SECTION XI: Summary and Conclusions

XI.A - Overview

Section 18.1 of the Bituminous Mine Subsidence and Land Conservation Act requires PADEP to compile, on an ongoing basis, information from mine permit applications, monitoring reports, and enforcement actions. It also requires PADEP to report its findings regarding the effects of underground coal mining on overlying land, structures, and water resources to the Governor, General Assembly and Citizens Advisory Council at five year intervals. This is the 4th such report and the second completed by a team from the University of Pittsburgh. The team brings together expertise in mine engineering, hydrogeology, and ecology.

The University team saw its goal as one of providing the best unbiased information possible. To accomplish that, the team made impartiality a central operating value. Virtually everyone that will read this report makes constant small decisions to turn on a light, or use a home appliance. Because coal supplies more than 40% of all electricity (U. S. Energy Information Administration 2013), we are all dependent on coal in the United States. This report addresses the costs of coal on very local scales, costs that are not necessarily reflected in coal's price or coal workers' paychecks. With clear knowledge we can make decisions about how to best manage our immediate and future needs for energy as well as our need for healthy ecosystems and vibrant communities. Coal is a natural treasure, a legacy passed down through the ages by the ecosystem that was on earth 300 million years ago. The University's intention with this report is to aid the people of the Commonwealth in the wise extraction and use of coal, thereby ensuring that coal's energy is used to build the natural and human legacy for the millennia yet to come.

In the 3rd assessment, PADEP asked only for a reporting of the effects of underground bituminous coal mining. In the contract leading to this 4th report, the University was also tasked with evaluating PADEP's effectiveness in implementing Act 54. The University has therefore focused on producing a report that provides both a detailed analysis of the effects of mining as well as data-based recommendations to PADEP on the process by which information concerning the effects of underground mining is obtained and managed.

XI.B - Summary

Data collection, error checking, and incorporation in the Act 54 Geographic Information System (Act54GIS) collectively represented by far the largest proportion of total University effort on this project. Once completed, this system contained spatially explicit information on all features for which the effects of underground coal mining are regulated by PADEP. Mining data came primarily from three sources – six-month mining maps provided by PADEP, mining maps and other spatial data provided by mine operators, and PADEP's Bituminous Underground Mining Information System (BUMIS). However, data for some undermined features (e.g. stream bio-monitoring stations and wetlands) came from additional paper documents the University discovered within the permit files and in the files of PADEP individuals working on specific permit issues. The data were received in various formats; all data was converted to Esri ArcGIS files with a NAD 1983 UTM 17N map projection. The Act54GIS also contained base layers that relate the extent of mining and its impacts to a larger landscape framework, including all roads, rivers and topographic features. The Act54GIS makes possible analysis and reporting of information required by the 4th assessment period contract between the University and PADEP, including comparisons with past assessment periods. Further, it provides a useful basis for organizing the information necessary for future reports.

The cost to the Commonwealth and the difficulty of constructing the GIS database could have been greatly reduced. Given difficulties encountered in attempting to extract necessary information from BUMIS, it is clear that the mining information system is not linked to a geographic information system. Records in BUMIS are sometimes missing altogether and frequently lack sufficient information to accurately determine their locations and feature type or to link them to other sources of information regarding that particular feature and effect. Furthermore, it was unclear whether or not the California District Mining Office (CDMO) of PADEP had a GIS database in place during the 4th assessment period. Although the Master Agreement between PADEP and the University states "The University shall make maximum use of information contained in relevant data layers maintained on the PADEP's geographic information systems," PADEP did not provide access to a PADEP geographic information system. In the 3rd assessment period, the University explicitly requested access to PADEP's geographic information system and was denied. During the 4th assessment period it remained unclear if a GIS system existed containing mining regulatory information; if it does exist, the University was not given access.

