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Acid Mine Drainage Loadings to the Chesapeake Bay Watershed

Literature Synthesis

Chesapeake Bay Program

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July 1998

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FOREWORD

Authorization

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Acknowledgments

Over the course of this literature synthesis, research scientists, environmental engineers, and environmental managers from the following governmental and non-governmental agencies were contacted for purposes of obtaining data relevant to this literature synthesis:

U.S. EPA Region III, Water Protection Division

Pennsylvania Department of Environmental Protection - Abandoned Mines and Reclamation

Pennsylvania Department of Environmental Protection - Bureau of Water Quality Management

Pennsylvania Department of Environmental Protection - Bureau of Mining and Reclamation

Pennsylvania Department of Environmental Protection - Wilkes Barre Regional Office

Pennsylvania Department of Environmental Protection - Pottsville District Mining Office

Pennsylvania Department of Environmental Protection - Hawk Run District Mining Office

Pennsylvania Department of Environmental Protection - Bureau of Mining and Reclamation

West Virginia Bureau of Water Resources

U.S. Geological Survey - Lemoyne Office

Maryland Bureau of Mines

Army Corps of Engineers - Baltimore Office

West Virginia Division of Environmental Protection - Office of Abandoned Mine Lands & Reclamation

Penn State University - Environmental Resources Research Institute

National Institute for Environmental Renewal

Par Government Systems

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Wildlands Conservancy

Maryland Department of Natural Resources

Southern Allegany Resource Conservation and Development Conservancy

Cambria County and Clearfield County Conservation Districts

Pennsylvania Department of Environmental Protection - Ebensburg Office

Susquehanna River Basin Commission

Sincere gratitude is extended to those individuals who contributed data, information, and guidance during the preparation of this literature synthesis.

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INTRODUCTION

Land use activities in the Chesapeake Bay watershed are diverse and contribute significantly to water quality. Because of the long history of coal mining in the upper reaches of the Chesapeake Bay watershed, much concern has been generated regarding the impact of acid drainage from active and abandoned coal mines. The U.S. Environmental Protection Agency has singled out acid drainage from abandoned coal mines as the number one water quality problem in Appalachia. Acid mine drainage from abandoned coal mines is the most severe and extensive water pollution problem in western Maryland, West Virginia, and northern, central and western Pennsylvania. Within the Chesapeake Bay Basin, drainage from abandoned coal mines poses a significant threat to water quality in the Susquehanna, West Branch Susquehanna, and Juniata River basins in Pennsylvania, as well as the North Branch Potomac River and its tributaries in West Virginia and Maryland.

Acid mine drainage (AMD) is formed when mining operations expose coal and bedrock high in pyrite (iron-disulfide) to oxygen and moisture. The drainage is characterized by low pH (less than 6.0) and high concentrations of sulfates, acidity, and metals (dissolved/particulate) such as iron, manganese and aluminum. Other principal elements of coal mine drainage include calcium, magnesium, sodium and potassium (Clark, 1969). Additional trace metals that have been detected in AMD in decreasing order of abundance are strontium, zinc, nickel, cobalt, lithium, barium, boron, copper, lead and cadmium (Wood, 1996). The acidity is produced by oxidation of metal sulfide minerals. Iron hydroxide and sulfuric acid that result from chemical and biological reactions eventually contaminate receiving streams and underground water. Sulfate is generally a conservative indicator of AMD production. Increases in the sulfate content of mine water indicate an acceleration in metal sulfide oxidation, primarily iron disulfide (pyrite). Sulfate concentration is affected minimally by geochemical changes to mine water (e.g., pH changes and dissolved oxygen content) and remains in solution to high concentrations determined primarily by calcium concentration and the solubility of gypsum. Biological oxidation and chemical oxidation of ferrous iron to ferric iron accompanied by the release of hydrogen ions leads to supersaturation of ferric iron as an oxyhydroxide mineral and forms orange (yellowboy) iron deposits in the sediment of receiving streams. In addition to iron and sulfate, elevated concentrations of aluminum and manganese are commonly associated with AMD. Insoluble ferric iron, aluminum and manganese often remain in solution in mine drainage as positively charged sols (suspended insoluble particles). Factors that affect the concentrations of AMD chemical constituents in coal mine drainage are mineral content of the coal, overburden (material above the coal deposits), and associated host rock; quantity of water flowing through the mine workings; residence time of water circulation in mine workings; the availability of oxygen and dissolved oxygen in the mine water; method of mining (e.g., deep underground or surface mining); water removal from mines through pumping; and the exposed surface area of pyritic minerals.

The purpose of this literature synthesis is to determine the significance of AMD in contributing trace elements (contaminants) to the Chesapeake Bay watershed and determine the extent of the contribution from a local, regional and Baywide perspective. In addition, this literature synthesis will provide the Toxics Subcommittee of the Chesapeake Bay Program with information for revision of the Chesapeake Bay Basinwide Toxics Loading and Release Inventory and establishing a loading baseline and reduction target for acid mine drainage.

The information presented in this report was obtained through literature searches and exchange with research scientists, environmental engineers, and environmental managers from federal and state governmental and non-governmental agencies and private organizations.

IDENTIFICATION OF ACID MINE DRAINAGE SOURCES

Sources of AMD in the Chesapeake Bay watershed are located in the Susquehanna River Basin (Anthracite Coal Region), West Branch Susquehanna and Juniata River basins (Bituminous Coal Region) in Pennsylvania, and the North Branch Potomac River and its tributaries (Bituminous Coal Region) in West Virginia and Maryland (Fig. 1). Acid mine drainage has impacted 1100 mi in 158 streams in the Chesapeake Bay drainage as indicated in the 1996 Pennsylvania, Maryland and West Virginia 303(d) reports (Table 1). The causes cited for water quality degradation from AMD are, for the most part, related to pH and/or metals.

In the Susquehanna and West Branch Susquehanna River basins, the greatest source of the mine drainage discharging into streams is from abandoned underground mine workings (Skelly and Loy, Inc., 1973b). Hornburger et al. (1990) discussed the spatial distribution of AMD in Pennsylvania and temporal variation in different types of AMD discharges. They also determined that 78% of the total AMD was produced by abandoned or inactive mines sites. Underground mines accounted for about half of the sources, but contributed more than half the AMD produced. They concluded that efforts to characterize AMD discharges must consider the common variability in flow and quality. Drainage occurs through various entryways to the mine (e.g., tunnels, shafts, slopes and drifts). Deep mine discharges in the Anthracite Region are less numerous than in the Bituminous Field, but contribute a much higher acid loading per discharge. Surface or strip mines in both anthracite and bituminous regions also contribute AMD. Improperly graded strip pits can trap surface runoff and form pools containing high concentrations of dissolved salts. During periods of heavy rainfall, the strip mine pools may overflow and discharge acidic water into nearby streams. Water trapped in the mine pits frequently emerges as seeps downslope from the mine site causing pollution of receiving streams. Leachate from coal refuse piles associated with abandoned mine sites are common sources of AMD. Refuse piles usually cover large areas and provide a source of minerals for the formation of acid drainage.

Anthracite Coal Fields - Susquehanna River Drainage

Northern Anthracite Coal Field

The northern anthracite coal field is drained, in part, by the Lackawanna River (Fig. 2). The Lackawanna watershed drains about 346 mi^2 and flows about 33 mi to the confluence with the Susquehanna River in Luzerne County, PA. The Lackawanna receives several AMD discharges upriver from Scranton from isolated mine pools which contribute little acidity. Klondike and Coalbrook mines contribute AMD through the Vandling and Simpson Drifts, respectively. Both are located between Forrest City and Carbondale. Farther downstream, between Carbondale and Scranton, three discharges originate from Jermyn Mine (Jermyn Slope), Lackawanna Mine (Peckville Shaft) and the Jerome Shaft of the Lackawanna Mine. Downnriver, near the confluence with the Susquehanna River, Old Forge borehole (Old Forge Mine) and Duryea breach (Senica Mine) are among the largest contributors of AMD in the Susquehanna Basin.

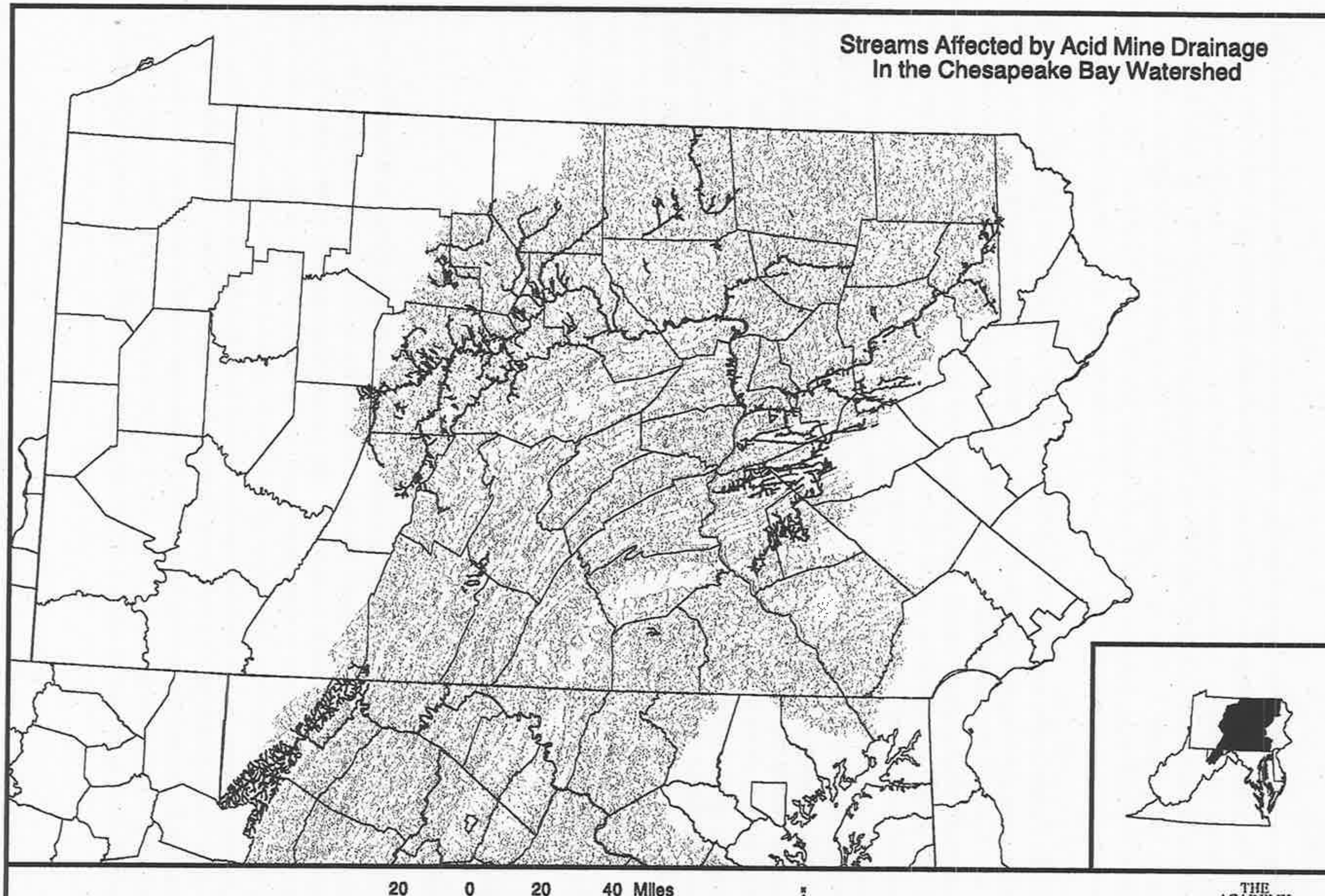

Streams Affected by Acid Mine Drainage
In the Chesapeake Bay Watershed
20 0 20 40 Miles
THE ACADEMY OF NATURAL SCIENCES

Figure 1.

Table 1. Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

Stream Name	Miles Degraded
Upper Susquehanna River Subbasin	
Tioga River	3
Morris Run	1
Fall Brook	2
Long Valley Run	1.6
Upper Central Susquehanna River Subbasin	
Lackawanna River	2.6
Roaring Brook	4
Aylesworth Creek	0.5
Powderly Creek	1.9
Coal Brook	1.9
Wilson Creek	0.6
Susquehanna River	20
Newport Creek	4.8
Solomon Creek	2.4
Black Creek	4.3
Little Nescopeck Creek	9.1
Catawissa Creek	27.5
Tomhickon Creek	10.6
Sugarloaf Creek	5.5
Lower Susquehanna River Subbasin	
Mahanoy Creek	52.2
Zerbe Run	5.8
Crab Run	1.3
Shenandoah Creek	5
Shamokin Creek	34.7
Carbon Run	3.7
Coal Run	3
Quaker Run	1.3
Locust Creek	1.6
North Branch Shamokin Cr.	4.6
Wiconisco Creek	16.2
Rattling Creek	2.2

Table 1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

Stream Name	Miles Degraded (based on length of study segment)
Lower Susquehanna River Subbasin	
West Branch Rattling Cr.	5.2
Doc Smith Run	1.5
Shale Run	0.8
East Branch Rattling Cr.	3.8
Stone Cabin Run	1.8
Nine O'Clock Run	0.6
Bear Creek	4.4
Pine Creek	6
Deep Creek	4.5
Hans Yost Creek	1
Rausch Creek	1.7
West Br. Rausch Cr.	3.5
East Br. Rausch Cr.	1.9
Swatara Creek	21.3
Baird Creek	1.4
West Branch Fishing Creek	3.6
Lower Rausch Creek	6.8
Lorberry Creek	1
Stumps Run	0.4
Middle Creek	17.5
Good Spring Creek	5.8
Poplar Creek	0.9
Coal Run	1.6
Gebhard Run	1.9
Panther Creek	1.7
Upper West Branch Susquehanna River Subbasin	
Sinnemahoning Creek	15.8
Bennett Branch Sinnemahoning Cr.	66.6
Dents Run	6.5
Trout Run	1
Spring Run	1.7
West Creek	12

Table 1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

Stream Name	Miles Degraded (based on length of study segment)
Upper West Branch Susquehanna River Subbasin	
Montgomery Creek	2.6
West Branch Susquehanna River	79.7
Laurel Run	1
Woods Run	3
North Branch Montgomery Cr.	0.9
Tinker Run	0.7
Hartshorn Run	1
Anderson Creek	10.3
Kratzer Run	5.1
Irvin Branch	1.5
Little Anderson Cr.	5.7
Wilson Run	1
North Camp Run	1.4
Rock Run	3
Bear Run	2.9
South Branch Bear Run	3.3
Alder Run	0.7
Sandy Creek	2.8
Big Run	1
Deer Creek	5
Surveyor Run	4
Little Surveyor Run	2
Trout Run	5
Taylor Springs Run	0.4
Pine Run	2.2
Lick Run	3.7
Fork Run	3.8
Clearfield Creek	71.9
Sanbourne Run	2.2
North Branch Upper Morgan Run	2.7
Little Muddy Run	4.5

Table 1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

Stream Name	Miles Degraded (based on length of study segment)
Upper West Branch Susquehanna River Subbasin (cont'd)	
Dutch Run	1.3
Brubaker Run	2
Birch Island Run	6.2
Little Birch Island Run	4.3
Amos Branch	1.6
Upper West Branch Susquehanna River Subbasin	
Sterling Run	9.7
Mosquito Creek	6
Curley's Run	1.2
Grimes Run	2
Moshannon Creek	1
Black Moshannon Creek	26.2
Cold Stream	1
Laurel Run	1
Goss Run	0.5
Central West Branch Susquehanna River Subbasin	
Pine Creek	4
Otter Run	3.8
Left Fork Otter Run	1.5
Right Fork Otter Run	0.4
Babb Creek	23
Wilson Creek	2.3
West branch Susquehanna R.	50.6
Lick Run	3.7
Tangascootack Creek	8.4
Drury Run (basin)	7.3
Stony Run	1.3
Woodley Draft Run	1.7
Sandy Run	1
Kettle Run	3
Two Mile Run	1.9

Table 1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

Stream Name	Miles Degraded (based on length of study segment)
Central West Branch Susquehanna River Subbasin (cont'd)	
Hidden Branch Two Mile Run	2.1
Cooks Run (basin)	6.8
Crowley Hollow	3.1
Camp Run	2
Rock Run	1.2
Beech Creek (basin)	26
Middle Branch Big Run	5.5
East Branch Big Run	2.4
Logway Run	0.8
Northfork Beech Creek	5.9
Lower West Branch Susquehanna River Subbasin	
Red Run	13.4
West Branch Susquehanna R.	3
Upper Juniata River Subbasin	
Bear Loop Run	0.8
Beaver Dam Branch	2.3
Sugar Run	6.3
Burgoon Run	3
Kittanning Run	4.2
Glenwhite Run	3.2
Shoup Run	4.7
Miller Run	1.4
Hartmán Run	0.6
Six Mile Run	3.5
Sandy Run	2.9
Longs Run	2.5
Kimber Run	2.7

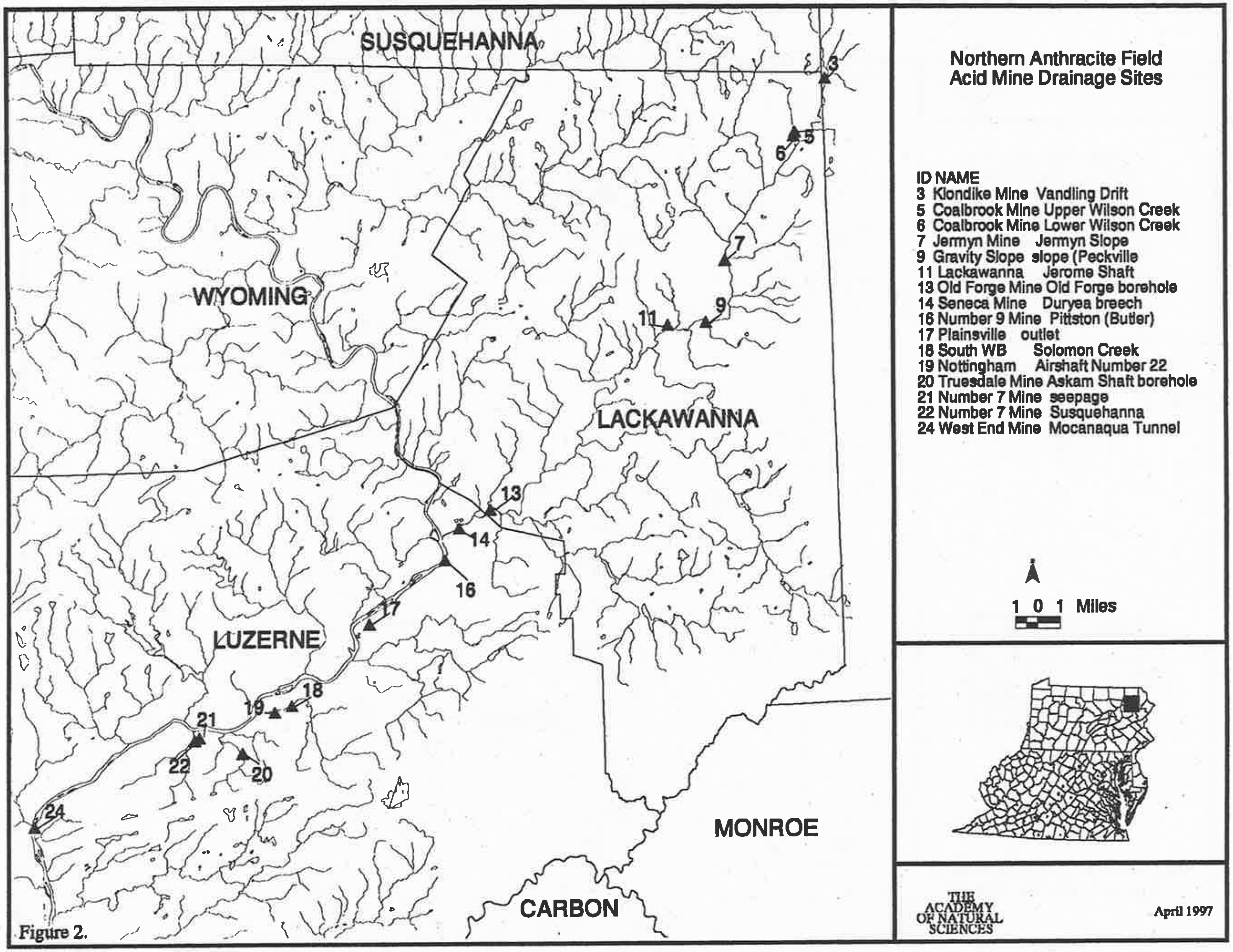
Table 1 (continued). Streams in the Chesapeake drainage affected by acid mine drainage and miles impacted. Compiled from Pennsylvania, West Virginia and Maryland 1996 303(d) lists.

