

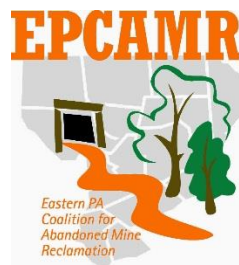
# ANTHRACITE MINE POOL MAPPING FOR THE SOUTHERN AND NORTHERN COAL FIELDS

PREPARED FOR: **SUSQUEHANNA RIVER BASIN COMMISSION**  
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- Supporting Maps - Coal and Misc. Investigation Series: I-528 1-6, I-529 1- 4, I-681 1 & 2, I-753, I-838 1 & 2,  
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## EXECUTIVE SUMMARY

This report summarizes the means and methods used to map the mine pools in the Northern and Southern Anthracite Coal Fields.

- Background
  - Since coal was first discovered in the Anthracite Region over 250 years ago, approximately 18 billion tons were removed from the Earth. This volume, not including surrounding rock that was removed to get to the coal, represents empty voids that now exist above and below ground. If these voids existed below the ground water level, they began to flood producing vast reservoirs of water held under the ground of varying chemistries. Coal companies would pump water from the mines to continue to mine deeper into the ground. Although there were many factors that lead to the demise of underground coal mining in the Anthracite Region, one important factor was tied to simple economics: the cost to pump vs. the market value of coal. Eventually deep mines were abandoned and the water began to fill up and discharge via mine openings to the surface. The Eastern PA Coalition for Abandoned Mine Reclamation (EPCAMR) recently completed an extensive, 4 year study and technical report, in 2011 for the Southern & Western Middle Anthracite Coal Regions, entitled, WATER QUANTITY, QUALITY, AND POTENTIAL USAGE FROM UNDERGROUND MINES IN THE ANTHRACITE REGION—WESTERN MIDDLE AND SOUTHERN FIELDS, EASTERN PENNSYLVANIA.
- Purpose
  - This report attempts to build on previous investigations to locate and quantify large volumes of water existing in underground mine voids, known as Mine Pools, in the Southern and Northern Anthracite Coal Fields of Eastern Pennsylvania. When pairing treatment with the ability to control the amount of water coming out of the mines, large flushes of stormwater that would normally escape untreated could be retained, later treated and released in times of low water or drought conditions.
- Goal
  - 3D Modeling of Eastern Pennsylvania Anthracite Mine Pools in Earthvision to Improve Water Quality Restoration and AMD Treatment Via Consumptive Use Mitigation Projects in the Susquehanna River Basin

## Conclusions

The complex geologic setting and historical mining of the anthracite mine pools creates a challenge to calculate the volume of water stored within the underground mines. This mapping effort has reasonably found that an estimated 8,831,448,000 gallons resides in storage in 10 mines in the Southern Field and approximately 435,293,822,000 gallons in all the Northern Field. Those results are summarized below.

### Southern Anthracite Coal Field (Part)

- Heckscherville Valley Mine Pools Volume Estimate: .....Total ~6,268,433,000 gallons
- Rausch Creek Valley Mine Pools Volume Estimate: .....Total ~2,563,015,000 gallons

### Northern Anthracite Coal Field (All)

- Lackawanna Valley Mine Pools Volume Estimate: .....Total ~160,923,304,000 gallons
- Wyoming Valley Mine Pools Volume Estimate: .....Total ~274,370,518,000 gallons

## 1.0 INTRODUCTION

Geologically, the largest most concentrated anthracite deposit in the world is found in northeastern Pennsylvania, United States. Locally called the “Coal Region,” the deposit contains 480 square miles of coal bearing rock which originally held 22.8 billion short tons of anthracite (Ashley 1945). Northeastern PA holds 75% of the world’s and 95% of the northern hemisphere’s Anthracite reserves.

In 2008, the Energy Information Administration (EIA) estimated the current demonstrated US coal reserve base at 496 billion tons distributed geographically among 31 states; with 27 billion tons in Pennsylvania. Pennsylvania is the fourth leading coal producing state, mining 68 million tons (Energy Information Administration, 2008). Almost 80 percent of this output came from 39 underground mines and the remainder from 377 surface mining and reprocessing sites. In addition, the Pennsylvania mining industry constitutes a major source of employment and tax revenue. In 2009, it created 49,100 direct and indirect jobs with a total payroll in excess of \$2.2 billion. Taxes on these wages netted over \$700 million to the coffers of federal, state and local governments. Current estimates show 4 to 6 billion tons of reserves of Anthracite left in the region.

Since coal was first discovered in the Anthracite Region approximately 18 billion tons were removed from the Earth. This volume, not including surrounding rock that was removed to get to the coal, represents empty voids that now exist above and below ground. If these voids existed below the ground water level, they began to flood producing vast reservoirs of water held under the ground of varying chemistries. Coal companies would pump water from the mines to continue to mine deeper into the ground. Although there were many factors that lead to the demise of underground coal mining in the Anthracite Region, one important factor was tied to simple economics: the cost to pump vs. the market value of coal. Eventually deep mines were abandoned and the water began to fill up and discharge.

The water levels of these developing mine pools eventually stabilized when spill-over points were reached at the lowest topographic elevation of a sizeable opening to the abandoned underground mine. In many cases, the spillover opening was the main tunnel, slope, or drift entry to the mine; in other cases the lowest opening was an airshaft, borehole, or some other underground mine feature. Consequently, about 100 large abandoned mine discharges (AMD) appeared in the four coal fields of the Anthracite Region (Growitz, 1985), (Wood, 1996). These major discharges and thousands of more minor seeps persist to the present day throughout the Anthracite Region.

The mine drainage discharges of the Anthracite Region generally have lower concentrations of acidity, sulfates and metals than the discharges of the Bituminous Coal Region of western Pennsylvania. This is

principally due to variations in paleo-environment, in that the coals and overburden strata of the Anthracite Region generally have low total sulfur contents due to deposition in a freshwater paleo-environment.

The abandoned deep mine discharges have polluted many of the streams and rivers of the Anthracite Region with (relatively high) concentrations of acidity, iron, manganese, aluminum, sulfate, and other constituents. The streambeds of these water courses are typically covered with “yellow boy” (i.e., iron hydroxide) and the waters are frequently devoid of fish and benthic aquatic life and macro invertebrates. However, many of these streams and rivers of the Region were already essentially dead from many years of receiving untreated discharges when the active underground mines were pumping the untreated mine water prior to 1966. Newer mining laws require mining companies to reclaim land and cleanup water impacted by mining activities, but these abandoned mine discharges and mine scarred lands are the legacy of over 250 years of mining.

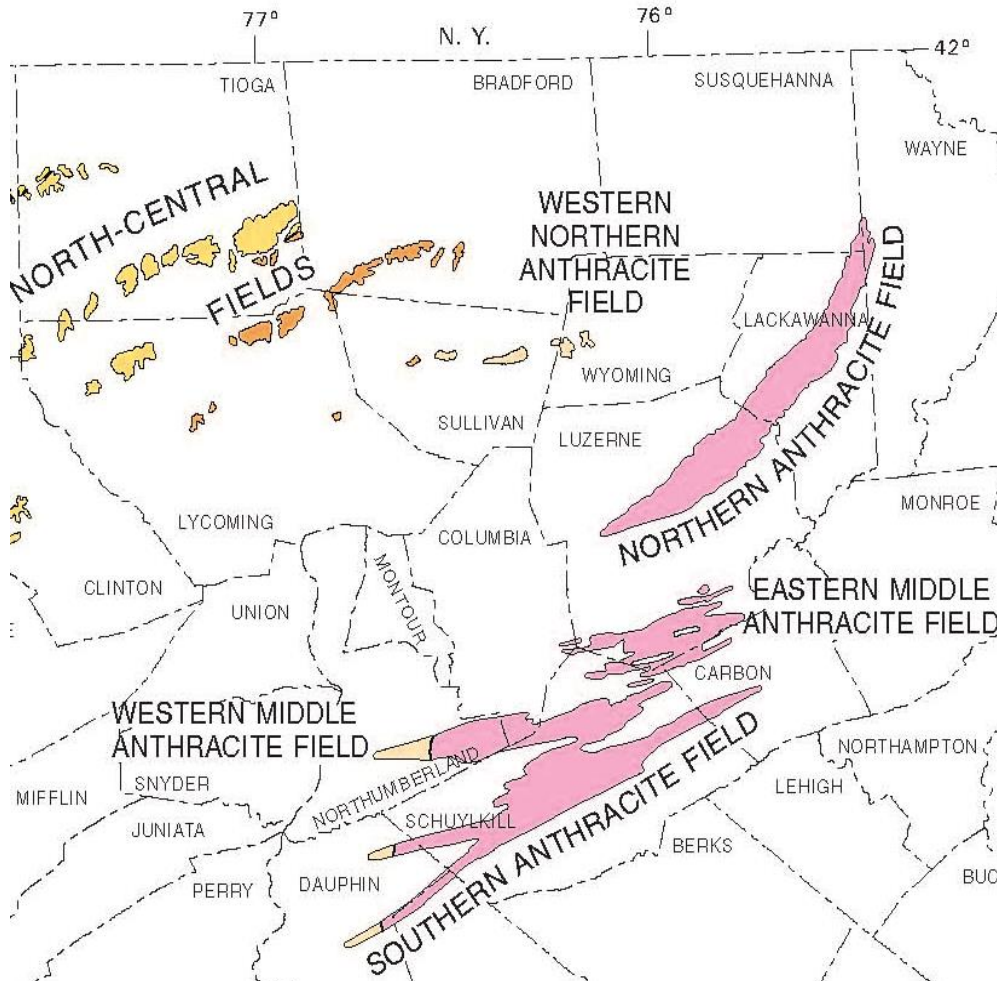
EPCAMR has updated earlier estimations of the conservative volumes of mine water and ground water storage capacities using computer programs such as ArcGIS, EarthVision, and the best available maps and mapping technology that would allow the SRBC to consider the re-utilization of the mine pools of the Southern and Northern Anthracite Coal Fields for consumptive use mitigation, low flow augmentation, industrial re-use, and for other economic development opportunities throughout the Basin.

As the old adage goes "When life hands you lemons, make lemonade". Instead of looking at these abandoned mine discharges as pure pollution, when broken down into its elements and treated, much can be done with the precipitated metals and water. Metals like iron have many marketable uses. Cold clean water can improve stream fishery values among other socioeconomic factors. The same goes for the tremendous potential to store and control volumes water in the underground mine workings. When pairing treatment with the ability to control the amount of water coming out of the mines, large flushes of stormwater that would normally escape untreated could be retained, later treated and released in times of low water or drought conditions. This report attempts to locate and quantify large volumes of water existing in underground mine voids, known as Mine Pools, in the Southern and Northern Anthracite Coal Field of Eastern Pennsylvania.

## 2.0 BACKGROUND

### 2.1 Site Location & Description

The Anthracite Coal Region of eastern Pennsylvania occupies portions of seven counties. It extends 50 miles east to west and 100 miles north to south covering around 484 square miles. Current estimates



show 4 to 6 billion tons of reserves of Anthracite left in the region (Council, 2011).

There are four main coal fields of the Anthracite Region: the Northern, Eastern Middle, Western Middle and Southern. There is also the Western Northern Coal Field that extends across Sullivan County into Wyoming County with several smaller discontinuous pockets of semi-anthracite.

Figure 1: Portion of the Distribution of Pennsylvania Coals map. Pink indicates Anthracite, Beige indicates Semi-anthracite (DCNR 2011)

The Southern Coal Field is the largest field and it extends from just northwest of the Borough of Lykens, Dauphin County, on the western end of the field, with a prong diving down towards the Borough of Dauphin, Dauphin County, northeastward to the Borough of Nesquehoning, Carbon County, on the eastern end. The westernmost tips of the coal field are semi-anthracite. Little has been written about the hydrogeology or hydrology of the Southern Anthracite Coal Field, although much information on the geologic structure and stratigraphy is contained in several studies by Charles R. Wood of the U.S. Geologic Survey (Wood, et al., 1956, 1963, 1969, 1970 and 1986). Figures 2a and 2b show the areas covered by this report.

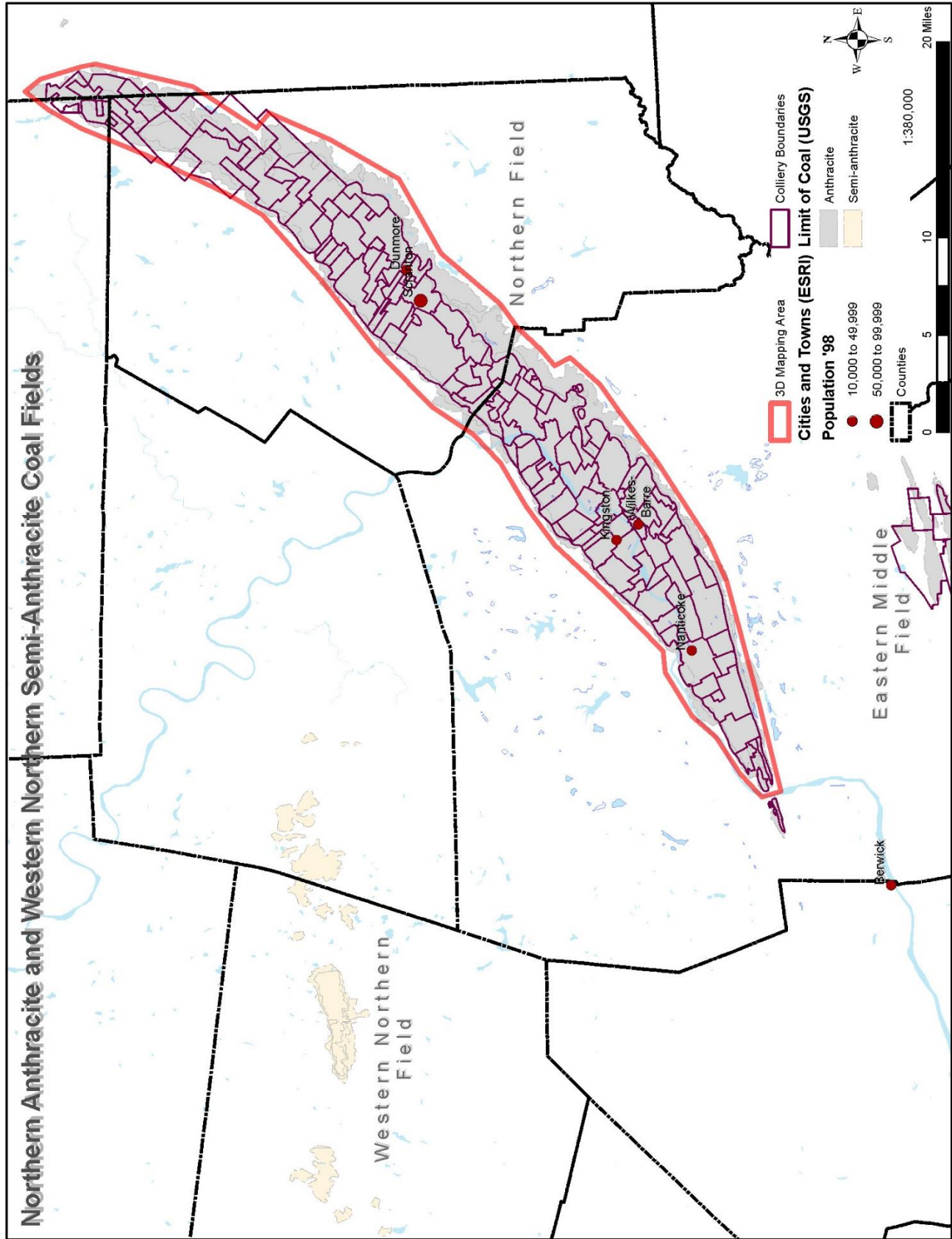


Figure 2a: Northern Anthracite and Western Northern Semi-Anthracite Coal Collieries of Eastern Pennsylvania



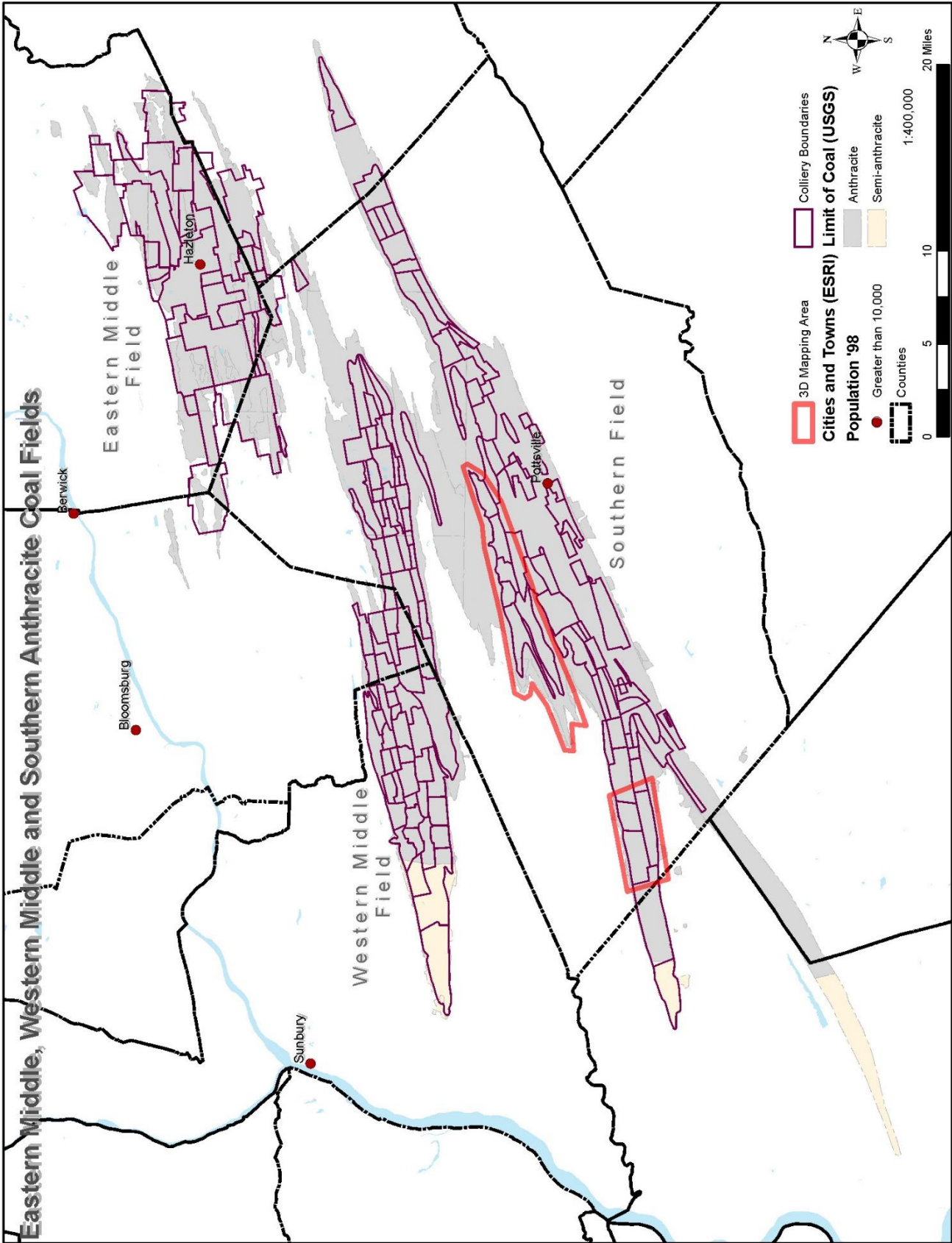


Figure 2b: Eastern Middle, Western Middle and Southern Anthracite Coal Collieries of Eastern Pennsylvania

## 2.2 Site History

Anthracite coal was discovered in eastern Pennsylvania around 1750. By 1850, numerous collieries (i.e. large underground mines and associated surface coal mine structures) had been developed, some having vertical shafts with depths of more than 1,000 feet.

Anthracite was highly sought as the cleanest burning solid fuel and remains as such on the commercial market today. Anthracite coal is a naturally high carbon, clean burning solid fuel with a typical sulfur



*Figure 3: Anthracite coal is generically a called “hard coal” mineral because it is of higher rank on the carbon scale (i.e. harder) than the coal beds of the Bituminous Coal Region of western Pennsylvania, its high luster, high carbon content, typically between 92-98%, and relatively few impurities (Stefanenko, 1983).*

content of less than 0.7% and volatile matter of just 4% to 6%. In fact, Coal companies have mined and prepared Anthracite coal for more than 150 years in this region. It has lower sulfur content than some heavy fuel oils. Its uses range from heating applications to water filtration media among many other uses. Anthracite’s heat value is measured in British Thermal Units (BTUs) like all other sources of energy. There are about 25 million BTUs per ton of Anthracite. This is the equivalent of 180 gallons of home heating oil and 260 therms of natural gas. Current estimates show between 300 to 500 years of Anthracite reserves remain in the ground today (Council, 2011).

The Pennsylvania Department of Environmental Protection’s (PA DEP) Bureau of Mine Safety and its predecessor, the Department of Mines and Mineral Industries (DMMI), has maintained coal production statistics since 1870, when the total yearly production was 14,172,004 tons. Most of the anthracite coal was deep mined up through the 1930’s, however, some surface mines existed and their coal production increased following World War II. Anthracite production peaked at just over one hundred million tons in 1917 (100,445,299 tons) and most of this was obtained by underground mining. Surface mining statistics are now divided into open pits and re-mining coal refuse banks (i.e., waste rock discarded from the collieries). Surface mine production did not exceed deep mine production until about 1960. At one time during this investigation it was suggested that EPCAMR use production statistics per colliery to estimate void volumes, but this information alone would not aide in mine pool volume calculation. These numbers can, however, be used in calibration of the 3D model and estimate of virgin coal volumes.

Due to over two centuries of mining, there are billions and billions of gallons of mine water in the flooded abandoned underground mines, contained within mine pool complexes, and surface mine water filled pits. For example, in the 1950’s S. H. Ash stated: “In the Southern Field are 37 underground water pools containing 37 ½ billion gallons of water.” “...3 of these pools are in active mines, where their water level

is controlled by pumps; and abandoned mines contain 32 pools that overflow to the surface and 2 where pumping plants control their water level.” The 35 barrier pillars investigated in the Western Middle Field have a total length of 19 miles between collieries often separating water into different pools. An estimated 135 trillion gallons of water was pumped to the surface from abandoned deep mines from 1944-1951, an average of 16 ½ trillion gallons per year in order to safely mine (Ash, et al., 1953). These calculations were made at a time in the 1950’s when many of the collieries were still mining and actively pumping water, so the present day total mine pool volumes for the Southern Coal Field would be much greater. This has been verified by measuring the water level in monitoring boreholes drilled into the mines and comparing their levels over time.

S. H. Ash’s figures and revised estimates serve as an excellent starting point to update current mine pool levels. EPCAMR has been attempting to update those levels and volumes with cutting-edge groundwater modeling applications, 3-D structural geology modeling, and geographic information system (GIS) available through our partners. The volumes of inundated coal reserves that remain in the Anthracite Coal Fields due to mine pool extents are vast, but are also reserves that could potentially be extracted to again boost to the economy of our Nation. The problem that remains is the removal of the water especially from depths greater than 1,000 feet below the surface. In the past, gravity drainage tunnel systems and pumps were used to dewater mines, but there were physical and economic limits to these technologies. Just such a proposal was made to the 77<sup>th</sup> Congress in 1941 and a series of investigative reports into the “Conowingo Tunnel” was commissioned by the federal government. A 137 mile long tunnel between 9-16 feet in diameter was proposed to outlet just below the Conowingo Dam on the Susquehanna River in Maryland for approximately \$280 Million [Ash Et. Al. 1957]. The movement eventually fizzled out with further study of potential environmental and economic impacts.

Today we know that mine pools of the Anthracite Region are typically stratified similar to natural lakes and “beach lines” in the mines are AMD production zones. As the water levels rise and fall with precipitation events beach lines in the individual coal veins erode away exposing pollution causing material to dissolve into the water which circulates throughout the mine. The initial flush of the Conowingo Tunnel would have been extremely devastating to the ecosystem of the Chesapeake Bay as it would dump trillions of gallons of AMD laden water with pollutant concentrations in the hundreds to thousands of milligrams per liter each parameter. The system would stabilize over time, but the newly exposed surface areas in the mines would ramp up the production of AMD to unseen levels and discharge consistently at 300-400 million gallons per minute. Stabilization of mine pools was the final recommendation this effort.

### 2.3 Physical Characteristics

The Anthracite Coal Region is located in the Anthracite Valley Section, portions of the Susquehanna Lowland Section, Anthracite Upland Section, and portions of the Blue Mountain Section, of the Ridge and Valley Physiographic Province.

The birth of anthracite and bituminous coals of PA are time equivalent (about 250-400 million years before present), but the anthracite coals are considered a metamorphic rock due to the original sedimentary rock being subjected to higher temperature and pressure during the mountain building episodes of the Ridge and Valley Physiographic Province. The geologic

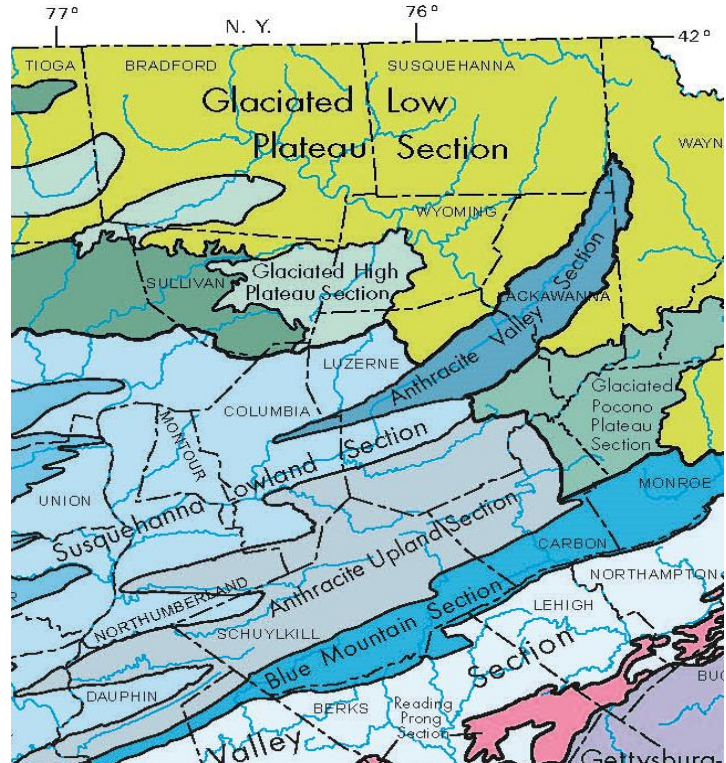


Figure 4: Portion of the Physiographic Provinces of Pennsylvania map (DCNR 2011)

structure of the four Anthracite fields consists of deep, steep-sided synclinal basins. Coal veins exhibiting dip in excess of 60 degrees have been measured in some of the Anthracite Coal Fields while others have been completely overturned and fold back on themselves. This is in contrast to the relatively flat-lying bituminous coals of the Allegheny Plateau Physiographic Province of western PA and Deep Valleys and Glaciated High and Low Plateau Sections of the northern tier of PA. Material deposition of pre-historic swamps, flora, fauna, and peat beds in the Carboniferous Geologic Period were eventually transformed to Anthracite coal. At that time, most of PA was a flat, tropical plain covered with steaming swamps thick with tall trees and wide spread vegetation.

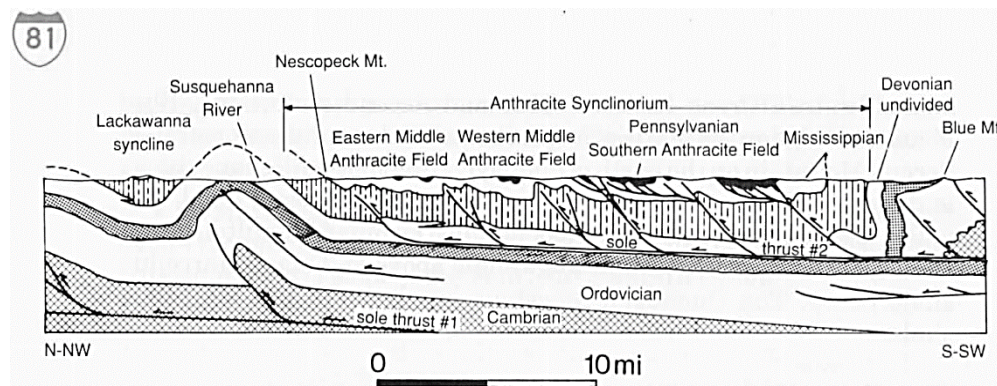


Figure 5: Geologic cross-section north-northeast from Blue Mountain near Hamburg through the Anthracite Synclinorium & Rte. 81 Corridor - Adapted from Socolow, A.A. 1980, Geologic Map of PA.

The geologic structure of the Southern Anthracite Coal Field is more complicated than that of any other portion of the Anthracite Region. This field also has greater columnar thickness and

number of mineable coal veins in its synclinal valleys, which are generally of less width to their proportion of depth. The dips of the limbs of the synclinals and anticlinals are generally much steeper than elsewhere making the basins long, narrow and deep (Ash 1949).

