination of the #1 fan chart shows a number of air pressure events occurred between 10 a.m. and 11:30 a.m. on January 4, 1997. Samples taken by MSHA inspectors on January 4, 1997, showed large amounts of coke at shields 172, 175 and 176, the tail motor and the shearer area. Recommendations were given to address this ignition as part of the WVOMHS&T report referenced.

July 3, 2003 Gas Inundation

The July 3, 2003, gas inundation was never reported to the WVOMHS&T. The information was obtained through testimony given during the investigation of the April 5, 2010, explosion and from information available from the MSHA Mine Data Retrieval System Website.

This 2003 event occurred on the #16 Longwall panel near shield 95 in the north reserves of the mine. There were no injuries reported, and ventilation changes were made to help ventilate the bleeder located in the mine floor in the gob behind the shields until the gas inundation subsided and mining operations resumed.

February 18, 2004 Gas Inundation

A reported gas inundation occurred on February 18, 2004, on the #17 Longwall panel. Workers heard a loud bumping or big thump at approximately 11:40 a.m. Wednesday morning followed by sounds of gas pressure being released in the gob. The section was not producing coal at this time due to a maintenance issue with the longwall shearer cable junction box.

Ventilating curtains were placed from the headgate to shield 87 along the jack line to assist in diluting the floor bleeder gases to a manageable level. This floor crack was most prominent in the mine floor around shields 106 and 107. The gas readings exceeded 5% methane at several locations and at various times during this event. By 3:20 p.m. Friday, February 20, 2004, the gas inundation had subsided and the control order regarding this incident was lifted and the section was released to resume coal production.

Geology

The gas involved in the longwall inundations appears to be originating from the mine floor. It is speculated that abutment stresses at the shields and pillars create floor heave and/or open floor fractures which then act as pathways for the gas. How the gas pockets accumulate and what their sources are is unknown, but information contained in **Appendix 2.2-1** gives conditions which might be factors.

A shale and sandstone stratigraphic sequence believed to be of marine origin exists under a small leader seam below the Eagle seam. Marine shales can be a source for natural gas, but, in order for the gas to be mobile, it must accumulate in open pore spaces or fractures in the rock. The marine shale below the Eagle seam (the Betsie Shale) is capped by a sandstone unit that may act as a reservoir for accumulating gas, and the lower shale units, or deeper shales, may be the source beds for gas. The thickness of rock between the floor of the Little Eagle seam and the Eagle seam itself is typically 10 to 15 feet. This interburden may act as an impermeable cap for gas, but one that can be ruptured by abutment stresses during mining. Abutment stresses are related to cover depth. The longwall inundations referenced above and the longwall face on April 5, 2010, were in locations where the depth of cover exceeded 800 feet, the point at which abutment stresses can challenge weakened rock.

The prior inundations have each occurred where the Little Eagle seam is comparatively thick. Corehole data shows that the Little Eagle seam achieves its greatest thicknesses in localized depositional channels which may be overlain with locally weak rock due to lithologic transitions resulting in differential compaction slips and/or fractures that weaken rock and might provide pathways for vertical migration of fluids and gases.

Structurally, the dominant extension fracture in the UBB mine roof trends approximately N25°W. This is similar to the mine floor, where fracture orientations are more difficult to ascertain, but which appear to be approximately N20°W. The dominant face cleat trends N80°E. The coincident alignment of the roof and floor joint systems at UBB may facilitate the occurrence of floor rupture and gas migration. This is not known for certain and requires further study. Additional information pertaining to these conditions and factors can be found in **Appendix 2.2-1**.

4 The Explosion

4.1 Operations in the 24 Hours Prior to the Explosion

4.2 The Explosion

4.3 Origin and Path of the Explosion

4 The Explosion

4.1 Operations in the 24 Hours Prior to the Explosion

Pre-Shift Examinations for the Midnight Shift

On Sunday, April 4, 2010, UBB was idle in observance of Easter. UBB resumed operations late Sunday night when midnight maintenance crews returned to work. Coal production at UBB, however, did not restart until the dayshift on Monday, April 5, 2010.

Before midnight maintenance crews could enter UBB, the mine had to be pre-shifted. Firebosses, who were to perform the pre-shift examinations of the mine prior to the Sunday night midnight shift, began arriving at UBB shortly before 6 p.m. John Neely, John Skaggs and John Bickford were to pre-shift the area of the mine inby Ellis Portal all the way to the longwall and the two continuous miner sections known as #22 Tailgate and #22 Headgate. Bruce Brackett and Terry Peterson pre-shifted the mine from the UBB Portal to the Ellis switch.

As part of that Sunday evening pre-shift examination, Neely, Skaggs and Bickford pre-shifted the pumps at Ellis, the Glory Hole and North Mains. Their reports indicate no methane or carbon monoxide were detected during their examinations of these areas, and that air movement around the pumps was good and that they found no hazards.

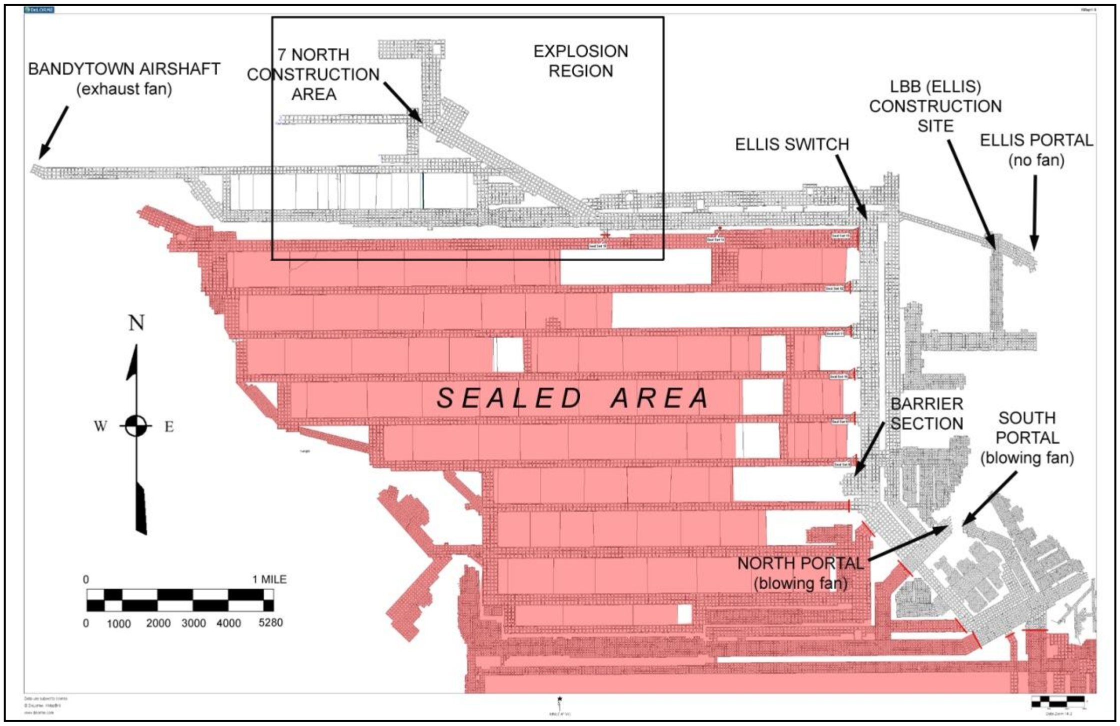


Figure 1. Map showing location of portals and fans. *See Explosion Region* inset map, below.

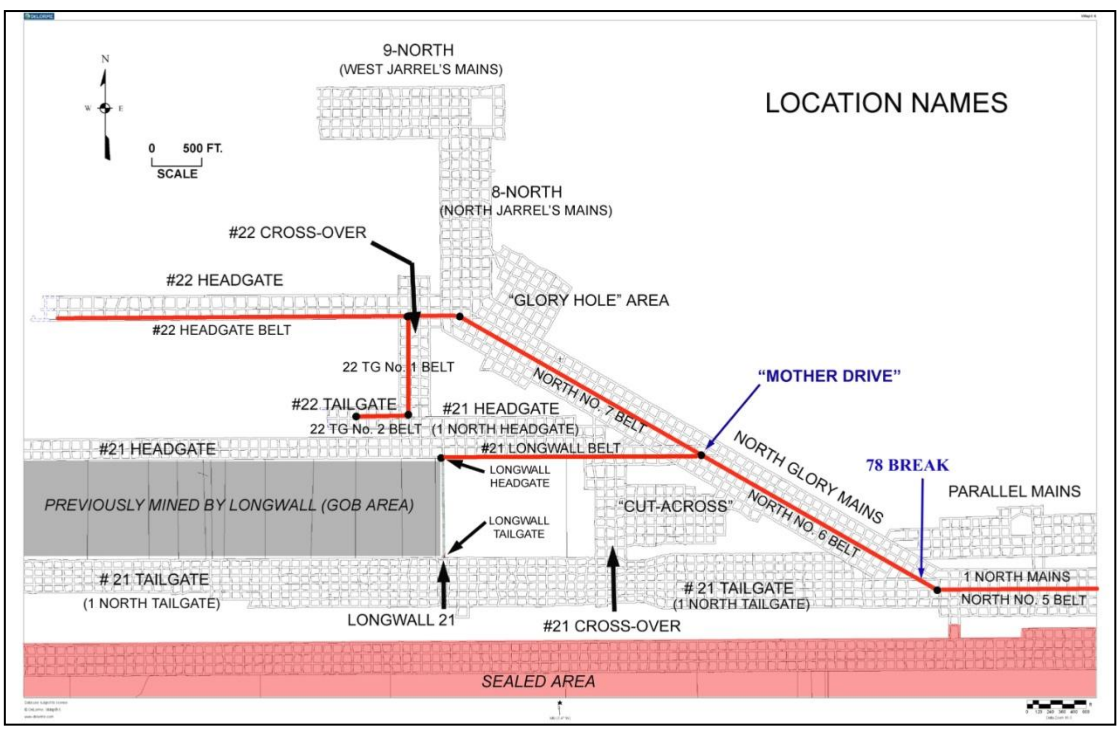


Figure 2. Map of the *Explosion Region.*

Neely pre-shifted #22 Headgate; Skaggs pre-shifted #22 Tailgate and the longwall[1]; and Bickford pre-shifted the Glory Hole and the Old North Mains areas of the mine. Neely's pre-shift examination report shows methane levels ranging from 0.1% to 0.25% in the face areas of #22 Headgate with no carbon monoxide present and that air movement was adequate on #22 Headgate. The pre-shift examination report reflects that there were soft ribs in all three entries of #22 Headgate and water was accumulating in the #3 face. The report also reflects that the haul roads needed additional cleaning.

Skaggs conducted the pre-shift examination on #22 Tailgate. His report shows no methane or carbon monoxide was detected in that area and air movement on the section was good. Skaggs' report indicated there was water up to his knees in the area in front of the section power center over to the return.

Bickford pre-shifted the 7 North Construction Area of the mine. His report indicates that no methane or carbon monoxide was found in this area, air movement was good and no hazards were found.

Brackett pre-shifted the Barrier section and inby toward the Ellis Switch, while Peterson pre-shifted the Portal section area of the mine. Neither individual reported detecting any methane or carbon monoxide in their pre-shift examination reports.

Since the midnight shift at UBB was a maintenance shift and did not produce coal, the belts did not have to be pre-shifted, except in areas where workers were required to work on this shift.

The Midnight Shift

The midnight shift at UBB was a maintenance shift for all areas of the mine, which was the case on April 5, 2010. The move crews on the midnight shift made splices on the belt at the #22 Headgate mother drive, moved belt on the #22 Headgate section, moved belt on the #22 Tailgate

[1] During his interviews, John Skaggs acknowledged he did not fireboss the longwall face and reported that fact to the longwall midnight foreman. See John Skaggs transcripts dated May 26, 2010 and March 1, 2011.

section and worked on the conveyor belt at the construction site just inby the Ellis Portal, commonly referred to as Ellis Construction Site or LBB Construction Site.

The longwall maintenance crew changed the headgate cowl on the shearer, moved the monorail down and worked on the longwall face conveyor chain replacing flights. In performing these tasks, the crew cut bolts on the face chain and the cowl with a cutting torch, and tack welded the nuts on the face chain and the nuts on the cowl. The longwall maintenance crew also changed the oil and the bits on the shearer. The shearer was near the headgate while this work was performed. The supply crew delivered the new cowl to the longwall and took the old cowl outside.

The rock dust crew dusted the longwall belt and crosscuts from the mother drive toward the longwall headgate. The rock dust crew utilized a pod duster that was pulled by a track mounted locomotive. The farthest inby point of travel for the duster during that shift on the longwall track was at approximately crosscut 17.

Pre-Shift Examinations for the Dayshift

Skaggs pre-shifted the LBB Construction Site for the dayshift. His report reflects that neither methane nor carbon monoxide was found in this area of the mine, there were no hazards found and air movement was good.

Neely pre-shifted the 7 North Construction Site for the dayshift. His report reflects that no methane or carbon monoxide was found in that area, the air movement was good and no hazards were found.

Bickford pre-shifted the pumps at Ellis, the Glory Hole and the North Mains for the dayshift. His report reflects that he found no methane or carbon monoxide in these areas of the mine, air movement was good and no hazards were found.

Skaggs pre-shifted the #4 Ellis, #5 Ellis and North #4 belts. No methane or carbon monoxide was detected. Skaggs did report that the #4 Ellis and #5 Ellis belts needed rock dusted. He also reported that the North #4 belt needed spot cleaned and rock dusted. Bickford pre-shifted the North #5 and North #6 belts and reported that no methane or carbon monoxide was found. His report also indicated that the North #5 belt needed spot cleaned from the #60 break to the flow-through and that the North #6 belt needed spot cleaned and dusted.

Larry Brown pre-shifted the longwall for the dayshift. His report shows no methane or carbon monoxide detected on the longwall and that there was adequate air movement with no hazards observed. Brown also pre-shifted the longwall belt and found no methane or carbon monoxide, and reported that the longwall belt needed spot cleaned.

Neely pre-shifted the North #7 belt, the Tailgate #1 belt and the Tailgate #2 belt and reported that no methane or carbon monoxide was detected. Neely did report that the North #7 belt needed rock dusted, the Tailgate #1 belt needed spot cleaned and spot dusted, and that the Tailgate #2 belt had no hazards.

Neely conducted the pre-shift examination on #22 Headgate for the dayshift. He found 0.3% methane in the #1 entry, and 0.1% methane in the #2 entry, the 2 right crosscut and the #3 entry. No carbon monoxide was detected, and the report shows that air movement was adequate. Neely also reported that the section needed cleaned and rock dusted.

Jason Thomas pre-shifted #22 Tailgate for the dayshift. He found no methane or carbon monoxide and reported good air movement. Joe Coon pre-shifted the Barrier section for the dayshift, found no methane or carbon monoxide and reported good air movement. He did, however, report soft ribs on the section.

Brackett and Peterson conducted the pre-shift examinations on the belts on the south side of the mine for the dayshift. They reported no methane or carbon monoxide. They did report areas on the belts that needed cleaned and rock dusted.

The Dayshift

Coal production resumed at UBB during the dayshift on April 5, 2010. The first coal-producing crews to enter the mine from the Ellis Portal were the #22 Headgate and the longwall crews, who entered at approximately 6 a.m. At 6:38 a.m., the pump crew entered the mine from the Ellis Portal. Two crews entered from the North Portal: The Barrier crew entered the mine at approximately 6:10 a.m. followed by the #22 Tailgate crew at approximately 6:40 a.m.

The #22 Headgate, #22 Tailgate and Barrier section crews produced coal throughout the day. The LLB Construction crew worked on cutting roof rock. Two men, Clifton Earls and James J. Woods, were working on the south side at East Mains pulling rails at the time of the explosion; however, they were in other areas of the mine earlier in the day performing other tasks.

Examinations of #21 Tailgate Conducted on April 5, 2010

During the dayshift on April 5, 2010, Jeremy Burghduff, foreman for the pump crew working in the bleeder area behind the longwall, recorded 0.15% methane in the #4 entry at the 100 break and 0.05% methane in the #3 entry at break 122.[2] Burghduff reported water levels ranging from 9 to 36 inches in the area from break 85 to break 125. Burghduff also reported a small roof fall at 52 break on Old 2 section on the track in the return and a damaged bolt at 83 ½ break.

Pre-Shift Examinations for the Evening Shift

Pat Hilbert received the pre-shift report for #22 Headgate from Dean Jones around 2:45 p.m. Mr. Jones reported to Hilbert that he was at the feeder and found nothing unusual on #22 Headgate. Mr. Jones did report methane levels of 0.3% in the #1 entry, 0.2% in the #2 entry, 0.3% in the #3 entry and 0.3% methane in the #1 right scrap cut. Mr. Jones also reported that the #1 entry needed rock dusted.

---

[2] During the testing of all methane detectors, records indicate that the Solaris multi-gas detector assigned to Jeremy Burghduff was not turned on during his entire shift on April 5, 2010. It was turned on during the evening hours after the explosion.

Rick Lane called out the pre-shift report for the longwall evening shift to Kevin Medley at 2:40 p.m. Mr. Lane reported no methane, carbon monoxide or hazards, and that there was adequate air flow on the longwall.

Michael Elswick pre-shifted the Glory Hole area and the belts on the North Glory Mains, including the #6 and #7 belts. Mr. Elswick also pre-shifted the 7 North Construction Area for the evening shift. He called this report outside at 2:30 p.m. His report reflects that he found no methane or carbon monoxide in the areas, air movement was good and no hazards were found.

Mr. Elswick pre-shifted the pumps located in the North Mains and in the area of the Glory Hole; Scott Halstead pre-shifted the pumps in the Ellis area of the mine. No methane or carbon monoxide was detected at the pumps, air movement was good and no hazards were found.

Mr. Elswick pre-shifted the North #7 belt, the #22 Headgate belt, the Tailgate #1 and Tailgate #2 belts; no methane or carbon monoxide was detected. Mr. Elswick did report that the North #7 belt and the Tailgate #1 belt needed rock dusted, while the Tailgate #2 belt needed cleaned at the tail. Mr. Elswick reported the #22 Headgate belt needed spot cleaned and rock dusted.

At 2:38 p.m., Steven Harrah called out the pre-shift examination on #22 Tailgate for the evening shift. He reported no methane or carbon monoxide, good air movement and no hazards.
Bobby Baker pre-shifted the LBB Construction Site for the evening shift. His report reflects that he found no methane or carbon monoxide in the work area, at the charger, at the pump or at the overcast. He also reported no hazards.

Jim Bowyer conducted the pre-shift examination of the belts on the south side of the mine for the evening shift. He reported no methane or carbon monoxide, but he did report that areas on the belts needed cleaned and rock dusted.

State and Federal Inspections That Day

WVOMHS&T Inspector Wayne Wingrove arrived at the UBB Portal mine office at approximately 7 a.m. to begin a quarterly inspection. After reviewing the mine map and the examination books, Wingrove went to the Barrier section to begin his inspection. While on the Barrier section that day he wrote three violations. One violation was for low air in the #2 entry. The second violation was for an unsupported kettle bottom. The third violation was written for a faulty manual disconnect on a scoop. Wingrove left the UBB mine at approximately 2 p.m. that day.[3]

MSHA Inspector John Syner arrived at the UBB Portal mine office at 5:20 a.m. to begin an EO1 (quarterly) inspection. He held a pre-inspection meeting with Gary May and Rick Foster, and gave a brief safety talk to the employees. He then went to the Barrier section to begin his inspection. Mr. Syner found a cable splice that was not sealed to exclude moisture and the section escapeway map was not up to date. A violation was issued for each. Syner found that the rock dusting was good on the Barrier section. He left UBB between 1 p.m. and 2 p.m.[4]

The Longwall

The longwall crew entered the mine at approximately 6:04 a.m. When the crew arrived at the longwall face the shearer was near the headgate. The first longwall call-out report occurred at 7:30 a.m. The 7:30 a.m. report indicates that they had made 0.2 passes, and the shearer was at shield 70 headed towards the tail. The crew continued mining and arrived at the tail and completed the shuffle between 8:30 a.m. and 9 a.m. At 10:30 a.m., the crew reported that the shearer was at the head and that they were preparing to change bits. In the 11 a.m. call-out report, the crew reported they replaced 25 bits and had lost the B-Lock on the tail ranging arm. The B-Lock problem persisted until sometime between 1:30 p.m. and 2 p.m. In the 2 p.m. call-out report, the crew reported that they had made an additional 0.2 passes and they were going to re-check the B-Lock. At this time, the shearer was at shield 65 and headed toward the tail. In

3 Transcript of Wayne Wingrove dated May 10, 2010.
4 Testimony of John Syner dated May 14, 2010.

questioning why the shields had not been advanced and the panline not pushed on the headgate side of the longwall face from around shield 60 to the headgate, production reports[5] and testimony [6] indicates that the crews had possibly been "swinging the face." The 2:30 p.m. call-out report states that the shearer was at shield 115 going toward the tail. At 2:40 p.m., Rick Lane called out the pre-shift report for the evening shift to Kevin Medley. In that report, Lane stated that he had detected no methane or carbon monoxide, no hazards and the air movement was adequate. This is the last known communication received from the longwall.[7]

4.2 The Explosion

First Indications of the Explosion

At approximately 3:02.18 p.m. on April 5, 2010, the Pyott-Boone system computer, located on the surface, recorded a communication loss from a CO monitor located at crosscut 99 on the 6 North conveyor belt (see **Appendix 2.5-3** and **2.5-4**). Due to the programming and data transfer speed of the system, the event log entry could have been delayed by approximately 108 seconds.[8]

---

[5] Production reports showing examples of mining extra footage from the tail or head the last few shifts on the #21 Longwall face. See **Appendix 4.1-1**.

[6] Kevin W. Medley testimony March 29, 2011

[7] Seventeen (17) individuals invoked their 5th Amendment rights and were not interviewed as part of the investigation process. These individuals may have knowledge of other communications from the longwall that the State Investigation Team was unable to learn.

[8] Pyott-Boone suggested the possible time delay, which would put the explosion earlier (3:00.30 pm)

All of the surface power for Ellis Portal was supplied via the Green High Voltage 12,470 volt circuit, which originates at the main substation located at the UBB North Portal. A digital video recorder (DVR), installed on the surface at the Ellis Portal, was powered by this circuit. As was the mother drive (longwall belt drive), located at crosscut 102(see **Figure 3**). This circuit received enough damage around crosscut 98 to de-energize the power. The internal clock on the DVR stopped at 2:57.00 p.m. on April 5, 2010 due to power loss. After calculating time drift and factoring in that the DVR records a time stamp in one minute intervals, the actual time is from 3:01.34 to 3:02.50[9] (see **Figure 4**).

The MSA Solaris Multi-Gas detector that was recovered from the longwall face at shield 82 recorded an over-range event for carbon monoxide and combustible gases sometime between 3:02.14 p.m. and 3:02.59 p.m. on April 5, 2010.[10]

The MSA Solaris Multi-Gas detector that was recovered from the #22 Tailgate mantrip recorded an over-range event for carbon monoxide and combustible gases sometime between 3:01.34 p.m. and 3:02.53 p.m. on April 5, 2010.[11]

The Joy Shearer has an internal data recorder referred to as a JAN 0 unit. A right handheld (tail side) remote control caused the shearer to stop sometime between 2:59.32 p.m. and 2:59.38 p.m., after correction, on April 5, 2010.[12]

[9] Times after time drift correction conducted at MSHA'S Approval and Certification Center
[10] Times after time drift correction conducted at MSHA'S Approval and Certification Center
[11] Times after time drift correction conducted at MSHA'S Approval and Certification Center
[12] Times after time drift correction conducted at MSHA'S Approval and Certification Center

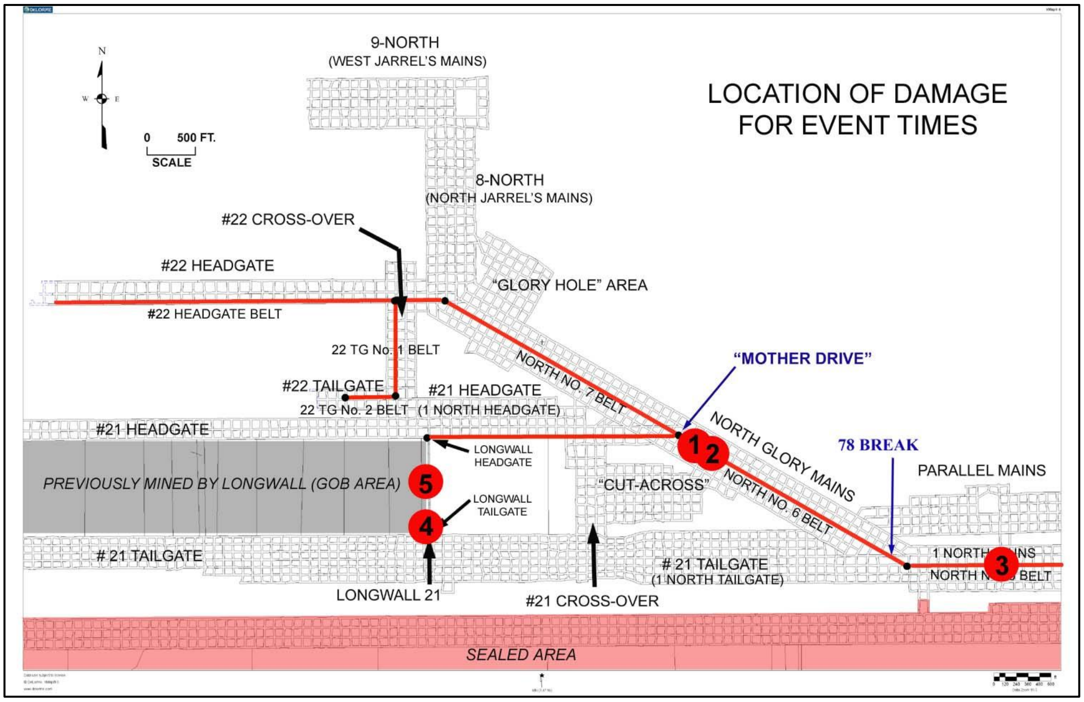


Figure 3. Location of events and damage summarized in the timeline below.

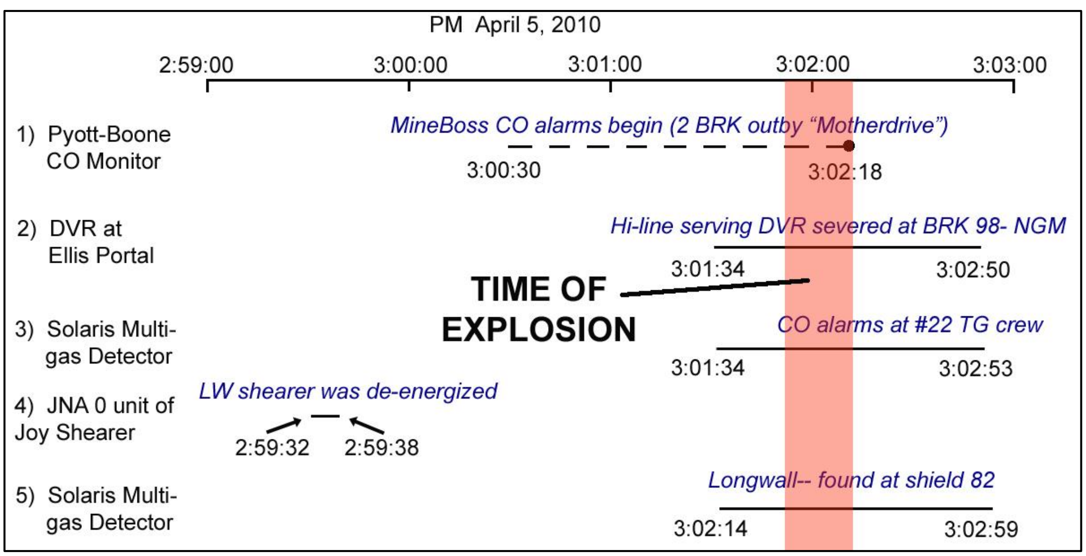


Figure 4. The timing of events around the time of the explosion (corrected for clock drift) expressed as a range. NOTE: 3:02:18 p.m. is the first CO alarm, corrected for clock drift, and 3:00:30 includes the possible delay in the Pyott-Boone system response. See **Figure 3** for locations.

At approximately 2:40 p.m., the #22 Tailgate crew left their section and began traveling by a battery powered, track-mounted mantrip to the surface. At approximately 2:58 p.m., James K. Woods called the dispatcher for the road to Ellis switch and gave his location as 78 break. At 3 p.m., the longwall crew did not call outside. Shortly after 3 p.m., Greg Clay began to call the longwall on the mine phone to get their 30-minute call-out report. He called two or three times and received no response. He then heard a loud, strange noise coming from the fan.[13] In his interview, Clay stated "I guess about three minutes after 3:00, I just heard this bam (noise). I thought the fan (north fan) had thrown a blade or something because it's making a real bad noise."[14] He looked out the window and saw dust and debris coming out the North Portals. The CO monitors were also alarming at this time.[15] A short time later the fan returned to normal operation. Brandon Davis stated in his interview that he was in the bathhouse at the North Portal "and then I remember when I heard that fan (north fan) start making that noise. I looked and it was two minutes after 3:00 on my watch."[16] Other eyewitnesses on the surface at the Ellis Portal also reported strong wind, dust and debris coming out of the portal openings.

On the Ellis Portal side of the mountain, the evening shift longwall crew was at the mantrip a few breaks underground at the time of the explosion. Crew members reported that at first they felt a small breeze, but the air quickly picked up until it felt like what they described as hurricane force winds carrying debris. Initially, crew members sought shelter in the crosscut and then exited quickly out the Ellis Portal.

At the time of the explosion, Clifton Earls and James J. Woods were working on the south side of the mine in the East Mains recovering rail when they heard something and stopped working. Thinking they were just hearing things, they started back to work. At 4:10 p.m. they left their work area to go outside. When they got outside they learned of the explosion. No one had contacted them to inform them to evacuate.

---

[13] Miners on the surface reported that the fan reversed; however, the State found no physical evidence that the fan completely stalled or reversed.
[14] Gregory Clay interview (June 23,2010)
[15] Transcript of Adam Jenkins,(June 12, 2010)
[16] Brandon Davis interview (September 1,2010)

Prior to the explosion, the dayshift LBB Construction crew had left their work area and were traveling inby toward Ellis Switch on their way to the UBB North Portal when they experienced intense pressure in their ears and then felt wind and debris hitting them. One member of the LBB crew reported that the wind was so strong it pushed the mantrip outby toward the Ellis Portal and that the foreman's gas detector began to alarm. During the explosion, something caused the power on their mantrip to go off. While they sat on the track in the mantrip, the foreman told his crew to get their self-contained self-rescue devices (SCSR) ready due to the high level of CO he was picking up on his detector. The crew prepared their rescuers for donning.[17] The crew members deployed their SCSRs and some crew members donned them. After the wind ceased blowing, the crew was able to energize the mantrip and immediately began to tram toward the Ellis Portal where they made it safely outside.

Tim Blake worked on the #22 Tailgate crew. Mr. Blake reported that the #22 Tailgate crew quit mining coal around 2:30 p.m. and began cleaning their section. At about 2:40 p.m. they left the section on the mantrip. When they got to about 67 crosscut on the North Mains track, Mr. Blake reported that all at once everything went black and it seemed like he was sitting in the middle of a hurricane. Debris was flying through the air hitting the mantrip and the crew members. The foreman's gas detector was alarming. Other members of the #22 Tailgate crew yelled for fellow workers to don their rescuers. Mr. Blake held his breath while donning his rescuer; he reported that the wind event lasted for approximately one to three minutes.

When things settled down, Mr. Blake got out of the mantrip and checked each crew member for a pulse. He put SCSRs on each crew member except one whose rescuer he could not find. When he finished working with each member of the crew, Mr. Blake looked at his watch; it was 3:57 p.m. he called on his radio for help, but received no response. His SCSR was running low on air due to him attending to each individual miner on the mantrip. Mr. Blake stated that the hardest thing he ever had to do was when at this time he left his crew to go for help. He walked approximately 20 breaks and saw a mantrip approaching that had entered the mine from the Ellis Portal.

[17] Transcript of Bobby Baker, dated August 23, 2010.

Initial Actions after the Explosion

Workers had entered the mine preparing for the afternoon shift that started at 3 p.m. When the forces from the explosion reached their locations near the drifts of the mine portals, it was apparent that something huge had occurred inby. After the initial forces subsided, these workers exited the mine.

Seconds after the explosion occurred, Dispatcher Adam Jenkins began calling the sections underground to tell them to evacuate.[18] About 15 minutes later, Jack Martin from the Barrier section responded to the call.[19] After receiving word to evacuate, Martin assembled all of his men and began exiting the mine by mantrip through the UBB North Portal.[20] Jenkins continued to call for the working sections inby 78 break for at least another 30 minutes after the explosion; however, there was no response.[21]

From the Ellis Portal

About 20 to 25 minutes after the effects of the explosion stopped coming out of the Ellis Portal, Chris Blanchard, Jason Whitehead, Jack Roles, Everett Hager, Wayne Persinger and Pat Hilbert entered the mine on a mantrip through the Ellis Portal. Hilbert was driving the mantrip, and when they got to the first overcast they stopped to clear cinder blocks from the track. When they arrived at the Ellis Switch, they called outside to report their position and proceeded inby. At approximately 47 break, they saw a single light walking toward them that was Mr. Blake. He told them his crew was about 20 breaks inby. Blanchard, Whitehead, Roles, Persinger and Hager left Hilbert and Mr. Blake with the mantrip and proceeded on foot inby. About ten minutes later, Roles ran back and said they needed the mantrip. Roles stayed with Mr. Blake while Hilbert took the mantrip inby.

From the UBB North Portal

---

[18] Testimony of Adam Jenkins dated June 12, 2010.
[19] Testimony of Adam Jenkins dated June 12, 2010.
[20] Testimony of Jack Martin dated July 20, 2010.
[21] Testimony of Adam Jenkins dated June 12, 2010.

Shortly after the explosion, Gary May entered the mine on foot from the UBB North Portal. Rick Foster then entered the mine through the UBB North Portal on a mantrip. Berman Cornett and James Walker were the next people to enter the mine through the UBB North Portal, doing so on foot. They met Foster who was removing pins from the double airlock doors just inby the portal. The three men together continued inby on the mantrip. They switched out at the Plumley Switch to allow the Barrier section crew to exit the mine. After the Barrier section crew passed, Foster's mantrip proceeded inby to the Ellis Switch. It was at this location where they met Gary May who had traveled to this point on foot. Together they proceeded inby on North Mains towards 78 break. At approximately 47 break they saw lights coming down the track. The lights belonged to Jack Roles and Mr. Blake who were walking outby.[22]

Performance Coal Company's Initial Rescue and Recovery Efforts

When Hilbert arrived at 66 break he saw the mantrip with the victims.[23] They loaded Steve Harrah, James Woods, Bill Lynch and Carl Acord on Hilbert's mantrip. Wayne Persinger rode out with Hilbert giving CPR to Mr. Woods. About two or three breaks outby, Hilbert met Gary May, James Walker and Berman Cornett. These three boarded Hilbert's mantrip to perform CPR on two of the other victims as they proceeded outside along with Rick Foster, who was driving the mantrip brought in from the North Portal. Blanchard, Whitehead and Hager loaded the other victims on the second mantrip and Hager brought them outside. After all the #22 Tailgate crew members had been loaded on the two mantrips and started towards the surface, Blanchard and Whitehead continued inby.[24]

Massey's Southern West Virginia Mine Rescue team is located near the main guard shack at Performance Coal Company. Rob Asbury, Mine Rescue Coordinator for Massey's southern team, received the emergency call shortly after the explosion. Asbury was informed to take the

[22] Transcript of James Walker dated August 17, 2010.
[23] Testimony of Pat Hilbert dated July 10, 2010.
[24] Testimony of Pat Hilbert dated July 10, 2010.

mine rescue truck and rescue team members to the Ellis Portal. After arriving at the Ellis Portal and benching their apparatus, the team began to enter the mine.

4.3 Origin and Path of the Explosion

Mine explosions have an ignition point and an explosion origin. While the location for both can be the same, much depends on the distribution of combustible fuel at the ignition point. Ignitions of fuel-rich gas bodies may not explode upon ignition but burn around their perimeter until the right mixture is found and then explode. Because coal dust must be in suspension for a dust explosion to begin, methane was the fuel for the ignition. Depending on the fuel distribution, the mine geometry and other factors, the explosion can take one path or multiple paths. Part of the job of investigators is to discover the evidence to make these interpretations about the origin and path of the explosion.

The origin of the explosion was determined initially by a process of elimination. Locations where explosion forces first propagated into, then propagated out of, cannot be where the explosion originated. Using the various tools and methods described in the report appendices, the sequence and direction of explosion wind forces can be established. Some of the essential information is summarized in **Figure 5**. Based on this information, candidate locations for the explosion origin were reduced to just a few possibilities. It was determined that the Tailgate region of the longwall was where the explosion began. Subsequent work narrowed the location further.

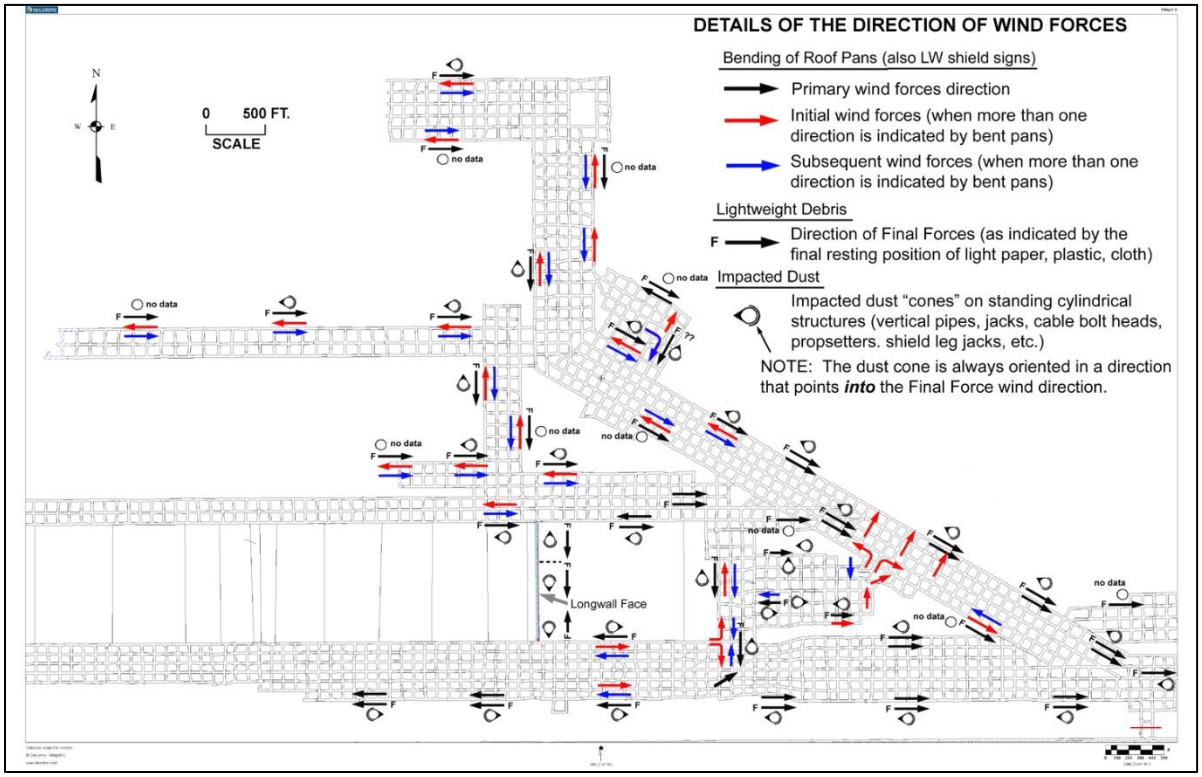


Figure 5. There are multiple directions of wind forces during a mine explosion. Using indicators of ***initial*** wind forces and ***final*** wind forces the explosion candidate locations for origin can be inferred. See **Section 7.9**, **Map 15** for larger map.

Investigators concluded that the explosion likely occurred in or on the rubble (gob) behind the shields at a location near the Tailgate (see **Figure 6**). The fuel for the ignition was methane that was mostly liberated behind the shields, either from floor cracks and/or by expansion of methane from the gob due to falling barometer and the ventilation gradient. It is believed the ventilating pressure gradient[25] and flow direction moved the methane along the gob until it reached the intersection of #7 entry at shield 176. Behind this shield is the corner of the gob; the gob extended across #7 entry creating blockage in that entry, restricting ventilation. Upon ignition, the gas could have burned as a wick into the gob before explosion generating forces occurred nearby. After burning for a time, a methane explosion occurred in the gob near the tailgate, which then propagated along multiple initial paths. The explosion dynamics due to gas explosion in and on the rubble would be highly turbulent and complex. A methane flame will

25 See Section 7.3

propagate through cracks that are at least 0.1 inch wide but the flame and gases cannot travel and expand freely, so in smaller openings flame propagation will be slower than in open air. The explosion front may be compressed due to multiple reflections on rock surfaces especially if the gas body and open spaces between the rubble are large, which would be the case near the edges of the rubble. Explosion of pre-compressed gases, called pressure piling, could create higher explosion pressures, and the explosion could have exited the gob with some force.

The explosion event gives evidence that it took multiple paths. One explosion path was along the gob fringe behind the shields (**A**), a second path was into the T-split area of the longwall (**B**), and a third split exited the gob approximately 300 to 400 feet west of the longwall shearer (**C**), (see **Figure 6**, **Appendix 7.9-5**).

Once in the #21 Tailgate, the methane explosion transitioned to a coal dust explosion propagating eastward in the #7 entry away from the "T-split", also southward, through the first crosscut outby the shearer and also westward from where explosion forces exited the gob a few crosscuts west of the longwall. The early stages of the dust explosion may have involved a hybrid fuel of methane and dust. As the explosion continued to propagate, the composition of fuel is believed to be coal dust generated from the natural rib spalling from principally the Top Coal bench and also float dust from mining operations (see **Appendix 8.2-1**).

