SECTION I: Introduction

I.A - Overview

This section focuses on the need for this study, an examination of its aims and objectives and the context in which the report is formulated and written. There are also background explanations of certain topics that are either germane to the subject or as context to statements in multiple sections.

I.A.1 – Need for this Study

Section 18.1 of the Bituminous Mine Subsidence and Land Conservation Act (BMSLCA) requires the Pennsylvania Department of Environmental Protection (PA DEP) to compile, on an ongoing basis, information from mine permit applications, monitoring reports, and enforcement actions. It also requires the PA DEP to report its findings regarding the effects of underground mining on overlying land, structures, and water resources to the Governor, General Assembly and Citizen Advisory Council at five year intervals.

The act further stipulates that the PA DEP is to engage the services of recognized professionals or institutions for purposes of assessing the effects of underground mining and preparing these reports. The PA DEP initiated a contract with the University of Pittsburgh (the University) on February 2, 2009 to fulfill the assessment and reporting requirements for the period from August 21, 2003 to August 20, 2008.

I.A.2 – Underground Bituminous Coal Mining's Historical Role in Pennsylvania

The extraction of bituminous coal from the Commonwealth of Pennsylvania's (the Commonwealth) rock formations plays a significant role in the state's economic development as it has for over 125 years. This role is still prominent today. In 2008, The Federal Energy Information Administration (EIA) reported Pennsylvania's bituminous underground coal mines employed 5,331 miners and produced 53,318 million tons (short tons) of coal (Anon, 2009a).

From a national perspective, Pennsylvania's mines represent:

- 8.7-pct of the total number of underground coal mines,
- 14.9-pct of the total production from underground coal mines,
- 10.8-pct of the total employment for underground coal mines, and
- 33-pct higher average production per employee per hour than the average underground coal mine in the nation.

All of these statistics indicate that Pennsylvania (PA) underground bituminous coal mines are larger and more productive than the national average.

While much coal has been mined, the EIA estimates there are still approximately 10.2 billion tons of recoverable reserves of bituminous coal remaining in Pennsylvania (Anon, 2008a). In addition, The Pennsylvania Coal Association estimates the coal industry directly and indirectly employs approximately 49,100 workers with an annual payroll of in excess of $2.2 billion and tax revenues of approximately $750 million (Anon, 2009b). This data demonstrates the prominent role coal plays in the lives of Commonwealth citizens.

I.A.3 – Environmental Consequence of Mining

As with the development of other natural resources, the extraction of bituminous coal by underground mining methods comes at a price to the environment. Up until the latter half of the last century, there were no widespread attempts to mine coal in a sustainable and environmentally neutral manner. It is not the purpose of this report to judge the ethics of these past practices. One fact appears to be clear -- coal was viewed as an asset to be exploited and this exploitation helped to fuel one of the greatest economic expansions in human history. Today, society places significant demands on the coal mining industry to extract this mineral in an environmentally acceptable manner. The manner in which the industry currently complies is the subject of this report.

I.B – Environmental Laws and Coal Mining

In the 1940's the Commonwealth began to realize the necessity of environmental stewardship to prevent permanent and widespread destruction of its land and water. The Clean Stream Law was amended in 1945 to include acid mine drainage as a pollution source that required regulation. In this same year, the Commonwealth passed the Surface Mining Conservation and Reclamation Act (Act 418), representing its first comprehensive attempt to prevent pollution from surface coal mining. From this point forward, the Commonwealth passed a number of laws that directly addressed environmental issues associated with the deep mining of bituminous coalbeds.

I.B.1 – Bituminous Mine Subsidence and Land Conservation ACT of 1966

The most significant of these was the BMSLCA of 1966. For the first time, structures built before April 1966 had to be protected from subsidence regardless of coal ownership rights beneath the structure. This law suggested that coal extraction ratios of less-than 50-pct be used to protect surface properties, but also indicated that specific guidelines could be set by the state.

Gray and Meyers (1970) suggested that the area required underground to minimize subsidence damage on the surface was dependent on the selection of an adequate angle of support (Figure I-1). The angle of support was most dependent on the geologic character of the rocks and, in their report, varied from 15 to 25-deg. The net result required the support base at the mining level to increase between 53 to 93-ft along its horizontal axis with every 100-ft of overburden. The outcome was a support area at 500-ft of overburden, at least 3.4 times that needed at 100-ft. This method, while straight forward, did not accommodate changing geologic and mining conditions and, therefore, has been replaced by more advanced methods.

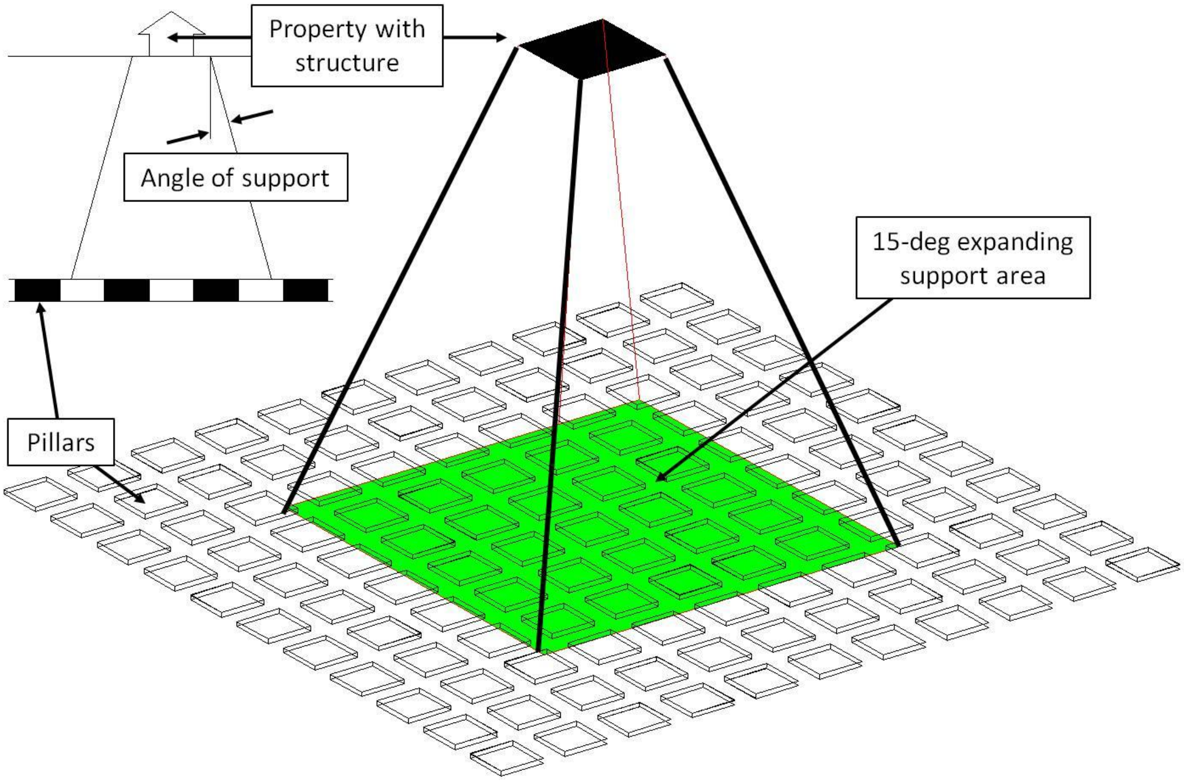

Figure I-1 – An interpretation of pillar support required by the BMSLCA (1966) to protect structures from subsidence damage (adapted from Gray and Meyers, 1970).