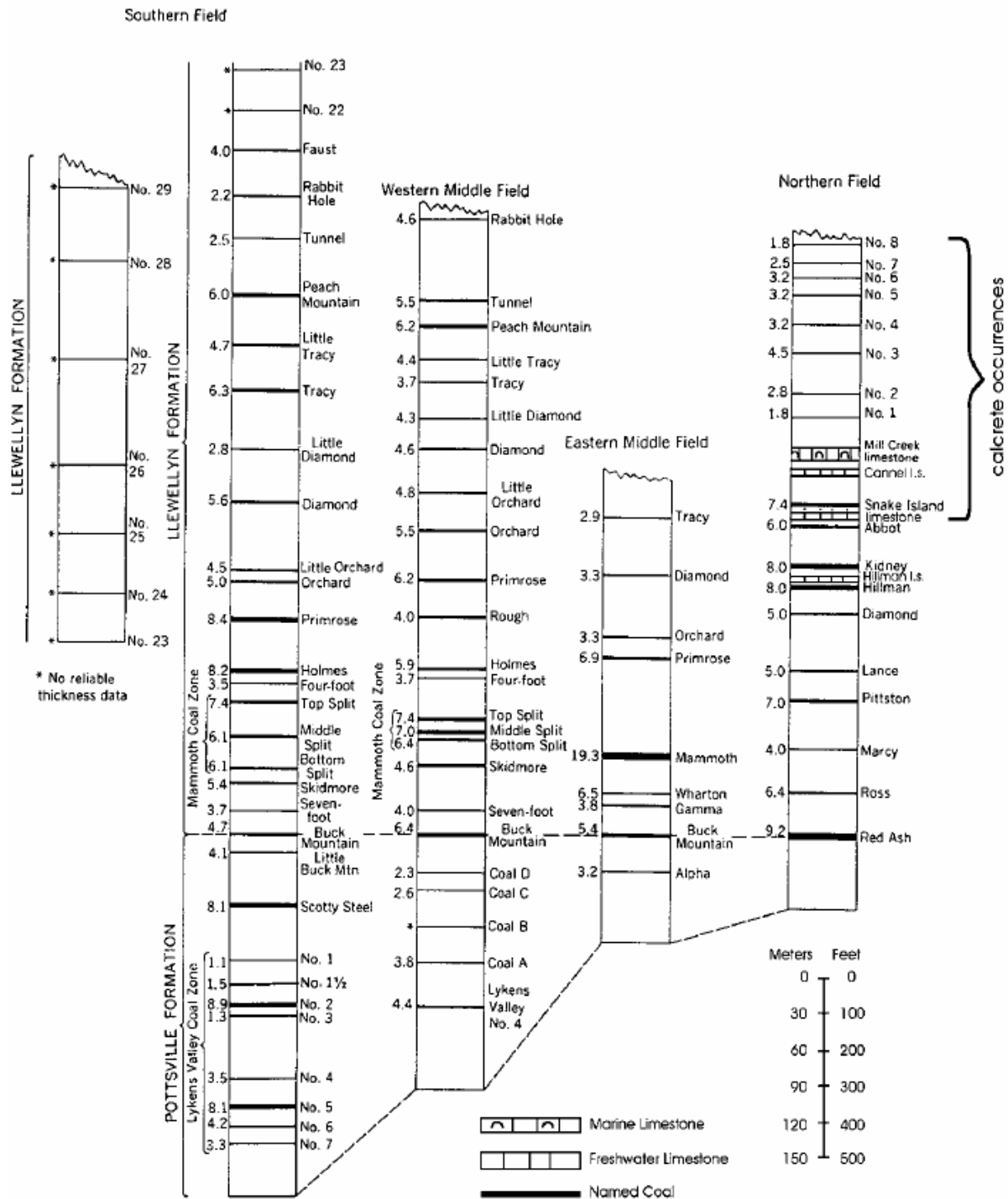


Figure 6: Generalized Columnar Sections Showing Names, Average Thickness of Coals (ft), and Intervals between Coal Beds in the PA Anthracite Coal Fields; primarily from (Wood, et al., 1986). Data from (Edmunds, et al., 1999), (Inners, 1997) have supplemented information on calcareous zones in the Northern Anthracite Coal Field

## 2.4 Previous Investigations

Previous mine pool studies were available as reference ranging from 1949 to 2011, detailed below:

- US Bureau of Mines (USBM) Mine Pool Reports - Starting with Technical Paper 727 in 1949, S.H. Ash and others had been recording and quantifying pools of water that were building up in underground mines in the Anthracite Region, complete with maps. The final of a series of 5 reports, USBM Bulletin 562 Mine Flood Prevention & Control Final Report in 1957 recommended building the Conowingo Tunnel to address the mine pool flooding issue. Additional reports in between went into further detail and recommendations on the condition of mine pools in the anthracite region (\* indicates Southern Field content):
  - USBM Bulletin 491 (Inundated Anthracite Reserves of the Eastern Middle Field 1950),
  - USBM Bulletin 494 (Buried Valley of the Susquehanna River 1950),
  - USBM Bulletin 508 (Acid Mine Drainage Problems in the Anthracite Region 1951)\*,
  - USBM Bulletin 517 (Barrier Pillars in the Lackawanna Basin 1952),
  - USBM Bulletin 518 (Surface Water Seepage in the Lackawanna Basin 1952),
  - USBM Bulletin 521 (Barrier Pillars in the Western Middle Coal Field 1953),
  - USBM Bulletin 526 (Barrier Pillars in the Southern Coal Field 1953)\*,
  - USBM Bulletin 531 (Mine Pumping Plants in the Anthracite Region 1953)\*,
  - USBM Bulletin 532 (Surface Water Seepage into Anthracite Mines Western Middle 1953),
  - USBM Bulletin 534 (Surface Water Seepage into Anthracite Mines Wyoming Basin 1953),
  - USBM Bulletin 538 (Barrier Pillars in the Wyoming Basin 1954),
  - USBM Bulletin 539 (Surface Water Seepage Anthracite Mines Southern Field 1954)\*.
- Office of Surface Mining (OSM) National Mine Map Repository (NMMR) - Several maps were available from OSM that showed estimated mine pool boundaries based on monitoring borehole elevations and staff knowledge of the condition of the underground mines ranging from the 1950s to the 1980s (the age of some maps were unknown).

- PA Department of Environmental Resources (DER) Operation Scarlift reports – Detail mine pool extents as they were known in the 1960's to 1970's (\* indicates Northern or Southern Field content)
  - SL 135-11-101.6 - Catawissa Creek
  - SL 135 - Jeansville Basin
  - SL 139 - Lackawanna River\*
  - SL 167 - Little Schuylkill\*
  - SL 173 - Mahanoy Creek
  - SL 181.4 - Mill Creek - Luzerne Co.\*
  - SL 181.3 - Nanticoke, Warrior & Solomon Creeks\*
  - SL 181.2 - Newport Creek\*
  - SL 135-10 - Quakake Tunnel
  - SL 112 - Rausch Creek\*
  - SL 113 - Shamokin Creek
  - SL 126-1 - Swatara Creek Part I\*
  - SL 126-2 - Swatara Creek Part II\*
  - SL 126-3 - Swatara Creek Part III\*
  - SL 25 - Wyoming Valley\*

PA Bureau of Forests and Waters Water Resources of the Schuylkill River Basin report by J.E. Beisecker et. al.- was used to fill in data gaps for mine pools, not already identified in previous reports, in the Heckscherville Valley in 1968.

- Surface Mine Permit (SMP) Cumulative Hydrologic Impact Assessment (CHIA) - maps produced by the PA Department of Environmental Protection (DEP) Pottsville District Mining Office (DMO) from the 1990's to the 2010's delineated mine pools and their impact on active mining operations.

- Mine Water Resources of the Anthracite Coal Fields of Eastern Pennsylvania Report by R.J. Hornberger and EPCAMR – report establishes mine pool boundaries in the Southern and Western Middle Anthracite Coal Fields and also estimates a range of volumes for the Western Middle using MODFLOW created in 2011.

### **3.0 MINE POOL MAPPING**

#### **3.1 Overview**

Several datasets related to abandoned mines in the Anthracite Region were available, either received by project partners through the data gathering process or already contained within EPCAMR's GIS Data Collection. In general there is an abundance of GIS data related to surface mine features, but not so when it came to underground mine feature layers. So in 2005, EPCAMR entered into an agreement with the Office of Surface Mining Technical & Innovative Professional Services (TIPS) to obtain software licenses such as ArcGIS, EarthVision and AutoCAD to start this technical work. TIPS provides tens of thousands of dollars' worth of software licenses annually to support the technical work of EPCAMR. In 2006 EPCAMR applied for a DEP Growing Greener grant to define mine pools in the Western Middle and Southern Anthracite Coal Fields with matching funding from the 319 Program and Foundation for PA Watersheds to begin to create data for the overall anthracite mine pool mapping initiative and gather existing datasets. Existing data layers used are discussed below:

##### Abandoned Mine Land Inventory System

Vector layers dealing with above ground abandoned mine features exist as a database created and maintained by the Pennsylvania Department of Environmental Protection Bureau of Abandoned Mine Reclamation (PA DEP BAMR) known as the Abandoned Mine Land Inventory System (AMLIS). This 3 part inventory identifies point features, polygon features and a third layer called the problem area which ties the points and polygon features together into one mine site. The point layer represents the location of mine features such as shafts and abandoned buildings. The polygon layer represents the area covered by features such as water filled strip pits and subsidence prone areas.

##### Abandoned Mine Discharges Layer

This layer shows where abandoned mine discharges emanate from the ground or create a large enough flow to be sampled. The original source of the data is from a USGS Water Resources Investigation Report 83-4274 by D. J. Growitz, L. A. Reed and M. M. Beard published in 1985 and updated in a USGS Water Resources Investigation Report 95-4243 by C. R. Wood published in 1996. This layer was developed to



showcase these USGS collections of locations and water quality of the anthracite discharges. Chemical and physical attributes were sampled several times from early 1960s to the late 1990s. Data represented within the attribute table is from the year 1975 when the most complete information is available, or averaged and interpolated when no data was present. With field verification, many of the discharge points are within acceptable deviation from their actual location, however some are as far off as 500 meters. Knowing that discharge locations can move over time with changes in underground hydrology or reclamation of the area, EPCAMR staff verified the location of data points based on aerial and topographic photo reconnaissance in ArcGIS and made changes when appropriate. Also, when needed, elevations were estimated based on location as compared to PA MAP LiDAR Elevation Data. The layer was updated by EPCAMR (2004-2005) to include additional sites identified in watershed assessment reports.

#### Borehole Data Layer

Southern and western middle borehole data was received from PA DEP BAMR's Wilkes-Barre Office. The western middle field information came with geographic reference (Latitude and Longitude) while the southern field data did not. EPCAMR staff extracted data and compared borehole locations in the U.S. Geological Survey Water Resources Investigation Report 85-4038. USGS staff verified both sets of borehole data based on their monitoring point database. This allowed them to assign locations to the boreholes in the southern fields.

#### Colliery Boundary Layers

Three colliery boundary layers were supplied by PA DEP Pottsville District Mining Office. One layer consisted of all the known collieries in the Anthracite Region, the other two contained only collieries in the southern and western middle coal fields respectively. There were several inconsistencies when the layers were compared. EPCAMR decided to use the colliery boundary layer that had the most coverage in all fields and update it based on boundaries found on mine maps.

Underground mine data for the Southern and Western Middle Fields was already produced for the Mine Water Resources of the Anthracite Coal Fields report published by EPCAMR in 2011.

### 3.2 Digitizing Published Maps

Several paper maps were scanned into digital format to portray underground mining features. These scanned raster images are often cumbersome to use in a mapping program such as ArcGIS because of their limited display properties and absence of a table to store information about individual attributes as

in vector data. EPCAMR staff georeferenced the raster maps and began creating individual sets of information from them. The process of transforming the raster information into vector data is called digitizing. Useful information contained in the tables and text of the reports was then added to the attribute tables of the individual vector layers.

Second PA Geologic Survey Maps (Chas. Ashburner) were specifically used in the Northern Field and the Nesquehoning Valley to digitize coal vein elevations for use in the Mine Pool Models. Coal Vein maps, especially in the southern field, contained extent of mining and coal vein contours for the Mammoth Vein, both were digitized using R2V (an automatic digitizing program that exports to both ArcGIS and EarthVision formats). Some maps contained drill hole logs that helped in determining regional coal vein thicknesses. The surface maps were georeferenced to help orient cross sections in ArcGIS. The cross sections were later “heads-up” digitized. “Heads-up” digitizing is manual method of tracing a mouse over features displayed on a computer monitor, used as a method of vectorizing raster data. This set of maps represents extent of mining by the 1890’s and future minable coal. Due to the age of the maps, data was used only when no other data existed, since approximate data is better than no data when using the EarthVision 3D modeler.

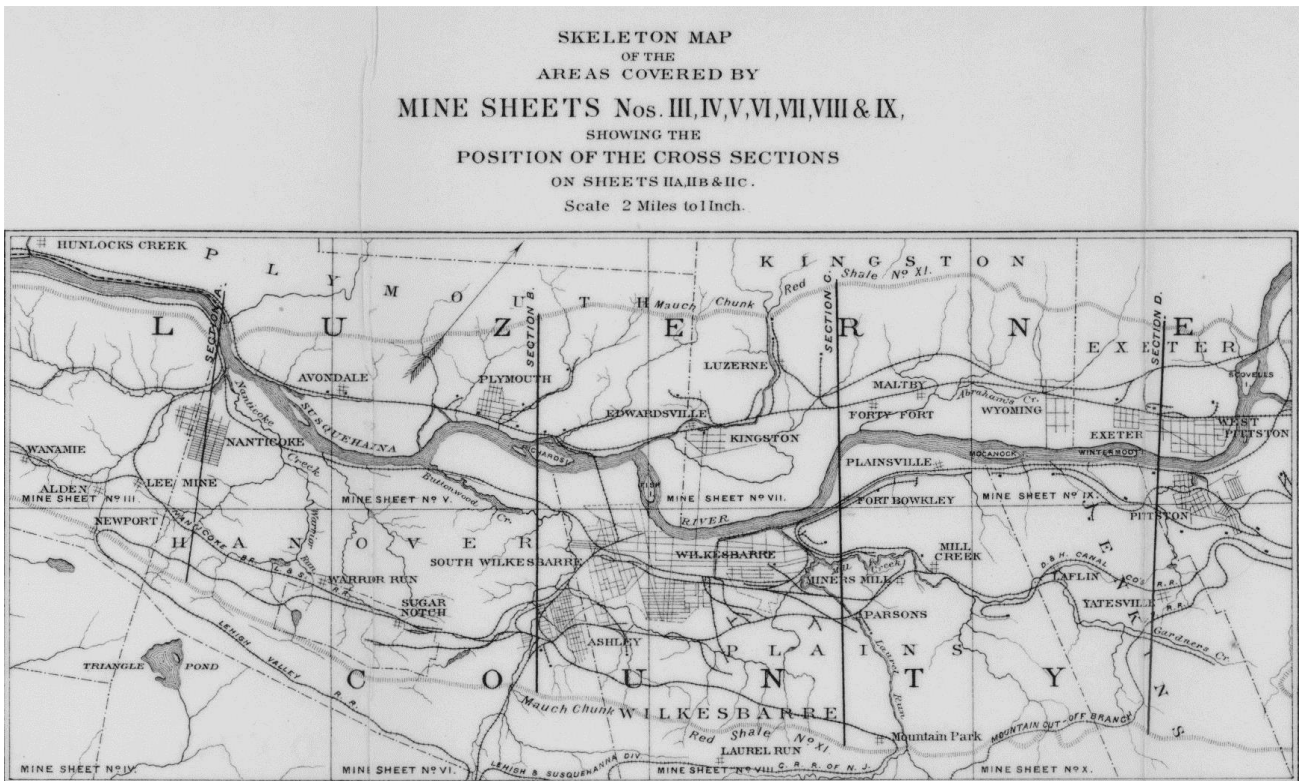


Figure 7: Wyoming Valley Extent of Coal Measures and Coal Cross Sections from the Second PA Geologic Survey

US Bureau of Mines Mine Pool Maps (S.H. Ash) were georeferenced in ArcGIS. Mine pools, barrier pillars and other features were digitized in ArcGIS from these maps to show historic mine pool boundaries,

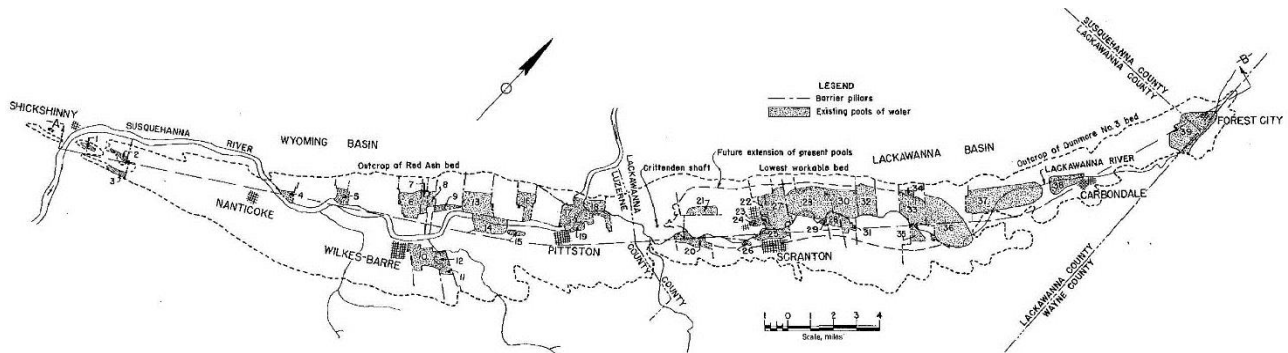


Figure 8: Northern Anthracite Field Mine Pool Map from U.S. Bureau of Mines Technical Paper 727 (Aka. "Ash Report")

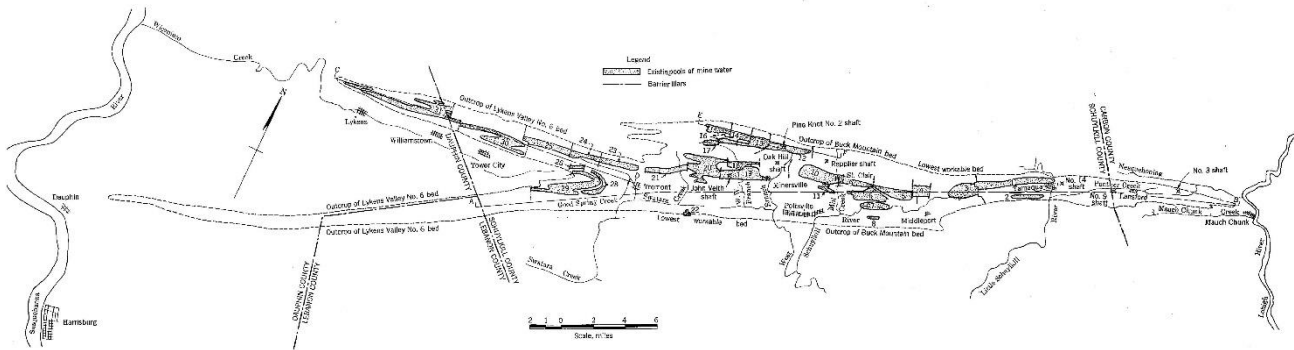


Figure 9: Southern Anthracite Field Mine Pool Map from U.S. Bureau of Mines Technical Paper 727 (Aka. "Ash Report")

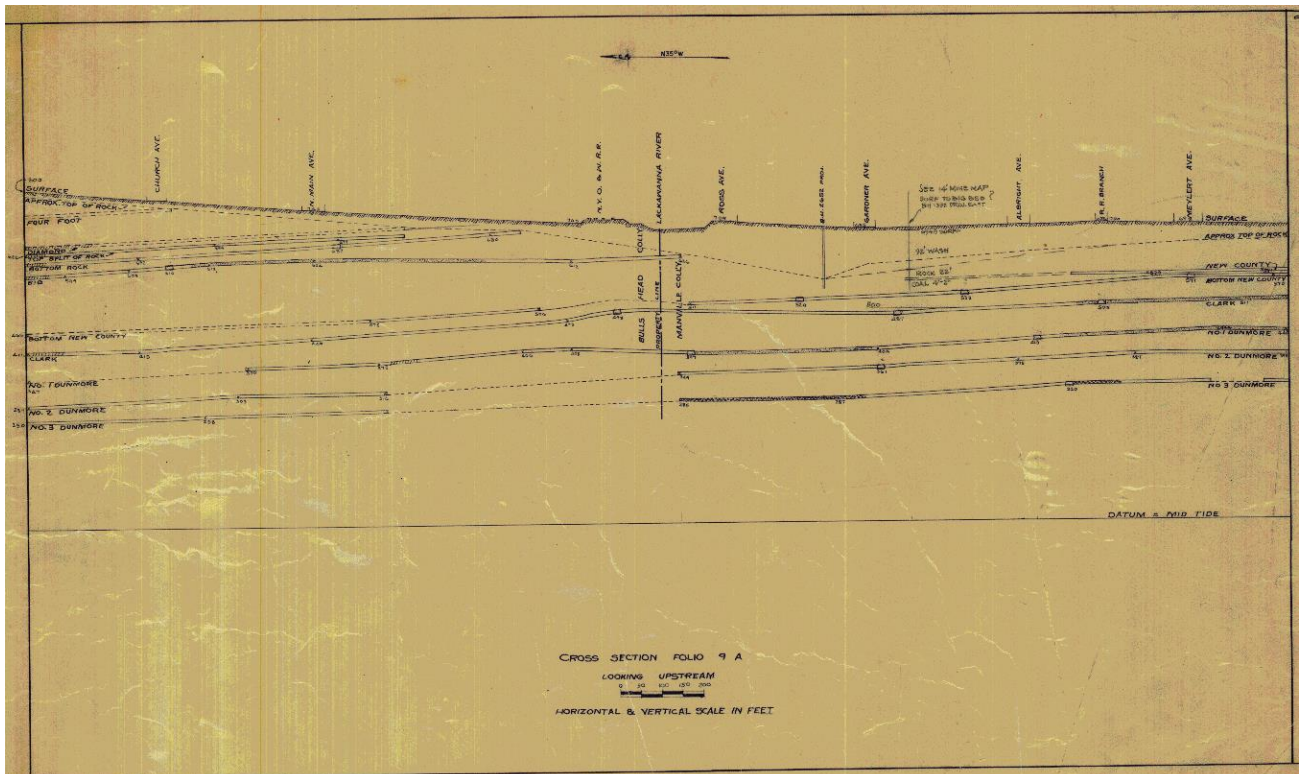


Figure 10: Cross Section of Coal Veins from OSM Mine Map Folio Collection 9A

statistics about mine pool features and existing mine pool volume information. Since much of the underground mine industry was still pumping water to mine lower, the mine pools are under sized in comparison to their abandoned states. These reports represent a snapshot of what was known about underground mine pools from the late 1940's - 1950's.

Office of Surface Mining (OSM) National Mine Map Repository (NMMR) maps were used in specific circumstances when historic mine pools were not represented on other maps (i.e. Neumeister Drift portion of the Glendower Mine). OSM Mine Map Folios are a subset of this collection with good coverage of the Northern and Western Middle Anthracite Coal Fields. OSM Folio cross sections were specifically used in the Lackawanna Basin to digitize coal vein elevations. This information was mashed-up with Ashburner cross sections to create the Upper and Lower Lackawanna Mine Pool Models. The surface maps were georeferenced to help orient cross sections in ArcGIS, which were later "heads-up" digitized in EarthVison. The maps range from the early to late 1900's and represent extent of mining in a specific mine. Most underground mining in general was completed by the 1950's in the Anthracite Region.

PA DEP Mine Map Collections were georeferenced and features digitized in ArcGIS when maps were not available from the OSM NMMR. Generally OSM Mine Map Folio coverage in the Eastern Middle and

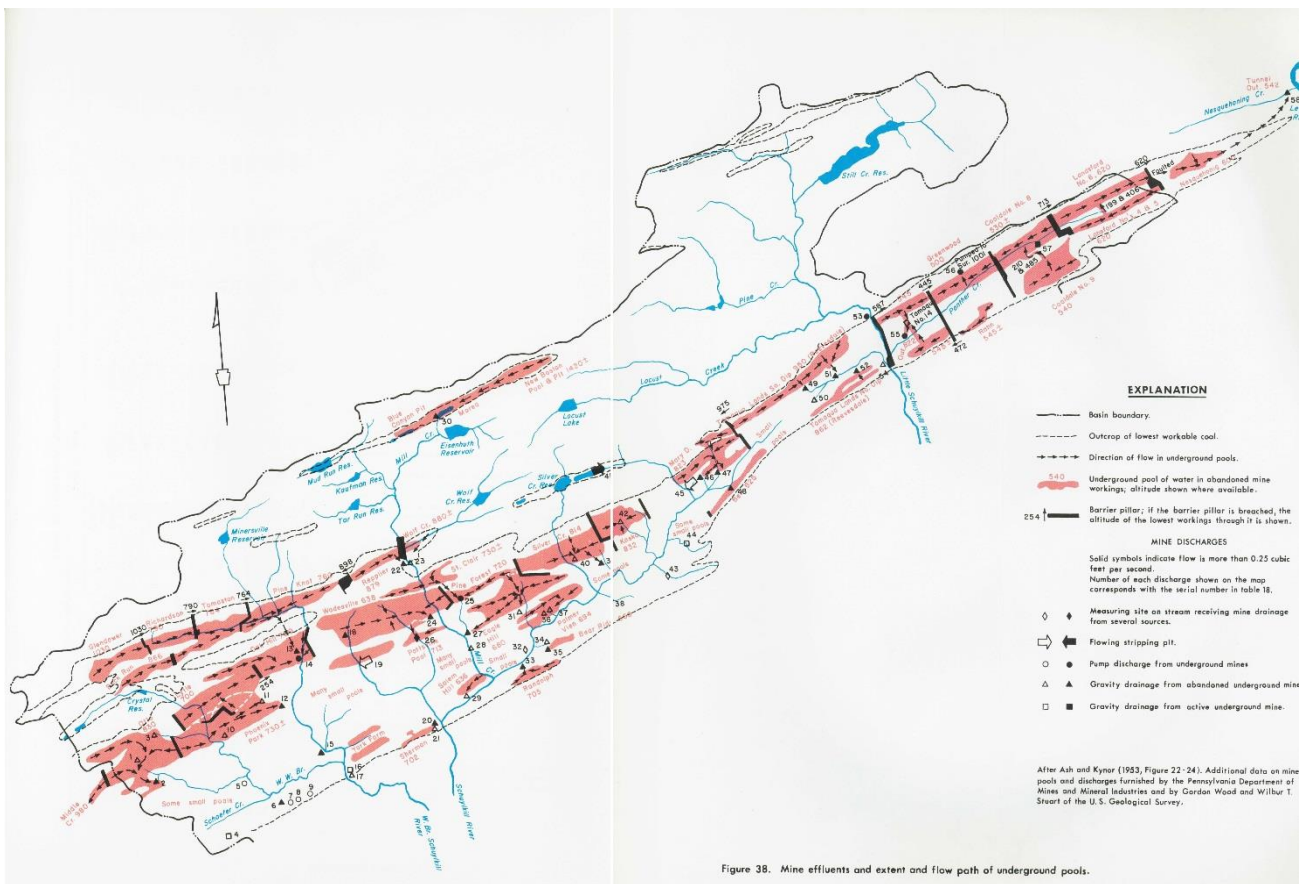


Figure 38. Mine effluents and extent and flow path of underground pools.

Figure 11: Pennsylvania Bureau of Forests and Waters Mine Pools Map (Beisecker 1968). Map showing mine pool extents, pool flow direction, barrier pillars and discharges in the northern portion of the Southern Coal Field. Larger version in Appendices.

Southern Fields is less than 50%. Like the OSM Folios, these maps also were missing legends and required interpretation of symbols. Pottsville District Mining Office (DMO) Deep Mine Safety (DMS) and Wilkes-Barre Bureau of Abandoned Mine Reclamation (BAMR) had collections of miscellaneous maps and reports that helped fill in gaps where digitized data would be missing (all digitized data is sourced). For example, the Water Resources of the Schuylkill River Basin report (Beisecker 1968) was used to fill in data gaps for mine pools in the Heckscherville Valley. Several Surface Mine Permit (SMP) Cumulative Hydrologic Impact Assessment (CHIA) maps produced by the Pottsville DMO were available for review and digitization in the Southern Field as well.

U.S. Geologic Survey Coal (C) and Miscellaneous Investigation (I) Series Maps were georeferenced in ArcGIS. Several features were digitized from the Coal maps including drainage tunnels, coal vein outcrops, coal vein contours, faults, sheer zones, barrier pillars, mine boundaries, mine entries, mine drainage points, anticlines and synclines. All of these were available for previous investigations in the Western Middle Anthracite Coal Field, but only coal vein outcrops, mine boundaries, mine entries, mine drainage points, faults, anticlines and synclines were available in the I-Series Maps for the Southern Field. Some maps contained drill hole logs and helped in determining regional coal vein thicknesses. Cross sections were available with I-Series maps and were digitized in EarthVison. These I-Series maps were used for a majority of raw data generation for the 3D Mine Pool Models for the Southern Field. Additional I-Series maps and cross sections were available for a portion of the Wyoming Valley. Water Resource Reports (WRR) were also available from USGS delineating mine pools in the Lackawanna (Hollowell 1975) and discharges throughout the whole Anthracite Region (Wood 1996). These maps and cross sections represent what was known of mining geology from the 1960's to the 1970's.

