3.0 THE IMPOUNDMENT BREAKTHROUGH INVESTIGATION

3.1 OSM Investigative Approach

The OSM investigation of the 1994 and 2000 breakthrough events encompassed the following tasks:

1. Review of information obtained from the MSHA interviews.

2. Review of the impoundment permit files and MCCC 1-C underground mine map files, including:

    - Underground mine maps.
    - The sealing plan.
    - MSHA and DSMRE review letters relating to the sealing plan.
    - MCCC response letters.
    - Certifications.
    - Blasting plan and records.

3. Analysis of photographs, including:

    - Aerial photographs obtained from the Kentucky Department of Transportation, GRW Aerial Surveys, Inc., and Photo Science, Inc.
    - Aerial video taken by DSMRE.
    - Weekly inspection photographs taken by Ogden during the construction of the seepage barrier.

4. Analysis of data obtained from:

    - Triad drilling.
    - DSMRE borehole video.
    - Enviroscan geophysical survey.
    - National Weather Service precipitation records.
    - Kentucky Geological Survey (KGS) earthquake seismic records.
    - MCCC mine-portal discharges.
    - MCCC impoundment-pool levels prior to and during the 2000 breakthrough.

5. OSM modeling, including:

    - Seepage barrier stability.
    - Underground mine pillar stability.
    - Blasting vibration levels.
    - Geologic modeling using Earthvision.
    - Precipitation and pond discharge trends.

In completing these tasks, OSM evaluated the conditions and sequence of prior events and determined the probable breakthrough mechanism for the 2000 breakthrough. In arriving at this determination, OSM evaluated other factors, such as designs and approvals, which could have contributed to the 2000 breakthrough. In OSM's report entitled *Criteria for Evaluating the Potential for Impoundment Leaks into Underground Mines (Existing and Proposed Impoundments),* Section E discusses "Failure Mechanisms." In this section, OSM states the following:

"Potential failure mechanisms include but are not limited to:

1. Failure of sealed underground mine openings: The opening seal (rock/soil or other material) fails, thus allowing water/slurry to flow in an uncontrolled manner into the underground mine. Underground mine openings include, but are not limited to "punchouts," (i.e., an intentional or unintentional void or tunnel-like connection of the underground mine to the surface), portals, horizontal drainage and ventilation borings, vertical utility or ventilation borings, adits [another term for a type of underground mine entry] and underground mines, and auger holes that connect with underground mines.

2. Breakthrough at an unsealed underground mine opening: Water/slurry flow into a mine opening that has not been sealed. These openings may have only been covered with soil.

3. Breakthrough at coal barriers (e.g., outcrop barriers; barriers between contour and underground mines; barriers between auger holes and underground mines; barriers between small drift mines or house coal adits): Pressures resulting from deposition of water/slurry/other materials may cause a failure at the coal barrier and allow water/slurry to enter the mine in an uncontrolled manner.

4. Breakthrough at strata overlying the coal seam: Water/slurry flow into a mine through natural fractures and joints and mining-induced fractures (e.g., roof falls, sinkhole subsidence, and trough subsidence)."

Throughout this study, OSM considered each of these potential failure (breakthrough) mechanisms.

3.2 1994 Breakthrough

3.2.1 Description: The breakthrough occurred on May 22, 1994, at the end of a 45-foot long, 20-foot wide dead-end entry in the underground mine in the Coalburg coal seam. The released material, primarily water, resulted in a blowout in the barrier between the underground mine and a contour mine cut near the Big Branch preparation plant. The event also caused a blowout of the South Mains Portal's seals. Impoundment water discharged into Wolf Creek (through the South Mains Portal); Mill Branch (through the Mill Branch Portals); and Big Branch (through the barrier blowout). At the time of the breakthrough, the pool was at 992 feet msl and about 28 feet above the roof of the mine (Figure 3 [Page 17]). The pool level then dropped by about 6 feet. In the October 17, 2001, report of investigation, MSHA estimated that 112 million gallons of water and slurry drained into the underground mine during the 1994 breakthrough. An unknown amount of water discharged from the underground mine to the surface drainage system.

According to the sealing plan:

- There was a "funnel shape" opening at the point of the breakthrough.
- Inspection of the breakthrough point after the event revealed that a sinkhole had formed in the partially consolidated slurry with side slopes less than 45 degrees.
- The breakthrough may have been the result of subsidence caused by a roof fall in the mine.
- During the breakthrough, the majority of the clear water in the impoundment, but only a small amount of slurry, drained into the underground mine.

3.2.2 Overburden conditions at the outcrop barrier: In order to determine the depth and lithology of the overburden materials at the 1994 breakthrough location, OSM examined information obtained after both the 1994 and 2000 breakthroughs. This included the sealing plan, the MSHA interviews, and the Triad drilling data. Some inferences were drawn from the Triad drilling near the 2000 breakthrough.

The sealing plan map shows about 60 feet horizontal distance between the 1994 breakthrough entry and the Coalburg coal seam cropline (Figure 3 [Page 17]). The position of the cropline was projected to the land surface from the elevation of the mine floor. The mining height at the breakthrough was 93 inches (7.75 feet). The map indicates about 21 feet of overburden in the same area. The surface of the slurry pond was about 28 feet above the mine roof.

There is a lack of detailed information on the overburden material (e.g., type, thickness, competence, etc.) above the mine at the 1994 breakthrough location. Neither the MSHA interviews nor the sealing plan identified the lithology or competence of the mine overburden. Based on the Triad drilling data, and assuming some degree of lateral stratigraphic continuity at the site, the overburden likely consists of natural, unconsolidated material (colluvium), sandstone with about two feet of shale above the Coalburg coal seam. The mine map shows that 25 inches of shale was mined, but it is not clear if the shale was above or interbedded with the coal.

There is nothing in the record on the mine roof or pillar conditions at the 1994 breakthrough. However, it was indicated in the MSHA interviews that the last 20 feet of the entry might not have been roof bolted. This is not an uncommon practice and is not a violation of the MSHA regulations. The regulations provide that miners work under a supported roof. However, continuous mining equipment can remove coal about 20 feet beyond the last row of roof supports while still protecting the operator.

3.2.3 Analysis: Given the shallow cover at the 1994 breakthrough, expected loss of rock competence due to weathering, possible existence of natural fractures, and likely absence of roof bolting near the outcrop, the roof and overburden was susceptible to caving. The added weight of the slurry and water may have contributed to the failure. In addition, seepage from the pool through the outcrop barrier may have induced piping (internal erosion) into the underground mine, as well as additional weathering of the rock overburden. Weakening of the strata may have occurred to the point where it could no longer support itself and the load above it, resulting in the collapse of the mine roof and at least some of the overburden.

Depending on the expansion of the roof rock when broken, roof falls can extend upward from two to five times the mining height (Peng, 1978). Considering the mining height of 7.75 feet at the 1994 breakthrough, a roof fall could have extended up to 38 feet. This would have intersected the surface and developed into a sinkhole. This sinkhole would have allowed slurry to flow into the underground mine.

Summary

- The 1994 breakthrough was probably caused by a roof fall.
- The mine roof at the end of Entry No. 1 may not have been bolted and may have been composed of partially or totally weathered rock and soils.
- The mine roof and overlying strata was not thick enough to prevent a roof fall from progressing up to the impoundment.

3.3 Preventative Actions After the 1994 Breakthrough

3.3.1 Sealing plan: On May 23, 1994, MCCC prepared an initial remedial plan in response to the breakthrough. The plan contained both short- and long-term corrective actions. The short-term actions included backfilling the breakthrough with rock excavated from a nearby area, opening the South Mains Portal to allow for more mine drainage, and restricting miner access into the North Mains until the water level in the mine receded. The long-term actions included the development and implementation of the sealing plan.

In a June 29, 1994, letter to MCCC, Ogden summarized the progress in developing the sealing plan, and identified three critical objectives related to ensuring mine safety and preventing a recurrence of a breakthrough. The objectives were:

- Protect the miners in the underground mine.
- To the extent practical, prevent future breakthroughs by limiting the quantity of seepage passing from the impoundment into the mine (accomplished by creating a "seepage barrier" and controlling water levels within the impoundment).
- To the extent practical, limit the rapid release of impounded water and fine coal refuse from the impoundment should a breakthrough take place. As conceived, the seepage barrier would provide the material that would plug any subsided area.

On August 8, 1994, Ogden submitted the sealing plan to MCCC, which then requested MSHA's approval of the plan. On August 18, 1994, Summit submitted the permit revision to DSMRE. The permit revision contained the sealing plan prepared by Odgen. The sealing plan had two primary components: (1) construct a seepage barrier within the impoundment, and (2) construct bulkheads within the underground mine to protect miners and the conveyer system in the North Mains from the consequences of a breakthrough. Further, a wet seal was designed for the South Mains Portal. The purpose of the wet seal was to prevent air and human entry into a large portion of the mine and to allow water to drain from the mine. Subsequent to MSHA's approval of the sealing plan and DSMRE's approval of the permit revision, MCCC obtained MSHA's approval to install a fence instead of the wet seal. MCCC did not request a similar authorization from DSMRE.

The proposed seepage barrier design and location are shown in Figure 5 [Page 20]. The seepage barrier construction involved contour mining the Stockton coal seam and pushing the blasted material downslope over the outcrop barrier of the underground mine in the Coalburg coal seam. The minimum design thickness of the seepage barrier was one to two times the height of the mine, or at least 12 to 25 feet. The plan provided for the planting of vegetation on the bench and seepage barrier to limit erosion.

The sealing plan provided a typical cross-section of the seepage barrier and adjacent mine outcrop barrier. A 45-degree subsidence angle of draw from the edge of the underground mine determined the "minimum toe limit for seepage barrier" (Figure 5 [Page 20]). Typically, the subsidence angle of draw describes the distance that trough subsidence would extend beyond the edge of the mine.[6] The seepage barrier was intended to plug all ground cracks that may form within the limits of subsidence. The upper limit of the seepage barrier was the base of the Stockton coal seam, about 100 feet above the roof of the underground mine. The plan stated that the amount of cover established by the elevation of the Stockton coal seam was consistent with the U.S. Bureau of Mines Information Circular (IC) 8741, "Results of Research to Develop Guidelines for Mining Near Surface and Underground Bodies of Water" (Babcock, C. and Hooker, B., 1977). The IC recommends that partial extraction, room-and-pillar underground mines, and bodies of water be separated by solid rock that is at least five times the entry width (5 x 20 feet = 100 feet at the MCCC impoundment) or 10 times the mining height (10 x 10 feet = 100 feet at the MCCC impoundment).

A critical component of the sealing plan entailed placement of slurry along the face of the barrier by periodically redirecting the "discharge" of the slurry. As the slurry settles and consolidates along the surface of the seepage barrier, permeability is decreased and the consolidated fine refuse retards water movement through the barrier. The plan also stated that the pool level in the impoundment should be maintained as low as possible, thereby reducing the quantity of clear water in the impoundment and the hydraulic head.

