SUSQUEHANNA RIVER BASIN COMMISSION

December 2011
Publication 279

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.

SRBC Contact: Tom Clark
Mine Drainage Program Coordinator
E-mail: srbc@srbc.net

Susquehanna River Basin Commission
1721 N. Front St.
Harrisburg, PA 17102
Phone: (717) 238-0423
Fax: (717) 238-2436
Website: www.srbc.net

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.

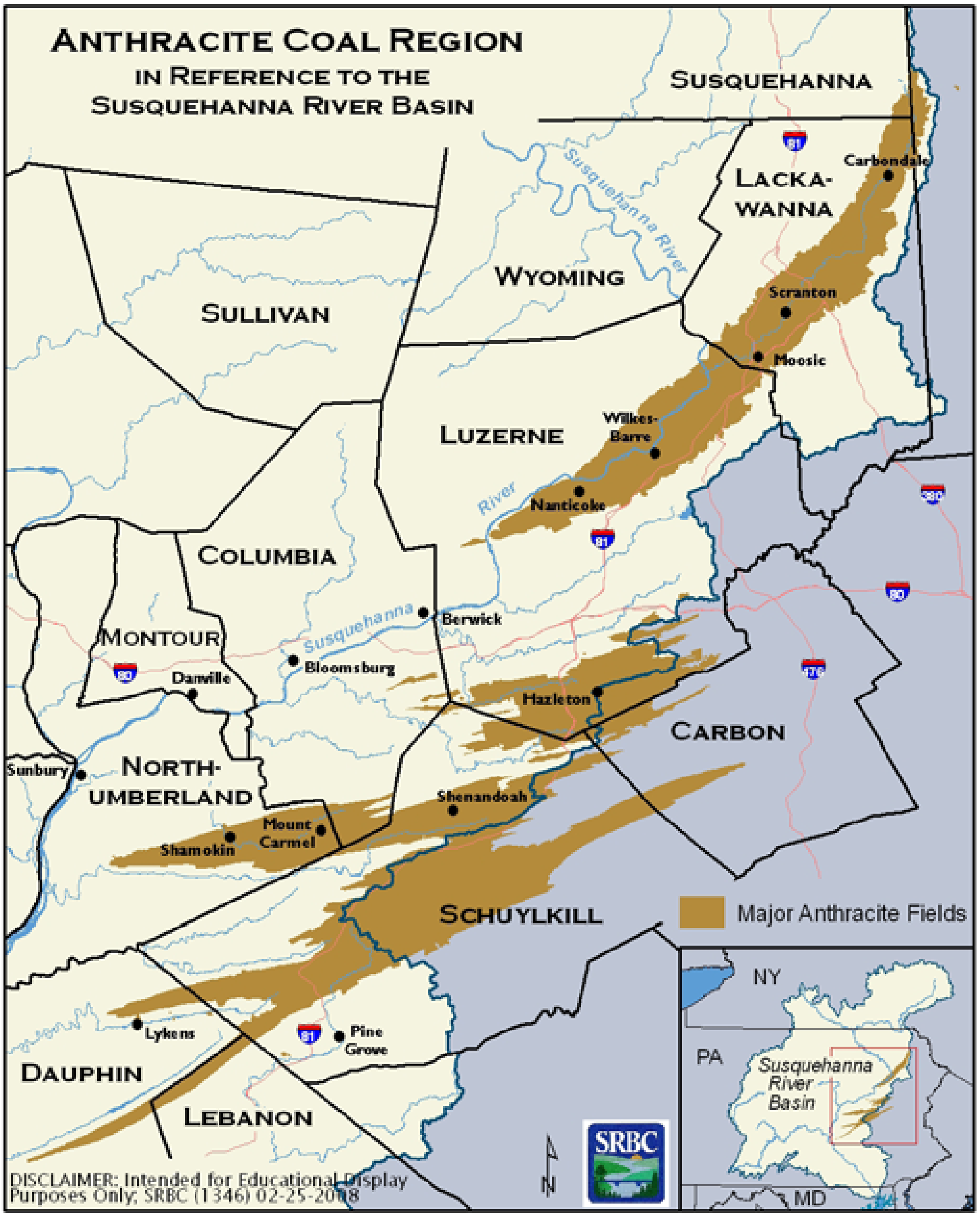


Figure 1. Anthracite Coal Region

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.

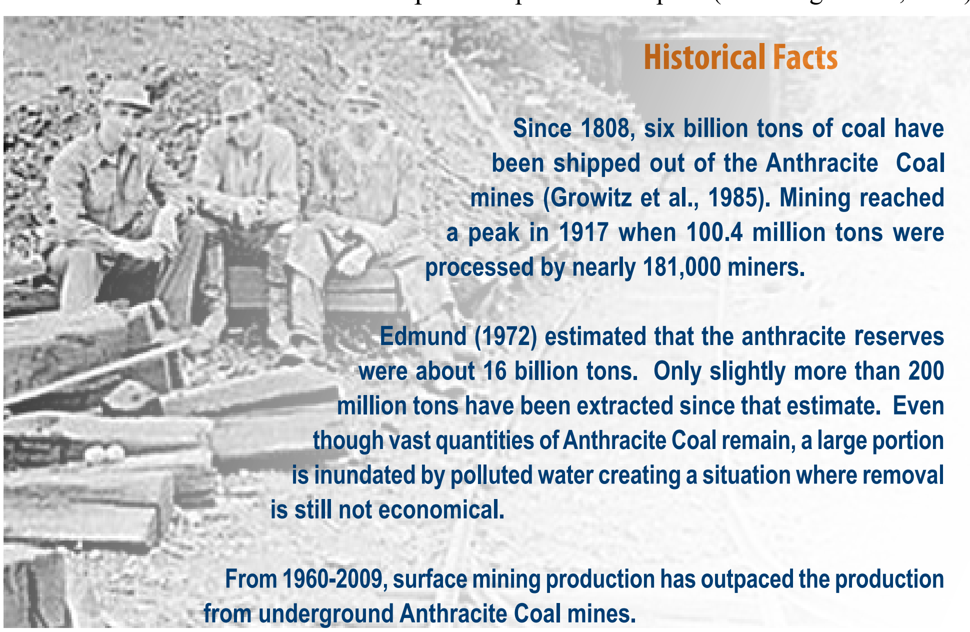
The Llewellyn Formation, overlying the Pottsville Formation, is as much as 3,500 feet thick (Hornberger et al., 2004). The maximum known thickness of the Pennsylvanian in Pennsylvania is approximately 4,400 feet near the town of Llewellyn in Schuylkill County (Edmunds et al., 1999). The Llewellyn Formation 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.

METHODS

Data Collection

This strategy is based entirely on existing data and information — no new water quality information was collected. The Pa. Department of Environmental Protection (PADEP) served as the primary source of information. Additional sources included the U.S. Geological Survey (USGS), SRBC monitoring data, Skelly & Loy, Inc., Dietz-Gourley Consulting, LLC, and Bloomsburg and Wilkes universities. In its calculations, SRBC focused on water quality data collected post-2000. Data from years prior to 2000, however, were not excluded and were utilized when more recent data were not available.

Data Review & Database Creation

In total, there are 745 unique stations in the database, containing 17,661 individual samples. The database emphasizes information on discharges and instream stations, but also includes information on boreholes, strip pits, and impoundments. Only instream and discharge stations were utilized for the analyses. Of the 745 unique stations, 346 are AMD discharge points while 399 are instream points. In the final strategy, of the 346 discharge points, only 320 were used for analysis because several points were sampled on the same total discharge flow.

Data Comparisons

Using GIS, SRBC calculated the amount of AML areas within each of the four Anthracite Coal Fields and the ten major Anthracite Coal Field watersheds. Calculations of AMD stream mileage were also made for the Coal Field watersheds.

Staff further compared the difference in discharge flows and metal loads/ yields between both the coal fields and individual watersheds.

Current Stream Conditions

Using the most recent data at mainstem sampling locations, SRBC selected 128 of the 399 instream data points to analyze current stream conditions.

Those 128 points were then used for a GIS mapping exercise to illustrate sections of the watershed mainstem not meeting water quality standards for pH and iron and/or aluminum concentrations.

AMD Loadings to the River

Fourteen tributaries that contain listed AMD impairment along with five AMD discharges from the Anthracite Coal Region flow into the Susquehanna River. Those fourteen tributaries and five discharges were analyzed for their direct AMD (iron, manganese, aluminum, acidity) loading contribution to the Susquehanna River. All five of the discharges that directly flow into the Susquehanna River are located in the Northern Field.

Comparison of Anthracite Coal Field Discharges

Flow, iron, manganese, aluminum, and acidity loading were calculated for all the 320 discharges found in the Anthracite Region of the Susquehanna River Basin. The 320 discharges were then ranked from highest to lowest for each parameter. The top 10 ranked discharges for each parameter were selected and are noted in Tables 3 - 7.

Twenty discharges were represented in at least one of the Top-10 parameter rankings. Since these 20 discharges comprise a vast majority of the flow and AMD loading that impacts the Susquehanna River Basin, they constitute the initial treatment system recommendations plan of this strategy, called the "Top-20 Plan." Based on strategic selection of treatment plant sites, in some cases, several Top-20 Plan discharges could be treated at the same plant. Strategic treatment plant site selections would also allow, in some cases, adjacent discharges not in the Top-20 Plan to be incorporated into the treatment plant. Consequently, 10 active treatment plants were suggested for construction consideration. These 10 plants would treat 16 of the Top-20 Plan discharges as well as 20 adjacent discharges for a total of 36 of the 320 total discharges.

Potential Consumptive Water Use Mitigation Sites

Due to massive mine pool water storage capacity, the Anthracite Coal Region holds tremendous potential as a center for consumptive water use mitigation projects that will also improve basin water quality. Using the Anthracite Region Water Quality Database, SRBC highlighted several potential consumptive water use mitigation/ water quality improvement projects to create a short list of examples for initial investigation. The estimated amount of water creation/storage for each of these prospective projects was calculated to illustrate the consumptive use mitigation potential held within the Anthracite Region of the Susquehanna River Basin.

Coordination

In 2009, a partnership emerged between SRBC and the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation (EPCAMR), particularly in light of EPCAMR's Anthracite Region Mine Pool Mapping Initiative in the Western-Middle Field. The two organizations began sharing data, which proved beneficial to both parties in their project endeavors. That partnership endures as both agencies work together to implement the restoration strategy and continue the mine pool mapping effort in the other Anthracite Coal Fields.

RESULTS AND DISCUSSION

COMPARISON OF THE ANTHRACITE COAL FIELDS

Impaired Stream Miles

Susquehanna River Basin streams that drain the four Anthracite Coal Fields contain 533.75 stream miles that are listed as AMD impaired by PADEP. Those impaired stream miles are fairly comparable between the four fields.

Abandoned Mine Lands

More than 12 percent of the total Anthracite Coal Field area within the Susquehanna River Basin (63.81 square miles) is listed on PADEP's AML Inventory System (AMLIS). Total AML acreage between the fields is quite different. The Northern and Western-Middle Fields contain 83.1 percent of the total AMLs, 48.8 and 34.3 percent, respectively. The Eastern-Middle and Southern Fields contain significantly less of the AML area: 16.9 percent of the total (9.6 and 7.3 percent, respectively). Nearly 52 percent of the Anthracite Region AML area within the Susquehanna River Basin is un-prioritized as of the end of 2010.

Discharge Numbers

According to the compiled historical water quality data, 320 AMD discharges are found within the Anthracite Coal Region of the Susquehanna River Basin. A majority of those discharges are found in two fields, the Western-Middle (40.0 percent) and the Southern (37.8 percent).

Discharge Flow

The amount of AMD discharge flow per field is not related to the amount of discharges per field. The Northern Field, which only contains 16.2 percent of the Anthracite Field discharges, contributes 38.0 percent of the Anthracite Field discharge flow. This is due to the fact that the Northern Field contains several very high flow discharges. In comparison, the Southern Field, which contains the second most discharges (39.9 percent), contributes the least amount of discharge flow at 10.9 percent.

AMD Pollution Loading

The AMD discharge loadings differ due to several geological and mining differences between the Eastern-Middle Coal Field and the remaining fields. The Northern and Western-Middle Fields create a majority of the iron (88.5 percent), manganese (75.3 percent), and acidity loading (60.7 percent) while the Eastern-Middle creates a majority of the aluminum loading (67.1 percent) and a significant percentage of the acidity loading (28.9 percent). The Southern Field is the least pervasive of the four fields in terms of AMD loading.

COMPARISON OF THE ANTHRACITE COAL FIELD WATERSHEDS

Impaired Stream Miles

The four Anthracite Coal Fields are drained by ten large watersheds: Lackawanna River, Nescopeck Creek, Catawissa Creek, Shamokin Creek, Mahanoy Creek, Mahantango Creek, Wiconisco Creek, Stony Creek, and Swatara Creek (Table 1). Several small watersheds also drain the area of the Northern Field that is not drained by the Lackawanna River and will be considered a separate tenth watershed area (Susquehanna River–Northern Field).

Impaired stream miles are fairly comparable between seven of the ten watersheds and range from 10.5 to 15.1 percent of the total AMD impaired mileage. Three watersheds, Wiconisco Creek, Mahantango Creek, and Stony Creek, contain significantly less impaired mileage: 5.0, 3.2, and 2.6 percent, respectively.

Abandoned Mine Lands

A large percentage (82.8 percent) of the AMLs are found in only four of the ten watersheds: Lackawanna River (27.4 percent), Susquehanna River–Northern Field (21.5 percent), Mahanoy Creek (20.9 percent), and Shamokin Creek (13.0 percent) (Table 1).

Discharge Numbers

Of the 320 compiled historical discharges, a large percentage (65.9 percent) of them are found in only three of the ten watersheds: Swatara Creek (25.9 percent), Shamokin Creek (20.9 percent), and Mahanoy Creek (19.1 percent) (Table 2).

Once again, the amount of discharges found in each watershed does not always correlate with the amount of discharge flow and loading created in each watershed. For example, Solomon Creek, located in the Susquehanna River–Northern Field, contains only two discharges (0.6 percent), yet is impacted by 9.3 percent (61.72 cfs) of the total Anthracite discharge flow within the Susquehanna River Basin.

Quaker Run — tributary to Shamokin Creek.