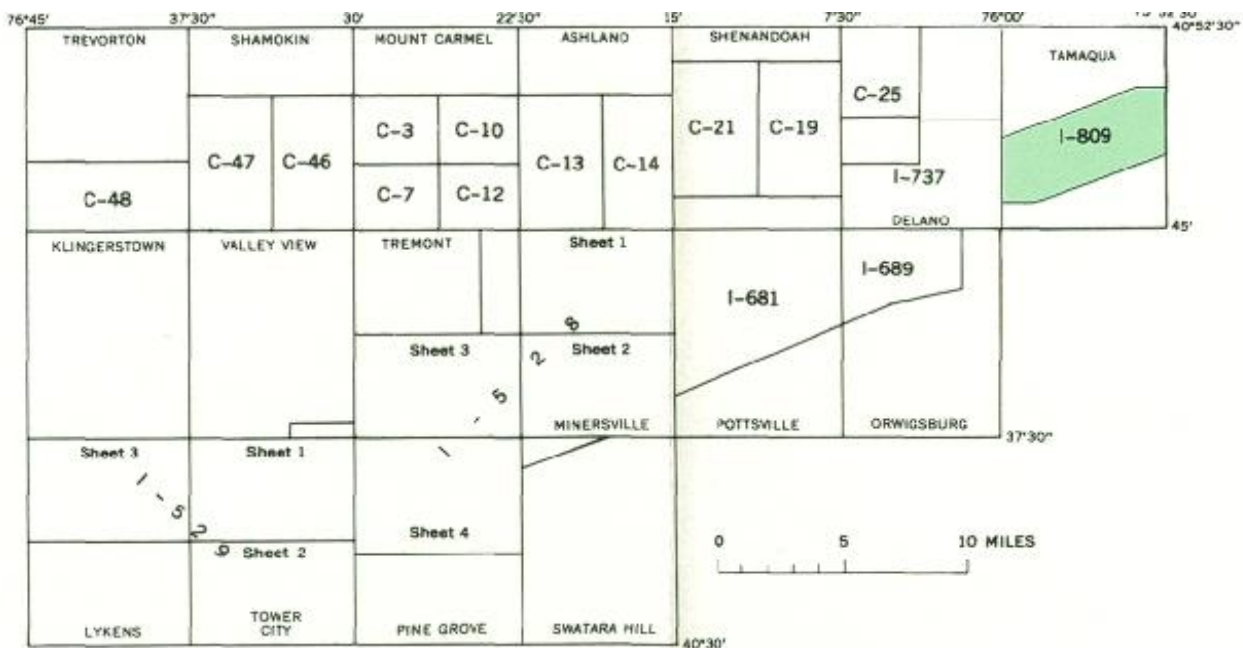


Figure 12: Index Map showing the coverage of C-Series and I-Series USGS Maps for the Western Middle and Southern Coal Fields



PA Department of Environmental Resources (DER) Operation Scarlift reports were georeferenced in ArcGIS. Mine Pools, Barrier Pillars, flow directions and other features were digitized in ArcGIS from these maps to show historic mine pool boundaries and existing information. These reports represent a snapshot of underground mining from the mid 1970's.

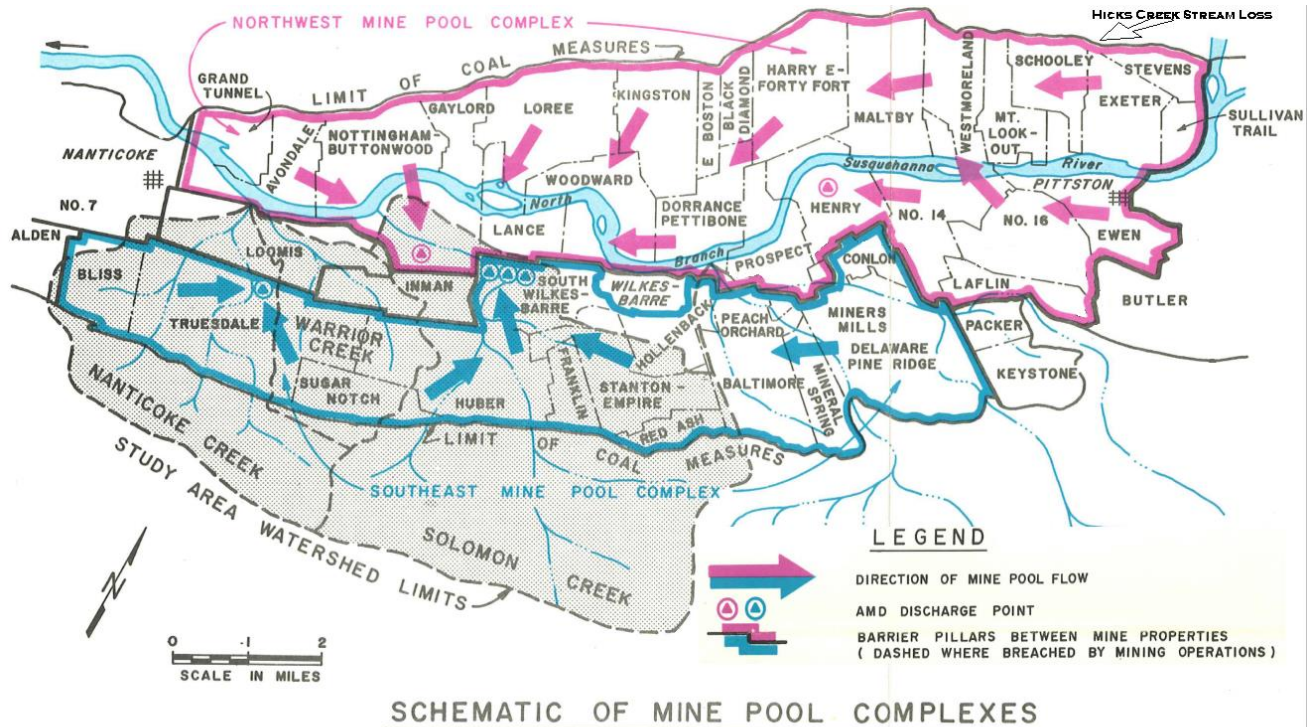


Figure 14: Wyoming Valley Mine Pool Extents, Direction of Pool Flow and Discharge Points from Scarlift Report 181-3

### 3.3 Field Work

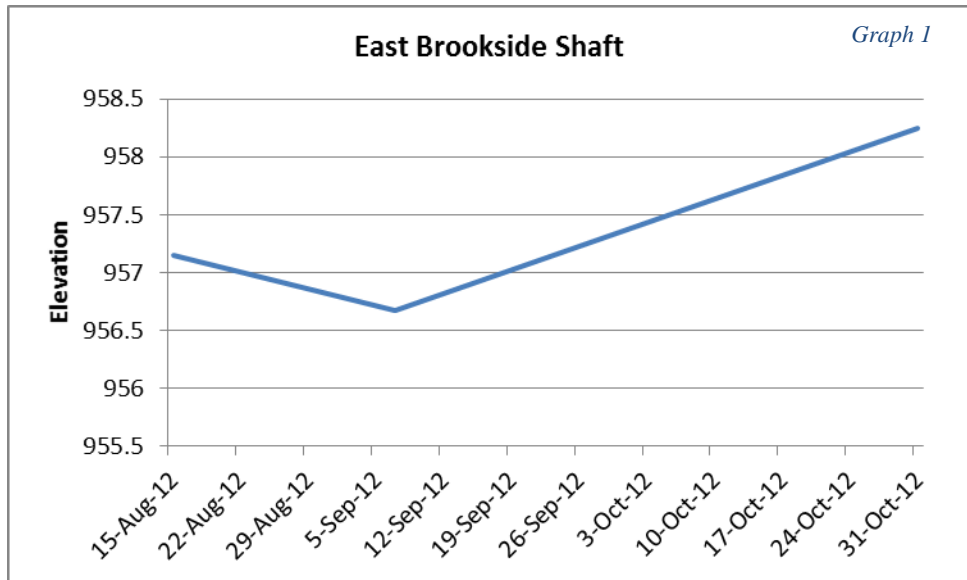
The PA DEP's Bureau of Abandoned Mine Reclamation, Wilkes-Barre Office, has maintained a sporadic program of measuring mine pool water levels for nearly 20 years. At times the monitoring was monthly, quarterly and yearly. They conducted measurements at 30 boreholes throughout the Western Middle Coal Field, 40 in the Northern Coal Field and 15 shaft locations for a portion of the Southern Coal Field. The surface and water elevation data associated with each of the Southern Anthracite Coal Field shafts are detailed in the Mine Water Resources of the Anthracite Coal Fields Report Part 4 Chapter 2 published by EPCAMR in 2011.

EPCAMR staff gathered mine pool elevations in the field using a Solonist or Heron Dipper-T water level meter. Regardless of the brand name, the devices work similar in that it beeps when water is sensed and a reading in feet is taken from the tape. To get the mine pool water elevation, the reading is subtracted

from the surface elevation. The average elevations were used to calibrate the model in the specific mine pool to calculate the volume. An intensive monthly monitoring program was conducted for the Northern Anthracite Field for this study, but only sampled the East Brookside Shaft in the Southern Field.

### East Brookside Shaft and Drill Hole

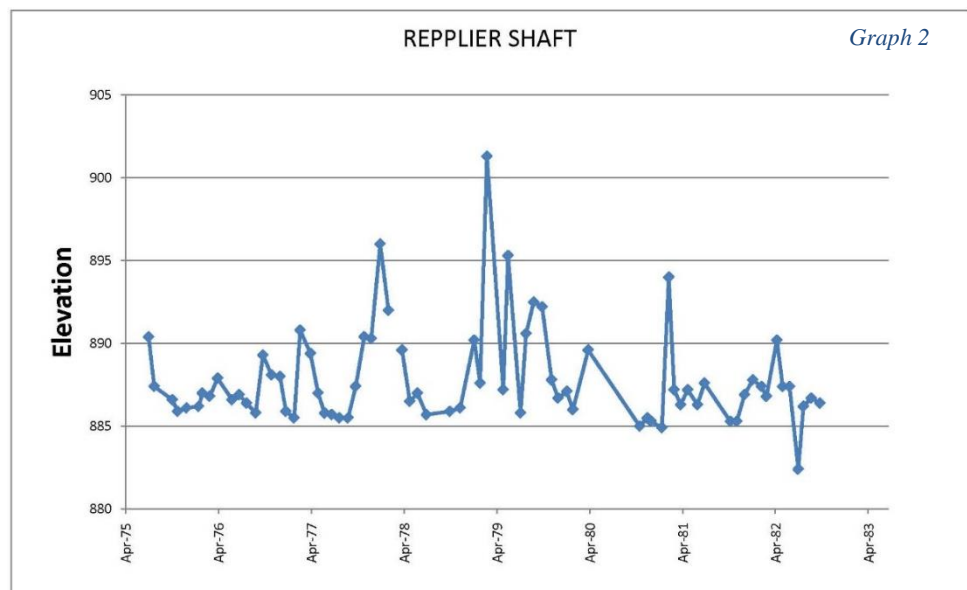
The East Brookside Shaft is located along a switchback railroad grade above Reinertown and is sunk 1000 feet into the south side of the Brookside Mine. The surface elevation was determined to be 1410 feet above mean sea level by LiDAR. The shaft was found in the field



and monitored 3 times during this investigation and the height ranged between 956.67 feet and 958.25 feet with an average of 957 feet, as shown in Graph 1. The Drill Hole is on the north side of the Brookside mine pool near the Valley View Tunnel. The surface elevation was determined to be approximately 1400 feet above mean sea level by LiDAR, but the drill hole could not be found in the field.

### Replier Shaft

The Replier Shaft was monitored for water levels by the PA DEP. The surface elevation is 1095'. The maximum water elevation was 901.3' in March 1979. The minimum water elevation was 882.4' in July 1982. The average water elevation in the shaft was 887.79'. The shaft water elevation range fluctuated by only 19', as shown in Graph 2.





“New” Pine Knot Borehole (See Appendix I)

The Pine Knot Borehole was drilled and monitored for water levels by the PA DEP Pottsville District Mining Office and U.S. Geologic Survey (USGS) from January 2012 to May 2013. The surface elevation is 958.25 feet. The maximum was 766.81 feet in May 2012 and the minimum was 763.39 feet in April 2012. The average water elevation was 764.15 feet. The table shows The Pine Knot Mine Pool elevation as measured in feet, the Pine Knot Discharge in cubic feet per second and the West Branch Schuylkill River above the Pine Knot Discharge in cubic feet per second.

Lackawanna Valley Boreholes (See Appendix J)

The Forest City #101 Borehole was sampled once during this investigation and has sporadic sampling data back to 1994. This borehole is quite a distance from the others, as it is in the very tip of the Northern Anthracite Field and probably explains the infrequent sampling data. It ranges historically between 1405' and 1435'. More recently it was sampled closer to 1435'. The discharge to the surface is at 1382', which indicates a barrier of some sort that impounds water in the northern portion of the mine.

The Jermyn #103 Borehole was recently day-lighted by EPCAMR and PA Tectonics staff in February 2012 as a part of this study to obtain water level information in the Jermyn Mine. Historic water levels were available for this borehole ranging between 919' and 921'. More recent data puts the water level at 923' to 924'. There was a Carbondale #102 Borehole portrayed on maps from the Office of Surface Mining and there was a “Fern Street” Borehole mentioned in the AMLIS Inventory and by PA DEP Staff. Both boreholes would indicate the water level of the Carbondale Mine pool, which overflows to the Jermyn, but during field investigation this borehole could not be located.

The Winton #105 Borehole was also recently day-lighted by EPCAMR and PA Tectonics staff in February 2012 to obtain water level information in the Gravity Slope Mine pool at around 827' as measured. The discharge is to the Gravity Slope Discharge. The Lackawanna Mine is isolated hydrologically from surrounding mines and has its own discharge. It also historically had a monitoring borehole that is now paved over. The mine pool elevation for this pool was taken from the elevation of the discharge instead.

The Scranton Metropolitan Mine Pool has several steps in elevation from the Old Forge to the Peck Shaft and Sterrick Boreholes. The Sterrick #107 and Peck Shaft #106A boreholes range from 740' to 800', which represents some of the higher elevations in the mine. The Cayuga #117 also jumps to this range in recent sampling events, but water was often heard running in the borehole, indicating an influence of water from a higher vein (a similar effect is noticed in the Number 9 #49 borehole). This could give a false reading with the water level meter. The Miles #110 and Olyphant #113A and #109 Boreholes lie in a

range between 700' and 740'. The rest of the boreholes, Underwood #116 to Sibley #127 all lay within a range between 580' and 660'. These include borehole numbers 116, 117, 121, 122, 123, 124, 127 and 51. The Central #130 Borehole is on the other side of the Moosic Saddle (discharge to the Duryea Breach) and holds a mine pool between 560' to 580'. Although not initially considered a Lackawanna Valley Borehole, the Number 9 #49 borehole is tapped into the same mine pool which fluctuates between 550' to 560' and discharges at the Duryea Breach in the Seneca Mine.

Wyoming Valley Boreholes (See Appendix K)

The Northwestern and Southeastern Mine pools lie between 520' and 540' as portrayed by borehole numbers: 3, 5, 131, 46, 135, 1, 45, 44, 43, 41, 136, 40, 132, 39, 134, 37, 36, 11 and 133. The Stanton #5 Borehole interestingly enough showed an affinity with the Askam and Sugar Notch mine pool at 580', but more recently within the study period, dropped to an affinity with the larger southeastern mine pool at 530'. The reason is unknown, but possibly due to a barrier pillar breach. Also the Delaware #3 borehole, in the southeastern pool, fluctuated during this time from 560' to 540'.

The Sugar Notch #7 and Askam #8 Boreholes holds a mine pool between 560' and 580'. The discharge dries up in the late summer when precipitation levels decrease. It is most likely connected to another discharge, the South Wilkes-Barre Boreholes Discharge.

The Alden #137 Borehole shows a mine pool between 750' to 780'. This pool overflows to the Susquehanna #7 Mine. The elevation is portrayed by the #34 borehole which fluctuates from 540' to 545' and discharges to the #2 Airshaft (Honey Pot) discharge.

The Wanamie #19 Borehole shows a mine pool between 580' to 620'. The pool discharges at a large stripping pit to form a 20 acre lake of AMD, locally known as Newport Lake. The lake discharges to Newport Creek.

The Glen Lyon Borehole discharges at 663', but drops to 630' at times as measured. It is most likely connected to another discharge, most likely the Newport Lake Discharge.

The EPCAMR Staff have found that several boreholes and shafts have become inaccessible over time whether, paved over with macadam by local municipal street departments or backfilled. EPCAMR believes that there is a need for an educational awareness campaign directed towards municipal officials to keep them apprised of the importance of not covering these Commonwealth-owned monitoring stations. Monitoring accessibility to EPCAMR and State abandoned mine reclamation staff are not only important to this project, but to the local communities as well for their value in determining the fluctuating rise and fall in the depth of the underground mine pool water elevations for future warnings related to flooding

possibilities and redevelopment use of the mine pool water as a commodity as opposed to a dormant underground pollutant pool (See Appendix L – Northern Field Borehole Awareness Campaign Tables).

In instances where no borehole elevations were available in a given mine pool, discharge elevations were used instead to calibrate the model for volume calculations. It would be better to have a borehole in instances where discharges are under pressure, unlike a gravity drain, the elevation could be interpreted incorrectly.

### 3.4 Data Layer Creation and Updates

In summary, this collection is a representation of underground abandoned mine features and may be used in conjunction with PA DEP BAMR's AMLIS Database, a collection of surface abandoned mine features. It is generally difficult to picture features that you cannot see under the ground, but thinking of them as surface water features the layers are akin to Watersheds & Lakes, Dams, Outlets, Streams & Currents, respectively. The files are in the Universal Transverse Mercator Zone 18 North (UTM) projection with a horizontal datum of North American Datum 1927 (NAD 27) and a vertical datum of National Geographic Vertical Datum 1929 (NGVD 1929). The layers are enumerated below:

#### Mine Pool Layers

There were 163 mine pools and hydrogeologic basins digitized via ArcGIS in the Southern and Western Middle Fields in the layer for the Mine Water Resources of the Anthracite Coal Fields report in 2011. 112 of these are separate pools of water that still exist in mine workings; most of these pools were drawn directly from the Bureau of Mines Reports. The other 51 are areas that drain directly to a mine pool or an above ground outlet (ex. drainage tunnel or borehole). Some drainage areas and mine pools can have one or many associated above ground outlets. For example, the Packer #5 discharge is the main drain for several mines in the Upper Mahanoy Creek Watershed, but there are several other seeps and outlets in different locations at similar elevation where water from the mine pool leaks out, especially during seasonal and high flow events. Connected drainage basins are also referred to as multi-colliery hydrogeologic units.

Mine pools and hydrogeologic basins were digitized for the Northern Field in this study from georeferenced U. S. Bureau of Mines, PA DER Operation Scarlift, PA DEP Cumulative Hydrologic Impact Assessment (CHIA) and other various mine studies mentioned above. See Appendix E & G, respectively, for maps of the Lackawanna and Wyoming Valleys. Southern Field maps are available in Appendix A & C, respectively for Rausch Creek and Heckscherville Valleys.

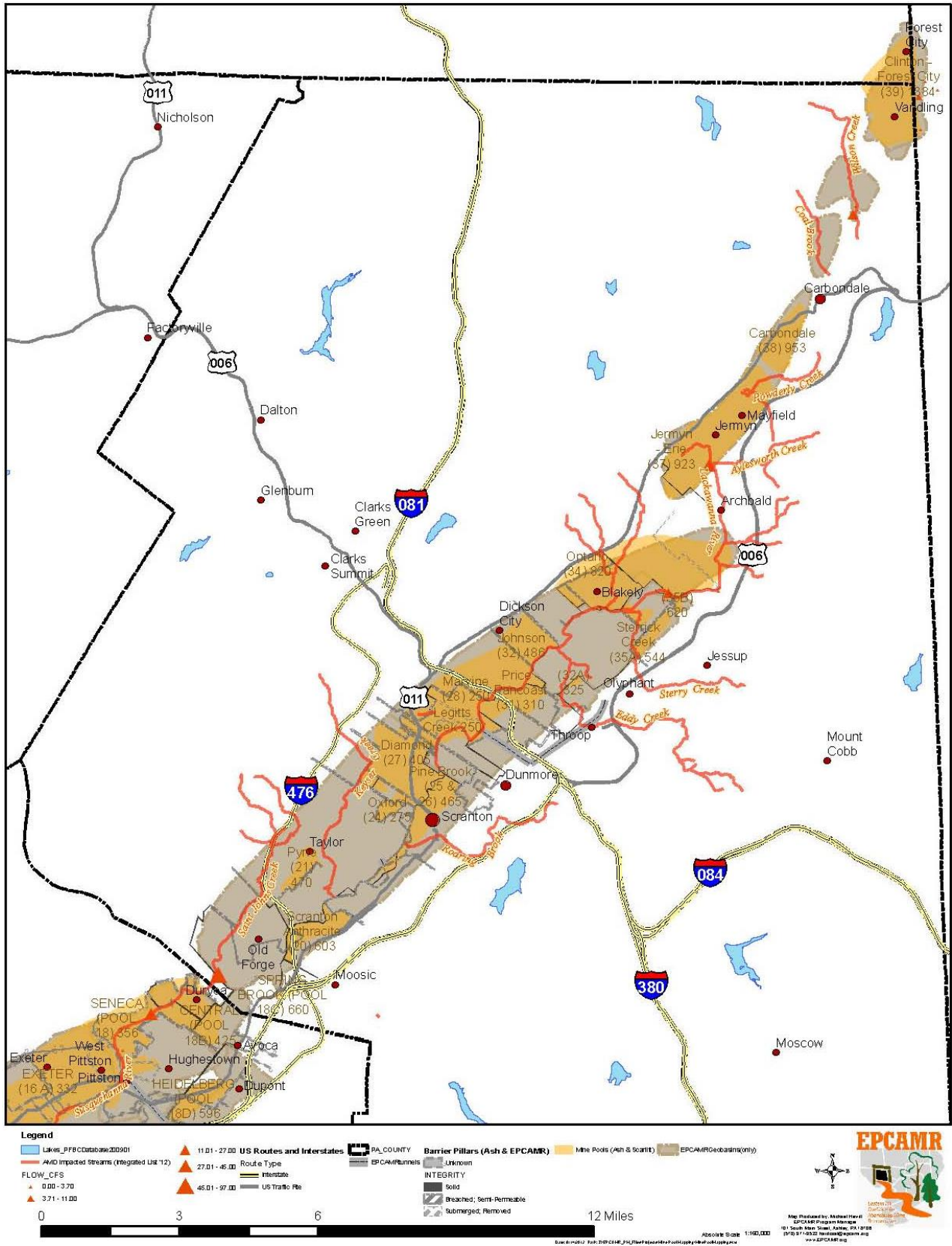


Figure 15: Example of Underground Mine Pool layers created for this report. Orange=Ash Mine Pool Extents, Brown=EPCAMR Mine Pool Extents.

### Raw 3-D Data Processing

I-Series maps were used for the majority of raw data generation for the 3D Mine Pool Models for the Southern Field. Additional I-Series maps and cross sections were available for a portion of the Wyoming Valley, which were mashed-up with Second Geologic Survey “Ashburner” cross sections to build the Wyoming Valley Mine Pool Model. Original coal mine maps and cross sections were used in the Lackawanna Valley along with Second Geologic Survey “Ashburner” cross sections to cover most data gaps in the Lackawanna Mine Pool Model.

Raw scattered data was digitized in two different methods. Both methods start with a georeferenced surface maps which contains lines of section. These lines were digitized in ArcGIS and later used to orient cross sections. Initially cross sections were “heads-up” digitized in R2V and imported with lines of section in to EarthVision using two manually coded command line scripts. Later a workflow was constructed to digitize directly in EarthVision using a 4DVX method of draping (created by Dynamic Graphics, Inc. the makers of EarthVision for this type of work). In the latter method, the line of section was imported into EarthVision as a traverse file and the cross section image was proportioned along the line of section traverse curtain. Both methods produce accurate X, Y and Z scattered data point values, but the “heads-up” digitizing method is less time consuming. Individual vein and fault data is culled from all the cross sections and separated into datasets using a text editor then modified to add names and vein thickness data. Thickness data was taken from borehole logs and barrier pillar reports.

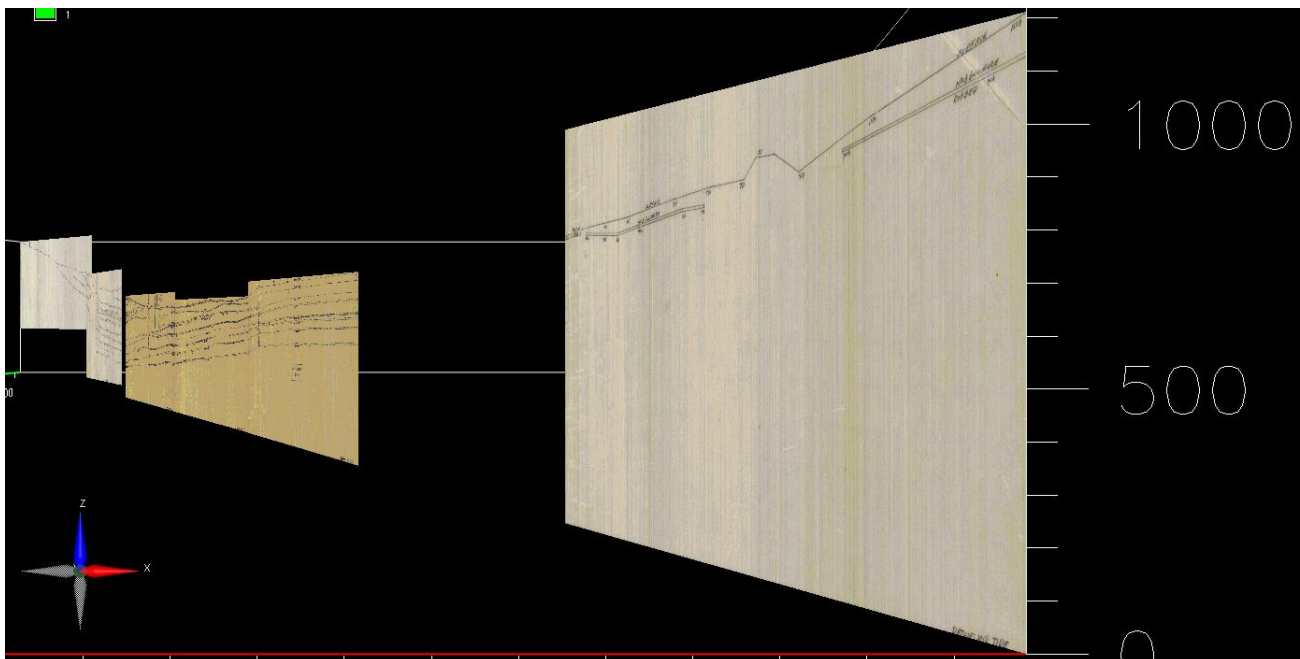


Figure 16: View of “Heads Up” Digitizing with 4DVX files in action. The raw data is digitized on the surface of the image. X, Y & Z coordinates are automatically put into the database in the digitizing process. Data and resulting grids can also be spot checked for accuracy

Using the original coal mine maps and cross sections for the Lackawanna Valley took considerably more time to digitize than expected since the maps were broken up in grid formats and/or separate colliery boundaries. All these separate sets were georeferenced and digitized separately using the original time consuming digitizing method. In some cases it took a dozen maps and cross sections to cross the valley when other sources combined this information into one map/cross section set. It could be argued that the original mine map data produces more perfect raw data on a smaller scale than combined sources that could introduce error. That error, however, is negligible in the regional datasets and models produced by this study.

Once the digitizing and modification is completed, the raw data is fed into the EarthVision WorkFlow Manager modeling tool. The surface, faults, and individual vein tops and bottoms are added to the stratigraphic sequencer. Smoothing factor is set to honor the data 95% of the time and curves are dampened by 1% to remove outlying data points. Clipping polygons are used to limit the area where the grids may form. The output of the tool is a 3D stratigraphic horizon model. The model is made up of several true 3D thickness grid layered representing rock and coal veins on top of each other. This model can be manipulated in the EarthVision 3D Viewer. Simulated layers of rock can be turned off and the grid can be sliced (limiting the view of X, Y and Z) to model only the veins of coal as seen in figures in this section above. Mine pool volumes can then be calculated with the instant volumetrics tool in EarthVision.

### 3.5 3-Dimensional Mine Pool Mapping

3-Dimensional Mine Pool Models and volumes were calculated in two geographic locations within the Southern Anthracite Coal field and for the entire Northern Anthracite Coal Field including the Lackawanna and Wyoming Valleys. Average borehole readings will be displayed in parenthesis beside the mine name.

