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.

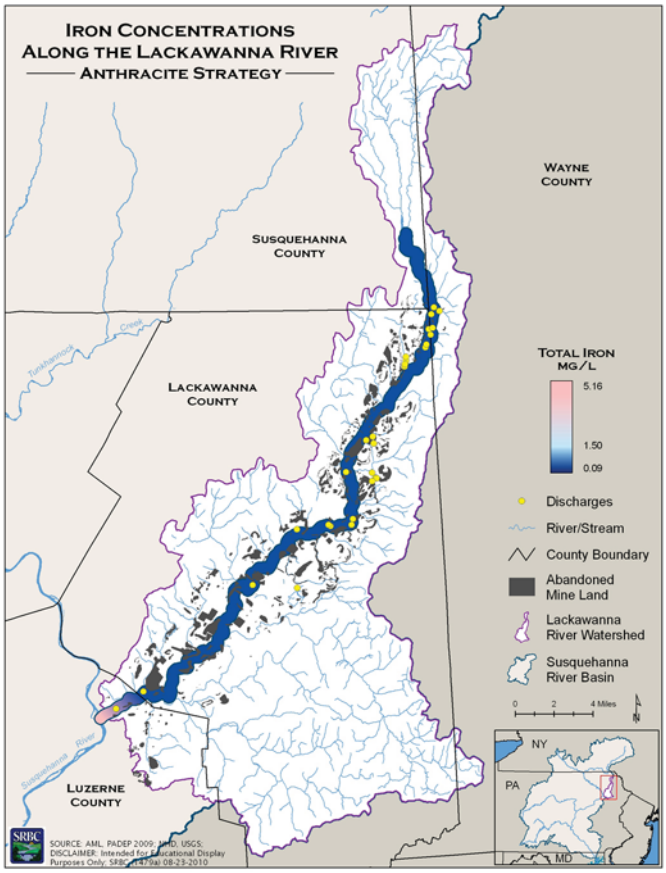


Figure 2. Iron Concentrations Along Lackawanna River

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.

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.