Table 1. AMD-impaired Stream Mileage and AML Land Coverage Data for Each of the Anthracite Coal Field Watersheds

Watershed	Total Watershed	Watershed Contained Within Coal Field	AMD Impairment	Total AMLs	PI AMLs	PII AMLs	PIII AMLs	Undetermined Priority	AML/ Watershed Area
	mi^2	mi^2	Stream Miles	mi^2	mi^2	mi^2	mi^2	mi^2	%
Lackawanna River	347.66	126.64	73.93	17.46	0.12	6.01	3.66	7.67	5.02
Susquehanna River–Northern Field	nd	99.84	80.78	13.68	0.24	4.20	1.78	7.46	nd
Nescopeck Creek	173.94	51.57	64.43	3.90	0.05	1.04	1.39	1.42	2.24
Catawissa Creek	152.69	25.77	56.13	2.37	0.20	0.50	0.13	1.54	1.55
Shamokin Creek	136.85	49.66	60.95	8.29	0.14	1.88	1.23	5.04	6.06
Mahanoy Creek	157.10	57.09	80.18	13.28	0.37	3.44	1.91	7.56	8.45
Mahantango Creek	164.63	19.57	16.87	0.80	0.00	0.28	0.14	0.38	0.49
Wiconisco Creek	116.37	14.78	26.60	1.21	0.00	0.40	0.01	0.80	1.04
Stony Creek	35.64	11.09	13.58	0.001	0.00	0.00	0.00	0.001	0.00
Swatara Creek	571.14	43.21	60.00	2.69	0.00	1.26	0.44	0.99	0.47
Total		499.22	533.45	63.68	1.12	19.01	10.69	32.86	

Table 2. Discharge Numbers, Flow, Loading Statistics, and Yields for Each of the Anthracite Coal Watersheds Containing Discharges

	Discharges	Flow	Fe Loading	Mn Loading	Al Loading	Alk Loading	Acidity Loading
	#	cfs	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Catawissa Creek	8	31.55	223.27	300.00	964.70	242.61	1,8697.17
Nescopeck Creek	12	95.94	2,781.84	2,200.66	5,051.74	5,340.01	35,967.51
Lackawanna River	30	147.12	18,285.08	2,574.93	251.55	51,206.89	8,334.24
Solomon Creek	2	61.72	12,499.37	1,291.02	78.04	103,339.39	22,171.76
Newport Creek	11	23.47	3,880.17	587.26	147.71	7,754.09	4,644.75
Nanticoke Creek	3	4.76	3,319.93	118.63	0.77	3,793.92	5,520.44
Susquehanna River–Northern Field	5	14.90	3,359.26	430.83	144.67	2,273.83	12,824.35
Swatara Creek	83	38.80	2,607.23	341.43	206.00	5,056.58	6,842.53
Mahantango Creek	23	16.75	1,616.22	232.48	176.56	1,414.75	8,690.85
Stony Creek	3	5.68	1.16	8.48	0.00	87.28	326.45
Wiconisco Creek	12	11.09	1,277.33	116.10	201.03	3,167.01	3,847.48
Shamokin Creek	67	79.63	10,670.58	1,396.27	657.17	13,695.79	26,176.75
Mahanoy Creek	61	132.18	13,325.32	3,330.12	1,084.76	58,179.64	35,400.02
Total	320	663.59	73,846.76	12,928.21	8,964.70	255,551.79	189,444.30
	Discharge Yield	Flow Yield	Fe Loading Yield	Mn Loading Yield	Al Loading Yield	Alk Loading Yield	Acidity Loading Yield
	$\#/mi^2$	cfs/mi^2	$lbs/day/mi^2$	$lbs/day/mi^2$	$lbs/day/mi^2$	$lbs/day/mi^2$	$lbs/day/mi^2$
Catawissa Creek	0.05	0.21	1.46	1.96	6.32	1.59	122.45
Nescopeck Creek	0.07	0.55	15.99	12.65	29.04	30.70	206.78
Lackawanna River	0.09	0.42	52.59	7.41	0.72	147.29	23.97
Solomon Creek	0.11	3.39	686.78	70.94	4.29	5,677.99	1,218.23
Newport Creek	0.79	1.68	277.35	41.98	10.56	554.26	332.00
Nanticoke Creek	0.40	0.63	440.31	15.73	0.10	503.52	732.15
Susquehanna River–Northern Field	0.02	0.06	12.90	1.65	0.56	8.73	49.26
Swatara Creek	0.15	0.07	4.56	0.60	0.36	8.85	11.98
Mahantango Creek	0.14	0.10	9.82	1.41	1.07	8.59	52.79
Stony Creek	0.08	0.16	0.03	0.24	0.00	2.45	9.16
Wiconisco Creek	0.10	0.10	10.98	1.00	1.73	27.22	33.06
Shamokin Creek	0.49	0.58	77.97	10.20	4.80	100.08	191.28
Mahanoy Creek	0.39	0.84	84.82	21.20	6.90	370.34	225.33
Total	0.15	0.31	34.24	5.99	4.16	118.52	87.85

Discharge Flow

The analysis of the compiled historical water quality calculated an average total flow of 663.6 cfs from the 320 discharges documented in the Anthracite Fields of the Susquehanna River Basin.

A slight majority (56.6 percent) of that flow is contained within only three watersheds: Lackawanna River (22.2 percent), Mahanoy Creek (19.9 percent), and Nescopeck Creek (14.5 percent) (Table 2). Of those, only Mahanoy Creek contains a significant number of actual discharges at 19.1 percent. Both the Lackawanna River and Nescopeck Creek can be characterized as watersheds that are impacted by several very large flow discharges, namely the Old Forge Borehole (~76.0 cfs), Duryea Breach (~27.7 cfs), and Jermyn Shaft (~18.1 cfs) in the Lackawanna River Watershed and the Jeddo Tunnel (~64.9 cfs) and Gowen Tunnel (~19.9 cfs) in the Nescopeck Creek Watershed.

When discharge flow yields ($ft^3/s/mi^2$) are analyzed, the Susquehanna River–Northern Field contains the highest. Solomon Creek is a small watershed that contains only two discharges; however, those two discharges, the Solomon Creek Boreholes and the Buttonwood Airshaft, are the third and fourth highest average flow AMD discharges in the entire Susquehanna River Basin portion of the Anthracite Coal Fields (Table 3). Consequently, the discharge flow yield in Solomon Creek is the highest of any watershed at 3.39 $ft^3/s/mi^2$. The other two small watersheds of the Susquehanna River–Northern Field, Newport Creek and Nanticoke Creek, contain yields of 1.68 $ft^3/s/mi^2$ and 0.63 $ft^3/s/mi^2$, respectively. Only one other watershed, Mahanoy Creek at 0.84 $ft^3/s/mi^2$, is higher than the yield found in Nanticoke Creek.

AMD Pollution Loading

The 320 discharges of the Susquehanna River Basin Anthracite Fields create 36.9 tons/day of iron loading, 6.5 tons/day of manganese loading, 4.5 tons/day of aluminum loading, and 94.7 tons/day of acidity loading (Table 2).

Almost three-quarters (74.1 percent) of the iron loading originates in four watersheds: Lackawanna River (24.8 percent), Mahanoy Creek (18.0 percent), Solomon Creek (16.9 percent), and Shamokin Creek (14.4 percent).

A large majority (83.5 percent) of the manganese loading originates in five watersheds: Mahanoy Creek (25.8 percent), Lackawanna River (19.9 percent), Nescopeck Creek (17.0 percent), Shamokin Creek (10.8 percent), and Solomon Creek (10.0 percent).

A slight majority (56.4 percent) of the aluminum loading originates in one watershed, Nescopeck Creek, due to the high aluminum loading of the Jeddo and Gowen Tunnels. Mahanoy Creek (12.1 percent) and Catawissa Creek (10.8 percent) contribute a significant amount of aluminum loading as well.

A majority (63.2 percent) of the acidity loading originates in four watersheds: Nescopeck Creek (19.0 percent), Mahanoy Creek (18.7 percent), Shamokin Creek (13.8 percent), and Solomon Creek (11.7 percent).

AMD pollution loading yields are generally the highest in small area watersheds that contain large flow/loading discharges. The two primary examples are Solomon Creek and Newport Creek found in the Susquehanna River–Northern Field. As mentioned, Solomon Creek contains the third (Solomon Creek Boreholes) and fourth (Buttonwood Airshaft) highest flow discharges in the entire Susquehanna River Basin Anthracite Field. Newport Creek contains the Susquehanna #7 Shaft and Newport Dump Discharges, the seventh and eighth largest flow discharges in the Northern Field, respectively.

Table 3. Top-10 Flow Discharges in the Susquehanna River Basin Anthracite Region

Ranking	Discharge - CFS	% Discharge Total	Site Number	Watershed	Mine Discharge
1	75.95	11.45	NFD016	Lackawanna River	Old Forge Borehole
2	64.89	9.78	EFD009	Nescopeck Creek	Jeddo Tunnel
3	31.21	4.70	NFD022	Solomon Creek	Solomon Creek Boreholes
4	30.51	4.60	NFD012	Solomon Creek	Nottingham-Buttonwood Airshaft
5	27.66	4.17	NFD020	Lackawanna River	Duryea Breach
6	20.19	3.04	WFD027	Mahanoy Creek	Packer #5 Breach and Borehole
7	19.94	3.00	EFD005	Nescopeck Creek	Gowen Tunnel
8	19.93	3.00	EFD001	Catawissa Creek	Audenreid Tunnel
9	18.06	2.72	NFD006	Lackawanna River	Jermyn Slope
10	14.47	2.18	WFD089	Mahanoy Creek	Gilberton Pump Discharge
Top 10 Total	322.81				
All	663.59				
% Discharge Total	48.65				

Current Stream Conditions

Lackawanna River

Even though the Lackawanna River contains several of the largest flow/loading discharges in the Anthracite, the mainstem meets water quality standards until near its confluence with the Susquehanna River.

In terms of pH, due to the fact that a vast majority of the discharges impacting the Lackawanna River are circumneutral in character, the mainstem maintains a pH above 6.0 from its entry to the Northern Field around Forest City, to its confluence with the Susquehanna River. Even though there are discharges in the watershed that produce acidity, the circumneutral discharges and the general water quality and size of the mainstem are able to assimilate the incoming acidity, allowing the river to meet water quality standards for pH.

The only other major AMD influence to the Lackawanna River is from iron loading, particularly from two discharges that impact the mainstem near its confluence with the Susquehanna River. The Old Forge Borehole and Duryea Breach contribute 98.7 percent of the total iron loading that impacts the mainstem of the Lackawanna River, 68.5 and 30.2 percent, respectively. The lower 2.75 miles of the Lackawanna River do not meet the water quality standard for iron due to the iron-loading impacts of these two discharges (Figure 2). The highest iron concentration on the Lackawanna River is 5.16 mg/l downstream of the Duryea Breach near its confluence with the Susquehanna River.

Lackawanna River impacted by the Old Forge borehole.

In contrast, due to the relative benign water quality nature and coldwater characteristics of the discharges upstream of the Old Forge Borehole, the Lackawanna River contains a long stretch of High-Quality Cold Water Fishery (HQ-CWF) classification water from its entry to the Northern Field to the entry of Hull Creek (Commonwealth of Pennsylvania, 2005). In addition, a 12.5-mile-long section of the Lackawanna River, from Coal Brook to Hull Creek, is classified as a Class A Brown Trout Fishery, the highest classification a stream can receive (Pennsylvania Fish & Boat Commission (PFBC), 2010). Consequently, the discharges of this area serve more as a coldwater resource than as a mine drainage impediment.

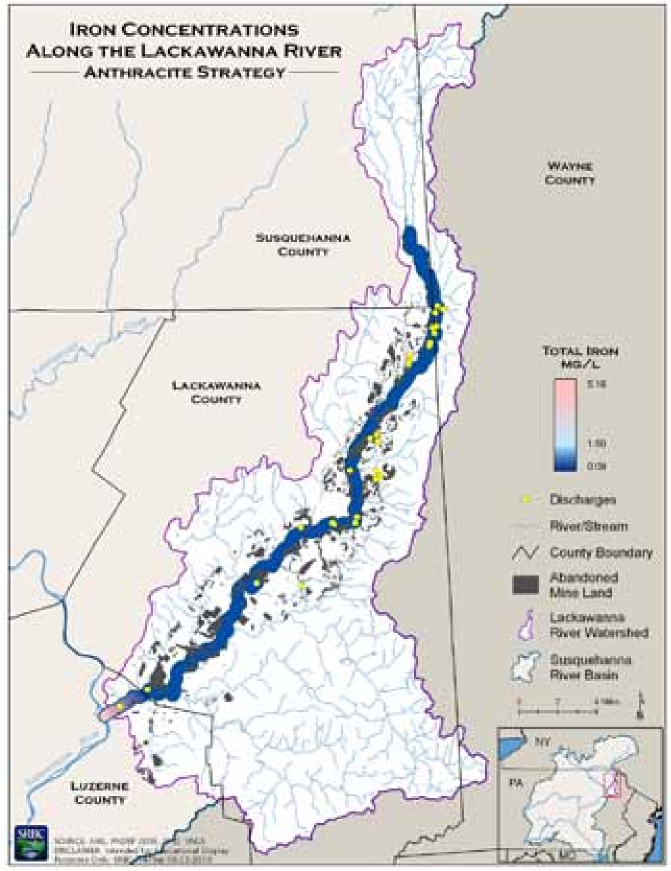


Figure 2. Iron Concentrations Along Lackawanna River

Susquehanna River — Northern Field

Besides the Lackawanna River, there are three other small watersheds that are impacted heavily by discharges of the Northern Field: Solomon Creek, Nanticoke Creek, and Newport Creek.

In terms of pH, only Newport Creek is heavily impacted by acidic discharges. The acidic impact to Newport Creek is heaviest in the headwaters, particularly downstream of the Glen Lyon Borehole. The pH of Newport Creek at this point averages 3.26.

All three watersheds are impacted heavily by elevated iron concentrations (Figure 3). The bottom third of Solomon Creek is heavily impacted by iron to the point that the mouth of Solomon Creek contains the highest average iron concentration (32.12 mg/l) of any stream from the Anthracite Fields that confluences with the Susquehanna River proper.

About one-half of Nanticoke Creek's mainstem does not meet the water quality standard for iron. The highest concentration of iron along Nanticoke Creek occurs downstream of the Dundee Outfall, averaging 24.42 mg/l.

The entire mainstem of Newport Creek does not meet the water quality standard for iron. The highest concentration is found just below the Susquehanna #7 Shaft, near its confluence with the Susquehanna River, averaging 30.69 mg/l.

Nescopeck Creek
The mainstem of Nescopeck Creek is impacted by the following two sources of AMD pollution: Little Nescopeck Creek, which carries the flow from the Jeddo Tunnel, and Black Creek, which carries the flow from the Gowen and Derringer Tunnels.

At the confluence with Little Nescopeck Creek, Nescopeck Creek meets neither the water quality standard for pH nor aluminum to its confluence with the Susquehanna River (Figure 4). The lowest pH and highest aluminum concentrations along Nescopeck Creek are found just below its confluence with Little Nescopeck Creek at 4.80 SU and 4.21 mg/l, respectively.

Catawissa Creek
Differing from Nescopeck Creek, Catawissa Creek is impacted by AMD in its headwaters, not meeting water quality standards for pH or aluminum concentrations from its onset (Figure 4). This is caused by several moderate to high flow tunnel discharges, the most severe being the Audenreid Tunnel. As Catawissa Creek flows west, water quality slowly improves through natural attenuation and dilution to the point that it meets standards for both pH and aluminum concentrations at its confluence with the Susquehanna River.