Southern Anthracite Coal Field:

Rausch Creek Valley (Donaldson & Brookside Basins)

In the north western “fishtail” portion of the Southern Anthracite Coal Field, the Brookside Colliery and the Valley View Colliery form a multi-colliery hydrologic unit. The Brookside Colliery appears to have more extensive workings within Big Lick Mountain, exclusively in the Lykens Valley Veins, than the Valley View Colliery. The mine pool is bound by barrier pillars to the east and west which are intact and isolate drainage from neighboring mines. The East Brookside shaft averaged 957’. However, the mine drainage from these two collieries emanates from the Valley View Tunnel (906’), which is tapped through the Valley View Mine into Brookside Colliery workings.

The Tower City Mine exist above the Brookside Mine in the veins Llewellyn Formation (above the Lykens Valley Formation) and are not connected to the veins in Brookside Mine. The pool is small due to the steeply dipping veins and drainage is bound to the east by a staggered barrier pillar. These veins are drained by the Tower City Tunnel at ~1250’. Further east of the staggered barrier pillar is the neighboring

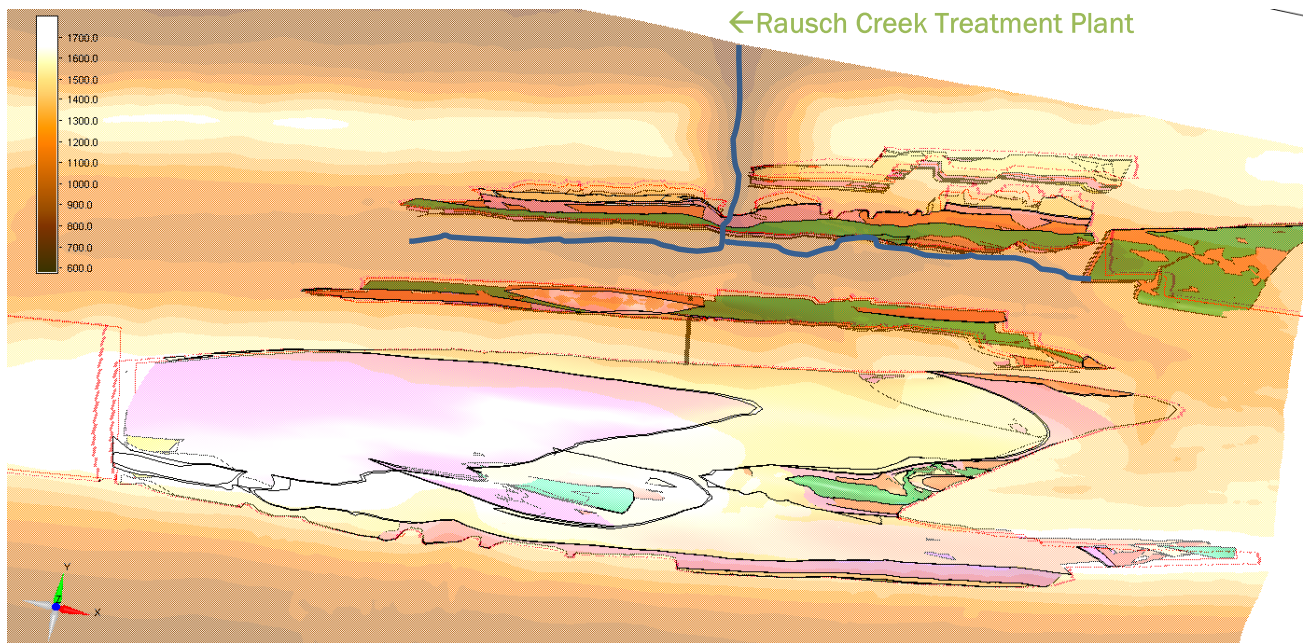


Figure 17: EarthVision Model of Underground Mines contributing to mine drainage in the Rausch Creek Valley. Shades of brown represent the surface. Other colors represent individual coal veins. Red lines indicate colliery boundaries. Blue line indicates the Rausch Creek. Thick black line indicates the Valley View tunnel.

Porter Tunnel Mine. A mine pool boundary cannot be drawn for the Porter Tunnel drainage area because there is insufficient mine map coverage in the area to make a determination, however geological barriers (ex. anticlinal ridges, faults and thickness between strata) exist to separate the drainage as depicted on surrounding maps.

The volume of drainage exiting the Porter Tunnel ranges from 700 to 7,000 gpm denoting a “flashy” pool. Typically a flashy pool has a large drainage area that collects precipitation/surface water, but a small pool and little groundwater influence. The discharge from a flashy pool is much smaller in magnitude (or even dries up) when precipitation has been low. Flashy pools can also be influenced by inter-mine overflow of neighboring pools. Volumes for these upper mine pools were not calculated.

On the opposite side of the Rausch Creek Valley in Bear Mountain, the Markson Mines constitute their own hydrologic unit and discharge through the Markson Columnway (861’). Mines in the Lykens Valley seams (Pottsville Formation) are mostly separate, drainage wise, from the mined seams in the Llewellyn Formation and therefore have their own small seasonal discharges at a higher elevation. See Appendix B for a 2D representation of current mine pool boundaries in the Rausch Creek Valley based off this 3D model.

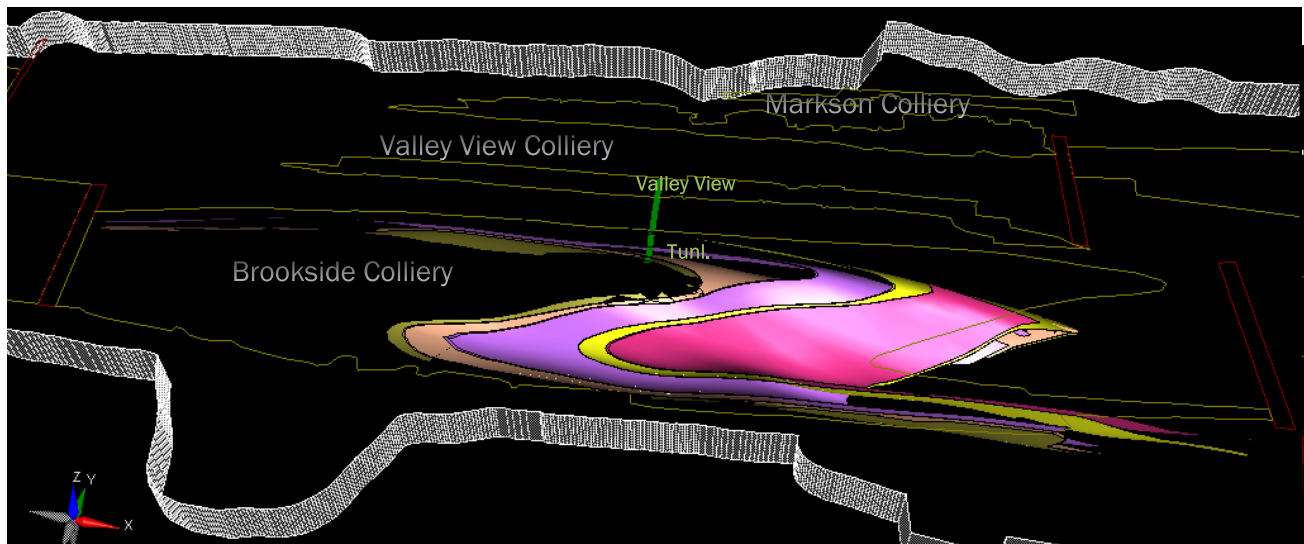


Figure 19: EarthVision Model of the Brookside Mine at 906 feet. Mine pool exists in the Lykens Valley veins only. Tan lines indicate colliery boundaries. Red lines indicate barrier pillars. Green line indicates drainage tunnel. 3D Grid: Dk. Pink=Lykens Valley #2, Yellow=Lykens Valley #3, Purple=Lykens Valley #4, Beige=Lykens Valley #5, Tan=Lykens Valley #6

Figure 18: EarthVision Model of the Markson Mines at 861 feet and Valley View Mines at 906 feet. View above is at a 45° angle. Below is a bird's eye view. Tan lines indicate colliery boundaries. Red lines indicate barrier pillars. Green line indicates drainage tunnel. Purple dots indicate historic discharge areas, not all are still discharging. 3D Grids: Blue=Top Mammoth, Fuchsia=Btm. Mammoth, Orange=Skidmore, Lt. Pink=Seven Ft., Dk. Pink=Lykens Valley #2, Yellow=Lykens Valley #3, Purple=Lykens Valley #4, Beige=Lykens Valley #5, Tan=Lykens Valley #6



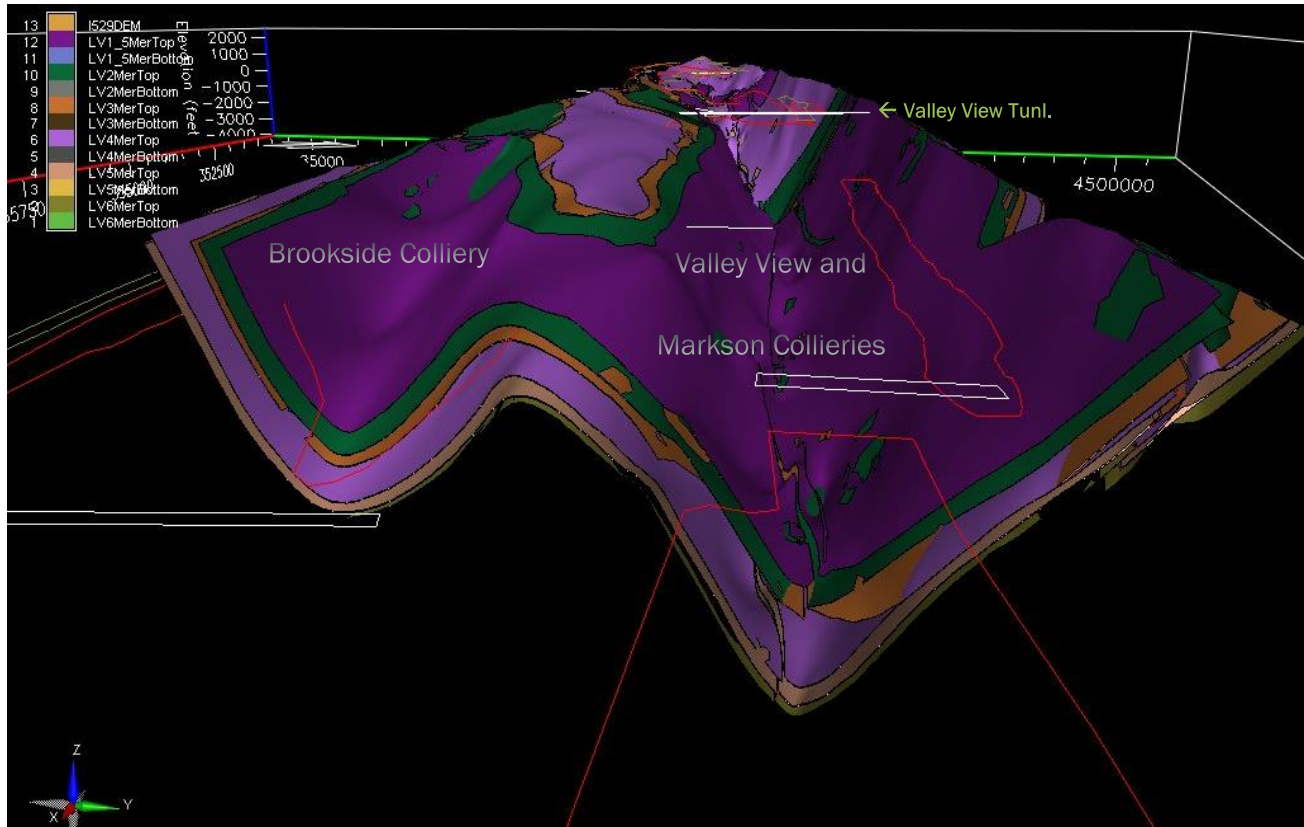


Figure 20: EarthVision Model of virgin coal volumes of the Lykens Valley Veins in the Brookside (left), Valley View (middle) and Markson (right) Mines cross section looking west at a 0° angle. Red lines indicate colliery boundaries. White lines indicate barrier pillars.

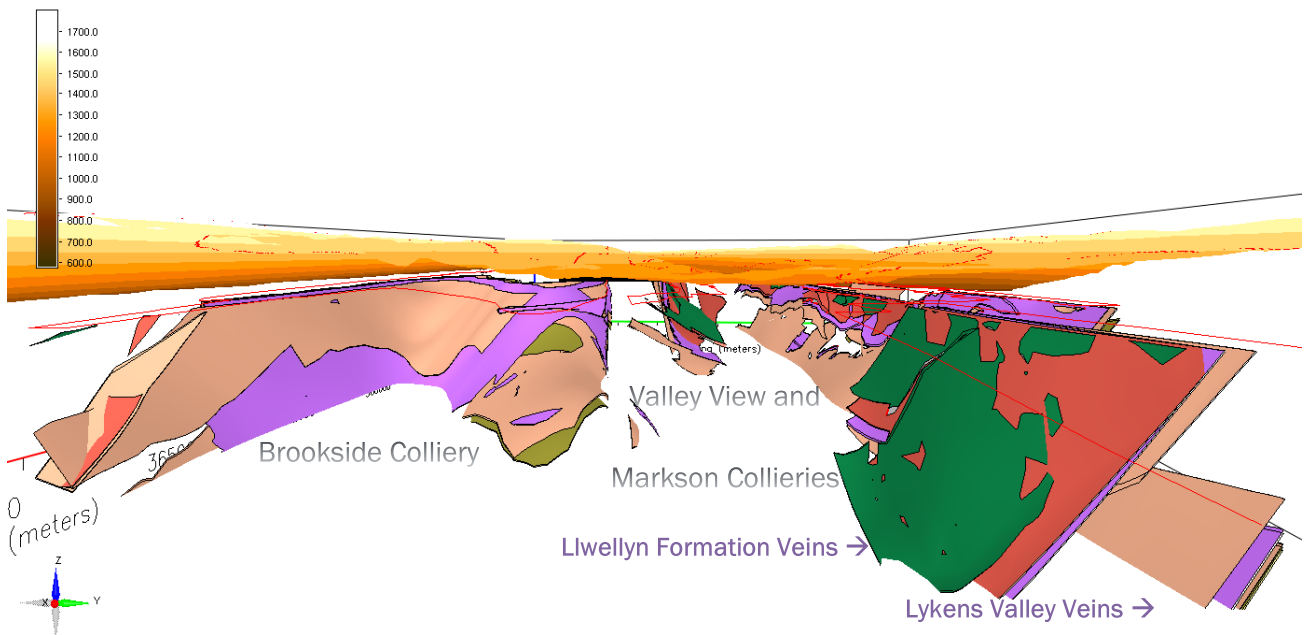


Figure 21: EarthVision Model of the Brookside (left), Valley View (middle) and Markson (right) Mines from 400 to 861 feet (extent of mining) cross section looking west at 0° angle. Compare to virgin coal volumes image, the Donaldson Basin was only mined on the flanks since the veins dive too deep under the valley to sustainably pump and mine. That coal was left intact and provides a barrier to water flow from the north dip (Markson) to the south dip (Valley View). Shades of brown indicate the surface elevations

### Heckscherville Valley

The largest multi-colliery hydrologic unit in the Southern Anthracite Coal Field is the Minersville Synclinorium near the Borough of Minersville in Schuylkill County. This unit includes all of the collieries in the Heckscherville Valley, except the Reppier Colliery. The abandoned underground mines included in this unit are the Buck Run Colliery, Glendower Colliery, Richardson Colliery, Thomaston Colliery, and Pine Knot Collieries (764'). The two major mine drainage discharges from this unit are the Pine Knot Tunnel and the

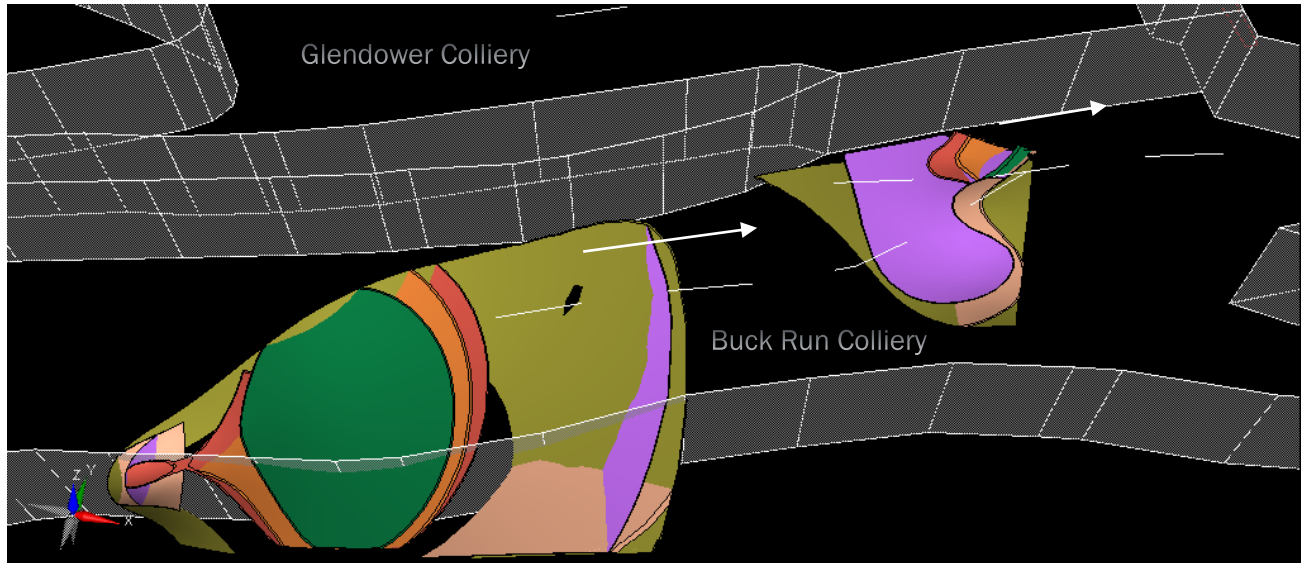


Figure 22: EarthVision Model of Buck Run (Dam Basin) between 1000 and 1203 feet looking south. White arrows show flow direction, gray curtains mark approximate colliery boundaries. 3D Grids (all above the Mine Hill Fault): Green=Mid. Mammoth, Orange=Btm. Mammoth, Red=Skidmore, Purple= 7 Ft., Pink= Buck Mtn., Tan=Ltl. Buck Mtn.

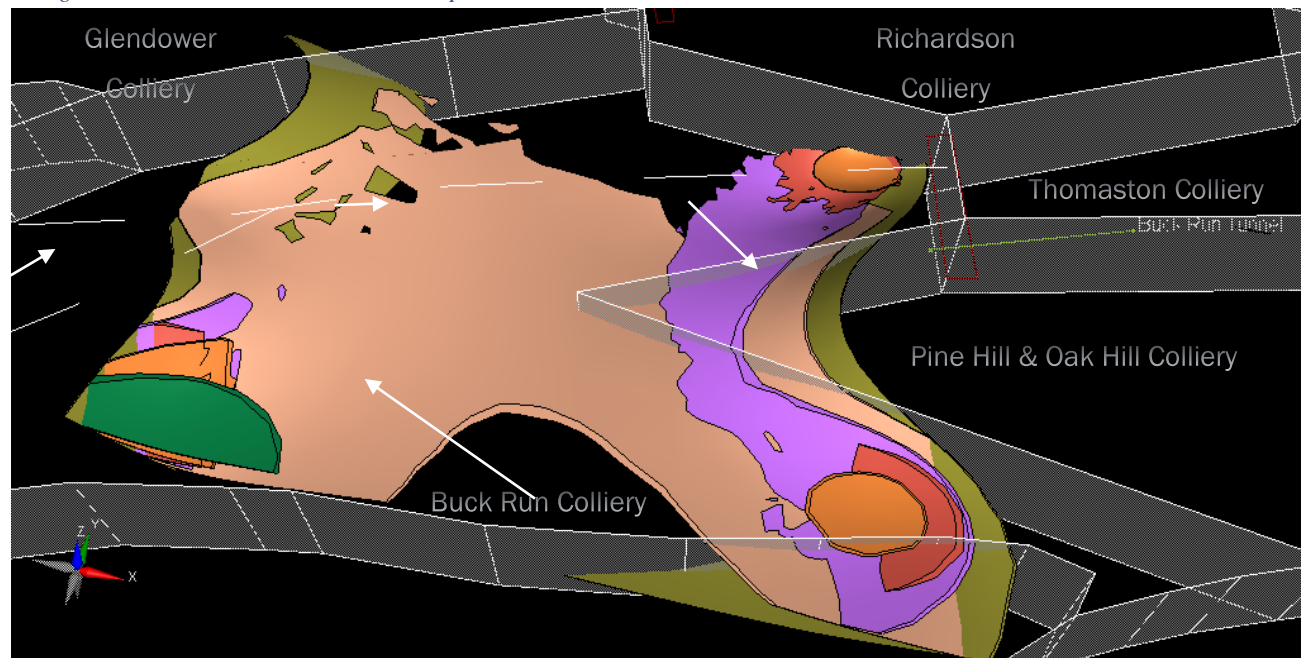


Figure 23: EarthVision Model of Buck Run (Old Basin) between 400 and 866 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids (all above the Jugular Fault): Green=Top Mammoth, Orange=Mid. Mammoth, Red=Btm. Mammoth, Purple=Skidmore, Pink= 7 Ft., Tan= Buck Mtn.

Replier Tunnel. The Pine Knot Tunnel is the largest mine drainage discharge in the Southern Anthracite Coal Field. The Replier Colliery (888') is also considered part of this unit because it is within the same basin, but it has its own discharge out the Replier Tunnel in to the near Rte 61 just before the Frackville Grade. There is an isolated portion to the north of the Juggular Fault which may hold a pool and drained by the Hexter's Tunnel, or it drains through the fault to the Replier or Pine Knot mines. There is insufficient mine map coverage in the area to make a determination. See Appendix D for a 2D representation of current mine pool boundaries in the Heckscherville Valley based off this 3D model.

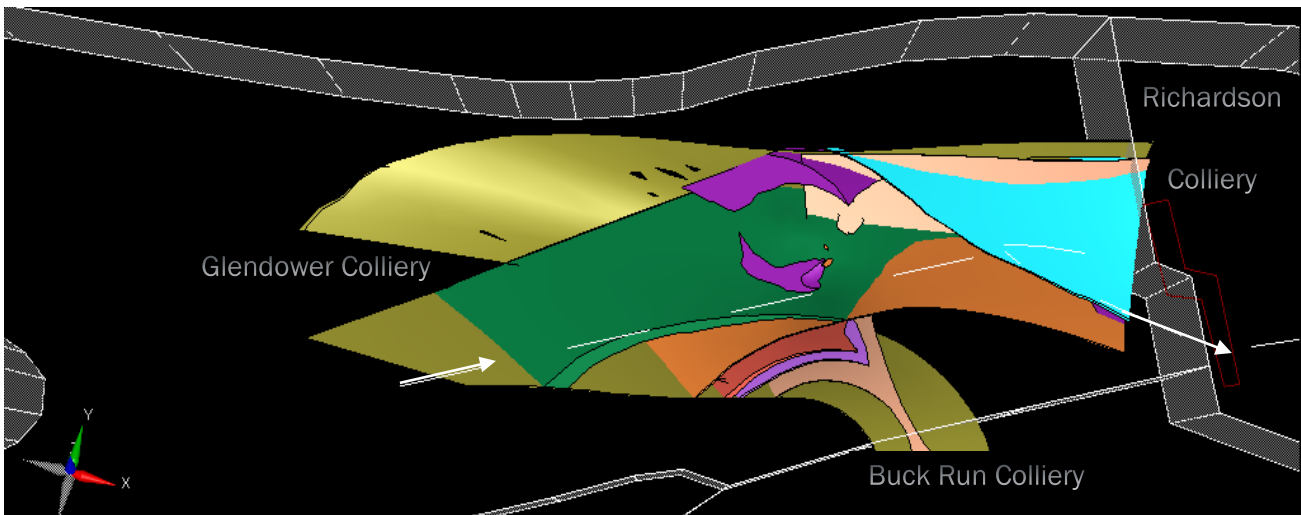


Figure 24: EarthVision Model of Glendower Mine between 400 and 1030 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. 3D Grids (above and below the Jugular Fault): Lt.Blue=Primrose, Dk. Purple=Holmes, Green=Top Mammoth, Orange=Mid. Mammoth, Red=Btm. Mammoth, Lt.Purple=Skidmore, Pink= 7 Ft., Tan=Buck Mtn.

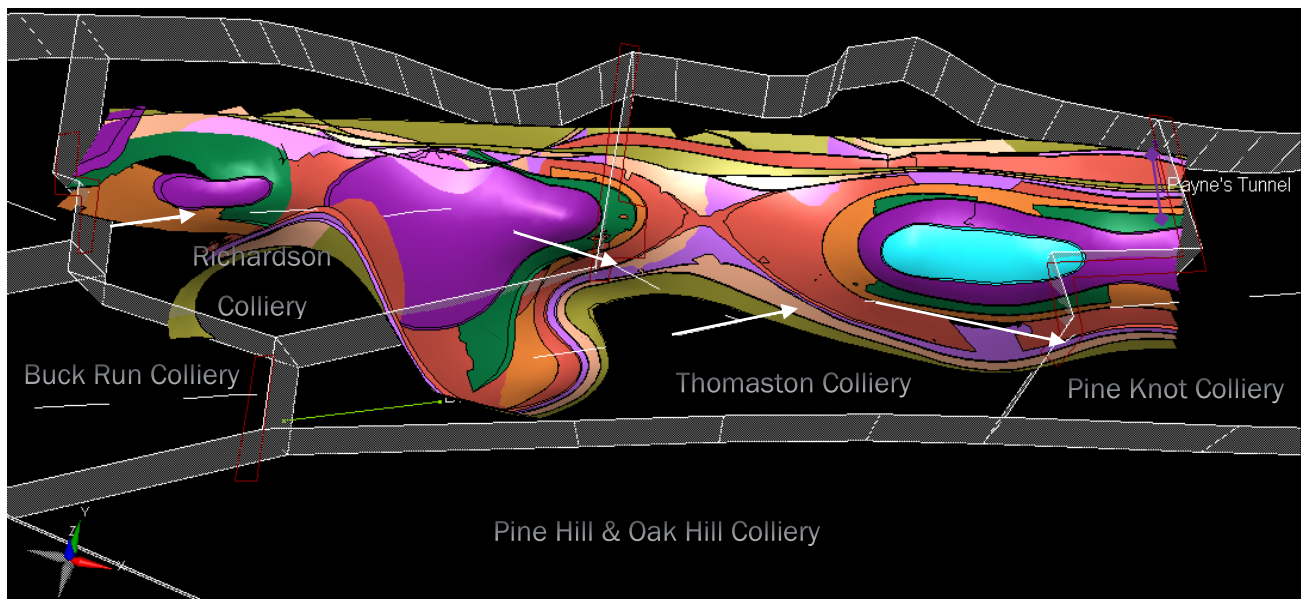


Figure 25: EarthVision Model of Richardson and Thomaston Mines between 300 and 790 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel to surface, Purple lines indicate interior (from vein to vein) drainage. 3D Grids (above and below the Jugular Fault): Lt.Blue=Primrose, Dk. Purple=Holmes, Green=Top Mammoth, Orange=Mid. Mammoth, Red=Btm. Mammoth, Lt.Purple=Skidmore, Pink= 7 Ft., Tan=Buck Mtn.