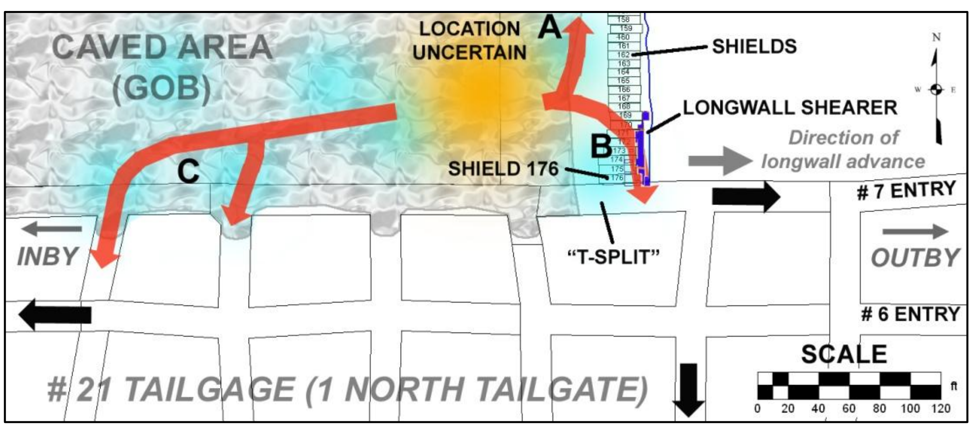


Figure 6: Evidence suggests the explosion began in the gob behind the longwall shields. RED arrows indicate the inferred path of the initial explosion. BLACK arrows show the initial paths of propagation once these forces found their way into #21 Tailgate. The actual ignition may or may not have occurred at the explosion origin.

Information contained in the *West Virginia Flames and Forces Map*, various compilations of summary maps, and other information were used to determine the likely initial path of the explosion through the mine. This appears in **Figure 7**.

Initial Path of the Explosion

The direction and sequence of explosion propagation was determined by mapping and analyzing bent roof pans (see **Appendix 7.9-2**), and determining the breach directions of ventilation stoppings, conveyor belt structures, waterlines, airlock doors, etc. (see **Appendix 7.9-4**), and also by compiling and analyzing other data such as the geometry of impacted dust on roof bolt heads (see **Appendix 7.9-1**). Final forces were determined by documenting the resting positions of lightweight paper, plastic, cloth, etc., and supplemented by "impacted 'V' dust deposits" on standing cylindrical structures (see **Appendix 7.9-3**). Explosion forces in the gob exited the tailgate entries, and the general direction of the explosion could be traced as it moved out of the tailgate entries.

Initial explosion forces in #21 Tailgate propagated westward toward the Bandytown fan and also eastward toward the #21 Cross-over. Eastward, the leading edge occupied the #7 entry until the #21 Cross-over was reached, and from there the flame speed in the southern entries increased relative to the northern entries, producing high pressure damage to roof pans and resulting in the #1 entry assuming the leading edge. East of the #21 Cross-over the leading edge remained in the #1 entry of #21 Tailgate for the remainder of its initial propagation to approximately the switch near break 78 , where propagation subsided to extinction.

A branch into the #21 Cross-over propagated north and then branched eastward into the southern entries of the Cut-across, continuing eastward. These wind forces necked down to just three entries when they merged with the North Glory Mains, resulting in increased pressures and severe damage to roof pans and belt structures in the crosscuts of North Glory Mains at this confluence. The explosion quickly subsided to extinction to the northwest of the confluence. Southeast of the confluence the explosion leading edge was in the south entries, and propagation continued until reaching the 1 North Mains and Parallel Mains where the explosion quickly subsided to extinction.

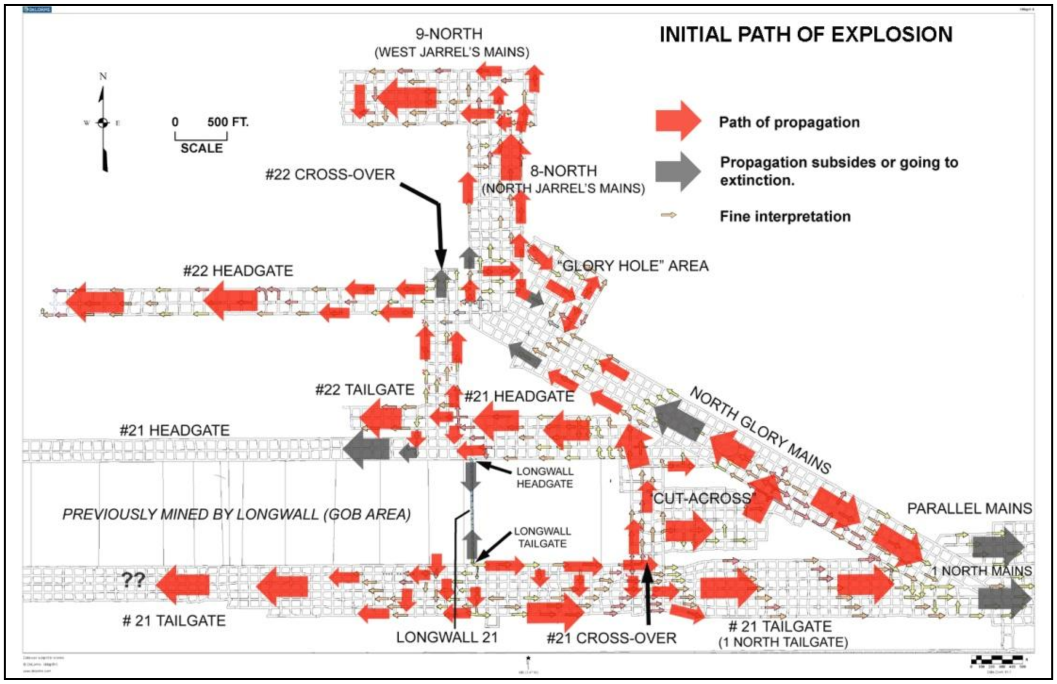


Figure 7: After the explosion in the longwall gob exited into the #21 Tailgate, its ***initial path*** continued to find fuel and propagated along a path indicated with RED ARROWS. Indicated with GRAY ARROWS are locations where the initial explosion forces subside, due to lack of fuel or other factors.

The branch of the explosion that continued north in the #21 Cross-over branched three ways at #21 Headgate. The east branch propagated quickly to extinction while the north branch crossed the #21 Headgate and entered North Glory Mains, where it propagated approximately 1,000 feet northeast then subsided. The west branch in #21 Headgate entered the belt entry[26] first but within a few hundred feet the opposite side (#4 and #5 entries) assumed the leading edge of the explosion, when flame velocity increased in the last 500 feet before the confluence with the #22 Cross-over. Pressures were high in this confluence, as evidenced by severe roof pan damage. One branch of the explosion then proceeded north into the #22 Cross-over and the remainder continued west into #22 Tailgate and the three remaining entries of the #21 Headgate. Forces also entered the longwall and subsided to extinction.

West of the #22 Cross-over, the forces that arrived at the three-entry #21 Headgate entered first at a crosscut near the mouth of #22 Tailgate and entered #21 Headgate through a water-filled

[26] The southern entry (or #1 entry)

dip. The explosion was quenched by this water barrier, quickly subsided to extinction and did not propagate further west in #21 Headgate (see **Appendix 4.3-1**).

The branch of the explosion that continued north in the #22 Cross-over appears to have lost some momentum as it crossed the mouth of #22 Headgate and branched east and west, and continued north. It subsided to extinction in the last few hundred feet of the #22 Cross-over after crossing the #22 Headgate. Upon making the turn west in the #22 Headgate (a three entry heading) the leading edge of the explosion entered the belt entry (the #1 entry), but within 1,000 feet the #3 entry had accelerated and caught up with #1 entry resulting in severe pan bending in the #1 and #2 entries. At the dead end of #22 Headgate high reflected pressures developed in the #2 and #3 entries.

The explosion forces from #22 Cross-over also turned southeast and into the North Glory Mains, while another branch propagated north into #8 North and entered the Glory Hole area from a second location. Along the southeast solid rib of the Glory Hole area is evidence of reflected pressure and severe pan bending from these forces propagating through the Glory Hole area.

The propagation of forces into #8 North (North Jarrell's Mains) gathered momentum as the explosion traveled north, producing severe damage to roof pans approximately 600 feet south of the #9 North (West Jarrell's Mains) headings. This damage was primarily along the outer entries. After making the turn west into #9 North, the leading edge of the westward propagation started in the southern entries; however the northern entries gained speed and developed into the leading edge of the explosion during the last 1,000 feet of propagation to the #9 North western dead end. Part of the dead end was flooded, so some information is unavailable, but forces at the dead end were determined to be north-to-south and they produced severe pan damage from reflected pressures in the southwest corner of #9 North.

Return Forces Sufficient to Bend Roof Pans

After the passage of the initial pressure, subsequent wind forces are generated by a variety of factors involving reflected pressures, cooling of combustion gases in the seconds after the explosion and, we believe in some cases, additional fuel consumption and propagation. The source of oxygen in this explosion was unusual in that the airflow to Bandytown fan was a straight run through in the #21 Tailgate and #21 Headgate entries, independent of ventilation controls. The UBB ventilation fans remained operational after the explosion, so that even though stoppings were destroyed, partial[27] ventilation resumed immediately after the explosion reverberations stopped.

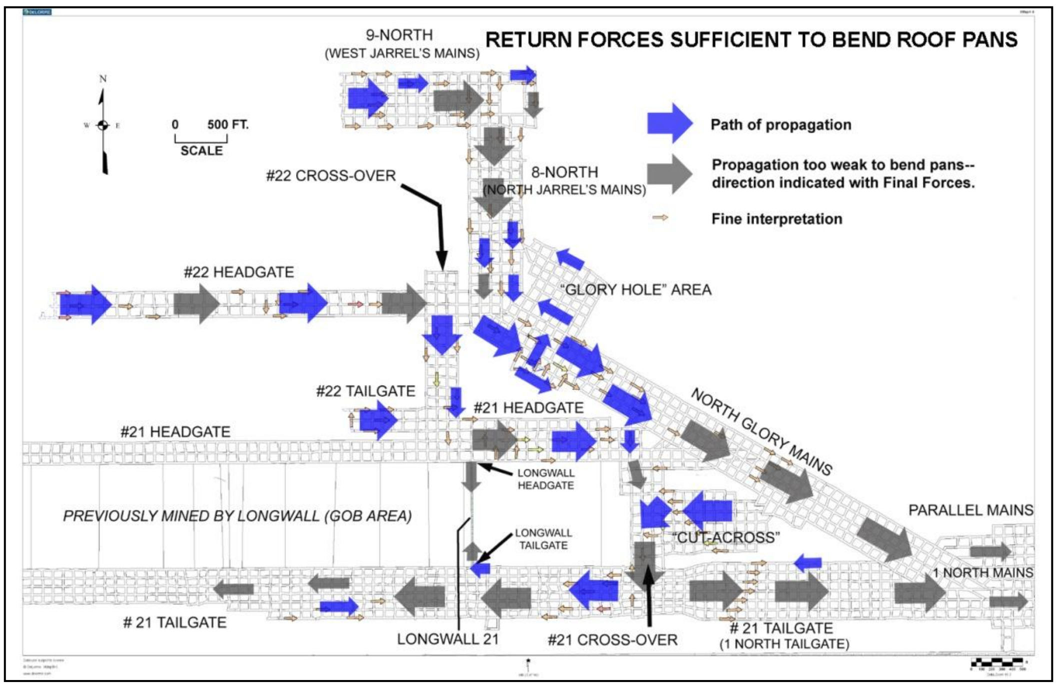


Figure 8: ***Return explosion forces of sufficient strength to bend roof pans*** are indicated with BLUE ARROWS. Indicated with GRAY ARROWS are locations where the initial explosion forces subside to extinction.

A sense of the relative strength of these secondary forces comes from the bending of roof pans. A summary of the subsequent bending of roof pans appears in **Figure 8**. The blue arrows show where explosion return forces were strong enough to bend roof pans. The gray arrows indicate

[27] Internal ventilation controls were destroyed

areas where return forces are too weak to bend roof pans, but their presence is known due to the Final Forces indicators observed and documented (see **Appendix 7.9-3**).

5 The Rescue and Recovery

5 The Rescue and Recovery

5.1 Chronology of Events

April 5, 2010

At approximately 3:02 p.m., an explosion occurred at the UBB mine located at Montcoal (Raleigh County), West Virginia. Within minutes members of the Massey Energy mine rescue teams were notified.

Shortly after the explosion, 10 employees from UBB entered the mine. One group of six men, Patrick Hilbert, Chris Blanchard, Jason Whitehead, Jack Roles, Everett Hager and Wayne Persinger, entered from the Ellis Portal on a battery driven mantrip on rail.[1] The other group consisting of four men, Rick Foster, Gary May, James Walker and Berman Cornett, entered the mine from the North Portal.[2]

Timothy Blake, one of the two survivors riding on the #22 Tailgate section mantrip that was in the explosion area, began exiting the mine on foot.[3] [4] He traveled approximately 20 crosscuts outby the stopping point of the mantrip when he saw lights of a mantrip coming in the mine. This was the mantrip that had entered from the Ellis Portal. Upon reaching Mr. Blake, the

[1] Patrick Hilbert interview July 10, 2010, page 57
[2] James Walker interview August 17, 2010, page 60
[3] Timothy Blake interview September 30, 2010, page 44
[4] The distance from crosscut 66 to Ellis Portal is 11,600 feet

mantrip stopped. One employee, Patrick Hilbert, remained with the survivor and the mantrip. The others proceeded on foot inby near crosscut 67 where they located the other eight miners. After finding the eight miners, Mr. Roles ran back to the mantrip where Mr. Blake and Mr. Hilbert were located and stated that the mantrip at their location was needed inby. Mr. Hilbert then preceded inby with the mantrip and Mr. Roles remained with Mr. Blake. When Mr. Hilbert reached the area where the original mantrip was located, the eight miners were then loaded on the two mantrips and driven to the surface. Chris Blanchard and Jason Whitehead continued to advance into the mine. After traveling toward the surface a short distance, those exiting the mine were intercepted by men who had entered from the North Portal. They boarded the mantrips with the victims and all three mantrips traveled to the Ellis Portal. These mantrips arrived at the Ellis Portal at approximately 4:45 p.m.[5]

A short time after the nine miners who were on the mantrip near crosscut 67 were brought to the surface, a three-man mine rescue team from the Massey Southern West Virginia team entered the mine from the Ellis Portal. Two of the team members were on foot traveling in front of the battery powered mantrip checking the atmosphere with a handheld detector and repairing the telephone line in order to have communications to the command center. The three team members traveled to North Mains, crosscut 78, where rail travel was no longer possible due to destruction and obstacles on the track. All three then started exploration on foot. While traveling alongside of the conveyor belt, the team encountered a break in the fresh water supply line. They retreated back to crosscut 42 to turn the water off. A second three-man mine rescue team from the Massey Southern West Virginia team entered the mine at 6 p.m. from the Ellis Portal and traveled by a battery powered rail mantrip to crosscut 78, where they met with the first three-man team.[6]

Both Massey Southern West Virginia teams left crosscut 78 and traveled a short distance in the North Glory Mains toward the longwall mother drive. They saw Mr. Whitehead and Mr. Blanchard walking toward them in the track entry of the North Glory Mains.[7]

---

[5] Whitesville Vol. Fire Department timeline
[6] Massey management command center notes, page 9
[7] Shane McPherson interview March 9, 2011, page 29

The WVOMHS&T Mine Rescue Teams were notified of the event after completing an afternoon of training at the Southern West Virginia Community and Technical College at Logan, West Virginia. The teams were deployed and arrived at the Ellis Portal at approximately 6:05 p.m. After a brief session with mine management, the teams were sent to the Upper Big Branch North Portal.

At approximately 7:42 p.m., two Massey Energy teams, Knox Creek and East Kentucky, entered the mine at the North Portal. Two WVOMHS&T State Inspectors, Danny Cook and Greg Norman, members of the WVOMHS&T Mine Emergency Team, accompanied by Scott Kingery and Jason Campbell, members of the Massey Southern West Virginia mine rescue team, also traveled with this group. Three MSHA Inspectors, Gerald Cook and Mike Hicks, who are members of the MSHA Mine Emergency Unit, and Fred Wills, who was not an apparatus wearer at the time, also traveled with this group by rail to crosscut 78. From that point they traveled on foot to the next fresh air base, which was established at crosscut 84.

Members of the Massey Southern West Virginia and East Kentucky teams began exploring the track and conveyor belt entries inby towards the #21 Longwall section. Six miners were located during these initial explorations. Victim #1[8] was located between the track and belt entry at the mother drive starter box.[9] Victims #2,[10] #3,[11] #4,[12] and #5[13] were in the track entry and Victim #6[14] was located at the longwall stage loader.[15]

Two members of the Massey Southern West Virginia team and Gerald Cook arrived at the longwall stage loader. The two Massey team members began to explore across the longwall

[8] Later positive identified as Michael Elswick
[9] Shane McPherson interview March 9, 2011, page 31
[10] Later positive identified as Adam Morgan
[11] Later positive identified as Cory Davis
[12] Later positive identified as Joshua Napper
[13] Later positive identified as Charles "Timmy" Davis
[14] Later positive identified as Rex Mullins
[15] Shane McPherson interview March 9, 2011, page 33

face. Mr. Cook remained near the headgate of the longwall to relay communications from the two Massey team members to the fresh air base.

As they started across the face, their detector was reading 20.8% oxygen, zero methane and 20 parts per million of carbon monoxide. Approximately halfway across the face, the carbon monoxide went from 20 to 40 parts per million, and somewhere between shield 120 and 125 the detector showed 60 parts per million of carbon monoxide and 2.0% methane.[16] Further travel down the longwall face was prohibited due to lack of communications. During the exploration, six deceased miners (Victims #7,[17] #8,[18] #9,[19] #10,[20] #11[21] and #12[22]) were located on the longwall face.[23]

At approximately 8:36 p.m., the WVOMHS&T South Team, with Eugene White as captain, was instructed to enter and explore the area known as the cross-over or longwall pull-off area. The WVOMHS&T North Team, with Barry Fletcher as captain, remained on standby at the fresh air base for the West Virginia South Team. Since the West Virginia South Team had never been in the area prior to the explosion, Chris Blanchard, a member of the UBB management team who had been located at the crosscut 78 fresh air base, accompanied them. There were foot prints in this area that were later to be determined as the footprints of Mr. Blanchard and Mr. Whitehead, who had been in the area after the explosion. The teams encountered damage to the ventilation controls and heavy soot in this area. The team members had apparatuses with them but, due to the air quality, had not gone under oxygen. The temperature of the atmosphere was hot. Team members exploring in this area of the mine noted that their eyes were burning.[24] The team returned to the fresh air base at 11:42 p.m.

[16] Shane McPherson interview March 9, 2011, page 34
[17] Later positive identified as Richard Lane
[18] Later positive identified as Grover Skeens
[19] Later positive identified as Joel Price
[20] Later positive identified as Gary Quarles
[21] Later positive identified as Christopher Bell Sr.
[22] Later positive identified as Dillard Persinger
[23] Shane McPherson interview March 9, 2011, page 34
[24] Eugene White interview May 20,2010, page 28

At 9:45 p.m., two additional mine rescue teams were deployed from the staging area. The teams were the WVOMHS&T Welch Team, with Bill Tucker as captain, and the Beckley ICG Team. The teams traveled to crosscut 78 then proceeded on foot to the next fresh air base at 11:42 p.m. At about crosscut 86 on 6 North Belt they discovered a small hot spot that was quickly extinguished.

The Knox Creek team was instructed to explore up to the Glory Hole. They made it to the Glory Hole belt head area, which was near crosscut 127-128. They were under oxygen. Their detectors indicated that they had from 80 to 100 parts per million of carbon monoxide; at one time, 1,500 to 1,600 parts per million of carbon monoxide was detected around the Glory Hole belt head. Their apparatuses began to get low on oxygen. They were relieved out by East Kentucky #2 team and a couple of team members from the Massey Energy Southern West Virginia team along with State mine rescue team members and MSHA Mine Emergency Unit team members. The Knox Creek team was then instructed to explore back to crosscut 78 by way of the # 5 entry in search of anything or anyone.[25]

At 10:55 p.m., the Massey Energy East Kentucky #2 team and the WVOMHS&T North team began advancing from the fresh air base towards the #22 Headgate continuous miner section. At 11:11 p.m., the Massey Energy Southern West Virginia team had located the emergency shelter on the longwall. The shelter had not been deployed. At 11:20 p.m., the East Kentucky #2 team went under oxygen. At 11:27 p.m., the team called its location as being three breaks inby the continuous miner panel of #22 Headgate. They had 14.7% oxygen, 8,676 parts per million of carbon monoxide and 3.3% methane. At 11:37 p.m., the team had advanced one crosscut and called out heavy smoke, 7.4% oxygen, 5,388 parts per million of carbon monoxide, 0% methane, and the temperature of 80 degrees F. At 11:55 p.m., the East Kentucky #2 team found a mantrip on the track near crosscut 19 on the #22 Headgate section between survey station 24394 and 24401. Six victims (#14,[26] #15,[27] #16,[28] #17,[29] #18[30] and #19[31]) were on the mantrip. All were deceased. No SCSRs had been deployed.

[25] Scott Kingery interview 1/5/2011, pages 22 & 24
[26] Later positive identified as Ricky Workman
[27] Later positive identified as Howard "Boone" Payne Jr.

April 6, 2010

At 12:16 a.m., the East Kentucky #2 team reported from just inby the mantrip that they had located on the track an air quality reading of 3.2% oxygen, 9,999 parts per million of carbon monoxide and over-range on methane. At 12:37 a.m., the East Kentucky team reported heavy smoke, that they could not determine air flow direction and that all detectors showed over-range on methane and carbon monoxide, with 3.2% oxygen. At 12:45 a.m., all rescue teams were ordered by the command center to retreat out of the mine due to the explosive mixture of gas and evidence of a fire.[32]

April 7, 2010

There were no rescue or recovery activities this day due to the conditions found on April 6, 2010, when the teams were exploring. Boreholes were being drilled from the surface into the mine. The boreholes were to be used to collect atmospheric samples, and at a later date, to inject nitrogen into the mine.

April 8, 2010

At 1:45 a.m., samples collected from the boreholes permitted reentry into the mine for rescue operations.

At 4:55 a.m. four mine rescue teams entered the mine. A member of the WVOMHS&T Mine Emergency Team and a member of the MSHA Mine Emergency Unit traveled with each team from this point forward.

All teams going underground continued to take supplies such as first-aid supplies, EMT kits, AEDs, CARE-vents, basket stretchers, ventilation curtain, pogo-sticks, telephones, telephone line and victim recovery apparatus that would be needed in the rescue and recovery.

---

[28] Later positive identified as Ronald Maynor
[29] Later positive identified as James "Eddie" Mooney
[30] Later positive identified as Kenneth Chapman
[31] Later positive identified as William Griffith
[32] State command center notes 4/6/2010, pages 13 & 14

As the teams traveled in the mine from the North Portal, one team member traveled on foot ahead of the mantrips to check the air quality and look for hazards. The teams stopped at crosscut 42 of the Old North Mains to check the seal (set 14). The seal was intact, water in the trap was empty and air was out gassing. Air quality was 16.6% oxygen, 0.25% methane and no carbon monoxide. The team continued to advance toward the longwall mule train with the mission of establishing a fresh air base.[33]

At 9:29 a.m., the command center received analysis of air samples taken from a borehole on the surface indicating that there was an explosive mixture of gas in the mine. The mine rescue teams were ordered to evacuate to the surface immediately.[34] At 10:55 a.m., all rescue teams had returned to the surface.

April 9, 2010

At 12:42 a.m., two mine rescue teams reentered the mine traveling by rail on a battery powered mantrip to crosscut 78. After reaching crosscut 78 they traveled on foot to the fresh air base that had been established near the longwall mule train. The teams advanced inby and established a fresh air base at Headgate 1 North (a.k.a. #21 Headgate), #2 entry between crosscuts 26 and 27. One team remained at this location as a back-up team, while the other team explored under oxygen. The team explored in the area at the mouth of #22 Tailgate where they encountered light smoke. When the emergency shelter was located it was observed that the shelter had not been deployed or damaged. The team retreated back to the fresh air base.

At 4:44 a.m., the command center received analysis of air samples taken from a borehole on the surface indicating that there was evidence of a fire and that a methane air mixture was close to explosive range. Teams were ordered to retreat to the surface immediately.[35] At 6:11 a.m., all rescue teams had returned to the surface.

[33] Massey management command center notes 4/8/2010, page 5
[34] State command center notes 4/8/2010, page 3
[35] MSHA command center notes 4/9/2010, page 3

At 4:15 p.m., two teams reentered the mine traveling by rail on a battery powered mantrip to crosscut 78. At this point, they traveled on foot to the fresh air base that had been established in the Headgate 1 North #2 entry between crosscut 26 and 27. From there they traveled the #22 cross-over entries toward the #22 Headgate section. One team remained near the mouth of #22 Headgate section while the other team explored inby towards the section. Team members were placed along the travel route to maintain radio communications back to the fresh air base.

At 7:28 p.m., two teams, along with members of Task Force 1, reentered the mine on a battery powered rail mantrip traveling to crosscut 78. At this point, they traveled on foot to the fresh air base that had been established in the Headgate 1 North #2 entry between crosscut 26 and 27. One team remained at the fresh air base while the other team began to advance across the longwall face. As the team advanced across the longwall face, team members were placed at locations to permit radio communications back to the fresh air base.

At 8:10 p.m., while exploring the #22 Headgate section, a rescue team under apparatus discovered Victim #20[36] near survey station 24446. At 8:16 p.m., near survey station 24447, Victim #21[37] was found. At 8:20 p.m. Victim #22[38] was found near survey station 24458. All were located in the track entry.[39]

At 11:20 p.m., while exploring across the longwall face, a rescue team member discovered Victim #13[40] in the #3 gate shield.

At this time, all missing miners had been found and preparation was made for recovery.[41]

[36] Later positive identified as Joe Marcum
[37] Later positive identified as Gregory Brock
[38] Later positive identified as Edward "Dean" Jones
[39] State command center notes 4/9/2010, page 5
[40] Later positive identified as Nicolas McCroskey
[41] See **Appendix 5.1-1**, list of victims (Victim Informational DataSheet).

April 10, 2010

At 12:15 p.m., there were four rescue teams along with Task Force 1 underground. Three teams proceeded to the surface while one team and Task Force 1 began preparing the victims along the longwall track and belt for transportation. After completing this task, they proceeded out of the mine, arriving on the surface at 2:37 a.m.

At 3:40 a.m., a battery powered rail locomotive with a rubber tired four wheeler secured on a lowboy entered the mine traveling to crosscut 78, where it was unloaded. The locomotive and lowboy then returned to the surface.

At 3:55 a.m., three mine rescue teams entered the mine and advanced to crosscut 78. The teams then traveled to the area of the longwall track that had been designated as a staging area, and continued to prepare the victims for transport.

At 6:46 a.m., another rubber tired four wheeled battery vehicle was hauled underground and unloaded at crosscut 78. Six of the deceased miners that had been brought to the staging area were then transported to crosscut 78 by a rubber tired trailer pulled by the battery powered four wheeler. These victims were then transported to the surface.

At 9:45 a.m., the mantrips with Victims #1-6 left crosscut 78 arriving on the surface at 10:15 a.m.[42]

At 1:59 a.m., a mantrip with Victims #8, #11 and #13 arrived on the surface, along with the recovery teams.[43]

At 3:58 p.m., mine rescue teams entered the mine and traveled to the longwall where they started bringing victims off the longwall face to the staging area near crosscut 78.

[42] MSHA command center notes 4/10/2010, page 9
[43] MSHA command center notes 4/10/2010, page 10

At 9:15 p.m., a mine rescue team left crosscut 78 for the surface. Two deceased miners were being transported at this time.

At 10:11 p.m., Victims #10 and #13 reached the surface.

At 10:30 p.m., two mine rescue teams left the surface traveling to crosscut 78. From crosscut 78 they traveled on foot to the 7 North Area.

At 11:30 p.m., two mine rescue teams left the surface traveling to crosscut 78. From crosscut 78 they traveled on foot to the staging area on the longwall track.

April 11, 2010

At 12:12 a.m., two rubber tired four wheeled battery vehicles with trailers on lowboys pulled by three locomotives entered the mine and traveled to crosscut 78.

At 12:35 a.m., two mine rescue teams proceeded to the 8 North/9 North Area.

At 1:30 a.m., the team exploring the 8 North Area went under oxygen. They called out atmosphere qualities of 20.8% oxygen, 36 parts per million of carbon monoxide and 0% methane. The team then called out atmosphere qualities at crosscut 149 with 19.8% oxygen, 2,151 parts per million of carbon monoxide and 1.3% methane. They continued to explore into the 9 North Area.

At 2:10 a.m., a rescue team at crosscut 78 retrieved the four-wheelers and trailers and traveled back to the fresh air base along the longwall track in preparation to start recovering the victims from this area.

At 2:24 a.m., the rescue team exploring the 9 North panel informs the command center that all ventilation controls are missing.

At 3:10 a.m., the team exploring the 9 North Area retreated back to the fresh air base.

At 3:30 a.m., a "mapping crew" consisting of State, MSHA and Massey personnel entered the mine. The mapping crew made a map of the areas where temporary ventilation controls were going to be installed to ventilate the mine to recover the victims in the #22 Headgate Area.

At 4 a.m., a mantrip with Victims #7 and #9 left crosscut 78 traveling to the surface.

At 4:58 a.m., a rescue team explored the #22 Tailgate panel while a back-up team remained at the longwall fresh air base. Two crosscuts into the panel, the team had atmosphere readings of 20.8% oxygen, 120 parts per million of carbon monoxide and 0.02% methane. Four crosscuts into the panel, the team had atmosphere readings of 20.4% oxygen, 225 parts per million of carbon monoxide and 0.04% methane.

At 5 a.m., a mantrip with Victims #7 and #9 arrived on the surface.

At 8:41 a.m., two mine rescue teams entered the mine. When they arrived at the fresh air base at crosscut 78 they began to carry supplies further into the mine.

At 11:20 a.m., the mapping crew returned to the surface.

At 2:24 p.m., all ventilation work at the mouth of Tailgate 1 North, the pull-off area and Headgate 1 North had been completed with curtains installed, but rolled up. This area was noted on a modification plan/map as areas A, B, C and D.

At 2:35 p.m., two mine rescue teams entered the mine.

At 3:07 p.m., nitrogen was being injected from the surface into #22 Headgate section.

At 5:01 p.m., motor crews were on the surface. A total of 35 mine rescue team members were underground.[44]

At 5:16 p.m., a team entered the mouth of #22 Headgate, while under oxygen, with a back-up team at the fresh air base at crosscut 129.

At 6:07 p.m., instructions were given by the command center to move the fresh air base from crosscut 78 to crosscut 129. It was determined that the walking travel time between the two fresh air bases was 45 minutes.[45]

At 10:03 p.m., all ventilation curtains that had been installed at the pull-off area and the Headgate 1 North Area (this area is noted as B – C – D on a modification plan/map) were dropped and secured.

At 10:30 p.m., ventilation curtains at the mouth of Tailgate 1 North and entries 3 through 7 (this area is noted as A on a modification plan/map) were dropped and secured. Teams in the area were instructed to check #1 and #2 entries to make sure that the curtains had been installed across the entries. At 11:38 p.m., all mine rescue team members were on the surface. No one remained underground.[46]

April 12, 2010

At 5:02 a.m., the command center made the decision to send in four mine rescue teams.

At 6:50 a.m., four mine rescue teams were sent underground.

At 9:15 a.m., two mine rescue teams were sent underground.

---

[44] State command center notes 4/11/2010, page 32
[45] State command center notes 4/11/2010, page 33
[46] State command center notes 4/11/2010, page 35

At 10:12 a.m., a rescue team was instructed to install checks across #4, #5, #6 entries at crosscut 129, directing the air up to the Glory Hole and then across the temporary seals at crosscut 140 in the 8 North Area.[47]

At 11:14 a.m., the rescue teams were instructed to start the re-ventilation process of #22 Headgate by installing curtains across the cut-through panel between #22 Headgate and #22 Tailgate.

At 11:19 a.m., three members of the WVOMHS&T team entered the mine accompanied by MSHA and Task Force 1. This group traveled by mantrip to crosscut 78 and then on foot to the fresh air base at crosscut 129 to remove the victims from the # 22 Headgate mantrip and prepare them for transportation to the surface.

At 12:12 p.m., atmosphere quality behind the 8 North temporary seals was taken at the end of a sampling tube that had been installed from the seal inby for 300 feet. The quality was 20.1% oxygen, 1,591 parts per million of carbon monoxide and 2.61% methane.

At 1:00 p.m., a new fresh air base was established at crosscut 135. At 2:01 p.m., the fresh air base was moved to survey station 24202 in #2 entry of #22 Headgate. Temporary ventilation controls were being installed between the #1 belt entry and the #2 track entry as the team advanced toward the face of #22 Headgate.

At 2:59 p.m., two mine rescue teams entered the mine.

At 3:52 p.m., the fresh air base requested permission to move to crosscut 7 of #22 Headgate. Permission was granted.

At 4:50 p.m., the team exploring #22 Headgate took an air quality measurement at crosscut 14. The quality was 17% oxygen, 175 parts per million of carbon monoxide and 2.0% methane.

[47] State command center notes 4/12/2010, page 38

At 5:36 p.m., a mine rescue team observed smoke at crosscut 116. There was 4 parts per million of carbon monoxide and 0% methane. The hot spot was smothered and two team members remained at the site.[48]

At 6:50 p.m., State and Federal team members walked along the curtain line to see that all controls were installed. Rescue team members were getting low on oxygen.

At 7:25 p.m., the recovery team arrived at the #22 Headgate mantrip.

At 8:18 p.m., the first victim was moved toward the fresh air base at crosscut 129.

From 8:29 p.m. until 8:42 p.m., 76 mine rescue team members, who included State and Federal mine rescue team members, entered the mine. Once this group of mine rescue personnel reached the fresh air base at crosscut 78 they were directed to spread out about every six crosscuts from that fresh air base inby to the last victim on #22 Headgate section, a distance of approximately 8,250 feet. Team members carried each victim from four to six crosscuts before passing them off to other team members. The walkway was often obstructed with debris and the route of travel was not often in a straight line. At least 140 mine rescue team members forming a human chain were used to remove the victims from the #22 Headgate section to crosscut 78 where they were placed on mantrips for transportation to the surface.

April 13, 2010

At 2:30 a.m., a mantrip with five victims arrived on the surface at the North Portal.[49] At 4 a.m., a mantrip with four victims arrived on the surface at the North Portal.[50]

At approximately 5:30 a.m., all mine rescue team members were on the surface. No one was underground. Recovery was complete.

[48] State command center notes 4/12/2010. Book 2, Page 8
[49] Whitesville Vol. Fire Department Timeline
[50] Whitesville Vol. Fire Department Timeline

Mine Rescue Teams that participated in the rescue and recovery of the Upper Big Branch Mine

Alpha Natural Resources

Brooks Run – North

Brooks Run – South

Rock Spring – Gold

Rock Spring – Blue

Kingston – White

Kingston – Red

Cobra

Black Mountain Resources

Kentucky – Blue

Kentucky – White

Cumberland Resources

Virginia – Maroon

Virginia – Black

Arch Coal

Mingo Logan – Mountain Laurel

Gold*

Patriot

Federal #2

Southern Appalachia

Magnum

ICG

Wolf Run – Blue

Wolf Run – White

Hazard – Flint Ridge Blue

Knott County – White

Beckley – Black

Beckley – Gold

Mountaineer Mine Rescue Assoc.

Mountaineer 1

Mountaineer 2

Southern Pocahontas

Apache

Cherokee

Consol Energy/Coal River Energy

Coal River – Red*

Coal River – Blue*

Massey Energy

Southern WV 1

Southern WV 2

East Kentucky

Knox Creek

MSHA

Beckley

Pittsburgh

West Virginia Office of Miners' Health, Safety & Training

Westover

Welch

Danville

Oak Hill

*Teams arrived at the mine on 4/5/2010 and were on standby but did not go underground.

5.2 List of Victims

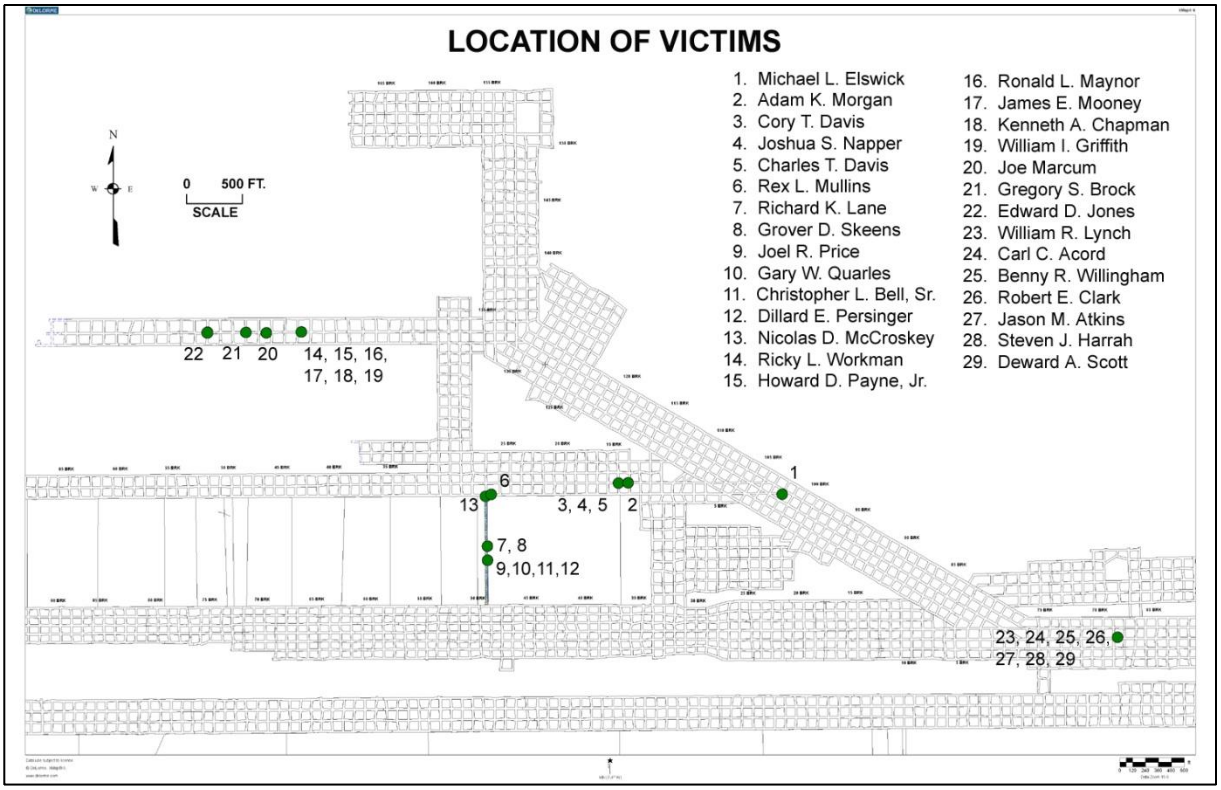


Figure 1. General locations of the deceased miners

Carl C. Acord, 52, roof bolter operator, #22 Tailgate section

Jason M. Atkins, 25, roof bolter operator, #22 Tailgate section

Christopher L. Bell, Sr., 33, utility person, #21 Longwall section

Gregory S. Brock, 47, electrician, #22 Headgate section

Kenneth A. Chapman, 53, roof bolter operator, #22 Headgate section

Robert E. Clark, 41, continuous miner operator, #22 Tailgate section

Charles T. Davis, 51, foreman, #21 Longwall section

Cory T. Davis, 20, apprentice, #21 Longwall section

Michael L. Elswick, 56, underground beltman fireboss

William I. Griffith, 54, continuous miner operator, #22 Headgate section

Steven J. Harrah, 40, production foreman, #22 Tailgate section

Edward D. Jones, 50, production foreman, #22 Headgate section

Richard K. Lane, 45, production foreman, #21 Longwall section

William R. Lynch, 59, shuttle car operator, #22 Tailgate section

Joe Marcum, 57, continuous miner operator, #22 Headgate section

Ronald L. Maynor, 31, scoop operator, #22 Headgate section

Nicolas D. McCroskey, 26, electrician, #21 Longwall section

James E. Mooney, 51, shuttle car operator, #22 Headgate section

Adam K. Morgan, 21, apprentice, #21 Longwall section

Rex L. Mullins, 50, headgate operator, #21 Longwall section

Joshua S. Napper, 25, apprentice, #21 Longwall section

Howard D. Payne, Jr., 53, roof bolter operator, #22 Headgate section

Dillard E. Persinger, 32, shield operator, #21 Longwall section

Joel R. Price, 55, shearer operator, #21 Longwall section

Gary W. Quarles, 33, shearer operator, #21 Longwall section

Deward A. Scott, 58, shuttle car operator, #22 Tailgate section

Grover D. Skeens, 57, maintenance foreman, #21 Longwall section

Benny R. Willingham, 61, roof bolter operator, #22 Tailgate section

Ricky L. Workman, 50, shuttle car operator, #22 Headgate section

5.3 Monitoring Conditions in the Mine

Part of the underground response to mine emergencies from fires or explosions involves drilling one or more boreholes into the mine to monitor its atmosphere to determine if the mine is burning and if there is a risk of explosion. Secondary explosions after a mine explosion are of great concern.

