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# Anthracite Region Mine Drainage Remediation Strategy

## About this Report

This technical report, *Anthracite Region Mine Drainage Remediation Strategy,* includes:

- introduction to the region's geology & mining history;
- mining techniques and impacts;
- strategy methodology;
- discussion of data findings;
- basin-scale restoration plan; and
- recommendations.

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*Sterling Slope Pump Discharge in the Shamokin Creek Watershed.*

The largest source of Anthracite Coal within the United States is found in the four distinct Anthracite Coal Fields of northeastern Pennsylvania. The four fields – Northern, Eastern-Middle, Western-Middle, and Southern – lie mostly in the Susquehanna River Basin; the remaining portions are in the Delaware River Basin. The Susquehanna watershed portion covers nearly 517 square miles (Figure 1).

The sheer size of these four Anthracite Coal Fields made this portion of Pennsylvania one of the most important resource extraction regions in the United States and helped spur the nation's Industrial Revolution. Anthracite Coal became the premier fuel source of nineteenth and early twentieth century America and heated most homes and businesses.

The Anthracite Region of Pennsylvania, however, bears the legacy of past unregulated mining. With almost 534 miles of waterways impaired by abandoned mine drainage (AMD), it is the second most AMD-impaired region of the Susquehanna River Basin. Only the Bituminous Coal Region in the West Branch Susquehanna River Subbasin contains more AMD-impaired stream miles.

These mining impacts degrade the environment and limit the use of the waters of the Susquehanna River Basin as a resource. These losses are not just limited to biology, habitat, and recreation, but affect human health, quality of life, and the region's socioeconomic status as well.

The long-term goal of fully restoring the Anthracite Coal Region of the Susquehanna basin is an extremely challenging and ambitious one, especially in light of current funding limitations. However, opportunities exist in the Anthracite Coal Region that could encourage and assist in the restoration of its lands and waters.

For example, the numerous underground mine pools of the Anthracite Region hold vast quantities of water that could be utilized by industry or for augmenting streamflows during times of drought. In addition, the large flow discharges indicative of the Anthracite Region also hold hydroelectric development potential that can offset energy needs and, at the same time, assist in the treatment of the utilized AMD discharge.

To help address the environmental impacts while promoting the resource development potential of the Anthracite Coal Region, the Susquehanna River Basin Commission (SRBC) determined there would be significant benefits to developing a remediation strategy for this AMD-impaired region. SRBC initiated a review and analysis of water quality impacts and prepared the remediation strategy to be used as a guide to help resource agencies and organizations achieve comprehensive, region-wide environmental results over the long term.

From the outset of this project, SRBC stated its intention not to duplicate the efforts of other agencies and organizations where problem-identification and problem-prioritization initiatives were already underway or completed. Instead, the purpose of this strategy is to help identify overlapping goals and opportunities, and to offer alternatives for remediation efforts through conceptual treatment plant suggestions.