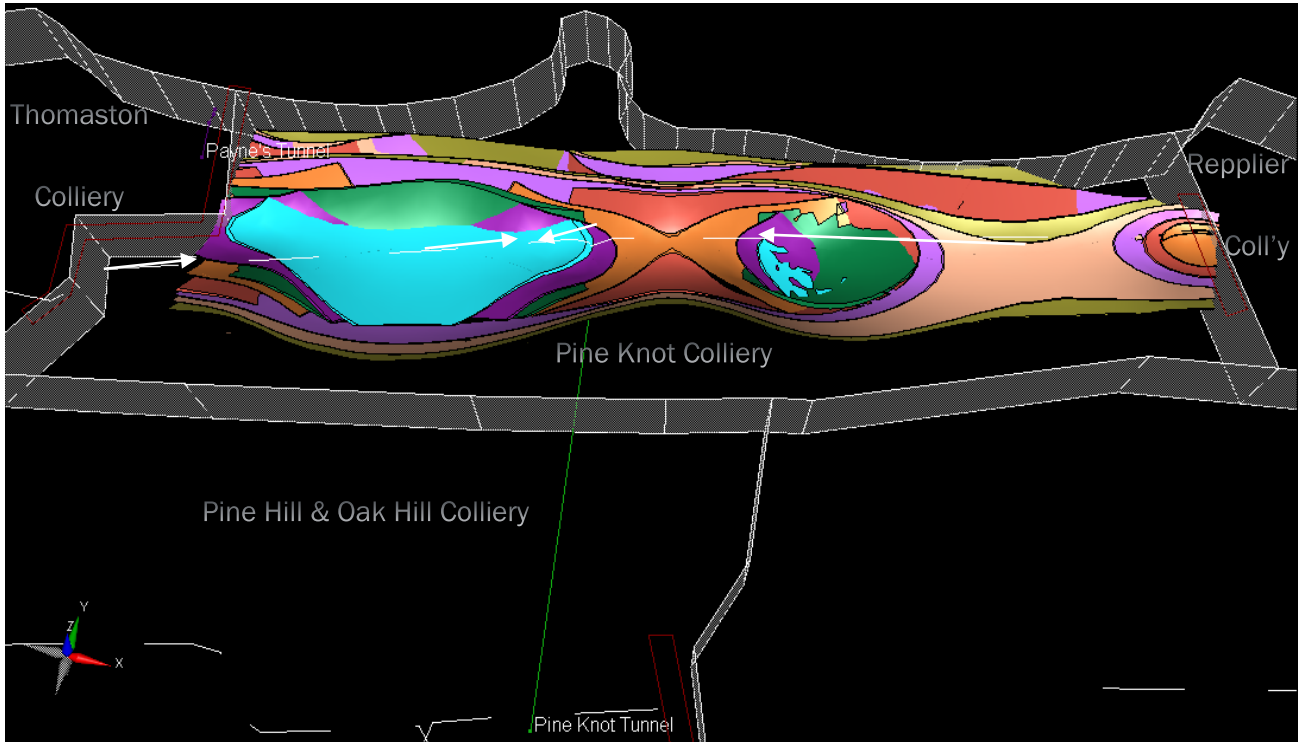


Figure 27: EarthVision Model of Pine Knot Mine between 300 and 760 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids (above and below the Jugular Fault): Lt.Blue=Primrose, Dk. Purple=Holmes, Green=Top Mammoth, Orange=Mid. Mammoth, Red=Btm. Mammoth, Lt.Purple=Skidmore, Pink= 7 Ft., Tan= Buck Mtn

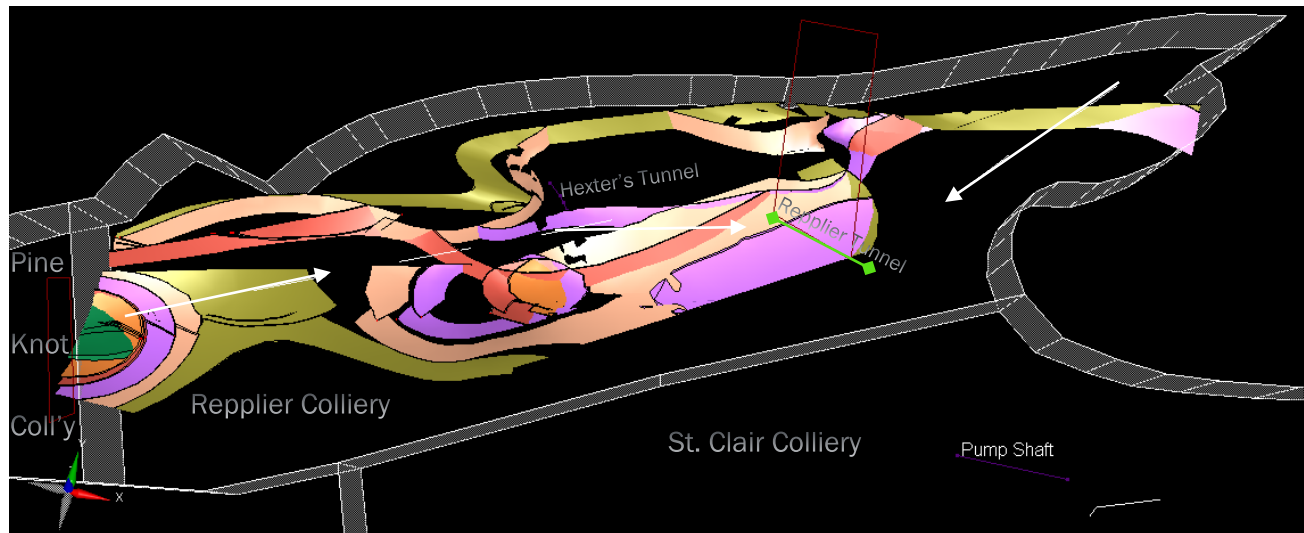


Figure 26: EarthVision Model of Repplier Mine between 750 and 876 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids (above and below the Jugular Fault): Green=Top Mammoth, Orange=Mid. Mammoth, Red=Btm. Mammoth, Lt.Purple=Skidmore, Pink= 7 Ft., Tan= Buck Mtn.

Northern Anthracite Coal Field:

Lackawanna Valley (North to South)

The Lackawanna Valley is traditionally separated into the Upper Lackawanna and the Lower Lackawanna separated by the Archbald Fault. The Upper Lackawanna Pools consist of the Forest City (1419'), Coalbrook, Carbondale, and Jermyn (924') Pools, the last two being the only ones that are connected to a common discharge, the Jermyn Outfall. The other two have their own discharges.

The Forest City mine pool exists in the Forest City, Clinton, Gray Slope, Northwest and Twin Hill Collieries. The Vandling Shaft/Drift drains the western portion and the Gray Slope drains the Eastern Portion.



Figure 28: EarthVision Model of the Forest City Pool at 1384 feet. White arrows show flow direction, gray lines approx. colliery boundaries. 3D Grids: Red=Top Clark, Lt.Purple=Clark, Pink= Mid. Red Ash, Tan= Btm. Red Ash.

The Gibson and Coalbrook Collieries contribute drainage to the Coalbrook Mine Pools. There are two discharges on either side of Wilson Creek to drain each side of the mine bisected by the stream. The Simpson Drift drains the eastern portion, while the Simpson Shaft drains the western portion.

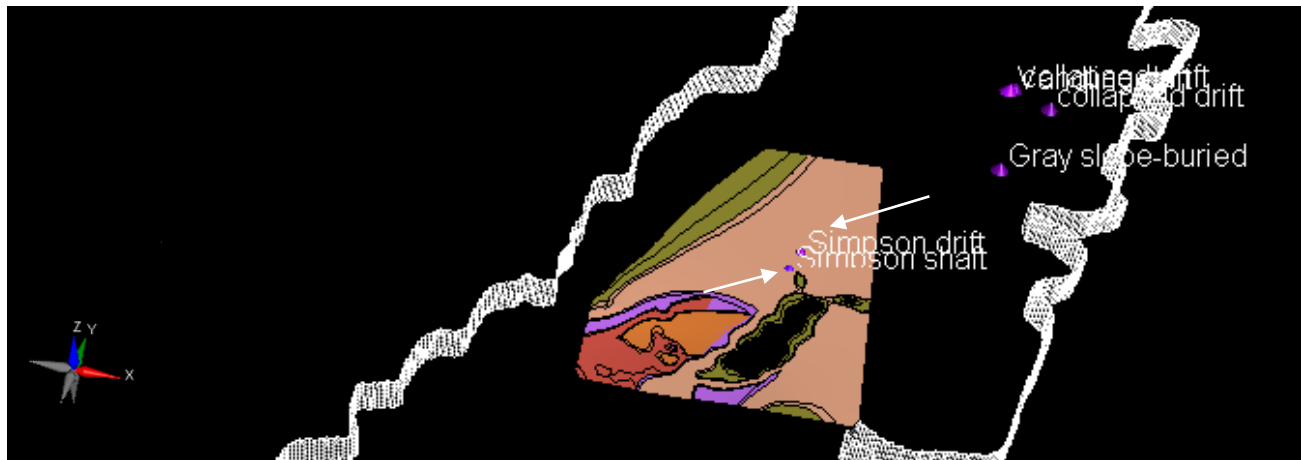


Figure 29: Earth Vision Model of the Coalbrook Pools at 1251 feet. White arrows show flow direction, gray lines approx. colliery boundaries. 3D Grids: Orange=Baltimore, Red=Top Clark, Lt.Purple=Clark, Pink= Mid. Red Ash, Tan= Btm. Red Ash

The Murrin, Powderly and Langcliffe Collieries contribute to the Carbondale Mine Pool controlled by an anticlinal ridge that crosses the valley. The Carbondale Pool overflows to the Jermyn Mine Pool. The Erie and Jermyn Collieries contribute to the Jermyn Mine Pool which has a discharge to the surface.

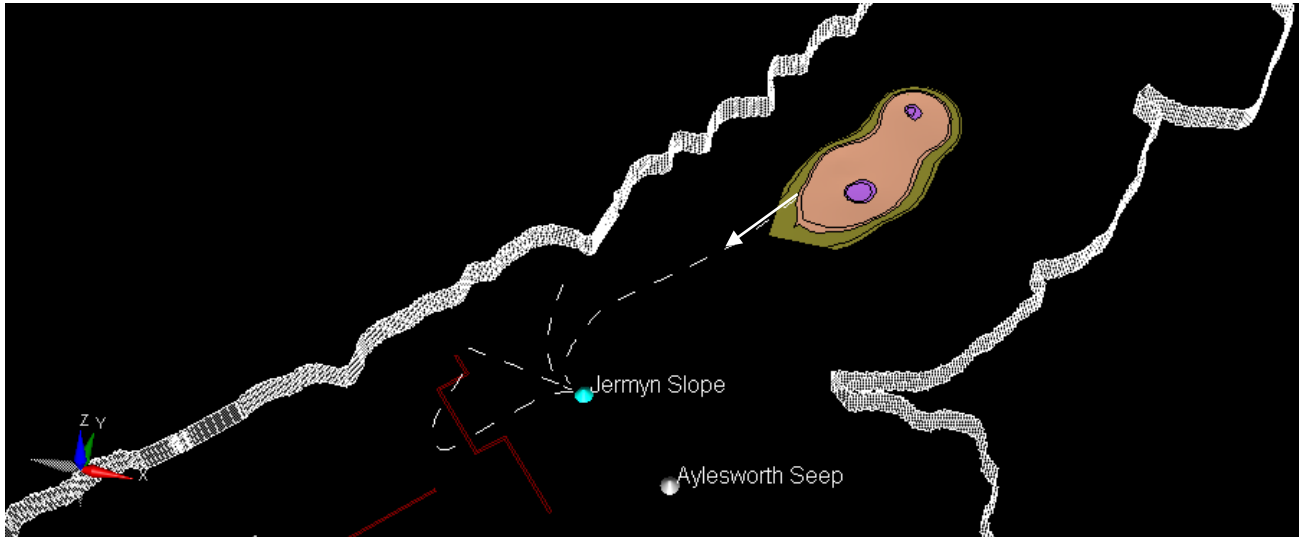


Figure 30: Earth Vision Model of the Carbondale Pool at 953 feet. White arrows show flow direction, gray lines approx. colliery boundaries. 3D Grids: Lt.Purple=Clark, Pink= Mid. Red Ash, Tan= Btm. Red Ash

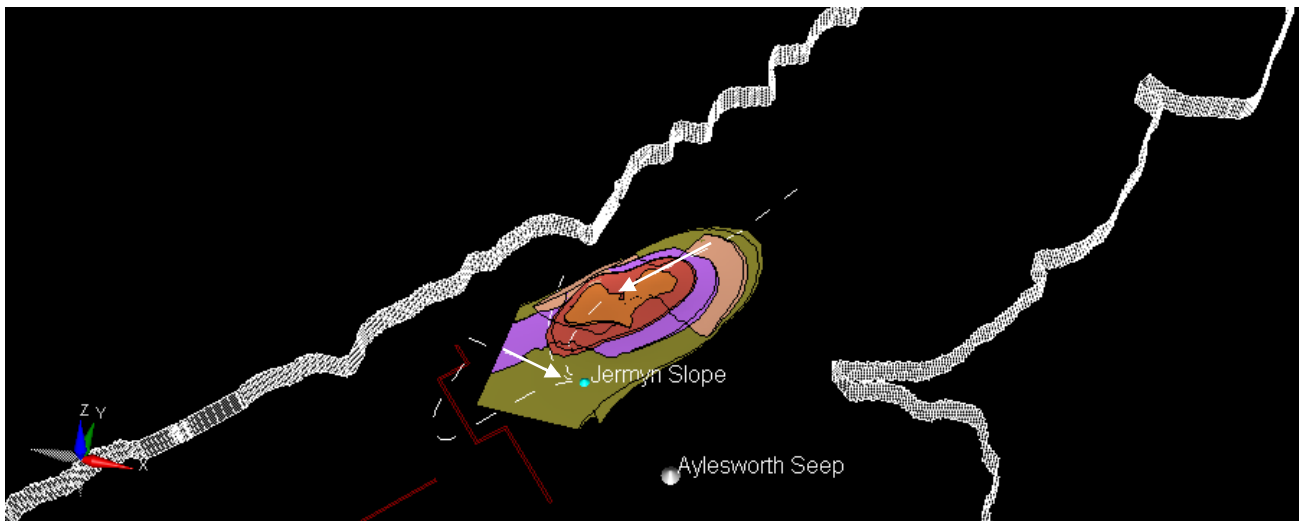


Figure 31: EarthVision Model of the Jermyn Pool at 942 feet. White arrows show flow direction, gray lines approx. colliery boundaries. 3D Grids: Orange=Baltimore, Red=Top Clark, Lt.Purple=Clark, Pink= Mid. Red Ash, Tan= Btm. Red Ash

Mines on the east side of the valley, on the other side of the Archbald Fault from the Jermyn Pool, also have their own mine pools and discharges perched between 1200 (Mount Vernon Pool) and 1300 (Archbald Pool) feet in the mountain. They are separated by the small valley dug out by White Oak Creek. Mining near and under the creek was restricted also creating a division.

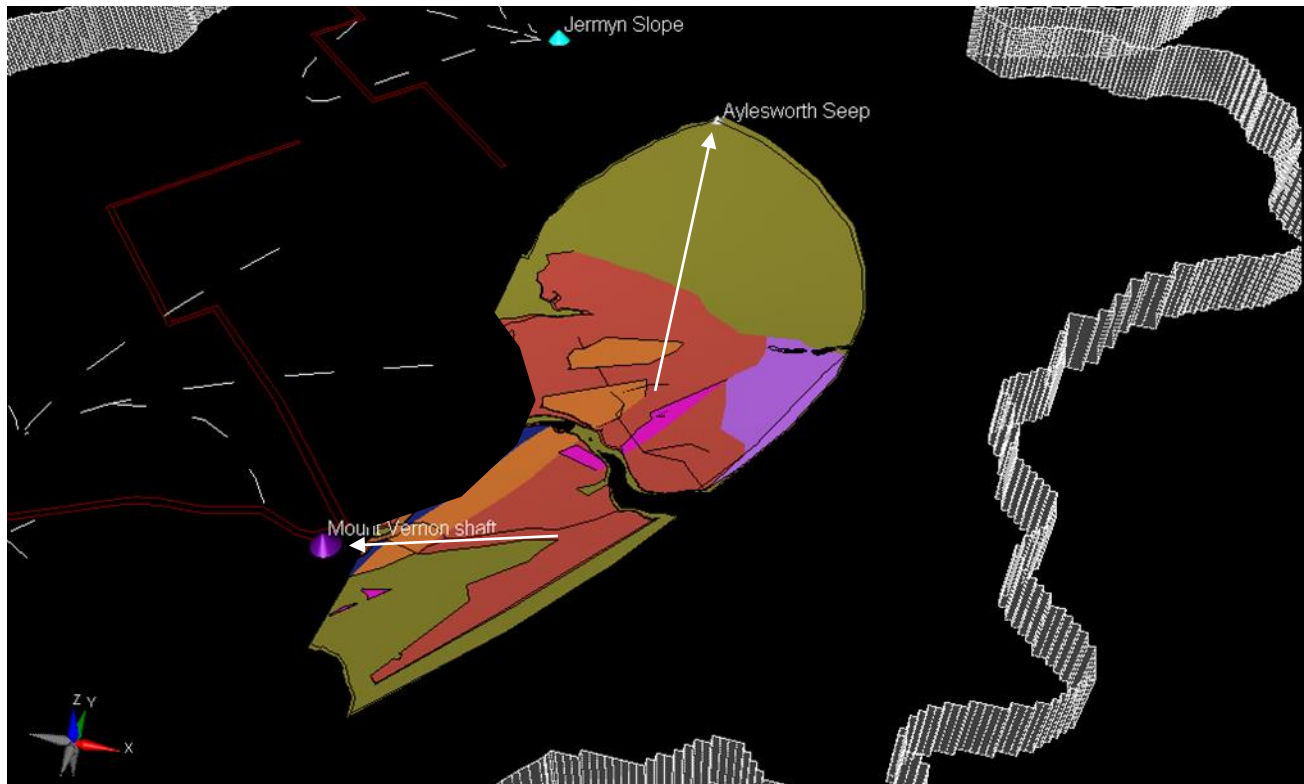


Figure 32: EarthVision Model of the East Side Pools at 1300 feet. White arrows show flow direction, gray lines approx. colliery boundaries. 3D Grids: Orange=Baltimore, Red=Top Clark, Lt.Purple=Clark, Pink= Mid. Red Ash, Tan= Btm. Red Ash

The Archbald fault is an arching slip fault that cuts the upper part of the valley and rotates the eastern most portion of the lower valley to the northeast, creating a combination fault/anticlinal ridge. This geologic formation creates a good geologic barrier to divide the Lower from the Upper Lackawanna basin.

#### Lower Lackawanna

The Lower Lackawanna Mine Pools start with two pools, the Gravity Slope (827') and Lackawanna which are separate from the larger Scranton Metropolitan Mine Pool. The Gravity Slope, PA Anthracite, and the western half of the Pompey Collieries contribute drainage to the Gravity Slope Pool. The Lackawanna Colliery is isolated hydrologically via barrier pillars from surrounding mines. Their discharges are the Gravity Slope and borehole discharges at 822 feet and the Jerome Shaft at 777 feet, respectively.

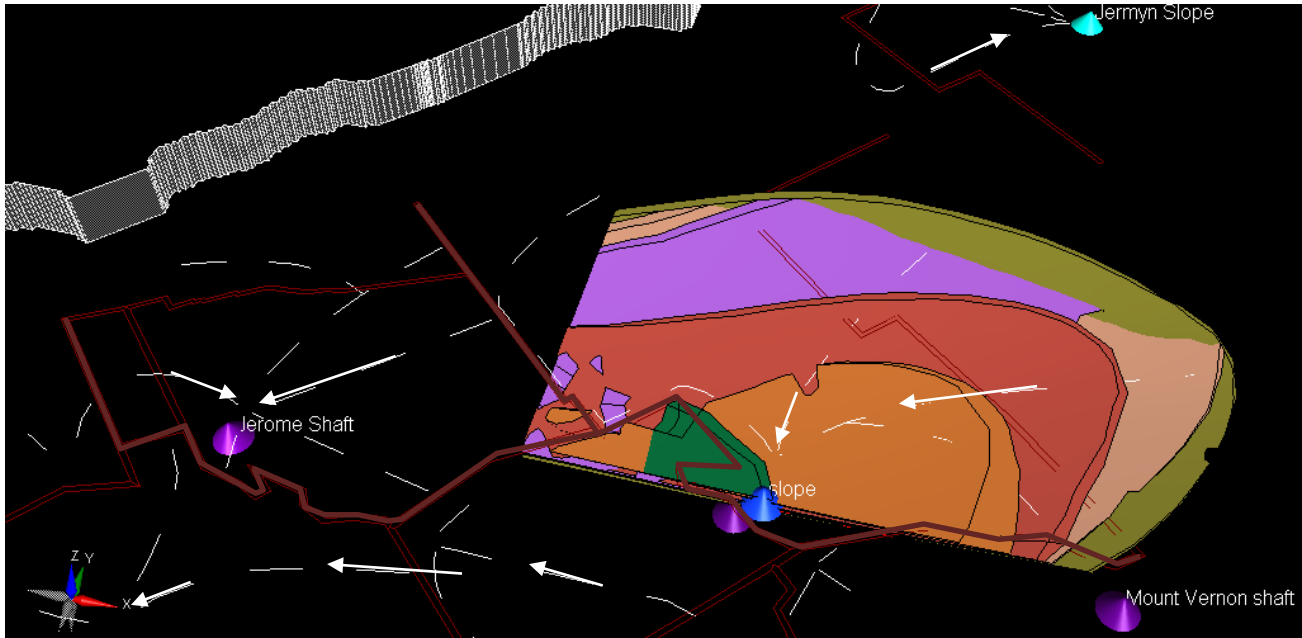


Figure 33: Earth Vision Model of the Gravity Slope Mine Pool at 827 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Green=Baltimore, Orange=Marcy, Red=Clark, Lt.Purple=Top Red Ash, Pink= Mid. Red Ash, Tan= Btm. Red Ash.

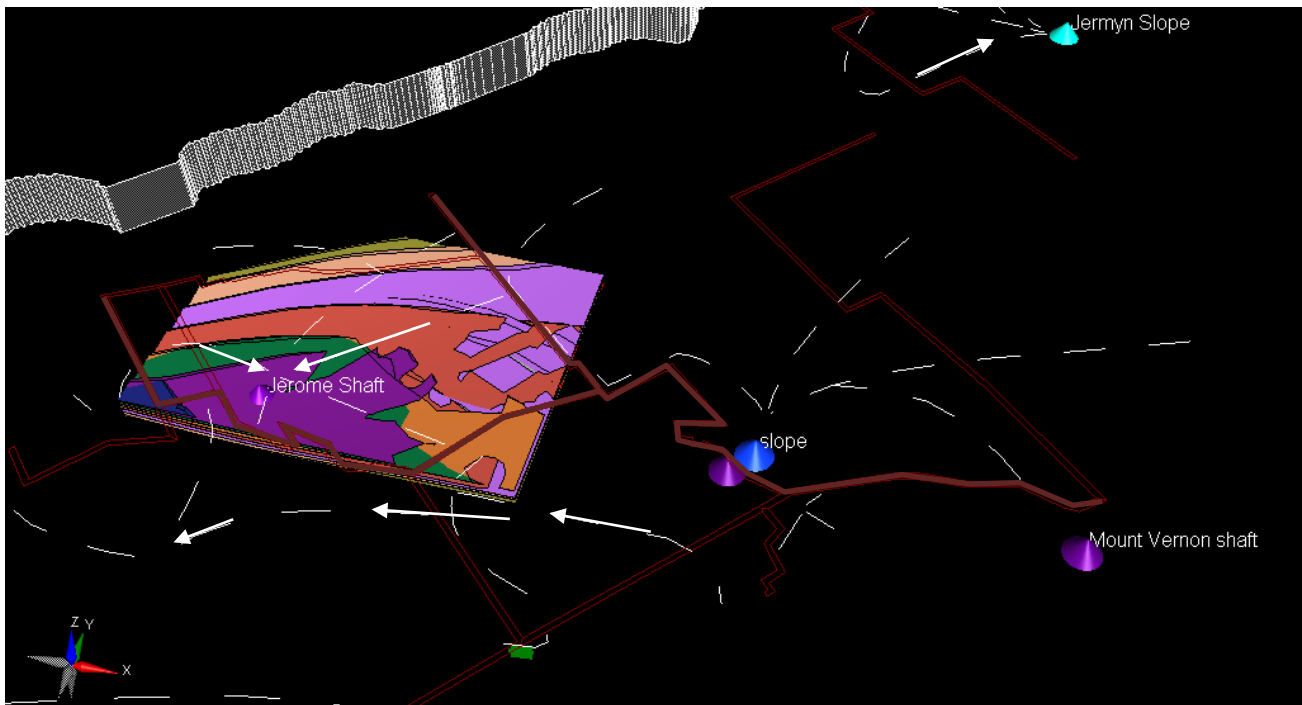


Figure 34: Earth Vision Model of the Lackawanna Mine Pool at 778 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Dk. Blue=Diamond, Lt.Blue=Top Rock, Dk. Purple=Rock, Green=Baltimore, Orange=Marcy, Red=Clark, Lt.Purple=Top Red Ash, Pink= Mid. Red Ash, Tan= Btm. Red Ash.

The Scranton Metropolitan Mine Pool makes up the rest of the area and has a common discharge at the Old Forge Borehole. The mines from north to south are as follows (with current borehole elevations if available): Pompay, Sterrick (762'), Peck Shaft (750'), Olyphant (717' & 723'), Humbert, Dolph, Temple, Miles (714'), Johnson, Underwood (603'), Storrs, Pancoast, Birds Eye, Marvine, Legetts Creek, Richmond,



Dickson, Von Storch, Bulls Head, Manville, Green Ridge (641'), Spencer, No. 1, Diamond (625'), Pine Brook (624'), Capouse (643'), Mount Pleasant, Oxford, Moffat (618'), National, Greenwood, Austin, Sibley (611'), Jermyn, & Old Forge (586'). A series of barrier pillars creates a 100 foot dam to trap water in the Johnson, Olyphant, Underwood and Collieries north as seen by borehole water levels.

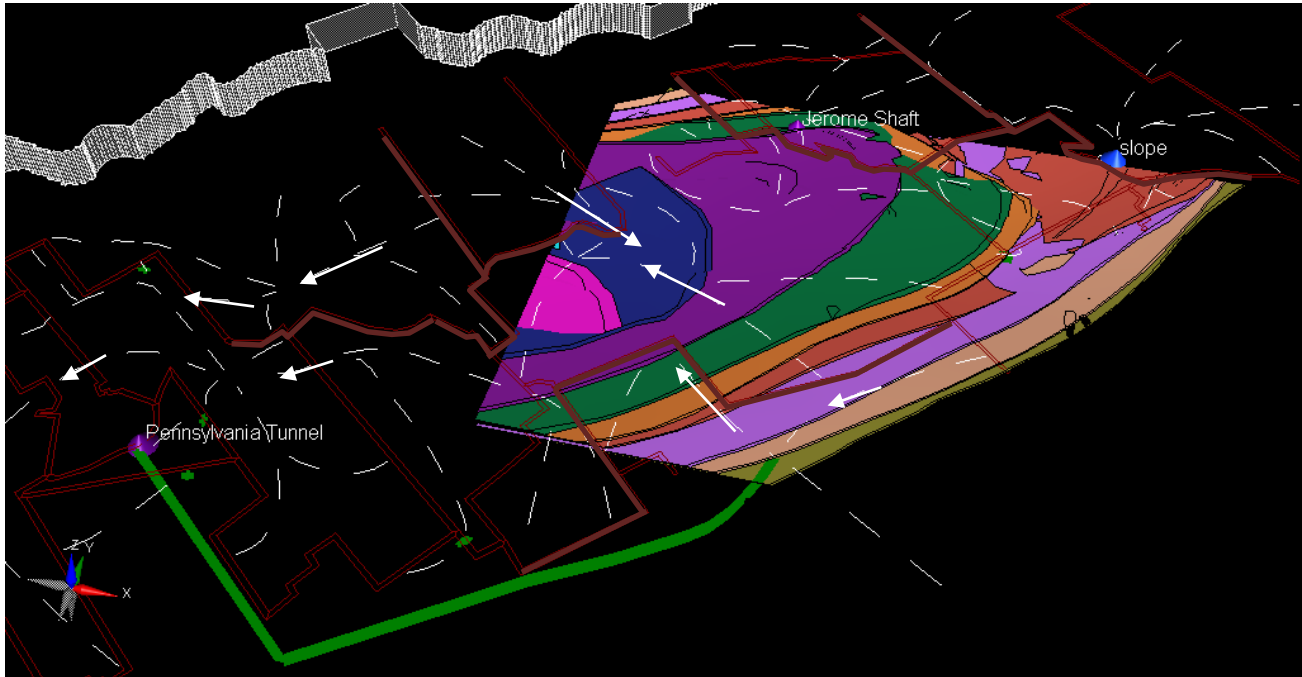


Figure 35: Lower Lackawanna (Scranton Metropolitan Mine Pool) Upper at 710 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Dk. Pink=Four Foot, Dk. Blue=Diamond, Lt. Blue=Top Rock, Dk. Purple=Rock, Green=Baltimore, Orange=Marcy, Red=Clark, Lt. Purple=Top Red Ash, Pink= Mid. Red Ash, Tan= Btm. Red Ash.