The lowest average pH and highest average aluminum concentrations along Catawissa Creek are found downstream of the Audenreid Tunnel at 4.15 SU and 4.32 mg/l, respectively.

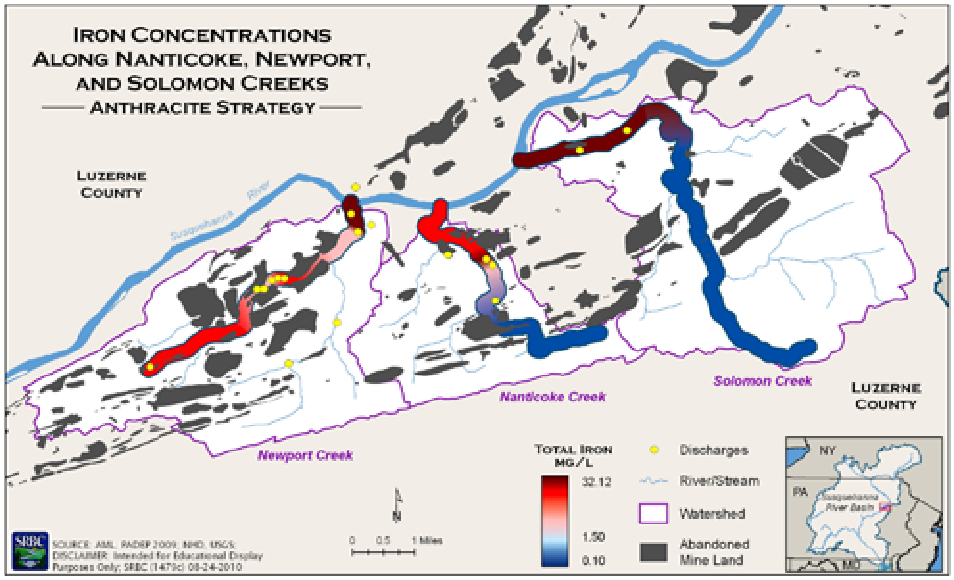


Figure 3. Iron Concentrations Along Nanticoke, Newport, and Solomon Creeks

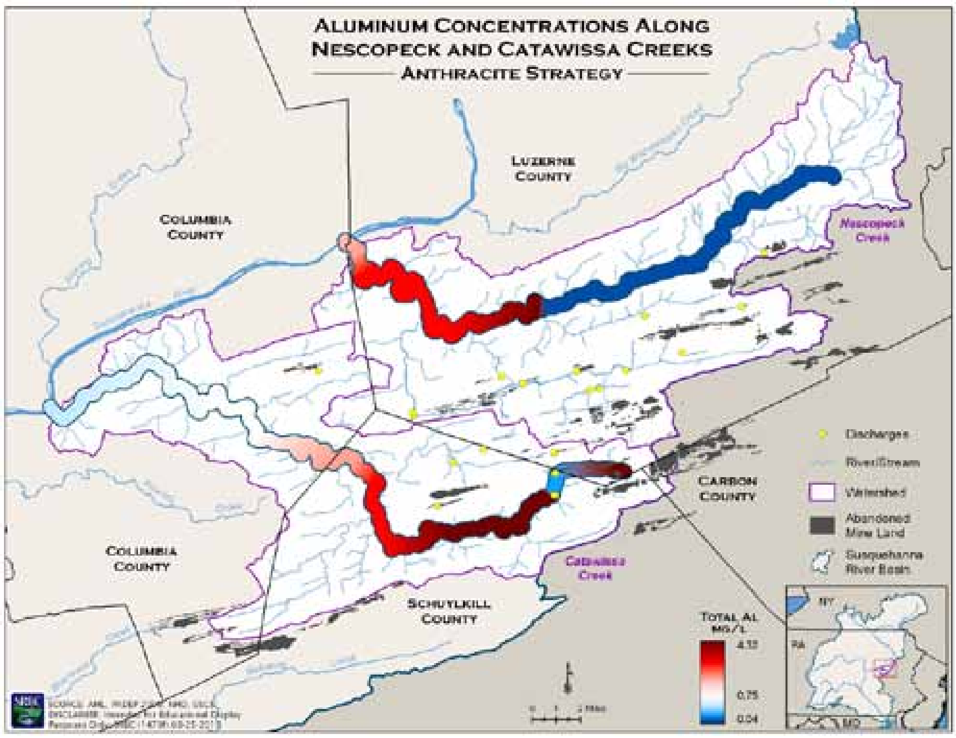
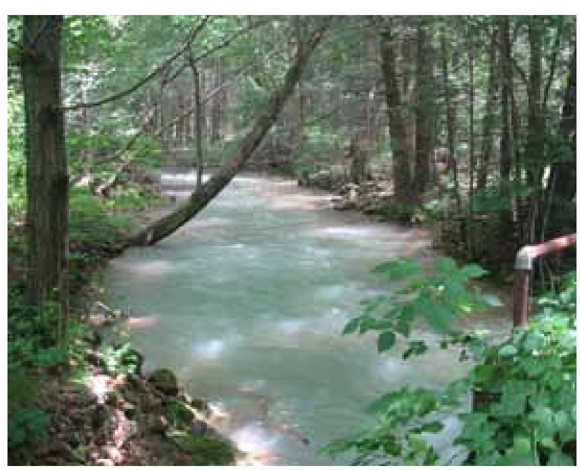


Figure 4. Aluminum Concentrations Along Nescopeck and Catawissa Creeks



(left) The confluence of Nescopeck and Little Nescopeck Creeks.

(right) Little Nescopeck Creek downstream of Jeddo Tunnel entry.

Shamokin Creek

Besides a very small portion of its headwaters, Shamokin Creek does not meet water quality standards throughout for its two major pollution constituents, pH and iron (Figure 5). Shamokin Creek does not meet water quality standards for pH or iron concentrations at its confluence with the Susquehanna River.

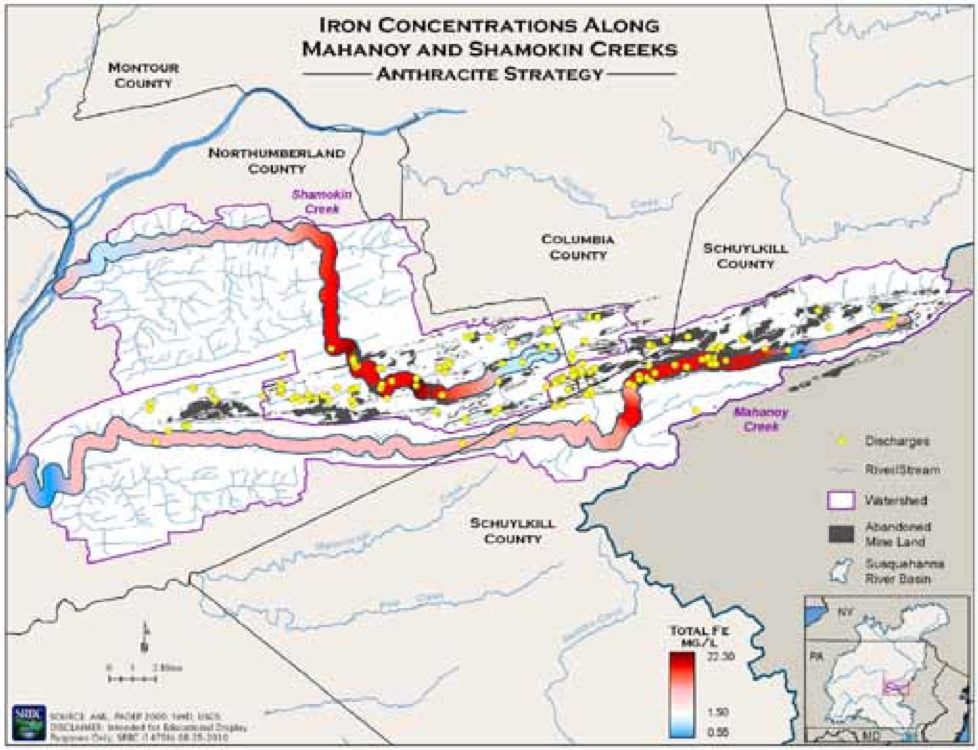


Figure 5. Iron Concentrations Along Mahanoy and Shamokin Creeks

The lowest average pH reading along Shamokin Creek is found just downstream of the Cameron Mine Pool discharges at 4.1 SU. The highest average iron concentration along Shamokin Creek is found just downstream of the Excelsior Strip Pit Overflow at 22.30 mg/l.

Mahanoy Creek

The current mainstem condition of Mahanoy Creek is slightly different from that of its neighboring Western-Middle Field watershed, Shamokin Creek. A large majority of Mahanoy Creek's mainstem does not meet the water quality standard for iron concentration (Figure 5); however, due to the watershed containing many high flow circumneutral discharges, Mahanoy Creek does meet the water quality standard for pH throughout most of its length. Only the extreme headwaters of Mahanoy Creek do not meet the standard for pH.

The lowest average pH reading along Mahanoy Creek is found just downstream of the confluence with the North Branch Mahanoy Creek at 4.38 SU. The highest average iron concentration along Mahanoy Creek is found just upstream of the town of Girardsville at 16.49 mg/l.

Pine Creek

Pine Creek, the largest tributary to Mahantango Creek, was impacted heavily by AMD pollution from one of its tributary streams, Rausch Creek. Given that Rausch Creek was such a large, single AMD point-source impact to Pine Creek, in 1972, PADEP constructed an active treatment plant that treats the entirety of Rausch Creek's flow. However, during times of very high flow, the plant is overwhelmed and the excess water is only treated via alkaline addition within the stream channel outside of the plant. Consequently, Pine Creek is minimally impacted during high flow periods.

This occasional impact on Pine Creek is not enough to depress pH to a point below the water quality standard. Each station on Pine Creek contains an average pH above 6.0 SU. However, the average iron concentration downstream of the Rausch Creek confluence does just exceed the water quality standard at 1.75 mg/l (Figure 6).

The Excelcior Strip Pit (EPCAMR) — upstream of the highest average iron concentration along Shamokin Creek.

Wiconisco Creek

Most of the Wiconisco Creek mainstem meets the water quality standards for both pH and iron. However, a small section of the headwaters meets neither standard due to the Porter Tunnel (Figure 6). In addition, a small section of Wiconisco Creek downstream of Bear Creek does not meet the water quality standard for iron due to iron loading impacts from Bear Creek.

The lowest average pH and highest average iron concentration reading along Wiconisco Creek are both found downstream of the Porter Tunnel at 3.92 SU and 4.85 mg/l, respectively.

Stony Creek

With only a historical sample collected at the mouth of Stony Creek, an analysis of current conditions could not be completed. This strategy includes a recommendation that an intensive water quality monitoring program be initiated in the Stony Creek Watershed, particularly downstream of its three AMD sources: Rausch Creek, Yellow Springs, and Rattling Run.

Swatara Creek

Due to most of the discharges being of a circumneutral character, only the extreme headwaters of Swatara Creek do not meet the water quality standard for pH. The lowest average pH in this section is 4.36 SU.

According to the historical data, there are three separate sections of Swatara Creek's mainstem that do not meet the iron water quality standard (Figure 6). The first is near the headwaters upstream of Panther Creek. The second section is downstream of Lower Rausch Creek and Lorberry Creek. The final section is around the Pine Grove Sewage Treatment Plant.

The highest average iron concentration on the Swatara Creek mainstem is 7.39 mg/l downstream of the confluence with Lorberry Creek.

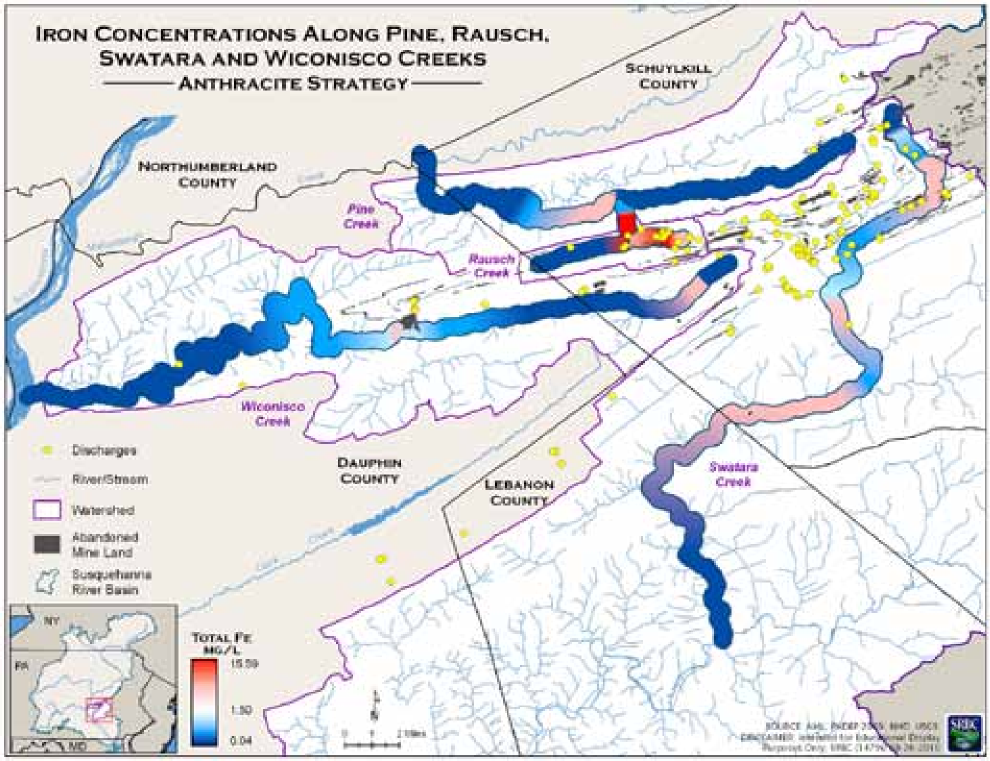


Figure 6. Iron Concentrations Along Pine, Rausch, Swatara and Wiconisco Creeks

Direct Tributary/Discharge AMD Loading Contribution to the Susquehanna River

Tributaries of the Susquehanna River that contain high amounts of AMD pollution loading do not always have a large impact to the Susquehanna River proper due to natural processes and dilution improving tributary water quality before the confluence.

In terms of direct iron loading impact to the Susquehanna River, three Northern Field tributaries contribute a majority (79.0 percent) of the total loading: Lackawanna River (40.3 percent), Solomon Creek (28.4 percent), and Newport Creek (10.4 percent).

In terms of direct manganese loading impact to the Susquehanna River, five tributaries contribute a majority (84.4 percent) of the total loading: Lackawanna River (26.1 percent), Nescopeck Creek (17.7 percent), Mahanoy Creek (16.7 percent), Solomon Creek (13.1 percent), and Shamokin Creek (10.8 percent).