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[6] Trough subsidence normally forms from pillar crushing or pillar extraction in the underground mine and is characterized by a broad dish-shaped depression at the ground surface. Tension cracks occur at the outer limits of the depression. This is in contrast to sinkhole subsidence, which is commonly formed from inter-pillar roof collapse. Sinkhole subsidence may result in relatively narrow and deep depressions that do not extend far beyond the edge of the mine entry. The sinkholes may extend beyond the edge of the mine entry when the land surface is composed of unconsolidated material and that material flows into the mine.

The sealing plan narrative also suggested that as the discharge of the relatively dense, fine refuse slurry progresses up the face of the seepage barrier and replaces the clear water, seepage into the underground mine should progressively decrease. The plan speculated that the potential for a breakthrough should be considerably reduced once the general pool level increases above the upper limits of the seepage barrier. It is noteworthy that the 2000 breakthrough occurred when the pool level was about 15 feet below the upper limit of the seepage barrier.

Summary

The stated purpose of the sealing plan was to:

- Protect the miners by installing bulkheads off the North Mains.
- Inhibit seepage into the underground mine by constructing a seepage barrier, limiting the water levels in the impoundment, and directing slurry against the seepage barrier.
- Limit rapid release of future discharges because the seepage barrier would plug any breakthrough.

3.3.2 Technical and programmatic concerns: Under the regulations, both MSHA and DSMRE approval of the sealing plan was required. OSM examined the sealing plan and the permit revision, documents pertaining to the MSHA and DSMRE reviews, and certifications and photographs of the construction activity. Several key issues in the design and construction of the sealing plan may have contributed to the 2000 breakthrough. These are discussed below.

3.3.2.1 Seepage barrier permeability and slurry coating: The stated purpose of the seepage barrier and slurry coating was to minimize infiltration of the impounded water and slurry into the underground mine. MCCC also asserted that the seepage barrier would limit the rapid release of water and slurry should a breakthrough occur.

According to the sealing plan, spoil would be pushed downslope in thick lifts and then graded to the approved slope configuration. Slurry would then be directed along the barrier by periodically redirecting the slurry discharge. Settling and consolidation of slurry was intended to further reduce seepage due to the resultant low permeability. As addressed below, the seepage barrier would be permeable, highlighting the importance of the slurry coating.

MSHA's September 9, 1994, letter to MCCC on the proposed sealing plan indicated a concern for material segregation and recommended that the material be placed in horizontal lifts. Also, DSMRE, in its October 24, 1994, letter on the permit revision, asked MCCC to address compaction. Ogden's responses of October 3, 1994, and November 9, 1994, indicate that they did not believe that compaction and gravity segregation was a matter of concern. Ogden recognized the potential for seepage into the underground mine. Ogden noted that the seepage could cause piping of fine material and that this could result in instability of the seepage barrier. However, Ogden stated that any instability resulting from a collapse or breakthrough would be "choked off" given the expected gradation of the seepage barrier. Ogden said that the function of the seepage barrier was to provide bulk and sealing in the event of a collapse or breakthrough.

Ogden contended that the primary seepage control would be provided by the fine refuse sealing of the face of the barrier, reducing the potential for piping of material through the outcrop barrier.

In the October 1994 response, Ogden also described general guidelines for barrier material placement: "Dozers and excavators can place material on the outslope with dozers following the material downslope. Material may also be trucked down along the face and spread with dozers if deemed necessary by MCCC personnel. Any lifts that are placed should not exceed 20 feet in thickness. Material larger than 5 to 6 feet in diameter should be isolated in the fill or moved to the toes to provide additional stabilization in a working pad that displaces mud and fines. During construction, larger rock will naturally segregate and roll to the toe and supplement the working pad."

Despite the plan stating that the lifts would not exceed 20 feet, the typical cross-section for the designed barrier profile shows that the toe of the seepage barrier is 22 feet thick (measured perpendicular to the slope). Consequently, the barrier could be constructed in a single lift, parallel to the slope, and still essentially be in compliance with the plan. The "push-down" method of construction would limit the depth of compaction to only one to one and one-half feet below the surface (Skelly and Loy, 1978). In the case of horizontal-lift construction, a minimum of 20 vertical feet for each lift would result in at least five lifts in a 100-foot high seepage barrier. This horizontal-lift construction method, however, would result in only thin bands of compacted material between uncompacted layers more than 18 feet thick. Neither approach significantly reduces permeability and would allow seepage to pipe fine material into subsidence openings.

According to photographs (examples are provided in Photos 9 through 14 [Pages 36 through 41]) taken during the seepage barrier construction, the seepage barrier appears to have been constructed by dumping spoil downslope and dozing the material to final grade. Consequently, the spoil was placed as a single lift, at times greater than 30 feet thick measured perpendicular to the slope (Figure 4 [Page 18]). The photographs also confirmed that some gravity segregation occurred, potentially resulting in higher seepage barrier permeability at its base. The base of the seepage barrier is near the Coalburg coal seam outcrop.

The sealing plan stated that seepage from the impoundment would be limited to 10^{-7} centimeters per second (cm/sec) if the "fine refuse is deposited in the impoundment" and "the pool level is maintained as low as possible." This seepage rate equates to 0.00028 feet per day or 3,528 days per foot. The permit, however, does not contain test results or a quantitative analysis to support the 10^{-7} cm/sec permeability rate. Further, the sealing plan does not specify the thickness of the slurry coating necessary to achieve that permeability. The permit also stated that the permeability of the spoil material used to construct the seepage barrier would vary and could not be estimated.

Research conducted by the Bureau of Mines found flow rates through spoil derived from massive gray sandstone ranged from 1.2×10^{-3} to 4.9×10^{-3} cm/sec (3.37 to 13.82 feet per day or 0.3 to 0.07 days per foot) (Hawkins and Aljoe, 1991). The Triad investigation independently confirmed high permeability of the seepage barrier material, which was largely sandstone-derived spoil.

Photo 9. Construction of Seepage Barrier (Dozer Work) - March 6, 1995. Source: GAI. The work is being conducted at the southwest side of the impoundment.

Photo 10. Construction of Seepage Barrier (End Dumping by Rock Truck) - March 6, 1995. Source: GAI. The work is being conducted at the southwest side of the impoundment.

Photo 11. Construction of Seepage Barrier (Long View of Dozer and Truck) - March 6, 1995. Source: GAI. The work is being conducted at the southwest side of the impoundment. Pool elevation 1,000 feet msl. Mine roof elevation 964 feet msl.

Photo 12. Seepage Barrier by 2000 Breakthrough (During Construction) - April 24, 1995. Source: GAI. The 2000 breakthrough area is located at the left-center of the photo. Pool elevation 1,000 feet msl. Mine roof elevation 973 feet msl.

Photo 13. Seepage Barrier by 2000 Breakthrough (During Construction) - June 8, 1995. Source: GAI. The 2000 breakthrough area is located at the left-center of the photo. Pool elevation 1,001 feet msl. Mine roof elevation 973 feet msl.

Photo 14. Seepage Barrier by 2000 Breakthrough (After Construction) - June 26, 1995. Source: GAI. The 2000 breakthrough area is located at the left-center of the photo. Pool elevation 1,006 feet msl. Mine roof elevation 973 feet msl. Contour bench elevation 1,075 feet msl.

Triad collected a bulk sample from the seepage barrier and estimated the permeability to be 10^{-3} cm/sec or about 2.8 feet per day.

The permeable nature of the seepage barrier highlights the importance of the slurry coating along the barrier. However, the sealing plan did not explain how the slurry coating process was to be conducted. Neither a timetable for moving the slurry discharge lines nor the required thickness of the slurry coating were discussed in the sealing plan.

3.3.2.2 Impoundment pool elevation: Another method of controlling seepage identified in the sealing plan relates to limiting the elevation of the pool and the depth of water above the settled slurry. This minimizes hydrostatic pressure at the barrier interface, thus limiting water infiltration through the spoil. However, the original plan did not indicate specific pool elevation limits above the slurry level that would be maintained. Only maximum pools were indicated on the supplied cross-sections. Thus, no operational controls for limiting the amount of hydrostatic head above the rising slurry level were in place.

3.3.2.3 Seepage barrier stability: To be effective, the seepage barrier must be stable against slides that would expose the outcrop barrier. A reasonable calculation of the barrier's "safety factor" requires that the engineering parameters, shape, and dimensions of the structure be accurately modeled.

The sealing plan contained a stability analysis of the seepage barrier and its slurry foundation. OSM found deficiencies in the analysis. As addressed in Section 3.5.5, OSM's review indicates that the seepage barrier stability did not contribute to the breakthrough. However, the issues identified below indicate that MCCC and Summit did not properly analyze the stability.

- The analysis used a 0.05 pore pressure ratio for both the seepage barrier and foundation. This value indicates only 10 percent saturation of the barrier and foundation. The 0.05 pore pressure ratio is not appropriate for the foundation because the foundation is saturated. Also, as the pool level increases, the seepage barrier will become increasingly saturated. The 0.05 pore pressure might be acceptable for the seepage barrier if it was constructed of impermeable material and effectively compacted. However, given the lack of compaction discussed above and the permeable nature of the spoil, a higher value would be more appropriate, representative, and conservative.

- For the seepage barrier foundation, the analysis employed friction-angle, cohesion, and unit-weight values for consolidated slurry (33°, 0 lb./ft.^{2}, and 100.1 lb./ft.^{3}, respectively) rather than unconsolidated slurry (22°, 0 lb./ft.^{2}, and 70 lb./ft.^{3}). Summit obtained this data from the 1983 Esmer & Associates, Inc. (Esmer) impoundment plan. The data may not have reflected the conditions at the time the seepage barrier was constructed. Laboratory testing was not done to confirm these values at the time the seepage barrier was constructed.

OSM performed its own stability analysis of the designed seepage barrier (Appendix 6). The analysis assumed the barrier and slurry were saturated and it used strength parameters for both consolidated and unconsolidated slurry. The analysis also assumed that the natural material underlying the seepage barrier was soil. The results indicate that the designed barrier has a safety factor as low as 1.3, compared to the Summit estimate of 1.6. While lacking site-specific parameters to increase confidence, the OSM stability analysis indicates that the seepage barrier would be stable at this lower safety factor.

3.3.2.4 Plugging of future breakthroughs: The sealing plan contended that the seepage barrier needed to be of sufficient thickness to provide a volume that would adequately plug an opening into the mine created by a breakthrough. Whereas the sealing plan specified that the seepage barrier should be one to two times the maximum 12-foot mining height, it did not explain how this thickness was sufficient to plug a future breakthrough. The plan also did not address the characteristics (e.g., mechanism, size, location) of potential failures that should influence the plugging effectiveness of the barrier. For example, the plan did not assess the height that an underground mine roof fall could extend upward. Roof caving will create sinkhole subsidence if the depth of solid rock overburden is less than the height of the roof cave. Figure 5 (Page 20), which is based on the sealing plan cross-section, shows the height that a roof cave could extend upward based on five times the mining height (Peng, 1978). As shown on the figure, a roof cave could extend nearly up to the surface of the seepage barrier for a location with a 70-foot outcrop barrier and a 10-foot mining height (conditions similar to the 2000 breakthrough). At the narrowest barrier location (35-foot wide barrier and about 7.5-foot mining height), a roof cave could extend to the surface of the seepage barrier. Such an assessment by MCCC would have indicated the possible need for other preventative measures.