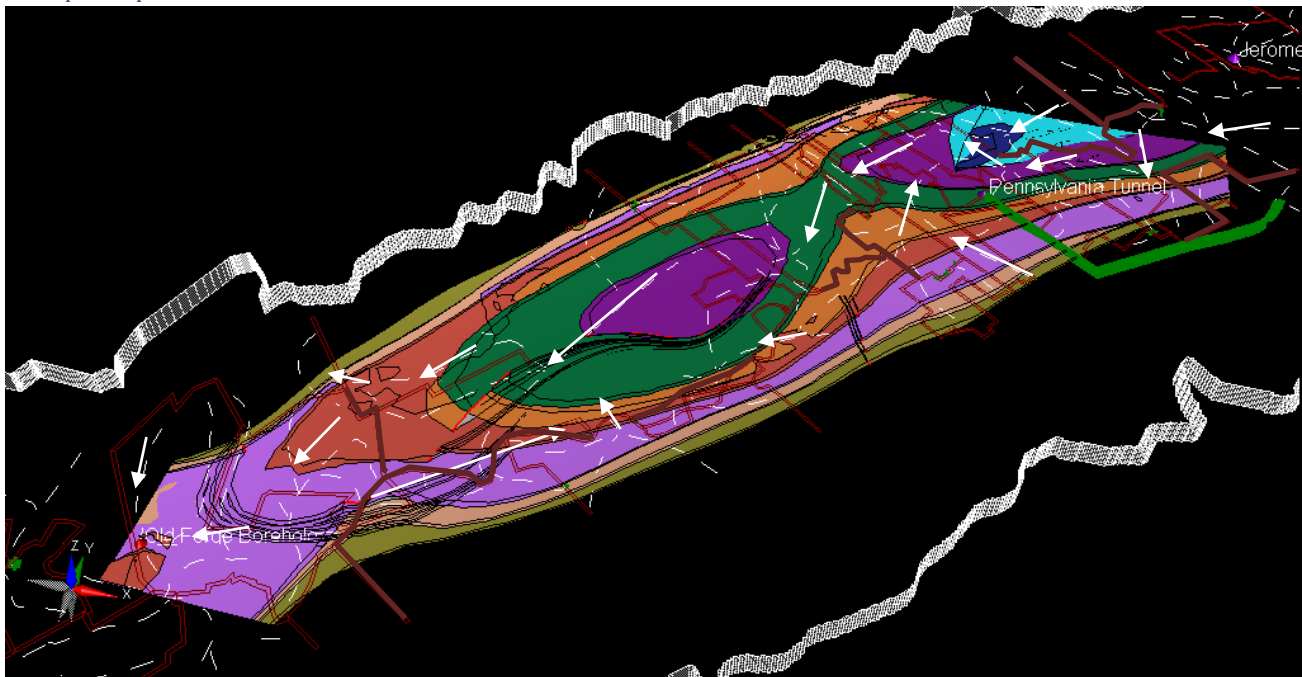


Figure 36: Lower Lackawanna (Scranton Metropolitan Mine Pool) Lower at 610 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Dk. Blue=Diamond, Lt. Blue=Top Rock, Dk. Purple=Rock, Green=Baltimore, Orange=Marcy, Red=Clark, Lt. Purple=Top Red Ash, Pink= Mid. Red Ash, Tan= Btm. Red Ash.

During high flow this divide can hold back enough water that it will cause a secondary discharge out the Pennsylvania Tunnel when the level rises above ~790. The collieries below this divide hold a pool at about ~610' in elevation as seen by the borehole readings. There is a second barrier pillar and fault dam holding back approximately 30 feet of water between the Moffat and Old Forge mines forcing all the water to back up to 554' through the Sibley Colliery before it discharges to the surface.

The Broadwell & Spring Brook mines on the east side of the fault allegedly discharges to the surface at ~660', but a field investigation did not turn up a discharge in the area of the Lackawanna River near Moosic, PA. A small mine pool exists, but was not modeled.

The Moosic Saddle, a geologic anticlinal ridge that runs perpendicular to the synclinal valley, mostly separates the Scranton Metropolitan Mine Pool from the Duryea Mine Pool. Three veins actually cross over the saddle, but a barrier pillar constricts the flow of water to an elevation of 470 feet.

The last mine pool that discharges to the Lackawanna River, the Duryea, has two water levels within the mine pool. The Central Mine Pool holds a water elevation of ~570' as determined by the Central Borehole (567'), restricted by a barrier pillar between the Central and No. 9 Colliery. The collieries that contribute drainage are the Central, Langcliffe, Hillside and half of the Heidleberg Mine. The Duryea Mine Pool sits at an elevation of ~550 feet as determined by the No. 9 Borehole (552') and the Duryea Breach discharge (552'). The No. 9 Borehole reading fluctuated between 590' and 552', but at times water was heard cascading down the borehole, so 552' is a more accurate reading. 590' might be a coal vein intersection with the borehole. The mines that contribute to the mine pool are the William A, Hallstead, No. 9 and Seneca (with possible leakage from the Clear Spring and Stevens mines on the west side of the Susquehanna River, but these boreholes are paved over. Recommend uncovering and monitoring water levels to confirm).

Most other discharges grow proportionate in flow to precipitation that falls over the area of the mine watershed, unlike this flashy mine pool. At high precipitation events during the investigation, the Duryea Discharge was recorded to double in flow indicating an overflow from the Old Forge Borehole. This intermittent overflow seems to happen when the Old Forge Borehole increased over 98 cubic feet per second (approximately 44,000 gallons per minute). Perhaps this is the limit of the 42" bore. See Appendix F for a 2D map of current mine pool boundaries in the Lackawanna Valley based off this 3D model.

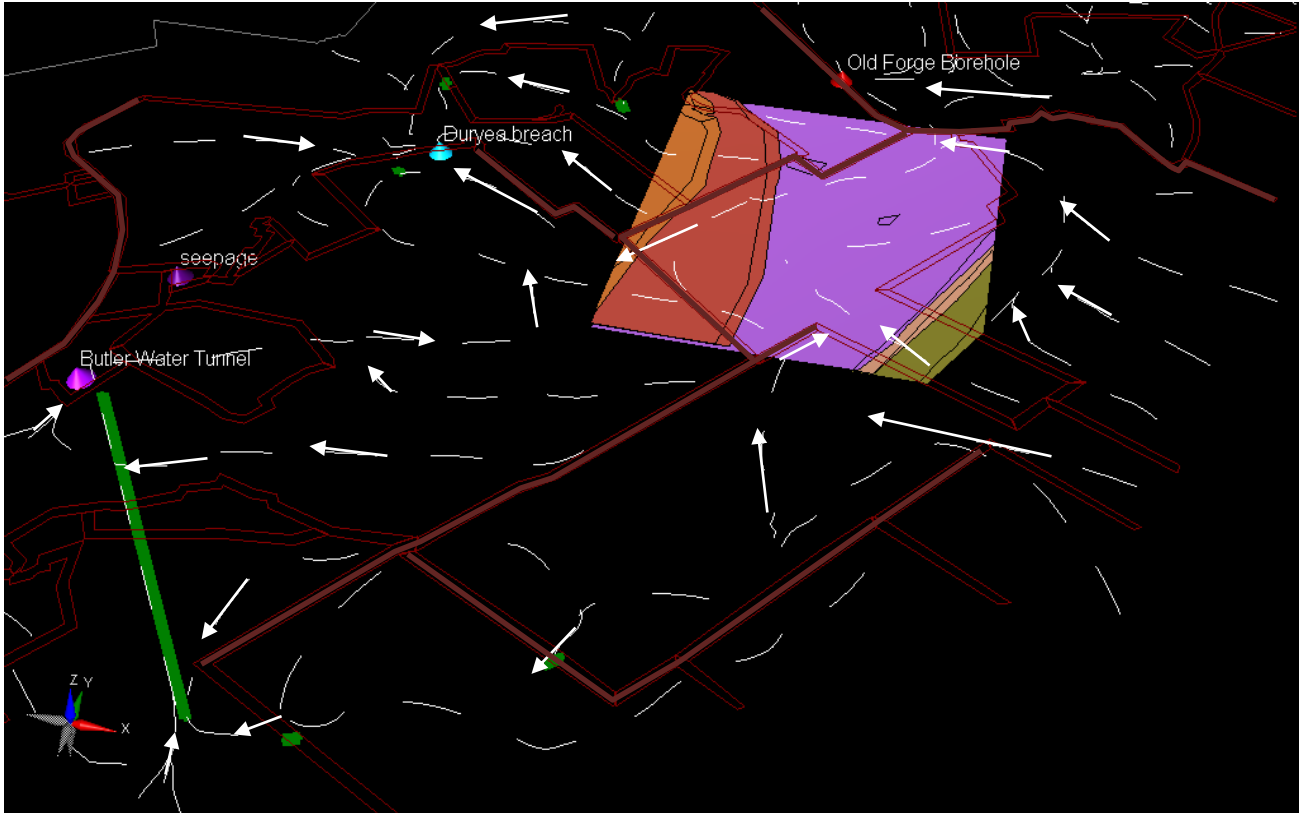


Figure 37: EarthVision Model of Central Mine Pool at 570 feet. White arrows show flow direction, gray lines approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Orange=Marcy, Red=Clark, Lt.Purple=Top Red Ash, Pink= Mid. Red Ash, Tan= Btm. Red Ash

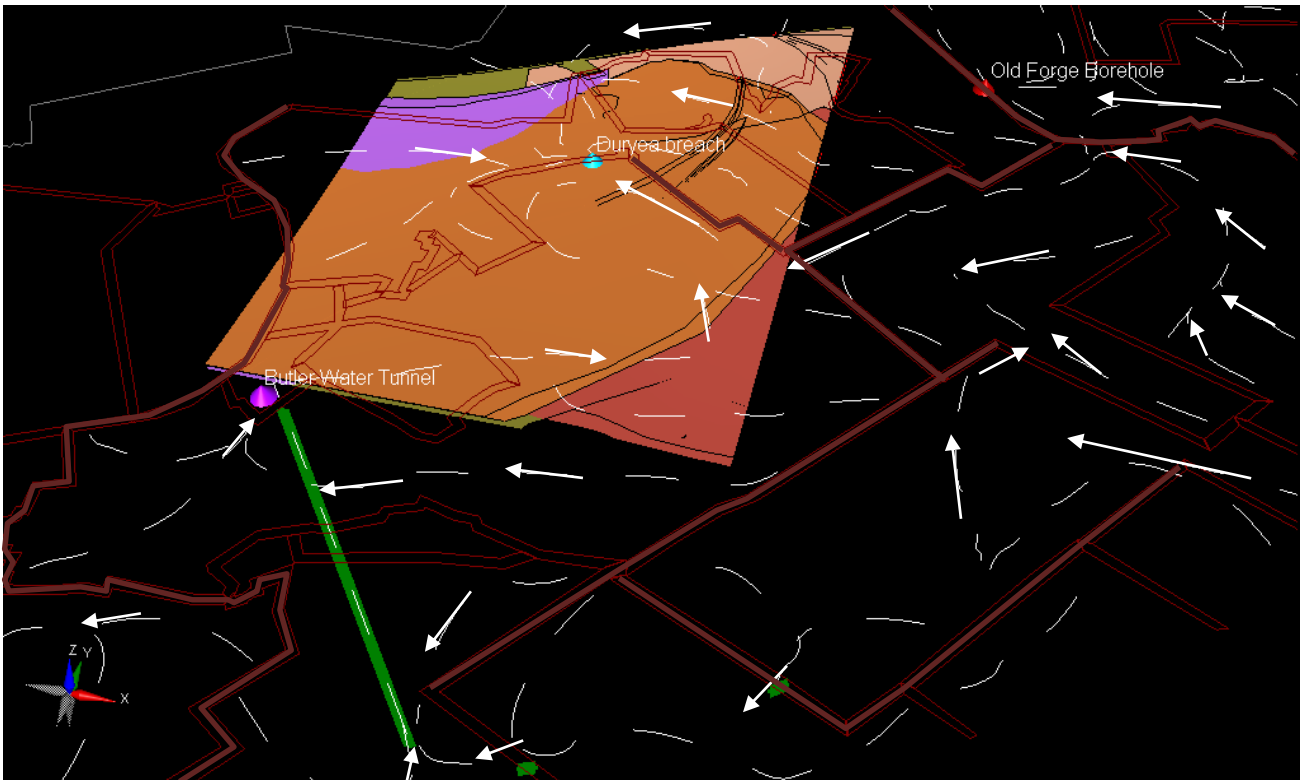


Figure 38: EarthVision Model of Duryea Mine Pool at 550 feet. White arrows show flow direction, gray lines approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Orange=Marcy, Red=Clark, Lt.Purple=Top Red Ash, Pink= Mid. Red Ash, Tan= Btm. Red Ash

Wyoming Valley (North to South):

The Butler Mine Pool is drained by the Butler Mine Tunnel directly into the Susquehanna River. This mine pool was not modeled in this study due to the lack of data in the specific area. The mines that contribute drainage to the Butler Water Tunnel are the Butler, Florence and half of the Heidelberg. Several mine pools exist in the Wyoming Valley including the Northwestern, Southeastern, Loomis and Inman Mine Pools. These mine pools were modeled together due to the intricacies of the boundaries and the inability of the regional model to be accurately sliced to isolate a correct volume, primarily. Secondly, the buried valley, a stratigraphic layer of rocks, gravel and sand that lays above the coal veins is known to convey mine pool water over barrier pillars, making these areas connected especially at times of high precipitation.

The mines that contribute drainage to the Northwest Mine Pool at a level of ~541 feet are the Stevens, Clear Spring, Exeter (541'), Schooley, Mt. Lookout (536'), Ewen (526'), Laflin, Packer, and Keystone. This system drains through the barrier pillar from Ewen into the Henry Colliery. The Westmoreland, Maltby (534'), Harry E, Henry and Prospect mines hold a pool at ~538 and discharge to the surface at the Plainsville Borehole. The Black Diamond, Pettebone, East Boston (529'), Kingston (529'), Woodward (526'), Loree (531'), Lance, Gaylord, Nottingham-Buttonwood (519'), Avondale (519') and the upper veins of the Grand Tunnel collieries all hold a pool between 520 and 530 feet and discharge via the Buttonwood Shaft to Solomon Creek.

The mines that contribute drainage to the Southeast Mine Pool at a level of ~544 feet are the Conlon, Delaware - Pine Ridge (542'), Peach Orchard, Mineral Springs, Baltimore (524'), Hollenback, Stanton - Empire (539') South Wilkes-Barre, Franklin and half of the Huber Colliery. This system discharges via the South Wilkes-Barre Boreholes to Solomon Creek. The western half of the Huber, Sugar Notch (575'), Truesdale, and Bliss (576') mines hold a minepool at ~590 feet and discharge via the Askam Boreholes (575') to Nanticoke Creek. Earth Conservancy recently constructed a treatment system to oxidize and collect the iron from the Askam discharge. The discharge is flashy, in that it can at times discharge up to 10,000 gallons per minute and in the summer it will completely dry up. This is an indication that it's own pool is small and is highly influenced by surface water infiltration during times of precipitation or connected to another discharge. Presumably the Askam discharge acts as a secondary outlet to water that cannot discharge to the South Wilkes-Barre Boreholes in a timely manner. The water builds up 40 feet in the Wyoming Valley Southeast Lower Mine Pool and overflows the Wyoming Valley Southeast Upper Mine Pool and out to the Askam Borehole. This could possibly be monitored with pressure transducers at the Stanton #5, Sugar Notch #7, and/or the Huber #135 Borehole (the last two would need to be daylighted).

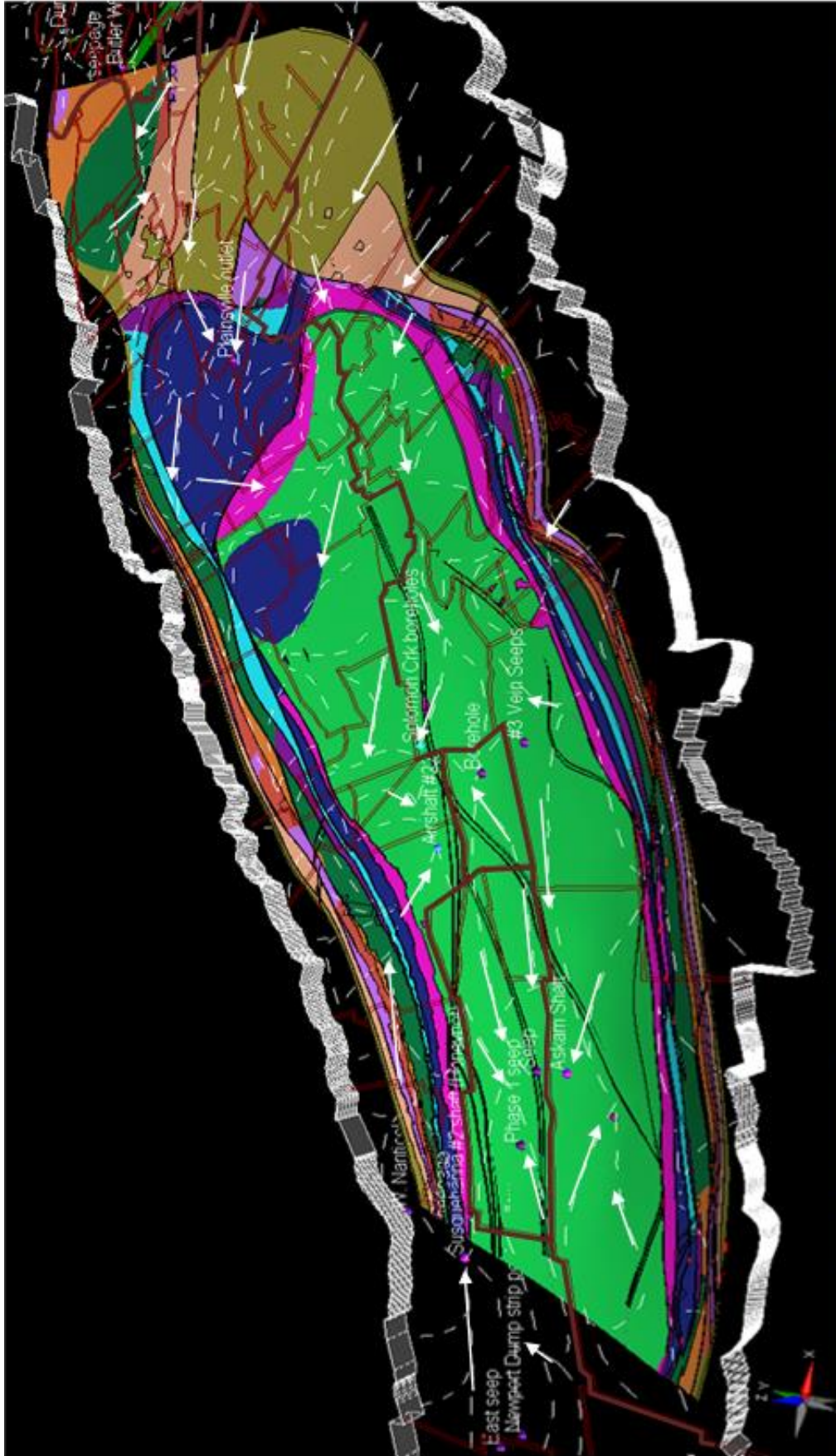


Figure 39 EarthVision Model of Northwestern, Southeastern, Loomis and Inman Mine Pool at 530 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Lt. Green=Five Foot Dk. Pink=Four Foot, Dk. Blue=Diamond, Lt. Blue=Top Rock, Dk. Purple=Rock, Green=Baltimore, Orange=Clark, Lt. Purple=Top Red Ash, Pink=Mid. Red Ash, Tan= Btm. Red Ash.

A portion of the Huber Colliery is isolated hydrologically behind a fault and has its own discharge near Doran Farm along St. Mary's road. The discharge to Solomons Creek is ~200 gpm in flow, has a small amount of iron and the pH is near neutral.

The Inman Mine is isolated by barrier pillars and holds a pool in the numbered veins above the Snake Island Vein at ~540 feet which discharges via a collapsed borehole to Solomon Creek. The discharge is relatively clean and does not need treatment.

The Loomis Mine (526') is isolated by barrier pillars and holds a pool at ~537 feet. The Espy Run Seeps emanate from the Loomis Mine as a neutral iron discharge. Earth Conservancy built a wetland based system to treat the discharges. A secondary periodic acidic aluminum discharge emanates from the Loomis Colliery directly to the Nanticoke Creek. The chemistry of the discharge indicates that it primarily drains the numbered veins above the Snake Island Vein.

Another acidic aluminum discharge emanates from the west side of the Susquehanna River from the northern portion of the Grand Tunnel Mine. The discharge drains the Red Ash Veins, as indicated by the chemistry.

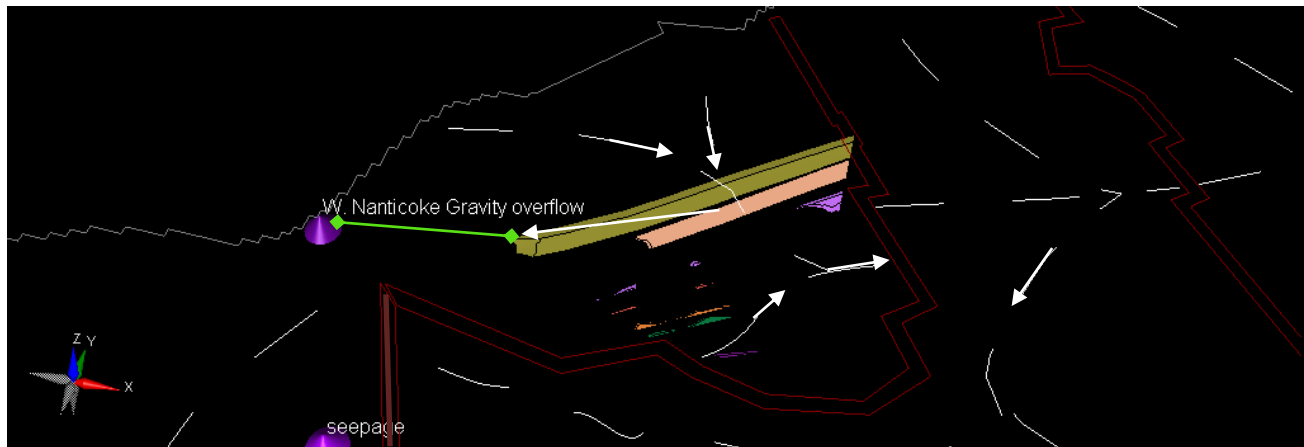


Figure 40: EarthVision Model of Grand Tunnel Colliery Mine Pool at 580 feet. White arrows show flow direction, gray lines approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Lt.Purple=Top Red Ash Pink=Mid. Red Ash, Tan=Btm. Red Ash.. Exists in Red Ash veins only, Top Red Ash & upper veins drainage contribute to Northwest Complex

Chemistry of mine drainage in the Wyoming Valley seems to follow a pattern. A conclusion can be drawn relatively easily when looking at the mine pools in a 3D context. In general, it seems that the less the mine pool resides in or passes through the Snake Island to Hillman Veins, the more acidic the resulting drainage. According to Edmunds et. al. (1999) there are calcareous (alkalinity producing) zones intermixed between these veins. See Figure 6 for more detail.

The Susquehanna #7 (538') and Alden mines contribute to drainage that discharges through the #2 Airway (Honeypot) Discharge to Newport Creek. The Alden Mine holds a pool at ~580 feet behind the barrier pillar.

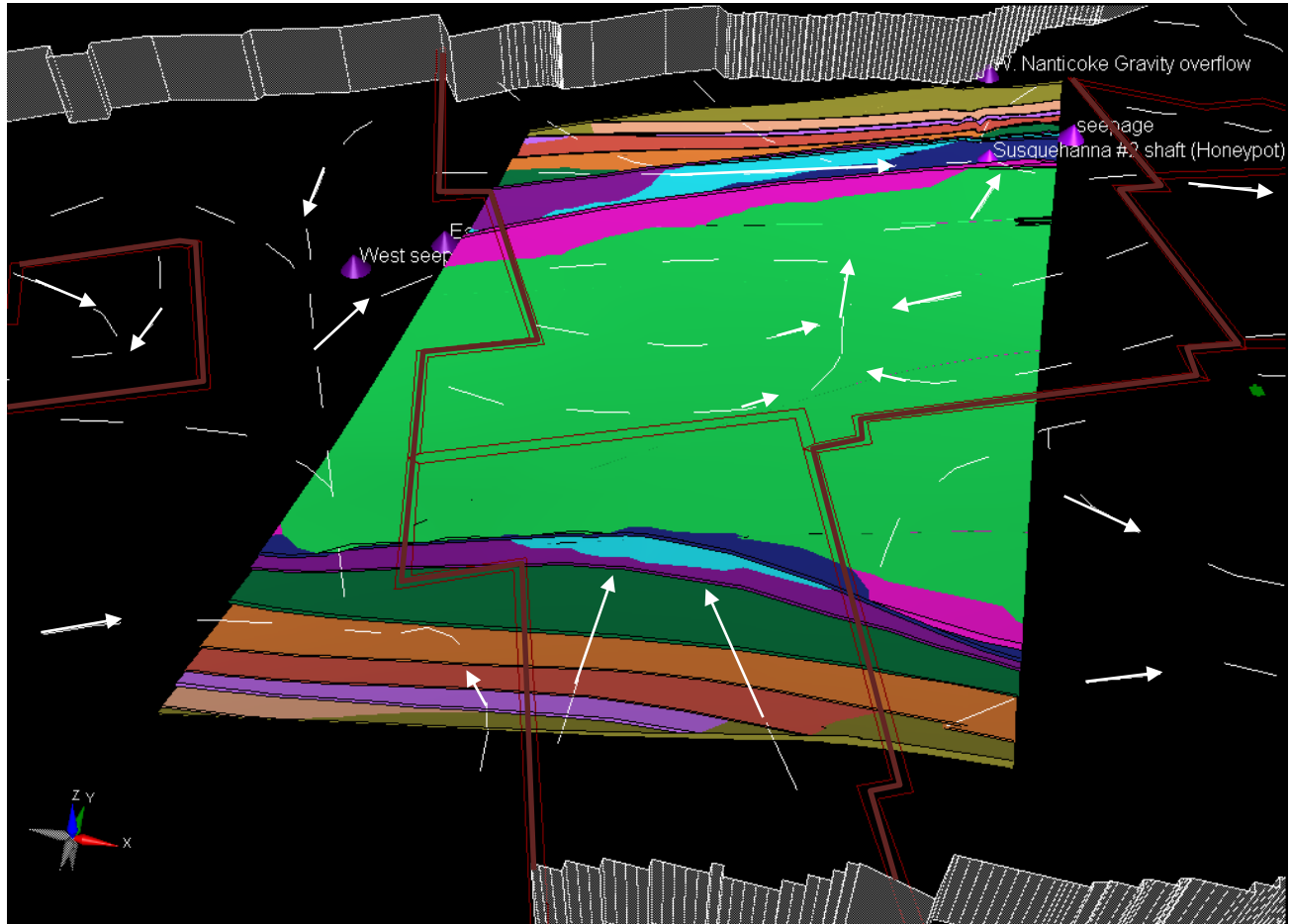


Figure 41: EarthVision Model of Susquehanna #7 Colliery Mine Pool at 540 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Lt. Green=Five Foot, Dk. Pink=Four Foot, Dk. Blue=Diamond, Lt. Blue=Top Rock, Dk. Purple=Rock, Green=Baltimore, Orange=Marcy, Red=Clark, Lt. Purple=Top Red Ash, Pink=Mid. Red Ash, Tan=Btm. Red Ash.

The Wanamie Mine (601') holds a pool at ~600 feet and discharges to a strip pit, creating a 20 acre lake of mine drainage (Newport Lake), which discharges to Newport Creek. Two seeps directly to Newport Creek also drain the pool. The discharge was treated for a time with a rotating limestone drum, but the unmaintained system went into disrepair and no longer treats the discharge. A secondary discharge is identified in the Scarlift report as the Auchenloss Seep to a branch of Newport Creek. The Stearns mine is completely contained within the Wanamie Mine by barrier pillars and holds a pool at 612 feet. Allegedly the pool discharges to the surface via a borehole to Newport Creek. Field investigation to find the discharge and borehole is needed followed further mine map interpretation.

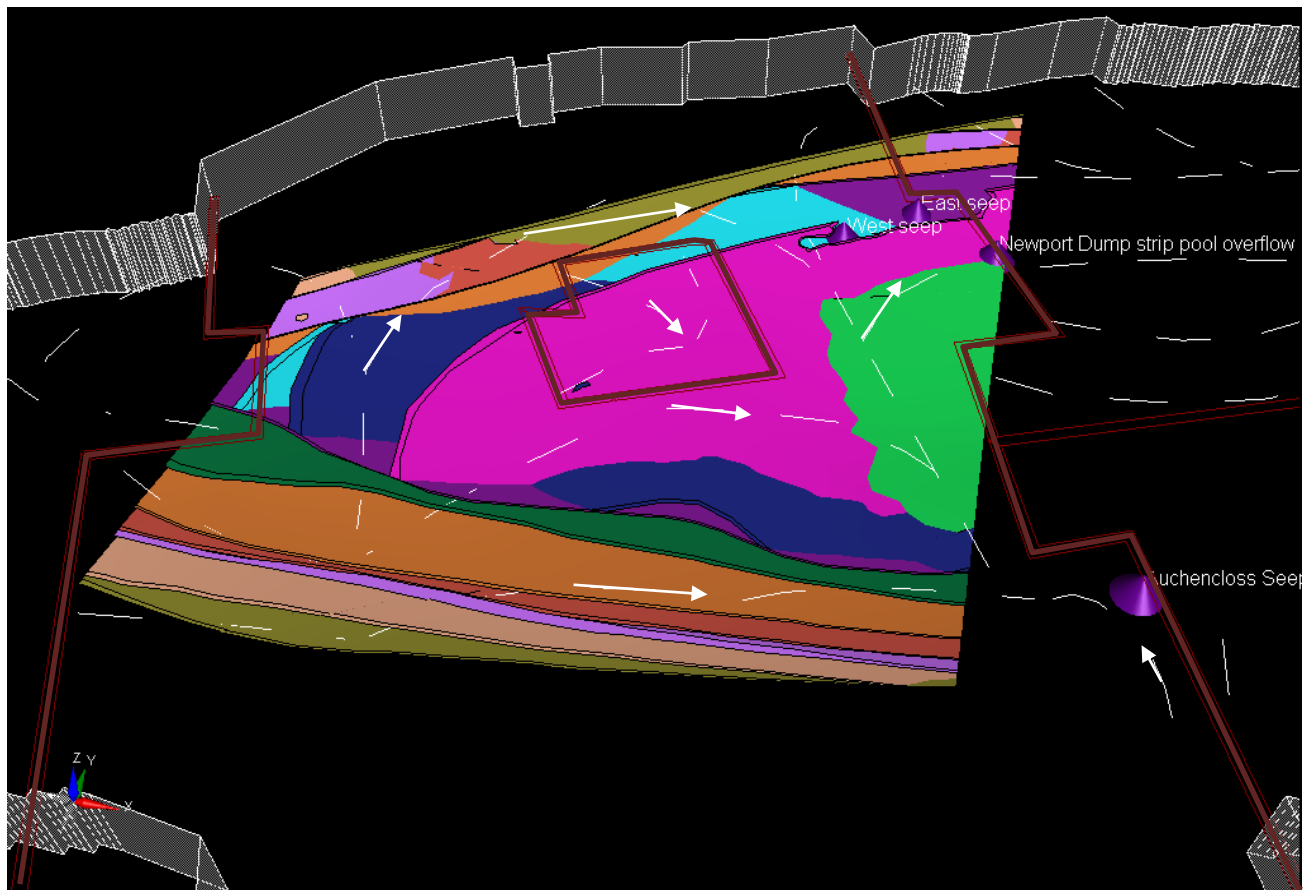


Figure 42: EarthVision Model of Wanamie and Stearns Colliery Mine Pools at 600 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Lt. Green=Five Foot Dk. Pink=Four Foot, Dk. Blue=Diamond, Lt.Blue=Top Rock, Dk. Purple=Rock, Green=Baltimore, Orange=Marcy, Red=Clark, Lt.Purple=Top Red Ash, Pink= Mid. Red Ash, Tan= Btm. Red Ash..