In terms of direct aluminum loading impact to the Susquehanna River, four tributaries contribute a majority (73.2 percent) of the total loading: Nescopeck Creek (37.5 percent), Lackawanna River (14.6 percent), Mahantango Creek (10.8 percent), and Catawissa Creek (10.3 percent).

In terms of direct acidity loading impact to the Susquehanna River, only two tributaries contribute a slight majority (58.3 percent) of the total loading: Lackawanna River (31.1 percent) and Nescopeck Creek (27.2 percent).

By concentrating restoration efforts on only two watersheds, Lackawanna River and Nescopeck Creek, 42.1 percent of the iron loading, 43.8 percent of the manganese loading, 52.2 percent of the aluminum loading, and 58.3 percent of the acidity loading currently entering the Susquehanna River proper from the Anthracite Region would be eliminated.

Coal silt pond along Powderly Creek in the Lackawanna River Watershed.

COMPARISON OF ANTHRACITE COAL FIELD DISCHARGES

Flow

The Anthracite Coal Fields of Eastern Pennsylvania are known for their large flow discharges that drain massive underground mine pools. For example, more than 21 percent of the total Anthracite AMD flow in the Susquehanna River Basin originates from only two discharges, the Old Forge Borehole in the Lackawanna River Watershed (11.5 percent) and the Jeddo Tunnel (9.8 percent) in the Nescopeck Creek Watershed (Table 3).

More than 50 percent of the Anthracite AMD flow in the Susquehanna River Basin originates from only 3.4 percent (11 discharges) of the 320 discharges. Taking the flow data further, greater than 75 percent of the Anthracite AMD flow in the Susquehanna River Basin originates from only 10.6 percent (34 discharges) of the 320 discharges.

Very similar results are seen when completing the same analysis for discharge AMD loadings. Very few of the Anthracite Region discharges create a majority of the AMD loading contribution. Consequently, the treatment of a small percentage of the Anthracite Region discharges would lead to significant Susquehanna River Basin water quality improvements. The analyses below is an attempt by SRBC to prioritize the discharges that should be the main focus when considering broad-scale water quality restoration of the Susquehanna River Basin.

Iron Loading

The 320 discharges of the Susquehanna River Basin Anthracite Fields create 73,847 lbs/day of iron loading pollution. The top ten iron loading producers contribute 63.1 percent of that total or 46,615 lbs/day (Table 4). The Old Forge Borehole alone contributes 16.8 percent of the total iron loading pollution.

In addition, the top four and seven of the top ten iron loading producers are located in the Northern Field. Cumulative, those seven discharges create more than 51 percent of the iron loading.

Manganese Loading

The 320 discharges of the Susquehanna River Basin Anthracite Fields create 12,928 lbs/day of manganese loading pollution. The top ten manganese loading producers contribute 61.5 percent of that total or 7,955 lbs/day (Table 5). The Old Forge Borehole and Jeddo Tunnel combined contribute nearly 25 percent of the total manganese loading pollution.

Aluminum Loading

The 320 discharges of the Susquehanna River Basin Anthracite Fields create 8,965 lbs/day of aluminum loading pollution. The top ten aluminum loading producers contribute 78.2 percent of the total or 7,007 lbs/day (Table 6). The Jeddo Tunnel produces nearly 43 percent of the aluminum loading itself.

Four of the top five aluminum loading producers are located in the Eastern-Middle Field. Those four discharges cumulatively create nearly 66 percent of the aluminum loading.

Acidity Loading

The 320 discharges of the Susquehanna River Basin Anthracite Fields create 189,444 lbs/day of acidity loading pollution. The top ten acidity loading producers contribute 51.7 percent of the total or 98,002 lbs/day (Table 7). Greater than 13 percent of the acidity loading originates from one source, the Jeddo Tunnel.

Five of the top ten acidity loading producers are located in the Northern Field. Those five discharges cumulatively create nearly 21 percent of the acidity loading.

Table 4. Top-10 Iron Loading Discharges in the Susquehanna River Basin Anthracite Region

Ranking	Fe Loading - lbs/day	% Loading Total	Site Number	Watershed	Mine Discharge
1	12,393.02	16.78	NFD016	Lackawanna River	Old Forge Borehole
2	6,700.92	9.07	NFD022	Solomon Creek	Solomon Creek Boreholes
3	5,798.45	7.85	NFD012	Solomon Creek	Nottingham-Buttonwood Airshaft
4	5,464.45	7.40	NFD020	Lackawanna River	Duryea Breach
5	3,435.41	4.65	WFD089	Mahanoy Creek	Gilberton Pump Discharge
6	3,319.93	4.50	NFD033	Nanticoke Creek	Truesdale/Dundee Outfall
7	2,746.11	3.72	WFD027	Mahanoy Creek	Packer #5 Breach and Borehole
8	2,544.26	3.45	EFD009	Nescopeck Creek	Jeddo Tunnel
9	2,434.14	3.30	NFD014	Newport Creek	Susquehanna #7 Shaft
10	1,778.10	2.41	NFD017	Susquehanna River	Plainsville Outlet
Top 10 Total	46,614.79				
All	73,846.76				
% Loading Total	63.12				

Table 5. Top-10 Manganese Loading Discharges in the Susquehanna River Basin Anthracite Region

Rankings	Mn Loading - lbs/day	% Loading Total	Site Number	Watershed	Mine Discharge
1	1,726.76	13.36	NFD016	Lackawanna River	Old Forge Borehole
2	1,461.01	11.30	EFD009	Nescopeck Creek	Jeddo Tunnel
3	785.01	6.07	WFD027	Mahanoy Creek	Packer #5 Breach and Borehole
4	739.48	5.72	NFD020	Lackawanna River	Duryea Breach
5	674.81	5.22	NFD012	Solomon Creek	Nottingham-Buttonwood Airshaft
6	660.77	5.11	WFD089	Mahanoy Creek	Gilberton Pump Discharge
7	616.21	4.77	NFD022	Solomon Creek	Solomon Creek Boreholes
8	582.27	4.50	EFD005	Nescopeck Creek	Gowen Tunnel
9	388.23	3.00	WFD116	Mahanoy Creek	Continental Plant Bypass
10	320.77	2.48	WFD114	Mahanoy Creek	Centralia Tunnel
Top 10 Total	7,955.32				
All	12,928.21				
% Loading Total	61.53				

Table 6. Top-10 Aluminum Loading Discharges in the Susquehanna River Basin Anthracite Region

Rankings	Al Loading - lbs/day	% Loading Total	Site Number	Watershed	Mine Discharge
1	3,847.62	42.92	EFD009	Nescopeck Creek	Jeddo Tunnel
2	937.87	10.46	EFD005	Nescopeck Creek	Gowen Tunnel
3	856.61	9.56	EFD001	Catawissa Creek	Audenreid Tunnel
4	337.01	3.76	WFD114	Mahanoy Creek	Centralia Tunnel
5	253.13	2.82	EFD004	Nescopeck Creek	Derringer Tunnel
6	182.23	2.03	SFD089	Wiconisco Creek	Porter Tunnel
7	167.77	1.87	NFD016	Lackawanna River	Old Forge Borehole
8	153.68	1.71	WFD127	Mahanoy Creek	West Penn Breaker Discharge
9	138.41	1.54	WFD019	Mahanoy Creek	Doutyville Tunnel
10	132.53	1.48	NFD025	Susquehanna River	Mocanaqua Tunnel
Top 10 Total	7,006.84				
All	8,964.70				
% Loading Total	78.16				

Table 7. Top-10 Acidity Loading Discharges in the Susquehanna River Basin Anthracite Region

Rankings	Acidity Loading - lbs/day	% Loading Total	Site Number	Watershed	Mine Discharge
1	25,410.56	13.41	EFD009	Nescopeck Creek	Jeddo Tunnel
2	16,570.82	8.75	EFD001	Catawissa Creek	Audenreid Tunnel
3	14,024.59	7.40	NFD012	Solomon Creek	Nottingham-Buttonwood Airshaft
4	8,147.17	4.30	NFD022	Solomon Creek	Solomon Creek Boreholes
5	7,130.31	3.76	EFD005	Nescopeck Creek	Gowen Tunnel
6	6,902.56	3.64	NFD025	Susquehanna River	Mocanaqua Tunnel
7	5,480.49	2.89	NFD033	Nanticoke Creek	Truesdale/Dundee Outfall
8	4,804.65	2.54	WFD027	Mahanoy Creek	Packer #5 Breach and Borehole
9	4,804.59	2.54	WFD114	Mahanoy Creek	Centralia Tunnel
10	4,726.07	2.49	NFD016	Lackawanna River	Old Forge Borehole
Top 10 Total	98,001.81				
All	189,444.30				
% Loading Total	51.73				

THE TOP-20 PLAN

Using the Top-10 Tables 4-7 and scoring each discharge listed (ten points for ranking first and one point for ranking tenth), a prioritization system was constructed according to combined impact. Twenty discharges throughout the Susquehanna River Basin Anthracite Region should be a focal point to begin basin-scale watershed restoration.

These 20 discharges, representing only 6 percent of the 320 total discharges, contribute 57.6 percent of the total discharge flow, 70.0 percent of the total iron loading, 72.0 percent of the total manganese loading, 80.8 percent of the total aluminum loading, and 63.0 percent of the total acidity loading entering the Susquehanna River Basin from the Anthracite Region (Table 8).

As mentioned, this Top-20 Plan is for basin-scale restoration. Even though the Top-20 Plan addresses a vast majority of the AMD pollution loading in the Northern and Eastern-Middle Fields, the plan offers less watershed-scale restoration in the Western-Middle and Southern Fields.

When analyzing the watershed-scale improvements that would occur if the Top-20 Plan is implemented, Nescopeck Creek, Lackawanna River, Solomon Creek, and Nanticoke Creek would be virtually restored. Catawissa Creek and the Susquehanna River proper would be nearly restored. Wiconisco Creek and Mahanoy Creek would be significantly improved. Newport Creek would be partially improved. No improvement would occur in Swatara Creek, Shamokin Creek, and Stony Creek. Due to the Rausch Creek Treatment Plant, no additional treatment is needed within the Mahantango Creek Watershed.

Of the three watersheds where no improvement would occur, only Shamokin Creek has a significant impact to the Susquehanna River Basin. Swatara Creek is impaired mainly in the headwaters and is completely restored by its confluence with the Susquehanna River. Stony Creek is impaired by mildly acidic discharges that contain virtually no metal concentrations. In addition, Rausch Creek, which is one of the AMD impacts to Stony Creek, is treated via limestone diversion wells constructed and maintained by the Doc Fritchey Chapter of Trout Unlimited. Consequently, only Shamokin Creek should gain secondary focus post Top-20 Plan implementation.

Table 8. Top-20 Prioritized Discharges within the Anthracite Region of the Susquehanna River Basin and Their Separated Pollution Contribution Percentages

Discharge	Field	Watershed	Flow %	Fe Load %	Mn Load %	Al Load %	Acid Load %	Loading Average %
Jeddo Tunnel	Eastern-Middle	Nescopeck Creek	9.78	3.45	11.30	42.92	13.41	17.8
Old Forge Borehole	Northern	Lackawanna River	11.45	16.78	13.36	1.87	2.49	8.6
Nottingham-Buttonwood Airshaft	Northern	Solomon Creek	4.60	7.85	5.22	0.53	7.40	5.3
Solomon Creek Boreholes	Northern	Solomon Creek	4.70	9.07	4.77	0.34	4.30	4.6
Gowen Tunnel	Eastern-Middle	Nescopeck Creek	3.00	0.19	4.50	10.46	3.76	4.7
Duryea Breach	Northern	Lackawanna River	4.17	7.40	5.72	0.42	0.88	3.6
Audenreid Tunnel	Eastern-Middle	Catawissa Creek	3.00	0.26	2.05	9.56	8.75	5.2
Packer #5 Breach and Boreholes	Western-Middle	Mahanoy Creek	3.04	3.72	6.07	0.08	2.54	3.1
Gilberton Pump	Western-Middle	Mahanoy Creek	2.18	4.65	5.11	0.63	1.72	3.0
Centralia Tunnel	Western-Middle	Mahanoy Creek	1.27	0.49	2.48	3.76	2.54	2.3
Dundee Outfall	Northern	Nanticoke Creek	0.72	4.50	0.92	0.00	2.89	2.1
Derringer Tunnel	Eastern-Middle	Nescopeck Creek	0.78	0.04	1.09	2.82	1.16	1.3
Mocanaqua Tunnel	Northern	Susquehanna River	0.62	2.02	1.85	1.48	3.64	2.2
Porter Tunnel	Southern	Wiconisco Creek	0.17	0.82	0.34	2.03	1.40	1.1
West Penn Breaker Plant Discharge	Western-Middle	Mahanoy Creek	0.27	0.96	0.75	1.71	0.40	1.0
Jermyn Slope	Northern	Lackawanna River	2.72	0.25	0.31	0.12	0.27	0.2
Doutyville Tunnel	Western-Middle	Mahanoy Creek	1.49	0.47	0.88	1.54	1.07	1.0
Continental Plant Bypass	Western-Middle	Mahanoy Creek	1.48	1.36	3.00	0.18	1.80	1.6
Susquehanna #7 Shaft	Northern	Newport Creek	1.43	3.30	1.70	0.23	0.49	1.4
Plainsville Outlet	Northern	Susquehanna River	0.69	2.41	0.62	0.14	2.08	1.3
		Total %	57.6	70.0	72.0	80.8	63.0	

Due to the massive flows and pollution loadings of its discharges, the Anthracite Region cannot be restored via typical passive treatment systems. Given the nature of AMD pollution in the Anthracite Region, active treatment, like the Rausch Creek Treatment Plant in the Mahantango Creek Watershed, is the most feasible restoration option to truly restore the waters in the Anthracite Region.

Strategic treatment plant site selections would allow, in some cases, several Top-20 discharges to be treated at the same plant, thus reducing capital, operation, and maintenance costs. Strategic treatment plant site selections would also allow, in some cases, adjacent discharges not in the Top-20 Plan to be incorporated into the treatment plant, increasing the percentage of total Anthracite loading being treated. The following are some possible active treatment plant scenarios.

Conceptual Plant #1 – Lackawanna River

The Old Forge Borehole (#2) and Duryea Breach (#7) are the largest and fourth largest producers of iron loading, respectively, within the Susquehanna River Basin Anthracite Field. Combined, nearly 25 percent of the iron loading and 20 percent of the manganese loading produced in the Susquehanna River Basin Anthracite Fields originates from these two discharges alone. At the watershed-scale, the Old Forge Borehole and Duryea Breach contribute 98.7 percent of the iron loading that enters the Lackawanna River Watershed.

The Old Forge Borehole from the western bank of the Lackawanna River.

With the circum-neutral character of the discharges, the cumulative iron and manganese loading captured, and the fact that these two discharges are in proximity to one another (1.7 miles), the collection and piping of both discharges to a centralized treatment plant could be a logical plan (Figure 7 and Table 9).