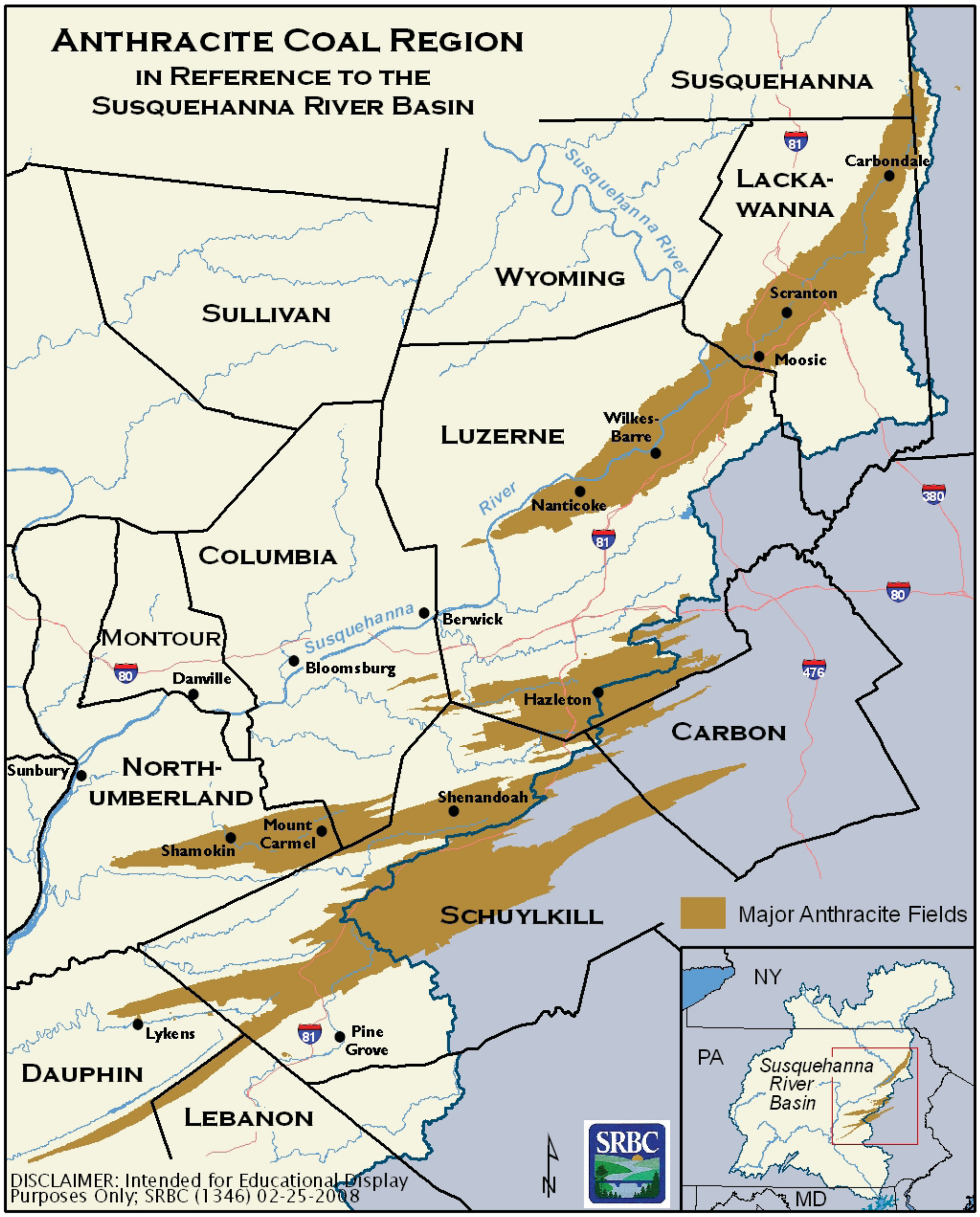



*Figure 1. Anthracite Coal Region*

## Geology

Pennsylvania's Anthracite Region – comprised of four distinct coal fields – is located in the Valley and Ridge Province of the Appalachian Mountains in eastern Pennsylvania. The four Anthracite Coal Fields are preserved in synclinal basins that are essentially surrounded by sandstone ridges (Hornberger et al., 2004).

Given the complexity of its geologic structure, the stratigraphy of the Anthracite Coal Region has not been studied as extensively as Pennsylvania's Bituminous Coal Region. The nearly vertical beds of coal and other rocks in some areas of the Anthracite Coal Fields have impeded the acquisition of stratigraphic data from routine exploration drilling. According to Wood et al. (1986), "Each coal field of the Anthracite Coal Region is a complexly folded and faulted synclinorium, with structural trends between N55°E and N85°E. The Southern Coal Field is the most highly deformed, with several highly faulted, closely spaced synclinal basins. Deformation is most complex toward the southeast, where it is characterized by hundreds of thrust, reverse, tear and bedding plane faults and tightly compressed, commonly overturned folds."