3.3.2.5 Dimensions and stability of the outcrop barrier: Sections 2.1.3 and 2.1.5 address the outcrop barrier dimensions, openings in the barrier, fractures in the barrier, and surface disturbance over the barrier. MCCC did not conduct a geotechnical investigation to determine the nature and width of the outcrop barrier. Based on the mine maps, the barrier width ranges from about 35 feet to more than 300 feet, and the overburden thickness at the mine limit ranges from about 13 feet to greater than 100 feet. At the western side of the impoundment, an entry has extended through the outcrop barrier to the surface. This "punchout" may have been sealed with concrete, but OSM could not find written documentation of the closure. Vertical fractures in the outcrop barrier may exist. Finally, the surface of the outcrop barrier has been disturbed by the construction of access roads.

The effectiveness of the seepage barrier in preventing a breakthrough, or allaying the effects of a breakthrough, is partly dependent on the conditions of the outcrop barrier and mine roof. Conceivably, sufficient data might have identified particularly thin and/or weak zones in the outcrop barrier and mine roof that would have warranted local adjustments to seepage barrier design and/or construction (increasing the size of the seepage barrier, applying a thicker coat of fine refuse, etc.). It appears, however, that the outcrop barrier, pillar stability, and mine roof data available during the development of the sealing plan was limited, or if available, was not used to assess possible subsidence impacts. The Triad drilling in Section 3.5.1.3 revealed a greater portion of the outcrop barrier to be composed of colluvium than what is indicated in the sealing plan. The sealing plan's cross-section (Figure 5 [Page 20]) shows that a solid coal seam extends from the mine to the surface. The cross-section does not contain any notations concerning the nature of the material overlying the coal. However, the plan states that the overburden consists primarily of "sandstone with some shale." During the MSHA interviews, an MCCC consultant stated that the cross-section was not intended to illustrate the composition of the outcrop barrier. While the cross-section may not have been intended to show the actual composition of the outcrop barrier, the cross-section and "sandstone and some shale" statement together indicate that the outcrop barrier was composed of solid coal and rock.

The seepage barrier design did not appear to consider surface disturbance in the outcrop barrier area. For example, at the 2000 breakthrough location, the mine map indicates a road or diversion ditch below the Coalburg coal seam cropline, and the June 1, 1989, DSMRE aerial video shows a road above the cropline. These surface disturbances are not shown on the sealing plan cross-section.

Using the 45-degree subsidence angle of draw, Figure 5 (Page 20) shows the lateral extent of subsidence for three outcrop barrier widths. These outcrop barrier figures are measured from the bottom of the Coalburg coal seam mine limit to the cropline.

(1) 35 feet

This width represents the narrowest outcrop barrier (at the entry adjacent to the punchout located at the western side of the impoundment) as measured by OSM on the 100-scale map attached to the sealing plan.

(2) 70 feet

This width represents the outcrop barrier at the 2000 breakthrough location.

(3) 110 feet

This width represents the "typical seepage barrier section" contained in the sealing plan.

For the outcrop barrier width (70 feet) at the 2000 breakthrough, subsidence with a 45-degree angle of draw would intercept near the base of the seepage barrier. For the narrowest width of the outcrop barrier (35 feet), subsidence with a 45-degree angle of draw would extend to the toe of the seepage barrier. The "typical seepage barrier section" did not provide consideration for the worst-case subsidence scenario (35 feet).

During the MSHA interviews, a GAI consultant to MCCC, who had worked for Ogden at the time of the sealing plan preparation, stated that the cross-section was drawn to size the seepage barrier based on "typical" outcrop barrier conditions. The consultant suggested that the section was not intended to represent either the minimum or maximum conditions or to distinguish solid from weathered coal. Thus, a single outcrop barrier width was used for the seepage barrier design.

Also, the sealing plan did not provide complete and accurate information on the conditions of the outcrop barrier as follows:

- The sealing plan did not provide correct information on the width of the outcrop barrier. During the review of the permit revision, DSMRE requested MCCC to locate and orient the stability cross-section to a particular mine map (October 24, 1994, deficiency letter, item 5.f). However, at the location provided in Summit's response for MCCC, the mine map shows the outcrop barrier to be about 400 feet wide, not 110 feet as indicated on the cross-section.

- The sealing plan did not provide information on the mine roof material or its competence. Information on roof material could have been obtained through exploration drilling. Some of this information could have been obtained from observations of the conditions in the North Mains.

- The sealing plan did not indicate that exploration was conducted to determine the condition of the outcrop barrier material. The plan also does not indicate that exploration was conducted to validate the horizontal distance between the underground mine and the cropline or vertical distance to the surface above the mine void. These shortcomings in the sealing plan development were confirmed in the MSHA interviews. While a portion of the outcrop barrier was covered with slurry, drilling to validate the location of the mine boundary and nature of outcrop barrier and mine roof material was still possible.

- The sealing plan did not address the methods proposed to seal the punchout (along the western side of the impoundment) or the portals (along the northeastern side of the embankment).

3.3.2.6 Potential effects of blasting: Surface blasting near underground mines has the potential to damage the mine roof. The sealing plan contained a blasting plan, but the plan did not contain an assessment of the potential for blasting impacts on the underground mine roof. OSM's review, as addressed in Section 3.5.3, did not indicate that blasting contributed to the breakthrough. However, the issues identified below indicate that MCCC and Summit did not fully analyze the effects of blasting.

With regard to the blasting plan's assessment of potential impact, the permit reviewer asked MCCC to: (1) specify how the slurry impoundment and underground mine will be protected from adverse impacts of blasting, and (2) discuss the possibility of subsidence and any adverse effects (October 24, 1994, deficiency letter, item 4.f). Summit responded that subsidence potential was addressed in the 1984 Esmer report submitted with Amendment #1. However, the Esmer report merely states "It is not anticipated that subsidence will be a problem, since the underground mines are situated only beneath the perimeter of the impoundment site and do not extend for any appreciable distance directly below the proposed structure." The Esmer report does not address the subsidence potential that could be caused by blasting. The permit revision only provides blasting control limits with respect to the underground mine seals. Even in this case, it is not clear whether the blasting limits apply only to seals located at the bulkheads off the North Mains, or whether they also apply to the seals at the entrance to mining areas #1 and #2 (Figure 2 [Page 4]).

DSMRE's regulations (405 KAR 16:010 Section 3) require that DMM and MSHA approve surface-mining activities, including blasting designs, if they will be conducted within 500 feet of an active underground mine. After DSMRE receives the design from the permit applicant and if the underground mines are active, DSMRE submits the design to DMM and MSHA for their approval. The design prepared by Summit incorrectly stated that the underground mine was abandoned and it did not identify the fact that the blasting was related to the sealing plan. Portions of the mine had been sealed off and were "inactive" but not "abandoned." Based on the statement in the design that the mine was abandoned, and apparently without knowledge of the purpose of the blasting, DMM recommended that DSMRE approve the blasting. OSM's review also noted that Summit, in a November 21, 1994, correspondence to DSMRE, said that seals in the underground mine would be inspected during blasting, but did not say how this would be done in an abandoned mine. Finally, there is no record in DSMRE's file that MSHA either approved or disapproved the blasting design.

The blasting design incorrectly calculated the powder factor (PF), which is the weight of explosive per cubic yard of rock to be blasted. The design calculated a PF of 0.22 for a 25-foot deep blast hole. Such a blast may not have had enough explosive energy to break the rock sufficiently to allow removal. The actual PF was 0.45 for a 12-foot hole.

3.3.2.7 Storage and control of breakthrough water in the underground mine: The sealing plan did not contain adequate contingency measures in the event of another breakthrough. The plan called for the construction of the bulkheads to prevent the water and slurry from entering the North Mains and wet seals at the South Mains Portal to allow the release of the liquid to the surface. These features address the protection of the mine workers, but did not provide for protection of the public and environment in the Wolf Creek watershed. Observations of key elements of this part of the sealing plan are as follows:

- Bulkheads: The plan assumed an 18-foot head to design the bulkheads adjacent to the North Mains. The 18-foot head estimate was based on the depth of water that would push against the bulkheads in the event of another breakthrough. The depth, in turn, was based on calculations indicating that water from a future breakthrough would flow out the South Mains Portal. Considering the inability of MCCC to determine the flow constrictions within the mine, it would have been prudent to assume a high head potential in the design of the seals.

  The sealing plan required the bulkheads to be comprised of three and one-half foot thick reinforced, poured concrete structures placed against existing seals located off the North Mains. Subsequent to DSMRE's approval of the bulkhead, MCCC submitted changes to MSHA, but not DSMRE. MSHA approved the changes. The revised plan required one-foot thick reinforced gunite (shotcrete) to be placed against the existing seals.

- Protection of residents, property, and the environment: The sealing plan would allow a breakthrough to freely drain through the South Mains Portal into Wolf Creek. Coldwater Fork would be protected by the bulkheads. During the review of the permit revision, DSMRE asked MCCC to address preventative measures for intercepting and controlling water (blowouts) from the underground mine (October 24, 1994, deficiency letter, item

4.g.). Summit responded that, "The preventative measures to be implemented for intercepting the water is the Impoundment Sealing Plan as proposed by Ogden. The release of the water is through the wet seals [at the South Mains Portal] as proposed by Ogden." The sealing plan did not provide for the interception or control of breakthrough water and slurry that would drain from the South Mains Portal.

The DSMRE permit reviewer asked MCCC to provide information on slurry injection into the underground mines (October 24, 1994, deficiency letter, item 9.f and 10.a-c). The reviewer apparently was concerned about the slurry injection notations on the 400-scale mine map attached to the sealing plan. Summit responded that the revision does not address slurry injection into the mine. However, the injected slurry should have been discussed in the sealing plan because it could reduce the capacity of the underground mine to store a future breakthrough.

3.3.2.8 DSMRE approval and implementation: Additional problems relating to the approval and implementation of the sealing plan are enumerated as follows:

- Permit review and inspection: None of the permit maps provided a comprehensive illustration of the full extent and stages of the embankment and impoundment construction. While these features are shown on map sheets (generally on seven separate sheets per construction stage) in the 1984 Esmer impoundment design, it undoubtedly was cumbersome for the permit reviewer to correlate the Esmer design with the surface features shown on the permit maps. Also, it was likely difficult for the DSMRE inspector to correlate the field conditions with the Esmer design and subsequent permit revisions.