North Branch Potomac River Subbasin	
Gladdens Run	11.8
Stony River	24.5
North Branch Potomac River	50
Slaughterhouse Run	2.17
Montgomery Run	2.81
Piney Swamp Run	5.51
Abram Creek	18.5
Emory Run	2.25
Glade Run	3.04
Little Creek	0.68
Deakin Run	1.15
Wills Creek	NA
Georges Creek	NA
Savage River	NA

A few miles downstream from the confluence with the Lackawanna River, the Susquehanna River receives AMD from several large borehole and shaft discharges and drainage from three tributary streams (Nanticoke, Warrior and Solomon creeks) impacted by mine discharges. Within this reach of the Susquehanna River between the Lackawanna River confluence and Shickshinny, the first large discharge emanates from the Number 9 Mine (Pittston Butler Water Tunnel). Farther downstream, the Plainsville Outlet, located between Pittston and Wilkes-Barre, discharges directly to the Susquehanna River. Nanticoke, Warrior and Solomon creeks drain subwatersheds in the vicinity of Wilkes-Barre. Mine drainage pollution in these streams is caused by large discharges from the South Wilkes-Barre Mine (Solomon Creek Boreholes) and the Nottingham-Buttonwood airshaft number 22 discharge to Solomon Creek and the Truesdale Mine (Askam Shaft borehole) discharge to Nanticoke Creek about 1.5 mi downriver from the mouth of Solomon Creek. Two large discharges, from the Number 7 Mine (seepage and the Susquehanna Number 2 Shaft) occur downriver from Wilkes-Barre. The West End Mine (Mocanaqua Tunnel) near the mouth of Black Creek, represents the last significant discharge emanating from the Northern Coal Field.

Eastern Middle Anthracite Coal Field

Major sources of mine drainage in the Eastern Middle Coal Field are located on the Nescopeck and Catawissa creeks (Fig. 3). Both streams are impacted by AMD mostly from water level tunnels. Nescopeck Creek drains 172 mi^2 with the southern part of the watershed


Northern Anthracite Field
Acid Mine Drainage Sites
ID NAME
3 Klondike Mine Vandling Drift
5 Coalbrook Mine Upper Wilson Creek
6 Coalbrook Mine Lower Wilson Creek
7 Jermyn Mine Jermyn Slope
9 Gravity Slope slope (Peckville
11 Lackawanna Jerome Shaft
13 Old Forge Mine Old Forge borehole
14 Seneca Mine Duryea breech
16 Number 9 Mine Pittston (Butler)
17 Plainsville outlet
18 South WB Solomon Creek
19 Nottingham Airshaft Number 22
20 Truesdale Mine Askam Shaft borehole
21 Number 7 Mine seepage
22 Number 7 Mine Susquehanna
24 West End Mine Mocanaqua Tunnel
1 0 1 Miles
SUSQUEHANNA
WYOMING
LACKAWANNA
LUZERNE
MONROE
CARBON
3
5
6
7
9
11
13
14
16
17
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20
21
22
24
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Figure 2.

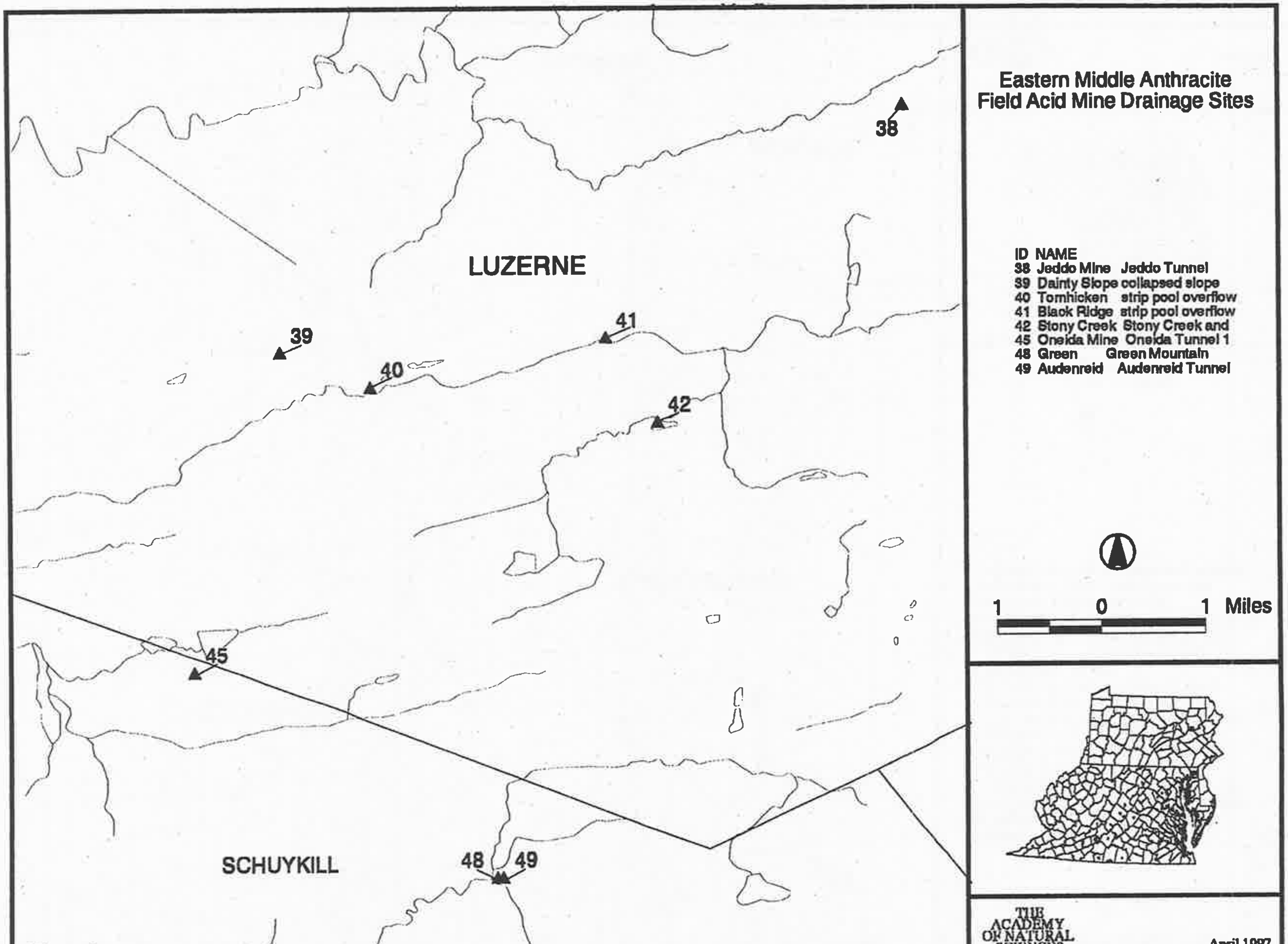
Eastern Middle Anthracite
Field Acid Mine Drainage Sites
ID NAME
38 Jeddo Mine Jeddo Tunnel
39 Dainty Slope collapsed slope
40 Tomhicken strip pool overflow
41 Black Ridge strip pool overflow
42 Stony Creek Stony Creek and
45 Oneida Mine Oneida Tunnel 1
48 Green Green Mountain
49 Audenreid Audenreid Tunnel
1 0 1 Miles
LUZERNE
SCHUYKILL
38
39
40
41
42
45
48
49
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Figure 3.

drained by Black Creek. The upper reach of Black Creek receives AMD from Dainty Slope Mine (collapsed slope), Tomhicken Mine (strip pool overflow), Black Ridge Mine (strip pool overflow), and seepage from Stony Creek Mine. Approximately 10 mi farther downstream, Black Creek receives almost all its AMD from the Gowen Mine (Gowen Tunnel) and Derringer Mine (Derringer Tunnel).

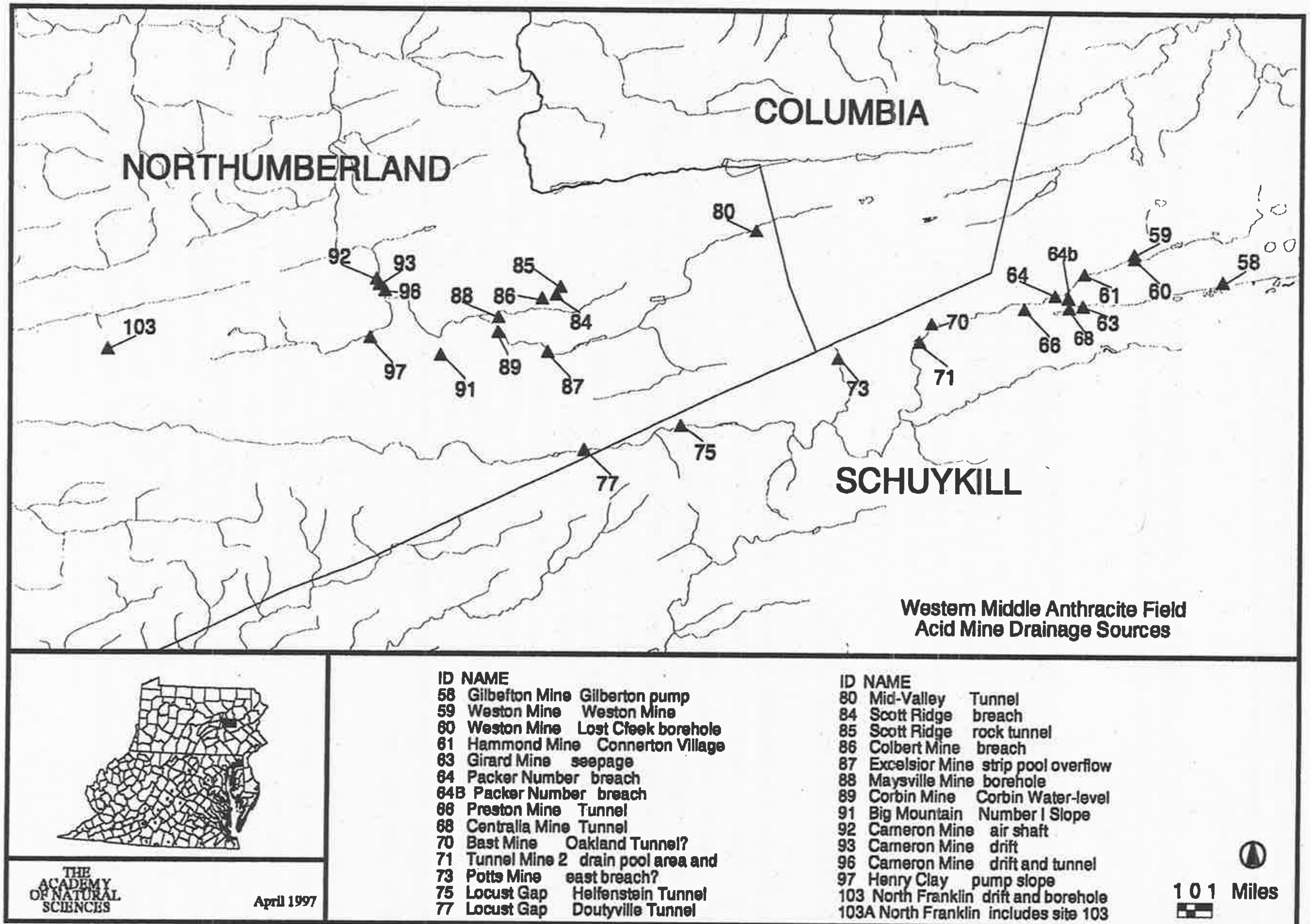
Nescopeck Creek receives essentially all of its AMD from Little Nescopeck Creek. The Jeddo Tunnel, on Little Nescopeck Creek, is one of the largest drainage discharges in the Anthracite Region.

The Catawissa Creek watershed drains an area of 155 mi^2. The headwaters of Catawissa Creek and Tomhicken Creek (a tributary to Catawissa Creek) drain the southern part of the Eastern Middle Anthracite Coal Field. Catawissa Creek is impacted by AMD primarily from discharges from the Green Mountain water level tunnels. The largest discharge of AMD drainage in the Catawissa Creek watershed is from the Audenreid Tunnel (Audenreid Mine). Oneida Tunnels 1 and 3 (Oneida Mine) and the Green Mountain Tunnel (Green Mountain Mine) are also major contributors of AMD to Catawissa Creek.

Western Middle Anthracite Coal Field

The Western Middle Anthracite Field is drained by Shamokin and Mahanoy creeks. Shamokin Creek is the northern most watershed impacted by mine drainage and encompasses 137 mi^2 in Northumberland, Columbia and Montour counties. The creek flows from Centralia Borough to the confluence with the Susquehanna River at Sunbury City. Shamokin Creek tributaries most affected by AMD are North Branch Shamokin Creek, Quaker Run and Carbon Run. Twelve large mine discharges were identified by Wood (1996) in the watershed (Fig. 4). The Mid-Valley Mine Tunnel is located in the upper reaches north of Mount Carmel. Other significant sources of AMD in Shamokin Creek and its tributaries between the towns of Mount Carmel and Shamokin include: Scott Ridge Mine (breach and rock tunnel discharge into Quaker Run); Colbert Mine breach; Excelsior Mine strip pool overflow; Maysville Mine borehole; Corbin Mine water-level drift; Big Mountain Mine Number 1 slope discharge into Buck Run; Cameron Mine drift and tunnel; and the Sterling Mine discharge to Carbon Run. Downstream from Shamokin, two more large discharges from the Cameron Mine (drift and airshaft) also contribute mine drainage.

The Mahanoy Creek watershed drains an area of 155 mi^2, part of which is in the Western Middle Anthracite Coal Field. Mahanoy Creek is impacted two tributaries, North Mahanoy Creek and Zerbe Run, which contribute substantial amounts of AMD. Mines discharging AMD in the watershed are numerous and for the most part located in the upper reaches between the towns of Ashland and Mahanoy City. Large mine discharges emanate from Vulcan Buck Mountain Mine (borehole), Gilberton Mine (pump discharge), Weston Mine (seepage and Lost Creek borehole), Hammond Mine (boreholes), Girard Mine (seepage), Packer Number 5 Mine (breach and boreholes), Preston Mine (tunnel), Centrailia Mine (tunnel), Bast Mine (Oakland Tunnel), Tunnel Mine #2 (drain pool and seepage), Potts Mine (east breach), and Locust Gap Mine



NORTHUMBERLAND
COLUMBIA
SCHUYKILL
Western Middle Anthracite Field
Acid Mine Drainage Sources
ID NAME
58 Gilbefton Mine Gilberton pump
59 Weston Mine Weston Mine
60 Weston Mine Lost Cfeek borehole
61 Hammond Mine Connerton Village
63 Girard Mine seepage
64 Packer Number breach
64B Packer Number breach
66 Preston Mine Tunnel
68 Centralia Mine Tunnel
70 Bast Mine Oakland Tunnel?
71 Tunnel Mine 2 drain pool area and
73 Potts Mine east breach?
75 Locust Gap Helfenstein Tunnel
77 Locust Gap Doutyville Tunnel
ID NAME
80 Mid-Valley Tunnel
84 Scott Ridge breach
85 Scott Ridge rock tunnel
86 Colbert Mine breach
87 Excelsior Mine strip pool overflow
88 Maysville Mine borehole
89 Corbin Mine Corbin Water-level
91 Big Mountain Number I Slope
92 Cameron Mine air shaft
93 Cameron Mine drift
96 Cameron Mine drift and tunnel
97 Henry Clay pump slope
103 North Franklin drift and borehole
103A North Franklin includes site 103
1 0 1 Miles
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Figure 4.

(Helfenstein Tunnel and Doutyville Tunnel). Approximately 23 mi downstream from the town of Ashland, Zerbe Run joins Mahanoy Creek. The major source of AMD on Zerbe Run is the North Franklin Mine (drift, borehole and seepage).

Southern Anthracite Coal Field

The Southern Anthracite Field is drained by 4 major tributaries impacted by AMD discharges in their headwaters (Fig. 5). The Rausch Creek watershed drains ~10 mi^2 in western Schuylkill County. The East and West Branches of Rausch Creek confluence to form Rausch Creek which flows northerly to its confluence with Pine Creek. Large mine drainage discharges in the headwaters of Rausch Creek include the Markson Columnway, Valley View tunnel, Buck Mountain drift, Good Spring Number 1 Mine, and at Horseshoe Trail above and in the East Branch.

The Wiconisco Creek watershed is composed of approximately 120 mi^2 in Dauphin and Schuylkill counties. Wiconisco Creek is affected by gravity discharges from several mine tunnels. The Keefer and Porter Tunnels are located in the headwaters of Wiconisco Creek upstream from Tower City. The Lykins-Williamstown Mine discharges from Big Lick Tunnel, Lykens Water-level Drift, a pump station, and from seepage. Big Lick Tunnel, located just west of Williamstown, is an alkaline deep mine discharge. Additional mine discharges impacting Wiconisco Creek include Tower City Number 1 Mine Tunnel, Erdman Coal Company pump discharge, seeps and borehole, and the Good Spring Number 1 Mine.

Swatara Creek drains almost 600 mi^2 and is impacted by mine drainage in its upper reaches above the town of Ravine. The northeastern headwaters area of Swatara Creek encompass approximately 19 mi^2, of which 10% has been disturbed by mining activity (Gannett Fleming Corddry and Carpenter, Inc., 1972). Deep mine pools are a significant source of AMD while drainage from active and strip mining was reported to be insignificant. The north central headwaters area is also impacted mainly by discharges associated with abandoned deep mine overflows with coal mine refuse as the second worst contributor of AMD. The northwestern headwaters area is drained by two tributaries, lower Rausch Creek and Lorberry Creek, both of which are affected by mine drainage.

Large AMD discharges in the headwaters of Swatara Creek emanate from Middle Creek Mine (a strip pool overflow), Blackwood Mine (Blackwood Water-level Tunnel), Eureka Mine (drift), East Franklin Mine (Lower Paoli Tunnel) and the Lincoln Mine drainage tunnel.