The BMSLCA also established various requirements such as permitting, mapping, protection of certain structures from subsidence damage, repair of subsidence damage to certain structures, and the right of surface owners to purchase support for their structures. Section 4 prohibited subsidence damage to certain structures, homes, public buildings, noncommercial structures, and cemeteries in place on April 27, 1966. Section 6 required operators of underground mines to 1) repair the damage within 6 months and 2) secure a surety bond to cover possible future property damage. Section 15 provided certain owners the right to purchase the coal located beneath their property. This law did not contain any provisions addressing water supplies.

I.B.2 – Surface Mining Control and Reclamation ACT of 1977

The BMSLCA was first amended in 1980 to help bring it in compliance with the minimum requirements of the recently passed federal Surface Mining Control and Reclamation Act of 1977 (SMCRA). Section 4, which provided protection to certain structures, was amended to allow the current owner of the structure to consent to subsidence damage, but the damage had to be repaired or the owner compensated. Section 5 was amended to require an operator of an underground mine to adopt measures to prevent subsidence causing material damage to the extent technologically and economically feasible, as well as to maximize mine stability and to maintain the value and reasonably foreseeable use of the surface. These measures were to be described in the permit application. The new language also specifically provided that the new subsection was not to be construed to prohibit planned subsidence or standard room-and-pillar mining.

I.B.3 – ACT 54

By the mid-1980's, new environmental concerns were being raised about the BMSLCA. In 1986, Arthur Davis, a Professor at the Pennsylvania State University, organized the Deep Mine Mediation Project to bring together the underground bituminous coal industry, agricultural, and Non-Governmental Organizations (NGOs) for the purpose of attaining a consensus position on the BMSLCA. Three years later, consensus was achieved to address:

- Replacement of impaired water supplies,
- Treatment of mine discharges,
- Incentives for re-mining previously abandoned areas,
- Additional remedies for structural damage, and
- Relaxation of regulatory obstacles to full extraction, i.e. longwall and pillar recovery mining.

The state legislature prepared a number of statutory amendments in 1992 and the governor signed the legislation on June 22, 1994, which became effective on August 21, 1994. This legislation is commonly referred to as ACT 54. For the first time the law extended the obligation of coal companies to pay for damage caused to homes and businesses, regardless of when they were constructed.

BMSLCA – revised structural damage repair provisions:

- Mine operators were required to repair or compensate for subsidence damage to any building accessible to the public, non-commercial buildings customarily used by the public, dwellings used for human habitation, permanently affixed pertinent structures and improvements, and certain agricultural structures.
- Entitled the structure owner or occupant to payments for temporary relocation and other incidental expenses.
- Allowed the mine operator to conduct a pre-mining survey of the structure prior to the beginning of mining.
- Voluntary agreements were authorized between mining operators and land owners.
- Underground mining allowed beneath any structure, except a certain limited class of structures and features, as long as the consequential damages are not irreparable and are repaired.
- Stipulated that irreparable damage can only occur with the consent of the owner.

ACT 54 imposed certain restrictions and responsibilities on mine operators and on the PA DEP. Coal operators were responsible for the restoration and/or replacement of a range of features located above, and adjacent to, active underground coal mines. It made the PA DEP responsible for ensuring the regulations and official mining permits were followed. PA DEP was designated to conduct field investigations, examine and approve permits, and report to the general public and industry representatives with their findings.

I.B.4 – Special ACT 54 Requirements

ACT 54 contained a special provision requiring the PA DEP to produce an assessment of the surface impacts of underground bituminous coal mining every five years. To date two reports have been issued. One, by the PA DEP in 1999 and later amended (Anon, 2001), covered the period from August 21, 1993 to August 20, 1998 (*known as the 1st assessment*), and a second by California University of Pennsylvania, (CUP), in 2005 (Conte and Moses, 2005), covered the period from August 21, 1998 to August 20, 2003 (*known as the 2nd assessment*). The University was contracted in 2009 to conduct the 3rd assessment, covering the period from August 21, 2003 to August 20, 2008 (*known as the 3rd assessment*).

I.C – Underground Bituminous Coal Mining Methods In Use in Pennsylvania

Mine operators use three general underground methods to extract bituminous coal. The most common method is room-and-pillar mining. During the 3rd assessment period, all of the 50 underground bituminous mines operating in Pennsylvania used some form of the room-and-pillar mining method. Thirty-six of these mines used only the room-and-pillar mining method. Six mines also used the room-and-pillar technique but, in addition, practiced pillar recovery and are herein designated as mines using the pillar recovery mining method. Eight mines employed the longwall mining method in conjunction with room-and-pillar mining.

I.C.1 – Room-and-Pillar Mining Method

Because every mine uses the room-and-pillar mining method, certain characteristics are similar between all mines. For example, rooms or entries are typically driven 18 to 20-ft wide with continuous mining machines. These rooms use outline pillars designed to prevent failure of the overlying strata and to support the overburden weight above the mine. As long as the pillars are sufficiently sized to support the overburden and the floor rock is strong enough to prevent the pillars from punching or pushing into the bottom, subsidence should not occur with this mining method. Heights of mining range from 3 to 7-ft with some localized areas extending above and below these values. In general, the room-and-pillar mining method relies on two primary components; the main entries and the panels (Figure I-2). Main entries serve as long-standing points of access and egress from the underground and provide the primary means of supplying the underground workings with air, materials and transportation of coal from the working faces. The panels are less permanent and focus on extracting the coal in ways that comply with federal and state mining standards and regulations. A production panel begins from the main entries, extending in a series of parallel faces several hundred to several thousand feet into un-mined blocks of coal. In general, impacts are minimal because subsidence generally does not occur, but a few room-and-pillar mines did have significant numbers of recorded impacts during the 3rd assessment period.