  During the review of the permit revision, DSMRE asked MCCC to show the extent of the abandoned underground mine on the Mining and Reclamation Plan (MRP) map (October 24, 1994, deficiency letter, item 4.g). Summit responded "The extent of underground mines have been shown on other maps. It would not benefit anyone to clutter the MRP map with more information." Summit is correct in stating that the underground mines are shown on other maps (map attached to the 1994, sealing plan and the map contained in July 23, 1984, Esmer impoundment design). However, it undoubtedly was awkward for permit reviewers and inspectors to correlate permitted surface features with the underground mines. This may explain the permit reviewer's acceptance of Summit's statement that blasting would not be conducted within 500 feet of an active underground mine. As another example of the difficulty of correlating permitted features with the underground mines, Summit, in Amendment #2 (in response to item 35.3 of the permit application), stated that the proposed coarse refuse, non-impounding embankment did not overlay an underground mine. However, portions of the South Mains, including the entries to the South Mains Portal, appear to lie under the proposed coarse refuse embankment. In this case, the applicant would have been required to describe the potential effects of subsidence on the structure.

- The public interest: The permit revision was classified as a "minor" rather than a "major" revision. According to Kentucky regulations at 405 KAR 8:010 Section 20(2)(a), a revision shall be deemed a major revision if the Cabinet determines that the proposed change is of such scope and nature that public notice is necessary to allow participation in the Cabinet's decision by persons who have an interest which may be adversely affected by the proposed change. By classifying the revision as minor, the application for revision did not require public notice. Considering the adverse consequences that could occur if the sealing plan did not function as designed, public notice should have been required.

- Certifications: The actions taken under the sealing plan were not fully certified (Appendix 7). MCCC did not prepare a certification of design (DSMRE form SMP-31) for the seepage barrier. DSMRE requires such certifications for impoundments, excess spoil fills, roads, etc. While the regulations do not specifically address certification of seepage barriers, DSMRE could have required certification of the seepage barrier design because the barrier is a component of the impoundment plan.

  An as-built stability analysis, for certification purposes, of the seepage barrier was not prepared, even though its final configuration was significantly different from the designed 2:1 outslope (two feet horizontal for every foot vertical). The final slope was about 3:1. This may have had a positive effect by increasing the thickness of the seepage barrier. However, it may have potentially decreased the stability of the barrier foundation because the seepage barrier extended farther out over the slurry.

  The annual certifications did not address the slurry coating of the seepage barrier. This may have been related to the lack of specifications concerning this requirement; and therefore, the weekly inspector may not have been aware of the requirement. See Section 3.3.2.1 for additional discussion.

  The annual certifications did not address the water monitoring conducted at the South Mains Portal. The 1995 certification form identified "leakage," but the attached narrative did not address the leakage. The 1998 annual certification did not address the bubbling that occurred in the impoundment in February 1998. Bubbling is an indication of leakage and, therefore, should have been addressed in the annual certification.

  DSMRE's certification files for the impoundment permit (Permit Number 680-8002) and the underground mine permit (Permit Number 680-5012) do not contain any certification documentation or reference to the bulkheads. The bulkheads are a component of the sealing plan and should have been certified. The design approved by MSHA required five steel reinforcing bars at the top and bottom of each bulkhead. The bars were supposed to extend into the mine roof and floor. However, a construction drawing that MCCC supplied to the contractor installing the bulkheads showed only three steel bars at the top and four at the bottom.

3.3.2.9 Impoundment monitoring: Discharges out of the South Mains Portal were monitored on a weekly basis starting in July 1994. Monitoring at the South Mains was addressed in the short-term plans prepared after the 1994 breakthrough. However, the results of the monitoring were not submitted to DSMRE nor assessed in the annual certifications. The plan did not contain any in-mine monitoring.

3.3.2.10 Employee awareness: The MSHA interviews revealed that not all of the MCCC personnel responsible for the impoundment had specific knowledge concerning the underground mine and its outcrop barrier and the intent of the seepage barrier. Consequently, early signs of leakage, if ever observed, may not have been identified as related to the underground mines. This is the case with the GAI employee who conducted the weekly impoundment inspections. The employee was never given drawings of the outcrop area or barrier seal, and he had no knowledge of the outcrop barrier. The MCCC preparation plant superintendent and the supervisor for the night shift had not seen, or could not remember seeing, the sealing plan and they had no knowledge about the outcrop barrier. Also, the supervisor was not aware of the bubbling reported in the impoundment during February 1998, or of the remedial action.

Summary

- Seepage barrier compaction and permeability (3.3.2.1). The sealing plan did not provide, except in a very general manner, any construction specifications for the method of placement and compaction. The plan would result in a permeable seepage barrier due to: (1) gravity segregation of large rocks at the base of the seepage barrier, and (2) lack of compaction. The seepage barrier appears to have been constructed in a single lift at times greater than 30 feet thick. The sealing plan stated that the lifts would not exceed 20 feet.

  MCCC did not provide permeability test results or a quantitative analysis to support its permeability estimate related to seepage from the impoundment. Also, the permit did not address the thickness of the slurry coating necessary to inhibit seepage.

  The sealing plan stated that slurry would be directed along the barrier to inhibit seepage into the barrier. However, the plan does not: (1) provide specifications on how this action would be conducted or (2) specify the required thickness of the coating. MSHA's interviews found that the slurry was discharged at only one location.

- Impoundment pool elevation (3.3.2.2). The sealing plan stated that MCCC would limit the depth of water above the slurry level. However, the plan does not provide specifications on how this action would be conducted.

- Seepage barrier stability (3.3.2.3). MCCC did not conduct material testing to verify the strength parameters used in the stability analysis and the analysis also used inappropriate saturation conditions. OSM's stability analysis of the designed seepage barrier indicates that it is stable; however, the analysis indicates that the safety factor is lower than the estimate in the permit revision.

- Plugging of future breakthroughs (3.3.2.4). The sealing plan indicated that the seepage barrier would plug future breakthroughs. However, the plan did not assess the seepage barrier's plugging capabilities for the various types of openings that could develop in response to subsidence. OSM's review indicates that sinkhole subsidence could extend through the designed barrier. Such an assessment by MCCC would have indicated the need for alternative preventative measures.

- Dimensions and stability of the outcrop barrier (3.3.2.5). The sealing plan does not indicate that MCCC conducted testing to: (1) verify that the outcrop barrier was accurately shown on the maps, and (2) determine the nature and competence of the outcrop barrier and mine roof. The sealing plan contained a cross-section showing a "typical" outcrop barrier rather than the narrowest barrier, and estimated, using the typical drawing, that subsidence would not extend to the base of the seepage barrier. OSM's estimated the extent of subsidence based on the narrow barrier and found that it would extend into the base of the seepage barrier. Neither the sealing plan, nor previous permitting actions, addressed how MCCC would seal an existing punchout and set of portals.

- Potential effects of blasting (3.3.2.6). The sealing plan addressed blasting; however, it did not assess the impacts that blasting could have on the underground mine roof. The revision did not contain any vibration limits to protect the roof. The revision stated that the underground mine was abandoned, and DMM recommended approval of the blasting based on the abandoned status. Further, apparently the blasting plan submitted to DMM did not address the impoundment. With regard to blasting near the underground mine seals, the revision incorrectly calculated the blasting PF and proposed a low PF that may not have been sufficient to break the rock.

- Storage and control of breakthrough water in the underground mine (3.3.2.7). The sealing plan used a water depth to design the bulkheads based on the assumption that the South Mains Portal would handle future breakthroughs. A more conservative water depth would have been appropriate. After MSHA and DSMRE approved the sealing plan, MSHA approved a bulkhead design change. However, MCCC did not request DSMRE's approval of the change. The sealing plan did not address how future breakthrough discharges would be contained within the permit area. The sealing plan did not address how slurry, previously injected into the underground mine, could affect future breakthrough discharges.

- DSMRE approval and implementation (3.3.2.8). The permit maps do not contain sufficient details on the embankment and impoundment. Also, the permit maps do not enable a concise correlation of the surface and underground mine features. The permit revision was treated as a "minor" rather than "major" revision, and consequently, public notice of the proposed revision was not required. MCCC did not prepare a DSMRE certification of design for the seepage barrier. The actions taken under the sealing plan were not fully certified. The constructed bulkheads were not certified, and an as-built stability analysis for the seepage barrier was not performed. An as-built stability analysis for the seepage barrier was warranted because of the difference between the constructed and designed configurations. Also, the annual maintenance certifications do not assess the drainage monitoring at the South Mains Portal.

- Impoundment monitoring (3.3.2.9). The South Mains Portal monitoring data was not submitted to DSMRE nor assessed in the annual certifications.

- Employee awareness (3.3.2.10). The MCCC employees responsible for the impoundment and the weekly inspector were not fully aware of the extent of the underground mines and the purpose of the sealing plan.

3.4 MCCC EAP

The EAP, as addressed in MSHA Program Information Bulletin No. P94-18 (Appendix 9), is intended to satisfy the regulatory requirements at 30 CFR 216-3(e). The EAP is not required by the OSM regulations. MCCC submitted an EAP to MSHA on April 10, 1991 (Appendix 8). The EAP was approved on June 14, 1991. The approved EAP addresses procedures to be taken when adverse conditions develop in the embankment. It includes emergency warning and evacuation notices to federal and state agencies, including MSHA, DSMRE, DMM, Sheriff's Office, Kentucky State Police, and DES. According to the MCCC transmittal letter to MSHA, copies of the EAP would be provided to these agencies subsequent to MSHA's approval of the plan.

The EAP includes a map showing only the area that could be impacted in the event of an embankment failure. The impacted area is shown as the portion of Wolf Creek located downstream from the embankment. The map does not show the areas that could be affected by a breakthrough into the underground mines (e.g., Big Andy Branch and Coldwater Fork). The approved EAP provides that any decision to evacuate the area would be made concurrently by MSHA, DMM, and DSMRE.

MSHA's interviews of MCCC personnel indicated that the supervisory personnel were not consistently knowledgeable of the provisions of the EAP. One supervisor was not aware that the plan required downstream notification. The security chief was not aware of the plan.

The MSHA interviews indicate that MCCC generally complied with the requirements of the EAP following the 2000 breakthrough. MCCC initiated corrective action, monitored stream conditions, and notified the federal and state agencies.

Summary

- The EAP did not cover all of the surface areas that could be affected by a breakthrough.

- MCCC generally complied with the requirements of the EAP following the 2000 breakthrough.

3.5 2000 Breakthrough

The breakthrough occurred on October 11, 2000, at the end of a 50-foot long, 20-foot wide dead-end entry in the underground mine in the Coalburg coal seam. This breakthrough resulted in a slurry discharge from the South Mains Portal. The slurry also destroyed one or more of the ventilation seals off of the east-west mains and the bulkheads off the North Mains, inundated the conveyor haulage system in the North Mains, and discharged from the Number 2 North Portals. At the time of the breakthrough, the pool was at 1,060 feet msl and 87 feet above the underground mine roof (Figure 4 [Page 18]). The pool level then dropped by about 14 feet. An estimated 306 million gallons of slurry drained into the underground mine, and an estimated 245 million gallons of slurry discharged from the underground mine to the surface drainage systems.

OSM determined the probable mechanisms for the 2000 breakthrough by reviewing the following: (1) information obtained from the MSHA interviews, (2) the impoundment permit files and 1-C mine map files, (3) photographs, (4) various other information, such as drill hole data, precipitation records, mine discharges, seismic records, and pool levels, and (5) OSM modeling.