In this report, the University is able to provide the most detailed information yet produced for Act 54. The University's contract from PADEP placed a strong emphasis on reporting on the effects of underground mining on streams and wetlands, since these are the effects that have been of greatest concern for both the mining industry and many citizens of the Commonwealth. For the first time, the University was able to assess a number of aspects of the relationship between underground mining and stream and wetland impacts with statistical estimates of certainty regarding the results. For the first time, PADEP also requested an assessment of underground mining effects on groundwater.

A total of 31,343 acres of Pennsylvania land were undermined by 46 underground bituminous coal mines during the 4th assessment period. This represents an 18% drop in bituminous coal production from underground mines in Pennsylvania compared to the previous 5-year reporting period. This drop results in part from a decrease in demand for coal and partly from the movement of mining activity in the large longwall Bailey Mine to the west, shifting increasingly into West Virginia. Six companies operated these 46 mines . The number of mines operated per company ranged from 1 to 20 and the percentage of all acreage mined per mining company ranged from <1 to 39%. Thirty-four of the 46 active mines used exclusively room-and-pillar methods, seven were longwall operations, and five were pillar recovery operations. Thirty-five of the 46 mines worked Kittanning and Freeport Coalbeds of the Allegheny Formations while the remaining 11 worked the Pittsburgh and Sewickley Coalbeds of the Pittsburgh Formation. Forty percent of the total area mined was in Greene County, 19% in Washington County with the remaining 39% spread over Armstrong, Beaver, Cambria, Clearfield, Elk, Indiana, Jefferson, and Somerset Counties. The average size of longwall panels has increased nearly four-fold since the method's introduction in Pennsylvania around 1970, from about 400-ft in width originally to as much as 1,560-ft currently. The University estimates that about 154,000 acres of minable coal remain in the Pittsburgh Coalbed, given current mining methods. At the current rate of mining (during the 3^{rd} and 4^{th} assessment period, an average of 4,161 acres were undermined per year) it will take approximately 37 years to mine the remaining coal in the Pittsburgh Coalbed. No estimates of remaining minable coal for the Kittanning and Freeport Coalbeds are made.

Subsidence is strongly associated with mining method with the vast majority of subsidence resulting from longwall mining. Subsidence from longwall mining is influenced by the depth of overburden; the deeper the overburden the smaller the magnitude of subsidence. Longwall panels are on average operating under deeper overburden in the 4^{th} assessment period relative to the 3^{rd} reporting period. Subsidence also occurs in room-and-pillar mines that practice pillar recovery. In general, room-and-pillar mines don't produce subsidence, although pillar punching or pillar instabilities can, on rare occasions, cause subsidence related impacts on the surface.

During the 4^{th} assessment period, 389 effects on structures were reported. Of these, 315 (81%) were associated with longwall mines. For 238 (61%) of the reported effects, the damage was determined to be due to undermining and thus the mining company was deemed liable. All but 59 (15%) were resolved during this assessment period. For the 330 effects with a final resolution, the average time to reach a decision was 169 days. Of those cases determined to involve mining company liability, 157 (66%) were resolved by agreement between the property owner and the mining company. Legally, PADEP is not privy to the details of these private agreements, so the extent to which the damage was repaired or the structure was replaced is unknown. Relative to the 3^{rd} assessment, the number of effects on structures dropped by approximately 14%, while the number of acres mined dropped by 18%. The challenge of identifying and tracking all structure effects was greatly increased by the frequent lack of unique structure identifiers in BUMIS.

During the 4^{th} assessment period, there were 855 reported effects to wells, springs, and ponds. These effects were nearly evenly split between room-and-pillar and longwall mining operations. Of these, 201 (23%) remained unresolved at the end of the 4^{th} reporting period. Among those that were resolved, the average time to resolution was 220 days. Of the 654 resolved effects, 57% were determined by PADEP to be due to underground mining. The mine operator was held responsible for the resolution of those cases. For those resolved effects for which the operator was held responsible the average time to resolution was 415 days. Seventy percent of all company-liable effects, representing 31% of all reported effects on water supplies, were settled through an agreement between the mining company and the property owner. For these effects, there was no way to know if the water supply was impacted and, if so, restored, replaced or abandoned.