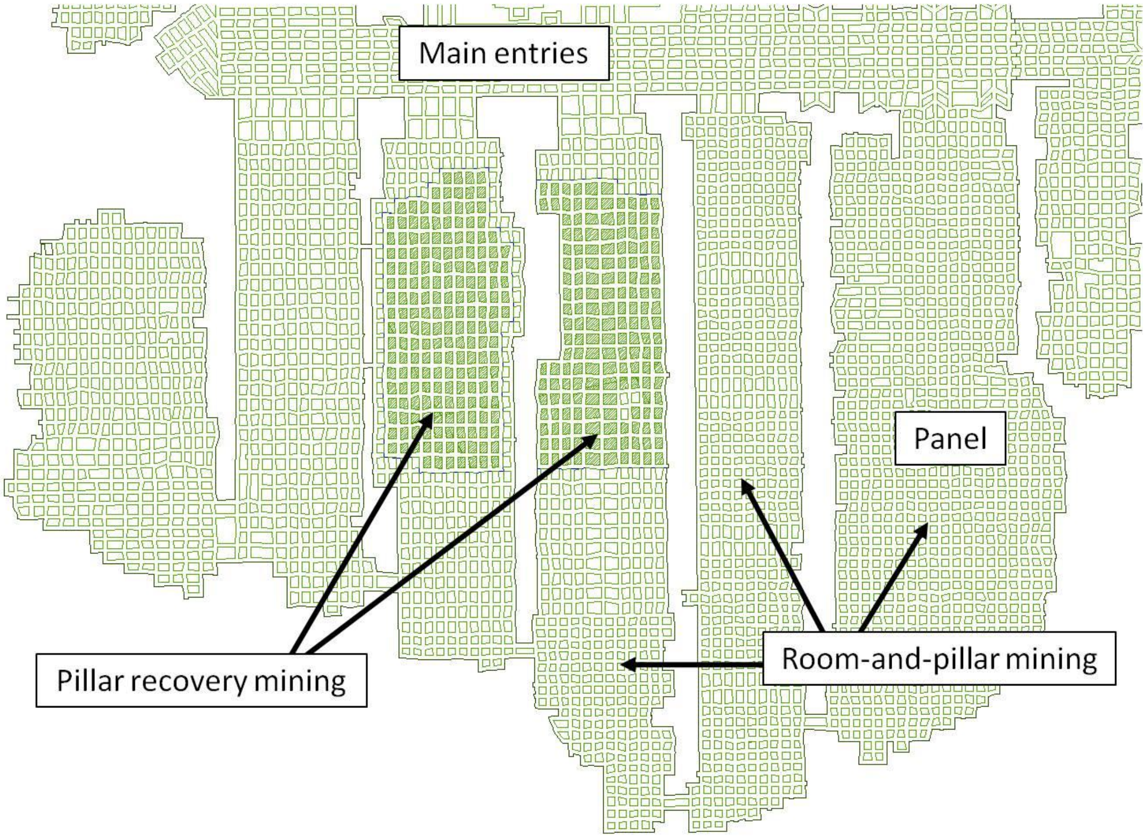

Figure I-2 - Example of a room-and-pillar mine where main entries provide long-term access to production panels. Six mines in Pennsylvania practice pillar recovery.

I.C.2 – Pillar Recovery Mining Method

Room-and-pillar mines use pillar recovery to more fully extract the coal in select production panels (Figure I-2). These areas of pillar recovery mining are of variable shapes and sizes. Figure I-3 shows an example of a partially mined pillar. During pillar recovery, the majority of the pillar is removed, causing the roof strata to collapse into the void created by mining. This method sees infrequent use and, when employed, occurs over a relatively small area. Impacts associated with the localized development of a subsidence basin do occur but represent a small fraction of the impacts recorded in the PA DEP's files. Only six of the 50 mines active during the 3rd assessment period practiced pillar recovery.

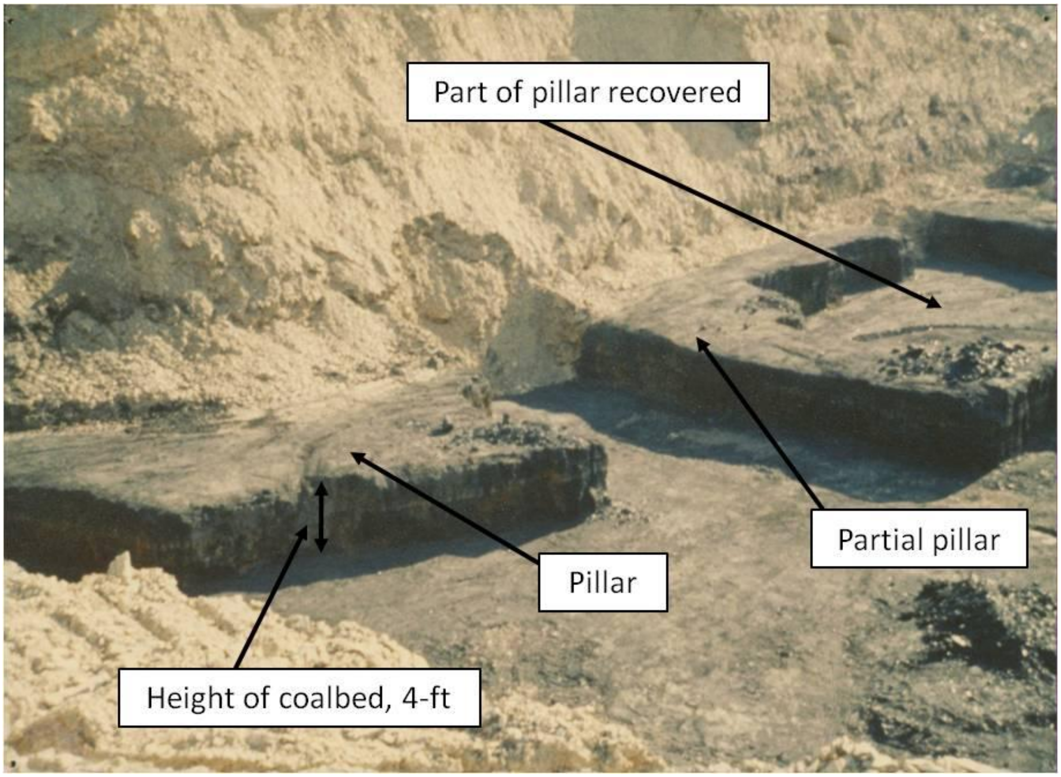

Figure I-3 - In this photograph an abandoned mine was uncovered by surface mining revealing a partially mined pillar (photograph courtesy of K. Brady).