Bituminous Coal Fields - Susquehanna River Drainage

Tioga River Watershed

The Tioga River and its tributaries drain approximately 1,391 mi^2. The river flows southwesterly from its headwaters in western Bradford County, Pennsylvania to the Bradford-Tioga County line. The river eventually turns north and flows to its confluence with the

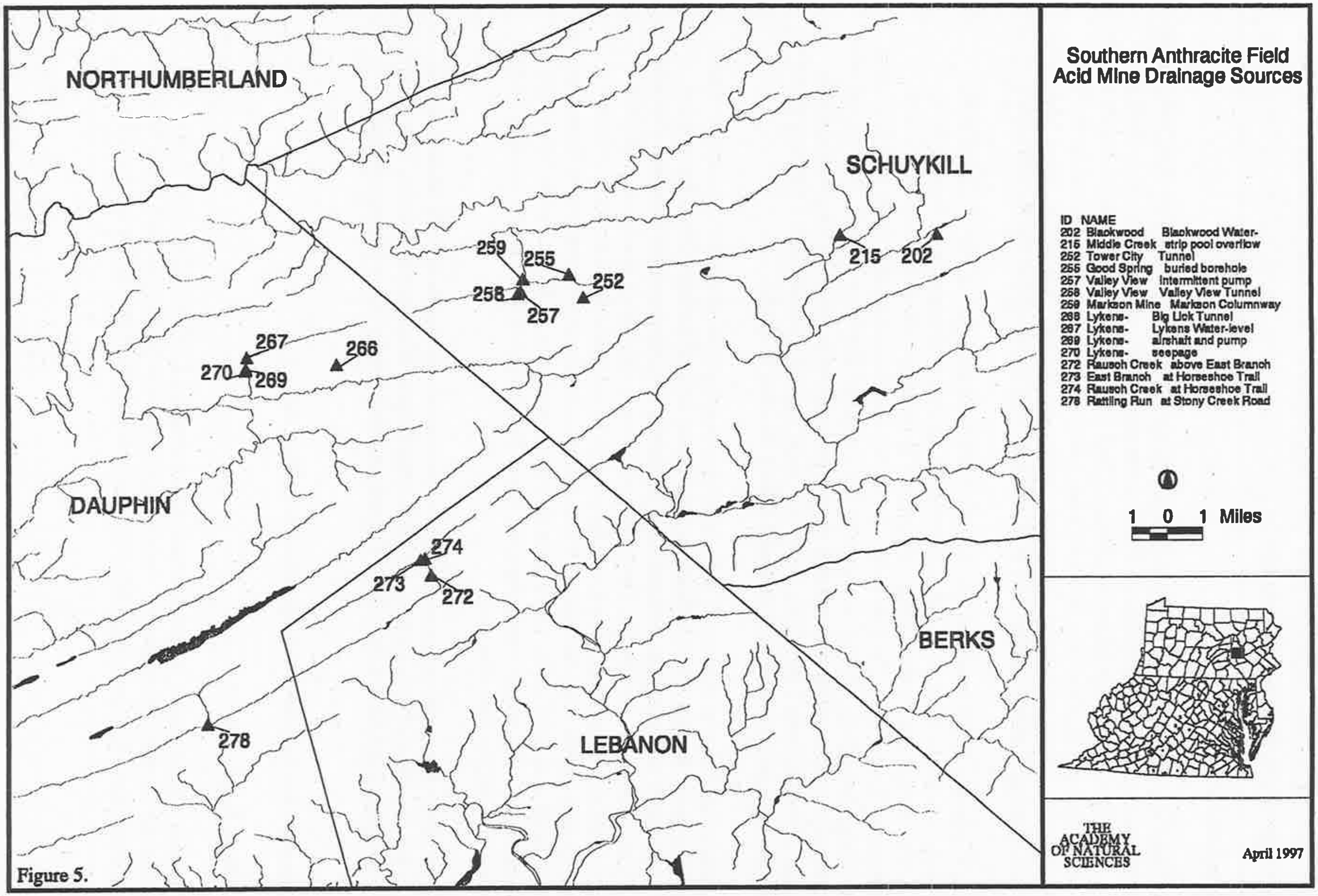
Southern Anthracite Field
Acid Mine Drainage Sources
ID NAME
202 Blackwood Blackwood Water-
215 Middle Creek strip pool overflow
252 Tower City Tunnel
255 Good Spring buried borehole
257 Valley View intermittent pump
258 Valley View Valley View Tunnel
259 Markson Mine Markson Columnway
266 Lykens- Big Lick Tunnel
267 Lykens- Lykens Water-level
269 Lykens- airshaft and pump
270 Lykens- seepage
272 Rausch Creek above East Branch
273 East Branch at Horseshoe Trail
274 Rausch Creek at Horseshoe Trail
278 Rattling Run at Stony Creek Road
1 0 1 Miles
NORTHUMBERLAND
SCHUYKILL
DAUPHIN
LEBANON
BERKS
202
215
252
255
257
258
259
266
267
269
270
272
273
274
278
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Figure 5.

Chemung River in New York State. The Chemung River flows to join the North Branch of the Susquehanna River just across the Pennsylvania border.

Numerous entryways or drifts, which were driven into coal seams, provide gravity discharges of mine drainage into the watershed. In addition to deep mines, strip mining activities have also impacted the watershed. The tributaries which are degraded by mine discharges include Morris Run, Coal Creek and Bear Creek (Skelly and Loy, 1973). There are numerous discharges within the Morris Run watershed, but only two gravity flow discharges from the Lower Kittanning coal seam contribute significant amounts of AMD. Coal Creek has one major source of AMD, a gravity flow discharge from a partly caved drift in the Lower Kittanning seam. Bear Creek is the only stream north of Coal creek which contributes AMD to the Tioga River.

Juniata River Watershed

The Juniata River Basin drains an area of approximately 3,400 mi^2. The headwater area of the Juniata River watershed drain into four major tributaries. The Raystown Branch and Augwick Creek drain a small part of the main Bituminous Coal Field and the Broad Top Coal Field. The latter coal field has geological characteristics of both the Anthracite Coal Fields and the main Bituminous Coal Field. The Little Juniata and Frankstown Branch drain a small part of the main Bituminous Coal Field. Deep mining was conducted above and below local surface drainage, therefore both gravity discharges and mine pool overflows contribute to AMD loads in the watershed.

Within the Little Juniata River subwatershed, the headwaters of Bell Gap Run have been impacted by strip mining activities.

One of the major recipients of AMD in the Frankstown Branch subwatershed is Beaver Dam Branch. Two tributaries to Beaver Dam Branch, Burgoon Run and Sugar Run, are affected by mine drainage. Burgoon Run has one large source of AMD, Kittanning Run, which receives an acid discharge from a deep mine in its headwaters. Sugar Run has one major source of AMD from a deep mine southeast of Gallitzin.

The Raystown Branch of the Juniata River receives AMD from Sandy Run, Six Mile Run, and Shoup Run. The largest single source of AMD in Six Mile Run is an artesian flow associated with the Clarion and Lower Kittanning coal seams. Another large discharge emanates from an Upper Freeport deep mine. Two deep mine discharges contribute AMD to Shoup Run. The largest source is a deep mine borehole located about one mile west of Broad Top City. The south branch of Sandy Run receives mine drainage mainly from deep mine pools and gravity discharges.

Roaring Run, a tributary to Sideling Hill Run, is a source of AMD in the Augwick Creek subwatershed. The alkalinity of Sideling Hill Run neutralizes the acid contributed by Roaring Run resulting in a net alkaline discharge to Augwick Creek (Skelly and Loy, 1973).

West Branch Susquehanna River Basin

The West Branch Susquehanna River drainage basin encompasses 6900 square miles in north central Pennsylvania (Gwin Dobson and Foreman, Inc, 1972). The watershed is bounded by the Chemung and Genesee River basins to the north, the Juniata River Basin to the south, the North Branch Susquehanna River Sub-basin on the east, and the Allegheny River basin to the west. The headwaters originate in the coal rich region of Cambria County and flows for approximately 240 mi to the confluence with the Susquehanna River at Northumberland. Tributary and direct contributions of AMD are added to the West Branch at irregular intervals along the first 142 mi of the West Branch from the headwaters to Renovo. Severe AMD pollution exists in numerous subwatersheds in the West Branch Susquehanna River Basin. Major tributaries impacted by AMD include Chest Creek, Anderson Creek, Clearfield Creek, Moshannon Creek, Sinnemahoning Creek, Kettle Creek, North Bald Eagle Creek, Pine Creek, Lycoming Creek and Loyalsock Creek.

The largest source of AMD is abandoned drift mines, while coal mine refuse and strip mines account for additional discharges of AMD into the watershed. Fifty-four active mining operations were identified in the watershed (Fig. 6); however, their impact on the watershed was not considered in this report. The available data from the Hawk Run District Mining Office provided pre-treatment mine drainage chemical constituent concentrations and estimated flows; therefore, AMD loads from post-treatment discharges could not be determined. Latitude and longitude coordinates for GIS mapping of the abandoned mines in the West Branch Susquehanna River were also not available.

West Branch Headwater Area

Gwin, Dobson and Foreman (1972) identified 8 deep mines and 12 major refuse piles as the largest sources of AMD discharging to the West Branch headwater area. Victor #9 and #10 Mines are located in the area from Carrolltown to Spangler on the northeast side of the West Branch headwaters. Drainage emanates from two drainage courses (a borehole and a slope entry). The Sterling #1 and #6 Mine Complex is located near Bakerton on the southwest side of the West Branch headwaters. Its surface discharge consists of a single flow from a drainage drift. Farther downriver, south of Carrolltown, the Lancashire #20 Mine discharges to the West Branch from a single point. Sterling #3 Mine is located east of Bakerton on the east side of the West Branch headwaters and discharges from four drainage courses to Leslie Run. The Heisley #2 Mine has three drainage courses located southeast of Bakerton on the east side of the West Branch headwaters. The final deep mine, Lancashire #15 Mine, initially contributed mine drainage during the course of the study; however after 1971 there was no discharge from its deep mine pool. Drainage from the deep mine sources discharged to surface waters through conventional mine openings such as boreholes, drainage courses and old portals. These discharges all occurred with 25-100 ft of the West Branch or one of its tributaries.

The refuse piles identified as significant sources of AMD were associated with the following mine sites: Lancashire #20, Sterling #6, Sterling #1 & Lancashire# 14, Lancashire #15, Watkins,

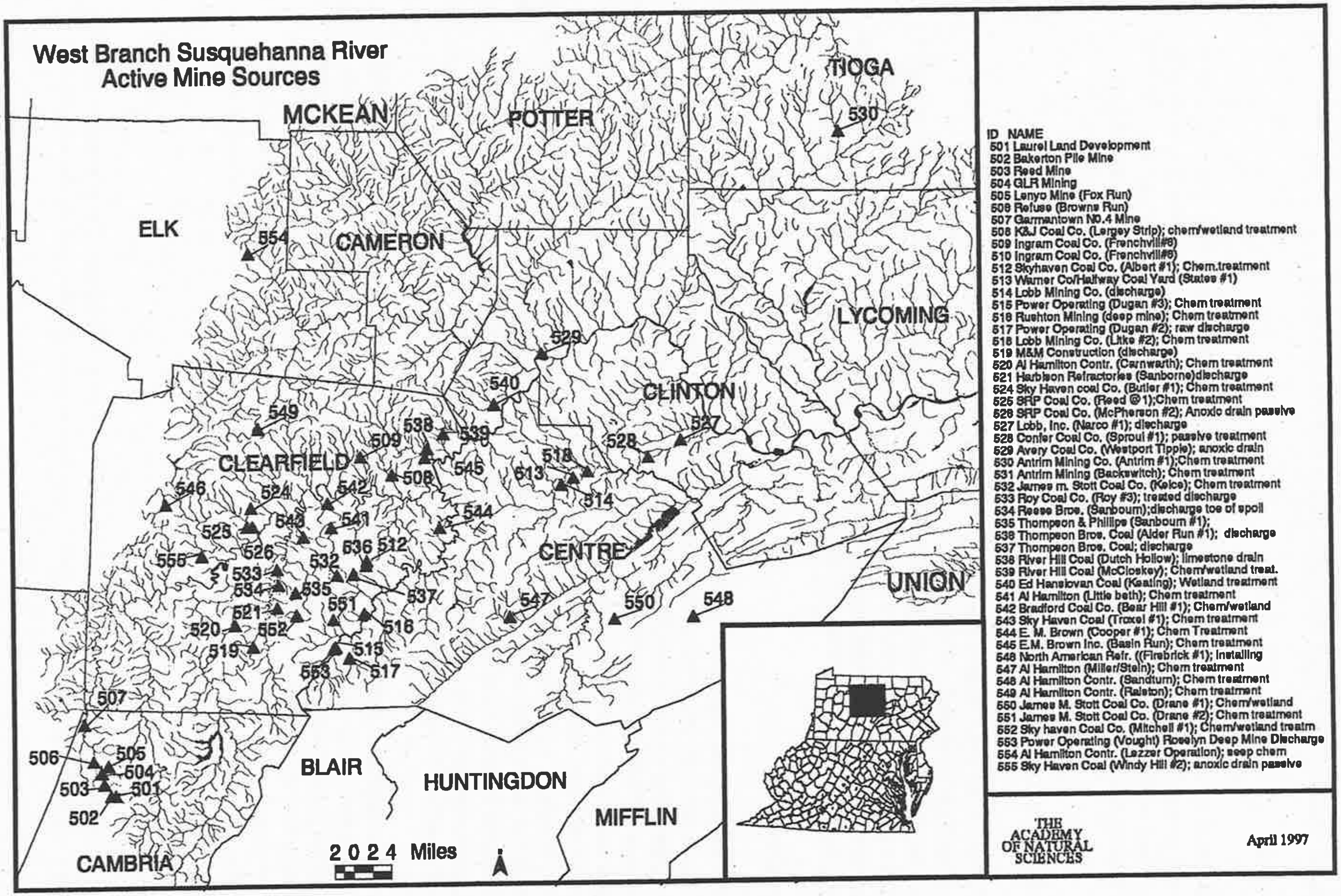
West Branch Susquehanna River
Active Mine Sources
MCKEAN
POTTER
TIOGA
ELK
CAMERON
LYCOMING
CLINTON
CLEARFIELD
CENTRE
UNION
BLAIR
HUNTINGDON
MIFFLIN
CAMBRIA
2 0 2 4 Miles
ID NAME
501 Laurel Land Development
502 Bakerton Pile Mine
503 Reed Mine
504 GLR Mining
505 Lenyo Mine (Fox Run)
506 Refuse (Browns Run)
507 Garmantown N0.4 Mine
508 K&J Coal Co. (Lergey Strip); chem/wetland treatment
509 Ingram Coal Co. (Frenchvill#6)
510 Ingram Coal Co. (Frenchvill#6)
512 Skyhaven Coal Co. (Albert #1); Chem.treatment
513 Warner Co/Halfway Coal Yard (States #1)
514 Lobb Mining Co. (discharge)
515 Power Operating (Dugan #3); Chem treatment
516 Rushton Mining (deep mine); Chem treatment
517 Power Operating (Dugan #2); raw discharge
518 Lobb Mining Co. (Litke #2); Chem treatment
519 M&M Construction (discharge)
520 Al Hamilton Contr. (Carnwarth); Chem treatment
521 Harbison Refractories (Sanborne)discharge
524 Sky Haven coal Co. (Butler #1); Chem treatment
525 SRP Coal Co. (Reed @1);Chem treatment
526 SRP Coal Co. (McPherson #2); Anoxic drain passive
527 Lobb, Inc. (Narco #1); discharge
528 Confer Coal Co. (Sproul #1); passive treatment
529 Avery Coal Co. (Westport Tipple); anoxic drain
530 Antrim Mining Co. (Antrim #1);Chem treatment
531 Antrim Mining (Backswitch); Chem treatment
532 James m. Stott Coal Co. (Kelce); Chem treatment
533 Roy Coal Co. (Roy #3); treated discharge
534 Reese Bros. (Sanbourn);discharge toe of spoil
535 Thompson & Phillips (Sanbourn #1);
536 Thompson Bros. Coal (Alder Run #1); discharge
537 Thompson Bros. Coal; discharge
538 River Hill Coal (Dutch Hollow); limestone drain
539 River Hill Coal (McCloskey); Chem/wetland treat.
540 Ed Hanslovan Coal (Keating); Wetland treatment
541 Al Hamilton (Little beth); Chem treatment
542 Bradford Coal Co. (Bear Hill #1); Chem/wetland
543 Sky Haven Coal (Troxel #1); Chem treatment
544 E. M. Brown (Cooper #1); Chem Treatment
545 E.M. Brown Inc. (Basin Run); Chem treatment
546 North American Refr. ((Firebrick #1); Installing
547 Al Hamilton (Miller/Stein); Chem treatment
548 Al Hamilton Contr. (Sandturn); Chem treatment
549 Al Hamilton Contr. (Ralston); Chem treatment
550 James M. Stott Coal Co. (Drane #1); Chem/wetland
551 James M. Stott Coal Co. (Drane #2); Chem treatment
552 Sky haven Coal Co. (Mitchell #1); Chem/wetland treatm
553 Power Operating (Vought) Rosslyn Deep Mine Discharge
554 Al Hamilton Contr. (Lazzer Operation); seep chem
555 Sky Haven Coal (Windy Hill #2); anoxic drain passive
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Figure 6.

Susquehanna #1, Victor #10 (Fox Run),Victor #9 (Fox Run), Springfield #4, Lancashire #9 (Porter Run), Moss Creek (Moss Creek), and Victor #17 (Emeigh Run).

Chest Creek

Chest Creek flows north from its headwaters in Cambria County near the town of Loretto to its confluence with the West Branch near Mahaffey in Clearfield County. Spoil piles, coal refuse and deep mines sources equally contribute AMD in the watershed (Skelly and Loy, Inc., 1973b). About 40 AMD discharges were located in the Brubaker Run watershed, a tributary to Chest Creek.

West Branch - Chest Creek to Clearfield Creek

This reach of the West Branch has been mined extensively on both sides. The only significant sources of AMD in this reach are Mine Run, a tributary located one mile southeast of Curwensville, and Anderson Creek. Smaller AMD sources in this reach include Hatshorn Run and Montgomery Run, both located downriver from Curwensville, and Moose and Wolf Runs which are located just upriver from the confluence of Clearfield Creek and the West Branch. One major deep mine discharge contributes to the poor water quality in the last mile of Hatshorn Run.

Anderson Creek

The Anderson Creek watershed is located in Clearfield County and drains approximately 78 mi^2. The creek flows for about 20 mi to its confluence with the West Branch near Curwensville. The two major tributaries of Anderson Creek are Kratzer Run and Little Anderson Creek. Gwin Engineers, Inc. (1974) identified 77 AMD discharges from deep and strip mines and mining refuse piles in the watershed. The majority of the AMD emanates from inactive deep and strip mines (coal and clay). All of the deep mining activity involved the removal of clay. These include the Widemire and Irvin mines east of Stronach, the Rankin Mine about one mile south of Chestnut Grove, the Way Mine just north of Curwensville, the Draucker #1 and #2 Mines, the Pearce Mine, the Wingert Mine, the Pentz Mine situated north of Chestnut Grove on the west side of Little Anderson Creek, and the Korb and Spencer mines east of Chestnut Grove. Additional smaller drift mines contributing mine drainage were of both clay and coal origin.

Among the tributaries discharging AMD to Anderson Creek, Little Anderson Creek is acid from its headwaters to its confluence with Anderson Creek. Rock Creek and a small tributary upstream from Rock Creek have four deep and strip mine discharges. Another discharge from a strip mine northwest of Chestnut Grove contributes additional mine drainage to Anderson Creek. About 1 mi from its confluence with the West Branch, Anderson Creek receives AMD from Kratzer Run. The Kratzer Run watershed has four major discharges emanating from strip mines located east and west of the town of Grampian.

Clearfield Creek

Clearfield Creek enters the West Branch east of the town of Clearfield. The watershed drains 396 mi^2 in Clearfield and Cambria Counties. Trapp Run is the southern most source of AMD from deep mine discharges in the Clearfield Creek watershed. Additional tributaries contributing AMD to Clearfield Creek include Brubaker Run, Little Laurel Run, Powell Run, Pine Run, Japling Run, Upper Morgan Run, Lost Run, Potts Run, Krebs Run, Long Run and Roaring Run. The largest mine drainage discharges originate the from Brookwood and Middle Penn #4 Mines. Other sources of mine drainage in the watershed include Coalport Bony Disposal Area, Swank's Mine, Shoff Mine, a deep mining complex at Mascot and Passmore Clay Mine (largest source of AMD to Morgan Run).

Clearfield Creek's largest source of AMD is from the Middle Penn No.4 Mine in the Japling Run watershed and the Brookwood Shaft Mine in the Muddy Run watershed. Deep mine discharges from Pennsylvania Coal and Coke Mines and the Taylor and McCoy Mine contribute AMD in the Trapp Run watershed. Much of Brubaker Run's mine drainage discharges from Red Ridge Mines, an unnamed deep mine and six strip mines. Within the Powell Run watershed, major producing AMD areas are located south of Blandburg. Mine drainage is discharges from the Bellefield Coal and Coke, Loydesville, Frick No.2 and Great bend No.4 mines. Strip mines exist above and adjacent to the old deep mines and also contribute AMD to the watershed.