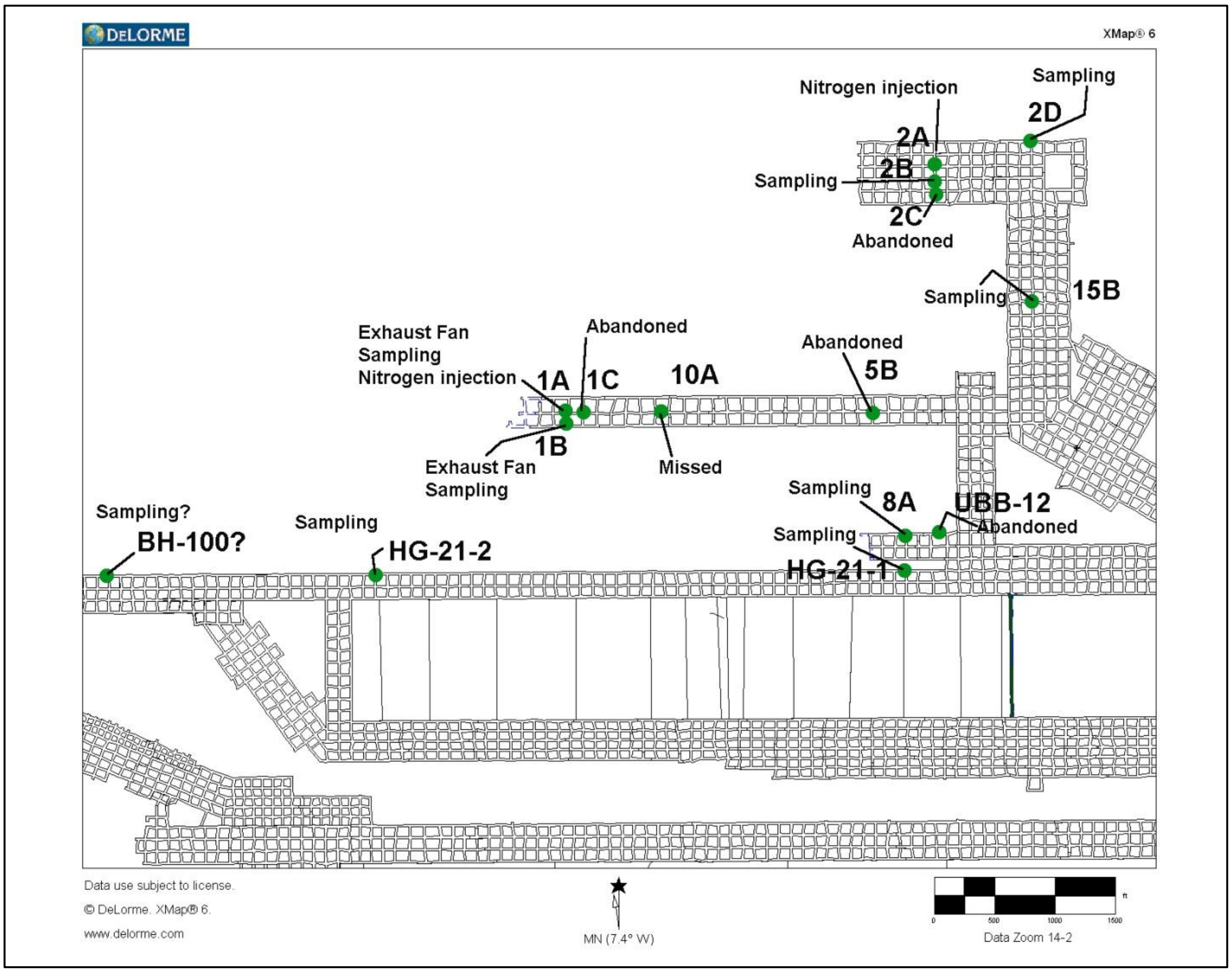


Figure 2: Location of some of the boreholes

In the late hours after the explosion on April 5, 2010 preparations were made to begin drilling boreholes of approximately 8 inches in diameter, and also to establish a seismic monitoring station to listen for signaling from possible survivors. A mobile response truck carrying seismic equipment was set up on the surface above #22 Headgate and began monitoring on April 6, 2010. The #22 Headgate was inaccessible for underground exploration by rescue teams due to the buildup of noxious and explosive gases after the explosion destroyed the ventilation system. The seismic monitoring detected no activity.

The first successful borehole to penetrate the mine was drilled near the end of #22 Headgate. This hole successfully penetrated to the Eagle seam at a depth of approximately 1,093 feet at 4:10 a.m. on April 7, 2010. Mine voids were encountered at approximately 75 feet and 380 feet depths. Steel casing was installed to a depth of 400 feet. This was remarkable given depth of drilling, the speed of drilling while keeping the hole on target, and successfully drilling through the abandoned mine works of the overlying Winifrede seam for which there were no available detailed mine maps to determine where a solid coal pillar might exist.

Additional boreholes were drilled for monitoring, and some of these were fitted with auxiliary fans to help ventilate the affected areas. Others were used for injection points to inject nitrogen in order to displace combustion gases with inert gas where ventilation could not reach.

No personnel were permitted inside UBB between April 13, 2010 and June 2, 2010, due to these gases and the potential of active "hot spots" to reignite combustible mixtures. Hot spots of glowing embers were still found in a few locations when the mine was reentered in June 2010.

6 Administrative Inquiry

6.1 Regulatory Compliance

6.2 Mine Examinations

6.3 Certifications

6.4 Rock Dusting

6.5 Refuge Stations

6.6 Inspections Prior to the Explosion

6 Administrative Inquiry

6.1 Regulatory Compliance

Violations Issued Post-explosion by the WVOMHS&T

Since April 5, 2010, WVOMHS&T personnel have conducted both an investigation of the UBB explosion and continued required inspections at the mine. During the course of the investigation, the WVOMHS&T issued 253 violations which include 1 Order and 2 Failure to Abate Orders. Twenty- two of the violations were special assessed. In addition, 3 Individual Personal Assessments (IPA) and 1 Withdrawal of Certification (WC) was issued. Violations by category: 15 Ventilation; 11 Equipment; 14 Foreman; 12 Fireboss; 1 Haulage; 6 Transportation; 2 Coal Dust & Rock Dust; 21 Roof, Face & Ribs; 1 Fire Protection; 147 Electricity; 1 Safeguards for Mechanical Equipment; 4 Surface Structures & Practices; 1 Underground Workings; 9 Miscellaneous Safety Provisions; and 8 Other Categories.

Furthermore, after a post-explosion audit of the company's accident history prior to April 5, 2010, 28 additional violations were issued for failing to notify the WVOMHS&T of reportable accidents.

6.2 Mine Examinations

Mine Examinations and Improper Record Keeping

The mining operations of UBB are mandated to follow the mining laws of the state of West Virginia. These requirements are available in written form, and are required to be provided to every miner upon his or her employment at any mine within the state. The operator is to see that all employees are properly trained in the areas of their responsibilities and necessary items are provided them to carry out these responsibilities in a safe manner.

The law clearly places the primary responsibility for the safety of all employees on the mine operator, in this case, Performance Coal Company. West Virginia law requires a minimum standard be met by the operator, and only the operator can assure that these standards are complied with on a consistent basis.

One of the concerns that arose as the investigation proceeded was the lack of specific knowledge some of the supervisors related under oath regarding certain plans or specifics of plans that had been put in place at the mine. This was most evident when supervisors were questioned about the current #21 Longwall Section Approved Methane and Dust Control Plan and the firebosses' lack of specific knowledge regarding the requirements in this approved plan.

During the investigation, testimony varied as to how workers performed their fireboss and supervisory duties. It is impossible to draw solid conclusions other than that additional training should have been given to assist firebosses and supervisors in their understanding of the plans and the importance of following all approved plans relating to their specific areas of responsibility.

Those who were responsible for the firebossing of the mine communicated by testimony that they felt in most instances they were given adequate time to conduct their examinations. Occasionally they would be rushed due to the need to correct problems or to take care of concerns they had found during the course of their examinations. In some instances they felt their other duties, including filling trickle dusters or shoveling and rock dusting belt heads, rushed them in their firebossing efforts and sometimes prohibited them from completing their examinations before the end of their shifts. All indications were that examiners were provided with the essential equipment necessary to perform their jobs.

Obvious problems observed while reviewing the pre-shift and on-shift books was the lack of clarity and full disclosure of findings, failure to accurately record corrections made and incomplete entries on work done to clear hazards or violations noted in the examination books. Extreme brevity of information was used on a daily basis in these record books in areas that additional information could have been helpful to those on the oncoming shifts. Also, there were many instances where there was no record of safety meetings or contacts required by law with workers prior to them engaging in certain activities, i.e. roof control plan review prior to securing the mine roof. There were omissions in the record books from one shift to the next where it was clear that work had been conducted, but little or no information was given to explain how conditions changed. Accurate record keeping in the fireboss books is one of the most reliable forms of communicating to mine management and the oncoming shift the hazards in the mine at the time examinations are performed. If used properly, these records are designed to be a useful tool to assure that hazards and conditions found are corrected to provide a safe workplace. State law requires the mine foreman of a mine to countersign the fireboss books, and to make necessary steps to assure all hazards and violations are corrected or promptly addressed. It is our belief that record books that were countersigned regularly by those acting as “Mine Foremen” at Performance Coal Company often contained information that should have been dealt with in a more compliant and timely manner and with more regularity. It was obvious from our review of numerous pre-shift and on-shift books that there was much to be desired in regards to the mine foreman’s involvement in seeing that these books were kept and maintained in a usable fashion. This was most evident in the records of the belt firebosses who regularly recorded the need for additional rock dust along the mine conveyor belts in the explosion areas inby the switch for North Glory Mains.[1]

As mentioned earlier, these record books, when filled out completely and accurately, should reflect not only the conditions found, but also the steps taken in each instance to correct the noted hazards. Failure to reflect the actual conditions found and the steps taken to correct each hazard and violation noted in the record books increase the risk of unnecessary exposure to unsafe conditions and affect the correction of these conditions in a timely manner. It is our belief that the lack of diligence in correcting the constant, reoccurring need for additional rock dust along the belt conveyors in the areas previously referred to contributed to the propagation of the explosion that occurred on April 5, 2010.

6.3 Certifications

Performance Coal Company provided an employee master list with all active and contract employees that were assigned to UBB at the time of the explosion. All employee names that were provided were checked through our safety information system (SIS) and found to have appropriate certifications.

6.4 Rock Dusting

The WVOMHS&T has concluded that inadequate rock dusting practices and standards contributed to the propagation of the coal dust explosion that occurred on April 5, 2010.

[1] Examples of re-occurring conditions that existed in the conveyor belt pre-shift record books. (see **Appendix 6.2-1**).

One of the most disturbing facts relating to rock dusting issues at UBB was that according to testimony the #21 Tailgate side of the longwall was never rock dusted after the longwall started production in September 2009. The only rock dust applied in this area of the mine was when the section was advancing on development. It is unclear why these active return airways were neglected as part of the regular rock dusting regimen.

The outside southern entries of the tailgate were return entries for the #22 Headgate and #22 Tailgate sections and were separated by a stopping line from adjacent entries. The entries nearest the longwall, or the most northern entries, were the return for the active longwall as it retreated. This return pulled toward the Bandytown fan. The #21 Longwall Section did not utilize a trickle duster or other means of mechanical dusting on the tailgate side of the longwall while mining the 1,000 foot wide longwall face.

Approximately 5,400 feet of the 6,700 foot-long panel had been mined without any record of rock dust being applied to the tailgate side entries. There was no testimony or records found to dispute these findings. Witness statements indicate that the bulk duster could not travel the tailgate side of the longwall due to low roof clearance in the track entry.

Another disturbing fact is that even though trickle rock dusters were placed near the Mother Drive, the #22 Headgate Drive and the 6 North Glory Mains Belt Drive, firebosses who traveled these areas on a daily basis routinely recorded in their examination books that these areas still needed additional rock dust (see **Figure 1**). These examination book entries were frequently carried over for days and even weeks at a time.

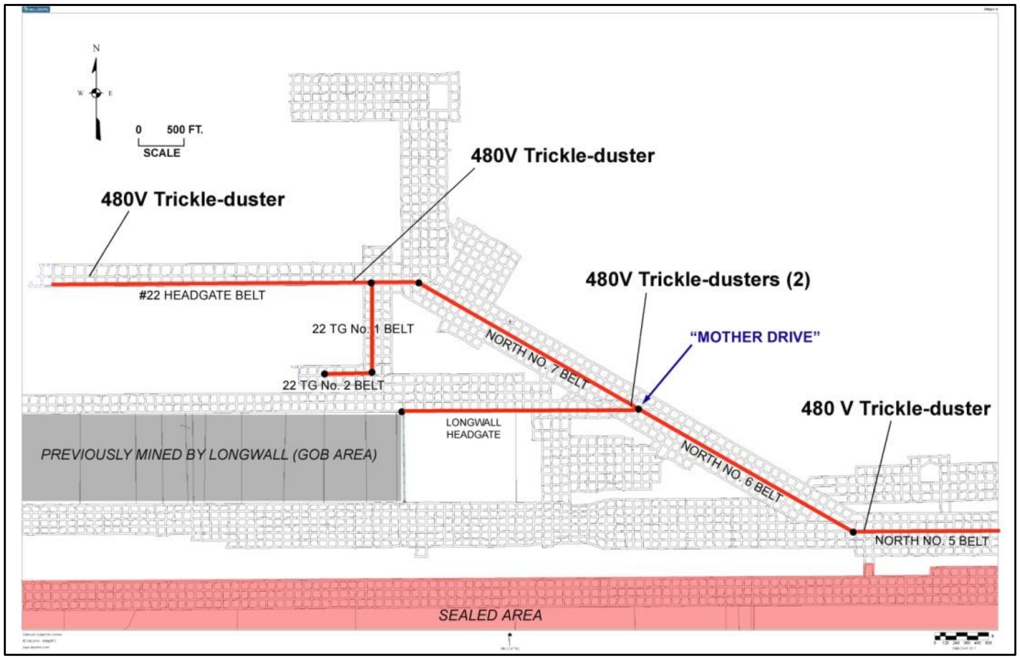


Figure 1. Location of "trickle dusters" found in the explosion area during the investigation.

Also, testimony, the notes provided by rock dusting crews and maintenance records indicate that the "orange" A. L. Lee track mounted bulk or double pod rock duster used in months prior to the explosion was quite frequently unavailable due to ongoing mechanical issues. Another track mounted bulk duster (white) was parked in the mine yard but had not been used in sometime due to major mechanical problems. The orange track mounted bulk rock duster was not a dependable or reliable means to apply rock dust sufficiently on a daily basis to a mine of this size. Testimony and written records indicate that when the bulk duster was down, rock dusting would occasionally be done by hand. From all information available, rock dusting procedures were not systematically organized, and equipment needed to keep a regular rock dusting program in place was not readily available. Mine management appears to have done little to insure that rock dusting equipment was maintained in a dependable fashion.

In addition to the concerns with the belt entries and the tailgate side of the longwall as described above, other entries throughout the mine in outby areas that were not near the track entries were not rock dusted on a regular and consistent basis.

6.5 Refuge Stations

Strata Emergency Shelter/Refuge Chamber Deployment Test March 31, 2011

A test of the required emergency shelters was conducted at UBB on March 31, 2011. Representatives from Strata Safety Products were at the mine site to perform the test. They were accompanied by representatives from Performance Coal Company and members of investigative teams from the WVOMHS&T, MSHA, UMWA and the Governor's Independent Investigation Panel. A deployment test was conducted underground on the three Strata shelters located in the explosion area.

Figure 2. Strata Emergency Shelter/Refuge Chamber; #22 Headgate, approximately 20 feet north of survey station 24548 in the #2 to #3 crosscut approximately 1,060 feet outby the furthest advanced #1 face.

The first of the three shelters deployed was located on the #21 Longwall Section, approximately 20-feet north of survey station 22738 in the #2 to #3 crosscut approximately 240 feet from the longwall working face. Thick soot and dust was impacted on the south, or deployment door, end of the shelter. A visual examination of the outer framework of the model #M2624-3.5 shelter showed there was no obvious damage to the shelter other than one of the deployment door latch seals was partially pulled out. It also appeared that the southern end of the shelter was moved slightly in an east to west direction by the force of the explosion. The control panel doors were opened and the gauges and pressures were checked and found to be in satisfactory condition with adequate pressures indicated. The pins and bolts were removed, deployment doors were opened and the inflatable tent was pulled out approximately four feet by hand. The “rip cord” was pulled and air cylinders activated to inflate the tent. Although there were some small traces of soot inside the deployment door lying on the bottom of the shelter, everything was fully operational and the shelter inflated as designed. Some members of the teams entered the tent and assisted in getting the necessary supplies from the storage area of the solid structure to activate the CO2 scrubber system. The system was activated and functioned properly. The other items in the shelter storage area were in good condition and usable at the time of the test.

The second shelter, model #M2624-3.5, was located on the #22 Headgate Section, approximately 20-feet north of survey station 24548 in the #2 to #3 crosscut approximately 1,060 feet outby the furthest advanced #1 face. This shelter also was moved slightly by the force of the explosion in an east to west direction on the south end. This shelter was examined and deployed in the same fashion as the longwall shelter with the same satisfactory results. There was no physical damage to the shelter. The gauges and air cylinders were in working condition with pressures on tanks at appropriate levels upon inspection. The only indication that the shelter had been through an explosion was that small traces of heat had entered the deployment door at three of the four corners of the door.

The third shelter, model #M2624-3.5, was located on the #22 Tailgate Section, 25-feet east of survey station 24469. The shelter is in line with the #3 entry of the #22 Tailgate Section, approximately 850 feet outby the #3 Face. When deployed, this shelter was in working condition. Some small traces of dust were located inside the deployment door and inside the control panel, and some visual signs of heat had entered through the emergency door latch. In addition, one of the hinge welds for the protective bar at the deployment door was broken. None of these conditions had any impact on the deployment of the shelter.

It is encouraging that the units performed as designed after being through an event the magnitude of the explosion at UBB. It is also worth noting that the three units deployed had not been serviced or altered for nearly a year since the explosion yet was capable of maintaining their usability and durability over an extended period of time without any maintenance or upkeep.

Mine Lifeline LLC 96 Hour Breathable Air Solutions—Outby Refuge Alternatives

There were two Mine Lifeline LLC 96 Hour Outby Refuge Alternatives in the explosion area. One was located in the #21 Longwall Tailgate entries at crosscut 9, directly north of survey station 22145 between #3 and #4 entries.

The second outby refuge alternative was located in the North Glory Mains at crosscut 89 between #3 and #4 entries, directly northwest of survey station 19698. The forces and pressures of the explosion destroyed the concrete block partitions and damaged the components of both of the erected outby refuge alternatives. The solid block walls erected as enclosure walls for the workers' refuge area were almost completely displaced. The bottom row of blocks and a small portion of the north end wall on the Outby Tailgate Refuge Alternative remained in place. Metal compartments with airlock doors integrated into the pre-built block room, where the workers would be housed during a disaster, were dislodged. Some of the access doors provided to the compressed air cylinders were damaged and open. Numerous compressed air cylinders enclosed in the shelter area were moved by the explosion forces but were intact. Although these shelters are not required by West Virginia Mining Law they were put in place as an additional alternative for workers in the event of a mine emergency.

Figure 3. This Mine Lifeline LLC Outby Refuge Alternative was located in the North Glory Mains at crosscut 89 between #3 and #4 entries, directly northwest of survey station 19698**.**

6.6 Inspections Prior to the Explosion

Summary of Violations for UBB (2009 and First Quarter 2010)

The WVOMHS&T issued 287 violations and five orders from January 6, 2009 to December 30, 2009. During this period, there were 137 inspection days and 17 different inspections. These inspections consisted of four regular inspections, three investigation inspections, one roof control inspection, eight check inspections and one electrical inspection. The electrical inspection for 2009 totaled 21 inspection days but was not completed.

Violations by Category: 74 Electricity; 34 Roof, Face & Ribs; 26 Transportation; 21 General Safety Provisions; 20 Other Categories; 17 Ventilation; 18 Foreman; 15 Equipment; 7 Safeguards for Mechanical Equipment; 6 Mine Maps; and 5 Fireboss.

In the first quarter of 2010, 39 inspection days were recorded and 44 violations were issued. This included one regular inspection and seven check inspections from January 6, 2010 to March 31, 2010.

Violations by Category: 11 Electricity; 7 Coal Dust & Rock Dust; 6 Roof, Face & Ribs; 4 Transportation; 3 Foreman; 3 Miscellaneous Safety Provisions; 3 General Safety Provisions; 2 Other Categories; 2 Equipment; and 1 Surface Structures and Practices.

Due to the size of this mine and its extensive outby travelways, two district mine inspectors were assigned to UBB as of April 1, 2010, which began the second quarter of 2010.

7 Investigation into The Cause of the Explosion

7 Investigation into The Cause of the Explosion

7.1 Structure of the Joint Investigation

On Tuesday, April 20, 2010, the initial investigative team of the WVOMHS&T was established. A meeting was held with the MSHA investigation team on Wednesday, April 21, to introduce the two teams, and start preparations for a joint investigation. A meeting was held later that day at Liberty High School to introduce the teams to the families. Also attending the family meeting was the Governor's Independent Investigation Panel led by Davitt McAteer.

Normally interviews do not begin until after the investigative teams have viewed the accident site. That did not occur during this investigation due to the dangerous conditions inside UBB that prohibited reentry into the mine by investigtors until June 29, 2010. After reviewing the initial documents provided by Performance Coal Company, interviews began on May 10, 2010. During this time, UBB employees, mine rescue personnel and state and federal mine inspectors were interviewed.

The MSHA investigative team presented the underground protocol to be followed during the investigation. WVOMHS&T requested several changes be made to give the state investigative team rights equal to those of the federal team during the investigation. These changes were agreed upon. The underground investigation began on June 29, 2010. The parties involved in the underground portion of the investigation included WVOMHS&T, MSHA, Governor's

Independent Investigation Panel, Performance Coal Company, including Massey Energy and any of its related entities aka the Company, and duly recognized representatives of the miners of UBB, including the United Mine Workers of America (UMWA). After the investigation was well underway, the Moreland and Moreland law firm went through the legal process with MSHA and were given miners' representatives rights; however, they never traveled with WVOMHS&T investigators underground to participate in the investigation.

The underground investigation primarily consisted of the following teams: 5 Mapping Teams, 10 Mine Dust Survey Teams, 3 Electrical Teams, 3 Photography Teams, 1 Flames and Forces Team, 1 Geology Team and 1 Evidence Gathering Team. The number of teams varied each day throughout the course of the investigation.

WVOMHS&T is responsible for doing its own investigation as required by West Virginia Code 22A-2-66 (d) and 22A-2-68. There are many obstacles to overcome during a joint investigation of such magnitude. During the course of the joint investigation, MSHA scheduled the teams and where they would go. The WVOMHS&T realized at some point the state team would require additional time underground to complete its investigation. While it was a joint investigation, we still analyzed the information independently of the other entities and draw our own conclusions. On September 13, 2010, the state Flames and Forces Team continued on their own gathering detailed information from the explosion area.

7.2 Interviews and Testimony

As part of the joint investigation, the WVOMHS&T and MSHA interviewed 269 people. The Governor's Independent Investigation Panel also participated in most of the interviews. The interview process began on May 10, 2010, and finished on October 6, 2011. Originally all interviews were conducted on a voluntary basis; however, due to a large number of individuals failing to appear for their interviews at the scheduled times, the WVOMHS&T began issuing subpoenas to all witnesses in August 2010.

Nineteen people subpoenaed asserted their rights under the Fifth Amendment of the United States Constitution.[1] Seventeen of the 19 asserting their rights under the Fifth Amendment never testified. One individual who originally asserted his Fifth Amendment rights later agreed to a voluntary interview.[2] Another who originally testified asserted his Fifth Amendment rights when subpoenaed to come for a second interview. Almost all interviews took place at the National Mine Health and Safety Academy in Beaver, West Virginia. A few interviews were held in the witnesses' homes or at the Charleston office of the WVOMHS&T.

7.3 Underground Ventilation System

Operating Fans

Ventilation was induced into the mine by three main fans. Fans installed in drift openings at the North and South Portals were operated blowing, and the fan installed on the 16-foot diameter shaft, called the Bandytown fan, was an exhaust fan. Some have referred to this fan as a bleeder fan. Blowing fans induce pressure above atmospheric pressure, which is at a maximum just inby the fan. This positive pressure causes air movement into the mine away from the fan. An exhaust fan creates a negative pressure, which is at its maximum just before the air enters the fan from the mine (see **Table 1** for information about the air quantity of each.)

[1] List attached in Appendix 7.2.1

[2] Rick Nicolau originally asserted his Fifth Amendment rights but later voluntarily agreed to an interview on May 19, 2011.

All values in cubic feet per minute (cfm) Fans, Intakes and Returns	Intake	Return
South Portal, #3 Fan	238,800	95,700
North Portal, #2 Fan	501,400	276,400
East portal, Return		238,900
Ellis Portal, Intake	43,000	
Total Intakes & Returns	786,200	611,100
Difference	175,100	
Bandytown, # 4 fan		402,900
Total Intakes	786,200	
Total Returns		1,013,900
Difference	227,700	

Table 1: Quantity of air at fans and other intakes and returns compiled from mine records. Note that 227,200 cfm more air leaves the mine than enters.

The South Portal #3 fan mostly ventilated the south area of the mine and had little influence on the Bandytown fan, which provided the ventilation to the explosion area. The North Portal #2 fan forced air into the mine, and a portion of this air eventually exited the mine through the Bandytown fan #4 (there wasn't a #1 fan). The North Portal fan ventilated the North Mains and North Parallel Mains section, abandoned areas on the east side of North Parallel Mains and neutral entries of Ellis Portal. Its influence continued to the Old North Mains where some slight positive pressure remained in the air as it entered the Bandytown area of influence just inby the junction to the Old North Mains. Also, the Bandytown fan received a small portion of its air, maybe 43,000 cubic feet per minute (cfm), unassisted from the Ellis Portal. These two fans operated simultaneously on the air current from the North Portal as it transferred between areas of influence, and a small amount returned to the North Portal after ventilating the seals installed around the large sealed area south of the Old North Mains. The Bandytown fan then provided the ventilation pressure to ventilate the area of the explosion, which included the active longwall and its associated gob area, both #22 Headgate and #22 Tailgate continuous mining sections, the belt entries to these active sections, the longwall bleeder entries and the intake air currents to these sections. The Bandytown fan also provided ventilation to all the open workings associated with this mining area.

Active Section Air Courses

The active longwall tailgate had seven entries, five of them were ventilated with intake air that had not ventilated a working face or belt entry; these were called neutral entries. Four of these neutrals were common. The remaining neutral (#7 entry of #21 Tailgate) was separated from the other four by ventilation stoppings and also contained intake air. The air currents of the #7 entry ordinarily diluted the longwall return air currents and moved them straight inby #7 entry to the Bandytown exhaust fan. However on April 5, 2010, there was a roof fall in #7 entry approximately 45 feet inby the longwall. Therefore, on this day the #7 entry air current mixed with the longwall face return at the first open crosscut outby the face and traveled to #6 entry. Also, the ventilation plan provided for air to travel around the last shield and inby to ventilate that corner of the gob.

Two other tailgate entries, #1 and #2, contained return air from the continuous mining sections. A typical excerpt from a longwall ventilation plan is shown in **Figure 1**. Each continuous miner section had three entries, and three separate air currents were required for each section: an intake separate from the conveyor belt, a ventilation air current for the belt which could not be used at the face[3] therefore was required to flow away from the face, and a return air current. The idle section north of #22 Headgate also had three separate air currents, although that air could be used as intake to #22 Headgate since it had not ventilated any working faces. The belt, or neutral air, was required to flow outby away from the sections. These neutral airflows entered the two continuous miner sections' combined return, most of it at an overcast outby the longwall section where the return crossed the longwall belt.

[3] Use of belt air is permitted with special precautions if approved by MSHA and WVOMHS&T, (see 30CFR Part 75.350 and 22a-2-4a), but such use was not permitted at this mine on April 5, 2010.

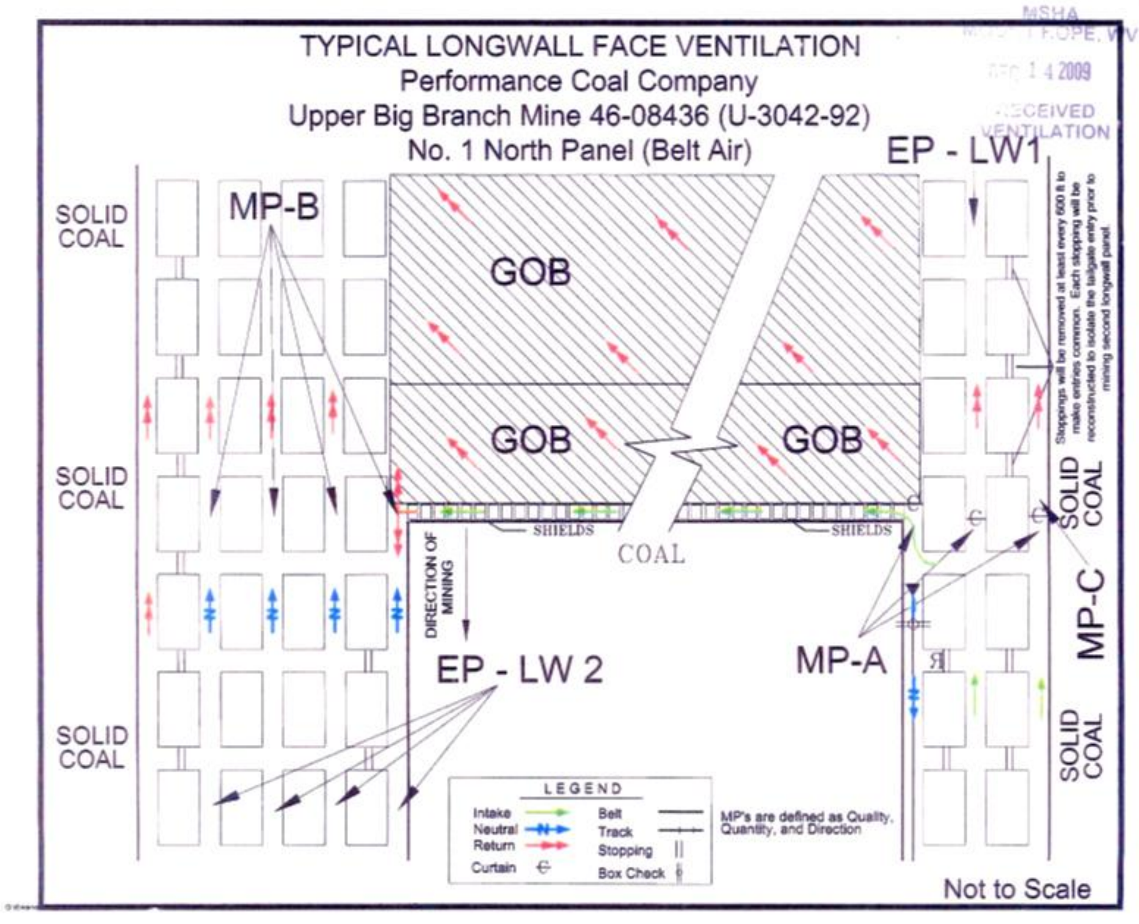


Figure 1: Typical longwall face ventilation plan included in Ventilation Plan approved December 18, 2009, showing typical ventilation and monitoring points (MP).

Overcasts were used where air currents crossed; however, several sets of airlock doors were used to provide access between the intake, return and neutral, or belt, air courses. For example, when traveling on the main track entry of North Glory Mains, which is ventilated by neutral, or belt air, one must go through airlock doors to enter the intake on the sections. See **Figure 2** for a ventilation schematic illustrating the basic ventilation layout.

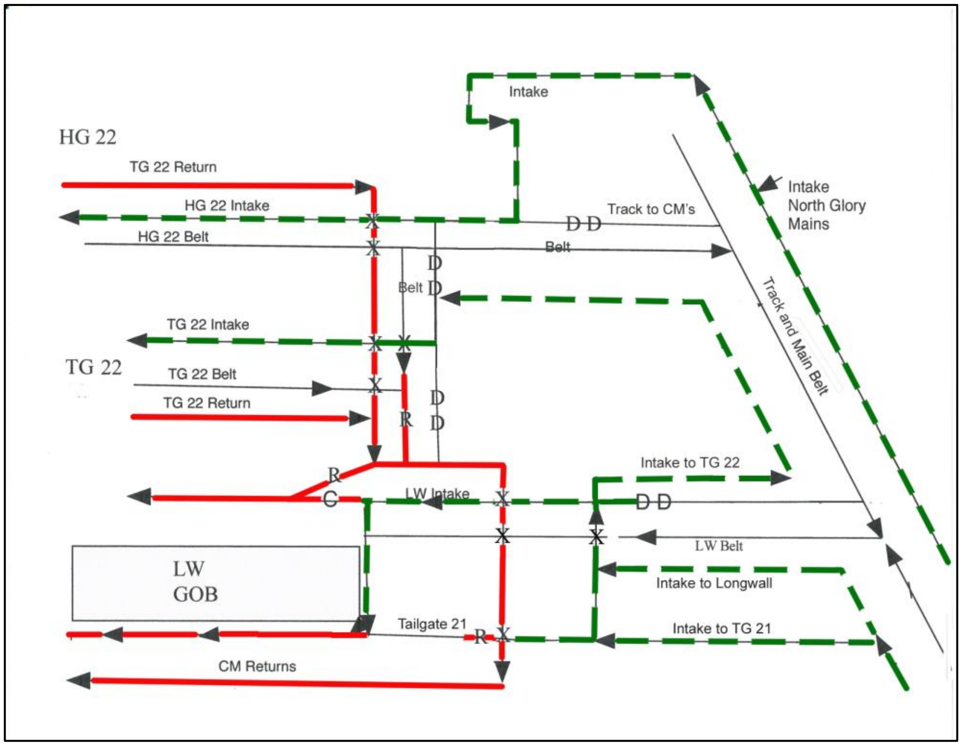


Figure 2: Schematic diagram of the approved ventilation plan at the time of the explosion

The Airlock Doors

The primary purpose of mine ventilation is to provide a moving air stream to the working faces to dilute and remove noxious and explosive gases, and to dilute and remove respirable dust generated during the mining process. To accomplish this, ventilation controls, such as stoppings, regulators, check curtains and line curtains are installed in the working section to direct the air to the face where it is most needed. These controls cause resistance to air flow. In order to permit access between air currents, such as the intake and neutral air splits, an airlock is formed with two access doors on each side that are opened one at a time to maintain the ventilation control intact. The doors are spaced far enough apart so that personnel or equipment can fit between the doors. Opening both doors in a set of airlock doors outby a section would provide a low resistance route for the air to take and allow it to bypass the higher resistance of the section, taking air away from the face and causing a decrease in the continuous miner section ventilation.

Testimony was consistent that constant repairs were needed on the doors along the track. The potential for leaving doors open and not closing them once they were traveled through was present and an ongoing issue according to numerous statements given under oath. The doors near the working sections were manually operated, so the assurance of them being closed was always dependent upon the individual's diligence and proper maintenance of the doors.

We believe the use of multiple doors to assist in controlling the ventilating current is a result of incomplete advance planning and frequent changes to the ventilation plan. When the unanticipated need for a ventilation control arises, installation of doors is much faster and more economical than permanent overcast or undercast. Mine ventilation systems can be designed in most cases without the need for doors on the haulage roads. Exhausting fans can make the design easier. A blowing fan system requires at least one set of doors just inby the fan. The numerous sets of doors installed along the haulage roads were an ongoing and time consuming proposition to maintain as an important element of the ventilation system. Proper maintenance of the doors was essential in assuring a safe environment in which to conduct daily activities while underground. At least 12 different sets of doors were in use at UBB at the time of the explosion on April 5, 2010.

The mine examiners' weekly air readings as recorded indicate that the ventilation system provided the required amounts of ventilating air to all the continuous miner sections. According to these records, both sections and the longwall air current exceeded the minimum requirements (see **Table 2** for a compilation of the section air readings taken by examiners). However, the continuous miner section ventilation was dependent upon the integrity of all the ventilation controls between the face, return and neutral entries. Some circumstances affecting the ventilation evidently occurred because considerable conflicting information was provided in the interview process. Witnesses indicated equipment airlock doors were frequently left open, and there were times when changes were made to enhance ventilation on-shift on the continuous miner sections. Citations for insufficient air, or ventilation traveling incorrectly, had been cited.

The airlock doors between the continuous miner section splits had little effect on the longwall section because it was in the direct line for the air to travel in order to get to the return. The longwall ventilation was dependent only on maintaining the check curtains across the headgate entries inby the longwall face and the regulators, or doors, at the mouth of the tailgate entries. Even if the longwall belt air reversed it would then travel across the longwall face and thereby add volume to the face (see **Figure 1**, ventilation of the longwall).

Ventilation Practices

The ventilation system had some conditions that detracted from its effectiveness. The longwall headgate and tailgate air splits were connected together at the inby end of the panel through the longwall set-up rooms, and the headgate and tailgate entries were separately regulated inby this connection. The regulators were inby the longwall set-up entries, which remained at least partially open and provided a connecting path between the gate entries. Therefore, each regulator affected both the headgate and tailgate splits, leaving the amount of air in either split depending upon the relative resistance of the air courses. This situation caused the pressure across the longwall gob to be equivalent to the resistance on the longwall face and air course resistance. The returns for the continuous miner sections and a portion of their belt air which was regulated into the return were common in #1 and #2 entries of #21 Tailgate but separate from the longwall returns, except that some continuous miner section return may have entered #3 entry of #21 Headgate through EP-65.[4] Increasing the longwall return regulation would result in minimal increases on the continuous miner sections and reduce the flow in the longwall section.

[4] Approximately 4,000 feet east of the fan at Bandytown these air volumes combined and traveled to the fan.

Ventilation Planning and Modifications

Bandytown fan was placed in operation, according to the fan examination book, on August 31, 2009, and the active longwall was started shortly after that. In September 2009, the original plan for the longwall ventilation, approved on Sept. 4, 2009, used the belt air for intake on the longwall face. The continuous miner section on #22 Headgate (MMU 029) was started November 30, 2009, to develop the headgate entries for the next longwall panel. In December the ventilation in #3 entry of #21 Headgate (the current longwall headgate), which was the return for #22 Headgate, deteriorated due to roof conditions, bottom heave and water accumulations. Since this entry could not be traveled, it could no longer be used as a section return. This initiated a series of changes of the intake, return and belt air of #22 Headgate. At the time of the explosion, and as approved on January 22, 2010, the #22 Headgate return came down #1 entry of #22 Cross-over, joined the #22 Tailgate return (which started on March 2, 2010), then went east in #4 and #5 entries of the #21 Headgate to overcasts leading across the longwall belt to #1 entry of #21 Crossover, then to #1 and #2 entries of the longwall tailgate. The ventilation maps show a regulator in #31 break between #3 entry of the #21 Headgate and #22 Tailgate return; however, there were no available air readings for this evaluation point EP-65.

On December 18, 2009, a plan was approved to reverse the longwall belt air so that it would not ventilate the face. The longwall face was still being ventilated with more than the minimum amount of air required, but the significance of this change is that it decreased the amount of air on the longwall face and introduced a series of changes in the ventilation system. On December 23, 2009 the company determined they could not effectively cause the belt air to travel outby from the face, and an interim plan was approved. This plan required the belt air to point feed at crosscut 29 and from this point travel both ways: inby to the section and outby to the return. The WVOMHS&T rejected this plan because it allowed potentially contaminated belt air from #22 Headgate to enter the belt air of the longwall section, which was part of the longwall intake. Performance Coal Company had implemented this change without approval from the state. A special assessed violation was issued upon inspection. This violation was corrected and the abatement was issued on March 2, 2010.

Date	Shift	Longwall	HG 22	TG 22
2/17/2010	Day	96,265	15,800	
2/17/2010	Eve	106,785	15,140	
2/25/2010	Day	77,770	13,680	
3/2/2010	Day	105,735	17,785	39,385
3/5/2010	Day	99,956	18,525	33,765
3/9/2010	Day	86,768	19,731	39,980
3/10/2010	Owl	116,300	21,546	40,183
3/11/2010	Day	99,720	18,308	64,300
3/18/2010	Owl	67,267	15,677	39,900
4/5/2010	Day	56,840	18,848	36,800

Table 2: Record of ventilation quantities on sections, on-shift. Air quantities are in cubic feet per minute (cfm).

The recurring changes to the mining plan and revisions to the approved ventilation plan indicate problems in both mine planning and mine maintenance. Some of the changes were the result of mine development scheduling or mine airways not being maintained. Planning with engineers can reduce problems in scheduling mine development. Engineers can estimate the progress of development sections and determine where development sections will be on any given date. By doing such, scheduling of development units can be more effective, requiring fewer changes. Mine ventilation construction, such as overcasts, location of air courses, power and haulage needs can be determined and made ready on schedule.

Because development of the next longwall panel was behind schedule, the continuous mining section had to develop #22 Cross-over and start #22 Headgate after the longwall production had started. This required the use of the #22 Cross-over for its coal haulage, causing the section belt to dump on the longwall belt at crosscut 29. The section returns used part of the #21 Headgate entries. Multiple ventilation plan revisions were necessary to create a belt haulage outlet onto #7 North belt and relocate the section intake and returns.

Failure to maintain the #21 Headgate entries caused the need to relocate the continuous miner section return from #3 entry of the headgate entries, and further approved plan changes were needed for the unplanned start-up of #22 Tailgate section. Original planning used the existing headgate entries for the new longwall tailgate.

Another factor, referred to earlier, entered the mix of circumstances requiring ventilation plan revisions when MSHA and WVOMHS&T apparently required the longwall belt air to be reversed from the direction approved on the longwall start-up. The belt air could no longer be used to ventilate the longwall face. This change was not successfully achieved on first trial, requiring additional ventilation plan revisions.

Recordkeeping and Map Updates

The records of weekly air readings, which are useful in ventilation monitoring, were incomplete. Routine testing for methane content at the gob edges seemed non-existent, as evidenced by lack of procedures to examine the approaches to the gob or air leaving the gob, even though the mine had experienced two outbursts of gas and an ignition in the gob. A monitoring station called MP-B was set in the approved plan to measure on a weekly basis the ventilation at a location in the tailgate near the beginning of the gob (see **Figure 1** for this location), but the weekly readings at this location were incomplete.

There were no quality or quantity air readings recorded in the fireboss books for the longwall tailgate MP-B locations after March 17, 2010. The only information noted concerning the MP-B monitoring points in the longwall preshift book in the previously noted timeframe was a repeated notation of the statement "air to gob", or "movement to gob." Testimony confirmed that the longwall foremen did not go into these tailgate entries on a regular basis. This location did not evaluate the methane content of air coming out of the gob in the tailgate. Had such a location been kept under surveillance the increase in methane liberation might have been detected before the explosion. In addition, records of the required air measurements had inconsistencies in the weekly examinations by various mine examiners. Discrepancies between total intake and return air flows are shown in **Table 1**.

The mine map was not kept up-to-date in that some ventilation controls were not removed from the map when they were no longer present or used. Some doors still shown in place were not used. A map in such outdated condition could not be an effective tool in ventilation management or decision making, and could be misleading in emergency situations when miners' lives may depend on the correct interpretation of the mine ventilation system. After the explosion most controls were destroyed and displaced. It was difficult to precisely determine what was where because the mine map could not be used as a reliable reference.