The Glen Lyon Mine holds a pool at ~660 feet to the north and ~860 feet to the south, separated by an anticlinal ridge. The northern portion discharges to the Glen Lyon Pump shaft (655'). This is an intermittent discharge that dries up especially in the summer months when the level of the mine pool goes below 663'. This indicates that it is connected to another larger discharge, which most likely is the Newport Lake discharge. The southern portion of the mine allegedly discharges to the surface and forms the headwaters of Black Creek. The discharge may be treated, a field investigation is warranted.

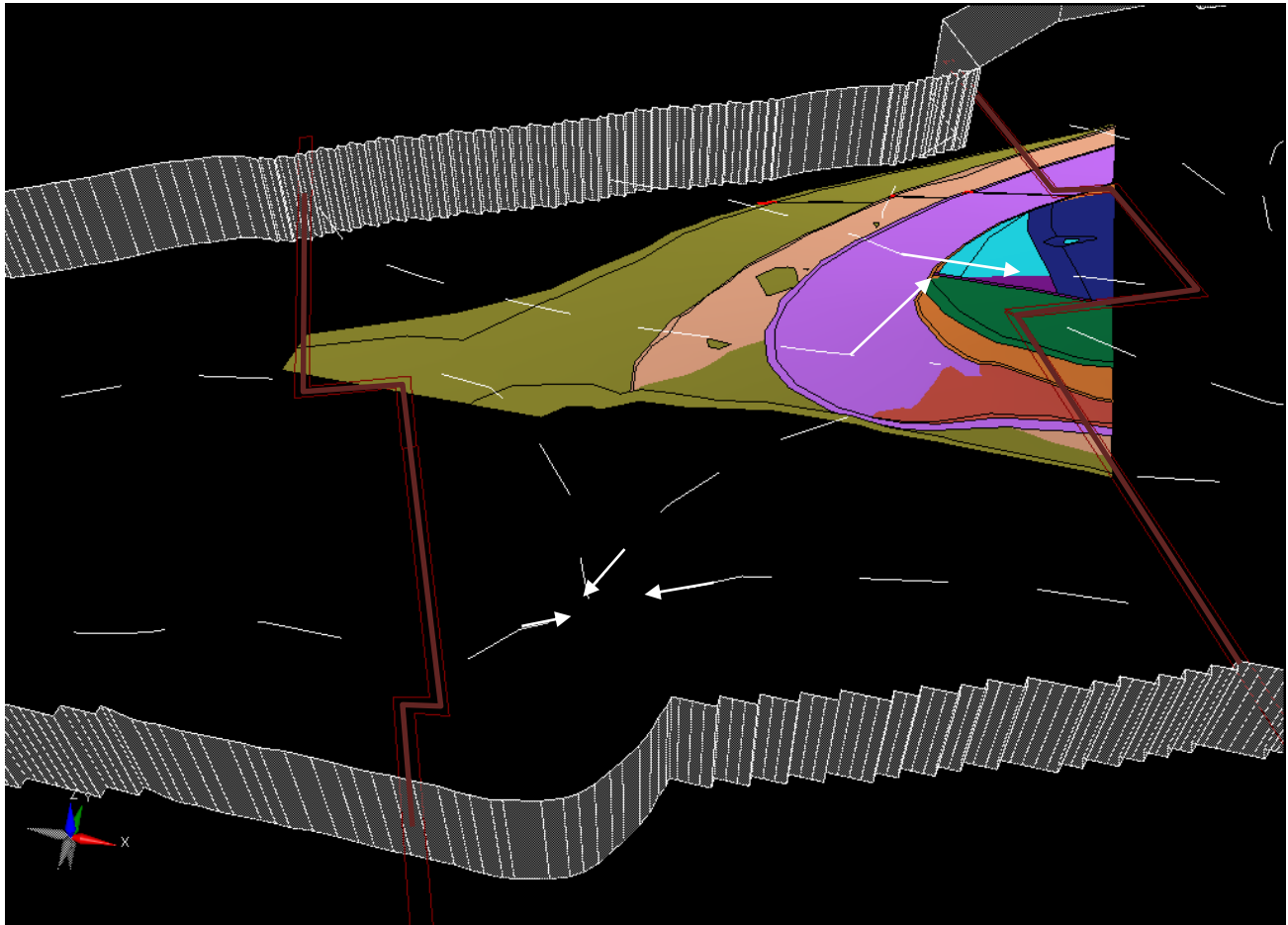


Figure 43: EarthVision Model of Glen Lyon Colliery Lower Mine Pool at 660 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Dk. Blue=Diamond, Lt.Blue=Top Rock, Dk. Purple=Rock, Green=Baltimore, Orange=Marcy, Red=Clark, Lt.Purple=Top Red Ash, Pink= Mid. Red Ash, Tan= Btm. Red Ash..

The West End Mine holds an upper pool at 700 feet behind an anticlinal ridge which acts as a dam to the lower pool at 580 feet. The upper pool may also backup to 780 feet in times of high precipitation and flow through the barrier pillar to the Glen Lyon to join flow in the southern portion of the mine. The lower pool is drained by the Mocanaqua Tunnel directly to the Susquehanna River at 524 feet. See Appendix H for a 2D representation of current mine pool boundaries in the Wyoming Valley based off this 3D model.

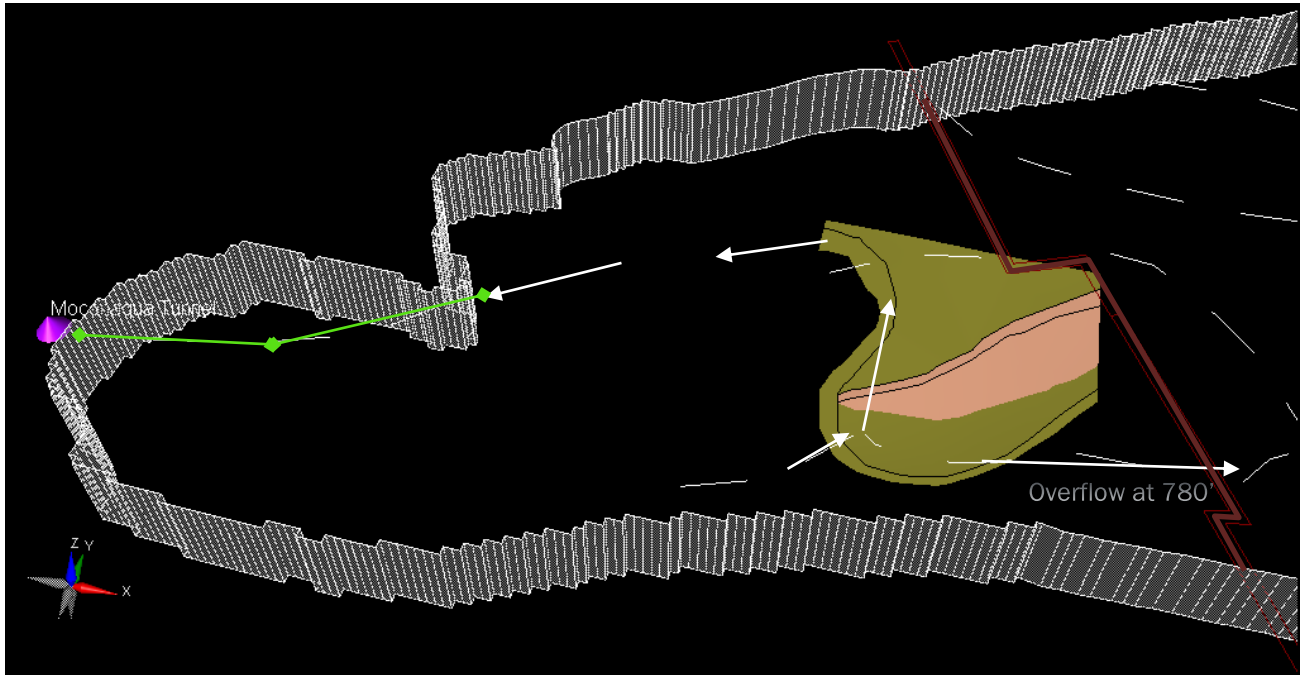


Figure 44: EarthVision Model of West End Colliery Upper Mine Pool at 700 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Pink= Mid. Red Ash, Tan= Btm. Red Ash.

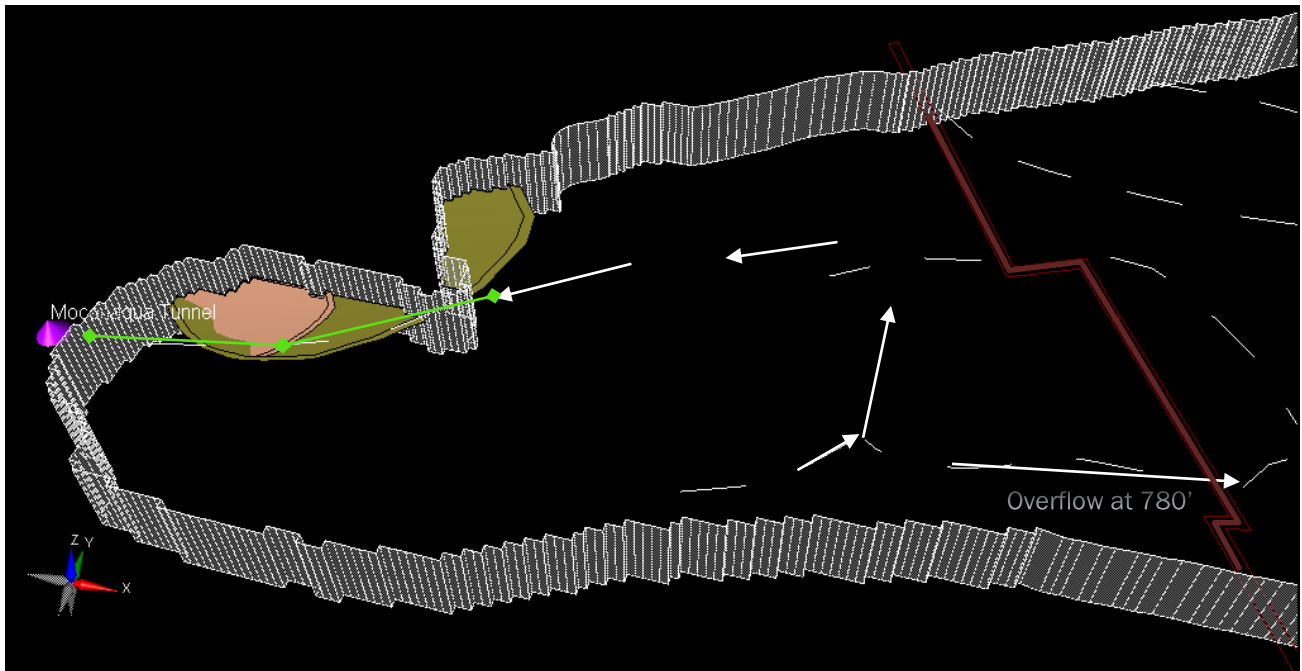


Figure 45: EarthVision Model of West End Colliery Lower Mine Pool at 580 feet. White arrows show flow direction, gray curtains approx. colliery boundaries. Red box indicates barrier pillar. Green line indicates drainage tunnel. 3D Grids: Pink= Mid. Red Ash, Tan= Btm. Red Ash.

### 3.6 Mine Pool Interpretation and Data Gaps

The EarthVision 3D Modeling software accepts raw input scattered data and interpolates grid values in between the given data. In general, as the model nears the edges of the data coverage, the incidence of error becomes greater as the model tries to interpolate grids with insufficient information. Also, because of the complex synclinal geology and faulting, drooping occurs between data nodes. The greater the distance between notes, the greater the droop. Data was calculated by averaging values between nodes to correct large drooping areas. More data around edges and between nodes is needed for a more accurate model. Site or mine boundary specific information may require additional boundaries, elevation data compilation and field work not proposed in the original scope of work. Slicing of the regional model to estimate calculated mine pool volumes is limited to the ability to slice on the X, Y and Z axes. The regional model cannot be clipped with a polygon the 3D Viewer, therefore the layers cross barrier pillars unintentionally as seen in Figure 41 related to the Susquehanna #7 Mine Pool 3D Model. In order to get better estimates, the individual mine must be clipped with a polygon boundary or extent boundaries using the 3D Modeling Tool.

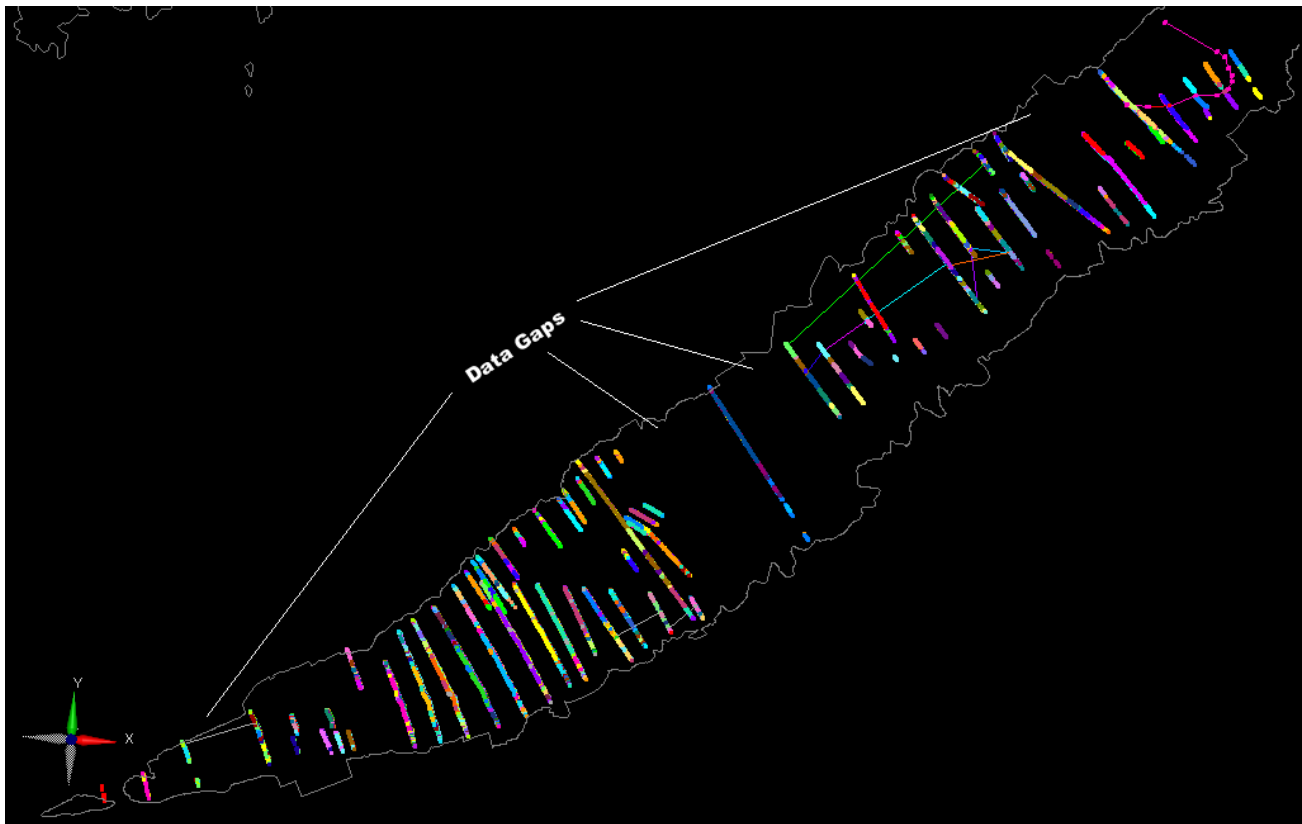


Figure 46: Data gaps in the Northern Anthracite Field below the Archbald Fault (Wyoming and Lower Lackawanna).

Previous studies used ModFlow, a U.S. Geographic Survey (USGS) modeling program, which estimates ranges of groundwater volumes based on the hydrology of the reservoir. This program was considered initially as a way to calculate mine pool volumes. The ModFlow program is good at estimating volumes,



Figure 47: Resulting 3D model of combined Wyoming and Lower Lackawanna Valleys scattered cross section data. 11 individual coal veins are represented with true 3D grids.

but does not produce true 3D grids nor can it take detailed geologic information (i.e. 100 foot contours instead of 500 foot contours). Therefore even regional models, like those produced in this report, cannot be as exact as volume calculations from EarthVision.

The original mine maps typically do not have legends and therefore require interpretive skills to decode the symbols. Often times the symbology is vastly different from map to map depending on the company that produced the map. S.H. Ash had this to say about the maps encountered in the 1950's: "In many instances the same bed is designated by different names at adjoining mines. The four beds generally known as the Dunmore beds in the Lackawanna Basin are below the Clark bed. The method of identifying them varies with different mining companies. The upper Dunmore bed is very thin, and some mining companies ignored it entirely and assigned names to the remaining beds as follows: No.1, No.2, and No.3 Dunmore beds. Other companies recognized the upper bed and assigned numbers to the four beds as follows: No.1, No. 2, No.3, and No.4 Dunmore beds. Consequently, the No.1 Dunmore bed at one mine may be known as the No.2 Dunmore bed at an adjoining mine, the No.2 Dunmore bed as the No.3

Dunmore bed, and the No.3 Dunmore bed as the No.4 Dunmore bed.” This is only one instance, some veins are called something entirely different.

EPCAMR staff relied on experience gained from the late Roger Hornberger and other mining geologists that collaborated on earlier mine pool mapping initiatives to help with the interpretation of these maps. A detailed analysis of flow regimes was not completed, but general flow direction was taken from Ash Reports and manipulated to assume present day conditions.

### 3.7 Analysis of Mine Pool Volumes

#### Southern Anthracite Coal Field

Cessation of underground mining occurred later in the Southern Anthracite Coal Field than many of the others. Therefore, many of the underground mine pools that were calculated by Ash and others in the 1950s have changed slightly to drastically. In some cases mine pools were not able to be calculated because the underground mines were still in operation. Present day estimates are gathered solely on 3D Modeling. Unless otherwise specified, elevations are measured in feet above mean sea level (MSL) and void space was estimated at 40%.

*Heckscherville Valley Mine Pools (West to East): Total 6,268,433,000 gallons*

There are at least 7 collieries with interconnected mine pools at different stepped elevations as the valley lowers in elevation from West to East, known as the Pine Knot Multi-Colliery Hydrological Unit (MCHU). They discharge through the Pine Knot Tunnel which flows through the mountain to the West Br. Schuylkill River. One mine pool in this complex (Neumeister), which originates in the Susquehanna Watershed, has its own discharge, but it flows into a pit that funnels the discharge back into the Pine Knot MCHU. One isolated mine pool (Repplier), with its own water level tunnel, discharges through the mountain to Mill Creek (East Br. Schuylkill River).

Note: This excludes the furthest west extent of the Glendower mine pool (Neumeister), due to lack of map and cross section data. Being on the edge of the model, the software cannot calculate an accurate mine pool for this area. Also, elevations were assumed from historical mine pool levels. Just recently, one borehole was drilled in the Pine Knot Colliery by DEP Pottsville DMO. The current borehole water elevations have been recorded between 762-764 feet above MSL.

Buck Run (Dam Basin) Mine Pool:

S. H. Ash Estimate = 53,000,000 gallons from 1080 to 1203 feet (overflow to another mine)

EPCAMR Estimate = 338,800,406 gallons from 1000 to 1203 feet (overflow to another mine)

Percent Difference = 145% perhaps due to additional mining post 1950.

Notes: This overflows to the Buck Run (Old Basin) Mine @ 1203 feet where the Mine Hill fault acts as a dam to the adjacent Buck Run (Old Basin) Mine to the east.

Buck Run (Old Basin) Mine Pool:

S. H. Ash Estimate = 477,000,000 gallons from 475 to 781 feet (discharge to surface, to another mine)

EPCAMR Estimate = 511,352,951 gallons from 400 to 866 feet (discharge to surface, to another mine)

Percent Difference = 7% relatively close due to this being an area that was mined before 1950.

Notes: This overflows to the Thomaston mine through the Buck Run Tunnel, a discharge that comes out of the west of the Rohresville Pit and seeps back into the eastern side of the same pit (directly to the underground mines). Barrier Pillar XII acts as a dam at 866 feet to the adjacent Thomaston Mine to the east where the Buck Run Tunnel penetrates.

Neumeister Mine Pool (western portion of the Glendower Mine):

S. H. Ash Estimate = unknown

EPCAMR Estimate = Not enough information to build a 3D model of the area

Notes: Cross sections show the mine dips to the west in the Little Mountain (or Deep Creek) Synclinal Basin (away from the Glendower Mine) at an anticlinal ridge that peaks just east of Interstate 81. The Neumeister discharge to the surface is on the easternmost flank of the mine at 1520 feet above MSL. There is also a related seep that seems to come from the base of Interstate 81 as seen on aerial photography. Both of these mine drains (about 500 gallons per minute) run along the surface and disappear into pits in the Glendower Mine where they most likely become part of the mine drainage that exits the Pine Knot Tunnel. It may be feasible to tap a drainage borehole into this mine from the south (Swatara) or north (Hans Yost Creek) drainage areas to the west to a treatment system and away from becoming additional mine drainage to the Schuylkill Watershed.

Glendower Mine Pool:

S. H. Ash Estimate = 403,000,000 gallons from 436 to 815 feet (was pumped at time)

EPCAMR Estimate = 928,859,161 gallons from 400 to 1030 feet (overflow to another mine)

Percent Difference = 79% mostly from 215 feet rise in mine pool due to cessation of pumping post 1950.

Notes: This mine was pumped to a surface elevation of 1315 feet, but now most likely overflows to the Richardson mine. Barrier Pillar XIII acts as a dam at 1030 feet to the adjacent Richardson Mine to the east.

Richardson Mine Pool:

S. H. Ash Estimate = 625,000,000 gallons from 374 to 871 feet (overflow to another mine)

EPCAMR Estimate = 1,213,266,701 gallons from 400 to 790 feet (overflow to another mine)

Percent Difference = 64% due to additional mining post 1950.

Notes: This mine overflows to the Thomaston mine. Barrier Pillar XI acts as a dam at 790 feet to the adjacent Thomaston Mine to the east. Barrier Pillar XIII acts as a dam at 1030 feet to the adjacent Glendower Mine to the west.

Thomaston Mine Pool:

S. H. Ash Estimate = 784,000,000 gallons from 375 to 871 feet (overflow to another mine)

EPCAMR Estimate = 1,073,047,286 gallons from 300 to 790 feet (overflow to another mine)

Percent Difference = 31% due to additional mining post 1950.

Notes: This mine overflows to the Pine Knot mine. Barrier Pillar X acts as a dam at 764 feet to the adjacent Pine Knot Mine to the east. Barrier Pillar XI acts as a dam at 790 feet to the adjacent Richardson Mine to the west.

Pine Knot Mine Pools:

S. H. Ash Estimate = 600,000,000 gallons from 208 to 682 feet (was pumped at time)

EPCAMR Estimate = 2,088,508,512 gallons total combined (discharge to surface)

Percent Difference = 111% due to additional mining post 1950.

Notes: Mine was pumped to the Pine Knot #2 shaft during Ash reports. The Pine Knot Tunnel drains this mine and several others to the west to a surface elevation of 732 feet as measured by a borehole newly drilled into the mine pool. Barrier Pillar VIII separates this mine with the adjacent Replier Mine to the east. Barrier Pillar X acts as a dam at 764 feet to the adjacent Thomaston Mine to the west. Two pools exist in this mine at different depths. East of the tunnel the pool was calculated to 1,706,411,495 gallons from 300 to 760 feet @ 40% void space. West of the tunnel, the pool was calculated to 382,097,017 gallons from 550 to 760 feet @ 40% void space

Replier Mine Pool:

S. H. Ash Estimate = unknown (was pumped at time)

EPCAMR Estimate = 114,598,235 gallons from 750 to 876 feet (discharge to surface)

Percent Difference = NA

Notes: Mine was pumped to a surface elevation of 1,006 feet during Ash reports and a mine pool was never calculated. The Replier Tunnel is known to drain this underground mine pool. Barrier Pillar VIII separates this mine from the adjacent Pine Knot Mine.

*Rausch Creek Valley (North to South): Total 2,563,015,000 gallons*

Markson Mine Pools (South Dip Donaldson Basin):

S. H. Ash Estimate = unknown (Scarlift #112 estimated 100,000,000)

EPCAMR Estimate = 239,454,838 gallons from 400 to 861 feet above MSL @ 40% void space

Percent Difference = NA

Notes: Markson South Dip mines discharging to Markson Columnway are from the Llewellyn Formation (Buck Mountain to Mammoth Veins) but a mine pool was never determined by Ash. An estimate was calculated in Scarlift Report #112. Barrier Pillar XXVII holds back the Good Spring No.1 pool on the east side. Perched pools exist in the Lykens Valley Veins up the hill and have their own discharge at H& R Coal Co. intermittent pump discharge at about 1,400 feet above MSL.



Valley View Mine (North Dip Donaldson Basin):

S. H. Ash Estimate = unknown

EPCAMR Estimate = 387,956,309 gallons from -400 to 906 feet above MSL @ 40% void space

Percent Difference = NA

Notes: Markson North Dip mines discharging to Valley View Tunnel are from the Llewellyn Formation (Buck Mountain to Mammoth Veins) but a mine pool was never determined by Ash. Barrier Pillar XXVII holds back the Good Spring No.1 pool on the east side Markson North Dip and South Dip mines are connected through the Markson No. 5 Tunnel, but the tunnel is steeply dipping and connects at 655 feet on one side and 917 feet on the other side (above both Markson Columnway and Valley View Tunnel discharge elevations), therefore rendering them unconnected under normal flow regimes. Veins above the Mammoth (i.e. Orchard and Diamond Veins) were intermittently mined under the East Rausch Creek Valley and several small seeps emanate near the stream channel, but no substantial mine pools are known to exist under the creek.

Brookside Mine Pool:

S. H. Ash Estimate = 1,944,000,000 gallons from -409 to 906 feet (discharge to surface)

EPCAMR Estimate = 1,935,604,349 gallons from -400 to 906 feet (discharge to surface)

Percent Difference = 0.4% very close to original; gravity drain conditions are similar to 1950s

Notes: The Brookside Mine exists in the Lykens Valley Veins only and S.H. Ash knew that as well. It is gravity drained by the Valley View Tunnel. The East Brookside shaft water elevation was measured at 950' while the water level tunnel discharge was at 906'. There could be a constriction in the mine that holds approximately 40' of water in the east side of the mine. The Tower City Mine exists in Llewellyn Formation above which is drained separately via the Porter Tunnel.