OSM determined that the mine entries or other openings did not extend to the surface near the 2000 breakthrough prior to October 11, 2000. This determination was based on a comprehensive review of the permit files, including maps, as well as photographs. By the events during and following the breakthrough, it is clear that two important components of the sealing plan did not perform as anticipated. The seepage barrier failed to plug the breakthrough, and the bulkheads failed to prevent the slurry from entering the North Mains.

3.5.1 Subsurface investigation: Triad, under contract with MSHA, conducted drilling at the 2000 breakthrough area. The drilling provided considerable detail of the subsurface conditions. The drilling was primarily conducted along three lines (numbered 1, 2, and 3) that run down the center of the mine entry associated with the breakthrough and two adjacent entries. The drill holes are numbered according to the line on which they are located. Holes were also drilled adjacent to the lines and these holes are given an "X" or "P" designation. The drill lines and holes are shown on Figure 6 (Page 53). The Field Test Boring Logs generated by Triad for the 47 drill holes were used as the primary source of the information for this section of the report.

3.5.1.1 Location of failure: The Triad drilling confirmed that the failure occurred at the southwest corner of the 50-foot long, dead-end entry at Line #1, as illustrated in Figures 2, 4 and 6 (Pages 4, 18, and 53).

3.5.1.2 Mine and surface map accuracy: The underground mine location and configuration is shown on the sealing plan map. The map also shows surface contours based on 1985 aerial photography. The underground mine rooms and pillars were superimposed on the topography by aligning the mine and surface survey data. The drilling, conducted under MSHA contract, generally confirmed the accuracy of the underground mine location and configuration at the breakthrough area.

To conduct the drilling program for MSHA, Triad conducted a land survey using both underground and surface survey stations to locate the underground mine in the general area of the breakthrough. Triad then staked the underground mine boundary on the land surface. Triad, under guidance from MSHA, conducted drilling in the vicinity of the 2000 breakthrough to verify the boundary of the underground mines as shown on the sealing plan map. The drilling also disclosed the types of material overlying the underground mine. The drill holes generally located coal and mine voids where the map showed coal and mine voids should exist. The drilling did not identify any missing or collapsed coal pillars. This is consistent with the mine map, which indicated that MCCC did not extract pillars.

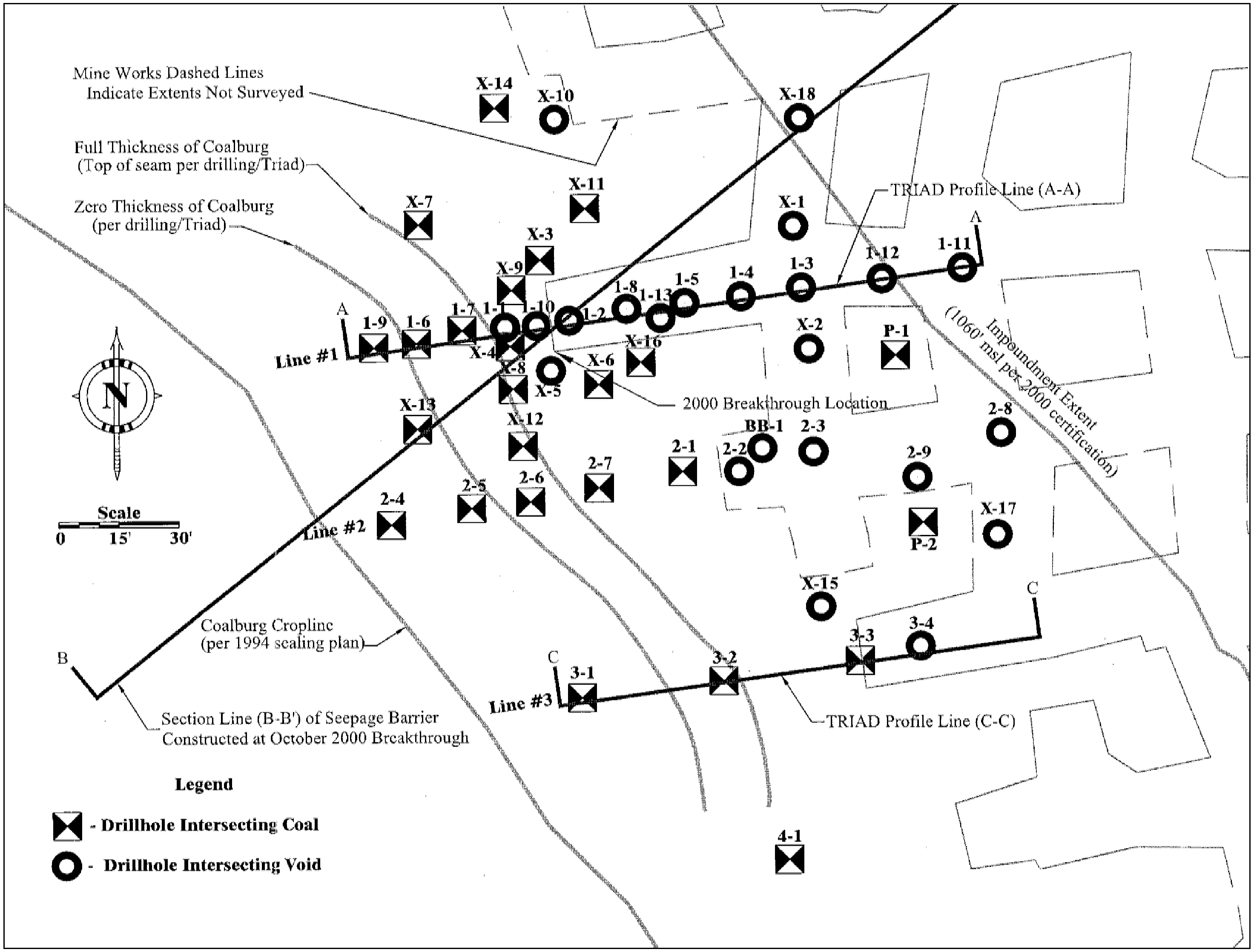

Figure 6. Drill Hole Location Map. Drawn by OSM using Triad drilling data. Note: The Triad drill logs did not indicate that voids were encountered by holes X-4 and X-8; however, these holes, along with X-5, are located in the breakthrough erosion channel.

The drilling, holes 1-1 and 1-10, identified a void beyond the mapped mine entry (mine limit) at the 2000 breakthrough. These drill holes were located along the centerline of the entry. This is in contrast to drill hole X-9, which did not identify a void near the left side of the entry. It is not known whether the "missing" coal was mined or eroded during the breakthrough. However, coal remaining at the base of the holes (1-1, X-4, X-5, X-8) suggests that the coal was eroded and not mined. Except for holes 3-4 and X-15, the Triad drilling indicates that MCCC mined the total thickness of coal.

In addition to showing the underground mines, the sealing plan map also presents the topography, various surface features and the projected cropline in the 2000 breakthrough area. MCCC projected the cropline by extending mine floor elevations horizontally to intersect the surface topography. The Triad drilling and surveying confirmed the general location of the projected cropline shown on the sealing plan map. At the 2000 breakthrough, the map showed 70 feet, measured horizontally, from the end of the mapped mine limit to the cropline.

3.5.1.3 Drill logs: The materials encountered during drilling (from top to bottom) include: refuse/slurry material, combined spoil zone (the seepage barrier and material used to plug the 2000 breakthrough), colluvium, sandstone, shale, coal, and mine floor rock.

As discussed in more detail in the following paragraphs, a significant portion of the overburden at the 2000 breakthrough was not composed of solid rock. At the end of the mine entry where the breakthrough occurred, the overburden, based on vertical measurements from Figure 7 (Page 55), was composed of about 14 feet of sandstone and 11 feet of colluvium. (Note: MSHA has characterized this distance by a diagonal measurement of 27 feet at the end of the mine entry. MSHA's measurement was made along Triad Profile D-D [see Inset Figure 4, Page 18] while OSM's measurement was made along Triad Profile A-A, Figure 7 [Page 55].) Further, more than fifty percent of the upper portion of this sandstone may have been weathered.

At the end of the 10- to 12-foot section of "missing coal" (Figure 7 [Page 55]), the overburden is composed of only about four feet of weathered sandstone and 15 feet of colluvium. This is in contrast to the sealing plan that indicates that the overburden was solid rock (Section 3.3.2.5). Further, the sealing plan's cross-section and maps indicate that the horizontal distance between the mine limit at the 2000 breakthrough and the surface was 50 feet at the top of the coal seam and 70 feet at the bottom of the coal seam. However, the drilling near the breakthrough indicates that the Coalburg coal seam extended less than half the distance from the mine limit to the surface. The full thickness of the Coalburg coal seam exists for only about 15 feet beyond the mine limit as mapped and then it thins to zero feet thick at about 33 feet from the end of the mine (Figure 6 [Page 53]). The Triad drill logs did not identify coal in the remaining portion of the 70-foot wide outcrop barrier. This coal is presumed to be in a weathered condition, and it may have been transported downslope due to hillside creep.