Uncertainties about the Ventilation System

Ventilation details have been difficult to reconstruct because the explosion damage destroyed and displaced almost all ventilation controls within the explosion area. The examination system where weekly air measurements were made and records kept was incomplete, and some measurements appear to be inconsistent or erroneous. The records that were available were studied carefully to determine the actual air quantities at the time of the explosion.

The longwall was ventilated by about 55,000 to 58,000 cfm, and on April 5, 2010, at 2:40 p.m., the pre-shift record showed the call-out reported 56,840 cfm. The continuous miner sections had values recorded for the last open crosscut as follows: 36,800 for #22 Tailgate and 18,554 for #22 Headgate on April 5, 2010.

The mine map is vague as to whether any return air from the continuous miner sections traveled through an indicated regulator in the #3entry of #21 Headgate at break 31 (see **Figure 3**).

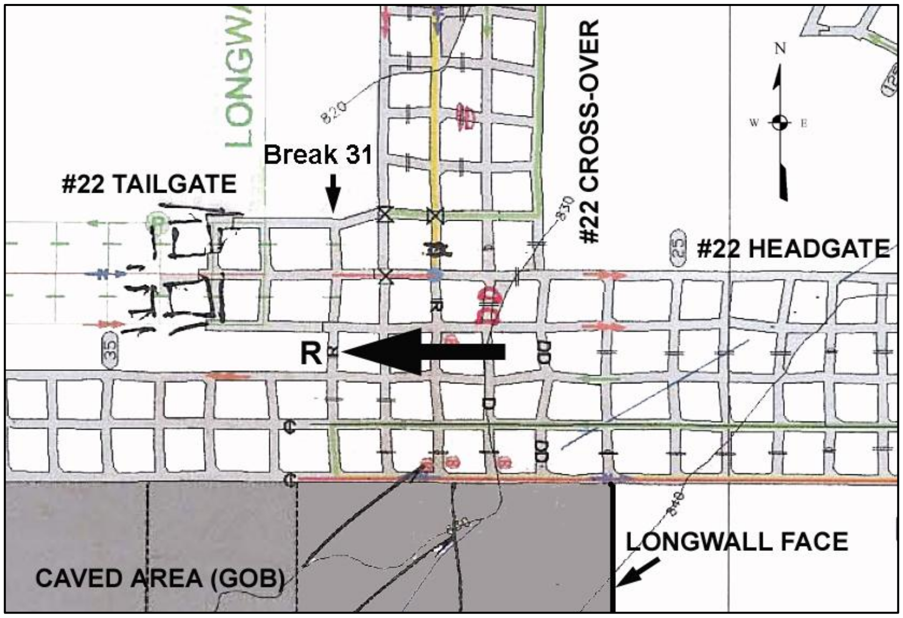


Figure 3. Regulator in #3 entry of #21 Headgate (EP 65). Adapted from a copy of the UBB wall map.

The regulator could have been closed off. This was also an evaluation point, EP-65, requiring a weekly air reading; none was found. The headgate entries had a quantity of 50,200 cfm recorded in the last weekly measurement at MP-36, located at crosscut 37. A problem exists in air balancing between MP-36 and EP LW-3, located in the headgate entries inby MP-36, where 147,000 cfm was measured the week of March 30, 2010. This is a difference of about 97,000 cfm that cannot be accounted for. It is possible the EP LW-3 location is such that some air from the tailgate entries were measured twice, which could account for the discrepancy (see **Figure 4)**. Also, it appears that some of the EP LW-3 readings were taken in regulators, which introduce opportunities for inaccuracies.

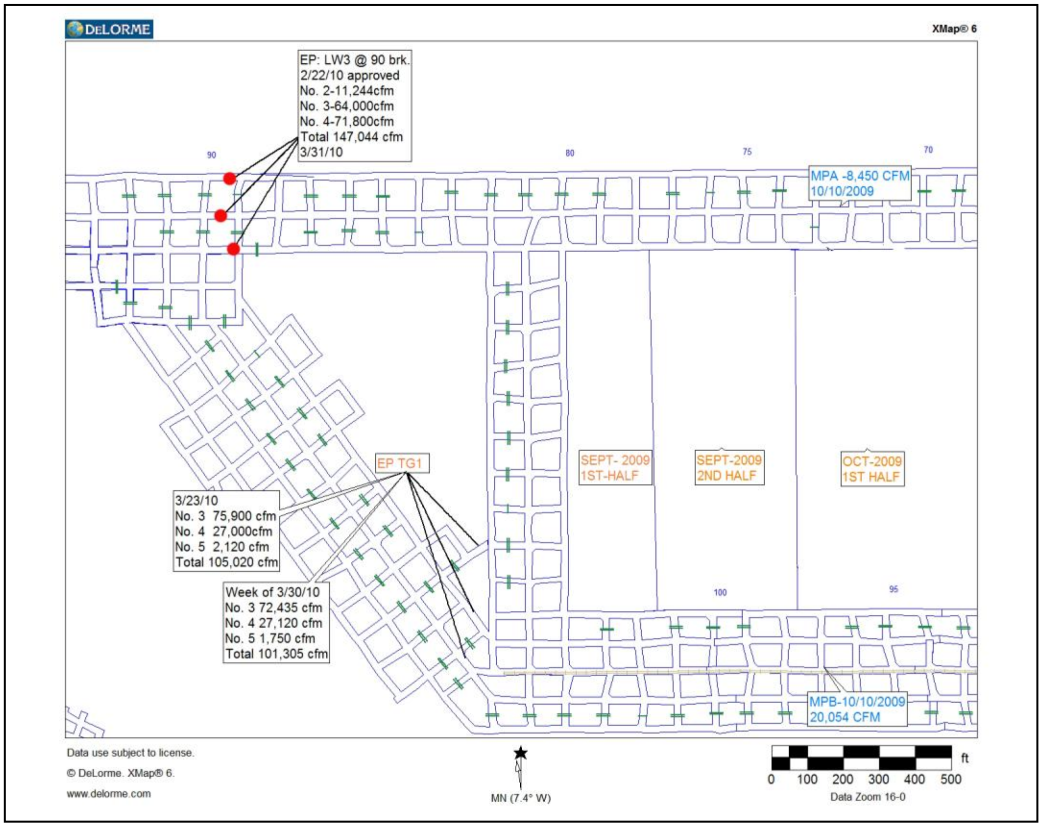


Figure 4. Portion of mine map showing the location on EP LW-3 and tailgate measuring locations.

The #21 Tailgate entries #3 through #6 had air currents moving toward the longwall face. The weekly reading for March 30, 2010, at #3 through #6 entries had a combined total of about 43,500 cfm. The air velocity in these entries ranged from about 59 to 114 feet per minute (fpm). This leaves an uncomfortable situation with such low velocities, not enough to control methane layering[5] or, for that matter, to have much energy to move methane away. The #7 entry readings were not available, but using information from the MSHA model about 10,000 cfm could have been moving inby in #7 entry. We have no record of the amount of air in this entry. The NIOSH model (WVMHS&T only has a draft of this model) shows 51,000, and the MSHA model shows 54,200 total in all tailgate entries.

[5] Kissell, F. N. Handbook for Methane Control, National Institute for Occupational Safety and Health, IC 9486, page 12.

After the tailgate air joins with the face air, the combined total volume would be about 111,000 cfm. The velocity in the tailgate entries inby the longwall face would be about 198 fpm, a better velocity for moving methane accumulations.

The investigators question the accuracy of the ventilation measurements at the Bandytown fan. Federal inspectors recorded quantities of 374,893 cfm on January 20, 2010, and 448,200 cfm on November 3, 2009. The latest mine examiner measurements recorded before the explosion were about 402,000 cfm.[6] These measurements were taken in high velocity air currents, near or above 1,000 fpm, and in those conditions errors caused by measuring technique or condition of the anemometers have a significant impact on the results.

Reconstructing the Performance of the Exhaust Fan at Bandytown

During this investigation the air quantity at Bandytown fan was investigated by other means. Information was used from an MSHA ventilation survey made September 28, 2010, when MSHA engineers made a careful ventilation survey in the longwall headgate and tailgate entries and captured the air quantity moving to Bandytown fan. They found 294,200 cfm. Records of the fan pressures for this time indicated the fan was operating at 6.5 inches water gauge. This operating point was not on any of the fan performance curves provided by the company, but it was an operating point for the fan in its present condition and no physical changes were reported. It is not unusual to find this situation because the operating speed of the fan may be slightly different than the speed used to draw the performance curves, or they may be a family of curves developed for a slightly different diameter fan and then calculated for this fan, or the fan blades could be at a different setting than reported. In any event, that established operating point can be used to make an intelligent estimate of the fan output at another pressure. The new operating point was plotted using the fan pressure of 5.5 inches water gauge, the pressure on April 5, 2010, before the explosion. At 5.5 inches water gauge the performance curves indicate the fan output to be about 300,000 cfm. In addition to further explore this question, calculations were made using the quantities at the other fans and portals, correcting for increase of volume

[6] MSHA Inspection record available on their website: www.msha.gov

due to temperature and pressure changes. A pre-explosion air quantity at the Bandytown fan was calculated to be about 307,000 cfm.

Immediately after the explosion, the Bandytown fan pressure reduced to slightly less than 3 inches water gauge. This extrapolates to about 315,000 cfm during the first few days after the explosion, and then the fan pressure gradually began to rise, (see **Figure 5** fan performance curves with operating points).

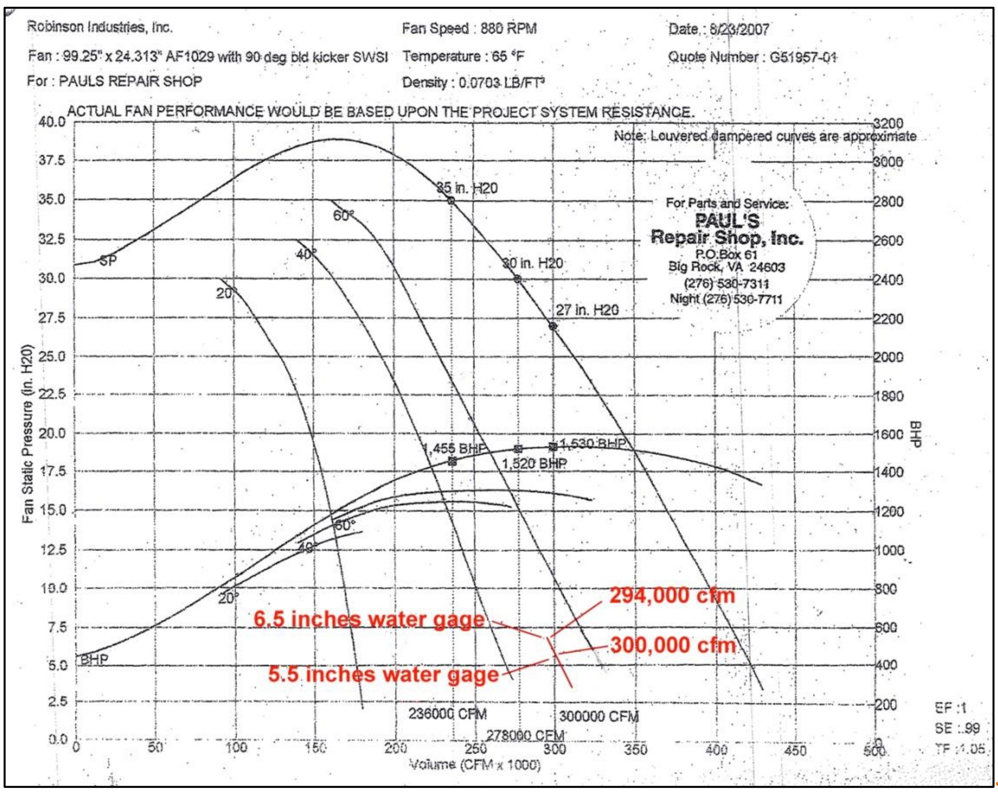


Figure 5. Performance curves for Bandytown Fan. The slope of the fan curve is such that the quantity increases about 6,000 cfm for each 1-inch drop in fan pressure.

The volume of air at Bandytown fan is a critical part of the calculation to determine the amount of methane liberation in a 24-hour period. The air analysis from samples collected during the MSHA inspection on January 20, 2010, averaged 0.182% methane. The fan chart for that time period recorded a water gauge of about 4.5 inches. At that pressure a quantity of 306,000 cfm is estimated. Using the air volume of 306,000 cfm, the methane liberation calculates to 802,000 cubic feet of methane in 24 hours. Adding the 55,000 cubic feet of methane in 24 hours found in the #1 return entry of North Portal results in a total of 857,000 cubic feet of methane in 24 hours. This return ventilated the seals containing the large sealed area south of the Old North Mains, which contains the locations of previous methane outbursts. The air quantities used by the inspector during the last federal inspection determined that over one million cubic feet of methane in 24 hours (1,067,510) was being liberated from the mine. These outbursts and an ignition that occurred in 1997 in an area that is now also sealed are discussed in more detail in **Section 3.2**.

Longwall Ventilation

Although several air quantity measurements are questionable and many are missing, there seems to be no question that the longwall face was ventilated in accordance with the approved plan.

Management of the tailgate supports and ventilation controls were not in keeping with best ventilation practices. The #7 entry of #21 Tailgate was found caved approximately 45 feet inby the face to the extent that a ventilating current could not turn inby in #7 entry towards the gob. So, rather than turn inby at the last shield and move any methane from the gob at the tailgate junction away from the face into #7 entry, the face ventilating air current was required to turn outby for a short distance and then turn right into the partially open crosscut along with the air current moving inby in #7 tailgate entry. This created eddy currents in that dead air space against the fall in #7 entry. Even though some small amount of air could move over and around the fall, the majority did not, and that could re-circulate methane (see **Figure 6**).

It is recognized that caving roof behind the longwall will fall across the tailgate entry and close it off, but best practices would require sufficient supports in the tailgate entry so as to delay the closing of the tailgate entry immediately behind the face and maintain some air opening to the first crosscut inby the longwall face. Stoppings typically should be removed from these crosscuts as the face advances to aid the passage of air. This would allow the ventilation to turn the corner in an inby direction and carry methane directly away from the face.

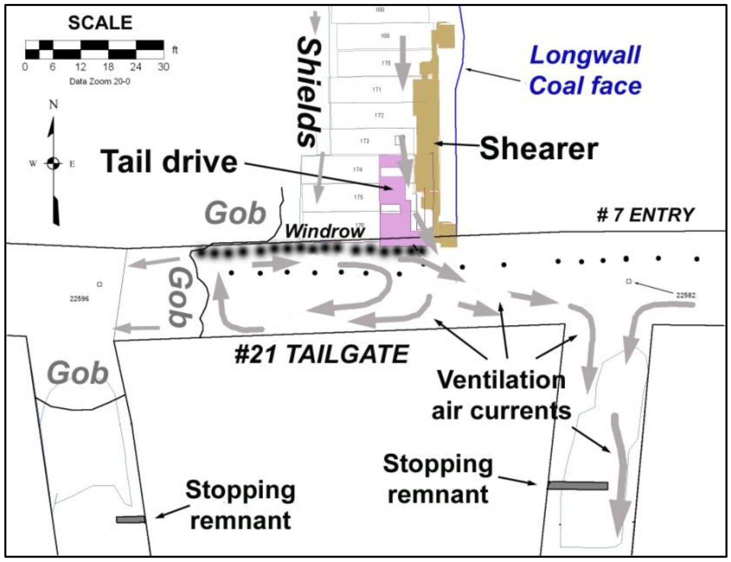


Figure 6. Junction of the Longwall with the #7 entry of #21 Tailgate. Normal ventilation path is blocked by gob.

The airflow patterns in and around gob areas are affected by the pressure across the gobs and the permeability of the gob as well as the method of directing air to the gob. Research has shown that flow paths around gobs are concentrated behind the shields, near the back end of the gob and along the tailgate entry where gob permeability is the highest.[7] At UBB, the investigators believe that most of the ventilating current on the longwall face flowed in the space under the shields' canopies, and most of that was over the conveyor and in the walking space next to the conveyor. Very little airflow occurred near the area occupied by the shield gob side hinge and even less adjacent to the gob behind the shields. It is likely that this airflow skirted the gob and did not penetrate any appreciable distance into the gob, leaving the large gob area as a potential reservoir of methane.

The Eagle coal seam is not highly gaseous and, as indicated by previous events, most of the methane liberation is from the floor. The Little Eagle coal seam lies below about 10- 15 feet (see **Section 2.2**). The methane liberation from the longwall face found in the immediate return appears minimal. Samples taken during the last federal inspection from the longwall immediate

[7] Yuan, L., Smith, A.C., and Brune, J. Computational Fluid Dynamics Study on the Ventilation Flow Paths in Longwall Gobs NIOSH, Pittsburgh, Pa.

return showed 0.06% methane in 61,650 cfm, which is 53,266 cubic feet of methane in 24 hours. The developing sections appeared to liberate more methane. Gas in the previously developed longwall panel has had time to migrate out of the coal. A sample in the #22 Tailgate section immediate return was 0.13% methane in 84,020 cfm, which is 157,285 cubic feet of methane in 24 hours. This quantity measured in the section immediate return was higher than any other reading found and might be from both continuous miner sections.

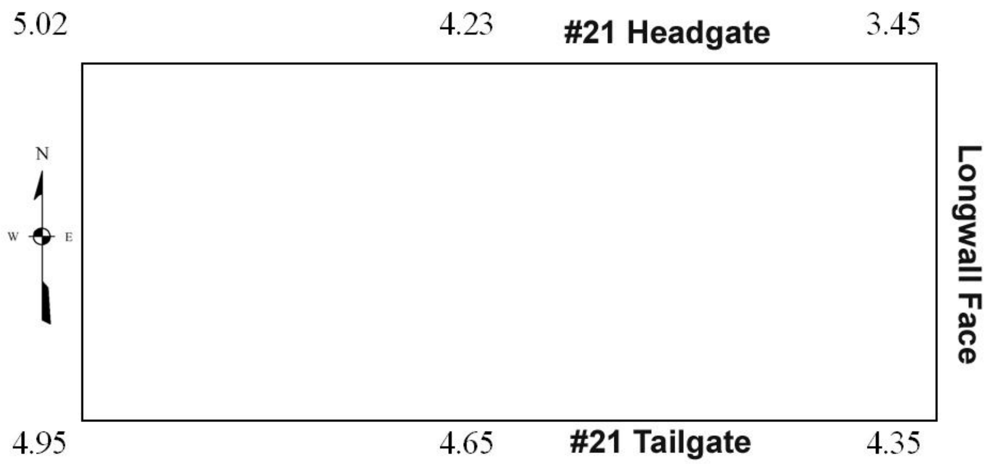


Figure 7. Sketch showing ventilation pressures in inches water gauge around the longwall gob, taken from the MSHA Ventilation Model. Pressure in the airstream is ventilating around the longwall gob. Pressures are negative and becoming more negative as one gets closer to Bandytown fan.

The longwall gob gases were probably expanding and exuding from the longwall gob at the time of the accident due to a decreasing barometric pressure. The barometric pressure had started increasing about 9 hours before the explosion, and about 11a.m., or 4 hours before, had begun a decrease. At the time of the explosion it had decreased 0.07 inches mercury from the 11 a.m. high. Now, 0.07 is not much of a change but that amount is equivalent to 0.95 inches water gauge. The pressure across the gob created by the ventilating system was slightly less than 1 inch water gauge near the face; however, inby, about mid-point in the panel, the gob probably had no pressure across it from one side to the other (see **Figure 7**). Gas was likely exuding from the cracks in the mine floor just inby the shields where methane was found during the investigation. This gas was likely moving along the gob behind the shields and into the tailgate entries inby the longwall face. It was probably present in #7 entry of #21 Tailgate against the gob blocking the entry just inby the face.

Due to their locations in the main longwall ventilating current, the methane monitors on the shearer and face conveyor tail drive would not detect gas behind the shields or in the severely blocked #7 entry against the rock fall.

The examinations made by the section foreman did not detect any appreciable methane prior to the explosion, and the methane detecting equipment on the face did not indicate a methane accumulation before the explosion. Evidence indicates that none of the monitors or detectors was positioned in the areas of the methane accumulations prior to the explosion. There were no additional examinations or tests required of the mine examiners based on the previous known gas outbursts or ignitions. There were also no specific safety precautions or practices that could be identified with that unusual hazard that was specific to this mine.

7.4 Mine Seals

Ventilation seals were constructed to eliminate the need to maintain, ventilate and examine the large gob areas south and southwest of the current UBB active workings; however, these seals were ventilated with a separate split of air directed to the return. The seals are identified by sets, and a total of 15 seal sets were installed. A total of 64 seals were installed.

A weekly examination of all seals was required. The last recorded weekly examination of seals 1-32 was March 30, 2010, and the last weekly examination of seals 33-64 was April 1, 2010. Also required was a daily examination of one gas valve from one seal of each set of seals. Examiners would note if the seals were “in-gassing” or “out-gassing” and the results of methane, oxygen and carbon monoxide tests when pumping the seals. These seals were last examined April 5, 2010.

A total of 12 seals were installed at Seal Sets 1 and 2. The approximate construction date for these Micon-type seals was 2003. The Micon seals are rated at 20 psi. Seal Sets 3-5 are Strata Packsetter-type seals. These sets have a total of 20 seals, and the approximate construction date was 2003. The Strata Packsetter seals are rated at 20 psi. Seal Sets 6-15 are a Mitchell-Barrett-type seal and have a total of 32 seals. Construction of these seals was late 2006 and early 2007. The Mitchell-Barrett seals are rated at 20 psi.

Six seals have been replaced at UBB. Five seals at Seal Set 3 were replaced approximately April 1, 2010. Seal 59 was replaced in Seal Set 13 approximately May 19, 2009. The seals were replaced with Minova Main Line Tekseal-type seals, which are rated at 50 psi.
Seal Sets 14 and15 are installed outby the tailgate side of the current longwall section. These two seal sets separate the previously mined longwall panel from the tailgate entries for the current longwall panel being mined. Seal Set 14 has one seal, and Seal Set 15 has two seals.

Structurally, Seal Sets 8-15 survived the explosion. However, natural deterioration at the perimeters, and/or empty water traps likely permitted some exchange of gases into the mine after the explosion from the sealed area.

7.5 Sources of Ignition

Embers from Welding

WVOMHS&T found no evidence that embers from cutting or welding contributed to the explosion of April 5, 2010. There were some questions raised about the use of torches and welding on the #21 Longwall face on the midnight shift the night before the explosion.

Testimony clearly indicates that cutting and welding was performed on the face conveyor chain and the headgate side cowl.

The tail side ranging arm where the "Face Side" B-lock is located had a cover missing from the face side of this particular B-Lock. Pictures taken and observations of the area clearly show that the cover had been cut off sometime prior to the explosion. No record was found that would give a precise time when this particular cover was removed. Records and testimony show that the Joy Shearer was not mining coal for nearly three hours on the dayshift of April 5 due to problems with the face side B-Lock on the tail ranging arm. The exact location where the B-Lock was being worked on is not certain, but it is believed the work was done on the headgate side of the longwall somewhere between shield 65 and the headgate.

As noted earlier, the owl[8] maintenance crew on April 5, 2010, had been changing flights on the face conveyor chain. This activity often involves cutting the bolts that secured the old flights then replacing the old flights with new ones. The new bolts were then tack welded on the new flights installed on the face conveyor chain. It is believed that this work was done near the headgate of the longwall face.

Smoking Materials

An examination of the record books provided indicated no record of smoking articles having been found during required searches of workers employed at the mine. Additionally, smoking articles were not found on any of the deceased miners recovered from the mine following the explosion on April 5, 2010.

Electrical Sparking

There is no indication that lightning or faulty electrical equipment on the longwall caused the explosion. An in-depth inspection of all of the longwall electrical systems was conducted, with

[8] Midnight.

attention given to damaged cables, permissibility, splices and other possible sources of ignition. Two questionable splices in the 4,160 volt shearer cable (one located at shield 45 and one at shield 87) were examined and found to be adequate. Two repaired places in the 4,160 volt tail drive cable (one located at shield 91 and one at shield 105) were examined and found to be adequate. Damage to the #6 AWG 3 conductor 110 volt lighting power supply cable at shield 171 and to the chock interface unit (CIU) at shield 171 were attributed to explosion forces traveling from the tailgate to the headgate. The #6 AWG 3 conductor 110 volt lighting power supply cable was damaged near shields 39 and 62. Both of these places were examined and determined to not have been an ignition source.

Lighting power supplies, lights, communication equipment (Comtrol phones) and other intrinsically safe components were inspected and /or tested for possible ignition sources. Both methane monitors, one located on the shear and the other near the longwall tail, were taken into evidence and tested and were found to be operational. No evidence of bridging out or bypassing these methane monitors was found. The high voltage motors on the shearer, tail drive, stage loader, crusher and head drives were tested with a 5,000 volt meggar for possible leakage in their insulation. All of these motors passed this test. The 4,160 volt shearer cable and the 4,160 volt tail drive cable, located on the longwall face, were also tested with a 5,000 volt meggar for possible leakage in their insulation. Both of these cables passed this test.

Welding leads were routed across the longwall face via a flat cable located in the face conveyor cable tray. This cable was found to be disconnected from any welder located at the headgate, thus eliminating them as possible ignition sources.

Falling Rock Ignition

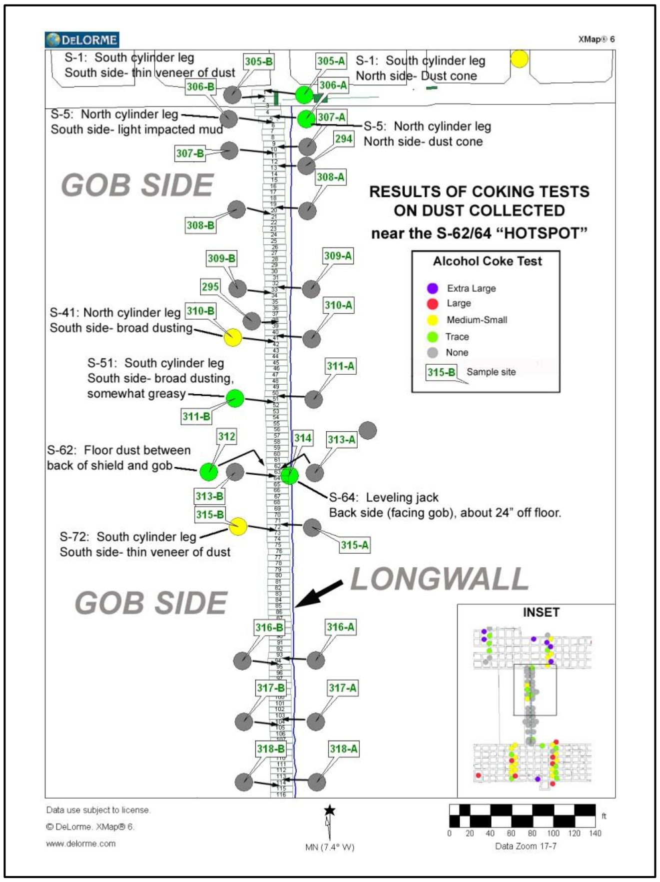
It is believed that the explosion occurred behind the shields of the longwall near the tailgate, and it is possible that it was triggered by a gas ignition in the same vicinity. As the longwall cuts strips of coal from the face, the shields are moved up, pushing the conveyor in front of them. Newly exposed roof then breaks behind the shields due to the overburden pressure and falls, striking rock already caved or perhaps sliding along the top of a steel caving shield. As mining was occurring and shields were being advanced, methane was being liberated behind the shields, from the floor cracks or expansion of methane from the gob due to falling barometer, or both, holding against the gob and migrating to the tailgate behind the shields. The methane would not be well mixed as it moved along with the slow moving air current along the gob, but the boundary between the methane body and air would be flammable. An ignition source here could involve sandstone rock, which was located above the shields. It has been demonstrated that sandstone rocks colliding and rubbing together while falling or striking the steel of the shields can create sparks hot enough to ignite methane.[9] Not all sparks created between falling rocks or rocks striking steel are incendiary, but it is possible to ignite an explosive mixture this way. Explosions from this mechanism have happened, even at this mine where an ignition in the gob behind the shields at the tailgate occurred on January 4, 1997, and was attributed to falling rock.

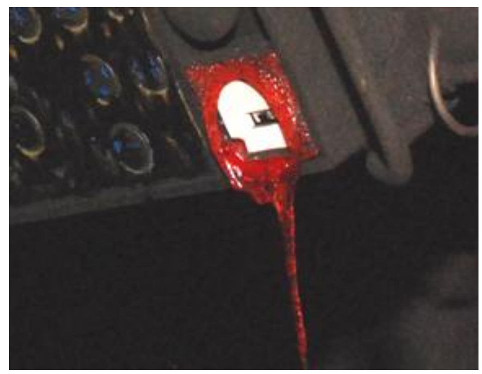
Evidence of heat from behind the shields is found on plastic shield and communication components between shield 72 and the headgate. Most of these shields show heat damage, while there is very little evidence of heat on the longwall to the south, until reaching shield 160 and from there to the tailgate. Small amounts of coking are found on shield cylinder legs between shield 41 and shield 72. There is also coking on shield surfaces and in the back of the shield, next to the gob, at shield 62 (**Figure 8**).

If methane ignited in the gob it likely burned along the gob behind the shields, where the methane was moving to the tailgate. Where only a thin zone of explosive (5-15%) mixture existed in the boundary between 100% gas and 100% air the gas would burn like a wick. This wicking process is analogous to a similar process that occurs when igniting a gas burner on a stove. The piloted flame ignition starts on one side and travels around the burner following the flammable boundary between gas feed and the air along this flammable boundary. Similarly, burning could occur along any methane roof layer that exists adjacent to the gob.

[9] Nagy, J. Frictional Ignition of Gas During a Roof Fall, Bureau of Mines, RI 5548. Page 7

Methane ignited here could burn along the gob behind the shields to the tailgate where increased turbulence and better mixing of the methane could result in the hot gas expansion and increasing intensity as flame propagates along the methane boundary. The flame propagation process opposite the face near or behind the shields (gob side) is similar to the January 4, 1997, event.[10] As the flame and turbulence entered the tailgate it dispersed combustible coal dust and initiated the coal dust explosion.




B. Shield 62—Control Box (CIU)

C. Shield 63—Light cover

Figure 8. Except for the headgate and tailgate regions, coked dust inside the longwall was found only between shield 41 and shield 72, together with other indicators showing evidence of flame and heating at this location. (A larger map can be found in **Appendix 7.9-1, Map 4**).

[10] In this 1997 event the flame propagated mostly between the gob and the shields (see **Appendix 3.2.1**).

Longwall Shearer Sparking

The other possibility is that a gas ignition occurred at the shearer cutting bits. Under this scenario the methane is liberated behind the shields, from the floor cracks or expansion of methane from the gob due to falling barometer, or both, holding against the gob and migrating to the tailgate behind the shields. Methane then enters the area in #7 entry of #21 Tailgate behind and around the last shield (#176). The methane begins to mix with the air current, but out of the main air stream and away from the tail drive mounted methane monitor, and the methane monitor on the shearer. As the recirculation occurred in this area in the #7 entry against the gob and far rib of the entry, the methane-air mix contained non-homogenous mixtures above and below the explosive limit. The thin boundary between these mixtures was flammable, and a hot smear from the bits rubbing and cutting sandstone can ignite methane if it came into contact with a flammable boundary.

The cutting bits used on the shearer had tungsten carbide tips inserted in steel (see photo, **Figure 9**). The tip is very hard and abrasion-resistant, much more so than steel. If the tip becomes worn down then softer steel of the bit can rub against the coal, or sandstone in this case, and rubbing of steel against sandstone can leave a hot streak behind the bit. For a very short time, about 20 milliseconds, this streak of hot material behind the bit can ignite methane. The streak is hot enough to ignite methane for about 5 cm behind the bit; after that distance it cools below the ignition temperature. This hot streak can be obtained with almost any bit material but is much more likely to occur with steel rather than tungsten carbide. Research has shown that a water spray directed to this hot streak location from a spray mounted directly behind the bit can cool the hot streak and prevent an ignition.[11]

[11] Courtney, W. Frictional Ignitions with Coal Mining Bits, Bureau of Mines, IC 9251

Figure 9: View of the tailgate shearer drum showing the cutter bits with tungsten-carbide tips. The bit lacing is designed to maximize the interactions of the bits as they cut away the coal and /or rock. Bits #16 and #17 are worn past most or all of their carbide tips.

The shearer was not equipped with sprays behind the bits, which is the most effective measure to prevent frictional ignitions. At least two shearer bits located on the tail side cutting drum showed signs of advanced wear to the bit and carbide tip. These two bits are located against the coal face side of the tail drum, referred to as the sump side. One of the bit blocks of these two bits showed wear of the steel shank in which that particular bit was located.

Such an ignition of poorly mixed gas and air takes some time to develop into an explosion, sometimes up to one or two minutes.[12] This explosion could propagate away from its tailgate location as a slow moving weak methane explosion, gathering speed into the tailgate entries where wind forces dispersed coal dust and transitioned into a coal dust explosion. A small gas

[12] Nagy, J. The Explosive Hazard in Mining, Bureau of Mines, IR 1119, page 52

ignition of 84.5 ft^3 of methane diluted to 6.5% in air is sufficient to lift coal dust and propagate a dust explosion.[13] Methane also likely burned along the gob behind the shields where the methane was moving to the tailgate. Where only a thin zone of flammable (5-15%) mixture existed in the boundary between 100% gas and 100% air the gas would burn like a wick. With limited air velocity in neutral entries and more rapid influxes of methane from gob expansion there may not be sufficient airflow to dilute and render harmless these layers.

The hot gas expansion due to unconfined burning of non-uniform gas-air mixtures produces eddies that will grow while the flame front searches out and follows and ignites along the flammable boundary. Some gas could have been in the tailgate entries or against the gob adjacent to the tailgate entries, layered due to the low velocity there. This could have added to the roof layer flame propagation, either as a continued gas explosion or hybrid gas, in combination with coal dust in the tailgate, increasing in velocity as it moved outby, consuming available fuel that may have been dispersed from rib and roof surfaces by local wind forces generated by the hot gas expansion process.

Water System to the Shearer

Water is supplied to the underground areas of UBB from two tanks, each approximately 100,000 gallons, located on the mountain side above the East Mains Portal. These tanks receive their water from three 480 volt, 150 HP pumps, located on a platform on the Coal River, near the Load-out.

The water enters the mine in the belt entry of the East Mains Portal. Ten Rosedale Filters are installed in this waterline, approximately 23 breaks underground. Water is then distributed throughout the mine via a 6 inch and 8 inch plastic water line to all of the conveyor belt lines, continuous miner sections and the longwall section.[14] On the #21 Headgate Longwall Section, the water is supplied to the Sunflo Pump through a 4 inch line. The water is filtered through a series of Rosedale Filters, and then goes up the monorail through two water hoses (2 inches in diameter). The water is then filtered through a wye strainer on the outby end of the gate boxes.

[13] Nagy, J. The Explosive Hazard in Mining, Bureau of Mines, IR 1119, page 39
[14] Danny Laverty interview (2/24/2011) Page #53 Lines 20-24, Page #54 Lines 1-16.

This water is then used for dust and fire suppression, fire valve outlets and running the conveyor (face chain torque converter drive).[15]

Because the primary water supply (Coal River) would become muddy after excessive rains, a separate freshwater supply from two wells provided water for the emulsion system on the longwall.[16] This was to prevent problems with the operation of the longwall shields.[17]

Because of these sediment issues, the drum sprays on the longwall shearer were constantly clogged. According to statements made during interviews, to correct this condition several drum sprays were routinely removed to allow the shearer drums to be flushed out. The shearer would continue to operate with the water sprays removed.[18] This practice was a violation of the approved Methane and Dust Control Plan in that the required minimum water pressure of 90 psi could not be maintained.

During inspection and testing of the shearer spray system on December 20, 2010, it was discovered that 24 of the 45 tail drum sprays were visible. A total of seven sprays were missing from the tail drum. Water pressure and water flow tests were conducted on the shearer water sprays.

<u>Water Test on the #21 Headgate 7LS Longwall Shearer</u>

Water was supplied for these tests from a 10,000 gallon tank, located on the surface at the 8A Borehole located above the #22 Tailgate Section. The water traveled through a 7 inch metal line, 1,260 feet down to the mine level. The water line was then reduced to a 4 inch metal line for approximately 3,400 feet to the shearer, located on the longwall tail. A wye strainer and pressure reducing valve were installed in this line before it was connected to a set of Rosedale Filters plumbed with 2 inch pipe connected in a parallel configuration. A 2 inch water hose was then connected to the water input of the shearer.

[15] Danny Laverty interview (2/24/2011) Page #54 Lines 16-24, Page #55 Lines 1-16.
[16] Danny Laverty interview (2/24/2011) Page #46 Lines 23-24, Page #47 Lines 1-11.
[17] Tommy Estep interview (3/1/2011) Page #47 Lines 8-14.
[18] Tommy Estep interview (3/1/2011) Exhibit #5 (Maintenance Report)

Water pressures up to 500 psi (pounds per square inch) of water were available at the shearer for these tests. Water pressure from 50 psi to 450 psi was connected to the water inlet of the shearer. With several tail drum sprays clogged and seven sprays missing, water pressure could not be measured on a pressure gauge attached to a spray port on the drum. With six sprays installed in the missing spray ports on the tail drum and 200 psi delivery pressure at 128 gpm (gallons per minute), 95 psi was measured on the pressure gauge attached to the tail drum.

One staple-loc spray was found in the pan line between shields 59-60. This spray was buried in the coal on the pan line.

7.6 Electrical Equipment

There is no evidence of electrical equipment malfunction or failure that can be identified as an ignition source. Inspection of the surface electrical installations at UBB was started on May 13, 2010. An electrical inspection team, consisting of WVOMHS&T, MSHA, Performance Coal Company and UMWA personnel inspected and/or tested the equipment. Inspections continued on all of the surface electrical installations until the Upper Big Branch mine was deemed safe for the investigation teams to enter. On June 29, 2010, two electrical inspection teams, consisting of WVOMHS&T, MSHA, Performance Coal Company and UMWA personnel began inspecting the underground electrical equipment and installations. During the next six months, two and three electrical teams continued to inspect electrical equipment and electrical installations underground at UBB. All of the high voltage cables from the main sub-station, located on the surface, to Ellis Portal and up to crosscut 10 on Old North Mains were inspected and identified. The "Green" high voltage circuit was also inspected and identified up to crosscut 47 of the Old North Mains. This circuit along with sections of the "Blue" and "Red" high voltage circuits were energized to permit additional testing and to provide power for de-watering pumps.

Electrical inspections were conducted on the section electrical equipment on the #22 Headgate and #22 Tailgate sections. Inspections were also conducted on the electrical equipment and installations on the #21 Headgate Longwall Section. Special attention was paid to the electrical installations and electrical equipment on the longwall section (see **Section 7.5**).

Outby equipment such as battery scoops, battery forklifts, de-watering pumps, battery chargers, roof bolters and other equipment were also inspected. Various equipment components were taken as evidence and were tested and evaluated for possible ignition sources.

A Long Airdox Shield Hauler, located outby the longwall head gate, was inspected. One set of battery leads were burnt into; these leads were inspected and the damage was determined to have been caused by the explosion forces.

WVOMHS&T electrical inspectors issued 168 violations during the course of this investigation.

7.7 Evidence Documentation

Representatives from WVOMHS&T and MSHA arrived on the accident scene soon after the explosion on April 5, 2010. A control order was issued by the WVOMHS&T to prohibit evidence surrounding this occurrence from being disturbed until after the investigation had been completed. The entire permitted mine area was included in the control order. MSHA also issued their appropriate paperwork to preserve the scene of the accident. This began the evidence and chain of custody procedures that were put in place and adhered to until the investigation was completed.

Initially, all physical evidence was collected through a joint effort between WVOMHS&T and MSHA. Many of the electrical components in mining equipment throughout the mine were checked to rule out any possible type of malfunction with the components. Other items were taken to be examined and analyzed to determine pressures exerted and extent of heat or flame in the explosion area. Items such as metal and plastic signs, plastic buckets, light fixtures and light cables, rope, various electrical cables, aerosol cans and pressurized containers were some of the items taken for evaluation and testing.

Physical evidence was collected following the approved protocol. Photographs, written logs, identification numbers, locations, measurements and signatures were all part of the protocol. These protocol approvals were for MSHA to initially pick up evidence. Other parties involved in the investigation early on had to identify items and then request those items be taken into custody. MSHA, at some later date, would collect these marked items. After MSHA completed their main physical evidence pick up, the WVOMHS&T evidence team continued gathering evidence, and Performance Coal Company began their physical evidence collection.

Approximately 900 pieces of physical evidence were collected during the investigation. Many components taken from electrical equipment in and at the mine were taken to the MSHA Approvals and Certification Center in Triadelphia, West Virginia, for testing and evaluation. Other electrical components were taken to different equipment manufacturers for testing, data retrieval and evaluation. These included Joy Manufacturing Co., Matric Corp., MSA Corp., and SMC Corp. All parties involved in the investigation had the opportunity to attend and observe the testing.

7.8 Sampling of Mine Dust

MSHA-directed Dust Band Sampling of Roof, Ribs and Floor

Ten dust collecting teams began collecting rock dust samples throughout the upper part of UBB in June 2010. The teams were led by MSHA and accompanied by members of the WVOMHS&T, Performance Coal Company and the UMWA. Approximately 1,803 samples were collected. The samples were sent to MSHA's Mount Hope lab to be analyzed for incombustible content and coke. They also were sent to an independent lab so the results could be verified. As illustrated in **Figure 10,** areas were sampled along selected profiles outby crosscut 67 and comprehensively sampled inby crosscut 67, the latter of which showed a generally deficiency of compliant rock dust amounts.