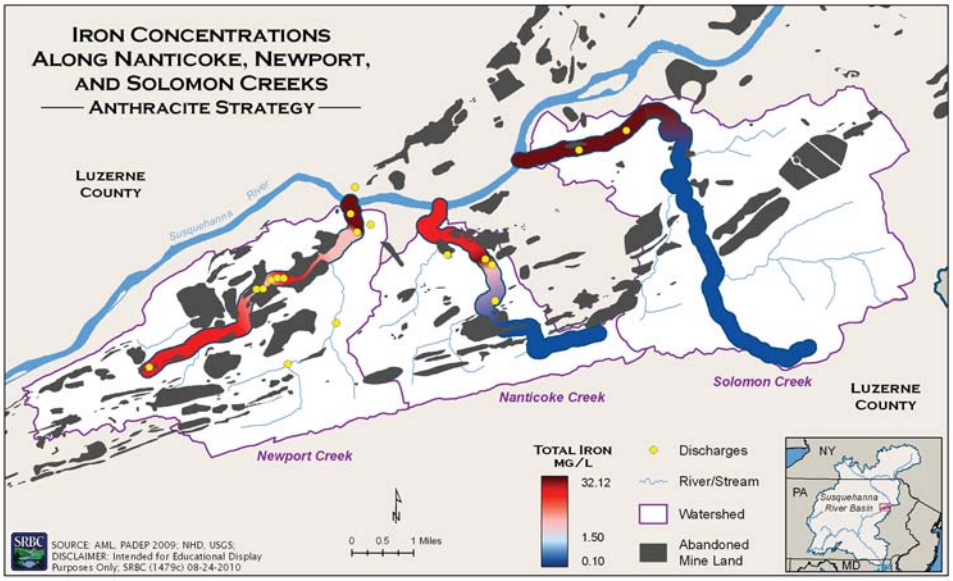


Figure 3. Iron Concentrations Along Nanticoke, Newport, and Solomon Creeks

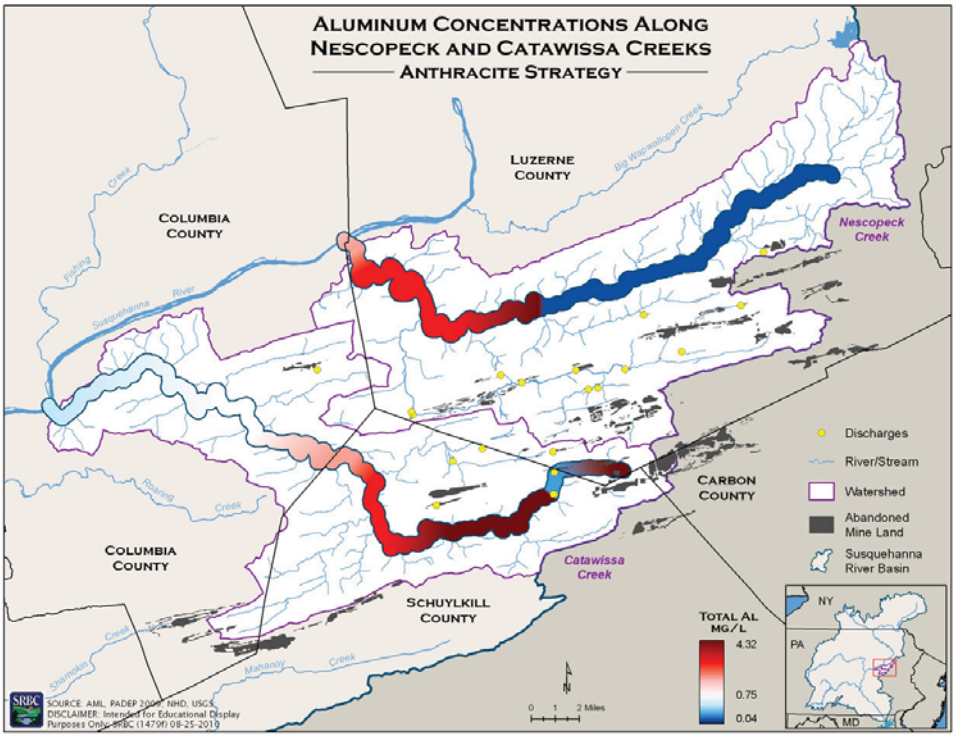
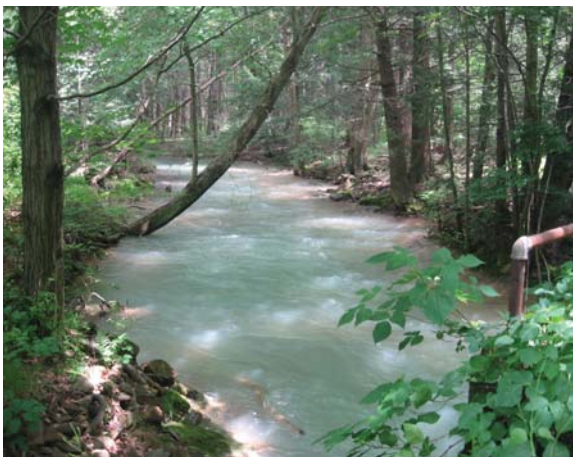


Figure 4. Aluminum Concentrations Along Nescopeck and Catawissa Creeks



(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.

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.