Approximately three-fourths of the company-liable water supply effects lay within PADEP's Rebuttable Presumptive Zone (RPZ), determined by a line at 35 degrees from vertical extending upward and away from the closest edge of the extent of mining to the surface. Within the RPZ effects are assumed to be due to mining unless the mining company can show otherwise. Thus, 25% of effects lie outside of the RPZ, as much as 85 degrees outward and upward from the edge of mining. Despite an 18% drop in number of acres mined, the number of reported water supply effects has increased by approximately 25%. The increase in reported water supply effects may be attributable to the encroachment of underground mining on more heavily populated areas in the 4th period and to increased public awareness of mining company responsibility for addressing any mining-related impacts on water supplies.

The ability to identify and track underground coal mining's effects on water supplies suffered from the same problems in BUMIS as did the tracking of reported effects on structures. The University makes specific recommendations regarding best practices in data management in this report.

The University organized available data to comprehensively understand the hydrologic changes following underground mining, particularly changes to groundwater. The hydrologic monitoring data is an additional body of data requiring substantial effort to organize and link to other existing PADEP data sources. There are over 750 distinct water quantity and quality sampling locations over longwall mines reported to PADEP during the 4th assessment period. Reported sampling of these locations include over 31,000 sampling events. This considerable data set does not seem to include substantial flow monitoring required as part of relevant permits but not included in regular hydrologic monitoring reporting. In general, due to the typical frequency and variability in reported monitoring and the complicated nature of local hydrology, pertinent questions are challenging to address. These shortcomings are demonstrated in efforts to clarify the causes of reported water supply effects in the focal watersheds using hydrologic monitoring data. Looking forward, with relatively minor changes to sampling and reporting, these hydrologic systems can be clarified and potential impacts from future mining more effectively mitigated.

During the 4th Act 54 assessment, 96 miles of stream were undermined. Longwall mining accounted for the undermining of 51 miles of stream, which represents a ~20% decline from the 3rd assessment, reasonably commensurate with the 18% decline in acres mined during this period. Nearly all reported stream impacts result from subsidence associated with longwall mining. Of the stream miles undermined by longwall techniques, 39 miles belong to streams that experienced mining-induced flow loss, pooling, or both, somewhere along their channel. On these streams, the maximum length of post-mining flow loss ranged from 936-ft to 10,883-ft in the dry season and from 96-ft to 8,106-ft in the wet season. Flow loss during the dry season may, in part, be a function of seasonal variations in water balance, so the University expects that wet season flow losses more accurately reflect the impact of mining. The locations and lengths of mining-induced pooling on individual streams could not be determined due to a lack of data. Maps in the Chapter 105 permits for gate cut mitigation either lack sufficient detail for georeferencing or focus on the restoration area and do not show the entire extent of pooling.

The procedure for tracking stream impacts at PADEP changed between the 3rd and 4th assessment periods due to the implementation of TGD 563-2000-655. Stream investigations are now only used by PADEP for streams undermined prior to TGD 563-2000-655. For streams undermined after TGD 563-2000-655, a period of investigation is no longer required to determine the cause of changes in stream flow. Instead, any change in flow that occurs at the time of mining is automatically assumed to be a mining-induced impact. A record of the impact is made in the BUMIS observation files and in the SSA stream data logs. The mine operator then has three years to mitigate the impact and submit data to PADEP for review. The data submission initiates a stream recovery report in the paper files at CDMO. If the review indicates stream recovery, then the stream is released. If the stream has not recovered after three years, PADEP can require a change in future mining plans. The mine operator then has two years to perform additional mitigation. If the final attempts at stream restoration are unsuccessful then PADEP will require compensatory mitigation. The new protocol at PADEP makes significant improvements over the 3rd assessment protocol in that changes in the stream at the time of mining are automatically assumed to be mining-related and streams can no longer be mitigated indefinitely. However, this protocol also makes it challenging to rapidly quantify the number of impacts and their final resolution status as one must now consult multiple data sources that either lack standardization or are written as narrative without organized data reporting.