I.C.3 – Longwall Mining Method

In the longwall method a high-powered double drum shearer mines the face of the longwall panel. The shearer cuts, on average, 36-in of coal from its short dimension (the width) known as the longwall face (Figure I-4). The mine operation uses the room-and-pillar mining methods to develop the main entries and the gate road entries that outline the rectangular panels. At some of the larger longwall mines, one pass of the shearer along a 1,400-ft long face supplies enough coal to fill a unit train. It can take several thousand cuts or slices along the longwall face to completely mine a panel. When a cut is taken, the longwall shield supports move behind the advance face and allow the strata above the previous position to fall into the void. The entire void area is called the "gob". These longwall gobs are the primary mechanism for subsidence and are a central focus of this study. Eight mines employed the longwall method during the 3rd assessment period.

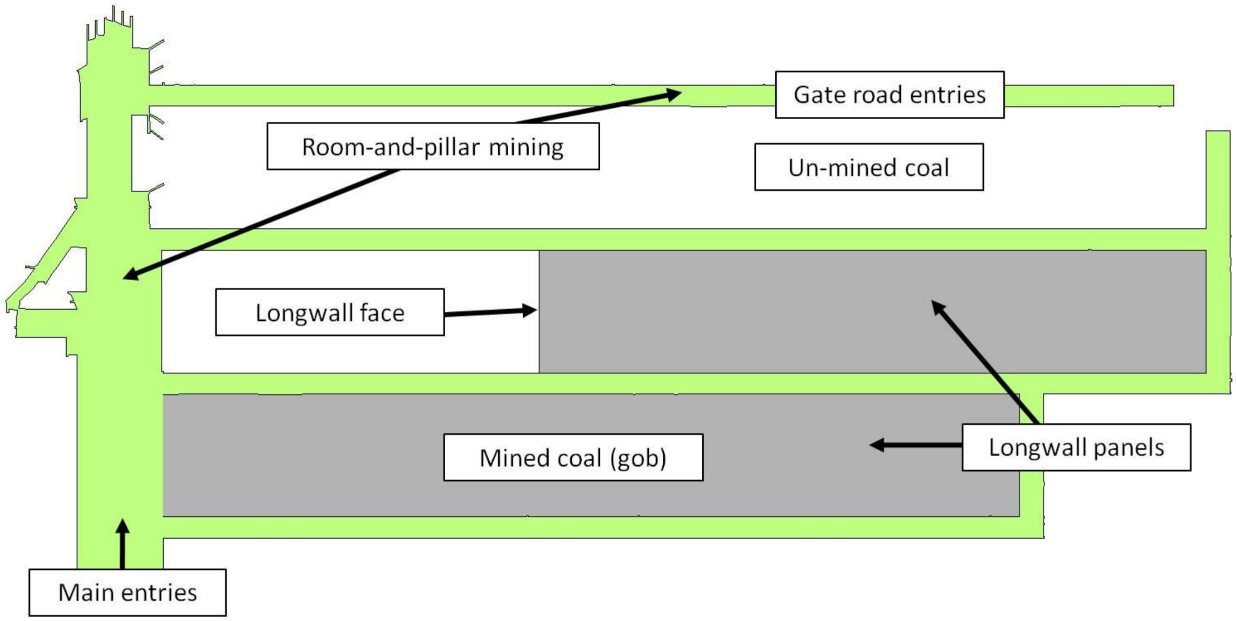

Figure I-4 - Example of longwall mining method where longwall panels are developed off main entries and accessed by gate road entries both developed via room-and-pillar mining methods.

I.D – General Description of Impacts and Resolutions Associated with Underground Bituminous Coal Mining

Historical analysis and documentation of the types of impacts commonly associated with underground bituminous coal mining by various researchers (Conte and Moses, 2005; Miller, 2001; Parizek and Ramani, 1996) provides a rich source of data. These findings provide excellent background on past trends for this report.

I.D.1 – General Description of Coal Mining Impacts

Impacts from underground bituminous coal mining include impacts to:

- Buildings and structures – Impacts to buildings and structures include shifting of foundations, extensional cracks in walls and floors, and buckling of walls and floors.
- Surface land – Impacts to surface land can be in the form of a) extensional cracks or fractures in the surface soil and rock that allow water to drain into them or that represent a public safety hazard, and b) flooding of fields or pasture lands caused by subsidence depressions that pool water.
- Water sources, both wells and springs – Impacts to water sources can diminish water flow or contaminate water composition thereby reducing its' residential, agricultural and commercial value and use.
- Streams, wetlands and water bodies, i.e. ponds – Impacts to streams consist of diminution, i.e. changes to the general seasonal water flow patterns, or contamination. These changes affect storage capacities and are capable of harming or eliminating existing species. Impacts to wetlands are more difficult to recognize in the span of a few seasons but, if left unchecked, can have a dramatic effect of the flora and fauna that

inhabit these environments. Wetlands are known to have special abilities to filter toxins and pollution from natural water systems and the elimination of wetlands can have long term detrimental impacts on water supplies. Impacted ponds typically are recognized by lower water levels and higher concentrations of contaminated water.
- Utilities, i.e. gas pipelines, water and gas service lines to residential and business structures, power lines, etc. - Damage to electrical lines and steel towers and/or ruptures or separations of underground water and gas service lines. All of these impacts result in some form of loss of service to residential and commercial customers.
- Public infrastructure, i.e. roads, highways, bridges, parks, dams, etc. – roads and highways might see transverse and longitudinal cracking and compression bumps, while bridge foundations might experience differential settlement.

I.D.2 – General Description of Coal Mining Resolutions

Pre- and post-mining agreements and settlements are commonly used to compensate land owners for damages. Other examples include:
- Buildings and structures – Mitigation techniques include trenching around structures to dissipate horizontal ground strains and bracing, bridging and banding to strengthen buildings to withstand differential movements caused by subsidence.
- Surface land – Mitigation techniques include filling of open fractures and milling of compression bumps that impact public safety or diminish land use. Also, if land use or access is negatively impacted, i.e. pooling in fields or pastures etc., corrections to surface drainage infrastructure may be required.
- Water sources, both wells and springs – Mitigation techniques include repairing wells and springs to enhance flow or improve water quality, drilling replacement wells or connecting to public water supplies. Temporary water replacement is often used to supplement water usage until a permanent water supply is provided.
- Streams, wetlands and water bodies, i.e. ponds – Mitigation techniques include augmenting stream flow, repairing stream and wetland ecologies, grouting fractures that rob stream of water, and re-grading stream gradients, i.e. gate cutting, to reduce pooling.
- Utilities – Gas transmission lines are often excavated and supported on the surface until subsidence ceases. The financial responsibilities for the cost associated with these resolutions differ. However, if residential gas or water service is interrupted, temporary supplies are provided at the company's expense until remedied.
- Public infrastructure – Mitigation techniques are varied and depend on local circumstances. For example, the cost of rehabilitating interstate highways is paid for by the government. In other cases, coal companies repair and improve public recreation areas. Figure I-5 shows the East Finley Township Park before and after restorations made by a coal company.