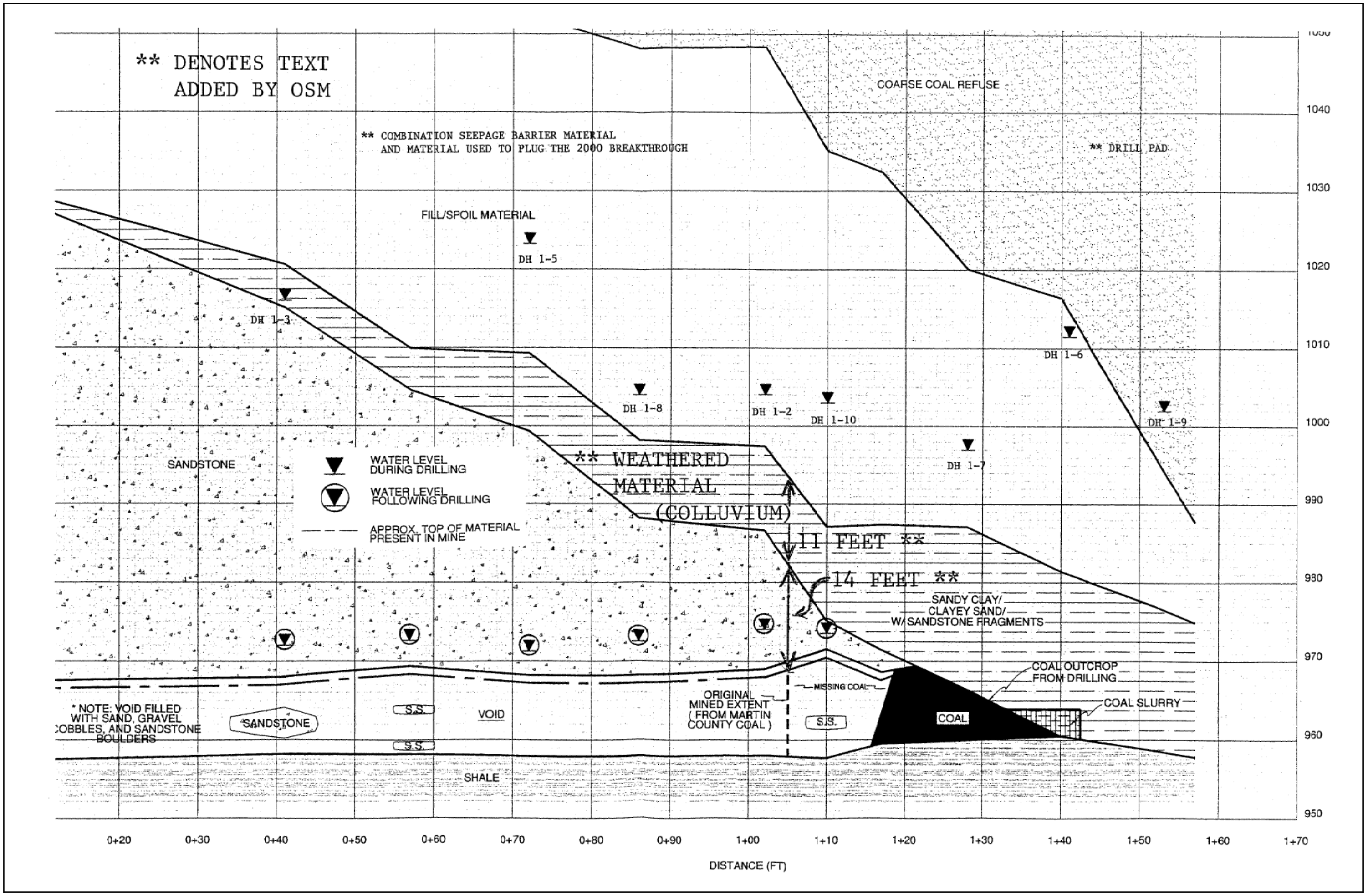

Figure 7. Triad Profile A-A. From Triad Report, Cross-Section at Line #1, Figure 6.

The following summarizes the data from the Triad drilling:

- Refuse/slurry: This material is described in the drill logs as coal refuse but most likely represents the unconsolidated material used to construct the drilling pad. The thickness varied from less than a foot along the eastern drill holes to 50 to 60 feet thick at the westernmost drill holes.

- Combined spoil zone: After the 1994 breakthrough, a seepage barrier was constructed with spoil derived from overburden removed from above the Stockton coal seam. The overburden above the Stockton coal seam included colluvium, as well as weathered and competent sandstone. The spoil was placed downslope of the Stockton coal seam, over areas where underground mining had occurred. Material similar to that in the seepage barrier was used by MCCC during the early hours of October 11, 2000, to plug the breakthrough and later to construct a drilling pad. These two material layers are referred to as the "combined spoil zone." Subsequently, during the expansion of the original drilling pad, the combined spoil zone was covered with coarse coal refuse.

  Because the two layers (seepage barrier and breakthrough plugging material) are composed of similar material, the drilling results could not differentiate them. Consequently, the surface of the seepage barrier could not be identified. The approximate configuration of the seepage barrier is shown in Figure 4 [Page 18]. The material primarily consisted of brown, clayey sand with abundant sandstone fragments and occasional boulders. This material was unconsolidated and soft as evidenced by the augering and driven, split-spoon sampling used to penetrate the zone. Typically, the auger is used until the driven, split-spoon sampler can no longer be advanced (commonly called "refusal"), at which time a rock core barrel would be used. In general, the auger and split-spoon drilling method was able to penetrate the material in this zone.

  The annual certification maps indicate that the seepage barrier varied from a few feet thick at the top (just below the Stockton coal seam) to more than 30 feet, measured perpendicular to that slope, at its base (Figure 4 [Page 18]). Based on the drilling data, it appears the seepage barrier eroded into the mine during the 2000 breakthrough.

- Colluvium: Detection of the interface between the combined spoil zone and colluvium was difficult since their lithologies are similar and because both zones could be penetrated by the driven, split-spoon sampler. The distinction between spoil and colluvium was made using the driller's notes, as well as changes in texture, color, and organic components. The natural material itself cannot be differentiated between colluvium (soil transported by gravity) and residuum (soil formed in-place by the weathering of the bedrock). This unit was typically shown as a brown to gray, mottled sandy clay with few rock fragments, only an infrequent boulder, and some defined root zones. The unit varied in thickness from a little over 5 feet to more than 27 feet. The drill logs for X-4 and X-8 did not show what was termed to be "natural or colluvial material." Also, the drill logs for X-5 (5.5 feet) and X-6 (4.3 feet) indicated thinner intervals of "natural or colluvial material" than would be expected based on a thickness of between 10 and 15 feet in other drill holes. The drill logs for X-4, X-5, X-6, and X-8 indicate that the colluvium was eroded during the breakthrough.

- Sandstone: This unit was distinguished from the unit above in part by refusal of the split-spoon sampler. The sandstone was mostly medium-grained and weathered from gray to brown. The weathered portion was reportedly brown, soft, and friable, while the unweathered portion was gray and hard. The sandstone in the core samples exhibited frequent iron staining, fractures, and occasionally carbonaceous and shale laminations. Along Line 1 (Figure 6 [Page 53]), the thickness of this unit ranged from 0.0 to 64.4 feet. The weathered sandstone varied in thickness from 0.0 to 8.2 feet.

  The entire sandstone column at drill holes 1-1 and 1-10 (4.1 and 3.6 feet thick, respectively) was weathered. This sandstone would comprise the mine roof if this area had been mined. OSM's review (see Coal below) indicates that the void encountered by the Triad drilling at drill holes 1-1 and 1-10, may have been created during the 2000 breakthrough. In drill hole 1-2, which is located near the end of the entry where the breakthrough occurred, approximately half of the upper portion of the 17.6-feet thick sandstone interval was also weathered. The location of these three drill holes relative to the mapped mine entry is shown on Figure 6 (Page 53).

  The sandstone is absent at X-4 and X-8, even though the surrounding drill logs (1-1, X-5, and 2-7) indicate that a few feet of sandstone should have been expected. Apparently, the sandstone was "eroded and/or transported" during the 2000 breakthrough. Evidence of erosion includes (1) sandstone showing thinner than expected (at 1-10) and (2) sandstone boulders being detected in the mine voids (at 1-10, 1-3, and 1-4).

- Shale: This unit is typically described as soft, gray shale. Based on the drill logs, this unit is relatively thin (0 to approximately 3 feet) and was noted in several of the drill logs where the coal was solid. The shale was typically not recorded in the holes that encountered mine voids. This does not appear to be a depositional feature (i.e., a "pinch-out") since the shale was consistently encountered in drill holes that penetrated coal. The Triad drilling does not indicate any roof falls beyond the breakthrough point.

- Coal: The Coalburg coal seam (when encountered in the drill holes) was simply shown as coal and was not described as to the presence of partings, cleat and fracture development, hardness, etc. The solid coal in the drill logs varied in thickness from zero feet toward the cropline to 11.1 feet at its thickest at drill hole X-3. Excluding the area toward the cropline where the coal thinned as a result of weathering, the median value for mineable thickness of the coal was 9.2 feet. Mine void heights varied from 9.5 feet at X-1 to 11 feet at 1-2 with a median value of 10.2 feet. The difference of one foot between the median values of the mineable coal thickness and the mine void thickness appears to be related, as previously discussed, to the presence or absence of the shale overlying the Coalburg coal seam.

  An exception to the range of coal seam thickness and mine void height was noted in the drill logs. First, the coal thickness in X-4, X-5, and X-8 was considerably thinner (2 feet, 1.2 feet, and 3 feet, respectively) than would be expected based on the surrounding drill hole information. Erosion of the upper portion of the coal into the mine during the 2000 breakthrough may have created voids beyond the limits of mining. According to the mine map, these holes would not fall within the plotted underground mine mines. Additional evidence for the erosion is that these voids are almost 14 feet high, considerably higher (approximately 40 percent) than the other underground mines encountered in the drilling program. Erosion from the 2000 breakthrough probably created the voids and enlarged them by scouring the bottom of the sandstone.

- Mine floor rock: The mine floor rock was consistently reported as soft to very soft gray, clay shale. This unit served as a good marker bed for establishing the bottom of the coal seam.

3.5.1.4 Seepage barrier slurry coating and saturation: As addressed in Section 3.3.2.1, the sealing plan required slurry to be directed along the seepage barrier by periodically redirecting the discharge of slurry. The MSHA interviews with the weekly inspector revealed that slurry was pumped into the pool from only the east, upstream side of the embankment. This discharge location is at the opposite end of the impoundment from the 2000 breakthrough. Thus, it appears that an effective fine refuse layer was not in place to prevent water at the clear-water zone from seeping through the seepage barrier.

Triad, during its drilling of the 2000 breakthrough area, identified the water level in the seepage barrier. The drilling along Line 3 indicated that the full thickness of the seepage barrier was saturated at the bottom of the barrier (Figure 8 [Page 59]). Line 3 is farthest from the breakthrough point and probably best represents the conditions prior to the 2000 breakthrough.

3.5.1.5 Enviroscan, Inc.'s Geophysical Survey: Under contract to MSHA, Enviroscan, Inc., conducted misa-a-la-masse electrical profiling at the Triad drilling site. The survey identified two primary subsurface electrical peaks or anomalies. The electrical peaks trend toward, but do not reach, the known breakthrough point. Triad assessed the survey results in conjunction with their drill-hole data. Triad concluded that there was no evidence of a possible breakthrough at the anomaly locations. The electrical peaks were interpreted as responding to bedrock fractures or joints.

3.5.1.6 Borehole camera analysis: DSMRE videotaped the Triad boreholes with a down-hole camera. Because the boreholes were cased down to the sandstone unit, the videotapes do not provide any information on the combined spoil zone or the colluvium. OSM reviewed the videotapes and observed some natural, mineral-stained fractures. The review did not identify any large bedding separations or fractures attributable to the 2000 breakthrough.

Summary

- Location of failure (3.5.1.1). The failure occurred at the end of a 50-foot long dead-end entry.