West Branch - Clearfield Creek to Moshannon Creek

The West Branch flows approximately 32 stream mi mostly east to northeast from Clearfield Creek to Moshannon Creek. Sixteen tributaries in this reach contribute AMD to the West Branch. Most AMD in these watersheds is discharged from deep mines with additional contributions from strip mines. Tributaries in this reach that are affected by AMD include Abes Run, Lick Run, Trout Run, Millstone Run, Surveyor Run, Murray Run, Congress Run, Moravian Run, Deer Creek, Sandy Creek, Alder Run, Rolling Stone Run, Basin Run, Rock Run, Potter Run and Rupley Run.

Moshannon Creek

The Moshannon Creek watershed occupies approximately 288 mi^2 in Centre and Clearfield Counties. Nearly all tributaries to Moshannon Creek are impacted by AMD discharges and the entire length of Moshannon Creek, except in the extreme headwaters is polluted by mine discharges. Moshannon Creek's AMD pollution is mostly from deep mines. Significant deep mine discharges were located along Moshannon Creek south of Osceola Mills, along Little Beaver and Coal Runs, Trout Run, Cold Stream, Laurel Run, One Mile Run, Wolf Run, and all tributaries west of the Moshannon Creek from Hawk Run north to Crawford Run. A single large deep mining complex discharges into all Moshannon Creek western tributaries from Hawk Run north to Weber Run.

Moshannon Creek receives its first significant AMD drainage between Bear and Trout runs from deep and strip mines located between these two tributaries on the south side of Moshannon Creek. Southeast of Osceola Mills a number of seepages from deep mines contribute AMD to Trout Run. Between Hawk Run and Grassflat Run, Moshannon Creek receives its largest discharges of AMD. Discharges from this area are mainly from deep mine complexes.

West Branch - Moshannon Creek to Sinnemahoning Creek

Along this reach, limited strip mining has occurred on the southeast side of the West Branch relative to the northwest side. Tributaries impacted by AMD in this reach include Laurel Run and Sterling Run which enter the West Branch from the southwest and Mosquito Creek, Saltlick Run, Upper Three Runs, Lower Three Runs and Loop Run which enter the West Branch from the northwest. These tributary watersheds have been extensively strip mined in their headwater areas.

Sinnemahoning Creek

The Sinnemahoning Creek drains 1,032 mi^2 and is the largest tributary to the West Branch. The watershed is composed of three large tributaries, Bennett Branch, Driftwood Branch and First Fork. Most of the coal deposits within the Sinnemahoning Creek watershed are located in the Bennett Branch watershed close to the headwaters. Berger and Associates, Inc. (undated, b) reported that abandoned deep mines were the greatest source of AMD to the watershed with coal mine refuse, strip mines and an active deep mine also contributing AMD to a lesser extent. The deep mine sources of AMD affecting Bennett Branch emanate from the Proctor No.2 Mine, Shawmut No.31 Mine, Proctor No.1 Mine, Tyler Mines, Proctor No.3/Owens No.3 Mines, Tyler No.14 Mine, Shawmut No.41-No.42 Mine, Penfield Coal and Coke No.2 Mine, Five Points Mine, Gobblers No.1/Penfield Coal and Coke No.1 Mine, and the Proctor No.4 Mine.

Bennett Branch is impacted by AMD, from Moose Run to its mouth, which subsequently affects the Sinnemahoning Creek downstream to its confluence with the West Branch. Within the area of Bennetts Branch between Penfield and Driftwood Run, tributaries significantly affected by AMD discharges include Moose Run, Mill Run, Tyler Run, Cherry Run, Laurel Run, Dixon Run and Dents Run. Dents Run is the last major contributor of AMD to Bennett Branch prior to its confluence with the Driftwood Branch to form the Sinnemahoning.

Deep and strip mines exist in the Dents Run watershed mainly in the Porcupine Hollow area south of the Dents Run mainstream. Six deep mine portals and mine strippings discharge into Porcupine hollow. Moose Run is impacted by drainage from five deep mines. Acid discharges into Mill Run emanate from drifts, a watercourse, and refuse seeps from two mines (Sarnoski and Proctor No.2 Mines). Proctor No.1 and No.2 Mines and Five Points Mine are the major contributors of mine drainage in Tyler Run. Within the Cherry Run watershed, Shawmut No.41 Mine, Country Bank Mine, Proctor No.1 Mine, and Five Points Mine discharge AMD from drifts, entrys and refuse seeps. Kersey Run is impacted by drainage primarily from the Shawmut No.42 and Proctor No.4 Mines. On Dixon Run, the Shawmut No.31 mining complex is the greatest source of mine drainage with the Caledonia Hollow Tunnel as the single largest outfall.

West Branch - Sinnemahoning Creek to Bald Eagle Creek

Along this river reach mine drainage originates in an area of mining near the mouths of Cooks Run, Milligan Run and Kettle Creek. Cooks Run receives mine drainage from its tributary Crowley Hollow Run about 1 mi from its mouth. Crowley Hollow Run is impacted by four deep mine discharges. Downstream from Cooks Run, the West Branch receives acid from Milligan Run. All sources of AMD to Milligan Run are discharged from old deep mine drifts. Kettle

Creek is the largest tributary to the West Branch in this reach and is the last downstream direct source of AMD. Kettle Creek is degraded by mine drainage for approximately 4 mi upstream from its mouth. A total of 11 deep mine discharges account for all the major sources of AMD in the Kettle Creek watershed.

Just west of Renovo, Drury Run discharges minimal AMD to the West Branch. The AMD in Drury Run is mainly of deep mine origin. Drury Run originates at Tamarack Swamp, in northeastern Clinton County, and flows for approximately 8 mi to its confluence with the West Branch at the village of Drury Run. Renovo Borough (1991) identified 17 AMD discharge sites within the Drury Run watershed. Mine drainage emanated from underground mines, surface mines, spoils, and an abandoned treatment pond. Tributaries affected by the mine drainage include Sandy Run, Whiskey Run, Slab Hollow and Stony Run.

Tangascootack Creek joins the West Branch from the south near Farrandsville. Overall water quality is degraded from AMD discharging from strip mines and deep mine complexes with the Scootac Mines as the largest complex (Loyd Wilson Chapter of Trout Unlimited, 1984).

Bald Eagle Creek

Bald Eagle Creek joins the West Branch just west of Lock Haven. Only one of its tributary streams, Beech Creek, is significantly impacted by AMD. Beech Creek watershed is composed of approximately 170 mi^2 in northern Centre and southwestern Clinton Counties. Beech Creek terminates at the eastern end of the watershed, near Beech Creek Borough, where it joins Bald Eagle Creek. Although some abandoned coal mining operations are located in areas tributary to its headwaters, their impact on Bald Eagle Creek is negligible.

Deep mines, open strip pits and associated refuse are sources of significant amounts of AMD in the watershed. An estimated 8 mi^2 within the watershed have been affected by coal and clay strip mining. During a one year sampling (Gannett Fleming Corddry and Carpenter, Inc., 1970) from 1968 to 1969, a total of 184 mine drainage discharges were located in the sub-basins of North Fork, Beech Creek and Sandy Run. Of that total, 160 continuously discharged mine drainage. Other discharges were found on the south side of Beech Creek between Kato Village and Logway Run; however, none was found downstream of the confluence of Twin Run and Beech Creek. Twenty-five of the discharges originated from deep mine entryways. An additional 16 discharges were associated with deep mines where AMD flowed over underclays and emanated at the surface as springs. Fifteen boreholes drilled to relieve pressure from deep mine pools also contributed AMD. A total of 168 discharges originated from a combination of strip and deep mines. Thirty-three refuse areas were identified which accounted for twenty-five discharges. Most of the AMD discharges emanate from the Sandy Run and North Fork sub-basins with minor contributions from Logway Run and Big Run.

West Branch - Bald Eagle Creek to North Branch Confluence

Within this reach, segments of Pine Creek, Babb Creek and Loyalsock Creek are affected by mine drainage. Pine Creek is affected by two coal fields that are extensions of the main bituminous field. The northern field is drained by Babb Creek and its tributaries and composes an area of approximately 129 mi^2 in Tioga and Lycoming counties. Drainage is contributed by three major tributaries: Lick Creek, Wilson Creek and Stony Fork Creek. The downstream waters of Wilson Creek and upstream waters of Babb Creek are impacted mostly by deep mine drainage. Surface mining above the deep mine complexes also contribute AMD to the watershed. Upper Babb Creek receives AMD discharges from the Arnot No.2 Mine, the Klondike Mine, and the Bear Run Mine. The mines at Rock Run in the Antrim Mining Complex also contribute AMD. Wilson Creek, between Antrim and Morris, receives the most significant portion of mine drainage in the watershed. Seven discharges were located in Wilson Creek (Skelly and Loy, Inc. 1973b). Significant AMD contributions were from the Antrim and Anna S mining complexes, located about 2 mi north of the town of Morris. The largest source of AMD to Wilson Creek is contributed by Basswood Run, a tributary to Wilson Creek, in its headwaters. Another discharge to Wilson Creek emanates from an old drift mine just south of the village of Antrim. The last major source of AMD discharged to Wilson Creek is from a stripped out drift mine.

Two miles downstream from the mouth of Wilson Creek, Stony Fork, a tributary to Babb Creek, is impacted by AMD. Stony Fork is only impacted by AMD by Paint Run. Two major discharges from an abandoned drift, the Rattler Mine, and a coal processing pond enter on the north side of Paint Run.

The southern coal field in the Pine Creek watershed is located near English Center in Lycoming County. Otter and English runs, two tributaries to Little Pine Creek, are impacted by AMD discharging from abandoned deep mines. Otter and English runs have a combined drainage area of 50 mi^2. The coal measures in the Little Pine Creek watershed have been mined by shallow drift mining techniques. As many as 30 drift mines have been located in the watershed (English Engineering Corporation, 1971). A small unnamed tributary to the Shingle Mill Branch of English Run is the site of five abandoned drift mines which contribute AMD to the Shingle Mill Branch. Pine Run, a tributary to English Run, has as its major AMD discharge a drift mine located adjacent to the stream. A liming device and impounding basins were constructed to treat the discharge from this outfall. Eleven additional drifts were located during the 1971 survey with the Carson Mine outfall as the only major contributor of AMD. Five drift mines, part of an abandoned mining operation known as the English Center Coal Company, contributed AMD to the headwaters of Pine Run and affected the entire length of the stream.

Buckeye Run, a major tributary to Otter Run, drains the central region of the Little Pine Creek coal basin and is bounded on both sides by drift and surface mines. Buckeye Run receives significant amounts of AMD from the Jack Cammal's Camp Run tributary.

Loyalsock Creek is the farthest downstream tributary of the West Branch that drains an area underlain by coal. The portion of the watershed impacted by mine drainage is situated in Sullivan County and the western edge of Lycoming County. The major area of mining activity and AMD is bounded by the Loyalsock Creek on the south, Birch Creek on the north and west, and Pigeon Creek on the east. The coal field in Sullivan County is relatively isolated from the bituminous fields to the west and the anthracite fields to the east. Pigeon Creek, a tributary to the Loyalsock Creek, receives AMD from an unnamed tributary which extends to the periphery of abandoned strip mine pits. Farther downstream, the Loyalsock receives the largest AMD drainage from the B Vein Connell Tunnel of the Connell Deep Mine Complex. Another major source of AMD emanating from the Connell Deep Mine Complex is the C Vein Connell Tunnel. The Birch Creek tributary carries runoff from a swamp area which is adjacent to abandoned strip mining pools. Bellante, Clauss, Miller and Nolan, Inc. (undated) determined the AMD impact as minimal; however, active strip mining was initiated in this tributary subsequent to their final sampling efforts. Additional sources of AMD in the Birch Creek drainage include an abandoned strip mine pool, the Gutten Deep Mine drift, and the Bernice Basin near the restored SBP Coal Company strippings.

Bituminous Coal Fields - North Branch Potomac River Drainage

Northwest Allegany County and Lower Georges Creek Complex

The Northwest Allegany County and Lower Georges Creek Complex covers approximately 107.7 mi^2 in Maryland, 81.9 of which are in Allegany County and 25.8 in Garrett County. The Complex extends from the Pennsylvania-Maryland border, between Big Savage Mountain and Dans and Piney mountains southwesterly to Westernport, MD. Almost the entire Complex in underlain by bituminous coal reserves and is drained by George's Creek, Jennings Run and Braddock Run. All three streams are tributary to the North Branch of the Potomac River. Jennings Run drains 107.7 mi^2 in the northwestern part of the Complex while Braddock Run drains only 8.6 mi^2 of the Complex. Jennings Run and Braddock Run flow in an easterly direction and confluence with Wills Creek. Jennings Run joins Wills Creek near Corriganville and Braddock Run meets Wills Creek farther downstream near Cumberland. Wills Creek enters the North Branch of the Potomac River at Cumberland. Georges Creek watershed occupies an area of 74.4 mi^2 and drains the southern and central portions of the Complex. Georges Creek forms a confluence with the North Branch of the Potomac River at Westernport.

Jennings Run and some of its unnamed tributaries have been adversely affected by AMD discharges. Braddock Run, downstream from the Hoffman Drainage Tunnel has also been degraded by AMD. The downstream portion of Georges Creek as well as several of its tributaries including Sand Spring Run, Winebrenner Run, Hill Run, Laurel Run, Butcher Run, Moores Run, Mill Run, and unnamed tributaries have been impacted by mine drainage.

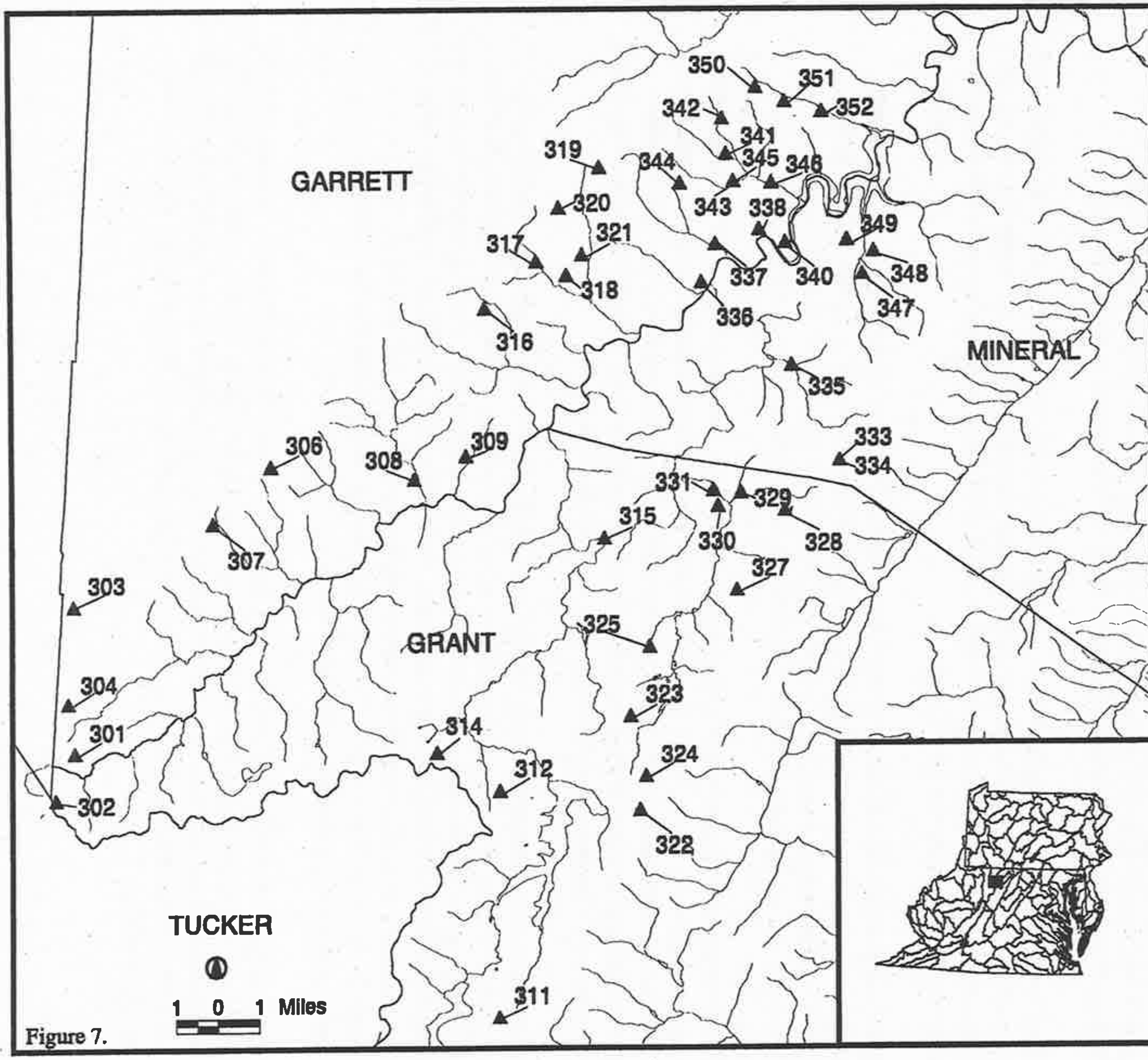
Sources of AMD in the Complex include deep mines, surface strip mines and mine refuse. Extensive deep mine workings compose about 34 mi^2 of the Complex. The most extensive deep mining was in the Pittsburgh coal seam. Three large mine drainage outlets, the Hoffman Drainage Tunnel, Midland Drainage Tunnel and the Allegany Water Ditch were constructed to alleviate water problems in the deep mines of the Pittsburgh Coal Basin. In addition to deep mining in the coal seams, some deep mining for clay and iron ore occurred in the Jennings Run watershed. About 9.2 mi^2 in the Complex have been affected by strip mining for coal and clay.

During an extensive mine drainage investigation in 1972-1973, 360 mine drainage discharge points were identified in the Complex, most of which originated from deep and strip mines (Green Associates, Inc. and Gannett Fleming Corddry and Carpenter, Inc., 1974). Georges Creek watershed contained 290 mine drainage discharge sites. Jennings Run and Braddock Run each had substantially fewer AMD discharges with 64 and 6, respectively. A total of 235 discharge points appeared to discharge continuously, while the others were intermittent. Of the 360 Complex mine drainage discharge points, 157 did not appear to be a significant contribution to pollution. Within the Pittsburgh Coal Basin, the Hoffman Drainage Tunnel continuously discharged the largest volume of mine drainage. The Allegany Water Ditch continuously discharges a smaller volume, while the Midland Drainage Tunnel intermittently discharges mine drainage. An additional 155 discharges drain by gravity from deep mines within the Complex. Of that total, 108 discharge directly to streams and 27 flow across strip mines before discharging into Complex streams. Seventy-one discharges were associated with surface and ground water discharging from strip mines. The remaining discharges were associated with springs, seeps and runoff from coal measures and refuse areas. Latitude and longitude coordinates for mines or discharge points were not identified in any of the available reports; therefore GIS mapping identifying such sites in the Complex was not completed.

North Branch Potomac River Watersheds - Upstream from Jennings Randolph Lake

The North Branch Potomac River Basin, from the headwaters to Jennings Randolph Lake, is composed of 70 subwatersheds encompassing 212 mi^2 in Maryland and West Virginia. The area has a long history of coal mining utilizing both deep and surface mining techniques. The underground mines were constructed to allow for gravity drainage of water from the inner workings of the mines to surface streams. Surface mining activities have resulted in highwalls, pits with standing water, and spoil piles. Abandoned underground and surface mines in this area contribute significant AMD pollution to the North Branch Potomac River and its tributaries.