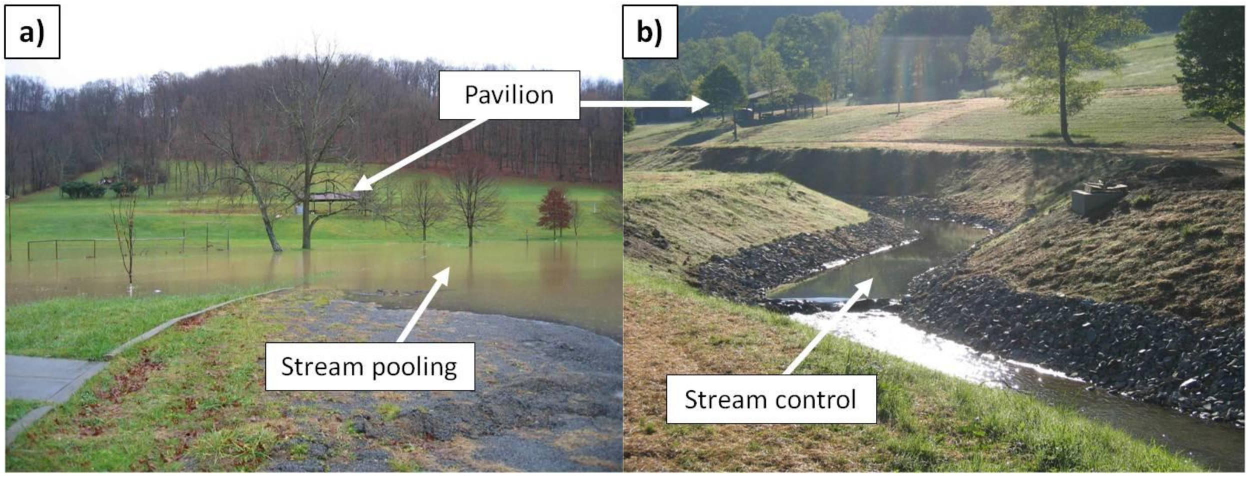

Figure I-5 - Photographs of a) stream pooling impacts to East Finley Township Park and b) coal company stream repairs to eliminate pooling and return the park to a functional state (Photograph from PA DEP files).

I.E – Subsidence Related Impacts

The majority of possible impacts discussed above are related to mining induced surface subsidence. The formation of a subsidence basin is typically associated with full extraction mining. Full extraction mining consists of longwall mining and pillar recovery after room-and-pillar mining has developed the underground areas. Longwall mining is the dominant mining method in Pennsylvania responsible for subsidence and is the focus of this report.

I.E.1 – Potential Impacts Associated with Room-and-Pillar Mining

Whenever coal is mined by the underground room-and-pillar mining method, an opening is created. Groundwater moving through overlying strata can often find its way into these openings. If care is not taken, water passing through the underground openings can become contaminated. The permit process requires designs that minimize this contamination and, if it occurs, requires treatment systems that return the water quality to acceptable levels. This report shows that room-and-pillar mining, with extraction ratios less than 50-pct, have a lower reported incidence of impacts to water supplies or surface features. However, altered groundwater flow paths can occur under specific conditions as discussed in this report (see Section VI) that may impact the quantity and character of water produced by wells and springs. Also, surface structural impacts can damage residential buildings, especially when increased extraction ratios allow under-designed pillars to punch into a softer floor rock (Figure I-6) and potentially produce subsidence on the surface.

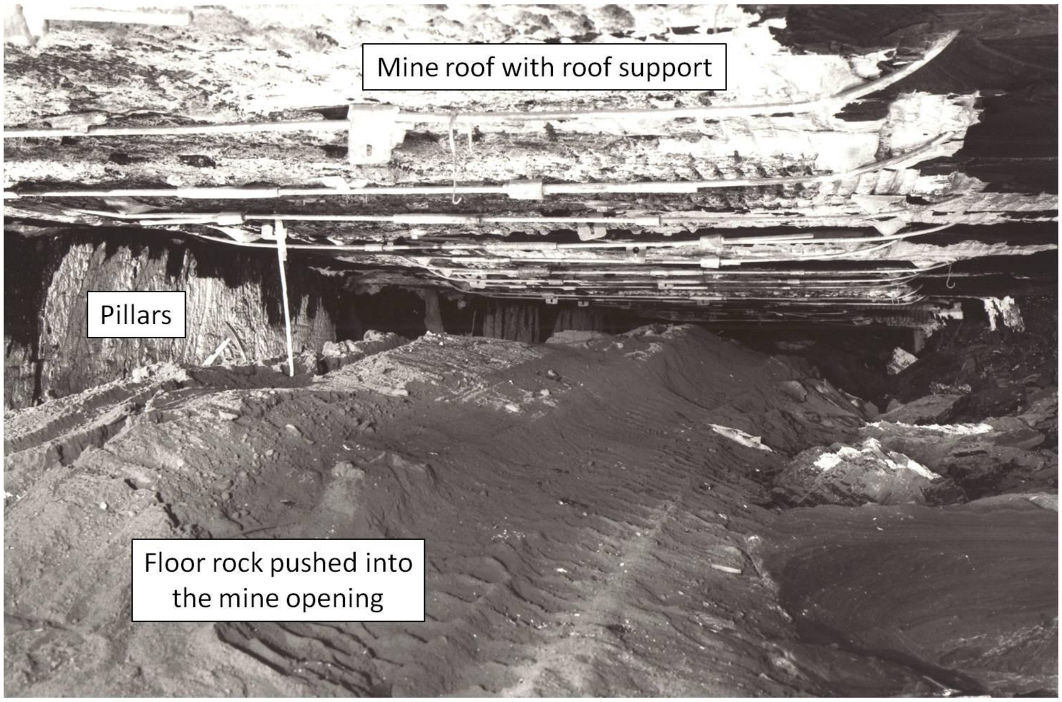

Figure I-6 - Example of floor heave at the Kitt Mine in West Virginia. The pillars in this photograph have punched into the mine's floor rock causing it to rotate upward into the entry (photograph courtesy of A. Iannacchione).

I.E.2 – Potential Impacts Associated with Pillar Recovery and Longwall Mining

More serious impacts can potentially occur when the supporting coal pillars are removed as in the pillar recovery mining method, or when large panels are mined as in the longwall mining method. Both methods allow the overlying strata to collapse into the mine void (Figure I-7). Immediately above the caved, un-stratified rock layers, is a zone of extensive fracturing, as much as 20 times the extraction zone height in thickness. In the Pittsburgh Coalbed, where all of Pennsylvania longwall mining occurs, the zone of extensive fracturing can extend over 100-ft above mining. Less extensive, but more persistent fractures can extend over much greater distances, and in relatively rare circumstances, can intercept the surface. Above this zone, the stratum gently bends into the subsidence basin. This bending promotes separations along bedding as the strata moves inward toward the center of the subsidence basin. These fractures and bedding plane separations can affect the water-bearing strata by altering the groundwater flow path and velocity. In addition, the bending stratum introduces complex three-dimensional strain patterns that can stress structures and introduce damage.