Both discharges, due to size of mine pool and flows, may also contain consumptive water use mitigation, hydroelectric, and geothermal potential that could be incorporated into the active treatment plant design. The Lackawanna River Corridor Association, EPCAMR, and SRBC are currently completing a flow monitoring project on the Old Forge Borehole to assess this potential.

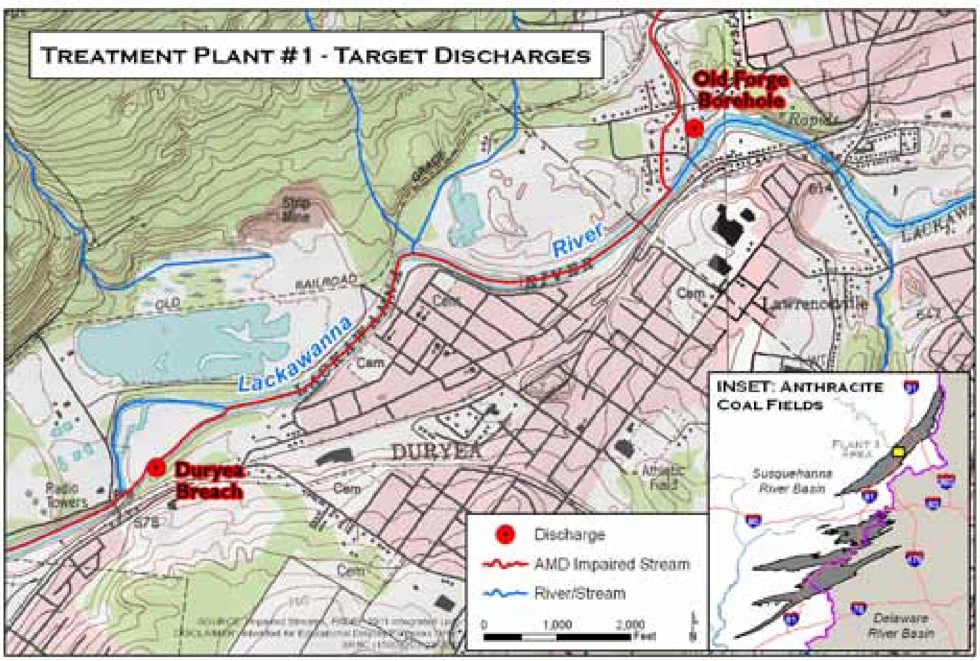


Figure 7. Treatment Plant #1 - Target Discharges

Table 9. Average Flow, Concentrations, and Loadings of Plant #1 Discharges and Plant #1 Mix Water

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Old Forge Borehole	75.95	5.96	30.25	4.21	0.41	84.44	11.53	12,393.02	1,726.76	167.77	34,596.49	4,726.07
Duryea Breach	27.66	5.97	36.62	4.96	0.25	87.07	11.16	5,464.45	739.48	37.25	12,991.83	1,664.95
Mixed	103.61	~5.96	31.95	4.41	0.37	85.14	11.43	17,857.47	2,466.24	205.02	47,588.32	6,391.02

Conceptual Plant #2 – Solomon Creek

Only 0.8 miles separate the Solomon Creek Boreholes (#4) and the Nottingham-Buttonwood Airshaft (#3) (Figure 8). Both discharges enter Solomon Creek just south of Wilkes-Barre. Combined, nearly 17 percent of the iron loading and 10 percent of the manganese loading produced in the Susquehanna River Basin Anthracite Fields originates from these two discharges.

Combining these discharges into one treatment plant creates a large flow; however, the chemistry should be circumneutral with a high iron concentration (37.55 mg/l) and low concentrations of manganese and aluminum (Table 10). Consequently, treatment of the water chemistry should not be difficult.

Due to the flow of these two discharges and the scale of the mine pools fueling the flow, the Solomon Creek Boreholes and the Nottingham-Buttonwood discharges may also contain consumptive water use mitigation, hydroelectric, and geothermal potential that could be incorporated into the active treatment plant design.

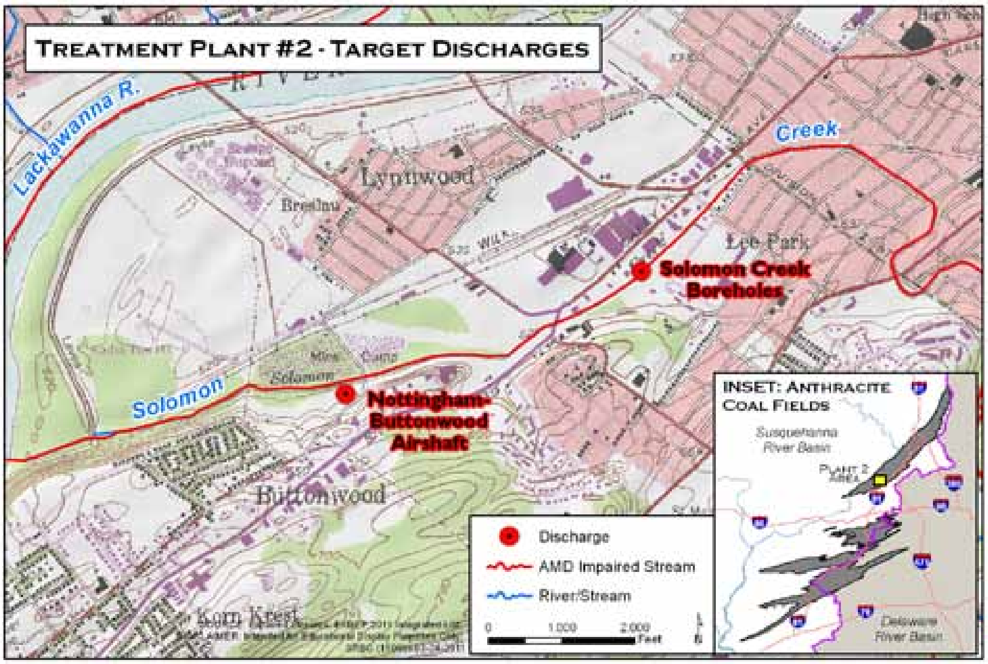


Figure 8. Treatment Plant #2 - Target Discharges

Solomon Creek borehole.

Conceptual Plant #3 – Nanticoke

Of all the Top-20 Discharges, the Dundee Outfall (#11) and the Susquehanna #7 Shaft (#17) have the most potential at being treated separately in passive treatment systems. However, several issues create a situation where combination into one active plant may be more favorable.

First, passive treatment on a portion (33 percent of average flow) of the Dundee Outfall has been attempted and has been mostly unsuccessful. A Phase II passive treatment system is being considered in the Nanticoke Creek floodplain. Due to size of flow, and the placement and available area for the passive treatment system, Phase II has a high probability of failure as well.

Solomon Creek near its confluence with the Susquehanna River.

Table 10. Average Flow, Concentrations, and Loadings of Plant #2 Discharges and Plant #2 Mix Water

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Solomon Creek Boreholes	31.22	6.3	39.78	3.66	0.18	172.31	48.37	6,700.92	616.21	30.31	29,021.03	8,147.17
Nottingham-Buttonwood Airshaft	30.51	6.1	35.23	4.10	0.29	451.54	85.21	5,798.45	674.81	47.73	74,318.31	14,024.59
Mixed	61.73	~6.2	37.55	3.88	0.23	310.47	66.61	12,499.37	1,291.02	78.04	103,339.34	22,171.76

The Susquehanna #7 Shaft Discharge contains land area nearby where a passive treatment system could be constructed. However, these properties are held by multiple entities. In addition, drilling into the mine pool to create another outfall may have to be completed to access all the land area needed for passive treatment.

With a distance of only 2.1 miles between the discharges, the mix water being circumneutral with a high iron concentration (37.55 mg/l) and low concentrations of manganese and aluminum, and the smaller footprint offered, an active plant may have a better cost/benefit ratio than two very large passive treatment systems that have a high failure probability (Figure 9 and Table 11).

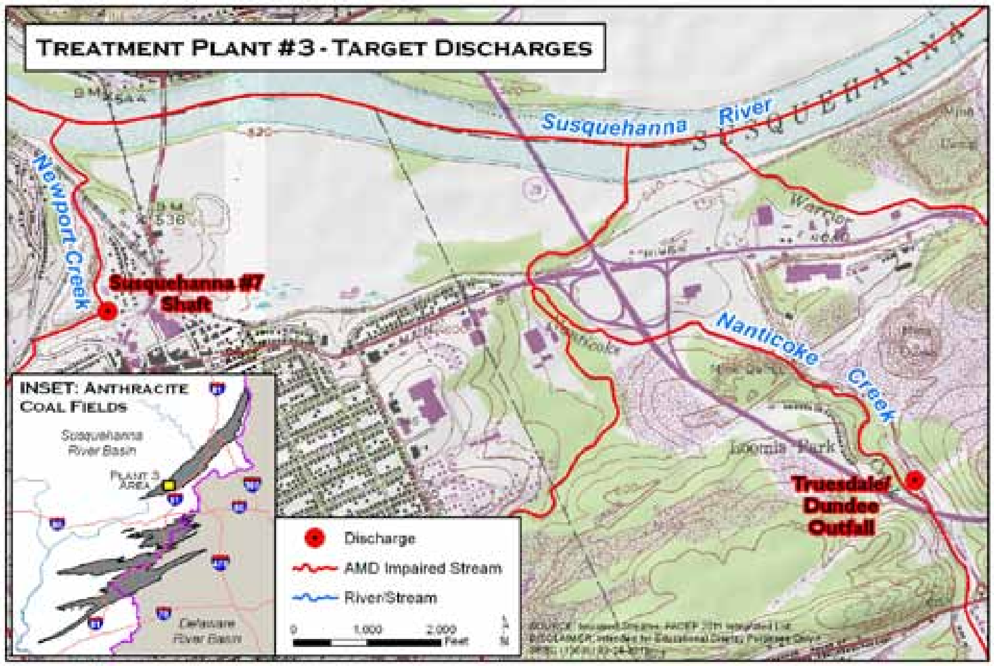


Figure 9. Treatment Plant #3 - Target Discharges

Table 11. Average Flow, Concentrations, and Loadings of Plant #3 Discharges and Plant #3 Mix Water

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Dundee Outfall	4.71	5.28	130.53	4.67	0.03	98.58	197.50	3,316.87	118.63	0.77	2,505.00	5,018.45
Susquehanna #7 Shaft	9.46	6.35	47.70	4.31	0.41	129.77	18.35	2,434.14	220.01	20.70	6,621.92	936.37
Mixed	14.17	~6.0	75.23	4.43	0.28	119.40	77.90	5,751.01	338.61	21.47	9,126.92	5,954.82

As with all the other mine pools, the Dundee Outfall and Susquehanna #7 Shaft discharges may also contain consumptive water use mitigation, hydroelectric, and geothermal potential that could be incorporated into the active treatment plant design.

Completion of Conceptual Plant #1, #2, and #3 could remove up to 46.6 miles from the PADEP Integrated List of AMD impaired waters. This would include 37.3 miles of the Susquehanna River mainstem, 4.0 miles of Solomon Creek mainstem, 2.78 miles of Nanticoke Creek mainstem, and 2.58 miles of Lackawanna River mainstem.

The outfall of the Susquehanna #7 Discharge.

Conceptual Plant #4 – Jeddo Tunnel

Due to its very high average flow, the Jeddo Tunnel (#1) is the largest acidity (13.4 percent) and aluminum loading producer (42.9 percent), second largest manganese producer (11.3 percent), and eighth largest iron producer (3.5 percent) in the entire Susquehanna River Basin Anthracite Fields.

The Jeddo Tunnel is by far the largest contributor of AMD loading to Nescopeck Creek, contributing 91.5 percent of the iron loading, 66.4 percent of the manganese loading, 76.2 percent of the aluminum loading, and 70.6 percent of the acidity loading.

Even though the Jeddo Tunnel has a high average flow of 64.9 cfs (only the Old Forge Borehole has a higher average flow), the concentration of

The Jeddo Tunnel flow entry to Little Nescopeck Creek. The Jeddo Tunnel is by far the largest contributor of AMD loading to Nescopeck Creek, contributing 91.5 percent of the iron loading, 66.4 percent of the manganese loading, 76.2 percent of the aluminum loading, and 70.6 percent of the acidity loading.

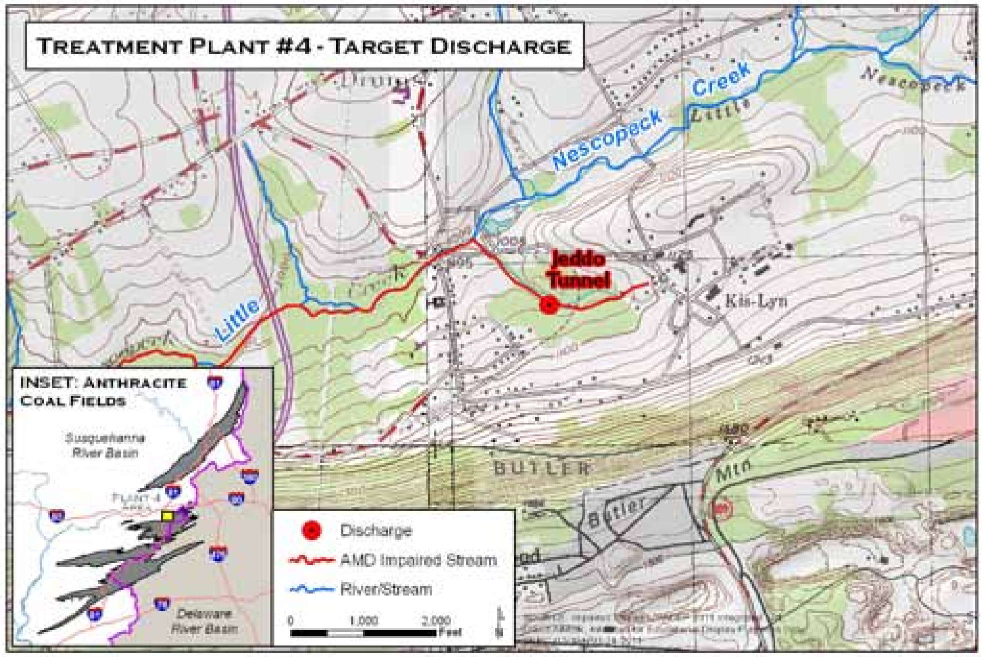


Figure 10. Treatment Plant #4 - Target Discharges

AMD parameters are relatively benign (Table 12). Consequently, treatment via an active treatment plant is plausible (Figure 10).