Morgan Mining and Environmental Consultants (1994) identified 52 AMD-producing sites during their comprehensive evaluation of the watershed in 1988-1989 (Fig. 7). These sites comprised 19 underground mines, 17 surface mines, 13 underground/surface mines and 3 loadouts with no associated mining. The majority of the sites was concentrated in Abram Creek (14 sites), Stony River (7 sites), Lostland Run (5 sites) and Three Forks Run (5 sites). From



Potomac River Watershed Acid Mine Drainage Sites

ID	NAME
301	underground mine refuse piles
302	surface mine
303	Davis Coal and Coke No. 42 mine
304	surface mine
305	
306	reclaimed surface mine
307	two surface mines
308	underground mine
309	underground mine
310	
311	surface mine
312	two surface mines
313	
314	loading facility/refuse piles
315	underground mine
316	underground mine
317	underground mine(reclamed)
318	underground mine collapsed draining entry
319	surface mine reclamation project
320	surface mine
321	surface mine
322	surface mine
323	surface mine
324	refuse pile
325	surface mine
326	
327	remined abandoned surface mine
328	surface mine
329	underground mine
330	underground mine complex
331	surface and underground mines
332	underground mine
333	underground mines and refuse piles
334	underground mines and refuse piles
335	Surface and underground mines
336	Shalimar Mines
337	surface mine
338	Hammil Mines (underground)
339	
340	underground mine
341	underground and surface mine
342	underground mine
343	surface and deep mines linked to #45
344	underground mine
345	surface and deep mines linked to #43
346	underground mine
347	surface mine
348	underground mines
349	underground/surface mine
350	surface and underground mine
351	surface and underground mine
352	surface and underground mine

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Figure 7.

extensive sampling during low and high flow conditions, they determined that 20 impacted subwatersheds produce the majority of the AMD. Almost 90% of the mine drainage discharged to the North Branch Potomac River originates from 15 sites in 4 watersheds and 2 direct discharges.

In Maryland, underground mines in Laurel Run and Three Forks Run and direct discharges to the North Branch at Shallmar and Kitzmiller are major contributors of AMD pollution. An abandoned surface mine in Abram Creek and two abandoned surface mines in Stony River are responsible for the majority of the AMD discharges in West Virginia.

Laurel Run drains approximately 9 mi^2. Mine drainage emanates from two shafts of an underground mine (No.42 Mine) located just north of Kempton, MD. Additional AMD is discharged from an abandoned surface mine located 500 ft north of one of the deep mine discharges. The surface mine contains piles of spoil material and a pit impoundment.

The Three Forks Run watershed is composed of about 9.5 mi^2. and is impacted by significant AMD discharges from underground and surface mines located between the Right Prong and the main channel of Three Forks Run near Vindex, MD. Additional drainage emanates from surface and deep mine sites along the Left Prong.

Significant AMD contributions to the North Branch Potomac River are the result of mine drainage emanating from the underground Shallmar Mines located 0.5 mi west of Kitzmiller, MD. AMD is discharged from three portals which combine to form one flow directly into the North Branch. An additional source of AMD on the site is drainage from refuse piles.

The underground Hammil Mines (Kitzmiller discharge), located 0.5 mi north of Kitzmiller, also discharge directly to the North Branch Potomac River. Mine drainage is discharged from nine collapsed portals. Runoff from three refuse piles also discharges directly to the North Branch. Additional tributaries located in Maryland that receive AMD include Shields Run, Glade Run, Steyer Run, Lostland Run, Wolfden Run and Elk Lick Run.

Stony River drains approximately 32 mi^2. and is impacted by mine drainage from a surface mine near Maysville, WV and another surface mine and loading facility near Bismark. Surface mining along the northwest side of Hemlick Run, a tributary to Stony Run, has produced multiple seepages from surface water contact with spoils. The loading facility has coal and refuse piles which are sources of acidic discharges during precipitation events, but not during low flow conditions in the river. The other surface mine impacting Stony River has four primary discharges as well as numerous seepages discharging to the river.

Abram Creek is the largest tributary watershed in the North Branch Potomac River upstream from Jennings Randolph Lake. The subwatershed is an area of about 44 mi^2. Drainage from one surface mine near Bismark and three mines near Mt. Storm contribute to the acidic conditions in Abram Creek. Additional tributaries that receive mine drainage in West Virginia include Deep Run and Fairfax Run.

METHODS FOR MEASURING AND ESTIMATING ACID MINE DRAINAGE CONTAMINANT LOADING IN RECEIVING STREAMS

Models and Statistics used for Evaluating AMD Water Quality and Contaminant Loads

For the most part, models used to evaluate AMD loads in surface waters have been designed to evaluate acid loading within a watershed for the purpose of designing appropriate abatement measures to mitigate the adverse impact of acidic conditions. The extensive evaluations of AMD impacted watersheds conducted by engineering firms in the early to mid 1970s monitored all detectable sources of mine drainage in a watershed for chemical constituents and flow. In addition to acidity and alkalinity, other chemical constituents of mine drainage measured were generally limited to iron and sulfates. Although aluminum and manganese measurements were obtained in a few watershed evaluations, these parameters were not measured with the same frequency as acidity, sulfates, and iron. In order to define the extent of AMD loads, it was necessary to determine the volume and chemical quality (concentrations) of mine drainage at discharge points within the watershed. In-stream water samples and flow measurements were obtained in addition to mine drainage discharge data to establish stream quality. Data were collected at regular intervals, usually monthly, over the course of one year to evaluate loads during low, average and high flow conditions.

The Susquehanna and West Branch Susquehanna River watersheds and the Allegany and Georges Creek watershed evaluations used similar methods and models to determine mine drainage impacts and mitigation measures. Mine drainage discharge conditions were established for each discharge point to establish abatement designs for average daily mine drainage volumes and chemical constituents during a year of normal precipitation; average daily mine drainage volumes and chemical constituents during high flow conditions caused by normal precipitation in spring; and maximum daily mine drainage volumes and chemical constituents resulting from maximum precipitation in a 24-h period occurring no more often than once in every 10 years. Discharge volumes were obtained at each mine drainage site with flow measurements in constructed weirs. The abatement designs were calculated using the annual chemical constituent concentration data and measured AMD volumes with adjustments to AMD volume based on precipitation records, assumed surface-water runoff coefficients and evaporation-transpiration losses.

Unlike previous studies to evaluate mine drainage impacts in watersheds, Morgan Mining and Environmental Consultants (1994) used synthesized flow volumes rather than constructing weirs and gauging discharge volumes at each sampling site, and data collection for AMD chemical constituent concentrations was limited to three sampling sweeps—during low, high, and average flow conditions. Initially, concurrent in-field measurements of stream velocity and cross-section were attempted; however, cross section measurements of the streams were difficult to obtain and velocities across the stream were highly variable. Synthesized flow was selected as an alternative to in-stream measurements to assign flows at each sample station. Data from USGS gauging stations and simulated flow values from the Tennessee Valley Authority - Hydrologic Simulation Model (TVA-HYSIM) were used to arrive at the synthesized flows for subwatersheds in the North Branch Potomac River study. In-stream measurements were used only for direct discharges to the North Branch. Because climatic conditions varied throughout the study area, a climatological factor was determined and applied to the USGS gauging station data to more accurately estimate flow conditions in the subwatersheds outside the watershed in which the gauging station was located. The climatological factor, based on precipitation and evaporation-transpiration rates unique to each subwatershed, was used as an adjustment factor to arrive at the estimated flow at sampling points selected for chemical analysis. Data from the USGS gauging station could only be adjusted and applied to subwatersheds with similar physiographic conditions. Subwatersheds with significantly dissimilar land uses required the use of the TVA-HYSIM model to estimate flow. The model was developed for the Appalachian coal region and designed for land-use studies. Predicted runoff generated by the model based on land use, physical parameters of a watershed, soil parameters, curve number, slope, and types and area of mining activity was used to estimate flows in the subwatersheds in which only climatological adjustments did not accurately predict flows. The accuracy of the synthesized flows were confirmed in areas where accurate in-stream measurements were possible.

Strategies for the abatement of AMD in the North Branch Potomac River utilized an acid loading model developed by Water Resources Management, Inc. The model uses a value referred to as the neutralization equivalent, which accounts for natural buffering capacities, rather than using pH or acidity and alkalinity to monitor the flow of AMD in a watershed. The neutralization equivalent value summarizes alkaline surplus or deficiency as related to a desired water quality endpoint (e.g., pH 6). Neutralization equivalent values were preferred because they are additive where as pH, alkalinity and acidity values are not. The model simulates downstream effects (pH and metal concentrations) encompassing the entire North Branch watershed upstream from Jennings Randolf Lake subsequent to abatement measures at single or multiple AMD discharge sites. Three models were developed for predicting stream responses during high, low and average flow conditions and for applicability to watersheds outside the study area given the necessary sampling data. The acid loading model was accurate at assessing relative changes in water quality constituents following hypothetical AMD abatement strategies; however, confidence limits could not be determined to quantify the degree of certainty associated with specific values at locations throughout the watershed.

Much of the available water quality, flow and chemical load data linked to AMD discharges obtained for this literature synthesis date back to 1970-1975. More recent data (Wood, 1996; and Hainly and Barker, 1993) were also used to determine loads of chemical constituents associated with mine discharges and in-stream measurements of tributary streams affected by AMD. However, sample sizes of the latter data were limited to a single sample obtained during high flow (April or May) and a single sample from low flow conditions (July) or low flow conditions (October-November). Chemical loads were calculated from integrated measurements of chemical concentration and instantaneous discharge rates at the time of sample collection. Current water quality and discharge flow data are needed to support or revise the estimated loads presented. Recent mine drainage discharge data for the Anthracite Coal Fields were limited to a single sampling sweep of large discharges. Recent data for discharges in the West Branch Susquehanna River were not available during the preparation of this literature synthesis; however, new data are being collected by watershed groups. The Wildlands Conservancy is collecting information regarding discharges from the Jeddo Tunnel in the Nescopeck Creek. Additional data has been collected in the Lackawanna River watershed and is currently being analyzed by Parr

Government Systems. The US Geological Survey is currently collecting water quality data from Swatara Creek to evaluate the efficacy of mine drainage remediation measures implemented at upstream sources. The Southern Allegany Resource Conservation and Development watershed association is currently sampling the largest 100 mine drainage discharges in western Pennsylvania with approximately 25 of the sites located in the Chesapeake Bay watershed. Mine drainage data has also been collected for the Cambria and Clearfield County Conservation Districts.

CONTAMINANT LOADINGS FROM ACID MINE DRAINAGE

Anthracite Coal Fields - Susquehanna River Drainage

Northern Anthracite Coal Field

The Lackawanna River enters the Northern Anthracite Coal Field below the Stillwater Dam about 1 mi north of Forest City. Tributaries upstream from the first mine drainage source, the Browndale Outfall, contribute little acidity to the river. The Browndale Outfall discharges as much as 100 pounds per day (ppd) acid following dry periods (Peters and Associates, 1971); however, 2-5 ppd acid is more common. One half mile downstream the Vandling Outfall discharges an average 166 ppd acid (Skelly and Loy, Inc., 1973b) and during periods of high flow it discharges 1,980 ppd sulfate (Wood, 1996) to the Lackawanna River. One mile farther downstream the Grey Slope Outfall discharges an average 45 ppd acid to the river.

Just north of Carbondale, Wilson Creek enters the Lackawanna River and contributes alkaline drainage from three major mine drainage outfalls. The average combined total loading from Upper Wilson Outfall, Lower Wilson Outfall, and Lower Simpson Outfall was 388 ppd alkalinity, 18 ppd iron and 7,155 ppd sulfate (Skelly and Loy, Inc., 1973b). During low flow the Simpson Drift (Upper Wilson Creek) contributes 0.2 ppd dissolved iron, 654 ppd sulfate and 0.6 ppd dissolved manganese and Simpson Shaft (Lower Wilson Creek) contributes 2 ppd iron, 3,163 ppd sulfate and 1 ppd manganese (Wood, 1996).

Farther downriver between Carbondale and Scranton, the Jermyn Outfall just south of the town of Jermyn controls the discharge of the Jermyn Pool. The Jermyn Pool extends from Jermyn to Carbondale and floods over 2600 acres of deep mines. The average loading from the outfall was 5,598 ppd acid, 276 ppd iron and 73,309 ppd sulfates (Berger Associates, Inc., 1978). Sampling in 1975 during high flow and in 1991 during low flow the outfall contributed 21-315 ppd dissolved iron, 12,265-46,154 ppd sulfates and 49-315 ppd dissolved manganese.

About 3.5 mi farther downstream the Lackawanna Rivers receives AMD from the Peckville discharge. The Peckville Shaft from the Gravity Slope Mine discharged 13-40 ppd dissolved iron, 4,115-21,033 ppd sulfates and 24-186 ppd dissolved manganese during low and high flow conditions and 173 ppd dissolved aluminum, 7.4 ppd dissolved cobalt, 1.9 ppd dissolved copper, 1.4 ppd dissolved lead, 3.7 ppd dissolved lithium, 13.6 ppd dissolved nickel, 27.2 ppd dissolved strontium and 22.3 ppd dissolved zinc during a period of high flow in 1975 (Wood, 1996). Also during high flow in 1975, the Jerome Shaft of the Lackawanna Mine discharged 1,937 ppd sulfates and 258 ppd dissolved iron.

Approximately 18 mi farther downriver, the Lackawanna River receives AMD from two major sources. The Old Forge borehole and Duryea breech drain an underground mine pool complex extending from Dickson City through the city of Scranton and the boroughs of Taylor, Old Forge, and Duryea. The area flooded by the pool covers 22,475 acres of deep mines. The combination of these two outfalls contributed an average 124,933 ppd acidity, 35,073 ppd iron and 8,537 ppd sulfates in 1971-1972. More recent data (1975 and 1991) indicate the Old Forge borehole contributed 153,631-406,992 ppd sulfates, and the following loads of dissolved metals: 9,145-20,871 ppd iron, 1,171-2,922 ppd manganese during low and high flow conditions, and 63 ppd aluminum, 57 ppd cobalt, 63 ppd lithium, 0.3 ppd mercury, 115 ppd nickel, 939 ppd strontium and 21 ppd zinc during high flow conditions. Results from six samples obtained from 1975 to 1991 at the Duryea breech discharge indicate the breech contributed 9,338-128,025 ppd sulfates, 783-8,779 ppd iron, 102-1,335 ppd dissolved manganese, 20-73 ppd dissolved aluminum, 0.04-1.7 ppd dissolved arsenic, 0.8-1.8 ppd dissolved cadmium, 4.5-11.9 ppd dissolved chromium, 7.5-27 ppd dissolved cobalt, 1.7-7 ppd dissolved copper, 3-23 ppd dissolved lead, 18 ppd dissolved lithium, 9.8-33 ppd dissolved nickel, 181 ppd dissolved strontium and 8.3-22 ppd dissolved zinc during flows ranging from 5.6 to 47 cfs.

Natural buffering in the Lackawanna River allows the river to recover to a net alkaline condition near the confluence with the Susquehanna River. Mine drainage data from 1971-1972 demonstrated 0.0 ppd acidity, 185,000 ppd alkalinity, 48,697 ppd total iron and 1,728,750 ppd sulfates near the mouth of the Lackawanna River.

The Susquehanna River, downstream from the mouth of the Lackawanna River, receives AMD from several large discharges. The first major discharge emanates from the Pittston Tunnel (Butler Water Tunnel). Discharge data from 1975 and 1991 showed chemical loads of 4,303-12,402 ppd sulfates and 46-117 ppd dissolved iron during low and high flow, and 50 ppd dissolved manganese during a low discharge of 2.5 cfs. The Plainsville Outlet, located between Pittston and Wilkes-Barre, was sampled during high flow in 1975 at which time the sulfate and iron loads were 54,438 ppd and 4,207 ppd, respectively.

Nanticoke, Warrior and Solomon creeks are tributaries to the Susquehanna River which drain subwatersheds in the vicinity of Wilkes-Barre. Major AMD pollution in these streams is caused by discharges from the Askam borehole into the Nanticoke Creek, discharges from three South Wilkes-Barre boreholes, and the discharge from the Buttonwood Tunnel into Solomon Creek. The AMD discharges emanate from abandoned deep mine pools that underlie the area. Solomon Creek borehole discharges sampled in 1975 and 1991 had chemical loads of 68,854-377,621 ppd sulfate and 559-3,566 ppd dissolved manganese. Samples obtained in 1975 (during high flow) showed dissolved metals discharge loads of 39,860 ppd iron, 210 ppd aluminum, 5.7 ppd arsenic, 46 ppd cobalt, 2.9 ppd lead, 38 ppd lithium, 0.1 ppd mercury, 117 ppd nickel, 776 ppd strontium and 29 ppd zinc. The Buttonwood discharge, sampled six times from 1975 to 1991 during flow conditions of 5-43 cfs, had the following loads of chemical constituents; 20,441-110,382 ppd sulfates, 1,425-13,798 ppd dissolved iron, 178 ppd dissolved manganese, 14-30 ppd dissolved aluminum, 0.7-2.8 ppd dissolved arsenic, 0.8-2.8 ppd dissolved cadmium, 2.8-3.1 ppd dissolved chromium, 8.4-11 ppd dissolved cobalt, 1.2-1.4 ppd dissolved copper, 3.1-21 ppd dissolved lead, 12-22 ppd dissolved nickel and 4.3-13 ppd dissolved zinc. In 1975, the Askam Shaft borehole discharge was 11 cfs with contaminant loads of 118,343 ppd sulfates and 5,917 ppd dissolved iron.

Two major AMD discharges, a seepage and the Number 2 shaft, emanate from the Number 7 Mine downriver from Wilkes-Barre. Chemical loads from the seepage in 1975 and 1991 were 497-26,358 ppd sulfates, 1.2-753 ppd dissolved iron, and 5.3 ppd dissolved manganese. During the same sampling time, the Number 2 shaft discharged 30,575-128,025 ppd sulfates, 1,342-4,572 ppd dissolved iron and 225 ppd dissolved manganese.

The last significant AMD source in the Northern Anthracite Field discharges to the Susquehanna River from the West End Mine located near the mouth of Black Creek across the river from the town of Shickshinny. Mine drainage from the Mocanaqua Tunnel contributed the following chemical loads during low and high flow; 8,908-21,216 ppd sulfates, 968-1,872 ppd dissolved iron and 125-324 ppd dissolved manganese. Dissolved metal loads from the tunnel during high flow conditions in 1975 were 187 ppd aluminum, 0.003 ppd arsenic, 11.5 ppd cobalt, 0.4 ppd copper, 0.3 ppd lead, 3.7 ppd lithium, 10.6 ppd nickel, 11.2 ppd strontium and 16.5 ppd zinc.

Eastern Middle Anthracite Coal Field

Major sources of mine drainage in the Eastern Middle Anthracite Coal Field are located on the Nescopeck and Catawissa creeks. The largest discharge impacting the Nescopeck Creek is the Jeddo Tunnel situated on the Little Nescopeck Creek. During low and high flow sampling in 1991 and 1975, the discharge at the Jeddo Tunnel was 24 and 65 cfs, respectively. The load of AMD chemical constituents during the low and high flows were 77,461-150,349 ppd sulfates, 361-2,098 ppd dissolved iron and 1,084 ppd dissolved manganese (low flow measurement only). The tunnel discharged an average acid load of 100,800 ppd to Little Nescopeck Creek (Skelly and Loy, Inc., 1973b) which resulted in a 71,518 ppd acid load to the Susquehanna River at the mouth of Nescopeck Creek.