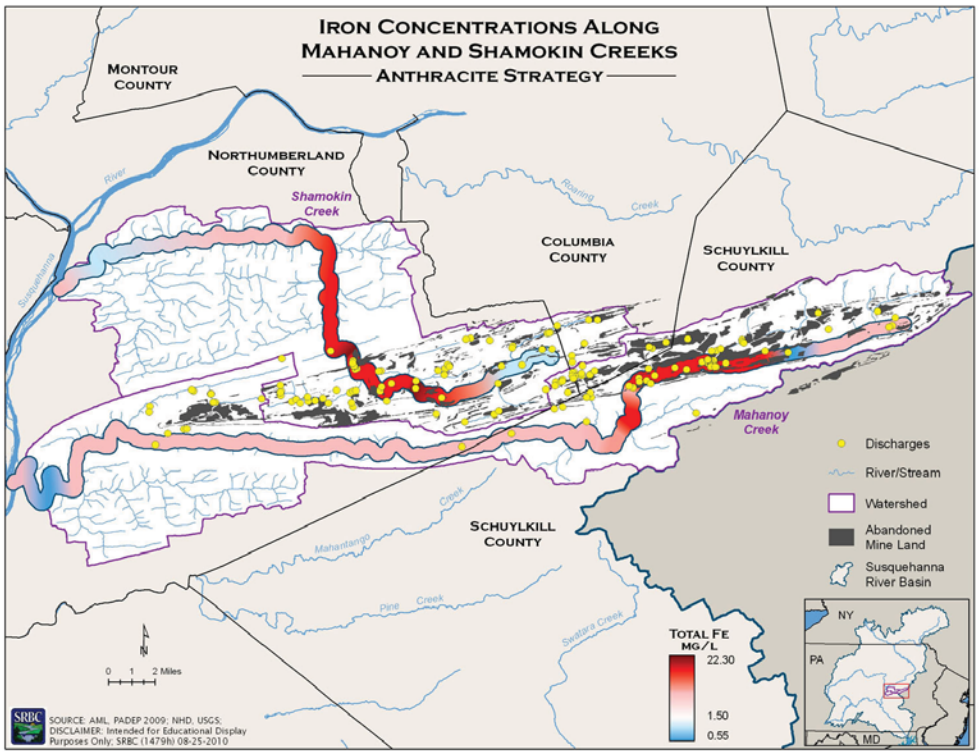


Figure 5. Iron Concentrations Along Mahanoy and Shamokin Creeks

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.

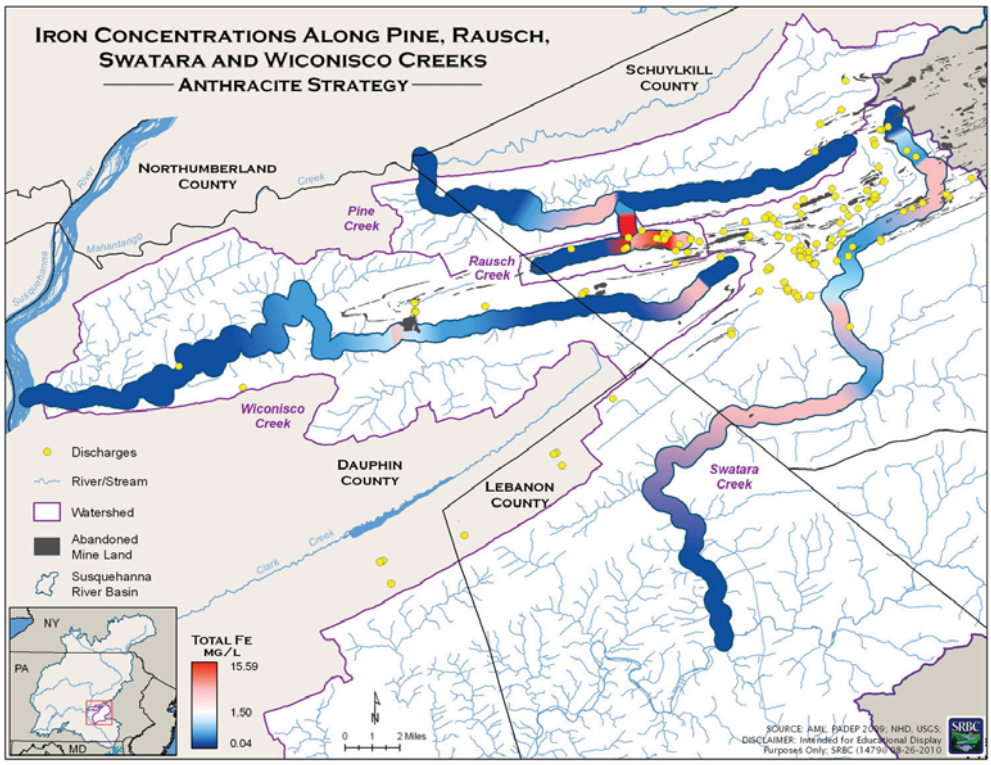


Figure 6. Iron Concentrations Along Pine, Rausch, Swatara and Wiconisco Creeks

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.