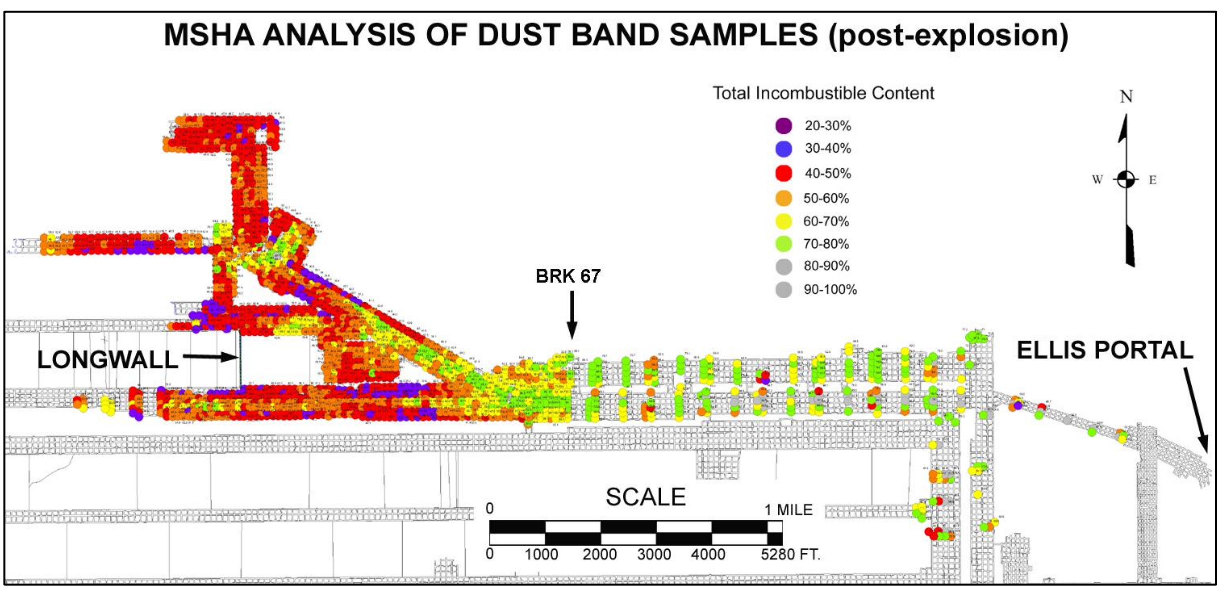


Figure 10. Locations (and results) of dust band samples collected after the mine explosion

WVOMHS&T Sampling of "Impacted Dust" Deposits

On September 13, 2010, the WVOMHS&T began a supplemental mapping and sampling initiative to document impacted dust deposits, which differ from the MSHA dust perimeter samples in that they may be more representative of actual airborne dust involved in the explosion. These are referred to in this report as "impacted dust" deposits and samples. For discussion purposes, the types of deposits fell into one of three categories: *Crevice Dust*, *Roof Bolt Head Dust,* and *Impacted "V" Dust Cones*.

1) Crevice Dust

Deposits of impacted dusts from the explosion were found in crevices of the rock ledges and along header boards, roof bolt plates and similar structures. These are simply pockets of dust that were captured from one direction of the explosion forces.

2) Roof Bolt Head Dust

Threaded ¾ inch roof bolt ends captured dust deposits on one side or on opposite sides, with the thickest deposit usually found on the windward side of the initial explosion. Deposits of dust on the heads of roof bolts were mapped and sampled across the explosion region. The most commonly used roof bolts at UBB have a threaded tip[19] which protrudes beneath a nut used to tighten it against the roof bolt plate and the mine roof. The protruding nut and bolt captured dust from the travelling explosion pressure wave(s), accumulating small deposits on one or two sides of the bolt. These bolts are installed on 4-foot spacing throughout the mine so they were a persistent sampling point. One limitation is that these samples need to be collected early in the investigation, as humidity changes and ventilating air currents cause their rapid deterioration. Because they were not mapped until the fall of 2010, their reliability may have been compromised to some degree in certain places.

[19] Variously called torque tension bolts, double-twist bolts, etc.

3) Impacted "V" Dust deposits

Cylindrical structures with diameters between 1.5 inches and 13 inches developed different dust structures. Conspicuous, durable impacted dust deposits which formed a distinctive dust wedge or cone running longitudinal down the long axis of the cylinder were characteristic. The half-circumference on the reverse side was thinly dusted and the remaining regions were typically clean (no dust). These are referred to in this report as "impacted 'V' dust cones," and were observed on support jacks, belt rollers, longwall shield cylinder legs, propsetters, etc. Their peaks point in the windward direction of the final wind forces of the explosion (see **Appendix 7.9-3** for a discussion of Final Forces).

Most of the samples analyzed by WVOMHS&T were from dust deposits on roof bolts. Approximately 362 samples of impacted dust were collected by WVOMHS&T during the investigation. These were analyzed for coke and TIC (total incombustible content), and the results summarized in **Appendix 7.9-1**.

Documentation of these dust deposits aided determination of explosion force direction, the sequence of multiple forces, the fuel involved in the explosion and quantities of incombustible contents of the explosion dusts. Some of this information is summarized in the maps contained at the end of **Section 7.9**.

7.9 Documentation of Flames and Forces

The part of the investigation which determined the origin, direction and magnitude of the primary explosion forces, as well as the origin and fuel involved, is referred to herein as "flames and forces."

The region of primary focus was inby crosscut 60 of the North Mains. Not all of these inby areas were accessible particularly the regions inby crosscut 83 of #21 Tailgate and crosscut 40 of the #21 Headgate. Some of the explosion region could not be reached and mapped due to roof falls, adverse roof conditions and/or deep water. The accessible area was large, approximately 315 acres,[20] and one walk-through of all accessible entries and crosscuts involved a distance of just over 50 miles.[21] Most areas were examined more than once and some as many as four or five times.

Access into the explosion region was via track to about crosscut 76 of the North Mains at which point the track forked with one fork continuing into the North Glory Mains approximately 600 feet and the other fork continuing into #21 Tailgate approximately 900 feet, but debris from the explosion prevented further access inby by rail.[22] Except for a brief time when a rubber tired battery jeep was allowed into the #21 Tailgate to access the longwall shearer, all access and work beyond these track terminals was by foot travel.

The Joint Investigation Team

The Joint Flames and Forces Investigation Team[23] began work inside UBB on July 7, 2010, and continued until September 12, 2010.[24] A supplemental effort was then undertaken by WVOMHS&T to develop a comprehensive Flames and Forces Map. This work began on September 13, 2010, and continued for approximately 13 months.

---

[20] Areal extent of the region examined, but exclusive of areas inby #21 Tailgate and #21 Headgate which were inaccessible to investigators, for safety reasons.

[21] Measured in linear footage, and comprised of the accessible mine crosscuts and mine entries

[22] The active track lines inby were otherwise generally intact.

[23] Comprised of MSHA, State of West Virginia (WVOMHS&T), The Governors Independent Investigative Panel (GIIP), Performance Coal. Co., and United Mine Workers of America (UMWA)

[24] A few trips underground after that date occurred as well.

Supplemental Mapping by WVOMHS&T

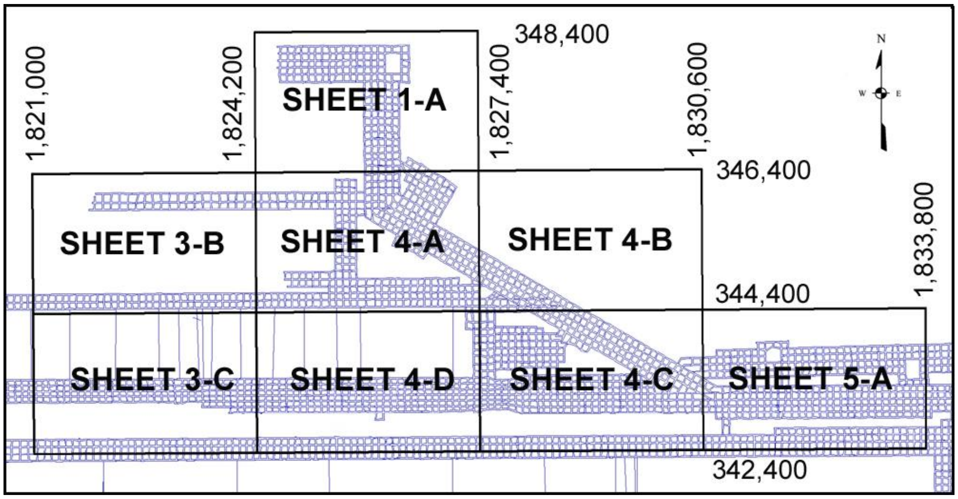


Figure 11. Index to the *WVOMHS&T Flames and Forces Map*. Coordinates are West Virginia State Plane, NAD 1927, WV-S zone.

The supplemental mapping by WVOMHS&T preserved details of explosion effects and explosion damage for the investigation and for future research. This work supplemented the MSHA Joint Mapping Team efforts which had previously mapped debris on the mine floor, the location of equipment and evidence of heat. The WVOMHS&T mapping effort documented remaining items such as roof pans, mine infrastructure (such as belt structure, waterlines, etc.), and dust/coking patterns. Remnants of ventilation stoppings were also examined in more detail.

The *West Virginia Flames and Forces Map* summarize the mapped information. It is comprised of eight (8) sheets (see **Figure 11**), and is located in **Appendix 9** of this report. These maps served as a working blueprint during the documentation and analysis stages of the investigation. Smaller maps were compiled by subject matter and appear in **Section7.9**, and a series of narratives found in other appendices of this report to explain their meaning and use in more detail. The principle subject categories of our mapping are summarized below.

1) Path of the explosion

Information contained in the *West Virginia Flames and Forces Map*, various compilations of summary maps and other information were used to determine the likely initial path of the explosion through the mine (see **Map 1**). After the passage of the initial forces, subsequent wind forces followed. These appear to be the result of a variety of factors involving reflected pressures, cooling of combustion gases in the seconds after the explosion, and, we believe, in some cases additional fuel consumption and propagation. A sense of the relative strength of these secondary forces comes from the bending of roof pans, which are the criteria followed to prepare **Map 2**. For more information see:

Section 7.9 Summary Maps:

Map 1. *Initial Path of the Explosion*

Map 2. *Return Forces Sufficient to Bend Roof Pans*

2) Roof Pans

Roof pans were used as indicators of the direction and sequence of explosion forces and of the degree of relative roof heating, and were documented across the explosion region of the mine. Roof pans are pre-shaped thin steel plates, about 1/32-inch thick, used with roof bolts to provide additional bearing surface against the roof, and are installed between a bolt plate[25] and the mine roof. Their primary purpose is for passive supplemental roof support.

Explosion damage to roof pans was recorded using a simple nomenclature developed by investigators. This and other map symbols document the direction of pan bending, numbers of pans bent per unit area, sequence of pan bending (when pans exhibit multiple bends), and the relative degree of pan rusting. This information was useful in determining the relative intensity, direction and sequence of wind forces from the explosion, as well as some indications of relative heating. For more information see:

[25] Bolt plates are 8"x 8" square steel plates that are installed with roof bolts to provide bearing surface for the roof bolt against the mine roof. When roof pans are used, they are installed between the 8"x 8" plate and the mine roof.

Appendix 7.9-2 Using *Roof Pans as Indicators of Wind Pressure and Heat*

<u>Section 7.9 Summary Maps:</u>

Map 3. *Observed Degree of Roof Pan Bending*

Map 4. *Observed Degree of Roof Pan Rusting*

Map 5. *Roof Pan Bending in the ENTRIES*

Map 6. *Roof Pan Bending in the CROSSCUTS*

Map 7. *Regions of Severe Damage to Roof Pans*

Map 8. *Roof Pans Bent in the Direction of First Forces*

Map 9. *Roof Pans Bent in the Direction of Return Forces*

<u>3) Conveyor Belt Structures</u>

Coal is transported from the working faces and to the outside via a series of conveyor belt systems. The belt structure in the explosion region of the mine is constructed primarily with C-channel steel beams which are bolted together to form two continuous, parallel structural rails onto which the roller frames and conveyor belts are attached. The belt structures were in most places suspended from the mine roof by chains, although in a few places floor stands are used.

Damage to conveyor belts varied according to the strength of explosion forces and the gauge of the C-channel used in their construction. The greatest damage occurred where they were impacted broadside by explosion forces, which deflected the structural laterally and induced a rotation to hanging belt structure that was clockwise from left hand forces when viewed along belt axis. For the most part, severe damage was confined to crosscut intersections, and damage quickly lessened away from the intersections where the coal pillars provided shelter from wind forces. Discernible directions of belt structure deflections were documented in the *West Virginia Flames and Forces Map*. For more information see:

Appendix 7.9-4 Using *Breached and Deflected Structures to Determine Explosion Forces*

<u>Section 7.9 Summary Maps:</u>

Map 10. *Direction of Belt Structure Deflection*

4) Ventilation Stoppings

Ventilation stoppings are used in underground mines to isolate air currents between adjacent entries. Most of the stoppings at UBB were of concrete block construction. Prior research shows that solid concrete block stoppings can withstand static explosion overpressures of approximately 2 psi. When they are impacted by overpressures they create a debris field which is a useful indicator of the direction of explosion propagation and also useful for determining which entry(s) were on the leading edge of the propagating explosion. Debris fields were studied to distinguish materials used in stopping installation from those left over from construction of the stopping. Observations and related details are depicted in the *West Virginia Flames and Forces Map*. For more information on ventilation stoppings, their debris fields and interpretation, see:

Appendix 7.9-4 Using *Breached and Deflected Structures to Determine Explosion Forces*

Section 7.9 Summary Maps:

Map 11. *Direction of Breach of Ventilation Stoppings*

5) Waterlines

Deflections of water discharge lines constructed of high density polyethylene (HDPE) pipe where documented where their deflection directions could be discerned. Some of these lines were in service at the time of the explosion, others were not. Details of the deflection directions attributed to explosion forces are noted on the *West Virginia Flames and Forces Map*. These deflections are indicative of the direction and strength of the wind forces that moved and/or broke them, which sometimes involved multiple events. When their deflections are opposite the direction of stopping breach, they are indicative of wind forces which arrived subsequent to the initial forces, and are useful in assessing their relative strength and direction. Similar to the conveyor belt structures, the strongest damage to the waterlines is in crosscut intersections. For more information on damage to discharge waterlines see:

Appendix 7.9-4 Using *Breached and Deflected Structures to Determine Explosion Forces*

<u>Section 7.9 Summary Maps:</u>

Map 12. *Direction of Waterline Deflection*

<u>6) Debris Transport</u>

Most of the airlock doors and some of the electrical power centers, capacitor boxes, and other mine structures which were transported by explosion forces or had parts transported during the explosion are shown on the *West Virginia Flames and Forces Map.* This information assisted in the determination of wind forces direction and sequence of explosion forces. Two examples are given in **Appendix 7.9-4**.

<u>7) Evidence of Extended Flame Duration</u>

Carbonaceous laminations on the mine roof and mine dusts on the coal ribs that were conspicuously coked and visible to the naked eye are referred to as "macro-coking". These deposits were observed on the mine roof in the form of cintered agglomerations and on the coal ribs as granular deposits, which in extreme cases resembled fine popcorn. Deposits of macro-coke are indicative of slow flame or flame of extended duration. Macro-coking was found throughout the explosion region of the mine, which gives evidence that coal dust participated extensively as a fuel for the explosion. A map summarizing the observed macro-coking is in:

<u>Section 7.9 Summary Maps:</u>

Map 13. *Observed Occurrences of Macro-coking*

<u>8) Impacted dust</u>

Deposits of impacted dusts from the explosion were systematically mapped across the explosion region of UBB using a series of mapping symbols developed by UBB investigators. Deposits on protruding roof bolts, standing roof supports, conveyor belt structure, rock crevices, etc., were mapped to help determine the direction and sequence of wind forces for the investigation and for future reference.

Impacted dust samples that were collected and analyzed for coking content and total incombustible content (TIC). They were collected primarily from the protruding threaded heads of roof bolts. Because these deposits were created from the dust of the propagating explosion they are useful in determining the composition of that dust, not what settled to the floor and on ledges after the explosion.

The analyses of these impacted dust samples are in good agreement with the MSHA dust band sample TIC analyses. They are less in agreement with the MSHA dust band sample coking analyses, and it is possible that the difference is related to transport of dust over the mine floor by moving air currents subsequent to the explosion. Local settlement of these dusts appears influenced by ventilation immediately following the explosion. The impacted dust samples collected by investigators were also studied under a scanning electron microscope for cenospheres[26], which give evidence of high temperature coal combustion. Approximately 65 samples provided to NIOSH for analysis using a scanning electron microscope showed cenospheres present in varying quantities in nearly all samples (see **Appendix 7.9-1**). This is one of the indicators that coal dust was a fuel for the explosion. For more information relating to documentation of impacted dust, see:

Appendix 7.9-1 *Sampling and Analysis of Mine Dusts*
Appendix 7.9-3 *Identifying Final Forces*
<u>Section 7.9 Summary Maps:</u>

Map 14: *Direction of Final Forces*
Map 15: *The Impacted "V" Dust Cones on Standing Supports*
Map 16: *Impacted Dust on Exposed Heads of Roof Bolts in the ENTRIES*
Map 17: *Total Incombustible Content (TIC) of Impacted Dust Samples Collected and Analyzed by WVOMHS&T*
Map 18: *Coking Results of Impacted Dust Samples Collected and Analyzed by WVOMHS&T*

[26] Cenospheres are microscopic glass spheres (10-50 microns), which are hollow and are indicative of coal particles burned at high temperature at power plants.

Map 19: *Analysis for High Temperature Glass Spheres (Cenospheres) in Impacted Dust*

9) MSHA Dust Band Samples

For reference, maps illustrating the results of MSHA dust band samples are included. They can be found at:

Appendix 7.9-1 *Sampling and Analysis of Mine Dusts*

Section 7.9 Summary Maps:

Map 20: *Total Incombustible Content (TIC) of Dust Band Samples Analyzed by MSHA*

Map 21: *Coking Results of Dust Band Samples Analyzed by MSHA*

10) Miscellaneous

Some locations of conspicuous floor heave are noted on the *West Virginia Flames and Forces Map,* as were other miscellaneous items whose purposes ranged from possible heat/pressure indicators to landmark reference points. Other items shown on the map are simply points of reference for investigators as landmarks to confirm map locations.

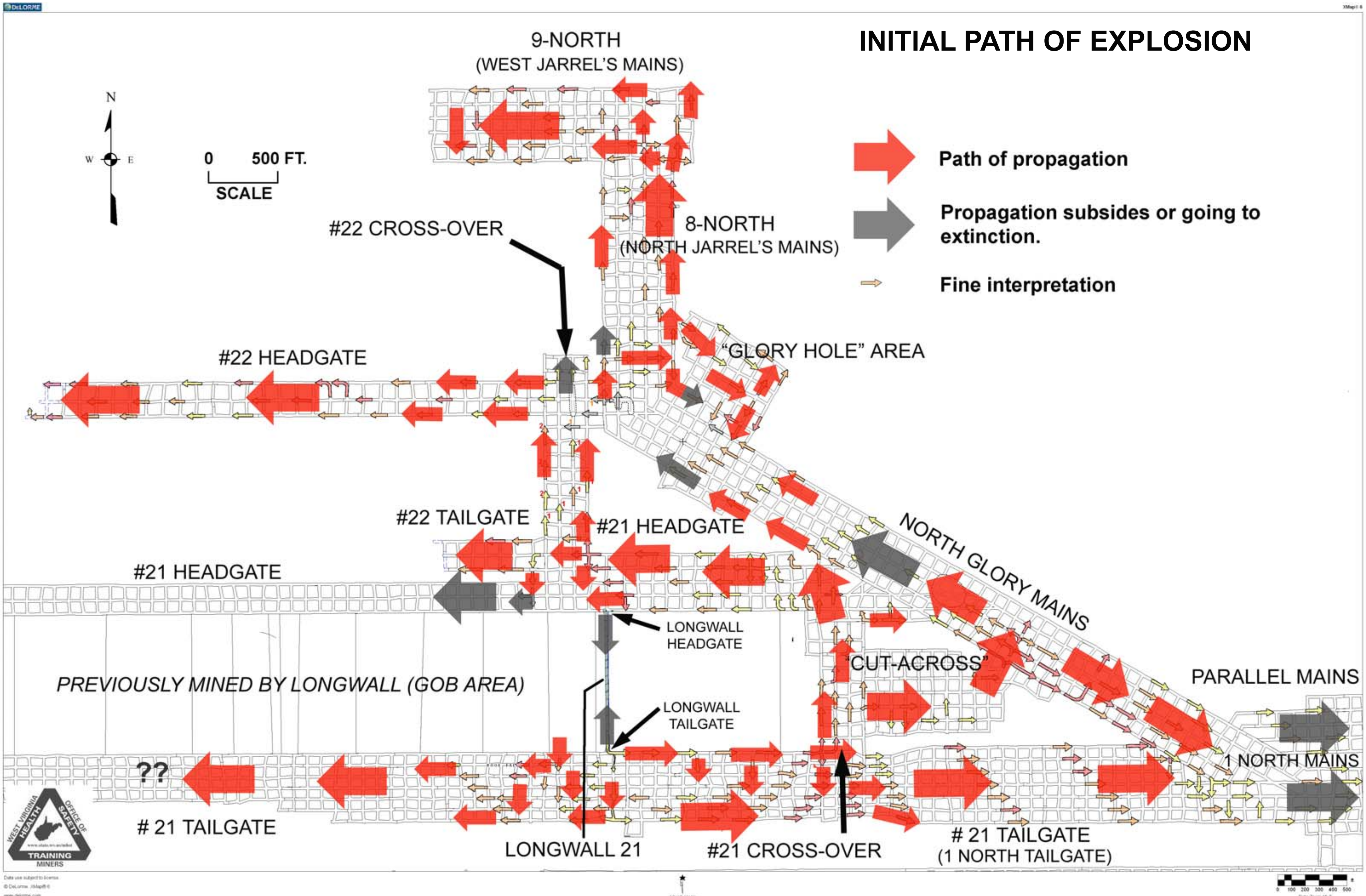
Limitations of Mapping

In order to avoid duplication where possible, the *West Virginia Flames and Forces Map* contains fewer details of floor debris and heat items, and fewer measured locations than the MSHA maps. In most instances the latter should be used for more precise location purposes. While some items in the WVOMHS&T map are drawn to scale, most items are drawn larger for clarity. Also, with a few exceptions the *WVOMHS&T Flames and Forces Map* makes fewer mapping adjustments to pillar and rib locations in the UBB base mine map than do the MSHA maps, which results in some minor difference in the depiction of mine works.

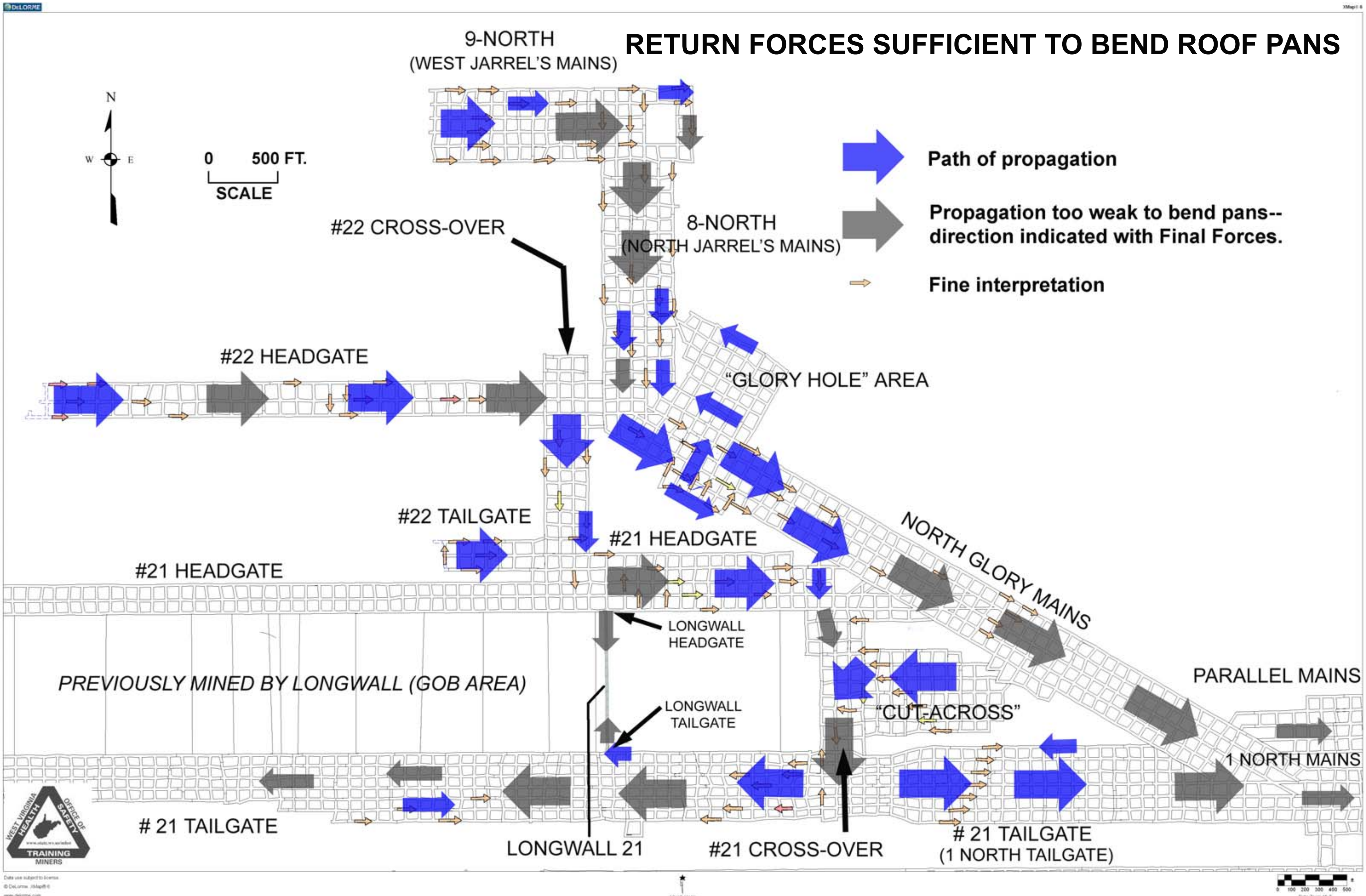
A digital map of the UBB mine workings was provided to WVOMHS&T by UBB shortly after April 5, 2010, and this served as the base map for our documentation and mapping effort. A raster map was prepared from the digital base map and certain layers were turned off digitally to eliminate clutter and provide space for our notations. Two legends are shown on the *West Virginia Flames and Forces Map* to help identify and distinguish the data added by investigators from the original base map features. Features shown originally on the UBB mine map were generally not removed or relocated, even if subsequent work indicated locations on the map were not current. Instead, our map notations often indicate approximate revised locations to certain mine features, including doors, stoppings, regulators, etc. Also, some survey spad numbers on the map did not match the numbers stamped on found monuments, which for the most part appeared to be a clerical transposition.

Indicators of explosion pressure

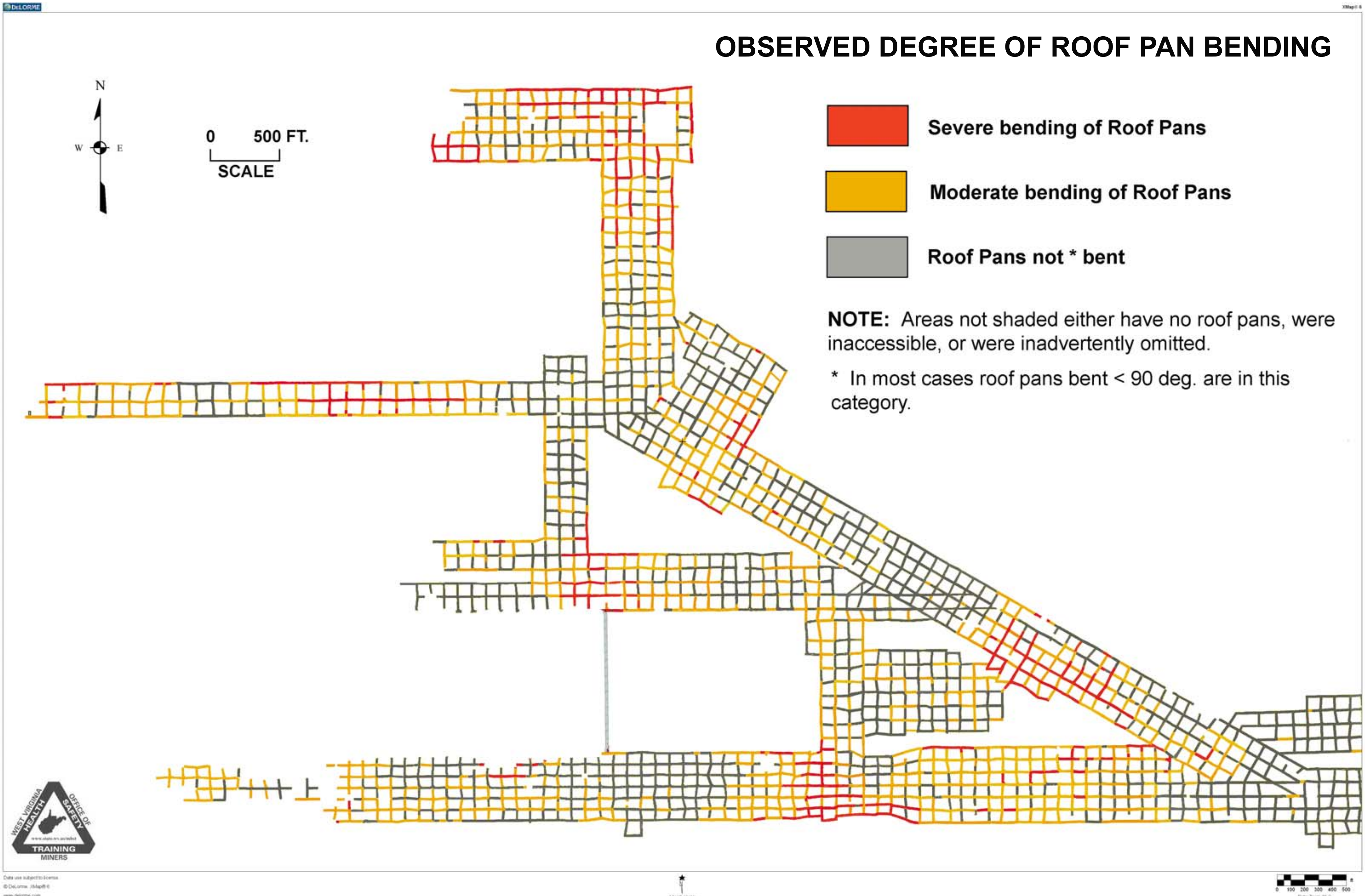
Explosion damage to roof pans, aerosol spray containers, light bulbs and displaced structural members were modeled by various means to estimate the explosion pressures involved. The work was performed by State and Federal investigators. See **Appendix 7.9-6** for more information.