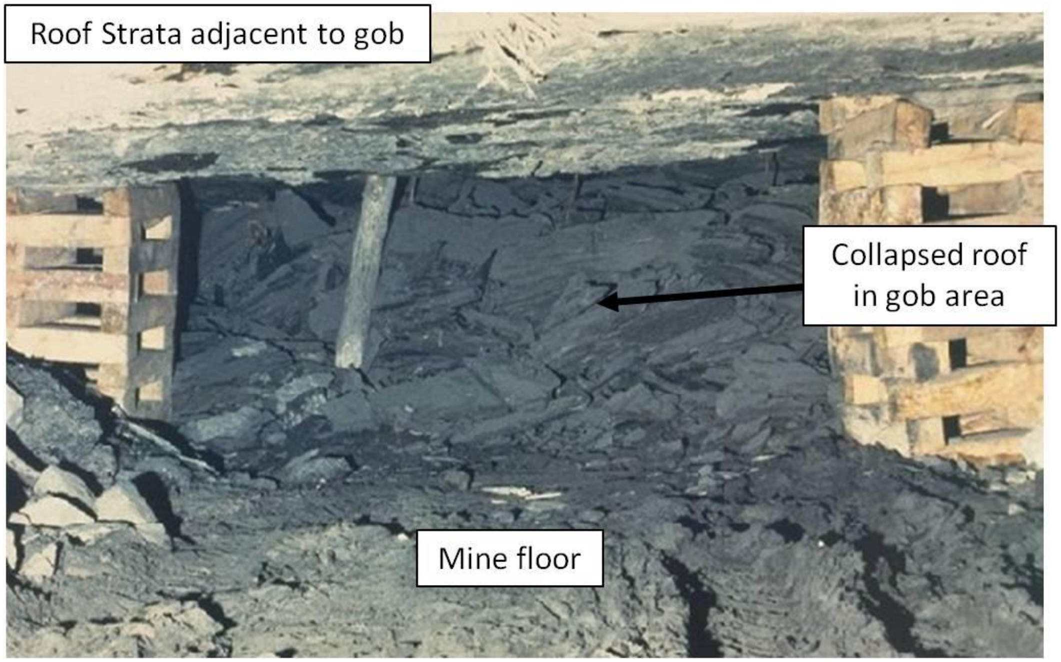

Figure I-7 - Example of full extraction mining at the VP No.3 Mine in Virginia. At this mine the roof rock collapses into the void created by the extraction of the longwall panel (photograph courtesy of A. Iannacchione).

I.E.3 – Formation of Subsidence Basins

A subsidence basin can form when the ratio of the width of the extraction zone to the depth of overburden (h) exceeds 0.25. In longwall mining, the width of the extraction zone is the width of the longwall panel, W. Since most longwall panels are deeper than 500-ft (h), a subsidence basin will form at panel widths (W) greater that 125-ft. As shown later (see Section IV), most Pennsylvania longwall panels are greater than 1000-ft wide, hence subsidence basins can be expected to form in association with every panel mined.

As might be imagined, a subsidence basin forms as the coal is mined and the overlying strata are allowed to fail and collapse into the recently created void (Figure I-8). As the working face of the coal mine advances, the extraction zone increases in size. The composition and thickness of the overlying rock helps determine the subsidence basin that propagates on the surface in advance of the working face underground. The angle between the vertical line at the extraction zone edge and the line connecting the extraction zone edge and point of critical deformation on the surface is called the angle of deformation, or δ, (Peng and Geng, 1982) (Figure I-8).

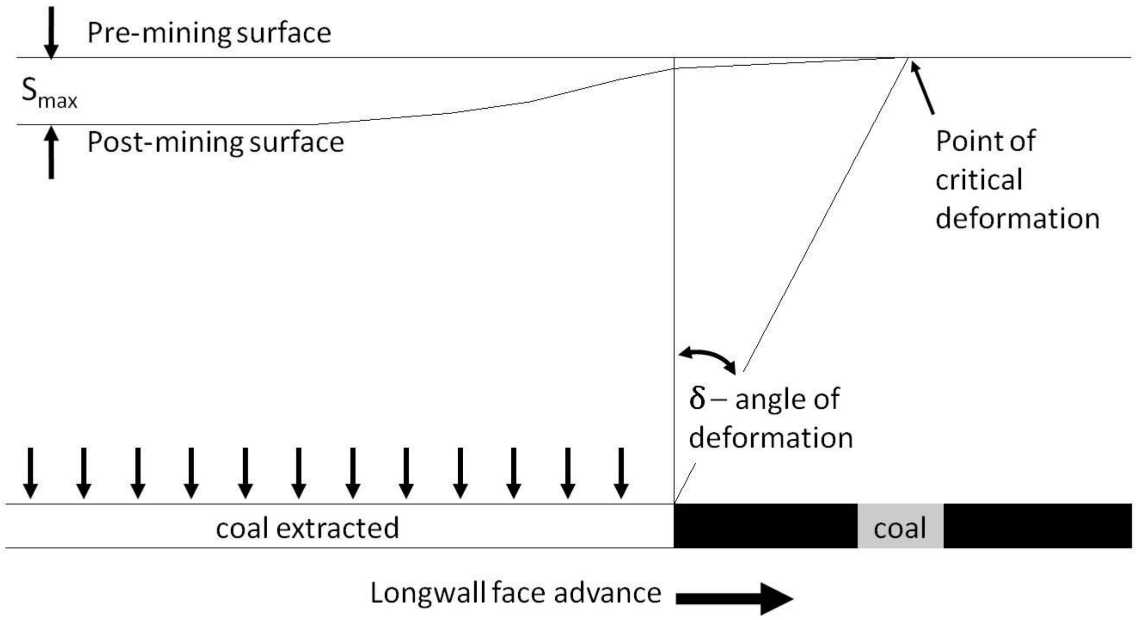

Figure I-8 - Generalized model showing how a subsidence basin forms in association with longwall mining.

From the point of critical deformation back to the point above the working face, the surface begins to subside even though it is over solid unmined coal. In this zone, the ground surface is extended causing tensional ground strains. Once the longwall face passes under a point on the surface, vertical subsidence accelerates and compression ground strains occur. Tension (extension) in the ground surface can initiate tensile fracturing in structures. Compression (buckling) in the ground surface can initiate shear ruptures and lateral offsets in structures. Finally, as the longwall face moves away, vertical subsidence gradually reduces and movement stops. At this point in time, the maximum subsidence (S_{max}) is achieved and is generally 0.4 to 0.6 times the thickness of the underground extraction zone. In Pennsylvania, the extraction zone generally ranges from 5 to 7-ft, so S_{max} typically ranges between 2 and 5-ft.