Black Creek, a tributary to Nescopeck Creek draining the southern portion of the watershed, is impacted by six major AMD discharge sites. In 1975, drainage from Dainty Slope Mine had a discharge of 1.6 cfs during high flow and contributed 69 ppd sulfates to the creek. Dissolved iron concentrations were below detection limits (1 mg/L) at the time the sample was collected. The Tomhicken Mine strip pool overflow contributed 52-959 ppd sulfates, 0.3-174 ppd dissolved iron and 9.5-22 ppd dissolved manganese during low and high flow conditions in 1991 and 1975. Other chemical loads associated with the high flow discharge were 2.9 ppd dissolved aluminum, 0.03 ppd dissolved cadmium, 0.5 ppd dissolved cobalt, 0.07 ppd dissolved copper, 0.04 ppd dissolved lead, 0.2 ppd dissolved lithium, 0.009 ppd dissolved mercury, 0.7 ppd dissolved nickel and 0.7 ppd dissolved zinc. The Black Ridge Mine strip pool overflow, sampled in 1975, discharged 194 ppd sulfates to Black Creek during a period of high flow. The dissolved iron concentration was below the detection limit. Stony Creek Mine seepage into Black Creek contributed 10.5-194 ppd sulfates, 0.4-22 ppd dissolved iron and 0.2 ppd dissolved manganese. The Gowen Mine Tunnel discharged 363-3,905 ppd sulfate, 4-71 ppd dissolved iron and 6.5 ppd dissolved manganese. The remaining significant source of AMD on Black Creek emanates from the Derringer Mine Tunnel. This discharge contributed 750-13,254 ppd sulfates, 0.7-11 ppd dissolved iron and 10.5 ppd dissolved manganese (low flow) to the creek.

The major mine drainage pollution sources on the Catawissa Creek watershed originate in three separate coal basins; namely, South Green Mountain Basin, North Green Mountain Basin and Jeansville Basin. Within the Jeansville Basin, the major source of AMD is the Audenried Tunnel. Drainage from the Audenried Tunnel enters the Catawissa Creek and affects water quality to the confluence with the Susquehanna River. On the basis of low, average and high flow sampling in 1972, the discharge contributed 340-800 ppd total iron and 21,000-95,200 ppd acid (Gannett Flemming Corddry and Carpenter, Inc., 1974). Subsequent sampling in 1975 and 1991 showed the following ranges in loads of chemical constituents: 9,521-28,617 ppd sulfates, 51-204 ppd dissolved iron and 121 ppd dissolved manganese (low flow). Three additional sources of mine drainage impacting Catawissa Creek are Tunnels 1 and 3 of the Oneida Mine and the Green Mountain Mine Tunnel. Oneida Tunnel 1 contributed 805-2,375 ppd sulfates, 5.7-34 ppd dissolved iron and 8.5 ppd dissolved manganese to the creek in 1975 and 1991. Oneida Tunnel 3 contributed 557-2,594 ppd sulfate, 0.7-11 ppd dissolved iron and 5.5-28 ppd dissolved manganese based on data obtained in 1975 and 1991 during high and low flow conditions. During high flow in 1975, Tunnel 3 discharged 132 ppd dissolved aluminum, 0.05 ppd dissolved arsenic, 0.10 ppd dissolved cadmium, 1.2 ppd dissolved cobalt, 1.7 ppd dissolved copper, 0.2 ppd dissolved lead, 0.7 ppd dissolved lithium, 3.2 ppd dissolved nickel, 1.5 ppd dissolved strontium and 11.7 ppd dissolved zinc. The Green Mountain Tunnel discharge, also sampled in 1975 and 1991, contributed 256-859 ppd sulfate, 1.4-11.3 ppd dissolved iron and 3.5 ppd dissolved manganese (at low flow).

Low buffering capacity (alkalinity) in the lower reaches the Catawissa Creek is not sufficient to neutralize the acid discharged in the headwater region of the watershed. As a consequence, Catawissa Creek discharges about 18,000 ppd acid to the Susquehanna River (Skelly and Loy, Inc., 1973b).

Western Middle Anthracite Coal Field

The Western Middle Anthracite Coal Field is drained by Mahanoy and Shamokin creeks. In 1973, a total of 31 mine drainage discharge points was identified in the Mahanoy Creek watershed; however only 12 of the points accounted for almost 91% of the total AMD discharge (Sanders and Thomas, Inc., 1974). Most of the discharges composing a large portion of the mine drainage flow are located in the eastern half of the watershed. A major source of AMD near Mahanoy City is the borehole at the Vulcan Buck Mountain Mine. This discharge contributed 648-8,435 ppd sulfate, 51 -527 ppd dissolved iron and 6.9 ppd dissolved manganese in 1975 and 1991. The Gilberton Mine pump discharged 26,853-123,722 ppd sulfate, 2,140-6,681 ppd dissolved iron and 394-1,980 ppd dissolved manganese. The Gilberton Mine discharge also included high flow loads of 87 ppd dissolved aluminum, 1.0 ppd dissolved arsenic, 40 ppd dissolved cobalt, 8.7 ppd dissolved lithium, 0.06 ppd dissolved mercury, 47 ppd dissolved nickel, 186 ppd dissolved strontium and 63 ppd dissolved zinc.

Farther downstream, the Weston Mine discharges AMD from a seepage point and the Lost Creek borehole. The ranges in chemical loads from the seepage are 108-23,884 ppd sulfate, 1.5-398 ppd dissolved iron and 1.4 ppd dissolved manganese (low flow). The Lost Creek borehole was sampled during high flow in 1975 and contributed 6,993 ppd sulfate and 108 ppd dissolved iron. The borehole at Hammond Mine had no discharge during low flow; however, during high flow in 1975 it discharged 10,974 ppd sulfate and 366 ppd dissolved iron. Seepage from the Girard Mine, located east of Girardsville, discharged 2,474-19,796 ppd sulfate, 204-861 ppd dissolved iron and 45 ppd dissolved manganese. The Packer Number 5 Mine, located north of Girardsville, discharges AMD from a breach and boreholes. Based on sampling in 1975 and

1991, the ranges in chemical constituent loads from the discharge were 94,136-314,684 ppd sulfate, 3,093-9,683 ppd dissolved iron and 1,318 ppd dissolved manganese.

Four major discharges from the Preston mine, Centrailia Mine, Bast Mine and Tunnel Mine 2 are located between Girardsville and Ashland. The Preston Mine Tunnel contributed 213-2.367 ppd sulfate, 23-237 ppd dissolved iron and 2.9 ppd dissolved manganese. Drainage emanating from the Centrailia Mine tunnel contributed 9,586-34,319 ppd dissolved iron and 86 ppd dissolved manganese. The Bast Mine is drained via the Oakland Tunnel and discharged 17,902-23,432 ppd sulfate, 585-710 ppd dissolved iron and 124 ppd dissolved manganese. The drain pool area and seepage from Tunnel Mine 2 contributed 4476 ppd sulfate and 210 ppd dissolved iron in 1975.

Downstream from Ashland additional AMD discharges emanate from Potts Mine and Locust Gap Mine. The east breach of the Potts Mine had no measurable discharge during low flow conditions; however, in 1975 during high flow conditions the breach discharged 16,525 ppd sulfate and 689 ppd dissolved iron. The Locust Gap Mine has two tunnel discharges, the Helfenstein and Doutyville tunnels. Loads associated with the Helfenstein Tunnel were 11,565-14,056 ppd sulfate, 210-296 ppd dissolved iron. Loads contributed by the Doutyville Tunnel were 5,003-48,951 ppd sulfate, 121-839 ppd dissolved iron, 36-448 ppd dissolved manganese, 54 ppd dissolved aluminum, 0.1 ppd dissolved arsenic, 12.6 ppd dissolved cobalt, 1.7 ppd dissolved copper, 5.6 ppd dissolved lithium, 24 ppd dissolved nickel, 41 ppd dissolved strontium and 38 ppd dissolved zinc.

In-stream measurements of AMD chemical constituents in Mahanoy Creek collected in 1973-1974 just upstream from the point where Zerbe Run confluences with Mahanoy Creek represent the cumulative AMD load contributed by upstream mine drainage. The range in the load of total iron was 7,685-41,499 ppd with an average of 21,657 ppd. The range in the sulfate load was 611,627-1,059,020 ppd with an average of 766,511 ppd. The range in the flow was 140-403 cfs with an average of 228 cfs.

Approximately 23 mi downstream from Ashland, Zerbe Run confluences with Mahanoy Creek. A major contributor of AMD to Zerbe Run is the North Franklin Mine. Mine drainage emanates from a drift, a borehole and seepage. During high and low flow conditions in 1975 and 1991 the combined discharge from the three sources was 2.2-8.3 cfs and contributed 4,852-25,003 ppd sulfate, 201-982 ppd dissolved iron and 37 ppd dissolved manganese.

Alkaline reserves of Mahanoy Creek are more than sufficient to neutralize the AMD introduced by Zerbe Run. At its mouth, Mahanoy Creek contributed 3,100 ppd alkalinity to the Susquehanna River (Skelly and Loy, Inc, 1973b). The total iron load at the mouth of the creek was 1,158-40,316 ppd with an average of 15,582 ppd (Sanders and Thomas, Inc., 1974) and the sulfate load was 543,264-1,044,835 ppd with an average of 761,178 ppd.

Mine drainage in Shamokin Creek is limited to the eastern part of the watershed. Gannett Flemming Corddry and Carpenter, Inc (1972) reported coal mining activity had been confined to approximately 50.5 mi^2 (37% of the watershed) in the headwater area. Streams impacted by

AMD in the headwaters area include North Branch, Locust Creek, Quaker Run, Buck Run, Coal Run, Carbon Run, as well as Shamokin Creek.

Eighteen mine drainage discharge points existed as overflows from 11 underground mine water pools. A total of 54 mine drainage discharge points was identified and associated with, in addition to underground mine water pools, refuse areas, deep mine entries, and strip mines. All 54 discharge points were located in the headwaters area upstream from Glen Burn Colliery. Of the 54 discharge points, only 35 appeared to discharge continuously. Based on the discharge conditions (1969-1970) with an annual precipitation in the watershed 5% less than normal, the following loads from the 35 continuous discharge points were approximated as: 11,740-26,400 ppd total iron with an average of 18,100 ppd (Gannett Flemming Corddry and Carpenter, Inc., 1972).

Subsequent sampling by Wood (1996) identified 12 major AMD discharge sites in the Shamokin Creek watershed. The eastern-most major source of AMD was the Mid-Valley Mine Tunnel which contributed 3,782-8,886 ppd sulfates, 378-476 ppd dissolved iron and 56 ppd dissolved manganese in 1975 and 1991.

Within Quaker Run, the Scott Ridge Mine discharges AMD by way of a breach and a rock tunnel. The breach discharged 9,295-17,924 ppd sulfate, 749-753 ppd dissolved iron and 111 ppd dissolved manganese. The tunnel, which was sampled during high flow conditions, discharged 39,537 ppd sulfate, 3,631 ppd dissolved iron, 549 ppd dissolved manganese, 73 ppd dissolved aluminum, 0.2 ppd dissolved arsenic, 23 ppd dissolved cobalt, 0.2 ppd dissolved copper, 7.3 ppd dissolved lithium, 0.6 ppd dissolved mercury, 26 ppd dissolved nickel, 26 ppd dissolved strontium and 20 ppd dissolved zinc.

Downstream from Quaker Run, the Colbert Mine breach discharged 2,469-3,201 ppd sulfate, 194-256 ppd dissolved iron and 38 ppd dissolved manganese to Shamokin Creek. The Excelsior Mine strip pool overflow contributed 10,506 ppd-27,972 ppd sulfate, 1,051-3,077 ppd dissolved iron, 122-378 ppd dissolved manganese, 66 ppd dissolved aluminum, 0.07 ppd dissolved arsenic, 9.8 ppd dissolved cobalt, 4.2 ppd dissolved lithium, 17 ppd dissolved nickel, 21 ppd dissolved strontium and 23 ppd dissolved zinc. Farther downstream in Shamokin Creek, a borehole discharges mine drainage from Maysville Mine Numbers 1 and 2. The chemical load associated with the discharge was 5,207-8,166 ppd sulfate, 343-888 ppd dissolved iron and 51 ppd dissolved manganese. Mine drainage from the Corbin Mine drift contributed 1,080-2,636 sulfate, 113-215 ppd dissolved iron and 14 ppd dissolved manganese.

Big Mountain Mine discharges AMD from the Number 1 slope to Buck Run. The load associated with the slope during sampling in 1975 and 1991 was 19-3,228 ppd sulfate, 1.6-215 ppd dissolved iron and 0.2 ppd dissolved manganese.

The largest contributor of AMD to Carbon Run is the Henry Clay Stirling Mine. Drainage from the mine contributed 7,907-27,811 ppd sulfate, 549-2,958 ppd dissolved iron and 66 ppd dissolved manganese.

Downstream near the town of Shamokin, the Cameron Mine discharges AMD to Shamokin Creek through an air shaft, drift and tunnel. The airshaft discharge contributed 11,673-16,998 ppd sulfate, 1,101-1,291 ppd dissolved iron and 122 ppd dissolved manganese. The drift contributed 1,498-27,811 ppd sulfate, 34-3,792 ppd dissolved iron and 8.4 ppd dissolved manganese.

Southern Anthracite Coal Field

Mahantango Creek drains the northern portion of the Southern Anthracite Coal Field. The Rausch Creek watershed is a subwatershed of Pine Creek which is tributary to Mahantango Creek. Anthracite Research and Development Co., Inc. (1970) reported 47 active and abandoned mining operations during 1968-1969 contributed to the acid mine drainage in Rausch Creek. The total acid load contributed by the operations was 11,800 ppd. The acid load beyond the confluence of the East and West Branches of Rausch Creek was 12,000 ppd. The added difference was probably accountable in the additions of acid by the leaching of spoils and refuse banks along the routes of the two streams. The total iron load was approximately 3,600 ppd. Beyond the confluence of the East and West Branches, there was found to be an estimated total iron load of 3,050 ppd. The decrease was likely due to oxidation and deposition of iron along the stream beds. The total sulfate load was 21,000 ppd. Beyond the confluence there was an estimated 25,850 ppd load of sulfate.

The major mine drainage pollution sources in the watershed were identified as the Markson Columnway, Valley View Tunnel, Buck Mountain Drift and Good Spring Number 1 Mine. The Markson Columnway, located just north of the confluence of the two branches of Rausch Creek, discharges directly into Rausch Creek and contributed 330-390 ppd sulfate and 73-86 ppd total iron, based on monthly averages generated from samples obtained in 1968-1969. The Valley View Tunnel is located just west of the confluence of the west and east branches of Rausch Creek and contributed 112-130 ppd sulfate and 28-33 ppd total iron. Buck Mountain Drift is located west of Rausch Creek immediately north of the two confluences. The drift discharged 354-408 ppd sulfates and 56-66 ppd total iron. The Goodspring Number 1 Mine is located on the north side of the East Branch Rausch Creek about 1.3 miles upstream from the confluence of the east and west branches. Mine drainage emanates from the airhole and contributed 276-327 ppd sulfates and 39-45 ppd total iron.

Subsequent sampling in the Rausch Creek watershed by Wood (1996) also identified the previously described outfalls as major contributors of AMD to the watershed. Valley View mine discharged AMD via an intermittent pump and a tunnel. In 1975 the pump was discharging 6,068 ppd sulfate and 516 ppd dissolved iron to Rausch Creek. There was no discharge from the pump in 1991. Mine drainage emanating from the tunnel in 1975 and 1991 discharged 753-4,260 ppd sulfate, 120-852 ppd dissolved iron and 15 ppd dissolved manganese. The Markson Mine discharges AMD through a columnway to the creek. Loads contributed to the creek by the columnway discharge were 5,293-6,390 ppd sulfate, 413-461 ppd dissolved iron and 104 ppd dissolved manganese. The Goodspring Number 1 Mine was sampled at a buried borehole which discharged 1,237 ppd sulfates and 118 ppd dissolved iron.

The Rausch Creek Treatment Plant is located just north of the confluence of the West and East Branches. This facility was constructed as an abatement measure to reduce the AMD pollution load downstream from the confluence.

Wiconisco Creek is impacted by mine drainage in its eastern portion from the town of Keefers to Lykins. In the headwaters area, Keefer Tunnel discharged an average 594 ppd acid (Sanders and Thomas, Inc., 1970). About 1 mi farther downstream, the Porter Tunnel discharged 1,069 ppd acid. Downstream from Tower City the stream recovers from the acid load discharged upstream to a net alkaline condition. Just west of Williamstown, Big Lick Tunnel, an alkaline deep mine discharge, contributed 5,766 ppd sulfate and 541 ppd dissolved iron in 1975 during high flow conditions (Wood, 1996). Bear Creek, a tributary to Wiconisco Creek, receives AMD from Lykens Water-Level Drift which contributed 252-1,243 ppd sulfate, 36-169 ppd dissolved iron and 2.5 ppd dissolved manganese. Additional major sources of mine drainage identified by Wood (1996) included an airshaft and pump station discharge and seepage from the Lykins-Williamstown Mine. The airshaft and pump station discharge yielded 651-6,455 ppd sulfate, 107-968 ppd dissolved iron and 14 ppd dissolved manganese. The seepage discharged 361-2,485 ppd sulfate, 66-237 ppd dissolved iron and 8.5 ppd dissolved manganese.

Water quality data collected downstream from all mine drainage discharges at the mouth of Wiconisco Creek indicated an alkaline condition with an average 6,700 ppd alkalinity, 575 ppd total iron and 15,250 ppd sulfate (Sanders and Thomas, Inc., 1970).

Swatara Creek is the southern-most watershed draining the Southern Anthracite Coal Field. During a sampling program conducted in 1970-1971, the northeast headwater area of the watershed was impacted by discharges from three mine pool overflows and one refuse pile. The four sources accounted for 93% of the acid load. The combined net average pollution load was 3,720 ppd acid and 220 ppd total iron (Gannett Fleming Corddry and Carpenter, Inc., 1972). During the sampling period of 1969-1970, the AMD load in the north central area mainstem of Swatara Creek was a maximum 50,000 ppd acid and 10,870 ppd total iron. The average for the area was 8,962 ppd acid and 953 ppd total iron.

A sampling of major AMD discharges in the Swatara Creek watershed in 1975 and 1991 identified the Blackwood Mine, Middle Creek Mine, Eureka Mine, East Franklin Mine and Lincoln Mine as significant sources of AMD pollution. The Blackwood Water-level Tunnel contributed 290-2,378 ppd sulfate, 0.8-15 ppd dissolved iron, 2.9-22 ppd dissolved manganese, 4 ppd dissolved aluminum, 0.8 ppd dissolved cobalt, 0.1 ppd dissolved copper, 0.3 ppd dissolved lithium, 1.7 ppd dissolved strontium and 2.9 ppd dissolved zinc. A strip pool overflow at Middle Creek mine discharged 1,614-9,489 ppd sulfate, 15-51 ppd dissolved iron, 3.7-127 ppd dissolved manganese, 116 ppd dissolved aluminum, 4.7 ppd dissolved cobalt, 1.6 ppd dissolved copper, 0.2 ppd dissolved lead, 1.0 ppd dissolved lithium, 6.9 ppd dissolved nickel, 7.4 ppd dissolved strontium and 32 ppd dissolved zinc. A drift in the Eureka Mine discharged 17-1,006 ppd sulfates, 0.5-18 ppd dissolved iron and 0.6 ppd dissolved manganese. The Lower Paoli Tunnel discharge associated with the East Franklin Mine contributed 25-2,335 ppd sulfates, 0.5-264 ppd dissolved iron and 0.08 ppd dissolved manganese. Discharges from the Rowe Drainage Tunnel (Lincoln Mine) contributed 497-4,476 ppd sulfates, 45 -344 ppd dissolved iron and 19 ppd dissolved manganese to Swatara Creek.

Summary of Mine Drainage Loads in the Anthracite Coal Fields

A summary of mine drainage chemical constituent loads is presented in Table 2. The watersheds of 10 major tributaries to the Susquehanna River are impacted by mine drainage. While acid is a significant constituent of mine drainage, the impacts are limited to the tributaries or stream segments within the tributaries. Natural alkalinity reserves in the Susquehanna River Basin allow the river to recover from acid discharges to a net alkaline condition.