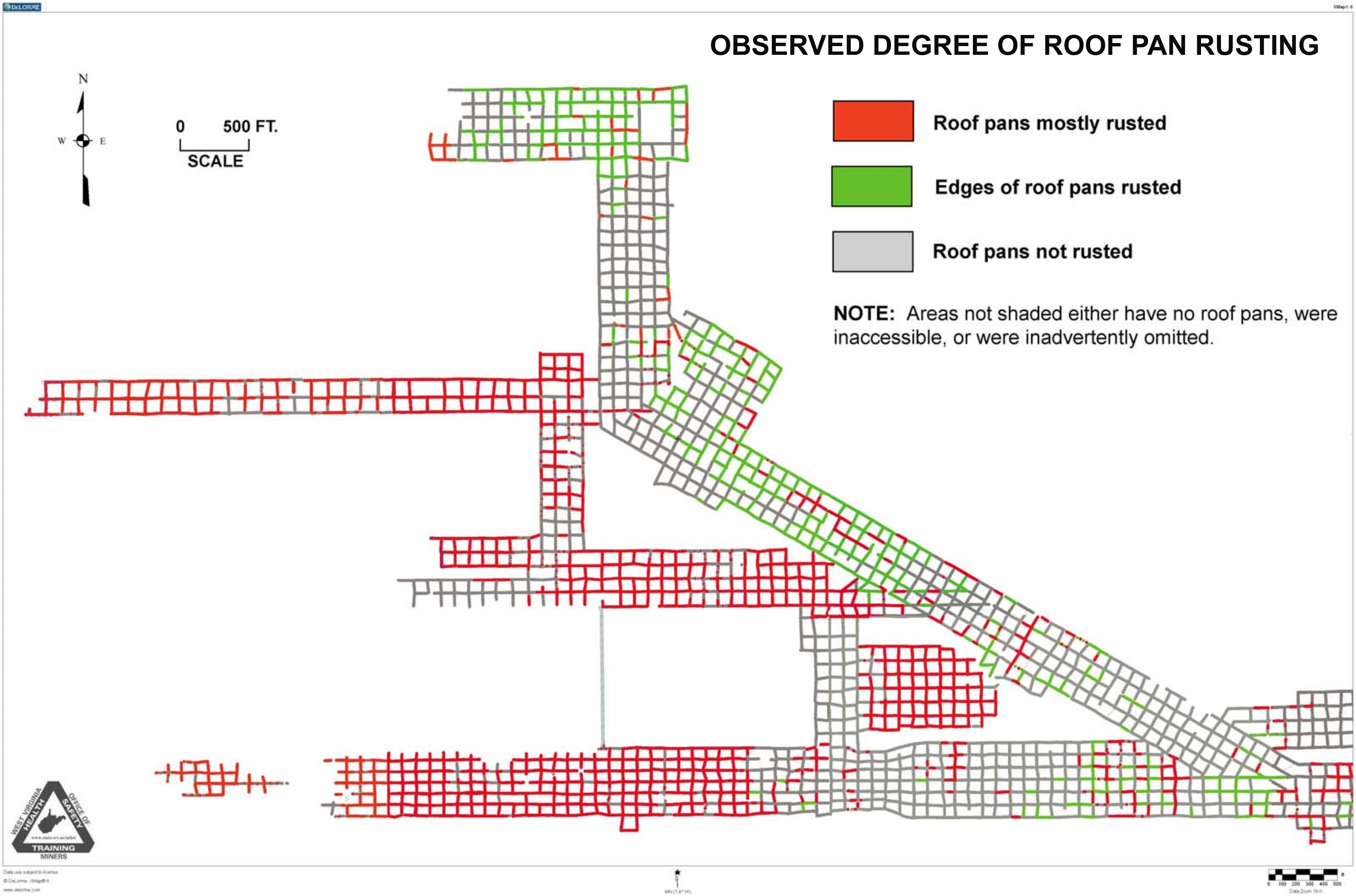
SECTION 7.9 MAP 1



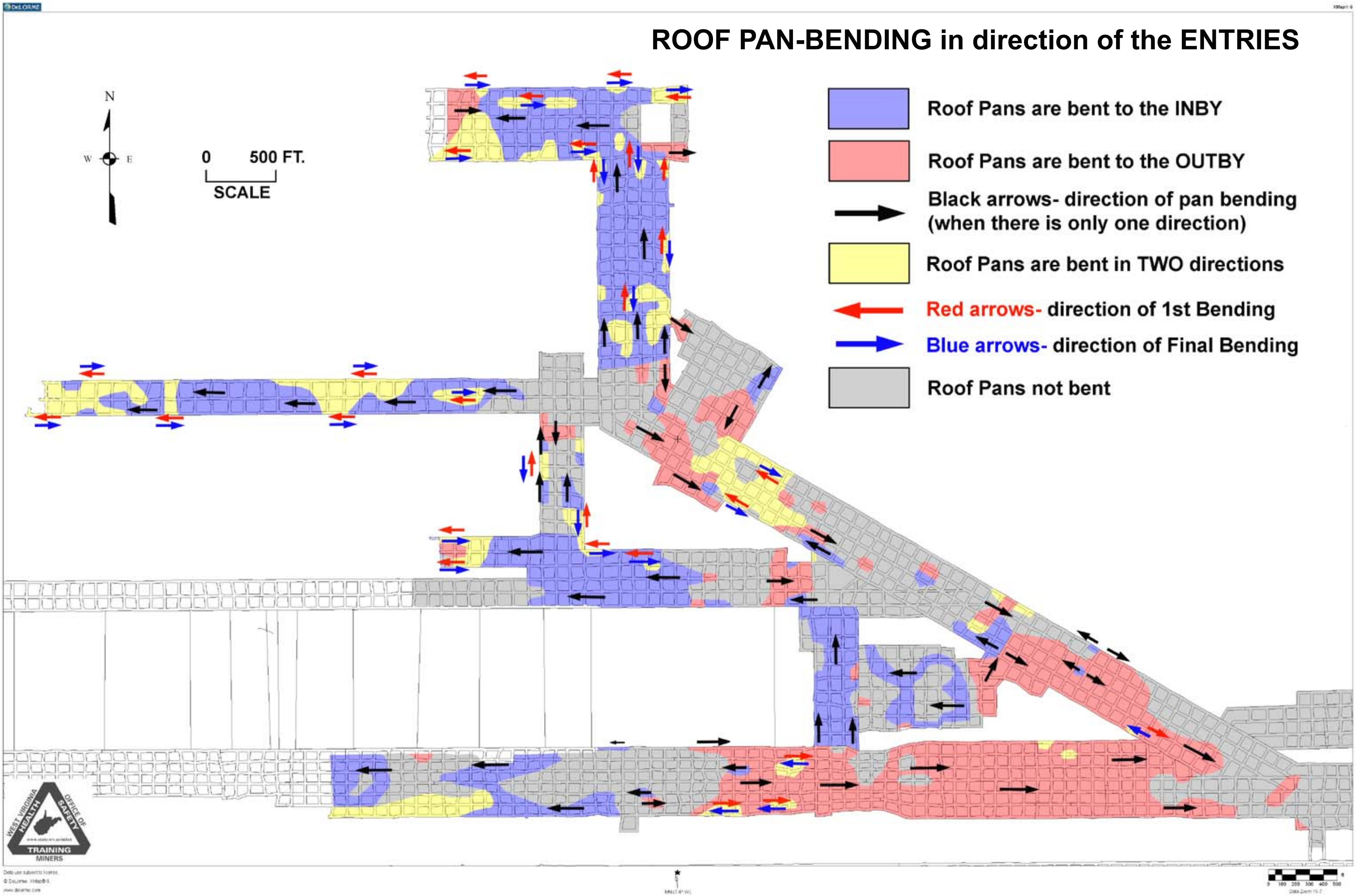
SECTION 7.9 MAP 2



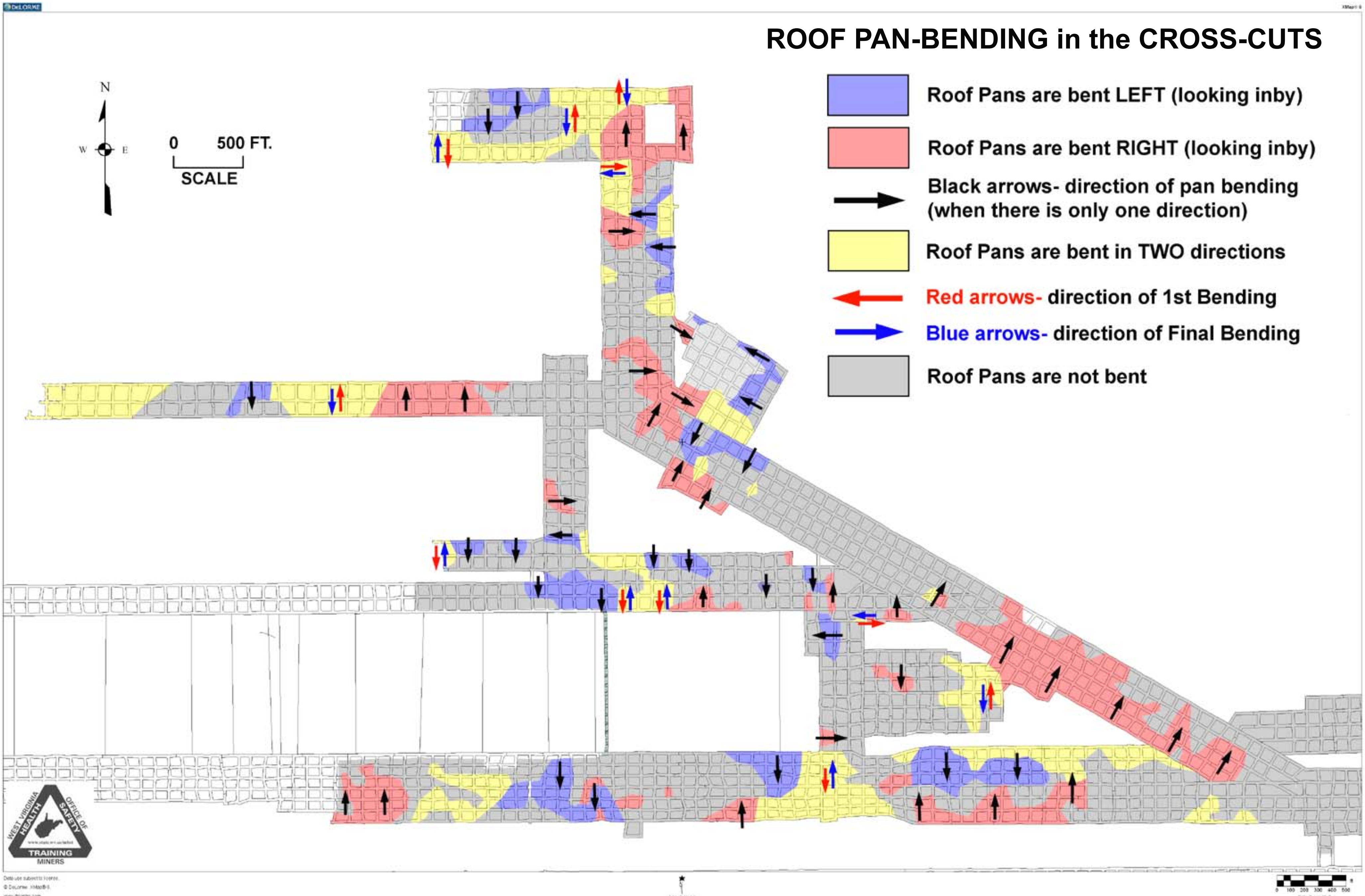
SECTION 7.9 MAP 3



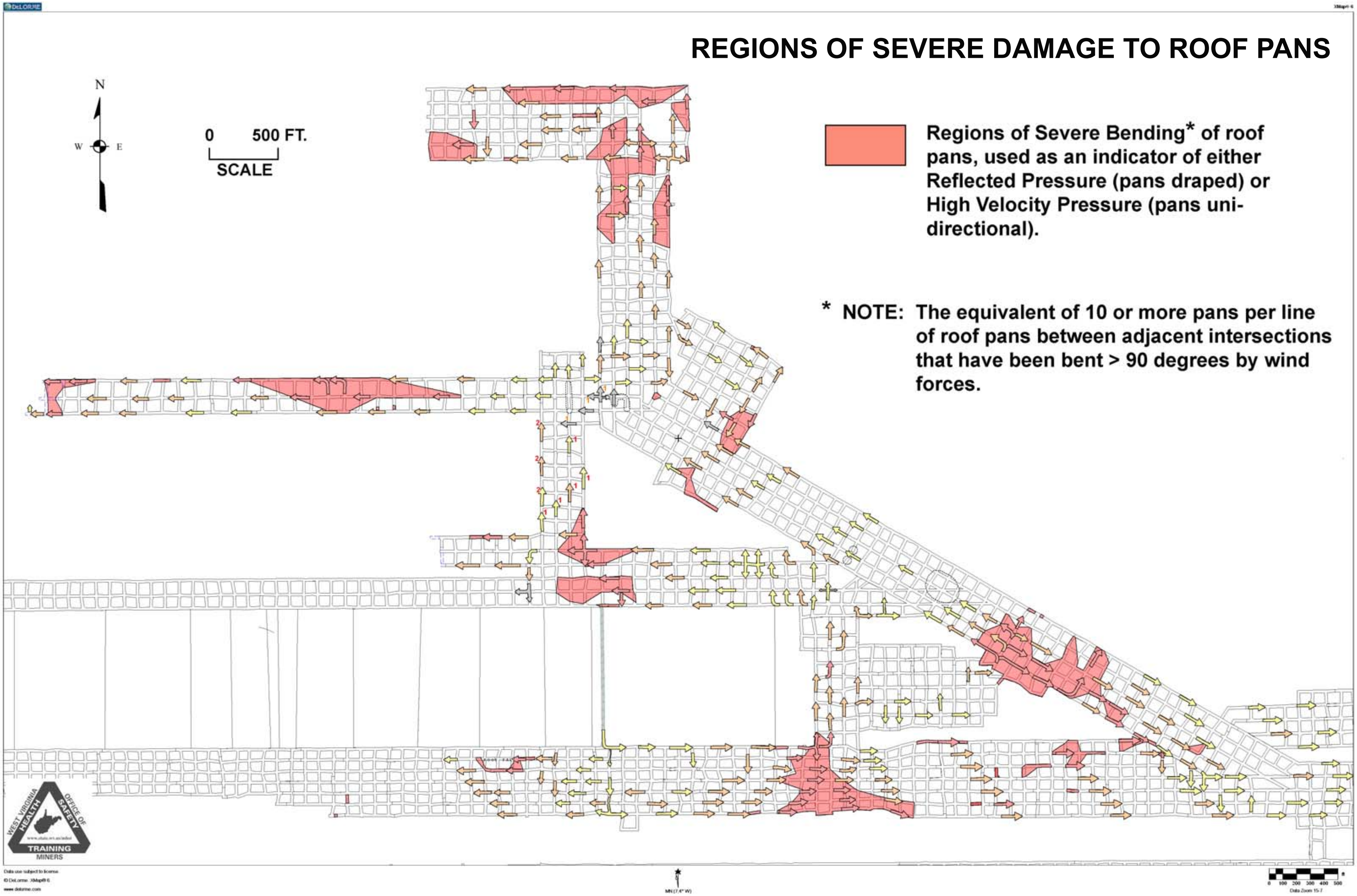
SECTION 7.9 MAP 4

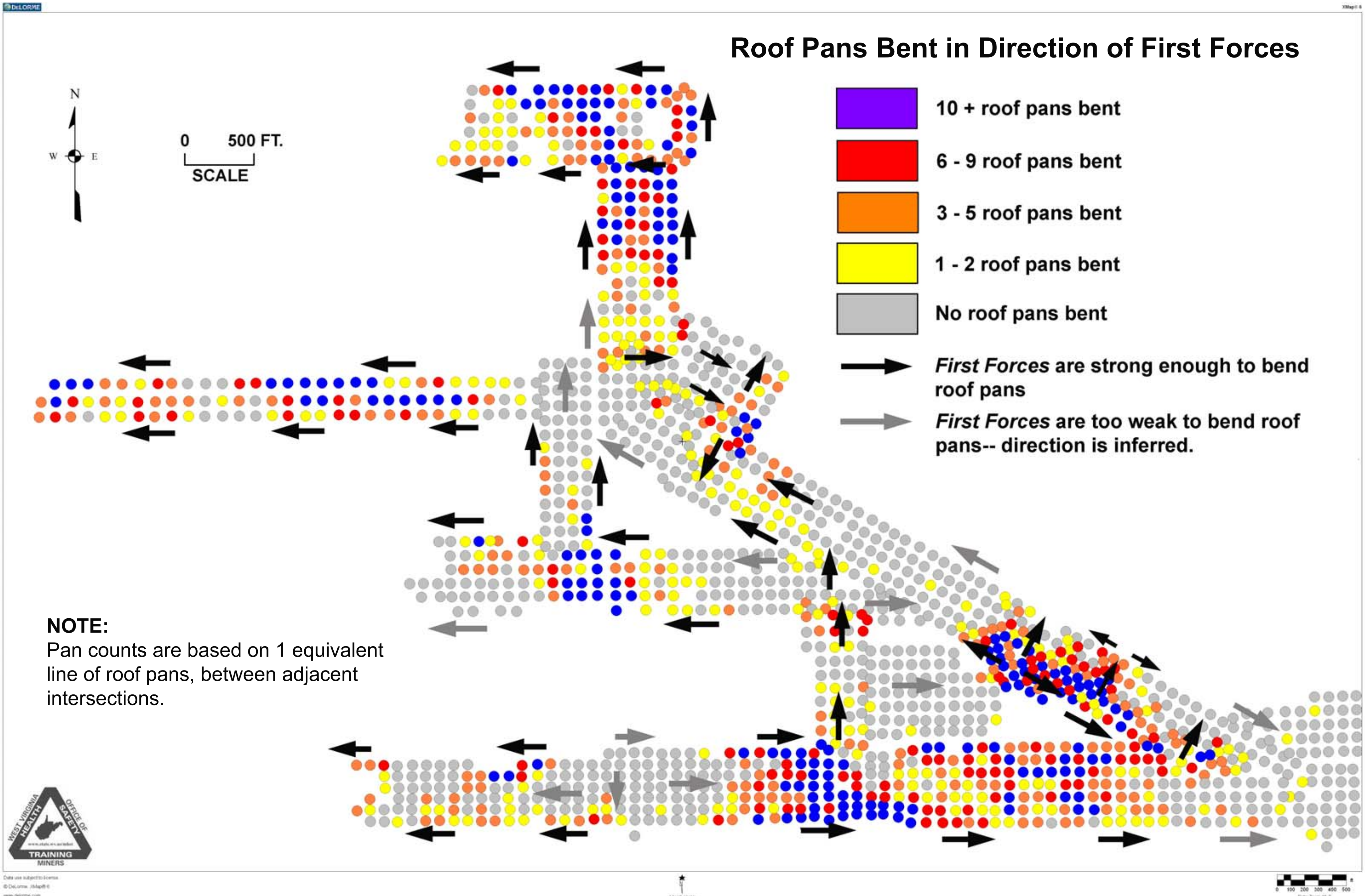


SECTION 7.9 MAP 5

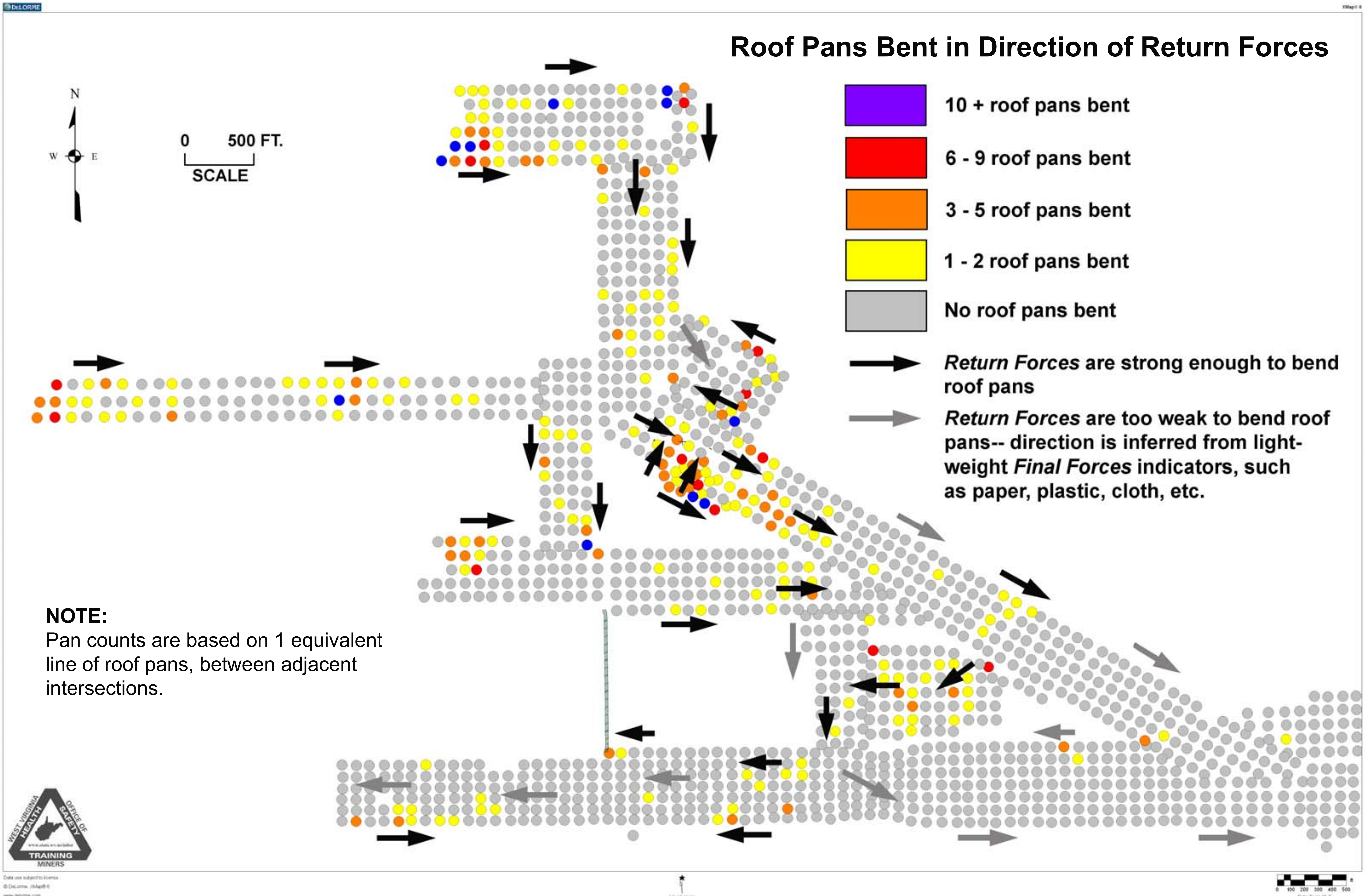


SECTION 7.9 MAP 6

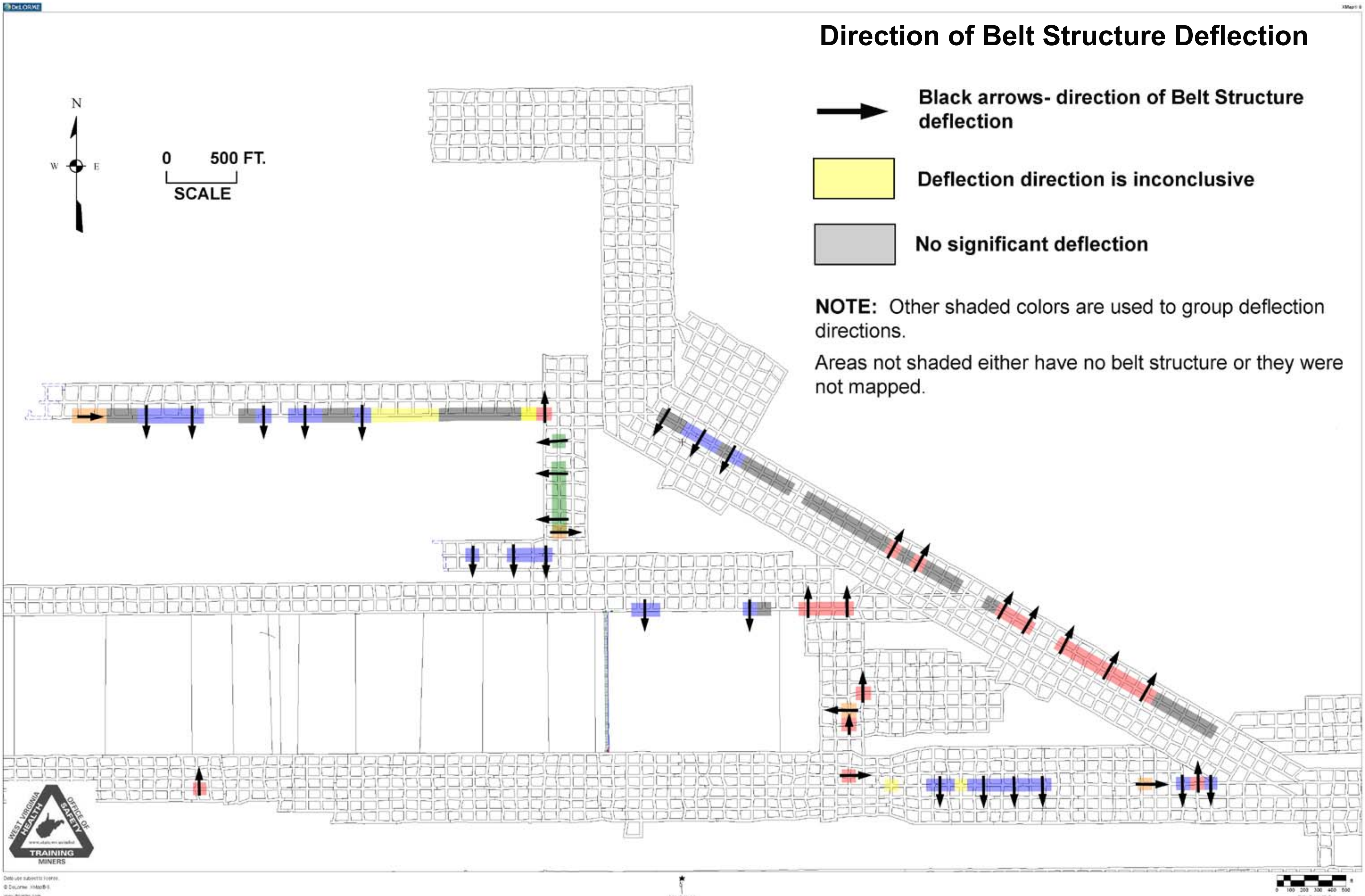

REGIONS OF SEVERE DAMAGE TO ROOF PANS
N
W
E
0 500 FT.
SCALE
Regions of Severe Bending* of roof pans, used as an indicator of either Reflected Pressure (pans draped) or High Velocity Pressure (pans uni-directional).
* NOTE: The equivalent of 10 or more pans per line of roof pans between adjacent intersections that have been bent > 90 degrees by wind forces.
WEST VIRGINIA HEALTH SAFETY OFFICE OF
TRAINING
MINERS



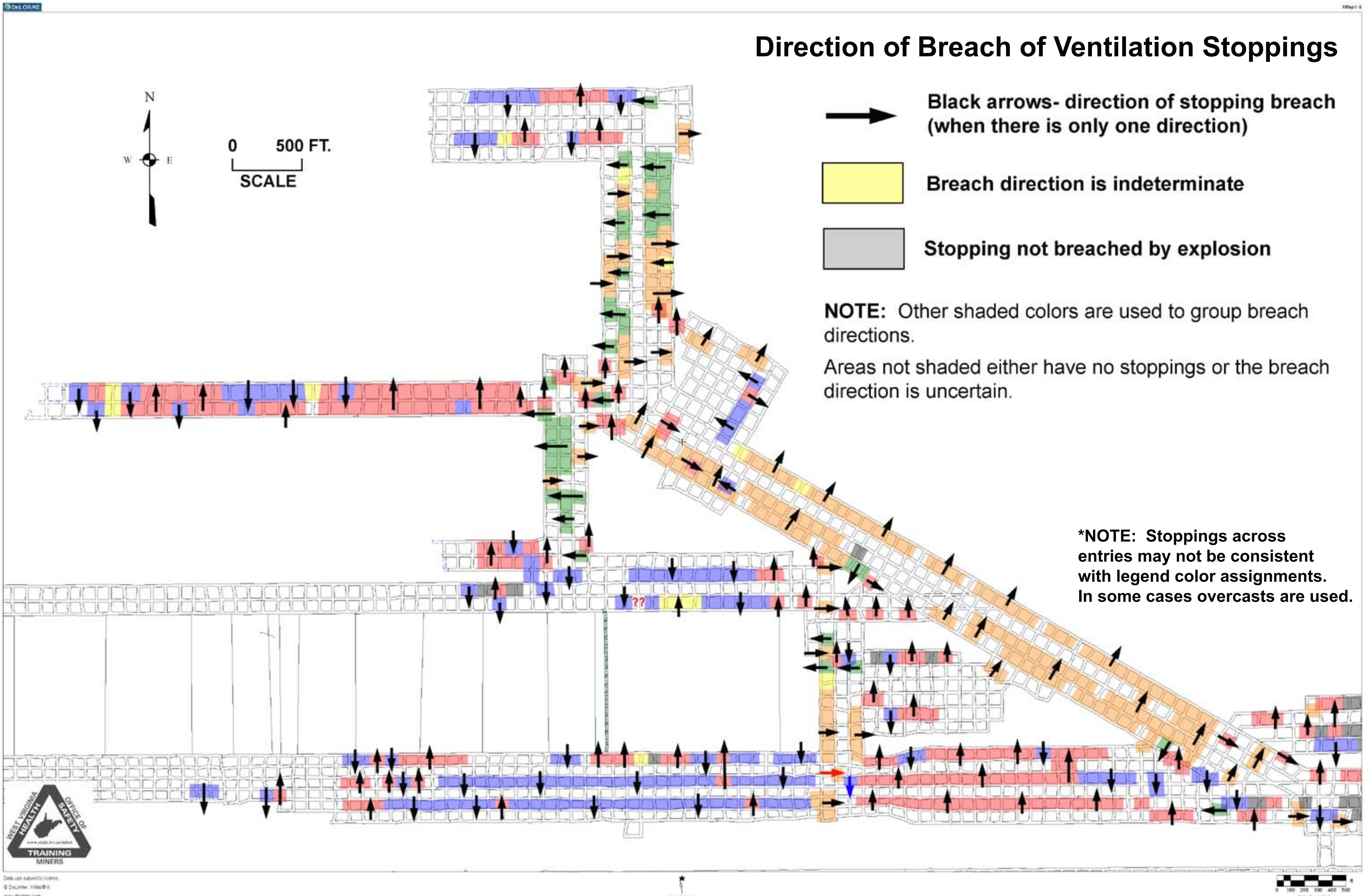
SECTION 7.9 MAP 8



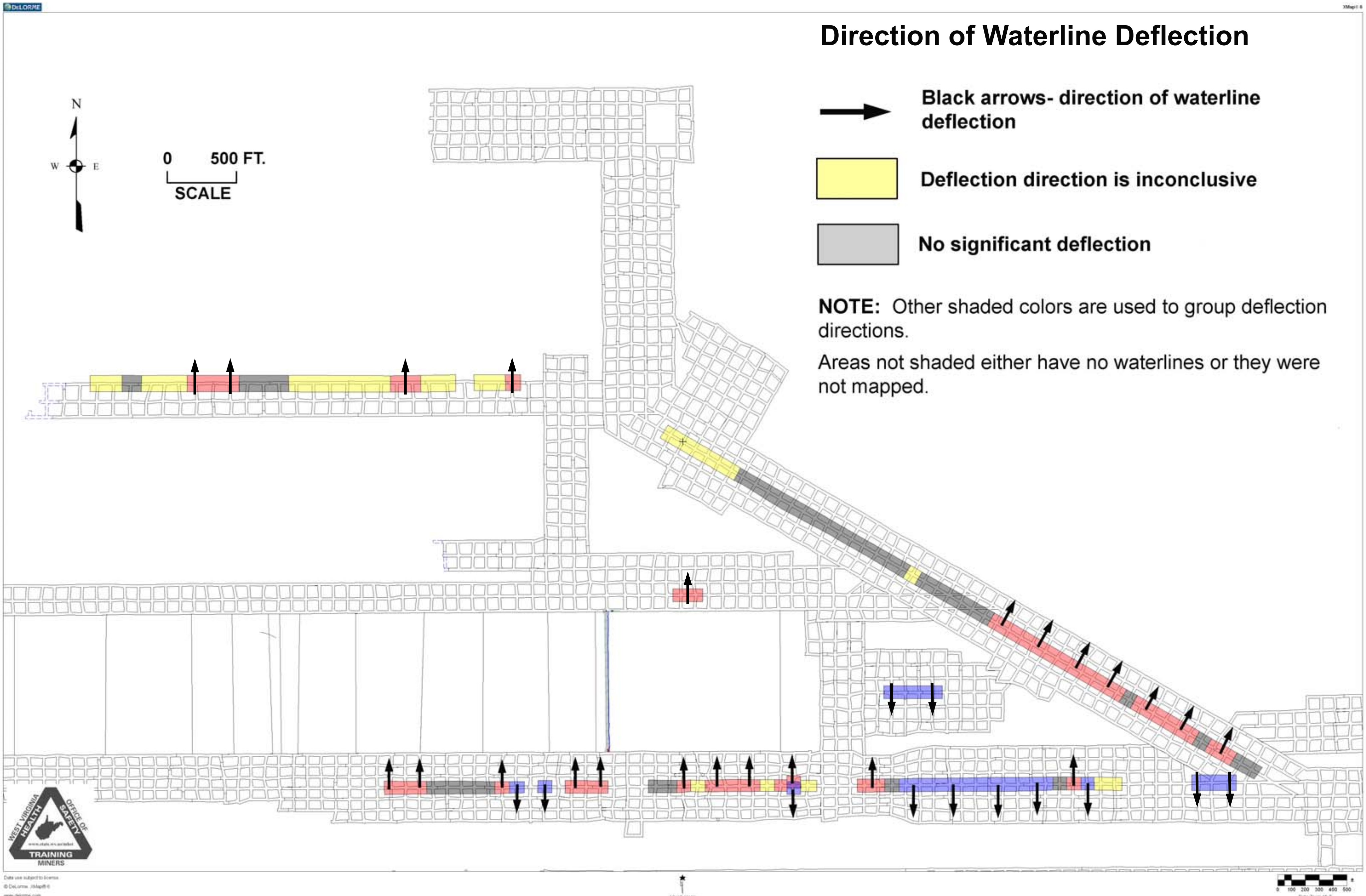
SECTION 7.9 MAP 9



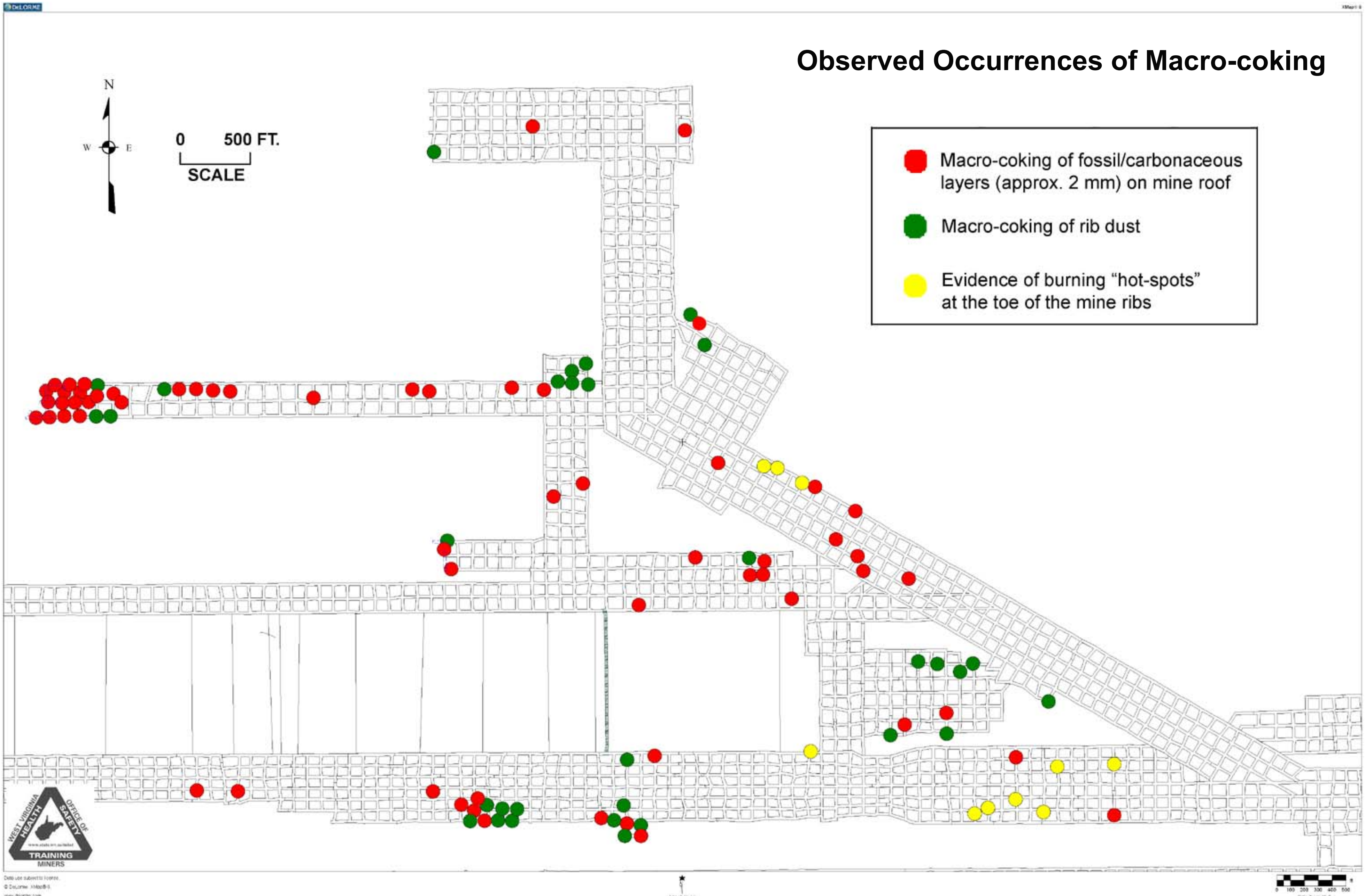
SECTION 7.9 MAP 10

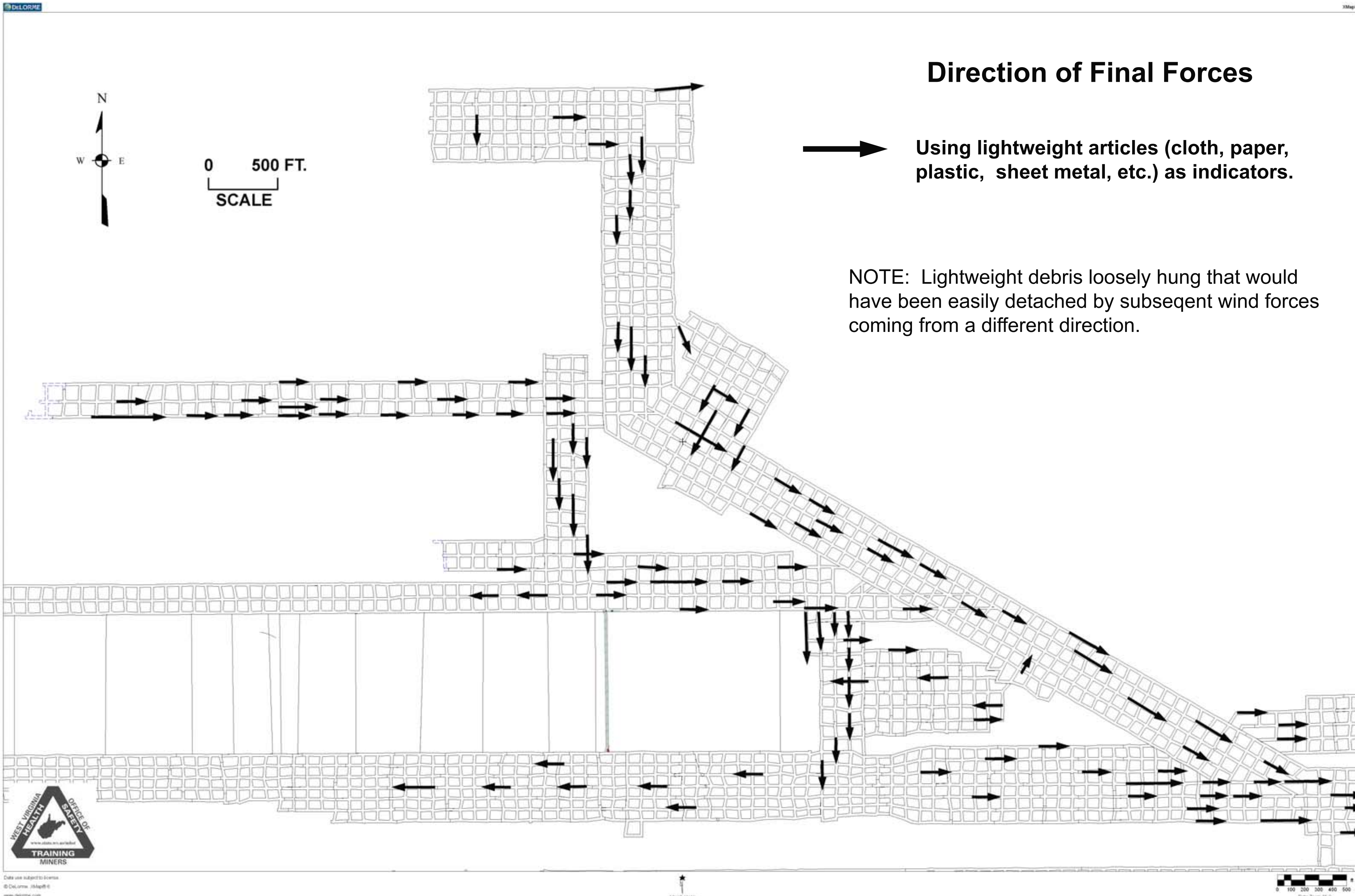


SECTION 7.9 MAP 11



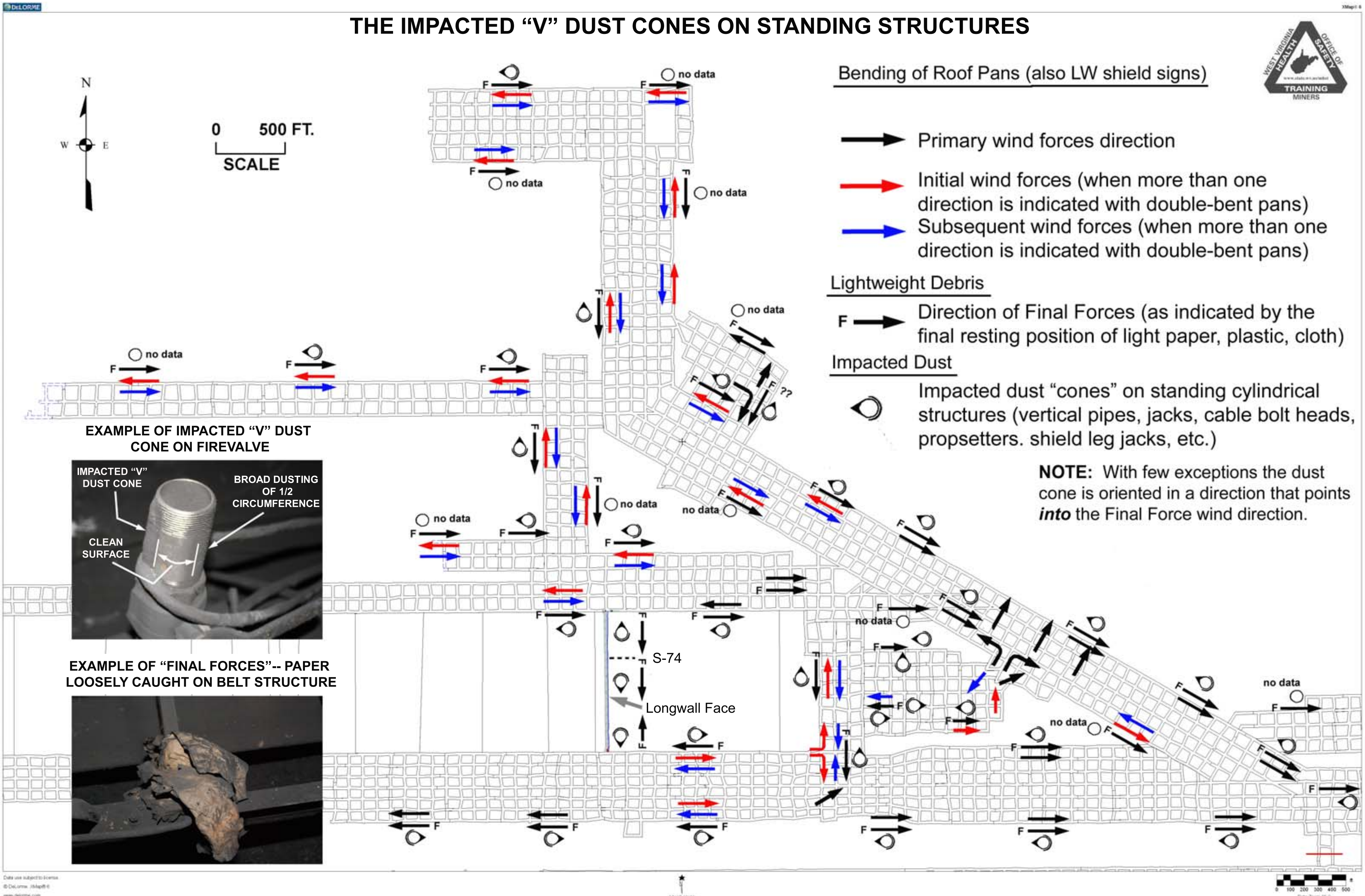
SECTION 7.9 MAP 12

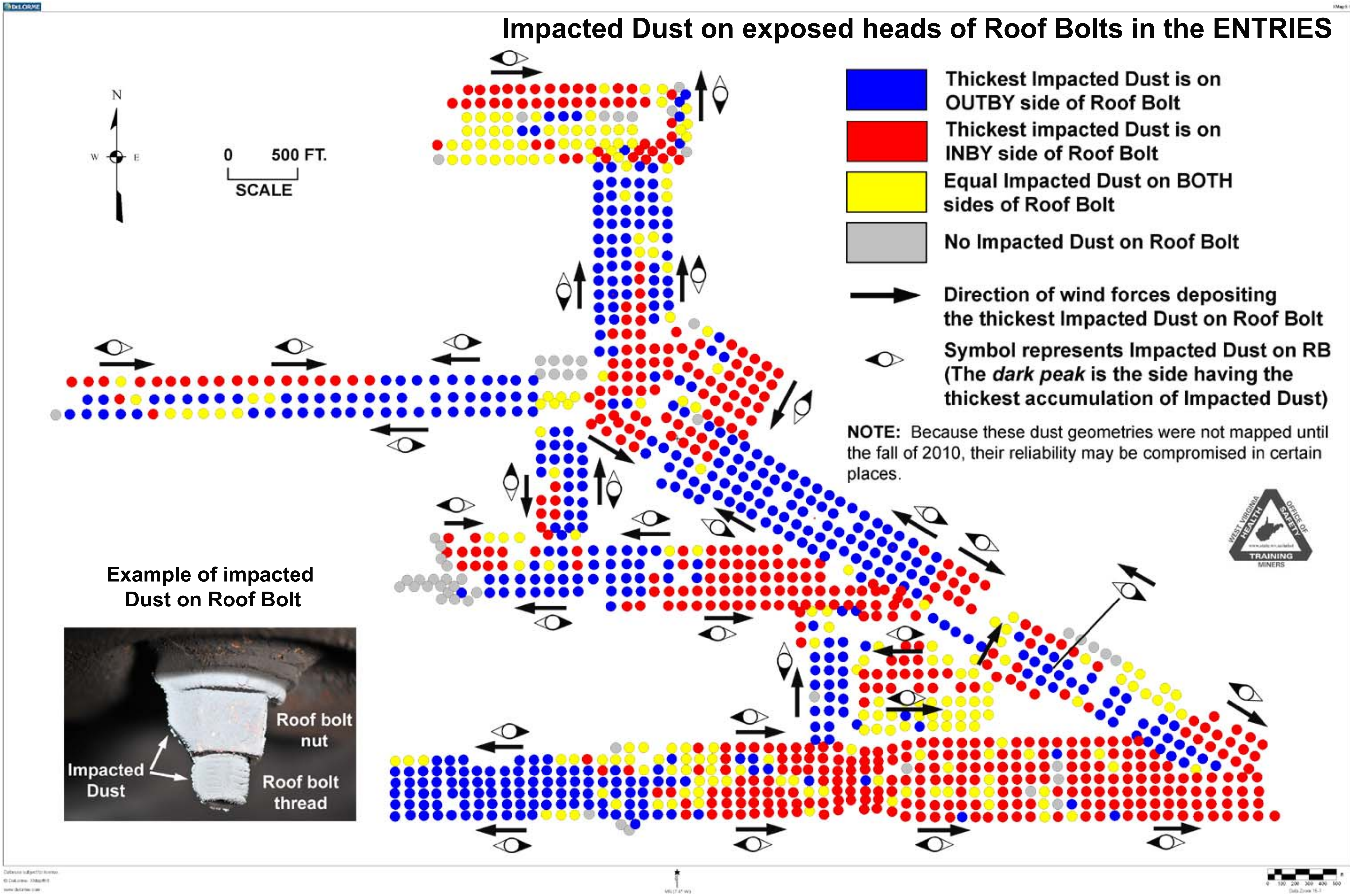

Observed Occurrences of Macro-coking
N
W
E
0 500 FT.
SCALE
Macro-coking of fossil/carbonaceous layers (approx. 2 mm) on mine roof
Macro-coking of rib dust
Evidence of burning "hot-spots" at the toe of the mine ribs
WEST VIRGINIA HEALTH
OFFICE OF SAFETY
TRAINING
MINERS



SECTION 7.9 MAP 14

THE IMPACTED "V" DUST CONES ON STANDING STRUCTURES



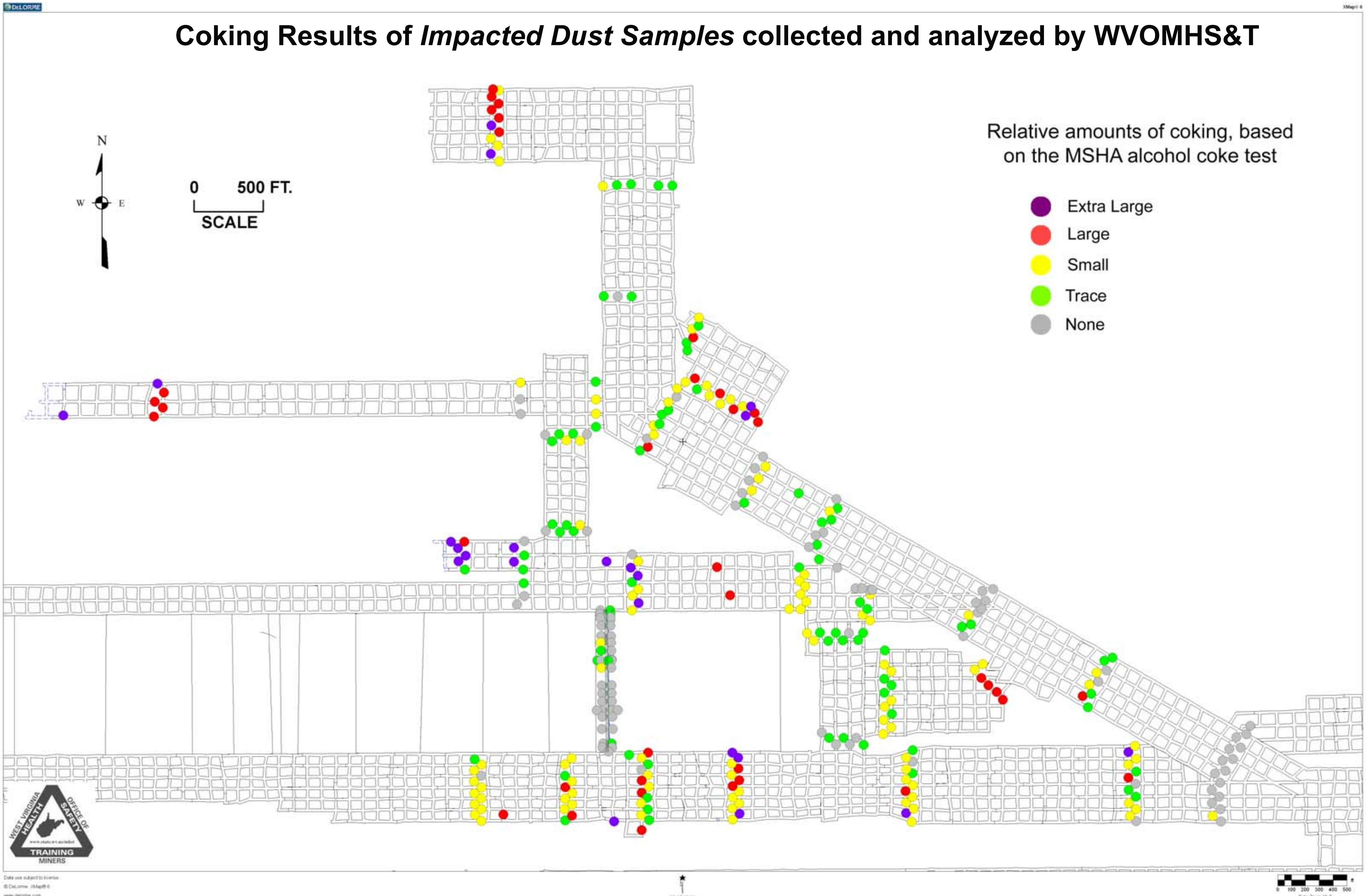


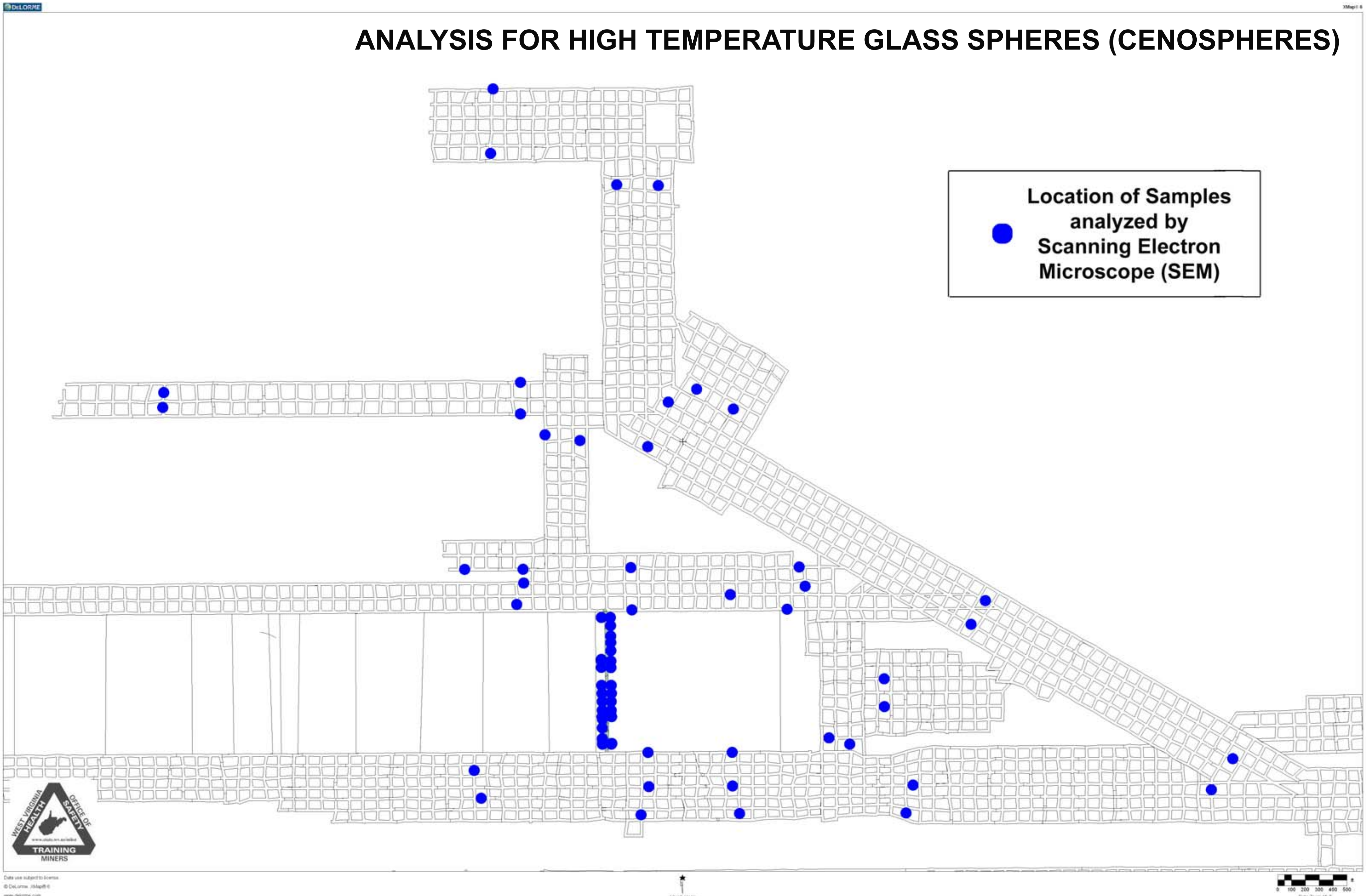
SECTION 7.9 MAP 16

Total Incombustible Content (TIC) of *Impacted Dust Samples* Collected and Analyzed by WVOMHS&T