I.E.4 – The Final Shape and Impact of the Subsidence Basins

Longwall mining subsidence basins are elliptically shaped, 3-dimensional surfaces (Figure I-9). The edges of the subsidence basin extend beyond the boundaries of the longwall panel. S_{max} occurs in the center of the basin and subsidence rapidly lessens above the edges of the rectangular longwall panels. The area of the elliptical subsidence basin is significantly larger than the rectangular longwall panel that produces it. Any structure that falls within the subsidence basin has the potential to be impacted. The reasons for this are many, including rapidly changing surface slope, curvature, and horizontal strain conditions. Impacts to water sources have been occasionally known to extend beyond the subsidence basin. All of these factors will be discussed later in the report (see Sections IV, V, VI, VII, and VIII).

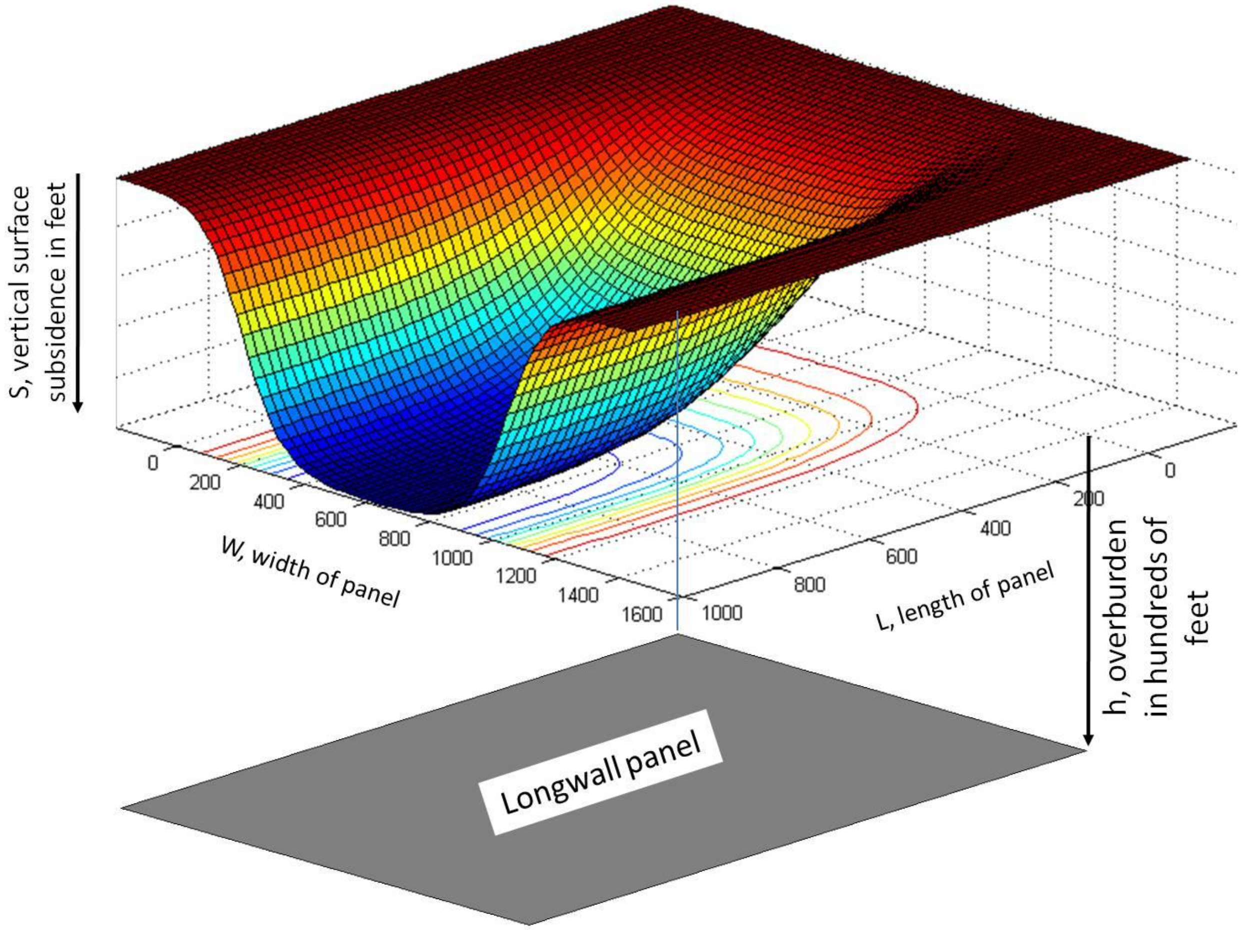

Figure I-9 - 3D view of an idealized subsidence basin overlying a portion of a typical longwall panel in Pennsylvania (adapted from Gutiérrez, et al., 2010).

<u>I.F – Context of this Report</u>

Information about underground bituminous coal mining impacts comes from observations and measurements collected by land owners, company representatives, PA DEP staff, and the University. The majority of the data used in this report is derived from the files, maps, and investigations by the PA DEP. Many of these files are contained within the Bituminous Underground Mining Information System (BUMIS) database or paper files maintained by the California District Mining Office (CDMO). The examination and analysis of these files is a primary work product of this report. Mining company data, mainly in the form of digital maps and files is incorporated into this report as well. There is no legal requirement for the companies to provide the University with this data. They did it willingly, saving the University considerable time and effort and increasing the accuracy of the data. In a few cases, selected interviews with private and public sector entities help supplement existing information. This report includes information from publicly available spatial data sources, such as eMapPA, Pennsylvania Spatial Data Access (PASDA), Western Pennsylvania Conservancy's Aquatic

Community dataset, and U.S. Geological Survey digital elevation models, as necessary to facilitate and supplement analytical work and the map preparation.

This report includes the results of University field investigations as required to gather additional information not contained within PA DEP files or to verify information contained within individual mine permits and on 6-month mining maps. University biologist's results of surveys of streams either undermined during the 3rd assessment period or undermined during previous assessment periods and recommended for analysis by the PA DEP are included in Section VIII. Despite best efforts to gather all pertinent information related to this subject matter, the University recognizes that certain proprietary information is not available to this study.

I.F.1 – 1st Assessment

The 1st assessment was conduct by the PA DEP with an initial report filed in June 1999. As reported by Conte and Moses (2005), a meeting of the Coal Caucus of the General Assembly in February of 2000 at Belle Vernon, PA, encouraged additional analysis and a supplemental report was produced (Miller, 2001).