Detailed mine maps of the abandoned underground mines and cross-sections through vertical shafts and nearly horizontal tunnels have added to the understanding of the structure and stratigraphy of the Anthracite Coal Fields; however, most stratigraphic efforts have been directed toward coal seam delineation (Hornberger et al., 2004). A current mine pool mapping initiative by the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation (EPCAMR) may better characterize Anthracite Coal Region stratigraphy. Details of the mapping effort are described later in this strategy

Pennsylvanian-age rocks, formed around 300 million years ago, contain all the coal seams of the Anthracite Coal Region of Pennsylvania. They are divided into two major formations: the Pottsville and the Llewellyn.

The Pottsville Formation ranges in thickness from a maximum of about 1,600 feet (490 meters) in the Southern Coal Field to less than 100 feet (30 meters) in the Northern Coal Field (Hornberger et al., 2004). The Pottsville Formation contains up to 14 coal beds in some areas, but most are relatively discontinuous and only a few persist outside of the Southern Coal Field (Edmunds et al., 1999). The base of the Buck Mountain Coal Seam is considered the top of the Pottsville Formation in the Anthracite Coal Fields of eastern Pennsylvania.

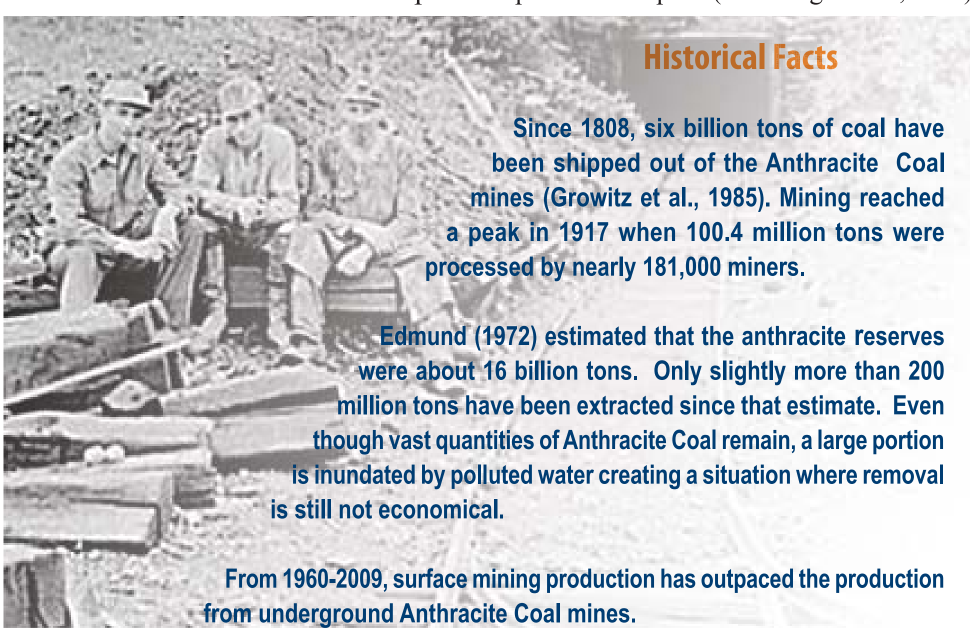
The Llewellyn Formation, overlying the Pottsville Formation, is as much as 3,500 feet thick (Hornberger et al., 2004). The maximum known thickness of the Pennsylvanian in Pennsylvania is approximately 4,400 feet near the town of Llewellyn in Schuylkill County (Edmunds et al., 1999). The Llewellyn Formation contains up to 40 mineable coals (Edmunds et al., 1999). The thickest and most persistent coals occur in the lower part of the Llewellyn Formation, particularly the Mammoth Coal Zone. The Mammoth Coal Zone typically contains 20 feet of coal, and thicknesses of 40 feet to 60 feet are not unusual. A local thickness of greater than 125 feet has been reported in the Western-Middle Field. This was attributed to structural thickening in the trough of the syncline (Hornberger et al., 2004). Interestingly, the nomenclature and stratigraphy of the coal bearing rocks of the Llewellyn Formation in the Northern Coal Field are different than in the Southern and Middle Coal Fields. For example, the lowest extent of coal in the Llewellyn Formation is called the Buck Mountain in the Southern and Middle Coal Fields, while that same seam is called the Red Ash in the Northern Coal Field (Edmonds, 2002).