The Jeddo Tunnel is the largest of the Anthracite drainage tunnels. Construction of the Jeddo Tunnel system started in 1891 and was completed in 1934. The Jeddo Tunnel system is nearly 9 miles in length and branches out to drain more than 32 square miles from four major coal basins: Big Black Creek, Little Black Creek, Cross Creek, and Hazleton (PADEP, 2005). SRBC and Wildlands Conservancy completed a very detailed study of the Jeddo Tunnel Complex in 1999 entitled *Assessment of Conditions Contributing Acid Mine Drainage to the Little Nescopeck Creek Watershed, Luzerne County, Pennsylvania and an Abatement Plan to Mitigate Impaired Water Quality Within the Basin* that should be used when progression of a plan to treat the Jeddo Tunnel flow is initiated.

The Eastern-Middle Anthracite Region Recovery Inc. (EMARR) out of Hazleton has been studying the consumptive water use mitigation, hydroelectric, and geothermal potential of this intricate set of connected tunnels that contribute AMD water to the Jeddo Tunnel. EMARR believes that this potential is real and significant, particularly in the area of the Hazelton Shaft. If treatment of the Jeddo Tunnel via an active treatment plant moves forward, EMARR should be contacted so that their opinions could be validated and possibly incorporated into the plant design.

Conceptual Plant #5 – Black Creek

The Gowen Tunnel (#5) and Derringer Tunnel (#13) are only separated by slightly over a tenth of a mile (Figure 11). Both discharges are very similar in water quality; however, the Gowen Tunnel is nearly four times the flow of the Derringer Tunnel (Table 13).

The Gowen and Derringer Tunnels are the only significant discharges on Black Creek, the largest tributary to Nescopeck Creek. They are also the second and third most impacting discharges to the Nescopeck Watershed behind the Jeddo Tunnel. Together, Gowen and Derringer contribute 6.1 percent of the iron loading, 32.9 percent of the manganese loading, 23.6 percent of the aluminum loading, and 25.9 percent of the acidity loading to Nescopeck Creek.

Table 12. Average Flow, Concentrations, and Loadings of Jeddo Tunnel (Plant #4)

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Jeddo Tunnel	64.89	4.38	7.27	4.17	10.99	8.46	72.59	2,544.26	1,461.01	3,847.62	2,960.55	25,410.56

Table 13. Average Flow, Concentrations, and Loadings of Plant #5 Discharges and Plant #5 Mix Water

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Gowen Tunnel	19.94	3.92	1.29	5.41	8.72	19.72	66.29	139.26	582.27	937.87	2,121.76	7,130.31
Derringer Tunnel	5.15	4.15	1.11	5.06	9.11	5.02	78.89	30.73	140.70	253.13	139.44	2,191.58
Mixed	25.09	~3.97	1.26	5.34	8.80	16.71	68.87	169.99	722.97	1,191.00	2,261.20	9,321.89

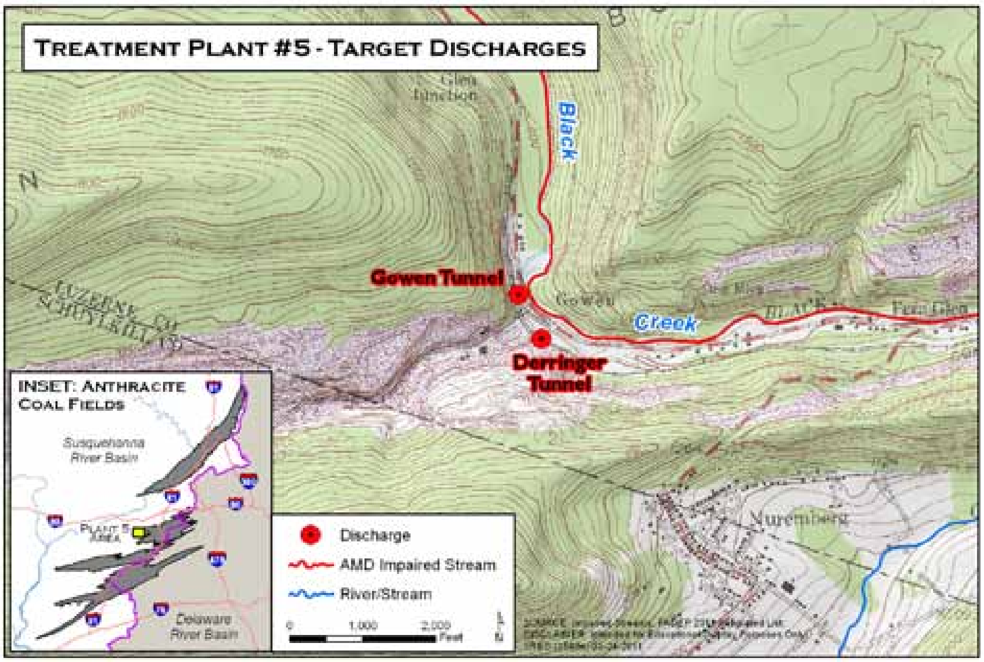


Figure 11. Treatment Plant #5 - Target Discharges

Combining the effects of Conceptual Plant #4 and Plant #5, 29.51 miles could be removed from the PADEP Integrated List of AMD impaired waters. This would include 6.33 miles of Little Nescopeck Creek, 5.37 miles of Black Creek, and 17.8 miles of the Nescopeck Creek mainstem.

In addition, much of Nescopeck Creek upstream of the AMD impacts is listed as a HQ-CWF (Commonwealth of Pennsylvania, 2005). Several Nescopeck Creek tributaries are also listed as containing Class A populations of trout, the highest rating achieved (PBFC, 2010). Consequently, cold water species recolonization could be quick upon AMD treatment.

As with all the other mine pool discharges, due to the size of the mine pools and flows, the Gowen and Derringer Tunnels may also contain consumptive water use mitigation, hydroelectric, and geothermal potential that could be incorporated into the active treatment plant design.

Conceptual Plant #6 – Catawissa Creek

A vast majority of the AMD pollution impacting Catawissa Creek originates from just one tunnel discharge. The Audenreid Tunnel (#6) contributes 85.2 percent of the iron loading, 88.5 percent of the manganese loading, 88.8 percent of the aluminum loading, and 88.6 percent of the acidity loading that impacts Catawissa Creek. Four other smaller tunnel discharges (Catawissa, Green Mountain, Oneida #1, and Oneida #3) comprise a majority of the balance.

Passive treatment has been attempted on three of the tunnel discharges. Two have been successful at Oneida #1 and #3. These systems have restored much of Tomhicken Creek, a large tributary to Catawissa Creek. The passive system at Audenreid has been significantly less successful. Soon after becoming operative, a significant storm created a tremendous flow exiting the Audenreid Tunnel, estimated at 300,000 GPM (Davidock, 2006). This flow, and the sediment plume it created, inundated the passive treatment system to the point that it is still not fully operational five years later.

Passive treatment was selected as the treatment method at Audenreid due to a lack of infrastructure near the discharge, namely electricity. However, flow volumes the size of Audenreid (average 19.93 cfs) are very difficult if not impossible to treat using present day passive treatment system technologies. SRBC is recommending that an active system be considered as a Phase II alternative to the passive system at Audenreid.

Another reason that an active plant should be considered is that the two other tunnel discharges currently not treated, Catawissa and Green Mountain, are extremely close to Audenreid (Figure 12). The Green Mountain Tunnel is only 328 feet from the Audenreid Tunnel and the Catawissa Tunnel is 0.9 miles upstream. The remoteness of these three discharges is the limiting factor for combining the discharges into a centralized plant.

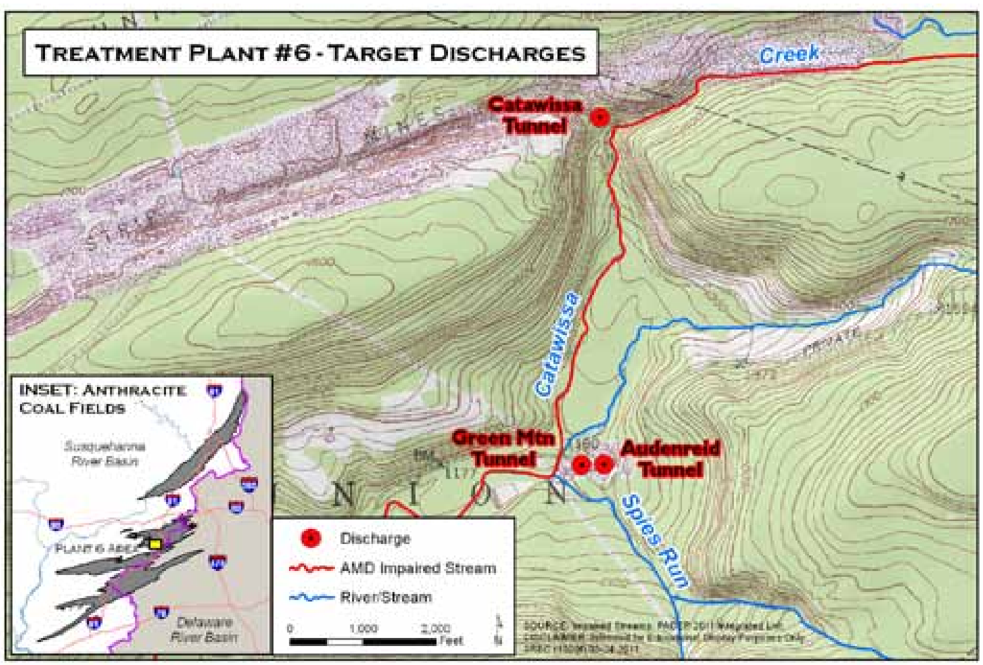


Figure 12. Treatment Plant #6 - Target Discharges

Cold water fishery habitat of Catawissa Creek.

However, the benefit is a completely restored Catawissa Creek, which is considered by many to be one of the most scenic and habitat-expansive tributaries of the Anthracite Region (Table 14).

The Pennsylvania Fish and Boat Commission (PFBC) has surveyed the mainstem of Catawissa Creek three times. In 1957, the first survey concluded that Catawissa Creek has excellent physical characteristics and water temperatures for trout management but was devoid of significant aquatic life due to AMD impairment. Chemical surveys of the stream in 1966 and 1976 found that it was still severely degraded. In the summer of 1997, the PFBC studied the Catawissa Creek Watershed to assess the level of management the streams in the watershed needed and their potential as fisheries, since they had never been documented. The study found substantial wild trout populations in the streams where water quality had not been severely AMD-impaired. The PFBC noted the Catawissa Creek's tremendous potential for cold water management if AMD pollution were remedied (Wnuk, 1998).

The hydroelectric and geothermal potential at the Audenreid discharge is real and already being utilized. EMARR recently completed a project to capture the power supplied by the flow of the Audenreid Tunnel Discharge to increase the automation of the passive treatment system. This micro-hydro project creates more energy than is required for the treatment system, but the lack of electrical infrastructure near the discharge prevents the productive use of the energy balance. Instead, the energy balance is currently converted to heat and extinguished to the atmosphere. A project like this could serve as an example of how energy from these discharges could be captured and used to offset the energy needs of an active system.

Combining the effects of Conceptual Plant #6 and the success of the Oneida passive treatment systems, 39 miles of the Catawissa Creek mainstem could be removed from the PADEP Integrated List of AMD impaired waters. Catawissa Creek would also become a cold water fishery destination.

Conceptual Plant #7 – Mahanoy Creek Plant #1

The first massive discharge to impact Mahanoy Creek is the Gilberton Pump Discharge (#9). The Gilberton Pump Discharge was installed to reduce basement flooding and runs about 40 percent of the time (Growitz et al., 1985). According to the historical data, when pumped, the flow of the discharge is around 22.3 cfs; however, the average flow is closer to 14.47 cfs due to the irregular pumping schedule.

The Gilberton Pump Discharge is circumneutral and is the largest source of iron (25.8 percent) and second largest source of manganese (19.8 percent) to Mahanoy Creek.

The West Penn Breaker Discharge (#15) is less than one mile downstream of the Gilberton Pump Discharge (Figure 13). The discharge is slightly net acidic with a relatively low flow containing high concentrations of iron and aluminum. It is the second largest aluminum loading producer in the Mahanoy Creek Watershed, and eighth largest in the entire Susquehanna Basin Anthracite Field.

Due to the relative low flow of the West Penn Breaker Discharge, especially in comparison to the Gilberton Pump Discharge flow, they could be easily combined for optimal treatment (Table 15).

The Gilberton Pump Discharge may have potential as a source of consumptive use mitigation water. According to SRBC, the Gilberton Mine Pool stores 1.86 billion gallons of water (Pytak, 2010). On average, the mine pool is pumped 146 days per year at 22.3 cfs. The period of the time (60 percent) that the mine pool is not pumped probably coincides with the dry summer months when consumptive use mitigation water is needed. The question then arises, can the mine pool be pumped at a rate of 8.92 cfs for 365 days per year and still maintain a level to eliminate basement flooding? If this or a different change in pumping rate is possible without causing property damage, then summer flows could be increased on Mahanoy Creek.

Table 14. Average Flow, Concentrations, and Loadings of Plant #6 Discharges and Plant #6 Mix Water

Discharge	Flow cfs	pH SU	Fe mg/l	Mn mg/l	Al mg/l	Alk mg/l	Acid mg/l	Fe Load lbs/day	Mn Load lbs/day	Al Load lbs/day	Alk Load lbs/day	Acid Load lbs/day
Audenreid Tunnel	19.93	3.74	1.77	2.47	7.97	0.73	154.13	190.28	265.45	856.61	78.36	16,570.82
Catawissa Tunnel	1.31	4.01	1.45	0.31	1.27	2.11	28.81	10.26	2.18	9.00	14.87	203.68
Green Mountain Tunnel	1.75	3.91	0.51	0.65	2.94	1.17	51.73	4.79	6.18	27.77	11.04	488.29
Mixed	22.99	~3.77	1.66	2.21	7.20	0.84	139.19	205.33	273.81	893.38	104.27	17,262.79

Table 15. Average Flow, Concentrations, and Loadings of Plant #7 Discharges and Plant #7 Mix Water

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Gilberton Pump Discharge	14.47	6.14	44.01	8.46	0.73	67.36	41.62	3,435.41	660.77	56.76	5,258.37	3,249.19
West Penn Breaker Discharge	1.78	4.76	73.87	10.11	16.01	15.09	78.98	709.17	97.04	153.68	144.91	758.16
Mixed	16.25	~6.00	47.28	8.64	2.40	61.64	45.71	4,144.58	757.81	210.44	5,403.28	4,007.35

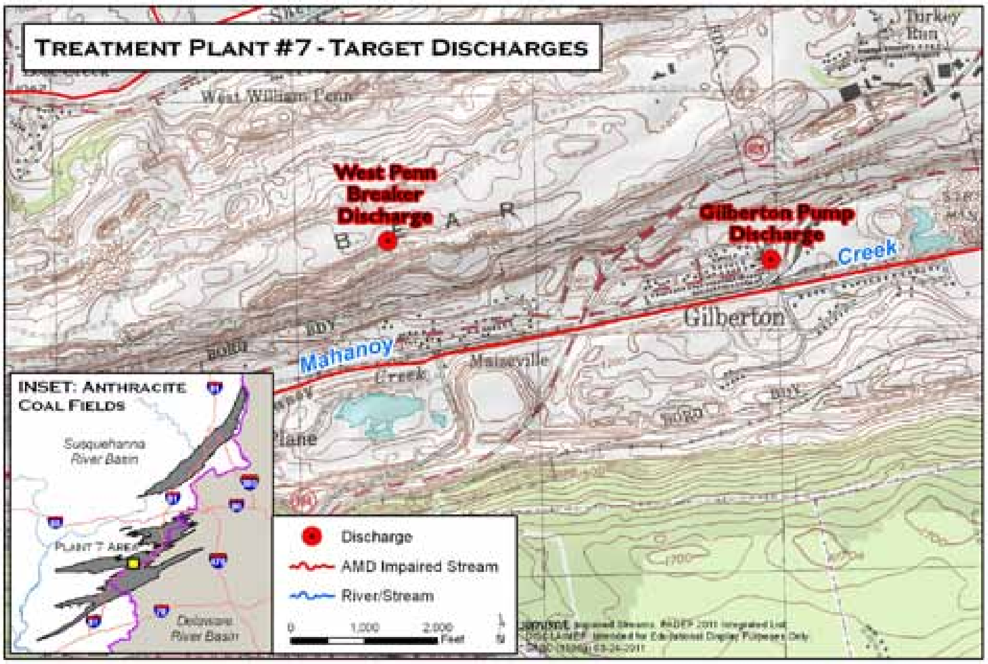


Figure 13. Treatment Plant #7 - Target Discharges

The Oakland Tunnel entry to Mahanoy Creek.