I.F.2 – 2nd Assessment

In 2004, CUP entered into a contract with the PA DEP to analyze the impacts of bituminous underground coal mining between August 21, 1998 and August 20, 2003. The researchers from CUP completed their analysis in 160-days and set a high standard for this report (Conte and Moses, 2005). During the 2nd assessment period, over 37,000 acres of land in ten counties was undermined. This mining was accomplished by nine longwall and 72 room-and-pillar mines (some of these mines practiced pillar recovery). Mining occurred under 3,033 properties and 3,656 structures of various kinds. The PA DEP received 684 reported effects of wells and springs that potentially impacted water supplies. In addition, almost 116 miles of streams were undermined and habitat assessment procedures were used and the post-mining conditions scored.

I.F.3 – 3rd Assessment

In 2009, the University of Pittsburgh began to assimilate data from the PA DEP files and other sources into a GIS database using ArcEditor software by the Environmental Systems Research Institute (ESRI). All relevant data collected between August 21, 2003 and August 20, 2008 are now part of the University's GIS database. The current assessment does not discuss repair cost since few records on this subject are available.

I.G – Current Contract Tasks and Report Structure

The contract that funded this report identified major areas of investigation including impacts to structures, water sources, land, streams and wetlands.

I.G.1 – Data Collection and Spatial Analysis (Section II)

Early in the project University researchers used BUMIS to determine which structures, water sources, land, streams and wetlands have been undermined during the 3rd assessment period. Data from BUMIS was segmented by mine and impacts and entered into Excel spreadsheets for analysis. A synopsis of the processes used is given in Section II and summaries of the data developed are provided in Appendix A and B. Next, University researchers investigated permit files to locate additional background information. At the same time, the University collected approximately 900 images of the 6-month mining maps from the CDMO, geo-referenced 317 maps, and placed the images within the GIS database (Appendix C). Lastly, information about the streams has been collected by the University and supplemented with information from PA DEP, i.e. BUMIS, stream investigation files, and compliance files (see Appendix D).

I.G.2 – Mining During the 3rd Assessment Period (Section III)

The University constructed a GIS database containing a complete dataset for all the properties, structures, water supplies, land, streams, and wetlands undermined during the 3rd assessment period. Strict buffers around the areas mined were used for the spatial inventory of the previously mentioned features. The 6-month mining maps were used to locate all active underground bituminous coal extracted during the 3rd assessment period and to estimate the total acres of coal mined. Geologic information on the structural elevation of the coalbeds and surface elevations for all 50 mines operating during the 3rd assessment period were created and used to determine the precise overburden above each mine. The value of the University's GIS database and the associated overburden information is demonstrated in Section III and Appendix C.

I.G.3 – Effects of Mining on Interstate 79 (Section IV)

Nine longwall panels were extracted under Interstate 79 (I79) during the 3rd assessment period. The specific or detailed affects were not assessed in this report due to the lack of centrally reported information. However, certain data was derived from summary reports prepared by the CDMO staff assigned to monitor this highway. The University evaluated the extent of impacts and the types of controls used to mitigate these impacts.

I.G.4 – Effects of Mining on Structures (Section V)

The University determined the impacts of underground mining on structures damaged during the 3rd assessment period. This required a detailed analysis of surface properties undermined during the period and a determination of which of those properties experienced mining-related impacts (land damage or structure damage). The University then calculated the number of undamaged and reportedly damaged structures (i.e., dwelling, barn, commercial building, etc.). The resolution status and type of resolution of all reported structure damage cases were summarized. All of these analyses were organized by mining method and type of structure. Also, examples of mitigation techniques were included.

I.G.5 – Effects of Mining on Water Supplies (Section VI)

The University reviewed and analyzed all data related to water loss problems and claims as reported by property owners and mine operators during the 3rd assessment period. Each reported effect and claim was associated with 1) a natural ground-water recharge cycle, 2) a location and type of underground bituminous coal mining, 3) water loss categories i.e., related to subsidence effects of underground mining, flooding of underground mines, and 4) causes other than underground mining, i.e., refuse disposal, surface mining, gas well drilling, etc. In addition, the overburden information and mining outlines contained in the University's GIS database were used to calculate the Rebuttable Presumption Zone (RPZ), i.e. the 35-deg angle projected upward from the outside of underground mining areas. The number of water supplies undermined during the 3rd assessment period were identified, with results organized by mining method and water supply type (well, springs, or public water connection) and water supply use (domestic, agricultural, industrial, etc.). The studied water supplies falling within the RPZ were analyzed, with results organized by mining method and water supply type. A complete analysis of the resolution status of each water supply was determined. The result was a better understanding of how shallow aquifers were impacted by underground mining.

I.G.6 – Effects of Mining on Land (Section VII)

The University reviewed and analyzed all data related to land reported effects. The resolution status of each reported effect was analyzed and the potential cause classified into one of five general categories: 1) tension cracks, 2) mass wasting, 3) settlement, 4) compression ruptures, and 5) unknown. Each of the eight active mines with land reported effects was analyzed separately and several examples of mitigation efforts were documented.

I.G.7 – Effects of Mining on Streams (Section VIII) and Wetlands (Section IX)

The University measured the number and length of streams undermined during the 3rd assessment period and examined the effects of underground mining on the biological integrity and flow status of undermined stream segments (Appendix D). Biological integrity was determined using "total biological score" calculated in accordance with the PA DEP Technical Guidance 563-2000-655 over 320-ft (100-m) stream segments. The requirements for evaluating and reporting the character of wetlands were changed mid-way through the 3rd assessment period. These changes did not afford the University the opportunity to adequately assess impacts to wetlands. However, several pre-mining wetland assessment reports have been submitted to the PA DEP in association with permit modifications. The University examined these recent submissions, compared them with previous submissions, and determined how effective they were in addressing past concerns.

I.G.8 – Effects on Utilities and Transportation (not covered)

Utilities potentially impacted by undermining include pipelines, power distribution lines, and water lines. Transportation units not covered in this report and possibly impacted include: State roads, local community roads, and railroads. CUP, during the 2nd assessment period, found it difficult to obtain information on these impacts. As a result, the PA DEP did not require the

University to include this information in the current report. However, it should be noted that utility and transportation related impacts are sometimes addressed within the report especially when they are related to other issues being discussed. For example, reported effects to structures that carry electrical utilities are covered in Section V. In addition, a few reported effects to water lines are addressed in Section VI. Lastly, it is obvious that considerable work continues to be done to mitigate potential impacts to utilities such as gas pipelines. The PA DEP occasionally notes gas pipeline mitigation activities, similar to the one shown in Figure I-10, when investigating other reported effects. However, these mitigation activities are often covered under legal agreements and are generally not discoverable through public inquiry.

Figure I-10 - Gas pipelines are routinely excavated and temporarily supported to mitigate the impacts from longwall mining (Photograph from PA DEP files).