Due to the changes in tracking stream impacts, just nine stream investigations were initiated during the 4th Act 54 assessment. Of these, four were unresolved at the end of the assessment period. For many of the stream investigations, flow data submitted by the mine operator and utilized by PADEP was inadequate to assess recovery. Fourteen stream recovery reports were filed during the 4th assessment. PADEP has released nine of these from further monitoring, while two cases require compensatory mitigation, and three cases are still under review. In the resolved cases, the University noted that PADEP would occasionally use one post-mining TBS rather than requiring the mine operator to submit two scores to assess biological recovery on a stream.

During the 4th reporting period the University was able to quantify aspects of stream mitigation efforts for the first time. In all, 95 streams had augmentation discharges installed along their channel and augmentation was active at 74 of these streams to maintain flow during or after mining. In all, 57 streams received grouting to mitigate mining-induced flow loss. Grouting involves the injection of bentonite, urethane or other mixes into stream bedrock fractures in an attempt to prevent surface water from flowing underground through the fractures. Estimates for one longwall mine suggest that ~50% of the stream lengths undermined received grouting. Three stream segments had liners placed in their channels to restore flow following mining-induced flow loss. Many miles of access road are constructed along streams as a part of the mitigation process. Over one longwall mine, nearly 8,000-ft of access roads were constructed to support mitigation activities in just a three month period.

For one mine, Bailey, the operator submitted a sufficient number of stream samples before and after mining that the University could compare pre- and post-mining TBS. On average, mining-induced flow loss significantly reduced TBS, resulting in an average drop in TBS of 13%. PADEP's policy states that a 12% or greater drop in TBS for any one stream indicates an adverse effect. This analysis suggests that on average streams are adversely affected. Mining-induced stream effects cause especially large reductions in two mayfly families, Ephemerellidae and Heptageniidae. The post-mining communities shift away from collector-gatherer and scraper macroinvertebrate taxa that are normally important components of healthy stream macroinvertebrate communities. Water quality is also affected by mining-induced flow loss. Conductivity and pH increase significantly at impacted sites, and the increases in conductivity push levels above the U.S. EPA's benchmark for aquatic life in this ecoregion. The ability of grout mitigation to restore streams to their pre-mining condition remains somewhat unclear. TBS appear to increase over time but slowly. Analyses indicate that on average, three and a half years are required for TBS to return to pre-mining levels. However, conductivity and pH remain elevated following mining and mitigation.

During the 4th reporting period 28 stream segments received gate cuts to alleviate mining-induced pooling (total miles mitigated: 4.2 miles). Data from Bailey and Enlow Fork Mines (the only usable data available) indicate that mining-induced pooling reduces TBS and is thus an adverse effect to streams. However, gate cut restoration is effective in restoring TBS to pre-mining levels. Macroinvertebrate community composition after gate cut restoration is statistically indistinguishable from pre-mining macroinvertebrate community composition. Based on the available data, the University views gate-cutting mitigation methods as successful in restoring stream ecology.

The University also carried forward the history of stream investigations from the 3rd assessment period. Of the 55 stream investigations that were initiated in the 3rd assessment, 51 reached a final resolution by the end of the 4th assessment period. The average time to resolution for these cases was 1,313 days or just over three and half years. Four stream investigations from the 3rd Act 54 assessment remain unresolved. These cases have been open for seven to eight years. PADEP is currently reviewing flow data for two of the cases, yet there is little information in BUMIS or the paper files at CDMO regarding the status of flow recovery for the other two cases.

Eight of the 51 or 16% of resolved investigations were resolved not because of recovery but because they have been deemed not recoverable. One of these involves a federal court settlement. Overall, these cases represent impacted streams that have not recovered from mining-induced flow loss, despite a variety of mitigation techniques. In general, the stream segments in these cases are characterized by shallow depths to mining, with impacts occurring in areas with overburdens less than approximately 500-ft.