**Northern Field**

Cessation of underground mining began in the 1950s, during Ash's investigations, and lingered into the 1960s due mainly to a weakening market demand for coal and rising pumping costs. In 1959, the Knox Mine Disaster occurred which opened a hole in the bottom of the Susquehanna River and completely

flooded most of the mines in the Wyoming Valley. The cost to pump this much water, as opposed to pumping to maintain a specific water level, would have been an astronomical cost. In the Lackawanna Valley, the last to operate the pumps in the Scranton Metropolitan Mine Pool was the Moffat Coal Company. By 1960 most mining companies had realized that deep mining in the Lackawanna Valley was an unprofitable endeavor. Massive pumping operations were being operated at great expense to dewater vast areas that were not being actively mined. These included Hudson Coal Company's Marvine and Eddy Creek collieries, as well as Moffat at Storrs, National, Hampton, and Pyne mines. Early in 1960 Moffat was informed by the Hudson Coal Company that it would cease its pumping operations on November 1, 1960. With the loss of Hudson's plant, Moffat would be forced to assume that pumping operation to prevent water from rising, and flooding its operations. This was too much for Moffat. So they also announced they would cease pumping on November 1st. Mining was abandoned abruptly in the Clark Vein, one of the more profitable veins. Many of the underground mine pools that were calculated by Ash and others in the 1950s have changed slightly to drastically. In some cases mine pools were not able to be calculated because the underground mines were still in operation. Present day estimates are gathered solely on 3D Modeling. Unless otherwise specified, elevations are measured in feet above mean sea level (MSL) and void space was estimated at 40%.

*Lackawanna Valley (North to South): Total ~160,923,304,000 gallons*

The Lackawanna Valley is typically generally broke up into two parts: the Upper Lackawanna and the Lower Lackawanna. The division point is the Archbald Fault near Archbald, PA. Elevations are measured in feet above mean sea level (MSL).

Upper Lackawanna Mine Pools: Total ~15,268,000,000 gallons

There are at least five perched/isolate mine pools in the Upper Lackawanna with their own discharges.

Limitations: There are no current borehole elevations in the Carbondale Pool. PA DEP Bureau of Conservation and Restoration staff in the Wilkes-Barre Office mentioned that there were possibly other boreholes they used to monitor. There is information existing in the Abandoned Mine Land Inventory (AMLIS) Database near Meredith Street between Business Route 6 and Express Route 6. These could not be discovered in field investigations. Also there are a few places where the pools could reach the surface (veins show above surface in the model). This could be an error in the model, but it could also indicate water filled pits or saturated zones where we could monitor the water levels.

Forest City Pool:

S. H. Ash Estimate = 701,875,000 gallons @ 1,384 feet (overflow to surface)

EPCAMR Estimate = 3,695,999,522 gallons @ 1,384 feet (overflow to surface)

Percent Difference = 136% see notes

Notes: Perhaps Ash only calculated the pool in the Clark vein as in the Carbondale Pool, but from what the OSM Folio cross sections show, the veins were mined all the way down to the Dunmore #3 (Bottom Red Ash). Also, the average elevation of the mine pool in the Forest City Borehole #101 is 1420 feet. The elevation of the discharge is 1382'. There could be a barrier pillar (or some other barrier) holding ~50 feet of water in the northern most portion of the pool.

Coalbrook Pools:

S. H. Ash Estimate = unknown

EPCAMR Estimate = 5,920,090,787 gallons @ 1,210 & 1,251 feet (overflow to surface).

Percent Difference = NA

Notes: Cross sections suggest all veins were mined, therefore all were used to calculate water volumes. Upper pool was a calculated via a subtraction (Both Pools 5,920,090,787 at 1,251 – Lower Pool at 2,981,934,525 at same elevation = Upper Pool at 2,203,105,208 gallons @ 1,210 feet). Hollowell basins do not line up properly based on model, but model lines up better with limit of coal shapes. Perhaps Hollowell basins are off to the southwest by 3,000 feet. No current boreholes, water levels assumed from discharge elevations at the Simpson Shaft (1210') and Simpson Drift (1251').

Carbondale Pool:

S. H. Ash Estimate = 27,847,000 gallons @ 953 feet (pumped at time)

EPCAMR Estimate = 21,447,654 gallons @ 953 feet (overflow to another mine)

Percent Difference = 26% see notes

Notes: Estimate represents the Clark Vein only; in this area Dunmore Veins were not mined. If not, it would be ~1.3 Billion. Ash probably knew this as well. 953 feet is the estimated spill over at the Middle Red Ash vein to Jermyn Pool. Pool may be higher since its not pumped, but no current borehole information

exists therefore 953 feet elevation was kept. Pool up to 1,000 feet would not reach surface and would begin to fill the Top Clark vein as well, yielding 348,438,396 gallons of water. Borehole #102, on maps from OSM, was never found in field investigations. RAMLIS Information on Problem Area 3756 indicates a borehole that may still exist near the intersection of Meredith St and old Rte. 6 (near PPL substation): “AMLF #5 (MO): THE OPENING IS A STEEL CASED (WATER FILLED) BOREHOLE. THE BOREHOLE IS LOCATED APPROXIMATELY 75' NORTHWEST FROM THE INTERSECTION OF ERIE AND GORDON STREET ONLY 24' WEST OFF THE CENTER LINE OF LACKAWANNA AVENUE. THE BOREHOLE WAS 24" DIAMETER STEEL PIPE WITH A 12" OPENING. THE PIPE ROSE 42" ABOVE THE GROUND SURFACE WITH WATER EXISTING ONLY 9' DOWN FROM TOP OF PIPE. THE BOREHOLE WAS PARTIALLY CONCEALED WITH TALL GRASS AND LIES ONLY 5' SOUTHEAST FROM A DETERIORATING WOODEN SHED. GARBAGE WAS SEEN LYING AT THE BOTTOM OF THE BOREHOLE (BOTTLES, WOOD, ETC.)”

Also, water filled pits exist in vicinity along RR tracks and may represent water level of mine pool.

#### Jermyn Pool:

S. H. Ash Estimate = 4,045,000,000 gallons @ 925 feet (overflow to surface)

EPCAMR Estimate = 4,020,320,872 gallons @ 921 feet (overflow to surface)

Percent Difference = 0.6% probably so close due to little mining after 1950 and similar drain scenario

Notes: Current water elevation at the Jermyn Borehole #103 used for model. The pool is drained by the Jermyn Discharge to the Lackawanna River at 925', but the model also shows a low area behind the Mobile Home Park off the Main Street in Jermyn at about the same surface elevation of the Jermyn discharge where Callender Gap Creek flows. The creek is on the list of impaired waters and may indicate a secondary discharge? Field investigation recommended.

#### East Side Pools:

S. H. Ash Estimate = NA

EPCAMR Estimate = 1,590,685,657 gallons @ 1,200 & 1,300 feet.

Percent Difference = NA

There are at least 2 mine pools opposite the Jermyn pool perched in the east mountain on the other side of the Archbald Fault. The Upper Pool calculated to 1,365,211,091 gallons @ 1,300 feet above MSL at 40% void space feeds the Aylesworth Creek Discharges. These discharges are acidic and contain mostly

aluminum as the main pollutant, which is an indication that the mine pool only exists in the Red Ash veins. The discharge is treated with an oxic limestone drain. The Lower Pool calculated at 225,374,566 gallons @ 1,200 feet above MSL at 40% void space feeds the Dana Tunnel and/or Mt. Vernon Shaft (would need better location via GPS). Water quality is similar to the Aylesworth Creek Discharges. There could be many more small pools further north, but there is an absence of data making the model all too speculative in these areas. More clarification could be gained with the Aylesworth Creek and Dana Tunnel Pools if raw data from the Upper and Lower Lackawanna Models were combined and modeled together.

Lower Lackawanna Mine Pools: Total ~145,655,304,000 gallons

The Lower Lackawanna basin consists of over a dozen different collieries. Almost all the water discharges to one point, the Old Forge Borehole. There are only two smaller discharge areas: the Lackawanna and the Gravity Slope.

Lackawanna Mine Pool:

S.H. Ash Estimate = 753,723,000 gallons @ 777 feet (discharge to surface)

EPCAMR Estimate = 384,507,199 gallons @ 777 feet (discharge to surface)

Percent Difference = 65% unknown reason for difference, area is lacking in data coverage

The Lackawanna and Ontario Collieries are isolated by barrier pillars from other mines and have their own discharge through the Jerome Shaft (Lackawanna) discharge. Wet weather flows also were known to back up to 933' and discharge to surface tunnel in Ontario Mine. The Lackawanna Borehole was inaccessible (paved over) and therefore the elevation of the discharge was assumed to be the water level. This area seems to be lacking in data coverage. Recommend daylighting borehole and finding more cross sections.

Gravity Slope Mine Pool:

S.H. Ash Estimate = 1,792,700,000 gallons @ 822 feet (discharge to surface)

EPCAMR Estimate = 2,860,040,202 gallons @ 828 feet (discharge to surface)

Percent Difference = 46% see notes

The Riverside and Gravity Slope Collieries are isolated by barrier pillars and the Archbald Fault and have their own discharge area at the Gravity Slope discharge @ 822' and boreholes. The Winton Borehole averaged a water level of 828 feet during the study period and was used to determine the current water level. The volume would be 1,895,612,530 without TRA and BRA veins, perhaps this is the difference in volumes from the 1950s.

Scranton Metropolitan Mine Pool:

S.H. Ash Estimate = 3,658,823,000 gallons @ 235, 250, 300, 310, 315, 320, 405, 416, 455, 475, 486, 490, 603 & 615 feet (several collieries pumping at the time)

EPCAMR Estimate = 133,788,056,324 gallons @ 610 & 710 feet (discharge to surface)

Percent Difference = 189% mines were pumped down in the 1950s to sustain underground mining

This collection of mines is nicknamed the Scranton Metropolitan Mine Pool and has a common discharge at the Old Forge Borehole. Approximately 128 Billion gallons of water is a conservative estimate when setting the water level at 610', but there are portions of the pool in the upper areas, Olyphant and Miles Collieries, which were observed by borehole water level readings @ 710 feet above mean sea level (100' higher). Therefore a 2 step approach was taken to calculate the mine pool. Olyphant Colliery and up the valley were calculated separately to 42,844,242,624 gallons at 710'. Collieries below Olyphant were calculated to 90,943,813,700 gallons at 610' for a combined total of ~133,700,000 gallons which discharges out the Old Forge Borehole and overflows to the Duryea Breach at times of heavy precipitation.

Duryea Mine Pool:

S.H. Ash Estimate = 1,865,200,000 gallons @ 177 & 454 feet (pumped at the time)

EPCAMR Estimate = 8,622,699,987 gallons @ 550 & 570 feet (discharge to surface)

Percent Difference = 128% mines were pumped down in the 1950s to sustain underground mining

The Duryea and Central Collieries are downstream of the Moosic Saddle, a prominent anticlinal ridge that runs perpendicular to the synclinal basin of the Lackawanna Valley. It essentially divides the Lackawanna from the Wyoming Valley geologically. The upper Central Mine pool was measured at 570' and separated

by a leaky barrier pillar to the Duryea Mine. The volume of this upper pool was estimated to be ~307,665,004 gallons @ 570 feet at 40% void space and leaks thru barrier. The lower Duryea Mine pool is at an elevation of 550' as determined by water levels in the Number 9 Mine Borehole and the Duryea Breach elevation. The volume of the lower mine pool was ~8,315,034,983 gallons @ 550 feet at 40% void space and discharges to surface through the Duryea Breach.

*Wyoming Valley (North to South): Total ~274,370,518,000 gallons*

Butler Mine Pool:

S.H. Ash Estimate = unknown (pumped at the time)

EPCAMR Estimate = not calculated (discharge to surface)

Percent Difference = NA

The Butler Mine Pool was not calculated due to lack of data in the area.

Northwestern, Southeastern, Loomis and Inman Mine Pools:

S.H. Ash Estimate = 2,831,210,000 gallons @ -170, 45, 60, 120, 122, 125, 160, 200, 278 & 340 feet (pumped at the time)

EPCAMR Estimate = 240,613,057,115 gallons @ 530 feet (discharges to surface)

Percent Difference = 195% mines were pumped down in the 1950s to sustain underground mining

The Northwestern and Southeastern mine pools each have two major discharges. A local mine pool study should be done to divide up the total into individual volumes for each mine pool. The Loomis mine pool also has two discharges, but they are different chemically, therefore they come from different strata in the mine. The Inman mine pool is isolated and the discharge is chemically neutral and devoid of heavy metals.

Grand Tunnel Mine Pool:

S.H. Ash Estimate = unknown (pumped at the time)

EPCAMR Estimate = 60,207,582 gallons @ 580 feet (discharges to surface)

Percent Difference = NA

The Grand Tunnel discharge exists in the Red Ash veins only above 540'. The lower portion of this mine overflows to Avondale joining drainage in the Northwestern Mine Pool.

Susquehanna #7 Mine Pool:

S.H. Ash Estimate = unknown (pumped at the time)

EPCAMR Estimate = 17,772,994,241 gallons @ 540 feet (discharges to surface)

Percent Difference = NA

The Susquehanna #7 mine pool discharges to the #2 Airway at 538' and secondarily to the Auchenloss Seep. A barrier pillar which acts as a dam for the Alden mine holds a pool at 580' and flows to the Susquehanna #7 pool below.

Wanamie and Stearns Mine Pools:

S.H. Ash Estimate = unknown (pumped at the time)

EPCAMR Estimate = 12,925,046,660 gallons @ 600 feet (discharges to surface)

Percent Difference = NA

The Wanamie Mine pool discharges to Newport Lake and related seeps. The Stearns mine pool is completely surrounded and isolated from the Wanamie pool by barrier pillars. The Stearns most likely has its own discharge via borehole as reported by previous reports.

Glen Lyon Mine Pools:

S.H. Ash Estimate = unknown (pumped at the time)

EPCAMR Estimate = 2,483,495,586 gallons @ 660 & 860 feet (discharges to surface)



Percent Difference = NA

The northern portion of this mine pool discharges to the Glen Lyon Pump at 660 feet. The mine pool is calculated at 1,798,735,996 gallons. The southern portion of this mine, separated by an anticlinal ridge, discharges to the surface at 860 feet and may be treated. The mine pool in this area is calculated as 684,759,590 gallons.

West End Mine Pools:

S.H. Ash Estimate = 237,270,000 gallons @ 500 & 800 feet (discharge to surface)

EPCAMR Estimate = 515,716,393 gallons @ 580 & 700 feet (discharges to surface)

Percent Difference = 74% unknown reason for difference other than difference in water elevations

The upper portion of the mine pool is held behind an anticlinal ridge at 700 feet. The pool is calculated at 403,478,223 gallons. In times of high precipitation the pool may discharge over the barrier pillar at 780 feet to the Glen Lyon southern mine pool. The lower portion of the mine is held at 580 feet and discharges through the Mocanaqua Tunnel to the surface at 524 feet. The lower mine pool is calculated at 112,238,170 gallons. This area has a great potential for storage similar to the Brookside Mine in the Southern Anthracite Field. The surface above is mostly forested and no homes are above this area. The pool is drained by a single tunnel. Monitoring boreholes should be placed in the 2 mine pools to obtain more current results and calibrate the model.

#### 4.0 DISCUSSION OF POSSIBLE MINE POOL MANIPULATIONS

Due to water's natural characteristic to "find the path of least resistance" and the law of gravity, anthracite mine pools tend to stratify like a deep freshwater lake. Also we know that "beach lines" in the mines provide the perfect environment to produce AMD pollution. As the water levels rise and fall with precipitation events, beach lines in the individual coal veins erode away exposing pyritic and other pollution causing material which dissolves into the water and circulates throughout the mine. If manipulation of mine pools is attempted, EPCAMR recommends at least 3 additions to water monitoring protocols be implemented as discussed below.

Stratification of mine water is discussed in three reports in the Bibliography: Barnes, et al. 1964, Ladwig, et al. 1988, and Brady, et al. 1998. Typically, the layers of water in the mine pools are referred to as "top water" and "bottom water". The top water is caused by shallow groundwater recharge and discharge cycles which is reported to account for approximately 75% of mine water flows, plus surface water entering the mine pool through subsidence features, fractures, faults, and other geologic features resulting in an opening to the mine (Ballaron 1999). The bottom water is in a deep zone that is usually not well circulated. The bottom water typically has sulfate concentrations of several hundred milligrams per liter and relatively high concentrations of acidity and metals. The top water, which is typically what discharges to the surface, has spent less time in the AMD production zones and carries sulfate and heavy metals concentrations less than 100 mg/l. Frequently these top water discharges meet the National Pollution Discharge Elimination System (NPDES) effluent limits for metals without treatment.

EPCAMR recommends that a chemistry depth sampling protocol be initiated, along with the water level monitoring, going forward throughout the Anthracite Region (approximately 40 locations) using a Kemmerer Bottle (or similar technology), where samples of the water quality at various depths within the boreholes at any number of mine pools can be obtained and tracked. The protocol would correlate to seasonal rainfall events, periods of suspected drought, and extreme weather events. A pilot test of this field testing application was initiated in the Jermyn Mine Pool at the Jermyn #103 Borehole at three different depths (surface of water, 10' below surface and 30' below surface) with Tom Clark, AMD Coordinator for the Susquehanna River Basin Commission, and was analyzed in a laboratory. EPCAMR was able to recreate results from reports like Ladwig et. al mentioned above. It was apparent that the deeper we sampled into the mine pool, the more severe the water quality appeared. Just in terms of the visual sample, black coal fines and heavy metal sediments that are often found in anoxic conditions were visually present.

This type of chemistry depth sampling protocol would be important in determining acceptable limits and depths within the mine pool should an entity consider drawing down the mine pool for reasonable

consumptive use projects. This would make sure the pumper would not jeopardize their operations by suddenly finding this stratified water and not having the ability to treat it properly or have a potential adverse effect on the drawing down of the mine pool. Pumping water down to a certain elevation within individual mine pools will have a drawdown effect that could lead to future subsidence, leading to roof collapses from within the mines beneath the ground. The effect could snowball to create artificial dams or blockages in the flooded mine workings backing mine water and increasing the elevation of the mine pools at various locations and possibly create unanticipated surface mine discharges, if it is not monitored carefully.

Existing mine discharges can vary in quantity seasonally with input of precipitation or snow pack melt leaking into the mines. Flushes of the mine can occur when extremely large amounts of water pour into the mine (i.e. flood events) and can overturn the water in the mine to flush out bottom water. For example in 2005, shortly after the \$2 million Audenreid Tunnel Treatment System went online, a storm event flushed “black goo” out of the Audenreid Mine directly into the collection system and the upwelling tanks of the limestone based passive system. Although a sample was never taken of this “goo” it was believed that this was a mixture of coal fines and anoxic forms of heavy metals precipitated in the mine over time and flushed out by the storm. The system has never operated at peak efficiency since this event. Considerable money will need to be spent to dig up the partially clogged piping and interstitial spaces in the limestone at the bottom of the tanks.

Artificially manipulating these natural seasonal fluctuations may be beneficial to control water quantity and quality flowing out of the discharge especially if these discharges are treated. An added benefit to retaining water and controlling the release is that water can be stored during storm events and released during times of drought. Each mine pool needs to be studied in depth to find the specific limits of mine pool water that it can hold before discharging in another location or destabilizing the surface causing subsidence. Wet weather sampling will obviously have to become a part of that sampling regime to catch storm flows and to assist with determining the lag time or residency time of the storm events and their correlation to how long it takes for the surface water or storm water to infiltrate the mine pools and have an impact on the quality and elevations within the respective mine pools.

Another water quality monitoring protocol that EPCAMR recommends is to install staff gauges on anthracite mine discharges to obtain proper flow readings throughout the year. Currently, this is being done at the South Wilkes-Barre AMD Boreholes, the Askam Borehole, and was attempted at the Duryea Breach. EPCAMR also recommends that a similar stream flow monitoring program be implemented on the dozens of periodically dry streams and surface tributaries (i.e. losing reaches) that feed the mine pools. An excellent example would be related to the “Duryea Swamps”, where Red Spring Run and Campbell’s

Run, feed the former Duryea Sand and Gravel operation pits. In an initial field investigation, water is seen feeding in, yet there is no apparent outlet of the surface runoff from this location to the river or another receiving stream. It is assumed that this water is lost to the mine pool below. A stream gauge placed above the pit to monitor the flow of water entering this area would be helpful in determining where inputs to the mine pool exist for possible diversion to keep water flowing on the surface.

The Brookside Mine, in the Southern Field, was studied in this project and could be an excellent candidate for trial of the above mentioned protocol, hypothesis and limits, since a majority of the land above the mine is State Game Land and few occupied structures exist in areas that have the potential for subsidence. In a cross section related to the Brookside Mine (in appendices), there was a proposal to place a brick dam within the Valley View Tunnel after the orchard vein intersection and raise the mine pool to a predicted 1040 feet. This is evidence to show that the coal company, who employed many engineers and surveyors at the time, thought that raising the mine pool was possible. The West End mine, at the furthest southwest end of the Northern Fields, is another mine with great potential for a pilot project to test practice of storing storm water flows in an anthracite mine and releasing during draught conditions. The West End mine is also above the Susquehanna Steam Electric Nuclear Power Plant, a consumptive user of water with the potential for expansion in the near future.

The Scranton Metropolitan Mine Pool connected to the Old Forge Discharge, on the other hand, has considerably more risk as a pilot project due to the thousands of occupied structures above the mine pool which are currently collapsing in the ground with natural fluctuations. A rise in only one (1) foot would produce an estimated 300 million gallons of additional water stored. A rise of only a five (5) feet, still within the natural seasonal fluctuation, however would produce a greater volume (1.5 Billion gallons) of potential storage capacity without much risk of collapse.

EPCAMR staff personally recall the flood in the summer of 2011, monitoring the mine pool levels and the aftermath of mine subsidence collapses in the local papers and news once the waters subsided (a month or 2 later). It was our conclusion that the elevated water inundating the mines created back pressure which loosened and flushed out rock and coal pillars. The subsidence did not occur right away since hydrostatic pressure helped to temporarily stabilize the surface, but after the water levels dropped and the mines dried out the collapses started happening very frequently. This could be the effect of artificially manipulating the mine water levels to the maximum.

Possibly the greatest proposal to manipulate mine pool levels and potential for devastating effects in the Anthracite Region was the idea of the Conowingo Tunnel in the 1950's. Instead of installing the Conowingo Tunnel, with remarkable foresight, \$17 Million was commissioned by Congress to backfill strip pits, install ditches, improve streams beds and install pumps to stabilize mine pools. Many neighborhood "flushing"

projects resulted from this pot of money to pump a flowable-fill slurry of waste coal and water to fill voids near the surface and mitigate subsidence before it happened. This and a national environmental movement led to the Surface Mining Control and Reclamation Act of 1977 setting aside a trust fund which still continues to reclaim surface mining features for environmental concerns, but had a byproduct of stabilizing the underground as well. An emergency program was, up until recently, administered by the Office of Surface Mining since 1980 to firstly control mine fires, but secondly to seal open mine portals and control surface subsidence that occur due to the collapse of underground mine voids. Residents of Pennsylvania enjoyed that benefit from the federal government up until 2010 when it was abruptly handed back over to the state and to be funded by the already taxed AML Trust Fund. Mine Subsidence Insurance is available from the state for those whose homes are at risk of collapse from underground mine voids.

## 5.0 PROPOSED NEXT STEPS FOR MAPPING

The intent of this study was to “paint a wide brushstroke” in estimating regional mine pool volumes of water. The specific mine pool volumes given are not as exact as they could be due to limitations of the EarthVision 3D Modeling software. It is EPCAMR’s recommendation to pick a pilot area (only one mine pool, i.e. Brookside Mine Pool) and digitize model directly from elevation points on mine maps (assuming they are available). Start by getting current surface elevations from LiDAR, then model this site specific area and start looking at areas with the most potential for subsidence as mine pools are artificially raised. Look for areas where new discharges would likely occur to another mine or to the surface.

Careful determination of what manipulated mine pool elevation could be achieved, should the mine pool be potentially used for storage, must be considered on a specific mine pool basis. Such a determination would also take into account the areas that could become discharge points. Utilizing the EarthVision 3D model for the manipulation of the mine pool would allow you to visually see what those elevations are that could be within an acceptable level for storage and release at a later time. Additional small diameter boreholes should also be considered to obtain elevation readings and/or water quality samples in specific areas where the determination is being made. The age and integrity of existing boreholes may factor in error depending on the specific condition of the bore. Other multi-colliery mine pools throughout the Anthracite Region can be evaluated and assessed in the same way. However, since they can be of much larger volumes and cover larger square mile areas, more time, additional funding, and considerable effort would have to be put into these hydrogeological investigations.

A detailed analysis of flow regimes was not completed in this report instead, general flow direction was taken from Ash Reports and manipulated to assume present day conditions. The individual flow paths of mine water can be determined by analysis of mine maps to determine specific vein elevations and porosity in all sections of the mines in question (i.e. pillar collapse sandwiching and seepage through weak barriers).

The idea of the Brookside Mine as a pilot project mentioned in the previous section would have an added benefit if peak water flows could be stored for later release and treatment. The Rausch Creek Treatment Plant treats the entire Rausch Creek year round. This plant was designed to treat a maximum amount of water at 12 CFS. Seasonally, this plant bypasses water that is excess of 12 CFS and other times it treats less than its maximum. Delayed release of the mine water at low flow times can aide in the efficiency of the plant instead of expanding the plant, and supply clean cold water to the fisheries and other water uses downstream. The use of SRBC’s Mine Water Treatment Portal to estimate downstream improvements as discharges are treated and pollutant sources are removed from the stream would provide measurable environmental results, pollution load reductions, and fishery improvements.

## 6.0 CONCLUSIONS

### Southern and Northern Anthracite Coal Fields

The complex geologic setting and historical mining of the anthracite mine pools creates a challenge to calculate the volume of water stored within the underground mines. This mapping effort has reasonably found that an estimated 8,831,448,000 gallons resides in storage in 10 mines in the southern field and approximately 435,293,822,000 gallons in all the Northern Field. Those results are summarized below.

- Heckscherville Valley Mine Pools (West to East): Total ~6,268,433,000 gallons
  - Buck Run (Dam Basin) Mine Pool: 338,800,406 gallons from 1000 to 1203 feet
  - Buck Run (Old Basin) Mine Pool: 511,352,951 gallons from 400 to 866 feet
  - Neumeister Mine Pool: Not enough information to build a 3D model of the area
  - Glendower Mine Pool: 928,859,161 gallons from 400 to 1030 feet
  - Richardson Mine Pool: 1,213,266,701 gallons from 400 to 790 feet
  - Thomaston Mine Pool: 1,073,047,286 gallons from 300 to 790 feet
  - Pine Knot Mine Pools: 2,088,508,512 gallons total combined
    - 1,706,411,495 gallons from 300 to 760 feet (east of Tunnel)
    - 382,097,017 gallons from 550 to 760 feet (west of Tunnel)
  - Repplier Mine Pool: 114,598,235 gallons from 750 to 876 feet
- Rausch Creek Valley (North to South): Total ~2,563,015,000 gallons
  - Markson Mine Pools (South Dip Donaldson Basin): 239,454,838 gallons from 400 to 861 feet
  - Valley View Mine (North Dip Donaldson Basin): 387,956,309 gallons from -400 to 906 feet
  - Brookside Mine Pool: 1,935,604,349 gallons from -400 to 906 feet
- Lackawanna Valley (North to South): Total ~160,923,304,000 gallons
  - Forest City Pool: 3,695,999,522 gallons @ 1,384 feet

- Coalbrook Pools: 5,920,090,787 gallons @ 1,210 & 1,251 feet
- Carbondale Pool: 21,447,654 gallons @ 953 feet
- Jermyn Pool: 4,020,320,872 gallons @ 921 feet
- East Side Pools: 1,590,685,657 gallons @ 1,200 & 1,300 feet
- Lackawanna Mine Pool: 384,507,199 gallons @ 777 feet
- Gravity Slope Mine Pool: 2,860,040,202 gallons @ 828 feet
- Scranton Metropolitan Mine Pool: 133,788,056,324 gallons @ 610 & 710 feet
- Duryea Mine Pool: 8,622,699,987 gallons @ 550 & 570 feet
- Wyoming Valley (North to South): Total ~274,370,518,000 gallons
  - Butler Mine Pool: The Butler Mine Pool was not calculated due to lack of data in the area.
  - Northwestern, Southeastern, Loomis and Inman Mine Pools: 240,613,057,115 gallons @ 530'
  - Grand Tunnel Mine Pool: 60,207,582 gallons @ 580 feet
  - Susquehanna #7 Mine Pool: 17,772,994,241 gallons @ 540 feet
  - Wanamie and Stearns Mine Pools: 12,925,046,660 gallons @ 600 feet
  - Glen Lyon Mine Pools: 2,483,495,586 gallons @ 660 & 860 feet
  - West End Mine Pools: 515,716,393 gallons @ 580 & 700 feet



## 7.0 LIMITATIONS

This report has been prepared in accordance with generally accepted geologic mapping practices for specific application to this project. This report has been based on assumed conditions and characteristics of the study area where specific information was not available.

The conclusions and recommendations contained in this report are based upon the data obtained during this investigation and on details stated in this report. The validity of the conclusions contained in this report is limited by the scope of field investigation and historic published data. Given the nature of subsurface conditions, absolute certainty is precluded; however this report represents the best available information using currently available data.

It is emphasized that subsurface modeling is dependent on available data and limited field work. Care should be taken to use the results as large scale estimation, as these models were built to quantify volumes within a region. Detailed limitations of the modeling software can be found in section 3.6 - Mine Pool Interpretation and Data Gaps and 3.7 - Analysis of Mine Pool Volumes. Site specific information may require additional data compilation and field work not proposed in the original scope of work. The validity of the projections and conclusions contained in this report may be affected by the available data collected that form the basis for those conclusions.

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