SECTION 7.9 MAP 17

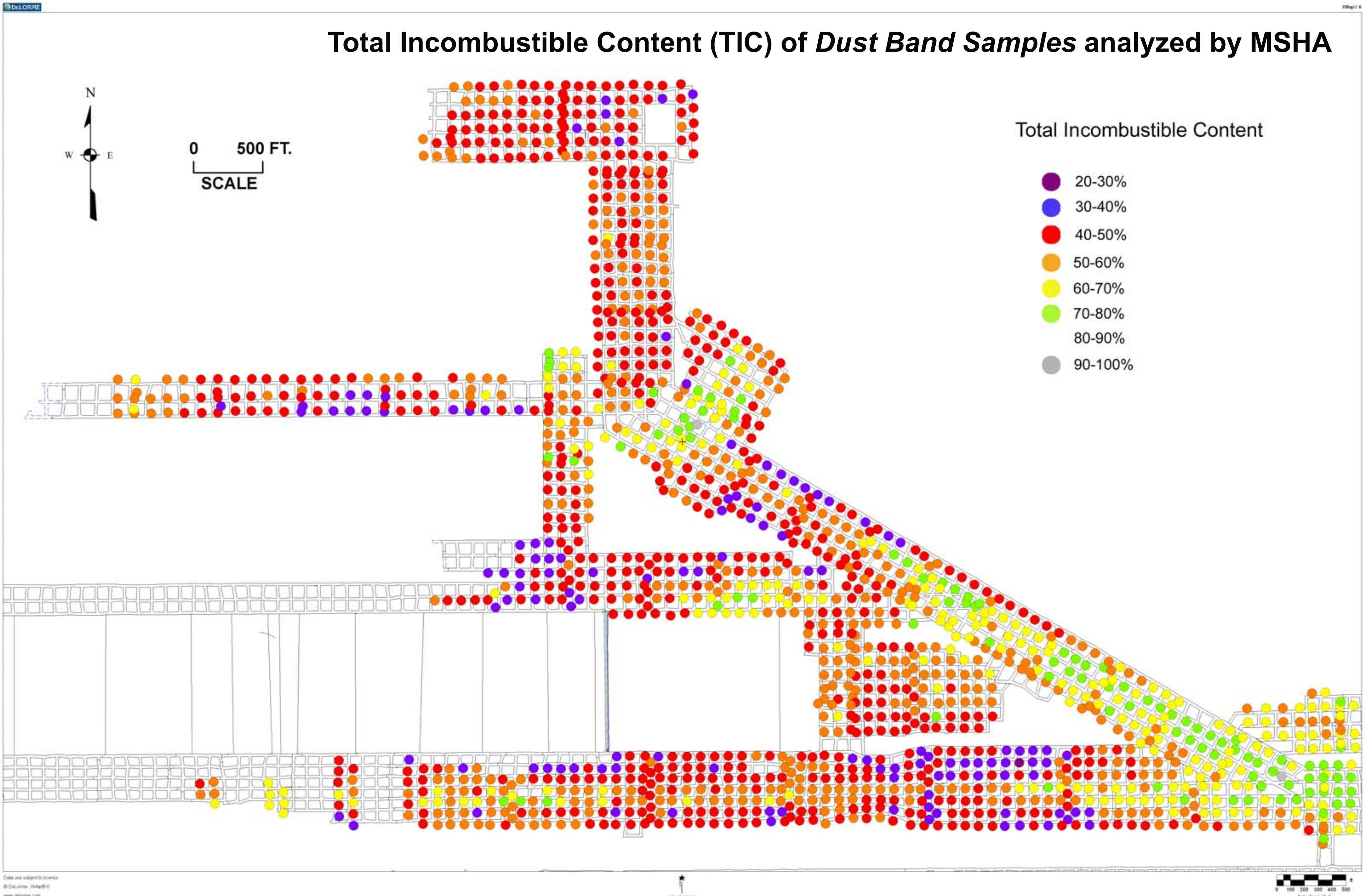
Coking Results of *Impacted Dust Samples* collected and analyzed by WVOMHS&T



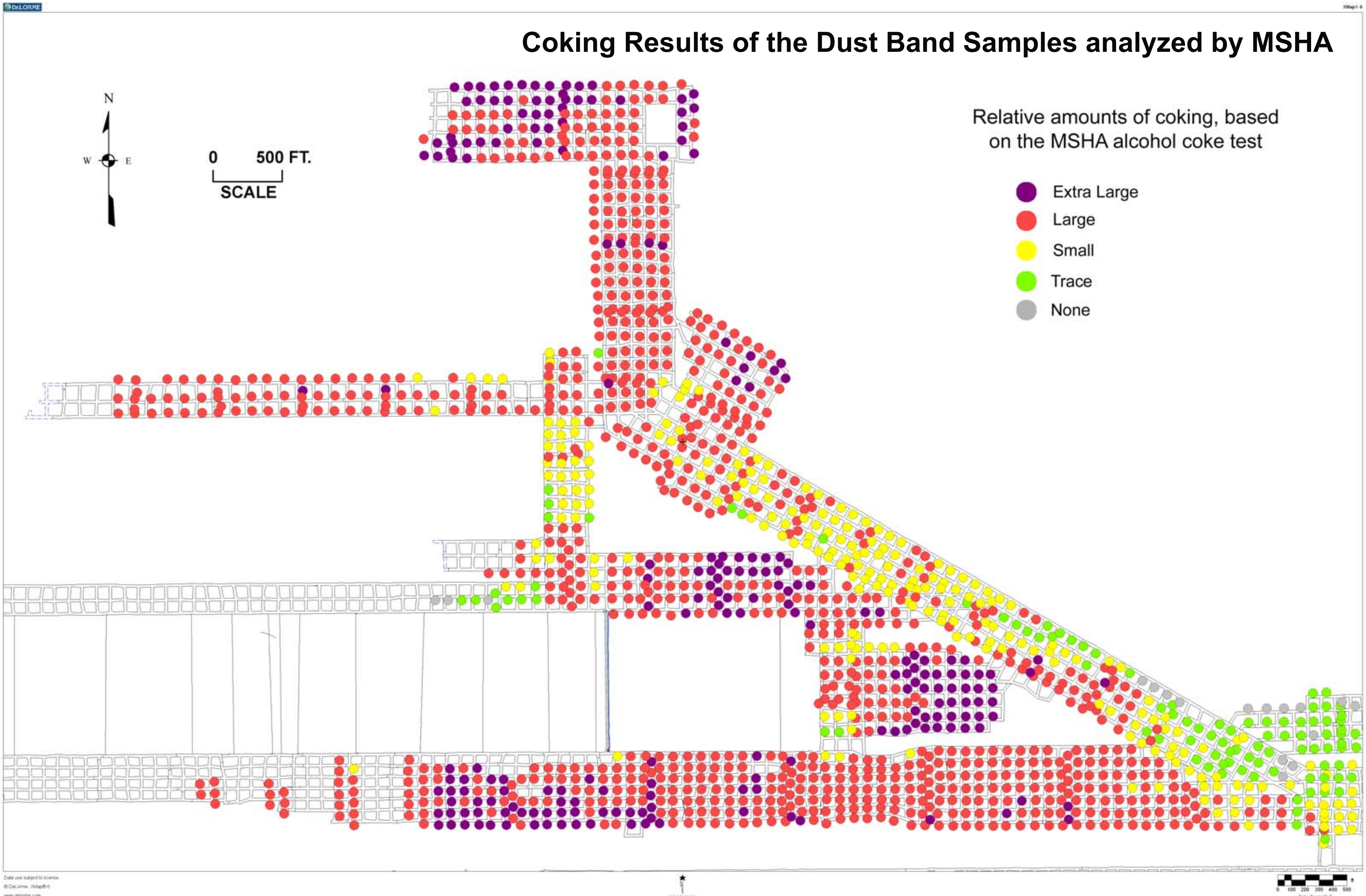


SECTION 7.9 MAP 19

Total Incombustible Content (TIC) of *Dust Band Samples* analyzed by MSHA



SECTION 7.9 MAP 20



SECTION 7.9 MAP 21

8 Source of Fuel for the Explosion

8.1 Mine Gases

8.2 Coal Dust

8 Source of Fuel for the Explosion

8.1 Mine Gases

Methane as Fuel for the Explosion

The ventilation system is central to a determination of the source of methane. A positive airflow was moving around the perimeter of the longwall gob, which is good. However, pressure drops across the gob between gate roads are believed to be minimal[1] and, as a result, it is believed the gob could accumulate and hold gas, especially when you consider that the gob was likely the most gas-producing area of the mine. Evidence obtained during the investigation indicates that the mine floor on the longwall face was a major source of methane. Air samples taken July 23 and 26, 2010, and October 26 and 28, 2010, from a floor crack near shield 160 contained methane, even though it was some months after the explosion. Air samples near the floor on #22 Headgate also contained methane. Analyses showed small concentrations of other hydrocarbon gases such as ethane, propane and even hydrogen. Samples from the cracks behind the shields when reduced to an air free analysis contained amounts of ethane and other higher hydrocarbons similar to samples taken from a gas well. See **Table 1** for the results of these air analyses. Gases associated with coal beds typically contain mostly methane, but it is not

[1] MSHA Ventilation Model

unusual to see other gases in small amounts as found at UBB.[2] The amounts of other gases did not significantly affect the lower explosive limit, which was calculated to be about 4.5% to 4.6% in air for the samples collected after the explosion.

Sample location	Date	CO	H_2	O_2	CO_2	CH_4	C_2H_6	C_2H_6/CH_4
Well head sample	4/22/10	nd	nd	nd	0.113	89.59	4.823	0.054
#197778 Shield 160	10/26/10	nd	0.103	15.4	0.077	23.19	1.59	0.068
#192340 Shield 160	7/26/10	nd	0.09	17.73	0.07	13.56	0.895	0.066
#PE-0201 Shield 160	7/23/10	nd	0.12	17.61	0.07	13.89	0.94	0.0676
#PE-0202 Shield 160	7/23/10	nd	0.21	14.26	0.12	28.13	1.84	0.0654
#193985 #3 entry HG 22	8/25/10	nd	nd	20.18	0.068	4.29	0.0011	0.00026
#193973 22 TG	8/18/10	nd	nd	5.15	0.34	75.01	0.0221	0.00029
#193974 22 HG	8/24/10	nd	nd	4.32	0.4	78.83	0.0111	0.00014
#193975 22 HG mouth	8/24/10	nd	nd	5.01	1.03	74.97	0.023	0.0003

Table 1. Analyses of gas samples taken in floor cracks behind the longwall shields and on development sections

Previous outbursts of gas occurring from cracks in the mine floor near longwall shields on February 18, 2004, and on July 3, 2003 (see **Section 3.2**), provide more evidence to indicate that the breaks in the mine floor can be a major source of gas.[3] The Eagle coalbed is not very gassy, but the longwall gob area is known to liberate gas. Further evidence of this fact is illustrated by the occurrence of a methane gas ignition at or near the tailgate in the gob directly behind the shields on January 4, 1997.[4] This ignition did not result in serious injuries and was attributed to friction between falling rock and/or rock striking the shields. This ignition occurred as the shearer cut out on the tail. The shearer was cutting down and the bits were not against the mine roof. The gas burned behind the shields on the face side of the gob for some period of time. In

[2] Kim, A. G., The Composition of Coalbed Gas, Bureau of Mines, RI 7762. Kim, A. G., Experimental Studies on the Origin and Accumulation of Coalbed Gas, Bureau of Mines. RI 8317. Kim, A. G., Gases Desorbed From Five Coals of Low Gas Content, Bureau of Mines, RI 7768.

[3] MSHA memorandum reports from Technical Support to the District Manager dated March 4, 2004 and July 13, 2004.

[4] Report of Methane Gas Ignition, Office of Miners' Health, Safety and Training, January 4, 1997 (see **Appendix 3.2-1**).

summary, it was known that the mine floor liberated gas, and sometimes quite a lot, as learned from the previous methane outbursts. The Little Eagle coalbed was below about 10 to 15 feet, and is considered to be a source of methane. See **Appendix 2.2-1** for more information.

Air currents follow the path of least resistance, and air currents flowed around the gob and to the fan following the open air courses. Little pressure incentive existed to cause airflow through the gob. Most of the air current on the longwall face stayed in the larger area under the shields, as evidenced by the air velocity readings taken on the longwall face. Methane that migrated out of the floor cracks behind the shields would be induced by slow air velocity at that location to move along the gob behind the shields to the tailgate. It most likely did not mix much with the air current on the face and stayed relatively intact as a gas cloud until it reached the tailgate.[5] Most of the air on the face under the shields made an abrupt turn to the left, outby, in #7entry, and then after a few feet turned right through the partially open crosscut to #6 entry. It was probably joined by air currents moving inby in # 7entry, which also turned through that crosscut. Gob had fallen across the #7 entry inby the shields blocking #7 entry allowing only a very small amount of the face air to penetrate that fallen area. This abrupt turn to the left resulted in part of the air current striking the far rib, resulting in eddy currents moving in somewhat a circle causing air recirculation in that space against the gob in #7 entry (see **Figure 1** and **Appendix 8.1-1**). This recirculation resembles that which occurs when a river bends and creates a recirculation pattern on the outside of the bend. The result is that methane can accumulate to above the explosive limit in a poorly mixed zone of methane and air, and this methane would have a direct connection to the gases moving along the gob's edge. The zone of poorly mixed gas and air, having complex air turbulence, could result in some explosive mixtures in the vicinity of the shearer cutting bits as the shearer cut through the sandstone at the tailgate.

We have studied the theory that the explosion was caused when a massive inundation of gas in the tailgate entry at the longwall face permeated the area and was ignited. Methane is light and easily moved by air currents such as those moving across the longwall face. It is highly unlikely that gas would have moved from the longwall tailgate against this face ventilating current and

[5] Kissell, F. N. Handbook for Methane Control, National Institute for Occupational Safety and Health, IC 9486, page 12.

contaminated the face area into the headgate. The air in the longwall face had a velocity of at least 700 feet per minute. Methane would not move upstream in that air current, nor does the evidence along the face indicate that a methane deflagration occurred on the longwall face, which surely would have occurred if flammable methane-air mixture had migrated upstream along the longwall face.

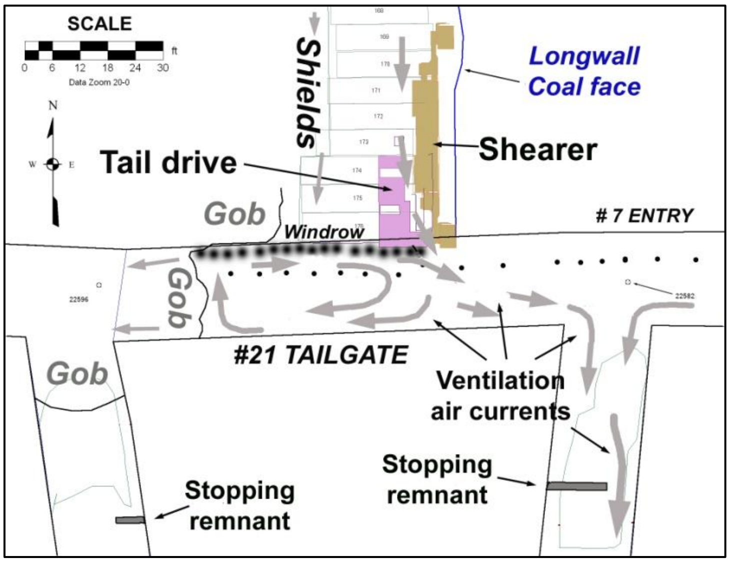


Figure 1. Junction of the Longwall with the #7 entry of #21 Tailgate. Normal ventilation path is blocked by gob.

The return from the longwall face combined with air in #7 entry totals about 67,000 cubic feet per minute. Air quantities used in this discussion are from the most recent examinations when available and when not contradicted with more reliable information. Using this quantity and the known area of the regulator, the velocity in that regulator to #6 entry would be about 1,600 feet per minute, sufficient to promote mixing of a body of gas from the tailgate area. A quantity of methane exceeding 3,300 cfm would be necessary to result in an explosive mixture past this regulator, assuming a complete mixing. Once through the regulator, the low pressure area, and air movement were toward the Bandytown fan. Methane diffused in the air current as it flowed through the high-velocity at the regulator into #6 entry, would not re-stratify or separate from the air and therefore it would be carried with the air as it flowed to the low pressure area on its way to Bandytown.

The air volume in tailgate entries 3 through 7 had air currents moving inby towards the longwall and on to the Bandytown fan. A volume of about 54,000 cfm total flowed in these entries and the air velocity ranged from about 59 to 114 feet per minute. If methane did migrate into this area from inby it could accumulate as a layer near the roof since such low velocities are not enough to control methane layering,[6] or, for that matter, to have much energy to move methane away. These aircourses were essentially flat, about 0.7% grade, so methane did not have much tendency to drift outby along the roof. Methane accumulations that might have layered in the tailgate entries would have been confined to that area because the high-velocity in the regulators upstream would have prohibited methane from moving out of the tailgate entries.

After the tailgate split mixes with the face air the combined total volume would be at least 111,000 cfm. The average velocity in the tailgate entries inby the longwall face would be about 198 feet per minute, a better velocity for moving methane to the Bandytown fan. The leading edge of such a methane-air body would reach the Bandytown fan in about one-half hour (the velocity speeds up when the airways are reduced to 4 entries inby the longwall panel).

Whether an increase in methane liberation along the face was of sufficient intensity and duration to cause some amounts of methane in the tailgate entries is unknown. The foreman in charge of the work behind the longwall traveled through that area about 1 p.m. or 2 p.m. on April 5, 2010. He reported the ventilation conditions as being normal but, based on the results of the download of the information stored on his detector, it was determined that the foreman's multi gas detector had not been turned on at any time during his normal shift while performing work behind the longwall on April 5, 2010.

Flame from an ignited methane accumulation along the longwall gob behind the shields or an ignited methane accumulation of a body of gas at the shearer would certainly have traversed some distance out the tailgate; however, it is not believed that the flame from a methane

[6] Kissell, F. N. Handbook for Methane Control, National Institute for Occupational Safety and Health, IC 9486, page 12.

explosion at this location could have continued throughout the explosion area since methane would not have spread outby prior to ignition.

Those with the opinion that a sudden massive outburst occurred look for evidence in the amount of gas found after the explosion in samples at the Bandytown fan in excess of the normal mine liberation and the relationship between ethane and methane in the samples collected at the fan. The first analysis available was from a sample taken at 8:30 p.m. on the day of the explosion, and it contained 0.42% methane. A WVOMHS&T inspector testified that he used his detector in the fan discharge at 5:20 p.m. and found 2.3% methane; a repeat test some time later indicated no methane. Without other substantive data, this information is inconclusive. No other air quality information is available in the Bandytown fan record until MSHA collected the air samples beginning at 8:30 p.m.

Rather than a dramatic outburst, it is more reasonable to believe that methane was liberated along the face in increased amounts caused by the breaks in the floor and from the gob, and that this increased liberation caused an undetected buildup against the gob behind the shields. Gas expansion, because of the decrease in the barometer 0.07 inches mercury or about 0.95 inches water gauge since 11 a.m., would cause additional methane to exude from the longwall gob, and this gas could come out near the face due to the ineffective pressure drop on the gob (see **Figure 2**). An unusual coincidence was discovered during a review of the ignition on the gob January 4, 1997. The barometer change was quite similar to the barometer trend during this explosion (see **Figure 6**).

Some methane likely entered the tailgate entries through the crosscuts to the gob just inby the face and contaminated that area inby the face against the gob fall in #7 entry. A portion of the face ventilation likely gradually passed through the shields to the gob along the 1,000 foot-wide face. This leakage was not enough to dilute the gob gas to below the explosive limit, but that flow direction, plus the amount of air remaining on the face, would have been sufficient to keep the active face area clear. Neither the methane monitors on the face equipment nor would the foreman with his detector on the face have detected this methane build-up.

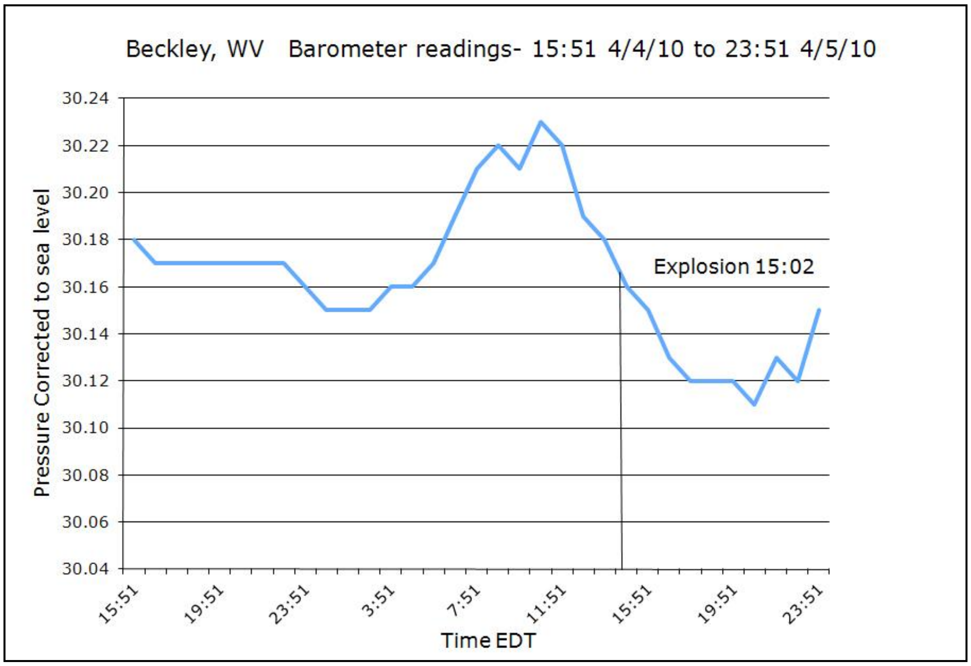


Figure 2: Showing Barometric pressure decline prior to explosion

Methane was still being liberated and found during the rescue effort. At 12:24 a.m., April 6, 2010, the rescue team advanced to shield 120, their farthest advance at that time, and detected over 2% methane. The ventilation on the longwall face would have been greatly reduced at this time because the ventilation controls to direct air to the face had been destroyed. No mention was made about sounds such as would be found from an on-going methane outburst.

A substantial source of methane after the explosion was the methane generated along with other combustion products during the explosion. This methane would have been distributed throughout the explosion area.[7] The products of combustion, including the methane, were gradually moved to the Bandytown fan by the ventilation currents.

[7] Conti, D. S. et al Rapid Sampling of Products During Coal Mine Explosion, NIOSH, Pittsburgh Pa

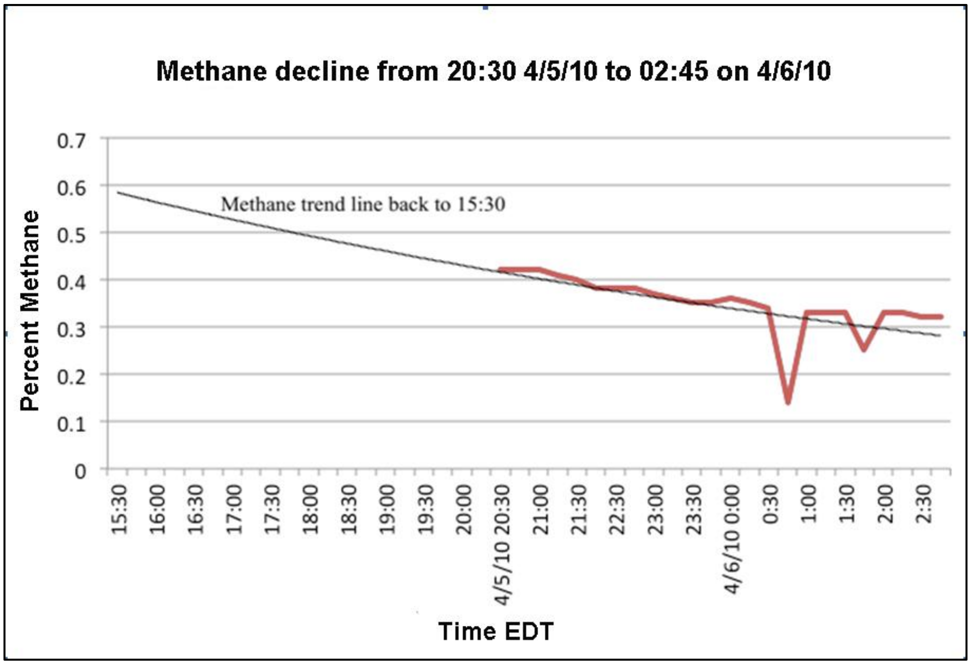


Figure 3: Methane trend after the sampling started projected back to 15:30

It is believed the combustion products started arriving at Bandytown about 3:30 p.m. and continued to be diluted and moved to the fan by the air currents. The combustion gases on the longwall gate entries and those mine openings in direct line with them should have been purged of the combustion gases within a few hours. Analysis of the gas trends suggest that about one-third of the combustion products had passed through the Bandytown fan by the time MSHA sampling was started at 8:30 p.m. (see **Figure 3**). Remnants of combustion gases remained in the continuous mining sections, the North area and Glory Hole area for some time until they were flushed out during recovery. The characteristics of this gas are found at Borehole #1 where sampling started at 10:55 a.m. April 7 (see **Table 2**).

TIME	GAS CONCENTRATION DATA FOR BOREHOLE NO. 1 – 4/ 7, 2010										Jones Trickett Ratio
4/7/10	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 %	
10:55	9979	15.31	75.78	3	14250	2.44	251	1001	300	0.91	
10:55	9424	15.68	75.93	2.8	13169	2.29	251	1001	300	0.91	0.65
11:30	9151	15.89	75.98	2.71	12812	2.17	251	1001	300	0.91	0.65
12:00	3374	17.63	76.86	1.8	8077	1.55	251	1001	300	0.91	0.70
12:45	8646	16.20	76.04	2.62	12072	2.44	251	1001	300	0.91	0.75
13:45	8404	16.26	76.03	2.64	11799	2.01	202	826	200	0.91	0.65
14:15	8152	16.51	76.27	2.46	11202	1.8	178	743	200	0.91	0.62
15:00	3284	18.74	77.19	1.29	5194	0.95	91	386	100	0.92	0.64
15:30	7437	16.86	76.17	2.51	9852	1.71	134	706	200	0.91	0.63
16:00	7467	16.89	76.19	2.4	9999	1.74	260	690	200	0.91	0.65
17:30	7437	16.86	76.17	2.51	9852	1.71	134	706	200	0.91	0.63
18:00	7122	17.14	76.27	2.36	9090	1.59	139	659	200	0.91	0.63
18:30	7406	16.95	76.13	2.52	9808	1.66	169	690	200	0.91	0.64
19:00	7343	16.99	76.14	2.52	9635	1.65	169	681	200	0.91	0.64
19:30	7124	17.04	76.14	2.51	9537	1.63	164	676	200	0.91	0.64
20:00	6964	17.11	76.15	2.50	9451	1.59	164	659	200	0.91	0.64
20:30	6664	17.27	76.22	2.42	8914	1.53	157	628	200	0.91	0.64
21:00	6697	17.25	76.20	2.46	9041	1.51	149	640	200	0.91	0.63
21:30	6564	17.30	76.17	2.46	8737	1.53	144	603	200	0.91	0.65
22:00	6562	17.35	76.20	2.45	8695	1.48	167	616	200	0.91	0.64
22:30	5683	17.93	76.49	2.07	7104	1.24	127	513	100	0.92	0.63
23:00	6107	17.65	76.31	2.29	7912	1.35	140	559	200	0.91	0.64
23:30	6017	17.67	76.29	2.3	8062	1.33	113	528	200	0.91	0.64
Data from MSHA records											

Table 2: Samples from Borehole 1 on the #22 Headgate section, collected 4/7/10

There were four independent sources of gases exhausting out the Bandytown fan. After the explosion, some methane, carbon dioxide and oxygen-depleted air entered the mine from the large sealed area south of Old North Mains. Damage to ventilation controls caused the air current ventilating the seals to reverse from seal set 8 through 15, and this ventilation now went to the Bandytown fan. Each seal set had water traps, with pipes in at least one seal per set, installed for water control through the seals. A total of 18 pipes existed in seal sets 8 thru 15, each pipe having diameters of approximately seven inches. The water traps in most of these pipes were found empty during re-entry, and they were likely empty immediately after the explosion due to the pressure wave from the explosion. The gradual decrease in the barometer (**Figure 4**) would cause expansion of the gases in the sealed area, and the water pipes provided sufficient path for the gas to escape in the ventilation to Bandytown. In addition, the pressure drop to the Bandytown fan would cause airflow into some of the pipes in seal sets farther away from the shaft, such as seal sets 8, 9 and 10, and flow out the remaining seal sets, especially 14 and 15. These air currents would affect the northeast segment of the sealed area. It is estimated that about 6,400 cubic feet per minute vented from this large sealed area to the Bandytown fan during the several hours after the explosion. Analyses of air samples from this sealed area indicate that it contained methane, carbon dioxide and oxygen-depleted air (see **Table 3:** Samples in the sealed area).

Isotech Mudgas Data
Job 16309
8 IsoTubes®

Company Lab No.	Isotech Lab No.	Sample Date	Sample Time	GC Date	H_2 ppm	O_2 + Ar ppm	CO_2 ppm	N_2 ppm	CO ppm	Methane C_1 ppm	Ethane C_2 ppm	Ethylene C_2H_4 ppm
Seal Set #8_#43 Seal	221010	9/14/2011	8:30	9/22/2011	nd	156700	24500	805600	nd	13100	108	nd
Seal Set #9_#44 Seal	221011	9/14/2011	9:15	9/22/2011	nd	79300	49700	854700	nd	16200	58	nd
Seal Set #10_#47 Seal	221012	9/14/2011	10:00	9/22/2011	nd	160500	25300	810800	nd	3350	7	nd
Seal Set #11_#50 Seal	221013	9/14/2011	10:45	9/22/2011	nd	155200	32100	812300	nd	377	nd	nd
Seal Set #12_#53 Seal	221014	9/14/2011	11:30	9/22/2011	nd	85700	44800	845700	nd	23500	219	nd
Seal Set #13_#56 Seal	221015	9/14/2011	12:15	9/22/2011	nd	101900	47000	843600	nd	7490	29	nd
Seal Set #14_#62 Seal	221016	9/14/2011	13:00	9/22/2011	nd	25700	86600	868700	nd	18900	29	nd
Seal Set #15_#63 Seal	221017	9/14/2011	13:50	9/22/2011	nd	19100	84800	850100	nd	45700	269	1

Chemical analysis based on standards accurate to within 2%. Hydrogen chemical analysis is accurate to within 10%
nd = not detected, na = not analyzed

Company Lab No.	Isotech Lab No.	Sample Date	Sample Time	GC Date	C_3 ppm	Propane C_3H_6 ppm	iC_4 ppm	nC_4 ppm	iC_5 ppm	nC_5 ppm	C_6+ ppm	Ethane / Methane Ratio
Seal Set #8_#43 Seal	221010	9/14/2011	8:30	9/22/2011	14	nd	4	2	1	nd	2	0.008
Seal Set #9_#44 Seal	221011	9/14/2011	9:15	9/22/2011	9	nd	6	2	1	nd	2	0.004
Seal Set #10_#47 Seal	221012	9/14/2011	10:00	9/22/2011	1	nd	1	nd	nd	nd	nd	0.002
Seal Set #11_#50 Seal	221013	9/14/2011	10:45	9/22/2011	nd	nd	nd	nd	nd	nd	nd	
Seal Set #12_#53 Seal	221014	9/14/2011	11:30	9/22/2011	29	nd	10	6	3	1	4	0.009
Seal Set #13_#56 Seal	221015	9/14/2011	12:15	9/22/2011	7	nd	4	2	1	nd	1	0.004
Seal Set #14_#62 Seal	221016	9/14/2011	13:00	9/22/2011	13	nd	7	2	1	nd	nd	0.002
Seal Set #15_#63 Seal	221017	9/14/2011	13:50	9/22/2011	23	nd	12	4	2	1	2	0.006
											Average	0.005

Table 3. Gas samples from sealed area taken 9/14/11

Another gas source includes the products of combustion, which include methane, hydrogen, carbon monoxide, carbon dioxide, acetylene, ethylene and ethane. The mine normally liberated methane and carbon dioxide from the mined coal and the gob areas. A fourth source of gas was the increased liberation of methane from the floor cracks, and during the investigation it was found that the gas from the floor cracks contained some ethane (see **Table 1**). All these gases mixed and left the mine through the Bandytown fan.

Efforts to use the ethane to methane ratio and determine how much of the methane coming out of the mine was from the floor cracks on the longwall face proved futile. Three gases that are combustion products, methane, carbon dioxide and ethane are also produced from other sources. Ethane is also contained in the floor cracks with methane. Carbon dioxide is also found in the mine returns and in increased amounts behind seals. Methane was normally liberated in the mine, and, in this instance, was entering the mine through the floor cracks. The primary gases in the mix that were only products of combustion were hydrogen, carbon monoxide and ethylene.

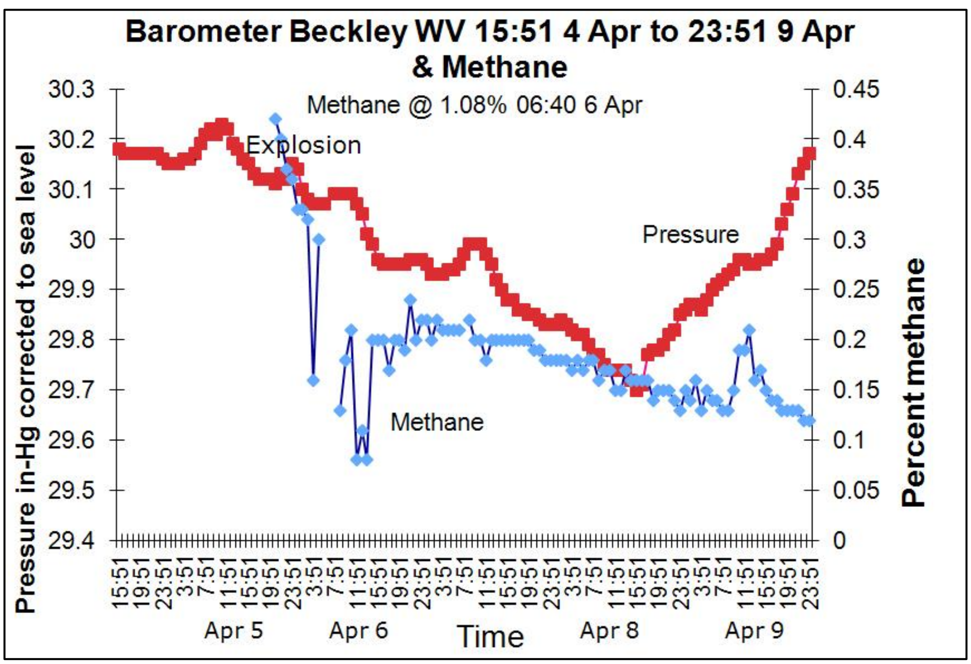


Figure 4: Showing barometer trend and methane at the Bandytown fan

Sampling of these gases did not start until 5 ½ hours after the explosion and some early data was not available; but, even had the data been available, the variables could not be isolated with confidence to make calculations that would allow the investigators to separate the sources of the gases. Some had multiple sources, and only one measurement was available after they all mixed.

The trends of the methane, ethane and carbon dioxide varied significantly at 6:40 a.m. April 6. An air sample from Bandytown contained 1.08% methane as well as increased ethane and carbon dioxide. The increased carbon dioxide could only come from combustion or the sealed area. No one was in the mine at that time. The barometer had declined some additional amounts (see **Figure 4** for the pressure trend line) and could have been a factor. The increased methane and ethane could come from either combustion or additional liberation from the floor cracks. Other minor fluctuations occurred in the gas trends at intervals on April 6 while no one was in the mine.

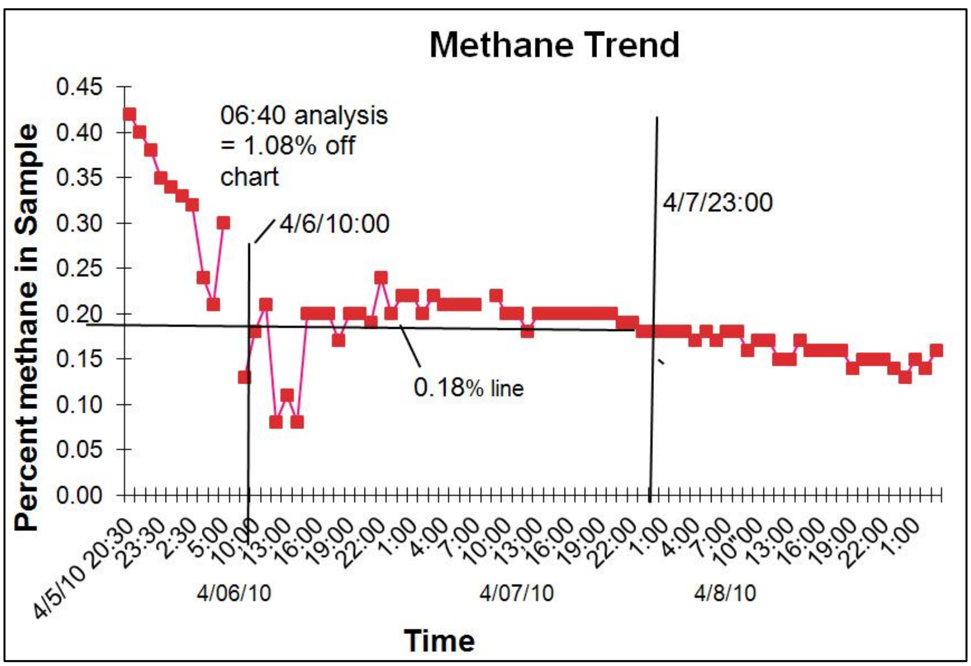


Figure 5: Showing methane trends with time

The last air samples taken by a federal inspector at Bandytown return, on January 20, 2010, contained an average of 0.182% methane and 0.11% carbon dioxide in 374,893 cfm of air. That same percentage of methane, 0.18, was the average of samples collected November 3, 2009; the air measurement then was 448,200 cfm. The quantity of air exiting the Bandytown fan is probably less than that measured by inspectors and examiners, but the percentage of methane has been consistent at 0.18%, even though both measure different air quantities. We assume that the normal amount of methane from Bandytown fan was about 0.18 percent. The investigators do not believe that more than 315,000 cfm was exhausted after the explosion.