The Jermyn, Gravity Slope, Lackawanna, Old Forge and Duryea outfalls are the largest contributors of mine drainage to the Lackawanna River. Based on data from 1971-1972, the Lackawanna River received 73,621 ppd sulfates and 1,545 ppd total iron during low flow sampling (156 cfs) and 1,768,601 ppd sulfates and 56,983 ppd total iron during high flow conditions 458 (cfs). Subsequent sampling of large discharges in the watershed in 1975 during a period of high flow conditions and again in 1991 during low flow conditions indicated the range of combined discharge loads were 621,688 to 183,166 ppd sulfates, and 30,263 ppd to 9,964 ppd dissolved iron dissolved iron. Comparisons between the sampling conducted in 1971-1972 and subsequent sampling are difficult because the earlier measurements monitored total iron while the latter monitored the dissolved fraction of metals in the discharges. Combined loads of 4,859 ppd manganese and 309 ppd aluminum were also discharged during low flow in 1975; however, not all the large discharge samples were analyzed for manganese and aluminum. A combined load of 1,251 ppd manganese was contributed by the large discharges during low flow sampling. The discharges were not analyzed for aluminum during the latter sampling sweep.

The ranges of combined loads contributed by large discharges directly to the Susquehanna River were 44,284 to 242,439 ppd sulfates and 2,357 to 11,521 during low and high flows measured in 1975 and 1991.

Large discharges contributed a combined load of 488,003 ppd sulfate and 53,658 ppd dissolved iron to Solomon Creek during high flow conditions in 1991. During low flow, 89,295 ppd sulfates were discharged. The cumulative load of iron could not be estimated at low flow because there was no measurement from the South Wilkes-Barre Mine discharge. Water quality data collected at the mouth of Solomon Creek in 1983 indicated the net contribution from all

Table 2. Summary of cumulative acid mine drainage chemical constituent loads in the Susquehanna River tributaries draining the anthracite coal fields in Pennsylvania. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow (cfs).

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum
Northern Anthracite Coal Field							
Lackawanna River	1971-1972	156.4	Low	73,621	1,545		
	1971-1972	457.5	High	1,768,601	56,983		
	April 1975	218	High	621,688	30,263	4,859	309
(in-stream at mouth)	July 1982	75		125,578	3,569	835	158
	Oct. 1991	95.7	Low	183,166	9,964	1,251	
Susquehanna R discharges	April 1975	35.7	High	242,439	11,521		
	Oct. 1991	10.9	Low	44,284	2,357		
Solomon Creek (at mouth)	April 1975	66	High	488,003	53,658		
	July 1983	37	Normal	191,851	17,732	1,549	240
	Oct. 1991	25	Low	89,295			
Nanticoke Creek (at mouth)	April 1975	11	High	118,343	5,917		
	July 1982	3		16,042	717	118	33
Eastern Middle Anthracite Coal Field							
Nescopeck Creek (in-stream at mouth)	April 1975	89.9	High	168,924	2,412		
	July 1982	98		116,450	196	1,694	3,732
	Oct. 1991	26.2	Low	78,636	366	1,110	
Catawissa Creek (in-stream at mouth)	April 1975	36.6	High	34,446	260		
	August 1982	66		16,042	82	246	998
	Oct. 1991	8.7	Low	11,139	59	139	

Table 2 (continued). Summary of cumulative acid mine drainage chemical constituent loads in the Susquehanna River tributaries draining the anthracite coal fields in Pennsylvania. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow (cfs).

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum
Western Middle Anthracite Coal Field							
Shamokin Creek (2.7 mi. from mouth)	1969-1970	65	Year Avg.		18,100		
	April 1975	64.7	High	188,182	17,846		
	July 1985	62.4		97,740	1,011	1,180	576
	Oct.-Nov. 1991	25.6	Low	54,169	4,576	589	
Mahanoy Creek (at mouth)	1973-1974	311	Year Avg.	761,178	15,582		
	April 1975	145	High	677,617	23,093		
	July 1985	121.4		208,082	2,083	2,017	385
	Oct.-Nov. 1991	51.4	Low	173,340	6,815	2,143	
Southern Anthracite Coal Field							
Swatara Creek (in-stream near Ravine)	April 1975	21.3	High	19,684	656		
	July 1985	20.8		18,050	115	212	16
	Oct. 1991	3.4	Low	2,443	98	35	
Wiconisco Creek (in-stream at mouth)	1973		Year Avg.	15,250	575		
	April 1975	20.6	High	27,584	2,098		
	July 1985	33.5		11,556	73	1	6
	Oct. 1991	2.7	Low	1,764	249	35	
Rausch Creek	1968-1969		Year Avg.	25,850	3,050		
	April 1975	13	High	16,858	1,900		
	Oct. 1991	4	Low	7,179	582	119	
Mahantango Creek (in-stream near mouth)	July 1985	37.7		7,315	300	18	230

upstream sources resulted in loads of 191,851 ppd sulfate, 17,732 ppd total iron, 1,549 ppd manganese and 240 ppd aluminum during a flow of 37 cfs.

The Truesdale Mine is the single largest source of mine drainage in Nanticoke Creek. The load of mine drainage indicators discharged from the mine was 118,343 ppd sulfate and 5,917 ppd iron during high flow. A later study evaluating tributary water quality conducted in 1982 indicated the net load of mine drainage indicators measured at the mouth of Nanticoke Creek was 16,042 ppd sulfates, 717 ppd iron, 118 ppd manganese and 33 ppd aluminum.

The Jeddo Tunnel discharge from the Jeddo Mine is the largest single source of mine drainage in the Nescopeck Creek watershed. During low and high flow sampling, the ranges in chemical constituents in the discharge were 77,461-150,349 ppd sulfate and 361-2,098 ppd iron. The combined loads contributed by the large discharges throughout the watershed were 78,636-168,924 ppd sulfate and 366-2,412 ppd iron. In-stream measurements from the mouth of Nescopeck Creek indicated the net loads of mine drainage indicators were 116,450 ppd sulfates, 196 ppd total iron, 1,694 ppd manganese and 3,732 ppd aluminum.

Large mine drainage discharges on Catawissa Creek contributed combined loads of 11,139-34,446 ppd sulfate and 59-260 ppd iron during low and high flow measurements. During low flow, 139 ppd manganese was discharged. In-stream loads near the mouth of Catawissa Creek indicated loads of 16,042 ppd sulfate, 82 ppd total iron, 246 ppd manganese and 998 ppd aluminum.

Shamokin Creek received combined loads of 54,169-188,182 ppd sulfate and 4,576-17,846 ppd iron from mine discharges during low and high flow measurements. In-stream measurements recorded 2.7 mi from the mouth of Shamokin Creek indicated net loads from all sources were 97,740 ppd sulfates, 1,011 ppd iron, 1,180 ppd manganese and 576 ppd aluminum.

The ranges of mine drainage loads from large discharges in Mahanoy Creek during low and high flow conditions were 173,340-677,617 ppd sulfates and 6,815-23,093 ppd iron. In-stream measurements indicated loads of 208,082 ppd sulfates, 2,083 ppd iron, 2,017 ppd manganese and 385 ppd aluminum at the mouth of Mahanoy Creek.

Mine drainage loads in Swatara Creek during low and high flow rates were 2,443-19,684 ppd sulfate and 98-656 ppd iron. In-stream measurements recorded downstream near Ravine, indicated loads of 11,556 ppd sulfates and 98-656 ppd total iron, 212 ppd manganese and 16 ppd of aluminum.

Large mine drainage discharges in Wiconisco Creek contributed 1,764-27,584 ppd sulfates and 249-2,098 ppd iron-the watershed during low and high flow conditions. In-stream measurements at the mouth of Wiconisco Creek indicated loads from all upstream sources were 11,556 ppd sulfates, 73 ppd iron, 1 ppd manganese and 6 ppd aluminum.

Rausch Creek mine drainage loadings during low and high flow were 7,179-16,858 ppd sulfates and 582-1,900 ppd iron.

Based on the available data, ranges in the cumulative loads of mine drainage indicator chemical constituents from the large discharges in the anthracite coal fields were 661,457-2,603,768 ppd sulfates and 31,006-143,707 ppd dissolved iron during low and high flow conditions. Combined net in-stream loadings measured at the mouth of the major tributaries draining the anthracite coal fields plus averaged discharge measurements from the large Susquehanna River discharges and Rausch Creek discharges were 952,531 ppd sulfates and 35,226 ppd iron. Estimates on the cumulative loading of other metals associated with mine drainage could not be calculated due to insufficient data.

Bituminous Coal Fields - Susquehanna River Drainage

Tioga River Watershed

Three tributaries of the Tioga River (Morris Run, Coal Creek and Bear Creek) drain this coal basin and are impacted by mine drainage from deep mines. Under low flow conditions, Coal Creek contributed 70% of all AMD entering the Tioga River (ACOE, 1972). Morris Run, Coal Creek and Bear Creek contributed an average 17,700, 21,000 and 3,750 ppd acid, respectively to the Tioga River. During both unusually low and high flow, the river receives AMD not completely neutralized by alkalinity reserves. Recent water quality data from Pennsylvania's surface water quality monitoring network indicate average AMD indicator loads of 97,649 ppd sulfates, 1,516 ppd total iron, 1,913 ppd total manganese, 1,958 total aluminum and 181 ppd total zinc derived from 12 monthly in-stream samples at Tioga Junction (downstream from AMD sources) in 1994. The average AMD indicator loads in the Tioga River in 1992 were 92,785 ppd sulfates, 547 ppd total iron, 1,224 ppd total manganese, 598 ppd total aluminum and 101 ppd total zinc.

Juniata River Watershed

Major tributary streams in the headwater area of the Juniata River impacted by coal mine drainage include Frankstown Branch, Raystown Branch and Augwick Creek. Within the Frankstown Branch subwatershed, Beaver Dam Branch is a major recipient of AMD. Beaver Dam Branch upstream from Burgoon Run is alkaline; however mine drainage from Burgoon Run degrades the water quality of Beaver Dam Branch. Farther downstream, Sugar Run contributed 630 ppd acid, 3,838 ppd sulfates and 4.3 ppd total iron to Beaver Dam Branch. Recent water quality data indicates average AMD indicator loads in Beaver Dam Branch near its mouth in 1994 were 52,451 ppd sulfates, 1,281 ppd total iron, 375 ppd total manganese and 1,253 ppd total aluminum during flows ranging from 28 to 674 cfs.

Acid mine drainage is contributed to the Raystown Branch of the Juniata River by Sandy Run, Six mile Run, Shoups Run and Great Trough Creek. The largest source of AMD to Six Mile Run is an artesian flow which discharged an average 2,000 ppd acid (Skelly and Loy, Inc., 1973b). The second largest contributor of AMD is a deep mine that averaged 1,300 ppd acid. A total of 7,900 ppd acid entered Six Mile Run. Shoup Run contributed approximately 3,200 ppd acid to the Raystown Branch, most of which emanates from two deep mine discharges. The south branch of Sandy Run received about 1,000 ppd acid from deep mine pools and gravity discharges; however, Sandy Run was not acid at its mouth.

Within the Augwick Creek watershed, Roaring Run contributed about 2,200 ppd acid to Sideling Hill Creek which is capable of neutralizing the acid resulting in an alkaline discharge to Augwick Creek.

Summary of Mine Drainage Loads in the Bituminous Coal Fields - Susquehanna River

Recent data were not available for estimating the loads of mine drainage chemical constituents from individual sources; however, in-stream measurements from the Pennsylvania Stream Monitoring Network indicate net loads in the Beaver Dam Branch tributary to the Juniata River were 52,451 ppd sulfates, 1,281 ppd total iron, 375 ppd total manganese and 1,253 ppd total aluminum.

Recent water quality data, also obtained from the Stream Monitoring Network, indicates average (based on 12 months of sampling) in-stream loadings of mine drainage indicators in the Tioga River downstream from all AMD sources averaged 92,785-97,649 ppd sulfate, 547-1,516 ppd total iron, 1,224-1,913 ppd total manganese, 598-1,958 ppd total aluminum and 101-181 ppd total zinc.

Bituminous Coal Fields - West Branch Susquehanna River Drainage

West Branch Susquehanna River Headwater Area

An extensive mine drainage study in 1971 (Gwin, Dobson and Foreman, Inc., 1972) evaluated water quality and loadings of AMD indicators in the West Branch Susquehanna River between Bakerton and Bower (just upriver from the Curwensville Reservoir). Cumulative in-stream loadings of sulfate and total iron reported from Bakerton (headwaters) downstream to the town of Bower were 159,447 ppd and 400 ppd, respectively, with a flow rate of 129 cfs. These values represented average pollutant loadings in the area. There were three continuous acid tributaries entering the West Branch in this reach. Leslie Run, near Bakerton contributed an average acidity of 250 ppd, while Fox Run, near Spangler and Bear Run at McGees Mills contributed 1,919 and 1,406 ppd acid, respectively.

Sources of mine drainage in the headwater area included refuse piles, deep mines and strip mines. A comparison of the pollutant loads emanating from each source indicated that approximately 75% of the acid load was attributed to refuse piles, and almost 25% of the acid load was contributed by deep mines, with strip mines contributing less than 1%. Iron and sulfate loads were nearly equally attributed to refuse piles and deep mines (approximately 50% each), with strip mines again contributing less than 1%. Major refuse piles contributed 34,006 ppd acid, 56,083 ppd sulfates and 2,797 ppd total iron (in June 1971) to the headwater area of the West Branch Susquehanna River.

Deep mine sources of AMD discharged through conventional mine openings such as boreholes, drainage courses and old portals. In 1971, the discharges from deep mines contributed 9,413-50,866 ppd acid, 23,560-160,544 ppd sulfates and 1,857-19,310 ppd total iron to the headwater area. The average acid, sulfate and iron contribution was 19,600 ppd, 59,424 ppd and 4,993 ppd, respectively. The Victor #9 and #10 Mines, located in the vicinity of Carrolltown to Spangler, discharged AMD through two drainage courses, a borehole and a slope entry. The average pollutant loads from these mines were 15,170 ppd sulfates and 1,447 ppd total iron. The Sterling #1 and #6 Mines, located near Bakerton, discharged an average 8,187 ppd sulfates and 1,092 ppd total iron. The Lancashire #20 Mine discharged from a drainage course and contributed 13,476 ppd sulfates and 954 ppd total iron. The Sterling #3 Mine is located east of Bakerton on the east side of the West Branch headwaters. Mine drainage emanated from four drainage courses and contributed 1,238 ppd sulfates and 22 ppd total iron. Three drainage courses associated with the Heisley #2 Mine, located southeast of Bakerton, discharged an average 299 ppd sulfates and 5 ppd total iron. The remaining deep mine source of AMD, the Lancashire #15 Mine, initially contributed a significant pollution load; however the mine pool level was lowered until its discharged stopped completely by April of 1971.

Although strip mines accounted for less than 1% of the mine drainage pollution load, the average acid, sulfate, and total iron contributions were 201 ppd, 1,725 ppd and 28 ppd, respectively. In addition to mine drainage from identified sources, diffuse unknown sources can increase acid loading up to an additional 50,000 ppd during periods of unusually high flow.

Chest Creek

Mine drainage in Chest Creek is discharged from spoil piles, coal refuse and abandoned deep mines. The contribution of AMD from each source in the watershed is about equal. Water quality data from 1970 to 1972 (Gwin Dobson and Foreman, Inc., 1972) indicate the average pollution load at the mouth of Chest Creek was 561 ppd total iron and 68,092 ppd sulfates during flows ranging from 31.3 to 500 cfs. Alkaline reserves in the watershed neutralize all acid contributed by mine drainage such that Chest Creek discharges alkaline water to the West Branch Susquehanna River.

West Branch - Chest Creek to Curwensville

Acid mine drainage impacting this reach of the West Branch occur mainly from Anderson Creek. The watershed has been extensively mined for both coal and clay. Two major tributaries to Anderson Creek, Kratzer Run and Little Anderson Creek, have been degraded by mine drainage from abandoned deep and strip mines. Seventy-seven AMD discharges were identified in the watershed in 1973-1974 (Gwin Engineers, Inc. 1974); however, a large percentage of the total acid discharging into the watershed came from a relatively small number of discharges. Six discharges accounted for 72 % of the acid load and a total of 14 discharges accounted for 88% of the daily acid load. Deep mine refuse piles represented episodic sources of AMD. Under dry conditions these piles did not contribute AMD discharges; however, during rainy periods the surface water percolates through the refuse and produces acidic discharges.

The AMD pollution load in 1973-1974 in Kratzer Run averaged 1,182 ppd acid, 50 ppd total iron and 7,856 ppd sulfates. Little Anderson Creek had average loads of 8,581 ppd acid, 512 ppd total iron and 13,334 ppd sulfates. The net load in Anderson Creek from mine drainage throughout the watershed was 7,783 ppd acid, 365 ppd total iron and 23,559 ppd sulfates.

Water quality data collected in 1971 indicated the AMD pollution load in Anderson Creek was 111 ppd total iron and 24,856 ppd sulfates (Gwin, Dobson and Foreman, Inc., 1972).

Hainly and Barker (1993) surveyed the West Branch Susquehanna River from Curwensville to Renovo to evaluate the water quality of tributary streams. May water samples were collected at the mouth of each tributary during baseflow conditions and again in July and analyzed for AMD indicator pollutants. Stream flows during the May sampling period were in the 60-70% duration range meaning the sampled flows were exceeded 30-40 % of the time as indicated by historical flow records. Stream flows during the July sampling period were in the 10-20% range. Results from the survey indicated that the pollution load at the mouth of Anderson Creek during the low base-flow conditions was 22,555 ppd sulfates, 5,825 ppd total iron, 2,730 ppd total manganese, 9,101 ppd total aluminum and 364 ppd total zinc. The pollution load during high base-flow was 76,044 ppd sulfates, 1,267 ppd total iron, 1,601 ppd total manganese, 1,601 ppd total aluminum and 107 ppd total zinc.

Clearfield Creek

The northern one-third of Clearfield Creek is polluted by mine drainage from two large deep mine discharges, from Brookwood and Middle Penn #4 Mines, and several smaller discharges. Clearfield Creek contributed an average 57,000 ppd acid to the West Branch in 1973 (Skelly and Loy, Inc., 1973a). The Brookwood shaft discharges to Muddy Run, a tributary to Clearfield Creek, and severely degrades this reach. The Brookwood shaft discharged an average 17,000 ppd acid to Muddy Run. Middle Penn #4 Mine discharges to Japlin Run and directly to Clearfield Creek. The average acid load contributed by Middle Penn #4 Mine was 35,000 ppd. These two Mines accounted for 90% of the total acid load measured at the mouth of Clearfield Creek.

In 1984, mine drainage indicator loads at the mouth of Clearfield Creek during a high base-flow period were 1,262,805 ppd sulfates, 39,688 ppd total iron, 15,334 ppd total manganese, 2,074 ppd total aluminum and 992 ppd total zinc. In the same year during low base-flow sampling, the loads were 335,416 ppd sulfate, 1,068 ppd total iron, 4,596 ppd total manganese, 2,981 total aluminum and 186 ppd total zinc. In 1971, sampling during low base-flow indicated the pollutant loads at the mouth of Clearfield Creek were 237,654 ppd sulfates and 292 ppd total iron.

West Branch - Clearfield Creek to Moshannon Creek

The West Branch flows approximately 32 stream mi mostly east to northeast from Clearfield Creek to Moshannon Creek. Tributaries in this reach impacted by mine drainage, mostly from deep mine discharges with additional discharges from surface mines, contribute AMD to the West Branch. Tributaries in this reach that are affected by AMD include Abes Run, Lick Run, Trout Run, Millstone Run, Surveyor Run, Moravian Run, Deer Creek, Willholm Run, Sandy Creek, Alder Run, Mowery Run, Basin Run, Rock Run, Potter Run and Rupley Run.

In 1984, tributaries contributing mine drainage in this reach were sampled for pollutant loads discharged to the West Branch. Total loads of mine drainage indicators during low base-flow conditions were 155,252 ppd sulfates, 2,727 ppd total iron, 3,969 ppd total manganese, 2,761 ppd total aluminum and 219 ppd total zinc. During high base-flow, the cumulative loads discharged to this reach were 60,473 ppd sulfates, 868 ppd total iron, 1,646 ppd total manganese, 680 ppd total aluminum and 52 ppd total zinc.