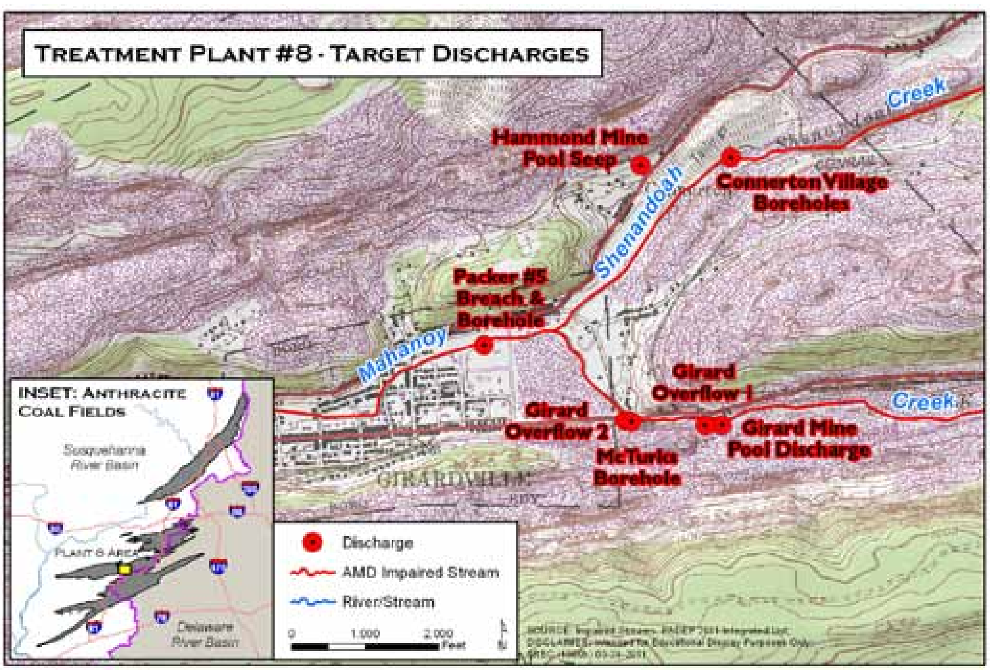


Figure 14. Treatment Plant #8 - Target Discharges

Conceptual Plant #8 – Mahanoy Creek Plant #2

Just upstream of the town of Girardsville is the second major impact to Mahanoy Creek, the Packer #5 Breach and Borehole (#8) and several other discharges in close proximity (Figure 14).

Similar to the Gilberton Pump Discharge, Packer #5 Breach and Borehole is circumneutral. It is the second largest producer of iron (20.6 percent) and largest producer of manganese (23.6 percent) to Mahanoy Creek. The Packer #5 complex could drain or partially drain as many as 14 different mine pools (PADEP, 2007).

There are several other low to moderate flow discharges in close proximity to the Packer #5 Breach and Borehole. The Girard Mine Pool Discharge, two Girard Mine Pool Overflows, and the McTurks Borehole are located less than one-half mile upstream on Mahanoy Creek. The Hammond Mine Pool Seep and Connerton Village Boreholes are located 0.8 miles upstream on Shenandoah Creek, which confluences with Mahanoy Creek at the Packer #5 Breach and Borehole site. Due to their proximity and the fact that mixing the discharges creates

Table 16. Average Flow, Concentrations, and Loadings of Plant #8 Discharges and Plant #8 Mix Water

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Packer #5 Breach and Borehole	20.19	6.49	25.21	7.21	0.07	164.41	44.11	2,746.11	785.01	7.12	17,907.26	4,804.65
Girard Mine Pool Discharge	3.52	6.05	23.22	3.99	0.43	57.89	60.56	440.91	75.86	8.19	1,099.29	1,150.07
Girard Overflow #1	0.97	6.40	18.65	nd	nd	48.50	44.93	97.54	nd	nd	253.67	234.96
Girard Overflow #2	0.09	3.70	10.69	nd	nd	0.00	99.20	5.24	nd	nd	0.00	48.61
McTurks Borehole	0.43	5.95	15.53	nd	nd	22.30	60.08	36.03	nd	nd	51.74	139.38
Connerton Village Borehole	3.48	6.26	45.29	nd	nd	198.10	124.60	850.12	nd	nd	3,718.30	2,338.70
Hammond Pool Seep	0.16	6.55	13.60	5.65	0.45	149.79	-7.17	11.70	4.86	0.39	128.82	-6.17
Mixed	28.84	~6.30	26.92	5.56	0.10	148.86	55.99	4,187.65	865.73	15.70	23,159.08	8,710.20

a circumneutral elevated iron water product, the combination and conveyance of these discharges to a centralized plant should be considered (Table 16).

As with all the other mine pool discharges, due to size of the mine pools and flows, the mine pool discharges that contribute flow to Conceptual Plant #8 may also contain consumptive water use mitigation, hydroelectric, and geothermal potential that could be incorporated into the active treatment plant design.

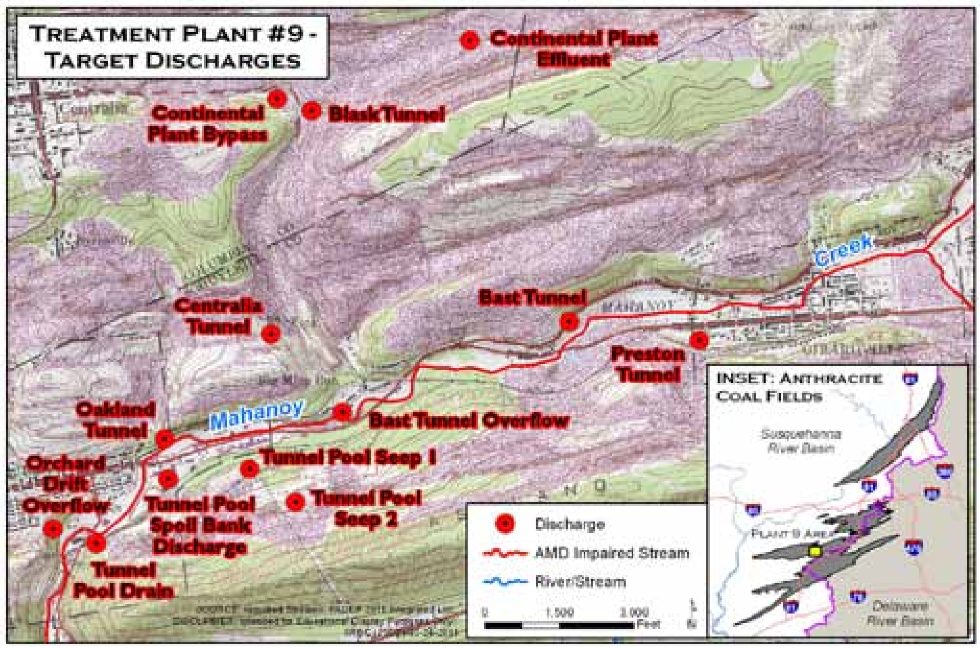


Figure 15. Treatment Plant #9 - Target Discharges

Conceptual Plant #9 – Mahanoy Creek Plant #3

Between the towns of Girardsville and Ashland, another set of discharges are located in close proximity to one another, including the Centralia Tunnel (#10) and the Continental Treatment Plant Bypass (#16) (Figure 15). In this group of discharges, the Centralia Tunnel is centralized. The furthest east discharge, Preston Tunnel, is 1.6 miles upstream on Mahanoy Creek. The furthest west discharge, Orchard Drift Overflow, is 1.1 miles downstream on Mahanoy Creek. The furthest discharge north, the treated portion of the Continental Discharge, is 1.4 miles upstream of an unnamed tributary to Mahanoy Creek. In comparison, the amount of pipeline set to convey the 21 discharges to the Hollywood Treatment Plant on the Bennett Branch Sinnemahoning Creek totals nearly 3.5 miles (Cavazza, 2011).

Negatives of this grouping include the number of discharges mixed (13), several discharges that have no flow analysis, and the fact that a majority are of acidic character, which creates a slightly net acidic mix water. Positives include the amount of discharges and loading that can be captured and conveyed in a relatively small area to a centralized active treatment plant and the possible use of the actively treated portion of the Continental Discharge as a dilution/alkaline solution. Adding the treated portion of the Continental Discharge, the eventual mix water ends slightly net acidic with only a moderate iron concentration of 11.17 mg/l and relatively low concentrations of manganese and aluminum (Table 17).

Conceptual Plant #9, just due to the sheer number of discharges and their differing chemical characteristics, is arguably the most difficult of the treatment plants suggested for consideration. However, it also captures a significant amount of AMD loading that presently enters the Mahanoy Creek Watershed.

The discharges combined contribute 18 percent of the iron loading, 29.6 percent of the manganese loading, 39 percent of the aluminum loading, and 34.3 percent of the acidity loading currently impacting the Mahanoy Creek Watershed.

Table 17. Average Flow, Concentrations, and Loadings of Plant #9 Discharges and Plant #9 Mix Water

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Centralia Tunnel	8.41	3.79	8.01	7.07	7.43	3.75	105.90	363.62	320.77	337.01	169.97	4,804.59
Preston Tunnel	1.54	6.39	13.35	1.15	0.10	68.94	43.74	110.90	9.56	0.79	573.34	363.44
Bast Tunnel	0.69	3.27	30.32	3.40	2.50	2.71	297.98	112.78	12.64	9.29	10.09	1,108.49
Bast Tunnel Overflow	1.12	nd	8.55	2.78	0.55	99.45	21.88	51.66	16.82	3.30	600.69	132.15
Oakland Tunnel	4.53	6.30	26.41	3.09	0.74	123.83	84.97	645.65	75.62	18.05	3,026.46	2,076.60
Orchard Drift Overflow	0.27	6.33	1.18	0.83	0.44	16.26	9.86	1.73	1.21	0.64	23.74	14.40
Blask Tunnel	nd	3.72	8.14	6.02	7.53	0.25	84.73	nd	nd	nd	nd	nd
Continental Plant Bypass	9.80	5.27	18.97	7.34	0.30	13.98	64.58	1,003.13	388.23	15.84	739.15	3,414.15
Continental Plant Effluent	12.96	8.33	0.83	2.25	0.54	73.68	2.12	57.97	157.24	38.07	5,151.23	148.43
Tunnel Pool Drain	0.25	7.07	12.16	1.79	0.02	315.27	15.22	16.41	2.41	0.03	425.61	20.55
Tunnel Pool Spoil Bank Discharge	0.16	6.07	37.21	2.73	0.35	29.97	85.63	32.00	2.35	0.30	25.77	73.64
Tunnel Pool Seep #1	nd	5.55	16.83	3.38	4.77	30.46	31.24	nd	nd	nd	nd	nd
Tunnel Pool Seep #2	nd	6.73	11.34	3.18	0.42	94.31	1.71	nd	nd	nd	nd	nd
Mixed	39.73	~6.40	11.18	4.60	1.98	50.14	56.71	2,395.85	986.85	423.32	10,746.05	12,156.44

As with all the other mine pool discharges, due to the size of the mine pools and flows, the mine pool discharges that contribute flow to Conceptual Plant #9 may also contain consumptive water use mitigation, hydroelectric, and geothermal potential that could be incorporated into the active treatment plant design.

Conceptual Plant #10 – Mahanoy Creek Plant #4

Besides the North Franklin Mine Pool Discharge impacts to Zerbe Run and the Potts Mine Pool Discharges, the final major impact to Mahanoy Creek is from the Doutyville (#18) Tunnel and the adjacent Helfenstein Tunnel. Both drain the Locust Gap Mine Pool. The Helfenstein Tunnel is 2.2 miles upstream of the Doutyville Tunnel (Figure 16). Both discharges are circumneutral with elevated iron concentrations (Table 18).