The analysis and reporting on underground mining effects on wetlands is still in its infancy. Many of the active mining operations during the 4th assessment received their permits prior to the deadline for compliance with TGD 563-2000-655. The permit applications therefore do not contain sufficiently detailed wetlands inventories, if any wetland information is present at all. The University therefore relied instead on permit renewals, containing information on pre- and post-mining data for all wetlands undermined in a five year period. Of the five longwall mines, Cumberland Mine had the greatest density of pre-mining wetlands, with 2.92 wetland acres for every 100 acres of planned longwall mining. The majority of all pre-mining wetlands (84%) were classified as palustrine emergent wetlands, meaning that they were freshwater systems dominated by erect, rooted, herbaceous vegetation.

In three of the longwall mines, there was a slight net gain of wetland acreage. However, among these mines, 33-41% of the original wetland acreage was lost after subsidence. The losses of original wetland acreage were offset by the emergence of new wetland acreage, mostly palustrine emergent, while the lost wetlands had a mix of emergent and scrub/shrub or forest vegetation. The emergent wetlands may eventually develop woody vegetation, but this could take decades. Currently, the new wetlands do not functionally replace the complexity and resources that were provided by the original wetlands.

Cumberland Mine was the only mine with a net loss (4.84 acres) of wetlands. The bulk of these losses occurred in palustrine emergent wetlands. Proposed mitigation along two streams, Dutch

Run and Whiteley Creek, will create 6.19 wetland acres but just 2.31 acres of palustrine emergent wetlands. Thus, the mitigation does not provide a 1:1 functional replacement of the lost wetlands. Past studies of wetland mitigation projects in Pennsylvania suggest that mitigation sites have lower functionality relative to natural wetlands. Clearly, close study of the Dutch Run and Whiteley Creek mitigation sites is warranted to ensure that these sites achieve their proposed function and that they are maintained for years to come; they are just now being established and so it is too early to make any assessment at this time.

Evaluation of subsidence-related changes in wetlands is complicated by natural variation in wetland size due to seasonal and annual fluctuations in temperature and precipitation. Multiple delineations on a focal group of control wetlands would allow agents to assess the extent of variation in wetland size due to natural factors and compare this to the observed changes after mining. This would provide a more objective means of determining the effects of subsidence on wetland size.

PADEP tasked the University with providing data-based recommendations on how to improve the implementation of Act 54. The aim of these recommendations is to enhance PADEP's regulatory efficiency and their ability to more effectively evaluate the impacts of mine subsidence. In summary, the recommendations fall into three broad categories:

1. Standardization of data acquisition and submission to PADEP.
    a. Further thought needs to be given to frequency and timing of certain kinds of field data acquisition, such as stream flow measures, macroinvertebrate sampling, and well and piezometer data. Details are given in the full report.
    b. PADEP should establish written requirements for the specific contents, formats and file types for the data required from the mine operators. All submissions should be in electronic form. File submission requirements would facilitate comparison across mines as well as rapid and accurate incorporation in both PADEP's information system and standard statistical software. Suggestions are provided in the report.
2. Quality control and quality checking in PADEP's data management process.
    a. Written quality assurance and quality control protocols should be developed and implemented; they are presently largely lacking.
    b. Quality assurance and quality control methods should also be applied to past data entries to correct errors.
    c. All submitted data should be checked for adherence to technical guidance documents and general policy soon after submission and rejected if standards are not met.
3. Determination and tracking of impacts and standards for determining resolution.
    a. Link BUMIS to a geographic information system.
    b. Develop a single centralized and standardized database for tracking stream impacts and their resolutions.
    c. Implement more rigorous methods for determining impacts and recovery of stream flow. These should be based on volumetric flow rather than presence or absence.

d. Develop data on regional temporal variation in wetland size for testing putative mining effects as compared to natural variation in wetland size. In addition, more rigorous assessment of changes in wetland function and of equivalent wetland function replacement is advised.