## Mining History

As far back as 1755, Anthracite Coal was being used to a limited extent as a fuel in homes (Sanders and Thomas, Inc., 1975). It was not until 1808 that the real potential of Anthracite Coal was demonstrated when Judge Jesse Fell of Wilkes-Barre discovered that Anthracite Coal could be burned with a forced draught on a grate of his own invention (Berger Associates, 1972). Limited commercial production began in the 1700s, but it was not until the period from 1825 to 1835 that Anthracite Coal mining became an economically important industry. By 1828, railroad construction began and quickly spread throughout the geographic region. By the time the rail line to Philadelphia was completed in 1842, the Anthracite Coal industry became one of the giant economic industries in the United States, with most of the major coal companies being formed between 1825 and 1875 (Sanders and Thomas, Inc., 1975).

Mining reached a peak in 1917 when 100.4 million tons were processed by nearly 181,000 miners. A general strike by anthracite workers in 1926 crippled the industry through loss of markets resulting in a gradual decline of coal production, including the abandonment of many collieries (Berger Associates, 1972).

Anthracite production saw another growth period, which peaked during World War II when about 60 million tons per year were mined (Growitz et al., 1985). After World War II, production declined significantly due to: (1) competition from cheaper and cleaner fuels; (2) labor disputes that disrupted supplies at critical times; (3) labor-intensive mining methods (cost of water pumping); (4) depletion of more accessible coal beds; and (5) liability for water treatment and environmental concerns. In 1976, only six million tons were removed from Anthracite Coal mines. By 2001, Anthracite production was reported as 2,979,287 tons, around 3 percent of its peak (Hornberger et al., 2004).



### Historical Facts

**Since 1808, six billion tons of coal have been shipped out of the Anthracite Coal mines (Growitz et al., 1985). Mining reached a peak in 1917 when 100.4 million tons were processed by nearly 181,000 miners.**

**Edmund (1972) estimated that the anthracite reserves were about 16 billion tons. Only slightly more than 200 million tons have been extracted since that estimate. Even though vast quantities of Anthracite Coal remain, a large portion is inundated by polluted water creating a situation where removal is still not economical.**

**From 1960-2009, surface mining production has outpaced the production from underground Anthracite Coal mines.**

*Pennsylvania mine workers on a farm in Union Township, Pennsylvania, circa 1940. Library of Congress,FSA-OWI Collection (Jack Delano).*

## MINING TECHNIQUES & IMPACTS

Anthracite coal mining involves deep mining, surface mining, and mining of surface coal refuse or culm banks.

Anthracite surface mining is normally conducted on hillsides. A trough or box-like cut is made to expose the coal seam. Parallel cuts are made and the spoil from each cut is deposited on the cut previously completed. The final cut leaves an open trench bounded on one side by deposited spoil material and on the other by an undisturbed highwall (Berger Associates, 1972).

For deep mining, each mine has its own system of shafts, slopes, and rock tunnels connecting the veins being mined (Gannett Fleming Corddry and Carpenter, Inc., 1972). Surface water and groundwater flowing into the levels being worked had to be pumped in stages from the deepest levels. The costs of mining and mine dewatering increased as mining progressed to yet deeper levels. Eventually, some mine operators decided to discontinue for a number of reasons, including increased costs and the depressed market for coal. This eventually led to most of the underground mines closing by the early 1970s while surface mining increased, particularly from 1944 to 1952 (PADEP, 2009). In the discontinued deep mines where mining had progressed beneath the levels of relief to surface streams, they began filling with water, forming underground pools.

Today, while there are both surface and deep mine operations active throughout the Anthracite Region, their production levels are well below the peak of Anthracite mining.

What remains prominent from the heydays of Anthracite mining is the legacy of scarred lands and water quality impacts. Within the Susquehanna River Basin portion of the Anthracite Coal Region, there are nearly 64 square miles of abandoned mine lands (AML) and nearly 534 miles of streams impaired by AMD.