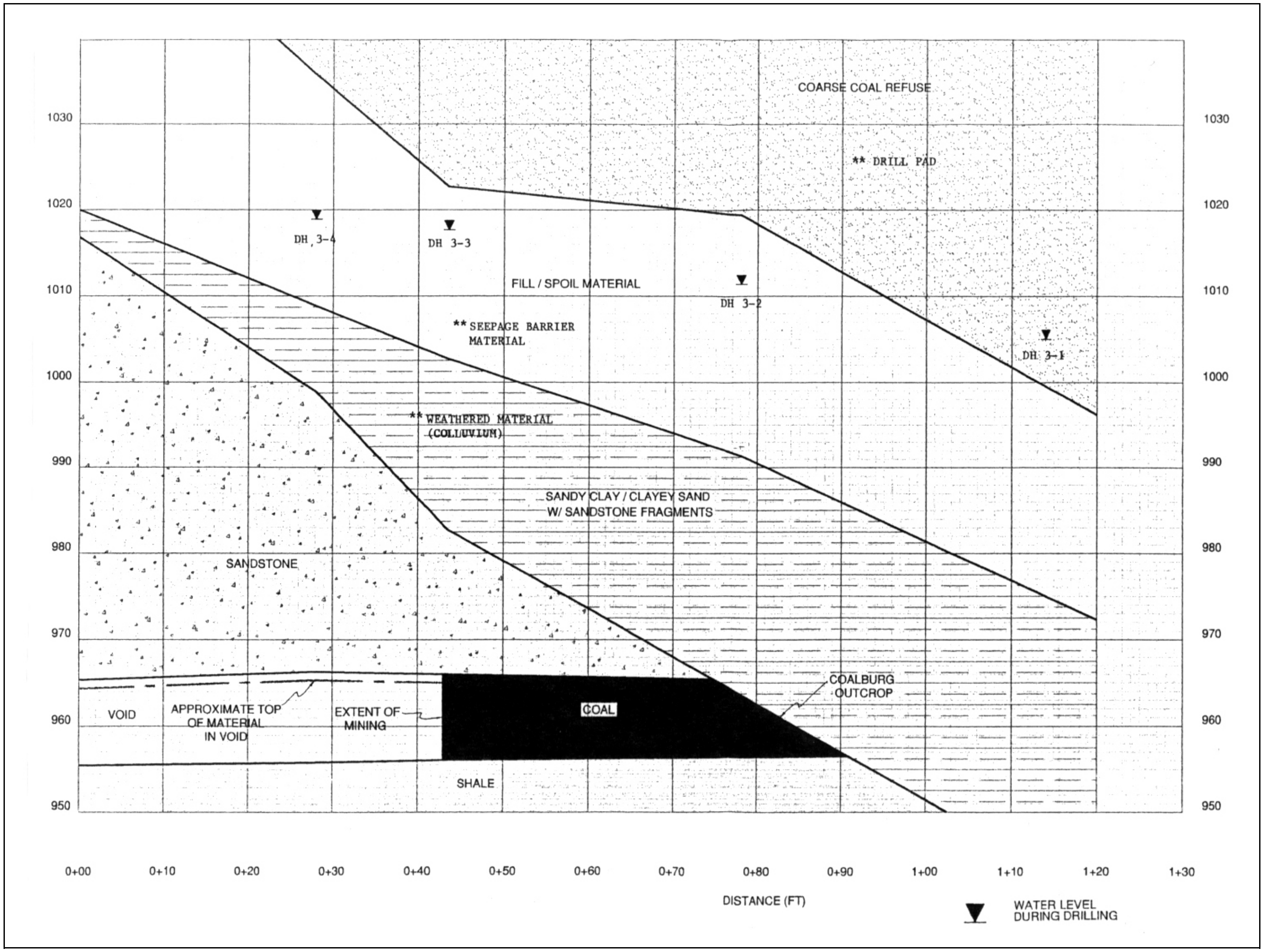

Figure 8. Triad Profile C-C. From Triad Report. Cross-Section at Line #3, Figure 6. ** Denotes Text Added by OSM.

- Mine and surface map accuracy (3.5.1.2). The Triad drilling generally confirmed the accuracy of the underground mine location and configuration at the 2000 breakthrough. The drilling identified 10 to 12 feet of missing coal beyond the end of the breakthrough entry. It is not known whether the "missing" coal was mined or eroded during the breakthrough. However, OSM's review, based on an examination of the drill logs, indicates that coal was eroded during the breakthrough.

- Drill logs (3.5.1.3). Based on the drilling near the 2000 breakthrough, there was approximately 14 feet of solid rock overlain by 11 feet of colluvium measured vertically at the end of the 50-foot long dead-end entry. More than 50 percent of the upper portion of this sandstone may have been weathered. At the end of the 10- to 12- foot section of missing coal, the thickness of the rock overburden may have been as little as four feet of weathered sandstone, and the unconsolidated material may have been about 15 feet (Figure 7 [Page 55]). At the breakthrough, the Triad drilling indicates the full thickness of the Coalburg coal seam extends for only about 15 feet measured horizontally beyond the mine limit as mapped, and then it thins to zero feet thick at about 33 feet from the mine limit (Figure 6 [Page 53]). However, the sealing plan cross-section and maps indicate that the full thickness of coal extended the total distance to the surface (70 feet from the mine limit to the cropline). The coal between the cropline and the coal encountered by the Triad drilling is presumed to have weathered.

- Seepage barrier slurry coating and saturation (3.5.1.4). The slurry coating was not conducted as required by the sealing plan. The Triad drilling indicates that the total thickness of the seepage barrier was saturated at the bottom of the barrier.

- Enviroscan, Inc.'s Geophysical Survey (3.5.1.5). The survey identified subsurface anomalies that were interpreted as bedrock fractures or joints. There was no evidence of a possible breakthrough at the anomaly locations.

- Borehole camera analysis (3.5.1.6). The review did not identify any large bedding separations or fractures attributable to the 2000 breakthrough.

3.5.2 Mine Discharge Data: In Appendix 10, OSM reviewed the discharge from the pond near the South Mains Portal to determine if the discharge provided a forewarning of the 2000 breakthrough. The pond received surface drainage from a 10.8-acre watershed as well as from the 1-C underground mine. The pond discharged through an 18-inch pipe. During the weekly inspections, the depth of flow in the pipe was measured and recorded.

Long-term, weekly monitoring plans for the South Mains Portal pond were contained in the August 8, 1994, sealing plan. The plan required the weekly inspector to immediately report to MSHA and MCCC any unusual change in flow that would indicate possible impoundment leakage. The sealing plan was attached to the August 18, 1994, permit revision. The permit revision's surface and groundwater monitoring plan did not address the monitoring at the pond nor its importance with regard to detecting impoundment leakage. Consequently, the information was not submitted to DSMRE and the DSMRE inspector may not have been aware of the requirement.

The annual certifications, as addressed in Section 3.3.2.10, do not indicate that MCCC or GAI analyzed the increased flow rates from the South Mains Portal pond.

In addition, MCCC monitored the pond discharges for compliance with the Kentucky Pollutant Discharge Elimination System (KPDES) permit issued by the Kentucky Division of Water (DOW). DSMRE incorporated the KPDES requirements into Permit Number 880-7000. The KPDES reports were submitted to DSMRE and DOW.

Wyatt, Tarrant and Combs, LLP, attorneys at law, representing MCCC, submitted pond discharge data and precipitation information to OSM, DSMRE, and MSHA on August 10, 2001, and September 13, 2001. This information covered the period from January 12, 1999, through October 23, 2000. The pond discharge data contains the KPDES information on flow rates (gallons per minute) and total suspended solids (TSS). The KPDES information includes the South Mains Portal pond, two other ponds that MCCC states are within the influence area of the impoundment, and three ponds that MCCC states are located outside the impoundment influence area. The submittal also contains precipitation information from the National Weather Service (NWS) Integrated Flood Observing and Warning System (IFLOWS) station number 3193, at Inez, Kentucky, and station number 3194, along Wolf Creek. Station number 3193 is about eight miles from the impoundment. Station number 3194 is about three miles from the impoundment and was the primary source of information for the OSM analysis. Finally, the submittal contains the flow depth from the weekly inspections for the South Mains Portal pond.

The KPDES monitoring was conducted by Blackburn Contracting, Inc. (Blackburn). Blackburn measured the flow rates with a flow meter to determine velocity, and they calculated the flow area using a chart (velocity times area equals quantity). The chart converts flow depth to area. MCCC's attorney submitted Blackburn's explanations of its measurement procedures to OSM, DSMRE, and MSHA on September 21, October 3, and October 11, 2001. For the South Mains Portal pond, Blackburn noted that it was difficult to obtain velocity "due to the discharge pipe being surrounded by rock. Therefore flow rates had to be estimated."

In its submittals, MCCC contends that the information does not indicate any "problem with the impoundment prior to the October 11, 2000 breakthrough." MCCC based these conclusions on three findings: (1) the precipitation amounts increased during 2000 when compared to 1999 and resulted in higher pond discharges, (2) all six ponds showed similar trends for both 1999 and 2000, and (3) there was a steady increase in the impoundment pool elevation. In addition, MCCC reported a decrease of TSS in the South Mains Portal pond and stated that this contrasted with an increase of TSS for the other five ponds during 2000.

Because the IFLOWS data was not available for precipitation prior to 1999, OSM used the Paintsville, Kentucky, NWS data to obtain a long-term trend. Figure 9 (Page 62) shows that while the Paintsville and IFLOWS rates differ, they both have similar trends.

In Appendix 10, OSM reviewed: (1) information provided by MCCC concerning discharge rates at the South Mains Portal pond and five other ponds, as well as precipitation amounts and TSS levels, and (2) South Mains Portal pond discharges and precipitation for an extended period to determine if there was a long-term trend. Based on this review, OSM found the following:

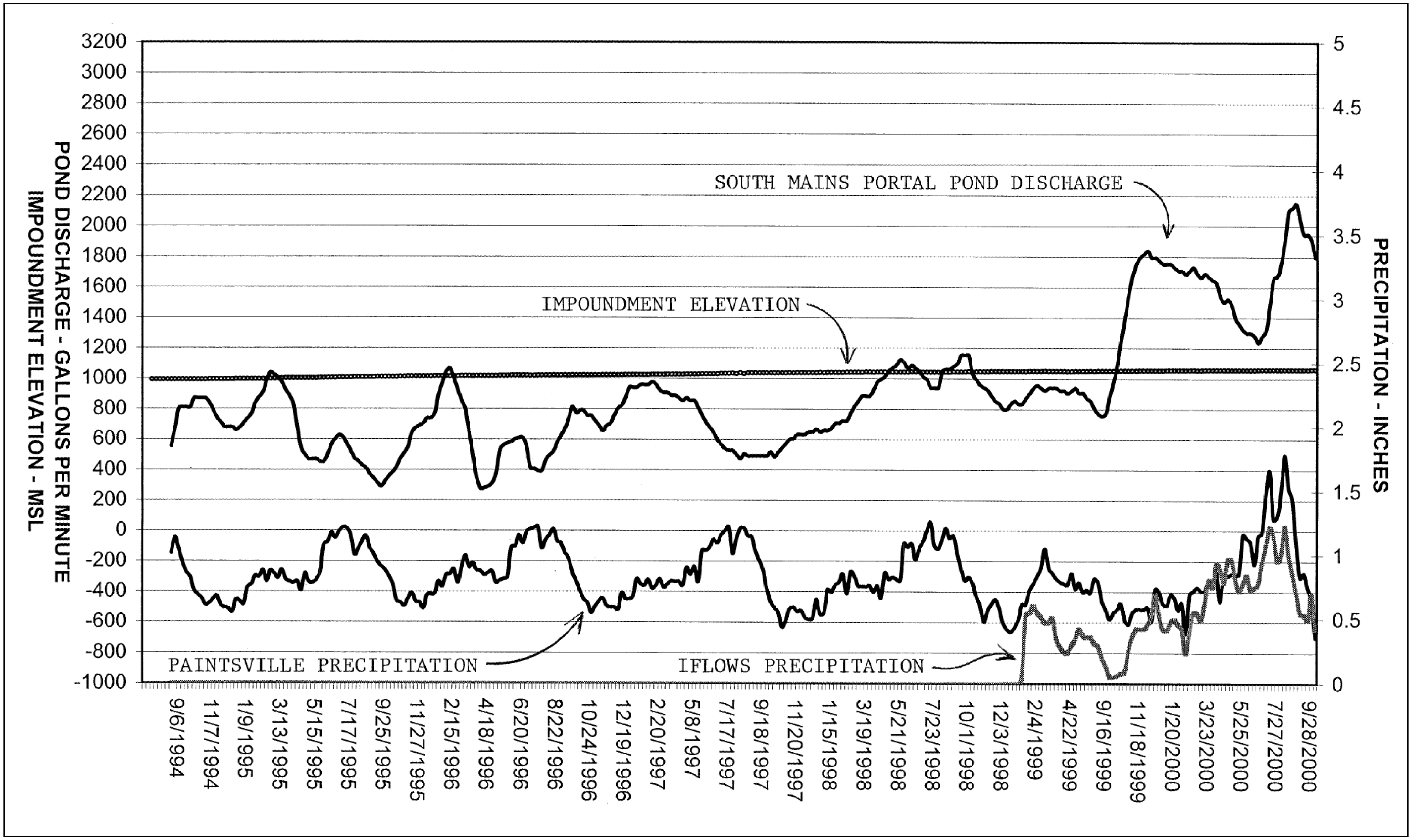

Figure 9. Impoundment Elevation, South Mains Portal Pond Discharge, and Precipitation. Impoundment elevation obtained from MCCC. Pond discharge calculated by OSM—for details see Appendix 10, Section 4. Precipitation obtained from National Weather Service, Paintsville, Kentucky and IFLOWS station number 3194. See Appendix 10, Figure 4 for data points. The discharge and precipitation lines are "trendlines" based on an eight point moving average.

- There was no clear, consistent trend between discharge rates and precipitation for the six ponds as contended by MCCC.

- There was not a relationship between precipitation and impoundment pool elevation.

- The TSS levels in the South Mains Portal pond discharge are not an indication of impoundment leakage.

- The KPDES rates reported by Blackburn and the flow depth reported by the weekly inspector do not exhibit similar trends.

- The discharge trendline analysis showed increased discharge, starting in September 1999, from the South Mains Portal pond which, in fact, was caused by increased drainage from the underground mine. This increased drainage was the result of leakage from the impoundment into the underground mine and not related to surface runoff from precipitation. This increased drainage was an indicator of the impending breakthrough.

- The elevated discharges in 1998 indicate an increase in the impoundment leakage into the underground mine. OSM could not, however, determine if the leakage was related to the February 1998 bubbling or to leakage at some other location within the impoundment.

OSM's review of the precipitation amounts from station number 3194 identified eight events with measurable rainfall in the 30 days prior to the 2000 breakthrough. The dates and amounts for these precipitation events are as follows: September 12, 0.04 inches; September 21, 0.2 inches; September 24, 0.16 inches; September 25, 1.83 inches; September 26, 0.04 inches, September 28, 0.04 inches; October 6, 0.04 inches; and October 8, 0.04 inches.

Summary

- The drainage out of the pond at the South Mains Portal significantly increased during September 1999. OSM's review found that the increased discharge was due to drainage from the underground mine. Further, OSM's review found that the increase was likely due to leakage from the impoundment into the underground mine and was an indicator of the impending breakthrough.

- Increased leakage from the impoundment into the underground mine may have started during early 1998. This leakage may have been related to bubbling identified west of the embankment.

- The permit revision's surface and groundwater monitoring plan did not address the monitoring at the South Mains Portal pond, nor its importance with regard to detecting impoundment leakage. Consequently, the information was not submitted to DSMRE and the DSMRE inspector may not have been aware of the requirement.

- The record does not indicate that MCCC or its consultant analyzed the discharge rates to determine if they indicated leakage from the impoundment into the underground mine.

- The precipitation amounts in the 30-day period prior to the 2000 breakthrough were not significant.

3.5.3 Effects of Blasting: In order to construct the seepage barrier, MCCC conducted blasting above the Stockton coal seam. OSM reviewed (Appendix 11) blasting record adequacy, PFs (amount of explosive use to break the rock), vibration levels at the underground mine roof in the area of the 2000 breakthrough, and vibration levels at the underground mine seals.

The review found that:

- The blast records were incomplete. They did not contain information concerning the location of the blasts. Consequently, a third-party reviewer is not able to determine the vibration levels at any particular location within the mine except by making worst-case estimates.

- The PFs are generally high, but the majority is acceptable considering the hard sandstone that was blasted. However, there were a number of blasts with PFs of 1.7 to 2.5. These could have resulted in undesirable effects such as excessive air blast, rock movement, and ground vibration.

- The blasting activity did not occur directly above the 2000 breakthrough. The vibration levels do not appear to have been high enough to damage the underground mine roof at the 2000 breakthrough. The vibrations may have reached 5.6 inches per second (in/sec), which is considerably below the 10 to 12 in/sec level that could have caused roof damage. The vibrations may have caused micro-fractures to form in the mine rock and weakened the roof; however, the degree of weakening cannot be quantified. The Triad drilling did not indicate roof falls near the breakthrough.

- The vibration levels may have been high enough to cause roof falls immediately under the blasts. If such roof falls did occur, the Triad drilling indicates that they did not extend to the breakthrough area. The vibrations under the blasts may have reached 19.2 in/sec.

- The blasting plan may not have been followed in respect to the protection of the underground mine seals; however, the estimated blasting vibrations, possibly 2.7 in/sec, were not high enough to damage the seals.

Summary

- The blasting records did not identify the location of the blasts. Consequently, vibration estimates can only be made based on worst-case estimates.

- Some of the PFs were high and could have resulted in excessive airblast, rock movement, and ground vibrations.

- The blasting vibrations at the 2000 breakthrough do not appear to be high enough to have caused roof falls. However, the roof may have been weakened due to blasting induced micro-fracturing. The extent of micro-fracturing and weakening cannot be quantified. Except at the breakthrough location, Triad's drilling did not identify any excessive mine height, or rubble on the mine floor, which would be indicative of a roof fall.

- The blasting vibrations may have been high enough immediately under the blasts to cause roof falls. However, if roof falls did occur, the Triad drilling indicates that they did not extent into the 2000 breakthrough area.

- MCCC may not have complied with the blasting limits associated with blasting near the underground mine seals, but OSM's review of the blasting levels indicates that the blasting vibrations were not high enough to damage the seals.

3.5.4 Effects of Natural Seismic Activity: On October 8, 2000, at about 2:30 p.m., a roof fall occurred at the Mine Number 2 of Excel Mining LLC (Excel), underground mine (Permit Numbers 880-8005 and 880-8006). The mine is located about four miles from the MCCC impoundment. Reportedly, the Excel roof fall was about 350 feet long, 22 feet wide, and 8.5 feet in thickness. OSM examined whether the Excel roof fall may have triggered the 2000 breakthrough or that an earthquake could have caused both the Excel roof fall and breakthrough (Appendix 12).

KGS monitors earthquake and ground vibration activity from Clay City, Kentucky, station ROKY. The station is located about 78 miles west of the MCCC impoundment. The station also records vibrations from blasting at coal mines (mostly to the east and southeast of ROKY) and limestone quarries (both east and west of ROKY).

Precise estimates of seismic energy at the MCCC site were not possible. However, based on the ROKY data, this study has made the following general observations on seismic activity in the region:

- Seismic energy arriving at ROKY from September 25 to October 27, 2000, was generally light.

- Considerable seismic activity occurred between 3:00 p.m. and 6:00 p.m. each day, Monday through Saturday, and was absent each Sunday. These times correlate well with blasting activity at the mines in eastern Kentucky.

- An earthquake occurred on October 25, 2000, at about 6 a.m. It had a four-minute duration and contained higher amplitude vibrations than the regional blasting vibrations.

- On October 8, 2000, at about 2:45 p.m., there was a minor seismic event, which is near the time of the roof fall at the Excel underground mine. The amplitude of the seismic event was much less than the earthquake and blasting vibrations.

- There was no seismic activity leading up to and through the 2000 breakthrough after 7:00 p.m. on October 10, 2000. Prior to 7:00 p.m., the seismic activity was consistent with the blasting activity at the mines.

Summary

- There was minor seismic activity near the time of the roof fall at the Excel mine; however, the activity was much less than earthquake and blasting vibrations.

- There was not any seismic activity for the five-hour period prior to the 2000 breakthrough. Prior to that five-hour period, only seismic activity consistent with blasting was identified.

3.5.5 Seepage Barrier Stability: OSM performed a stability analysis of the seepage barrier at the 2000 breakthrough (Appendix 6). The analysis used both the designed and constructed outslopes of 2:1 and 3:1, respectively, and accounted for both consolidated and unconsolidated slurry for the foundation. It also assumed that the seepage barrier extends down to approximately 986 feet msl, which is also the approximate slurry elevation at the time of the 1994 breakthrough. The assumption is based on: (1) the 2000 breakthrough is located at the rear of the impoundment and the seepage barrier was constructed about one year after the 1994 breakthrough, and (2) the slurry added after the 1994 breakthrough probably did not have time to consolidate sufficiently to support the dumped spoil. For purposes of this analysis, OSM assumed that the constructed seepage barrier did not extend to the level of the Coalburg coal seam outcrop.

The study determined that the seepage barrier had a safety factor of at least 1.1 (for the 3:1 outslope and unconsolidated case) when the slurry level was at 986 feet msl and 1.8 with the slurry at 1,045 feet msl and the pool at 1,060 feet msl. The pool was at 1,060 feet msl at the time of the 2000 breakthrough. The failure zone for the 1.1 safety factor is shallow, and should not have adversely affected the structural stability of the seepage barrier. The most significant effect of this type of failure would have been to strip away the fine refuse coating on the surface, thus increasing the permeability of the barrier. The next lowest safety factor is 1.2 with the pool at 1,000 feet msl. This failure would have extended into the slurry foundation and produced a noticeable head-scarp at about 1,040 feet msl. This condition was not noted on the weekly inspection reports or in the annual certifications.

Summary

- Shallow sloughing of the seepage barrier may have occurred.

- The review did not identify a high potential for structural instability, and the weekly inspection reports and annual certifications did not report any slides.

3.5.6 Underground Mine Pillar Stability: OSM reviewed the stability of pillars at the 2000 breakthrough (Appendix 13). The pillar stability calculations were performed for 20-foot by 25-foot pillars, 10 feet high, and 600 pound per square inch coal strength. At this location, the overburden was assumed to be 70 feet in order to represent the loading of the natural ground, seepage barrier, slurry, and water. Based on these calculations, OSM determined that the pillars had a safety factor of at least 1.7, and thus, should be stable. This determination was confirmed by the Triad drilling, which did not find evidence of pillar failure.

Summary

- The review indicates that the pillars adjacent to the 2000 breakthrough are stable. The Triad drilling did not find evidence of pillar failure.

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