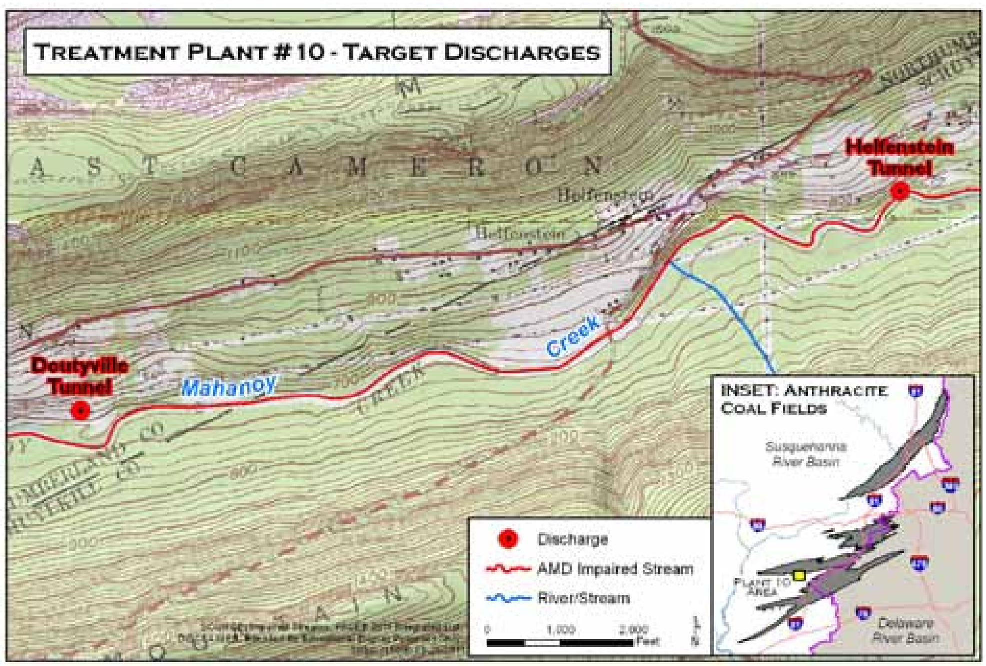


Figure 16. Treatment Plant #10 - Target Discharges

Table 18. Average Flow, Concentrations, and Loadings of Plant #10 Discharges and Plant #10 Mix Water

Discharge	Flow	pH	Fe	Mn	Al	Alk	Acid	Fe Load	Mn Load	Al Load	Alk Load	Acid Load
	cfs	SU	mg/l	mg/l	mg/l	mg/l	mg/l	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Doutyville Tunnel	9.86	6.05	6.52	2.14	2.60	6.23	38.10	347.05	113.90	138.41	331.46	2,026.37
Helfenstien Tunnel	5.64	6.46	12.89	3.61	0.88	63.52	13.73	392.50	109.91	26.79	1,932.96	417.75
Mixed	15.50	~6.20	8.84	2.68	1.98	27.08	29.23	739.55	223.81	165.20	2,264.42	2,444.12

Combined, Doutyville and Helfenstein contribute 5.5 percent of the iron loading, 6.7 percent of the manganese loading, 15.2 percent of the aluminum loading, and 6.9 percent of the acidity loading presently entering the Mahanoy Creek Watershed.

Due to the fact that both tunnels drain the same isolated mine pool, there could be a way to create a condition where all water exits one tunnel with the mine pool then manipulated for consumptive water use mitigation.

Even though the four conceptual plants suggested for Mahanoy Creek do not treat every large discharge (Vulcan-Buck Mountain Pool Discharge, Pott Mine Pool Discharges, and the North Franklin Mine Pool Discharge), there is the potential to remove about 45 miles from the PADEP Integrated List of AMD impaired waters. This is because the four conceptual plants would treat 86 percent of the iron loading, 85.1 percent of the manganese loading, 75.1 percent of the aluminum loading, and 77.2 percent of the acidity loading presenting impacting Mahanoy Creek.

Other Conceptual Plants – Jermyn Slope, Mocanaqua Tunnel, Porter Tunnel, Plainsville Outlet

The treatment of the four final Top-20 Discharges is significantly less important than the combination of discharges suggested for treatment in the ten conceptual active treatment plants.

When analyzing from the basin-scale, the discharges combined into the ten conceptual active treatment plants comprise 68.3 percent of the iron loading, 72.6 percent of the manganese loading, 78.7 percent of the aluminum loading, and 60.1 percent of the acidity loading created in the Anthracite Region of the Susquehanna River Basin.

The Jermyn Slope (#19) is the ninth largest flow discharge in the Susquehanna River Basin Anthracite Fields; however, the water quality of the Jermyn Slope is fairly good. Besides a slight concentration of average acidity (5.33 mg/l) and an average iron concentration (1.88 mg/l) that is just slightly higher than the water quality standard of 1.50 mg/l, all other parameters are within standards.

You can even argue that the Jermyn Slope is a resource to the Lackawanna River due to the large cold water flow it provides that allows the Lackawanna River to be a viable cold water fishery throughout its length until the entry of the Old Forge Borehole. Consequently, the only restoration measure that should be considered for the Jermyn Slope is alkaline addition to remove the slight concentration of acidity. The pH increase will then assist in the quick precipitation of iron from the discharge in the Lackawanna River, where it should not cause a significant problem.

No impoundments should be considered for this discharge as atmospheric heating of the water will diminish the large cold water benefit of the Jermyn Slope to the Lackawanna River.

The Mocanaqua Tunnel (#12) is the last major Northern Field discharge to impact the Susquehanna River. The tunnel drains the West End Basin Mine Pool and it is the seventh highest acidity loading producer in the Susquehanna River Basin Anthracite Fields.

However, the Mocanaqua Tunnel is less important from the other Top-20 Discharges because it does not impact a tributary, and if the other major discharges of the Northern Field are treated, the loading of the tunnel is not at an amount that would impact the Susquehanna River significantly enough to be listed as impaired by PADEP.

Due to the fact that the Mocanaqua Tunnel may drain an isolated mine pool, it may serve as a site for consumptive water use mitigation, and this potential may increase the attractiveness of treatment.

The Porter Tunnel (#14) is the largest AMD impact to Wiconisco Creek. The tunnel contributes 47.3 percent of the iron loading, 37.4 percent of the manganese loading, 90.6 percent of the aluminum loading, and 68.9 percent of the acidity loading that impacts the Wiconisco Creek Watershed.

According to the Wiconisco Creek Restoration Association web site, the Porter Tunnel has recently been treated via a calcium oxide pellet dosing system that increases the pH of the discharge before it enters a pond/wetland system for metals precipitation (Wiconisco Creek Restoration Association, 2008). Consequently, no future restoration action is needed unless the alkaline dosing system ceases to function.

The Plainsville Outlet (#20) is a very similar situation to the Mocanaqua Tunnel. It impacts no tributary, entering the Susquehanna River proper. Likewise, the loading of the outfall is not at an amount that would impact the Susquehanna River significantly enough to be listed as impaired by PADEP. In addition, the outlet enters a large impoundment, which may allow for significant iron hydroxide precipitation before entering the Susquehanna River.

POTENTIAL CONSUMPTIVE WATER USE MITIGATION SITES

Consumptive water use mitigation projects using mine pools are already underway in the West Branch Susquehanna River Subbasin.

Beyond the low flow mitigation benefits, the three projects together – Lancashire #15, the Hollywood Plant, and the proposed Cresson Plant – will result in the restoration and improvement of large stretches of streams within the Susquehanna River Basin.

Given the vastness of the mine pools and the relatively better discharge water chemistry that exists in many of the Bituminous Region mines, the implementation of similar projects that combine water quality improvements with low flow mitigation in the Anthracite Region would be of great significance.

Summary
Susquehanna River Basin Anthracite Region Recommendations

Implement the Top-20 Discharge Treatment Plan for water quality reclamation within the Anthracite Region of the Susquehanna River Basin.

Assess the 33 square miles of Abandoned Mine Lands that are not currently prioritized under the Surface Mining Control and Reclamation Act.

Complete a restoration study for the Shamokin Creek Watershed after implementing the Top-20 Plan.

Initiate a water quality monitoring program for the Stony Creek Watershed given the lack of available data.

Complete a flow monitoring study of the Old Forge Borehole to assess storage and consumptive water use mitigation potential.

Complete a study of the consumptive water use mitigation and hydroelectric potential of the Jeddo Tunnel.

Explore active treatment alternatives for the Audenreid Tunnel and surrounding discharges.

Complete a study focusing on the consumptive water use mitigation potential of the West End Mine Pool (Mocanaqua Tunnel).

Initiate a water quality/quantity monitoring program for the Upper Lackawanna River discharges to support a study on consumptive water use mitigation potential.

Enhance the implementation of the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation's borehole monitoring plan with the use of more advanced monitoring technology needed to characterize pool/discharge volumes.

Complete a study of the 260 flooded surface mines within the region for prioritizing potential consumptive water use mitigation.

Explore the use of mine pools along the Susquehanna and Delaware drainage divide.

REFERENCES

Albert Peters and Associates. 1971. Lackawanna River Mine Drainage Pollution Abatement Project Part I. Pennsylvania Department of Environmental Resources. Operation Scarlift No. SL-139.

Ballaron, P.B., C.M. Kocher, and J.R. Hollowell. 1999. Assessment of Conditions Contributing Acid Mine Drainage to the Little Nescopeck Creek Watershed, Luzerne County, Pennsylvania, and an Abatement Plan to Mitigate Impaired Water Quality in the Watershed. Susquehanna River Basin Commission in cooperation with the Wildlands Conservancy. Publication No. 204. Susquehanna River Basin Commission, Harrisburg, Pennsylvania.

Berger Associates. 1972. Swatara Creek Mine Drainage Pollution Abatement Project Part II. Pennsylvania Department of Environmental Resources. Operation Scarlift No. SL126-2.

Cavazza, E. “Hollywood Questions.” Email Message. February 1, 2011.

Commonwealth of Pennsylvania. 2005. Pennsylvania Code, Title 25. Environmental Protection, Department of Environmental Protection, Chapter 93. Water Quality Standards.

Davidock, T. 2006. Audenreid: Updates on the Progress of the Construction of the Audenreid AMD Treatment System in the Catawissa Creek Watershed. http://audenreid.blogspot.com.

Edmunds, W.E. 2002. Coal in Pennsylvania. 2nd Edition. Pennsylvania Geological Survey. 4th Series. Educational Series 7.

______. 1972. Coal Reserves of Pennsylvania: Total, Recoverable, and Strippable. Pennsylvania Geological Survey. 4th Series. Information Circular 72.

Edmunds, W.E., V.W. Skema, and N.F. Flint. 1999. Pennsylvanian (Part II. Stratigraphy and Sedimentary Tectonics). In: The Geology of Pennsylvania. C.H. Schultz, ed. Harrisburg: Pennsylvania Geological Survey and Pittsburgh Geological Society. pp. 149-169.

GAI Consultants. 2007. Final Report - Phase I SRB Low Flow Mine Storage and Treatment Project Evaluation. GAI Project Number: C060164.10.

Gannett Fleming Corddry and Carpenter, Inc. 1972. Mine Drainage Abatement Measures for the Shamokin Creek Watershed. Pennsylvania Department of Environmental Resources. Operation Scarlift No. SL-113.

Goode, D.J., C.A. Cravotta III, R.J. Hornberger, M.A. Hewitt, R.E. Hughes, D.J. Koury, and L.W. Eicholtz. 2011. Water Budgets and Ground Water Volumes for Abandoned Underground Mines in the Western Middle Anthracite Coalfield, Schuylkill, Columbia, and Northumberland Counties, Pennsylvania – Preliminary Estimates with Identification of Data Needs. United States Geological Survey. Scientific Investigations Report 2010-5261.

Growitz, D.J., L.A. Reed, and M.M. Beard. 1985. Reconnaissance of Mine Drainage in the Coal Fields of Eastern Pennsylvania. United States Geological Survey. Water Resources Investigations Report 83-4274.

Haentjens, P. “Anthracite Meeting Questionnaire.” Email Message. March 11, 2010.

REFERENCES

Hawkins, J.W., E.F. Perry, and M. Dunn. 2005. Hydrolic Characterization of a Large Underground Mine Pool in Central Pennsylvania. In 2005 National Meeting of the American Society of Mining and Reclamation, Breckenridge, CO, June 19-23, 2005. ASMR, Lexington, Kentucky.

Hewitt, M.A. “Eastern Field Aluminum.” Email Message. December 17, 2010.

Hornberger, R.J., C.M. Loop, K.B.C. Brady, and N.A. Houtz. 2004. Geology of the Pennsylvania Coal Region. In Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania. Pennsylvania Department of Environmental Protection and Penn State Materials Research Institute. pp. 20-52.

O’Neill, K. and B. McGurl. 2002. Graphic Representation of the Llewellyn Formation through the Lackawanna River Corridor. Data from Albert Peters and Associates. 1971. Lackawanna River Mine Drainage Pollution Abatement Project Part I. Pennsylvania Department of Environmental Resources. Operation Scarlift No. SL-139.

Oregon State University. 2006. Average Annual Precipitation, 1971-2000, Pennsylvania. PRISM Climate Group and Oregon Climate Service Map. http://www.prism.oregonstate.edu/pub/prism/state_ppt/pennsylvania300.png.

Pennsylvania Department of Environmental Protection. 2009. Pennsylvania Annual Reports on Mining Activities. http://www.dep.state.pa.us/dep/deputate/minres/bmr/historicalminingreports/index.html.

_____. 2007. Mahanoy Creek Watershed TMDL. http://www.dep.state.pa.us/watermanagement_apps/tmdl/default.aspx.

Pennsylvania Fish and Boat Commission. 2010. Class A Wild Trout Waters List. http://www.fish.state.pa.us/classa.pdf.

Pytak, S.J. 2010. Pump Fails at Gilberton Mine Pool. Republican Herald. March 25, 2010 ed. http://republicanherald.com/news/pump-fails-at-gilberton-mine-pool-1.698775.

Sanders and Thomas, Inc. 1975. Mahanoy Creek Mine Drainage Pollution Project. Pennsylvania Department of Environmental Resources. Operation Scarlift No. SL-197.

Wiconisco Creek Restoration Association. 2008. Tour of Wiconisco Creek. http://dauphincreeks.org/Wiconisco_tour.html.

Wnuk, R., R. Moase, T. Copeland, and R. Mulberger. 1998. Catawissa Creek Basin (405E) Fisheries Management Report. Pennsylvania Fish and Boat Commission Bureau of Fisheries. Fisheries Management Division.

Wood, G.H., Jr., T.M. Kehn, and J.R. Eggleston. 1986. Deposition and structural history of the Pennsylvania Anthracite region. In Lyons, P.C., and C.L. Rice, eds. Paleoenvironmental and Tectonic Controls in Coal-Forming Basins of the United States: Geological Society of America Special Paper 210. pp. 31-47.

United States Census. 2009. Pennsylvania State Census Quickfacts. http://quickfacts.census.gov/qfd/states/42000.html.

Newport Lake Discharge (EPCAMR).

The Centralia Tunnel Discharge.

The confluence of Shamokin Creek and Quaker Run (EPCAMR).

The Maysville Borehole entry to Shamokin Creek (EPCAMR).

SRBC wishes to thank these people who contributed to the Anthracite Region Mine Drainage Remediation Strategy:

Charles Cravotta III, United States Geological Survey

Jon Dietz, Dietz–Gourley Consulting, LLC

Peter Haentjens, Eastern Middle Anthracite Region Recovery Inc.

Michael Hewitt, Eastern Pennsylvania Coalition for Abandoned Mine Reclamation

Robert Hughes, Eastern Pennsylvania Coalition for Abandoned Mine Reclamation

Michael Korb, Pennsylvania Department of Environmental Protection

Bernie McGurl, Lackawanna River Corridor Association

Frank Viozzi, Doc Fritchey Chapter of Trout Unlimited

Todd Wood, Pennsylvania Department of Environmental Protection

Ed Wytovich, Catawissa Creek Watershed Association

Printed on FSC-certified paper. FSC-certified paper and print products contribute to conservation, responsible management, and community level benefits for people near the forests that provide your paper.

www.srbc.net

SRBC • 1721 N. Front Street • Harrisburg, PA • 17102

(p) 717.238.0423 • (f) 717.238.2436

srbc@srbc.net

www.srbc.net