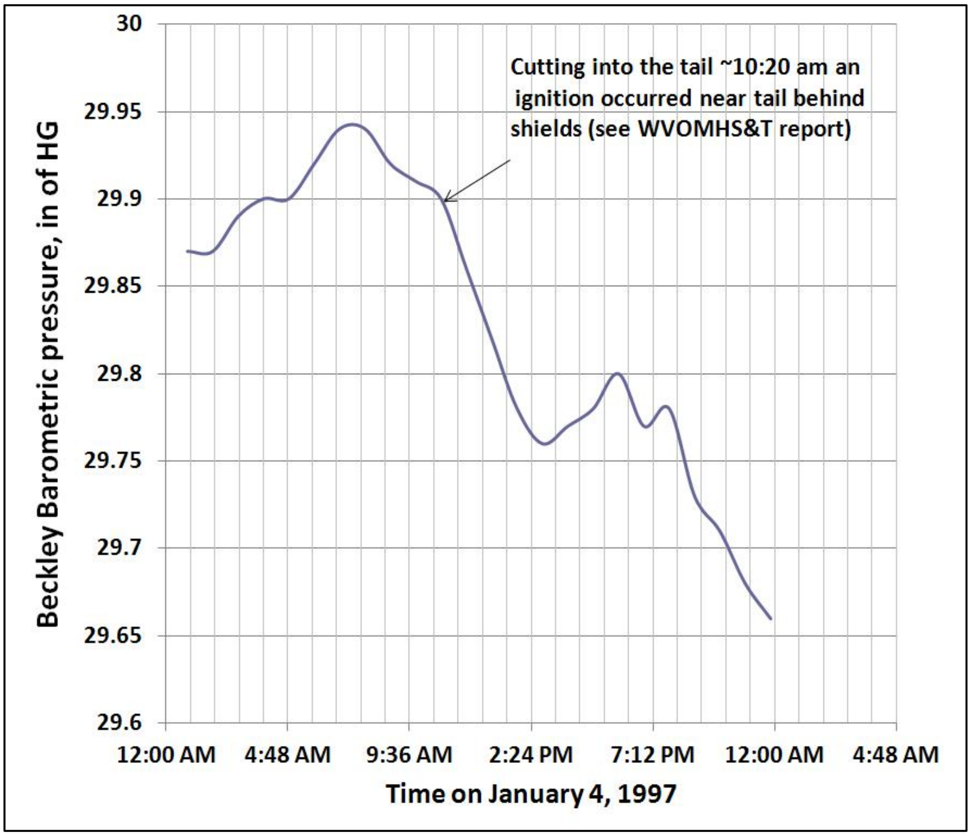


Figure 6: Barometer trend on January 4, 1997

It is believed that an increase in methane liberation from floor cracks behind the shields accumulated along the space behind the shields and was not moved away and diluted by the ventilation system. The excess methane observed coming from the mine after the explosion was from the combustion products, the floor cracks, and some from the large sealed area. The air analysis from samples collected at the shaft indicated that the methane content in the air reached near normal levels by 9:30 a.m., April 6, 2010, which was 18½ hours after the explosion. As the recovery work progressed the gases remaining began to be flushed out, increasing the methane content at the shaft until all areas were re-ventilated (see **Figure 5**).

8.2 Coal Dust

Coal Dust as Fuel for the Explosion

The methane ignition resulted in sufficient force to disperse and ignite coal dust. The methane source for this explosion was much larger than the minimum amount of methane determined in experimental work. Research has found that a small gas ignition of 84.5 cubic feet of methane diluted to 6.5% methane in air is sufficient to lift coal dust and propagate a dust explosion. An explosion pressure of 2.5 psig is enough to initiate a coal dust explosion where sufficient dust, such as float dust, is present.[8]

The ensuing coal dust explosion generated sufficient combustible gases, such as hydrogen, carbon monoxide, methane and ethylene, to overwhelm the gas detectors at various locations in the affected area.

A mine explosion is not a single event where forces radiate out uniformly from the explosion source. The static pressure of an explosion varies with the speed of the expanding heated gases of combustion and the reflections caused by the geometry and any obstructions in the entry. Obstructions increase turbulence and improve mixing of the gases or dusts, thereby affecting the explosion dynamics. The explosion speed may vary depending on the available fuel and concentration distribution as it spreads from the ignition source. The forces reverse direction at least once, and sometimes more often, leaving damage with conflicting information. It is difficult to trace the exact path of the explosion and careful detailed examination of all the evidence is essential.

The hot gas expansion due to unconfined burning of non-uniform gas-air mixtures produces eddies that will grow while the flame front searches out and follows and ignites along the flammable boundary. Some gas could have been in the tailgate entries or against the gob along

[8] Nagy J. The Explosive Hazard in Mining, Bureau of Mines IR 1119

the tailgate entries, layered due to the low velocity there. This could have added to the roof layer flame propagation, either as a continued gas explosion or hybrid gas in combination with coal dust in the tailgate, increasing in velocity as it moved outby consuming available fuel that may have been dispersed from rib and roof surfaces by local wind forces generated by the hot gas expansion process.

Rock dust had been applied in the mine, and the available incombustible content was instrumental in slowing the explosion propagation (see **Section 6.4** for a discussion of rock dusting practices). The amount of incombustible content to stop a dust explosion depends upon the size of the dust particles. Sixty-five percent incombustible is necessary to inert average mine coal dust, but because of the fine dust particle sizes created by modern mechanical mining processes, 80% incombustible is required.[9,10]

Monitoring the amount of rock dust applied to ensure compliance is an on-going problem in mining operations. From an enforcement perspective there are not many tools for use in evaluating adequacy of rock dust applications. Inspectors must first determine whether rock dust has been applied, which can easily be determined by observation. Then the inspector must determine if the amount of rock dust present meets the requirements, which is most difficult. Even the most experienced inspectors cannot regularly discern whether an area has 50% or 70% incombustible, and, for this reason, federal inspectors collect dust samples. Generally, citations for visible determinations of non-compliance are supported by dust samples collected at the site violated. There is a period of several days between collecting the sample and when the results are available. As a result, most judgments, or determinations of the rock dust adequacy for enforcement of the regulations or evaluations by mine officials or employees, depend upon visible evaluation. WVOMHS&T inspectors relied on visible observations to determine adequacy.

---

[9] Cashdollar, K. L. et al Post-Explosion Observations of Experimental Mine and Laboratory Coal Dust Explosions, NIOSH Pittsburgh, Pa.

[10] Cashdollar, K. L. et al Recommendations for a New Rock Dusting Standard to Prevent Coal Dust Explosions in Intake Airways, Report of Investigations 9679 NIOSH Pittsburgh, Pa.

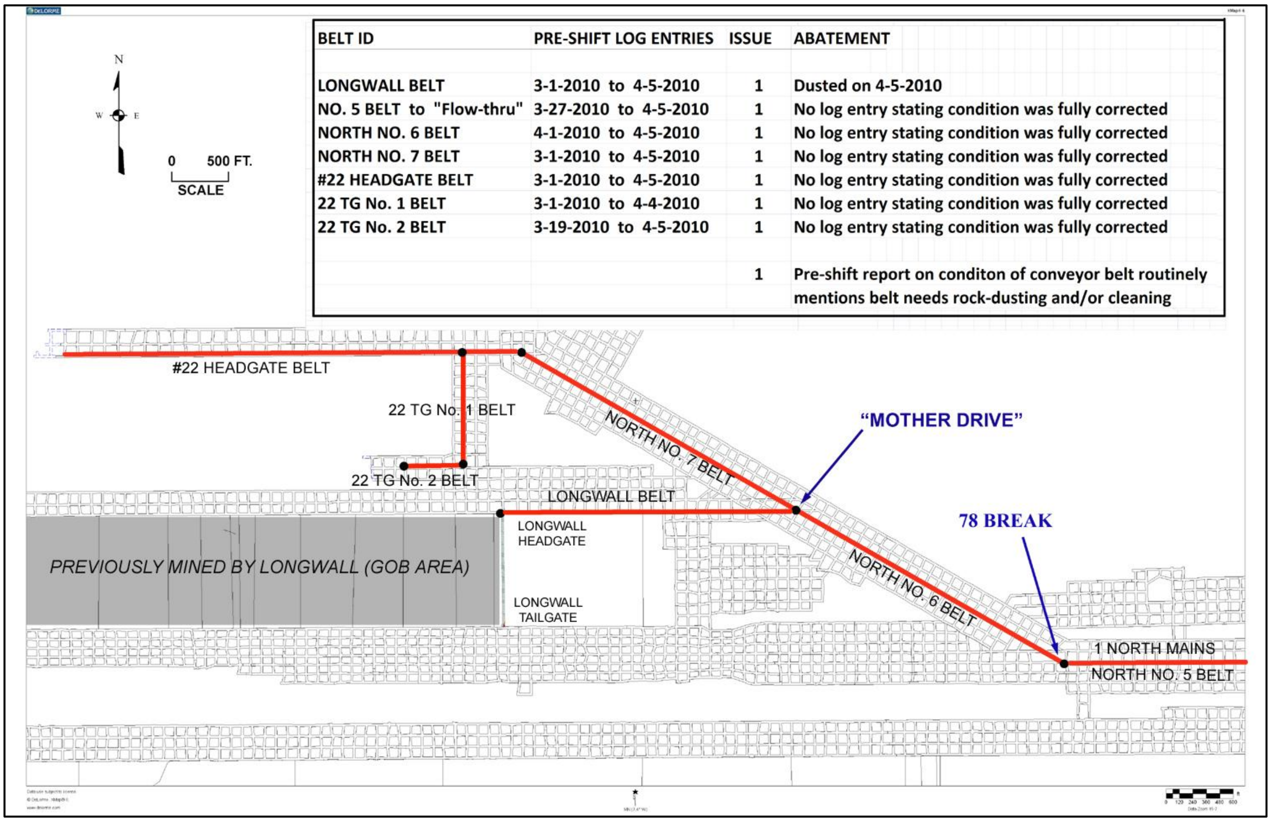
Dust accumulations from operations

Airborne dust is produced at many operations in the mine. Continuous mining machines and longwall shearers generate the most. Shuttle cars raise dust in suspension as they travel the haulage routes, such as large trucks do on dusty roads. This airborne dust is carried by the air currents and settles out towards returns. Transfer points on conveyor belts where coal moves between belts are serious dust generating locations and need constant attention to remove accumulations and re-apply rock dust. This dust enters the air stream and is deposited downwind.

In summary, rock dust needs to be applied in all the dust-exposed areas on a regular basis to maintain incombustible content at the proper level. Areas need rock dust applications on a repeated basis, and, in some cases, trickle dusters are used to continuously apply rock dust in the immediate returns from longwall shearers and continuous miners. There is no evidence this was done at UBB. The success of the rock dusting program depends on organization, planning and inspections. The records at the mine indicate that inspections regularly identified locations that needed rock dust applied. Interviewed witnesses indicated a perceived deficiency in rock dust applications at various locations. Shortly before the explosion, pre-shift log entries indicated the need for additional rock dusting along active conveyor belts (see **Table 4**).

Based on the available information and records, it is believed that some areas would be rock dust deficient at any given time. These deficient areas and areas with less than 80% incombustible provided sufficient fuel for the dust explosion. Mines should be proactive in the rock dust program instead of waiting until rock-dust-deficient locations have been identified.

The explosion started in the tailgate entries where return air from the longwall shearer provided the opportunity for airborne coal dust to travel and settle leaving deposits of float coal dust in the tailgate entries. This dust would settle on all mine surfaces, including elevated surfaces such as ledges on the coal ribs. More rock dust is necessary to prevent explosion propagation if heavy float dust deposits exist with a substantial amount of these deposits on elevated surfaces near the roof. Coal dust on elevated surfaces, such as coal ribs, is more easily suspended by air turbulence.[11,12]



BELT ID	PRE-SHIFT LOG ENTRIES	ISSUE	ABATEMENT
LONGWALL BELT	3-1-2010 to 4-5-2010	1	Dusted on 4-5-2010
NO. 5 BELT to "Flow-thru"	3-27-2010 to 4-5-2010	1	No log entry stating condition was fully corrected
NORTH NO. 6 BELT	4-1-2010 to 4-5-2010	1	No log entry stating condition was fully corrected
NORTH NO. 7 BELT	3-1-2010 to 4-5-2010	1	No log entry stating condition was fully corrected
#22 HEADGATE BELT	3-1-2010 to 4-5-2010	1	No log entry stating condition was fully corrected
22 TG No. 1 BELT	3-1-2010 to 4-4-2010	1	No log entry stating condition was fully corrected
22 TG No. 2 BELT	3-19-2010 to 4-5-2010	1	No log entry stating condition was fully corrected
		1	Pre-shift report on conditon of conveyor belt routinely mentions belt needs rock-dusting and/or cleaning

Table 4: Pre-shift log entries for the month preceding the explosion indicate the conveyor belts needed rock dusting /cleaning, but the condition was not confirmed to have been fully corrected.

Direct observations about the condition of the tailgate entries were available in statements made by company mine examiners. Mine Examiner Charles Semenske stated the tailgate area was not well rock dusted, but it did not look that bad. It didn't look as bad as it did outby.[13] The WVOMHS&T inspector who was conducting an inspection at the mine had not traveled the tailgate entries in some time so he could not provide direct observation of the conditions. The #3 through #7 entries outby the face were intakes requiring 65% incombustible content, under the current regulation; after the face was passed they became returns where 80% incombustible was required. Airborne dust generated at the shearer was deposited in these returns. The

[11] Sapko, M.J., Weiss, E.S., Watson, R. Explosibility of Float Coal Dust Distributed over a Coal-Dust Substratum, NIOSH, Pittsburgh, Pa.
[12] Nagy, J., Mitchell, D.W., Kawenski, E.M, Float Coal Hazard in Mines, A Progress Report, Bureau of Mines RI 6581
[13] Interview of Charles Semenske, October 26, 2010, page 17 & 57

shearer generates a great deal of dust, and an essential part of respirable dust control is ventilation to dilute and carry the dust away.

On March 9, 2010, ventilation was found by a federal inspector going outby in #5 to #7 entries, a violation to the plan. During this time, float dust would have been deposited outby in these entries. Rock dust sample analyses indicating incombustible content in these entries outby the longwall were not available. Available records indicated that the tailgate area outby the longwall had not been sampled during the routine sampling procedures by MSHA, and testimony established that it had not been re-rock dusted since the area had been developed many months before the explosion.[14]

Rib Dust Accumulations

WVOMHS&T investigators had noticed the accumulation of fine coal dust at various locations on the coal ribs as the investigation continued, and decided to investigate the character of the dust. In August 2011, about 1½ years into the investigation, WVOMHS&T investigators collected dust samples from the ribs in the area of the #21 Tailgate entries outby the longwall. The coal seam was divided into two benches by a shale parting. This parting and the difference in strength of the two coal benches influenced the manner in which the coal seam spalled.[15] Since the top bench of coal was more friable, a profile of ledges was created at and below the parting on the bottom bench where the fine coal from the top bench collected. The amount of fine coal particles, less than 200 mesh, was influenced by the amount of fusain parting material in the top bench. Fusain is extremely soft and crumbles readily into fine, soot-like powder and it closely resembles charcoal in terms of both chemical and physical properties. Laboratory tests revealed that these deposits were low in incombustible content and the dust was explosive,[16] and the investigators concluded that rib spalling had occurred prior to the explosion. These entries

[14] Interview of Charles Semenske, October 26, 2010, page 17 and Interview of Harold Lilly, August 24, 2010, page 67.
[15] The weight of the strata above the coal can cause fracturing, spalling, and cavitation of coal ribs if the strength of the coal is less strength than the roof or floor strata
[16] Report from NIOSH see Appendix 8.2-2

were developed 1½ years before the explosion, and any fine coal accumulations up on the rib would have been available for dispersion by the forces of the methane ignition (see **Appendix 8.2-1**). Visible deposits of coked coal were found on the roof and ribs in the tailgate entries near their junction with the longwall face, indicating that coal dust burned in this area (see **Figure 7** depicting the locations of visible macro-coking).

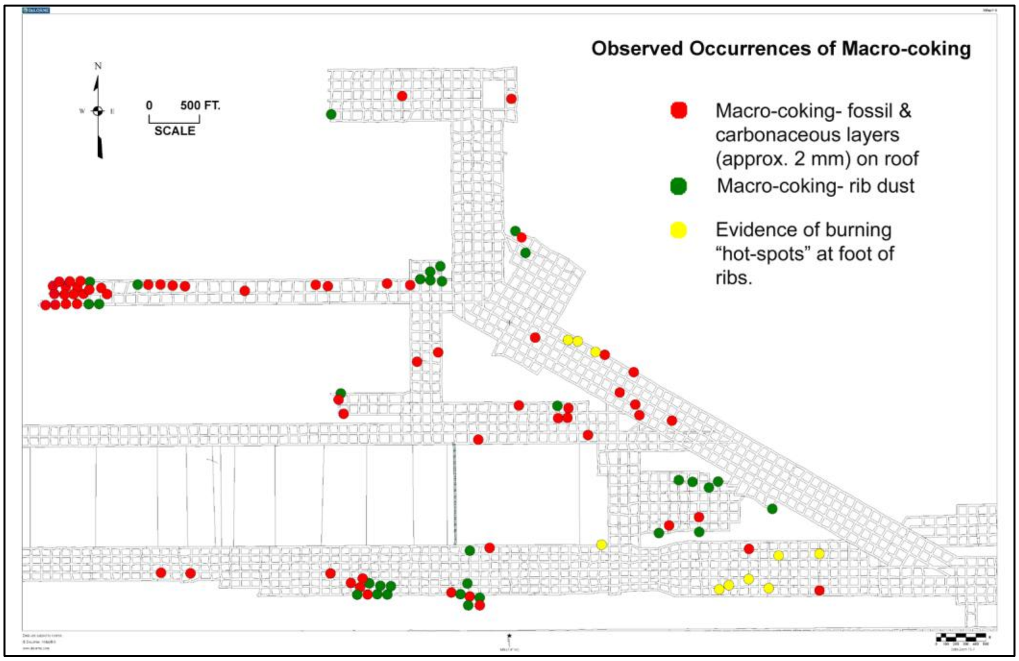


Figure 7: Locations where large amounts of coke and burning were found during the investigation.

The coal dust explosion could be traced from the tailgate area. It propagated at various speeds determined by the amount of fuel and incombustible rock dust, and moved east and north from the tailgate entries. The flame speed of a coal dust explosion decreases with its incombustible content (for uniform mixtures of coal and rock dust). For example, Cybulski documents a flame speed of 385 feet per second at 55% incombustible and about 144 feet per second at 65% incombustible with 85% minus 200-mesh coal dust.[17]

[17] Cybulski, W. G. [1975] Coal Dust Explosions and their Suppression, Translated from Polish, Warsaw Poland, National Center for Scientific Technical and Economic Information, NTIS No. TT-54001

Regardless of the precise location of the ignition source the WVOMHS&T investigators believe they have sufficient evidence to determine that the explosion propagated from the tailgate area as a coal dust explosion (see **Appendix 7.9-5**). Both gas and dust explosions will leave similar results, and it sometimes is quite difficult to determine which occurred. A gas explosion will suspend coal dust in the air and pyrolize some of the dust in an oxygen deficient atmosphere, leaving coke particles and coke residue even though the dust did not add significantly to the explosion strength. A hybrid explosion,[18] where coal dust and methane both contribute to the explosion, will leave coke particles and coke residue. Methane in a hybrid mixture will more quickly consume most of the oxygen before the coal particles heat and release their volatile matter to the combustion process depleted of oxygen and contributing little to driving the leading edge of the flame propagation. Therefore, the degree and rate of the combustion of coal dust in a hybrid mixture depends on the concentration of methane and availability of oxygen. A propagating coal dust explosion leaves visible coke deposits in far greater quantities than gas or hybrid explosions.[19] The amount of visible deposits of coke found supports a determination that coal dust burned and propagated the explosion, (see **Figure 7**).

Fires and visible coke in place at various locations in the explosion area evidence the extent of flames (see **Section 7.9**, **Map 13**). The presence of visible coke is influenced by the flame speed. In weak and slow explosions the most vigorous combustion occurs near the center of the mine passageway and little or no combustion takes place in the boundary layer along the roof and ribs.[20,21] Methane in explosive quantities could not have existed in all these areas prior to the explosion because many were ventilated by strong intake air currents.

Further evidence of a coal dust explosion is found by analyzing the air samples collected after the explosion in Borehole #1. The first of these samples was collected at 10 a.m. on April 7, 2010, while the ventilation was stagnant in the area and the gas mixture was undisturbed. The

[18] Nagy, J. The Explosive Hazard in Mining, Bureau of Mines IR 1119, page 33
[19] Rice, G. S. et al Coal Dust Explosion Tests in the Experimental Mine 1913 to 1918 Inclusive, Bureau of Mines Bulletin 167
[20] Hartman, I., Studies on the Development and Control of Coal Dust Explosions in Mines, Bureau of Mines IC 7785, page 12
[21] Richmond, J.K., Liebman, L., Miller, L.F., Effects of Rock Dust on Explosibility of Coal Dust, Bureau of Mines RI 8077, page 4

Jones-Trickett Ratio[22] was developed and tested on many experimental mine explosions to help differentiate between gas or dust explosions. When the ratio is between 0.4 and 0.5, methane was the primary fuel; values between 0.5 and 0.9 indicate that the fuel is primarily coal. We used the component of the gases collected and analyzed by MSHA from Borehole #1 to calculate the Jones-Trickett Ratio, and the results indicate the combustion products were from a coal dust explosion (see **Table 2** showing the results of this sampling).

Microscopic evidence of coal as fuel

Other evidence of a coal dust explosion exists. Coal dust particles that participate in dust explosions are subject to rapid heating causing them to pyrolize and to soften or melt into a plastic phase. The surfaces of these burned residues are rounded and smooth in contrast to the angular features and sharp edges of unburned coal or coke. The burned particles are pockmarked with blowholes, and some are blown into large cenospheres (empty hollow spheres).

Approximately 65 samples of impacted dust taken at various locations by WVOMHS&T (see **Figure 8** for locations where samples were taken) were analyzed by NIOSH using a Scanning Electron Microscope. Nearly all 65 samples[23] demonstrate the presence of particles that have been heated, leading to the conclusion that coal dust participated in an explosion (see **Figure 9** for representative images of these particles).

[22] Morris, R The Jones-Trickett Ratio-a Worthwhile management Tool, Journal of The South African Institute of Mining and Metallurgy May 1997 Page 149
[23] A few samples from the shield cylinder legs on the Longwall lacked distinct cenospheres

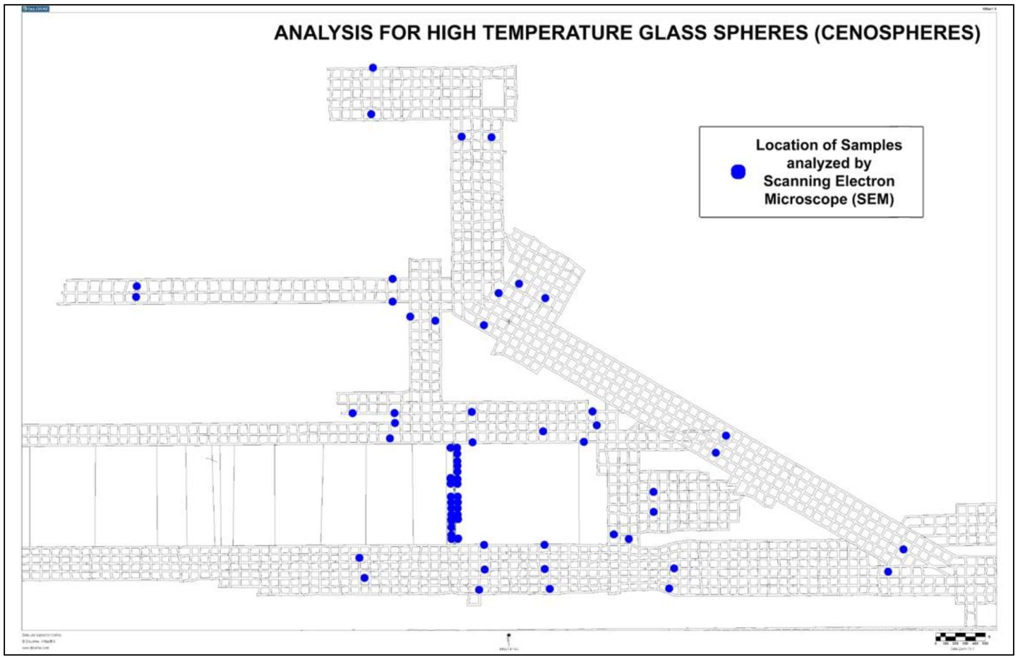


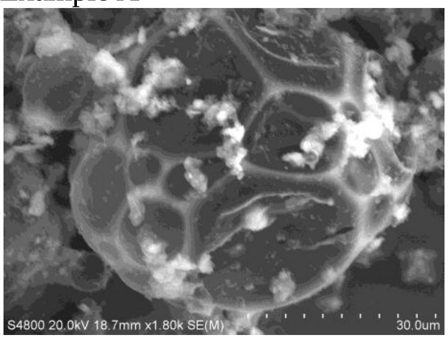
Figure 8: Locations where impacted dust was analyzed for cenospheres. All locations had relatively abundant cenospheres, except for the Longwall, where cenospheres were present but less abundant.

Flame traveled throughout much of the area of the longwall entries and inby. MSHA dust samples collected during the investigation to determine the incombustible content were routinely analyzed for amounts of coke using the alcohol coke test. Research has found that coke found by such tests indicate the passage of flame in the mine entry,[24] and the samples indicate that flame traveled throughout most of the area, including the tailgate entries to about 1,500 feet inby the longwall face. The flames traveled into #22 Headgate section, the #8 North and #9 North Areas, and the Glory Hole Area. Fires were started in the North Glory Mains near survey station 20057. Evidence of flame exists in the tailgate entries near the junction of North Glory Mains. Heated materials were found on the longwall face near shield 62 that probably came from burning methane behind the shields before, during or slightly after the main explosion in the tailgate. Flame evidence exists in the North Mains to about where the entries make a turn to the left. Heated gases deposited soot stringers beyond this point.

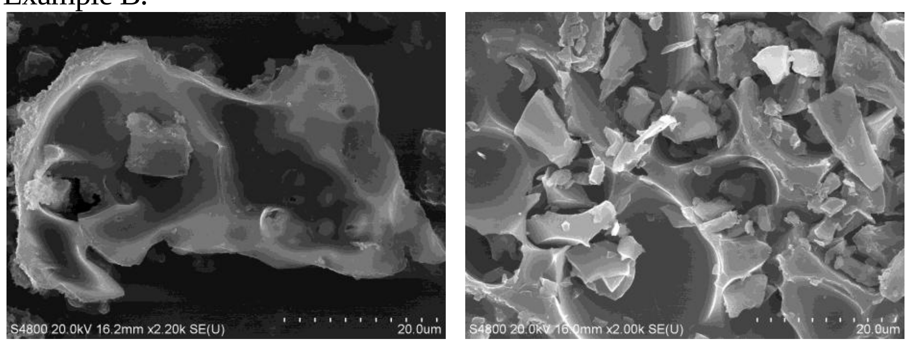
[24] Man, C. K. et al Determining Flame Travel Measurements From Experimental Coal Dust Explosions, NIOSH, Pittsburgh, Pa.

Additional information about cenospheres in UBB samples can be found in **Appendix 7.9-1, Appendix 8.2-3,** and **Appendix 8.2-4**.

Example A



Example B.



Example C.

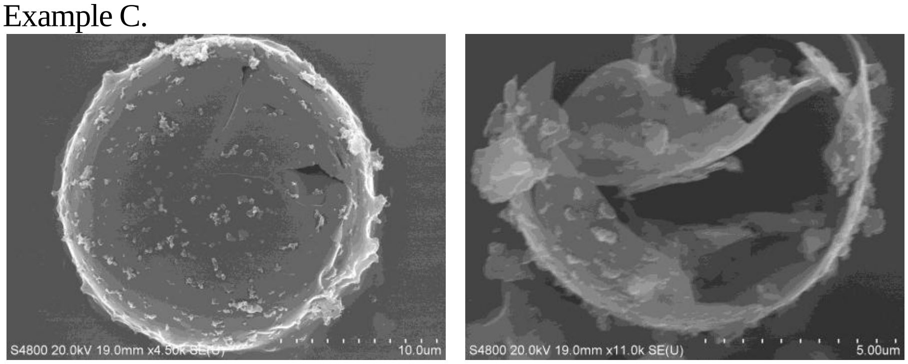


Figure 9: These photographs taken under a scanning electron microscope depict the type of burned residues present in the samples.

9 Conclusions and Recommendations

9 Conclusions and Recommendations

9.1 Conclusions

1) The explosion at the Upper Big Branch Mine on Monday, April 5, 2010, occurred at approximately 3:02 p.m. The explosion was the result of methane accumulating in the #21 Longwall Tailgate T-split area and in the gob behind the longwall shields, which was then ignited.

2) There are two possibilities for the ignition. It is possible that sandstone roof rock falling behind the longwall shields ignited gas by rock-on-rock impact or rock-on-steel impact. However, the more likely cause is that it occurred on the longwall as the shearer was cutting sandstone roof, igniting gas by steel-on-rock impact along the shearer bits producing hot smears as it cut sandstone roof.

3) Approximately 90 seconds elapsed from the time the shearer was de-energized until the time of the explosion.

4) The actual explosion most likely began in the gob behind the longwall shields, between shield 173 and shield 117. Explosion forces propagated along a flammable gas fringe behind the shields north to approximately shield 65 to 55, where access to fuel and space were restricted and the forces were diverted into the longwall where they subsided to extinction. Explosion forces also propagated west/southwest through the gob, exiting the gob 300 to 400

feet west of the longwall shearer. Additionally, explosion forces from the gob propagated south/southeast entering the longwall a short distance north of the shearer and traveled across the shearer as it exited the longwall and entered the #7 entry of the #21 Tailgate. From these two locations in the #21 Tailgate, the explosion transitioned into a coal dust explosion which continued propagating east and west and throughout an extensive area of the mine.

5) Coal float dust, combined with fine coal dust derived from rib spalling, is believed to be the principle source of fuel for the propagating explosion.

6) An airflow restriction, approximately 45 feet inby the shearer in the #7 entry of #21 Tailgate, caused by roof caving associated with the advancing longwall would have allowed any gas migration into that location to build up. A small amount of air could move over and around the fall, but the majority of the air did not.

7) Methane, mixed with other gases, is emanating from a source beneath the mine floor. A combination of overburden cover depth, mine floor rock strength, and local fracturing (natural and induced) influence where connecting pathways to gas are intercepted during mining. Prior gas events and the April 5, 2010, explosion appears correlated with local thickening of an underlying coal seam located 10 to 15 feet below.

8) The removal of hazards and violations identified during required mine examinations were not corrected in a timely manner.

9) There was no indication that the #21 Tailgate entries west of the #21 Cross-over had been rock dusted since the Longwall began production in September 2009. Based on testimony and available information there is no evidence that additional rock dust was applied after initial development throughout this extensive area.

9.2 Recommendations

Additional Explosion Defenses

1) The lines of defense to eliminate mine explosions are adequate ventilation, detection of explosive gases, removal of ignition sources, cleanup of fine coal dust accumulations and rock dusting. In other words:

a) prevent methane accumulations or find the accumulation before it becomes a problem.

b) prevent the ignition if an accumulation occurs undetected.

c) prevent a coal dust explosion if an undetected accumulation of methane becomes ignited.

All these defense mechanisms failed at UBB.

Additional defenses are needed to prevent propagation of a methane explosion into a coal dust explosion. Explosion barriers have been studied for years and have been found to be effective in stopping an explosion.

Investigators found evidence that a water barrier just west of #22 Cross-over stopped the explosion from propagating further inby in the #21 Headgate entries. The first arrival of explosion forces entered through a water-filled dip and then passed over a gob pile which reduced the opening height to about 4 feet. The result was recorded by impacted mud deposits, instead of impacted dust, and by the rapid decay in heat and pressure forces inby. The explosion subsided to extinction between breaks 31 and 35 of #21 Headgate, and further evidence of an explosion was not found as far west as could be safely traveled and examined.

Research is needed to demonstrate the practical application of water barriers, rock rubble barriers and other explosion mitigation strategies as supplemental protection, with generalized rock dusting, to prevent explosion propagations. It is recommended that NIOSH renew their research into the subject of barriers and develop systems that can be used in operating coal mines.

Ventilation Systems

1) WVOMHS&T currently have insufficient statutory language to regulate the way that coal mines are ventilated.

2) Coal operators must take a more proactive approach to the ventilation of each coal mine under their authority and responsibility. The industry has taken a step back over the years in proper planning and preparation as long-term plans are developed. The operator must once again lead the way in doing the hard and extensive work necessary to properly ventilate each mine. Registered Professional Engineers can help bridge the gap between prudent planning and maintenance of mine ventilation. Mine managers and regulators must allow the Professional Engineer to do his/her job and should not be so quick to disregard the engineer's professional judgment, which he/she is charged by charter to do in order to protect public safety.

3) A closer look must be taken concerning the use of belt air during longwall mining to assure that the most effective means are being utilized to maximize ventilation to the longwall face and the active gob areas including the tailgate T-Split (i.e., where the longwall face intersects its principle return air course).

4) The T-split is a critical location where longwall ventilation can become blocked, which is what happened at UBB. Additional measures to support the roof at this location are prudent and recommended. Many operators are already doing this. In addition, should the T-split become blocked, there should be supplemental precautionary measures that are initiated to ensure the ventilation system is keeping gas mixtures properly diluted.

5) The excessive use of airlock doors along the ventilating current must be minimized to assure that ventilation is not compromised. Although this is currently addressed in the West Virginia Code, it requires clarification with stricter guidelines for enforcement.

6) Critical air splits in the mine should be adequately monitored at strategic locations to give warning of unusual or dangerous amounts of methane, carbon monoxide or other harmful gases. This system should alert the operator if an air reversal or a drastic change occurs in the ventilating air volumes. These devices should give warning to a central location on the surface so workers in the affected areas can be alerted to hazardous conditions.

7) Mine management should review the mine ventilation, roof conditions and any other specific hazard to the mine, such as inundation potential, and organize and schedule mine examinations to ensure conformance to the law and regulations, being specifically attuned to the potential hazards at the mine. Examiners should be trained in the examination schedule and locations.

Mine Examinations

1) Additional training must be conducted to assure that the operators and those entrusted by the operator to make the required safety exams in the mines be adequately trained in the performance of their duties. Training to clearly identify hazards and the corrective actions to eliminate those hazards must become standard throughout the mining community and immediately replace the routine haphazard practices in place today. This training should be an extensive part of the foreman continuing education classes required by the WVOMHS&T.

2) The system for mine examiners to record their findings for review must be overhauled to allow for a more thorough recordkeeping and review process of noted conditions. This would enhance the ability of coworkers who are charged with correcting these hazards and violations to properly evaluate their findings and develop a precise plan to correct the hazards and violations. The current fireboss books being used need updated or redesigned

so that the hazards recorded can be easily tracked to assure they have been corrected promptly.

3) Every person who is given the task of making required mine examinations must use a multi-gas detector that will log or record their findings during the course of their firebossing assignments. A means must be available for their detection device to log its readings and be made available to be printed out or recorded for review and scrutiny by the operator and the regulatory agencies. This record must be kept like any other required record for a designated period of time and made available for review upon request by the proper authorities.

4) All continuous miners and longwalls should have methane monitors maintained in a workable condition at all times. If the methane monitor becomes inoperative, the machine should be taken out of service. The methane monitors should be calibrated every 15 days in a known gas mixture and a record kept of these calibrations.

5) Individuals involved in the day to day decision making at the mine must be held accountable regardless of their title. The mine foreman is the highest ranking official that current state law addresses.

Rock Dusting

1) Each mine should have a means to track the amount of rock dust that is delivered to the mine and when and where it is applied underground. This recordkeeping should be done in a manner that will allow the operator to easily review and track not just the amount of rock dust used but also monitor the frequency in which the rock dust is being applied to the mine surfaces. This record should be made available upon request.

2) Rock dusting should be maintained to 80% total incombustible content within 500 feet of an active section or any ignition source within 500 feet downstream of mine seals.

3) Each mine should conduct its own rock dust surveys to assure compliance with the laws pertaining to total incombustibility of 80%. This should also include periodic analysis of the rock dust being used to assure that the quality of the dust being used is compliant. The way we currently sample and apply rock dust needs to be modernized, using the latest research knowledge and most appropriate sampling and analyzing methods available. A record should be kept of testing results and made available upon request.

4) Clarification of some basic rock dust and rock dusting facts should be communicated to the mining community regarding adequate rock dusting methods and the need for increased frequency of rock dusting. A better understanding of how a dust explosion begins and then propagates would help the average miner to understand why it is crucial to conduct adequate exams and to rock dust properly and would encourage workers to be more diligent concerning rock dusting the work place.

Emergency Responders

1) Hazards associated with new urethane glues, sealants, foams and fine silica dusts, including cenosphere fragments which are heated at high temperature and dispersed during a mine explosion, are not well understood. In the event another emergency response and investigation of an underground coal mine as extensive as UBB were to occur, it is recommended that steps be taken to examine the health risks of working in such an environment. Organic respirators or other breathing protections should be made available for mine rescue personnel and investigators who work underground.

9.3 Acknowledgements

Special recognition is given to Timothy Blake of the 22 Tailgate crew. The WVOMHS&T employees, the coal miners and citizens of the State of West Virginia would like to thank you for your heroic efforts on April 5, 2010. Your efforts to assist your coworkers will always be remembered.

The West Virginia Office of Miners' Health, Safety and Training wishes to acknowledge and thank all of the family members and mine employees past and present who participated and assisted this agency and followed the proceedings of our investigation. Special recognition is due to those who appeared at the hearings and for the forthright manner in which they gave their testimony and their forbearance while spending many hours traveling or waiting to appear.

We would like to thank the citizens of the Whitesville/Big Coal River area for all the continued support, prayers and hospitality that they extended to us throughout our stay in your community. We appreciate the support that the Whitesville Fire Department and EMS showed, as well as all of the other area emergency medical services and local fire departments.

We especially want to thank all the mine rescue teams for their support and assistance during the rescue and recovery events.

Our thoughts and prayers continue to be with James K. Woods survivor of the 22 Tailgate crew.

The following groups and individuals were involved with the events or the investigation surrounding the disaster that occurred April 5, 2010:

The MSHA Upper Big Branch Investigative team; Norman Page, lead investigator

Performance Coal Company

United Mine Workers of America (UMWA) led by Max Kennedy

Governors Independent Investigative Panel led by Davitt McAteer

National Institute of Occupational Safety and Health Administration (NIOSH)

Governor Earl Ray Tomblin

Senator Joe Manchin III (Former Governor)

The Governor's Office Staff

West Virginia Homeland Security

Southern West Virginia Community College Task Force One

West Virginia State Medical Examiners' Office

Local and County government agencies

West Virginia State Police

Raleigh and Boone County Sheriff Departments

Raleigh and Boone County Commissions

West Virginia Department of Health and Human Resources

West Virginia Regional Response Team

C.A. Phillips, Director, WVOMHS&T

Eugene White, Deputy Director, WVOMHS&T

WVOMHS&T Upper Big Branch Investigative Team, William Tucker lead investigator

Mr. Barry Koerber, Assistant Attorney General, State of West Virginia

Ronald Wooten, (former Director, WVOMHS&T)

Terry Farley, (former Administrator, WVOMHS&T)

Monte Hieb, Chief Engineer, WVOMHS&T, your tireless efforts in leaving no stone unturned is appreciated. Your open minded approach since the onset of this tragedy has kept the focus on finding the facts surrounding the events which occurred April 5, 2010.

Jack E. Tisdale, consultant. Your expertise in ventilation, explosions and explosion prevention were integral to the development of this report.

Jeff Kohler, Michael J. Sapko, Jürgen Brune and Isaac A. Zlochower, NIOSH. Thank you for rendering technical assistance to this investigation.

University of Kentucky; Mr. Cortland F. Eble, Mr. Henry Francis

10 List of Appendices

APPENDIX 1

Definitions

Errata

APPENDIX 2

Geology and Mining Conditions

- **2.2-1** Geology
- **2.2-2** Petrographic and X-ray diffraction analysis of sandstone roof from the Longwall

Communication and Tracking System

- **2.5-1** The Approved Communication and Tracking Plan
- **2.5-2** Violation and extensions
- **2.5-3** Time drift correction: Pyott-Boone PC clock
- **2.5-4** Calculations for 108 second delay: Pyott-Boone

APPENDIX 3

Incidents of Prior Gas Inundations

- **3.2-1** Report of a Methane Ignition at UBB, January 4, 1997

APPENDIX 4

Origin and Path of the Explosion

- **4.1-1** Longwall production reports
- **4.3-1** Effectiveness of a water barrier in stopping the explosion in the inby reaches of #21 Headgate

APPENDIX 5

Chronology of Events

- **5.1-1** List of Victims

APPENDIX 6

Regulatory Compliance

- **6.2-1** Belt Books

APPENDIX 7

Structure of the Joint Investigation

- **7.2-1** Individuals who exercised 5th Amendment Rights

Flames and Forces Mapping

- **7.9-1** Sampling and Analyzing of Mine Dusts
  - **Exhibit 1**- WVOMHS&T impacted dust samples: Summary of test results
- **7.9-2** Using Roof Pans as Indicators of Wind Pressure and Heat
  - **Exhibit 1-** Format for describing condition of roof pans
- **7.9-3** Identifying Final Forces
- **7.9-4** Using Breached and Deflected Structures to Interpret Explosion Forces
- **7.9-5** Forces and Heat on the Longwall
  - **Exhibit 1-** MSHA shield inspection data
  - **Exhibit 2-** Mallett Technology Report, executive summary; CFD analysis of shield signs and CIU E-stop buttons.
- **7.9-6** Explosion Pressures
- **7.9-7** West Virginia Flames and Forces Map---Eight (8) sheets (see **Appendix 9**)

APPENDIX 8

Mine Gases

- **8.1-1** Tailgate Intersection

Coal Dust

- **8.2-1** Mine Dust and Rock Dust
  - **Exhibit 1** Petrographic Analysis of Coal Samples
- **8.2-2** Particle size analysis and explosibility analysis on rib dust samples
- **8.2-3** The Imaging of Post-Explosion UBB Samples using a Scanning Electron Microscope
- **8.2-4** The Imaging of Additional Post-Explosion UBB Samples using a Scanning Electron Microscope

APPENDIX 9

West Virginia Flames and Forces Maps

Sheets 1 thru 8: D-size (34” x 22”)