XI.C – Conclusions

In implementing Act 54, the Pennsylvania General Assembly declared the following:

1) "The protection of surface structures and better land utilization are of the utmost importance to Pennsylvania.
2) Damage to surface structures and the land supporting them caused by mine subsidence is against the public interest and may adversely affect the health, safety and welfare of our citizens.
3) The prevention or restoration of damage from mine subsidence is recognized as being related to the economic future and well-being of Pennsylvania.
4) The preservation within the Commonwealth of surface structures and the land supporting them is necessary for the safety and welfare of the people.
5) It is the intent of this act to harmonize the protection of surface structures and the land supporting them and the continued growth and development of the bituminous coal industry in the Commonwealth.
6) It is necessary to provide for the protection of those presently existing structures which are or may be damaged due to mine subsidence. It is necessary to develop an adequate remedy for the restoration and replacement of water supplies affected by underground mining.
7) It is necessary to develop a remedy for the restoration or replacement of or compensation for surface structures damaged by underground mining.
8) It is necessary to provide a method whereby surface structures erected after the effective date of this act may be protected from damage arising from mine subsidence." (Act 54).

Importantly, the Act further stipulated that "Nothing in this act shall be construed to amend, modify, or otherwise supersede standards related to prevailing hydrologic balance contained in the Surface Mining Control and Reclamation Act of 1977… nor any standard contained in the act of June 22, 1937 known as the "The Clean Streams Law," or any regulation promulgated thereunder by the Environmental Quality Board." (Act 54).

The successful management of land during periods of repetitive subsidence disturbance requires the collection, organization, and analysis of a wide variety of data. The growth of computing power and automated sensors has created challenges in many fields, challenges that are loosely grouped into what is called "big data". The term big data refers to a situation where the data collection exceeds one's ability to manage the data, precluding the data from being included in decision making frameworks. The management of land above underground coal mining is at the cusp of such challenges.

Early implementation of Act 54 focused on challenges facing citizens of the Commonwealth who reside over undermined areas. Since that time, processes for protecting residents have become standardized. There are clear best management practices to mitigate and repair subsidence effects to structures and water supplies. If properly implemented, the hindrance to local residents can be minimized.

However, as more attention is focused on undermined surface water systems, the path forward is not as clear. When a wall is cracked, the crack is repaired. When a well is obstructed, a new well is drilled. However, when a stream runs dry, how do we “put it back?” It is in protection and mitigation of surface and ground water effects where data needs grow quickly. How much flow should be in a stream at a given point in the year? What if it’s a dry year? This question requires the collection of data before, during, and after undermining. The question also requires the collection of data tailored to a specific location. When we fix a wall, the blocks are a standard size. When we drill a well, the casing is a standard diameter. Natural waters do not come in standard sizes or configurations, requiring an iterative, data- intensive approach to “putting things back.” We must examine management practices to ensure they work “best” in any single system.

Recent guidance from PADEP has improved the ability to interpret and mitigate the impacts of underground mining on surface and ground waters (PADEP 2005). Data presented in this report indicate that certain mitigation measures (e.g. gate cuts) are effective in restoring stream systems across a number of sites that vary in mining and environmental conditions. However, big data challenges limit evaluation of other mitigation techniques (e.g. grouting) and other impacts (e.g. hillside springs). As underground mining continues in the Commonwealth, best practices for managing big data should be utilized to ensure that the land areas above underground mining are managed well. Practices such as data standardization, electronic submission, and rapid error and standards checking for data submission can cascade through processes that have evolved for data gathering, enhancing the ability of all who rely on the data to protect the Commonwealth.

XI.D – References

PADEP. (2005) “Surface Water Protection – Underground Bituminous Coal Mining Operations,” Technical Guidance Document 563-2000-655, October 8, 2005, 43 p.

U.S. Energy Information Administration (2013). “Electric Power Annual 2012,” http://www.eia.gov/electricity/annual/