Moshannon Creek

Moshannon Creek is impacted by mine drainage throughout most of its length. Nearly all tributaries to Moshannon Creek are acid and the creek contributed an average 130,000 ppd acid to the West Branch as determined by Skelly and Loy, Inc. (1973a) during an extensive sampling of mine drainage in the watershed. Moshannon Creeks acid load is primarily from deep mine sources. The largest deep mining complex discharges into all of Moshannon Creeks western tributaries from Hawk Run to Weber Run. The average acid load from this complex was 66,000 ppd.

Loading of mine drainage indicators in 1984 at the mouth of Moshannon Creek during high base-flow was 939,812 ppd sulfates, 28,194 ppd total iron, 13,784 ppd total manganese, 21,929 ppd total aluminum and 877 ppd total zinc. During low base-flow, water quality and flow data indicated loads of 373,332 ppd sulfates, 3,215 ppd total iron, 5,496 ppd total manganese, 25,926 ppd total aluminum and 290 ppd total zinc were discharged to the West Branch. Pollutant loadings recorded in 1971, with flow rates similar to the 1984 low base-flow, were 240,413 ppd sulfates and 52,412 ppd total iron.

West Branch - Moshannon Creek to Sinnemahoning Creek

Along this reach, limited strip mining has occurred on the southeast side of the West Branch relative to the northwest side. Tributaries impacted by AMD in this reach include Laurel Run and Sterling Run which enter the West Branch from the southwest and Mosquito Creek, Saltlick Run, Upper Three Runs, Lower Three Runs and Loop Run which enter the West Branch from the northwest. These tributaries have been extensively strip mined in their headwater areas. Saltlick and Loop Runs are the highest in acid concentrations as a result of their watersheds being enclosed by strip mining. Upper and Lower Three Runs and Mosquito Creek headwaters drain areas outside coal measures and provide alkalinity to neutralize acid discharges located lower in the their watersheds.

Cumulative loadings of AMD chemical constituents contributed by tributary streams in this reach during high flow conditions in 1984 were 160,113 ppd sulfates, 1,396 ppd total iron, 3,064 ppd total manganese, 1,973 ppd total aluminum and 244 ppd total zinc. Subsequent sampling in that year during low base-flow conditions indicated the pollutant loads were 94,003 ppd sulfates, 225 ppd total iron, 1,686 ppd total manganese, 643 ppd total aluminum and 75 ppd total zinc.

Sinnemahoning Creek

Bennett Branch, together with the Driftwood Branch, form the Sinnemahoning Creek. A comprehensive evaluation of mine drainage in the Bennett Branch subwatershed in 1973-1974 (Berger Associates, Inc., undated, b) determined a maximum acid load of over 163,000 ppd in Bennett Branch at the town of Driftwood and an average load of 68,000 ppd. At this same sampling point, the maximum total iron load was 8,000 ppd with an average of 700 ppd. Abandoned deep mines were the most significant source of mine drainage with coal mine refuse as the second worst source. Eleven of the major abandoned deep mines collectively produced half the acid loading downstream from the Village of Benezette. These combined mine discharges contributed an average 28,430 ppd acid and 5,121 ppd total iron to Bennett Branch.

Within the area of Bennett Branch, between Penfield and Driftwood, there are 11 tributaries that contribute acid. The tributaries and their average discharge loads of acid and total iron to Bennett Branch in 1973-1975 were:

Tributary	Acid (ppd)	Total Iron (ppd)
Moose Run	10,837	2,563
Mill Run	5,036	1,841
Tyler Reservoir Run	6,472	438
B&S Railroad Dike Run	232	420
Tyler Run	27,583	3,109
Cherry Run	2,539	356
Kersey Run	1,850	899
Dixon Run	19,432	2,587
Trout*		757
Mt. Pleasant Church Run	110	5
Dents Run	3,386	101

*Trout Run is an alkaline stream that has exhibited acidic characteristics at its mouth due to a 2-mi reach of mine drainage degradation.

The AMD discharged to Bennett Branch renders the reach between Moose Run and the confluence with Driftwood Branch acidic creating an acidic condition in the Sinnemahoning Creek downstream to its confluence with the West Branch.

Mine drainage indicator chemical constituents sampled at the mouth of Sinnemahoning Creek in 1984 during high flow indicated the watershed contributed 436,851 ppd sulfates, 5,825 ppd total iron, 2,730 ppd total manganese, 9,101 ppd total aluminum and 364 ppd total zinc. Loads discharged to the West Branch during low flow conditions were 87,602 ppd sulfates, 322 ppd total iron, 483 ppd total manganese, 179 ppd total aluminum and 36 ppd total zinc.

Sinnemahoning Creek to Bald Eagle Creek

Downstream from the confluence of Sinnemahoning Creek, the West Branch flows along the southeastern edge of the bituminous coal field. This area with coal deposits extends to the town of Renovo. Downstream from Renovo, the West Branch flows through areas which contain no coal formations until just southeast of the town of Glen Union at which point the river flows through small isolated coal measures. The West Branch, downstream from Tangascootac Creek, flows through an area devoid of coal measures down to Bald Eagle Creek.

The West Branch reach between Sinnemahoning Creek and Renovo receives mine drainage from several tributary streams. Kettle Creek is the largest tributary and the last significant source of AMD in the West Branch. Kettle Creek is impacted by mine drainage for about four miles upstream from its mouth. Deep mines are responsible for all the major AMD discharges into the creek's tributary streams. Huling Run, Two Mile Run, and Butler Hollow discharged 5,200, 6,000 and 750 ppd acid to Kettle Creek (Skelly and Loy, Inc., 1973b). At its mouth, Kettle Creek discharged 10,000 ppd acid during flow conditions of 83 cfs. Data collected during low base-flow (269 cfs) in 1984 indicated loads of 104,611 ppd sulfates, 3,487 ppd total iron, 2,179 ppd total manganese, 2,615 total aluminum and 131 ppd total zinc were discharged to the West Branch. During high flow (694 cfs), the pollution loads were 78,717 ppd sulfates, 2,474 ppd total iron, 1,012 ppd total manganese, 2,624 ppd total aluminum and 150 ppd total zinc.

Mine drainage in Cooks Run, the first tributary downstream from the mouth of Sinnemahoning Creek, originates from four deep mine discharges each contributing over 1,000 ppd acid to Crowley Hollow Run, a tributary of Cooks Run. The discharges emanate from a deep mine drift portal along Nefeur Hollow Run, and a mine seal and two deep mine drift entries on the west side of Crowley Hollow Run. Cooks Run discharged 9,936 ppd sulfates and 899 ppd total iron to the West Branch in 1971 during sampling when the flow was 16 cfs. In 1984, Cooks Run contributed 20,741 ppd sulfates, 959 ppd total iron, 239 ppd total manganese, 1,037 ppd total aluminum, and 29 ppd total zinc during a high base-flow (48 cfs) sampling event and 31,111 ppd sulfate, 1,225 ppd total iron, 408 ppd total manganese, 972 ppd total aluminum and 41 ppd total zinc during low flow (36 cfs).

Just west of Renovo, Drury Run confluences with the West Branch and is the last direct source of mine drainage. Drury Run originates at Tamarack Swamp in northeastern Clinton County and flows south-southeasterly for 7.7 mi to its confluence with the West Branch Susquehanna River at the Village of Drury Run. The area draining to the Drury Run reservoir, approximately 5 mi downstream of the Tamarack Swamp, consists of small hallows and the Sandy Run watershed. Downstream of the reservoir, two major drainage basins (Woodley Draft and Stoney Run) as well as small tributaries drain into the main stem of Drury Run. Sources of mine drainage in the watershed are underground mine discharges in Sandy Run, an upwelling mine discharge and an abandoned treatment pond discharge to Whiskey Run, Quinn Elk Mountain Mine, underground mine discharges to Slab Hollow, a coal stock area adjacent to Stony Run and the abandoned Quinn West Branch surface mine. In 1971, loadings of 4,720 ppd sulfates and 286 ppd total iron were measured during flow at 23.4 cfs (Gwin, Dobson and Foreman, 1972). A later sampling (1984) at the mouth of Drury Run indicated the pollutant loads were 18,181 ppd sulfates, 40 ppd total iron, 569 ppd total manganese, 422 ppd total aluminum and 28 ppd total zinc during a flow of 34 cfs and 29,167 ppd sulfates, 32 ppd total iron, 972 ppd total manganese, 567 ppd total aluminum and 36 ppd total zinc at a time when the flow was 30 cfs. Data collected in 1990 indicated the cumulative loads of AMD chemical constituents at the mouth of Drury Run were 11,314-13,772 ppd sulfates, 8-14 ppd total iron, 299-363 ppd total manganese, 257-282 ppd total aluminum, and 15-16 ppd total zinc during a flow range of 19.8-22 cfs (Renovo Borough, 1991).

Smaller tributaries (excluding Kettle Creek) between Sinnemahoning Creek and Renovo had combined loads of 138,243 ppd sulfates, 3,601 ppd total iron, 2,063 ppd total manganese, 4,741 ppd total aluminum and 396 ppd total zinc during high base-flow conditions in 1984. During low flow, the cumulative loads discharged by these tributaries were 244,769 ppd sulfates, 5,172 ppd total iron, 3,418 ppd total manganese, 3,985 ppd total aluminum and 1,064 ppd total zinc.

Tangascootack Creek joins the West Branch near the town of Farrandsville. The majority of the mine drainage in this watershed discharges directly to Tangascootack Creek. The largest deep mine complex in the watershed is the Scootack Mines. The overall water quality of Tangascootack Creek is generally of poor quality with increased acidity, manganese and sulfates from the deep mine complexes to the mouth. One of the tributaries, North Fork Tangascootack Creek, has excellent water quality and appears non-impacted by the AMD from active strip and abandoned deep and strip mines located along the Tangascootack Creek. An evaluation of the watershed in 1984 indicated the range of pollution loads in Tangascootack Creek, prior to the confluence with the North Fork Tangascootack Creek, were 4,407-17,618 ppd sulfates, undetectable-64 ppd total iron, 68-456 ppd total manganese and 19-242 ppd total aluminum during flows ranging from 5 to 39.3 cfs (Lloyd Wilson Chapter of Trout Unlimited, 1984).

Bald Eagle Creek

Bald Eagle Creek confluences with the West Branch just west of town of Lock Haven. Beech Creek is the only tributary to Bald Eagle Creek that is significantly impacted by mine drainage. Within the Beech Creek watershed, 184 AMD discharge points were identified. Most of the discharges (145) flowed to the North Fork of Beech Creek and its tributaries. Seventeen more discharges were located on the south side of Beech Creek between Kato Village and Logway Run. The remaining discharges were located throughout the watershed to Twin Run. No discharges were identified downstream from the Twin Run and Beech Creek confluence. Sixteen discharge points were adjacent to deep mine workings. Fifteen discharge points were from underground mine pools. Mine drainage from 134 strip mines drained through 168 discharge points. Refuse areas contributed AMD to numerous discharge points. Of the 184 discharge sites, 160 appeared to continuously discharge mine drainage. The major AMD loads in the watershed were from two tributaries, North Fork Beech Creek and Sandy Run. Smaller AMD contributions were from Logway Run and Big Run. Historical data indicate North Fork Beech Creek contributed 17,288 ppd sulfates and 1,488 ppd total iron when flow volume was 8.5 cfs (Gannett Fleming Corddry and Carpenter, Inc., 1970). Sandy Run discharged 26,090 ppd sulfates and 1,668 ppd total iron, during a flow rate of 10.1 cfs, to Beech Creek. The total loads to Beech Creek, including minor contributions from smaller tributaries, were 47,782 ppd sulfates and 3,223 ppd total iron.

Although Beech Creek is a major source of AMD pollution reaching Bald Eagle Creek, all acidity is neutralized within a short distance downstream from their confluence. Bald Eagle Creek contains negligible concentrations of iron and has little or no evidence of AMD drainage at its confluence with the West Branch Susquehanna River.

West Branch - Bald Eagle Creek to Susquehanna River

The water quality of the West Branch significantly improves in this reach. The alkalinity introduced by Bald Eagle Creek neutralizes all the acid under normal flow conditions. Exceptions are periods of unusually high flow when acid slugs or plumes from sources upriver are introduced. Although the West Branch does not flow through an area underlain by coal deposits within this reach, two tributaries (Pine Creek and Loyalsock Creek) that drain areas containing coal measures do contribute mine drainage downstream from the mouth of Bald Eagle Creek.

Pine Creek is affected by two coal fields that are extensions of the main bituminous field. The northern most coal field is drained by Babb Creek, a tributary to Pine Creek, and its tributaries. Babb Creek is impacted by AMD discharged to three major tributaries, Wilson Creek, Lick Creek and Stony Fork Creek. The downstream waters of Wilson Creek and upstream waters of Babb Creek are impacted by mine drainage primarily from deep mine discharges. Wilson Creek between the towns of Antrim and Morris receives the most significant portion of mine drainage in the watershed. Within this reach, two mining complexes contribute greater than 60% of the mine drainage. The Antrim mining complex in 1975-1976 contributed an average 4,499 ppd acid, 10,350 ppd sulfates and 186 ppd total iron with a flow of 4.28 cfs and the Anna S mining complex contributed 2,713 ppd acid, 4,232 ppd sulfates and 226 ppd total iron with a flow rate of 1.97 cfs (Boyer Kantz and Associates, 1976). The Rattler Mine is the only significant source of AMD flowing into Stony Creek via Paint Run. Mine drainage is discharged to Paint Run from three major sources of the underground mine. These sources discharged an average 1,313 ppd acid, 1,460 ppd sulfate, and 257 ppd total iron with an average flow of 0.3 cfs. The acid discharged from Rattler Mine is neutralized by alkaline reserves in Stony Run and therefore does not impact Babb Creek. Two additional mining complexes contribute significantly to the discharge of AMD in the Wilson Creek watershed. The Klondike mining complex discharges to Red Run, a tributary to Lick Creek, from two major sources. The average combined flow from the two sources was 1.04 cfs with a pollutant load of 687 ppd acid, 1,535 ppd sulfate and 40 ppd total iron. The Bear Run mining complex is situated 0.5 miles west of the Babb Creek and Lick Creek confluence. Four major sources of AMD impacting Babb Creek are located along the southeastern portion of the mining complex. The combined load from these four sources discharged to Babb Creek was 1,386 ppd acid, 1,942 ppd sulfate and 99 ppd total iron with a flow of 1.20 cfs. The net contribution of all AMD discharges in the Babb Creek watershed in 1975-1976 was measured at the mouth of Babb Creek. The average mine drainage indicator loads were 10,364 ppd acid, 113,497 ppd sulfate and 288 ppd total iron with an average stream flow of 191.7 cfs.

The southern most coal field in the Pine Creek watershed is drained by Little Pine Creek. Two tributaries to Little Pine Creek, Otter and English runs, are affected by mine drainage emanating from abandoned deep mines. Within the English Run watershed, Shingle Mill Branch is impacted by mine drainage discharged from five abandoned drift mines. Pine Run, the major tributary to English Run, is affected by 12 drift mine discharges. An extensive AMD study conducted by English Engineering Corporation (1971) indicated the mine drainage pollution load near the mouth of English Run was an average 4,997 ppd sulfate and 46 ppd total iron. Otter Run water quality is degraded by AMD discharged to its major tributary, Buckeye Run. Buckeye Run drains the central portion of the Little Pine Creek coal deposits and is bounded on both sides by drift mines and surface mines. The net contribution of mine drainage in Otter Run was determined from samples collected at the mouth. Average loads of 14,385 ppd sulfate and 123 ppd total iron were discharged to Little Pine Creek from Otter Run during the year of the study (1970-1971).

Loyalsock Creek is the farthest downstream tributary of the West Branch that drains an area underlain by coal measures. Two drainage tunnels from the abandoned Connell Deep Mine Complex are the primary sources of AMD in Loyalsock Creek. The C Vein Connell Tunnel contributed an average 528 ppd acid, 1,082 ppd sulfate, and 12 ppd total iron during an average flow of 6.41 cfs (Bellante, Clauss, Miller and Nolan, Inc., undated). The B Vein Connell Tunnel drainage, the larger of the two discharges, average flow was 6.51 cfs and contributed 1,224 ppd acid, 3,326 ppd sulfate and 23 ppd total iron to the Loyalsock Creek. Water quality is affected by these AMD discharges in the reach between the towns of Lopez to Forksville because of low alkaline reserves in this part of the watershed. In-stream water quality and flow measurements recorded downstream from the AMD pollution sources in the watershed indicated a net loading affect averaged 1,595 ppd acid, 14,999 ppd sulfates and 450 ppd total iron. Water quality improves downstream of the confluence with Little Loyalsock Creek which contributes alkalinity.

Summary of Mine Drainage Loads in the Bituminous Coal Fields-West Branch Susquehanna River

Estimates of the cumulative mine drainage chemical constituent loads from the bituminous coal fields drained by the West Branch Susquehanna River and its tributaries are presented in Table 3. Impacted tributaries contributing the greatest mine drainage loads are Anderson Creek, Clearfield Creek, Moshannon Creek, Sinnemahoning Creek, Kettle Creek and Pine Creek. Natural alkaline reserves in the West Branch watershed downstream from Bald Eagle Creek are capable of neutralizing acid contributed by upstream tributaries, therefore acid loading was not considered in the cumulative loading. It should be noted that during unusually high flow conditions subsequent to excessive rain events in the bituminous coal fields natural alkalinity reserves may not be sufficient to neutralize all the acid in the West Branch. .

Estimated loads are based on net cumulative loads calculated from in-stream measurements during low and high flow conditions at the mouth of tributaries impacted by mine drainage. Additional data from in-stream water quality measurements from the Pennsylvania Stream Monitoring Network and Operation Scarlift reports were used in calculating cumulative loads in the West Branch watershed. The ranges in the loads of mine drainage indicators during low to high flow conditions from Anderson Creek to Brewery Run were 1,367,478-3,561,572 ppd sulfate, 12,549-88,394 ppd total iron, 21,936-53,614 ppd manganese, 37,967-70,590 ppd aluminum, and 1,040-4,087 ppd zinc. In addition to those ranges, added contributions of average

Table 3. Summary of cumulative acid mine drainage chemical constituent loads in the West Branch Susquehanna River tributaries draining the bituminous coal fields in Pennsylvania. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow.

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum	Zinc
Headwaters Area	1971	129	Year Avg.	159,447	400			
Bakerton to Bower (in-stream at Bower)								
Anderson Creek	1973-1974	78.4	Year Avg.	23,559	365			
	May 1984	247	High	76,044	1,267	1,601	1,601	107
	July 1984	48	Low	22,555	75	544	467	31
Tributaries between Anderson Creek and Clearfield Creek	May 1984	359	High	155,252	2,727	3,969	2,761	219
	July 1984	27	Low	60,473	868	1,646	680	52
Clearfield Creek	1971			237,654	292			
	May 1984	1,670	High	1,262,805	39,688	15,334	20,746	992
	July 1984	230	Low	33,542	1,068	4,596	2,981	186
Tributaries between Clearfield Cr. and Moshannon Cr.	May 1984	598	High	472,096	7,058	12,671	9,418	1,005
	July 1984	104	Low	237,810	2,009	4,551	3,290	176
Moshannon Creek	1971			240,413	52,412			
	May 1984	1,160	High	939,812	28,194	13,784	21,929	877
	July 1984	192	Low	373,332	3,215	5,496	25,926	290
Tributaries between Moshannon Cr. and Sinnemahoning Cr.	May 1984	430	High	160,113	1,396	3,064	1,973	244
	July 1984	69	Low	94,003	225	1,686	643	75
Sinnemahoning Creek	May 1984	3,370	High	436,851	5,825	2,730	9,109	364
	July 1984	331	Low	87,602	322	483	179	36

Table 3 (continued). Summary of cumulative acid mine drainage chemical constituent loads in the West Branch Susquehanna River tributaries draining the bituminous coal fields in Pennsylvania. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow.

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum	Zinc
Cooks Run	1971	16	Year Avg.	9,936	899			
	May 1984	48	High	20,741	959	239	1,037	29
	July 1984	36	Low	31,111	1,225	408	972	41
Kettle Creek	May 1984	694	High	78,717	2,474	1,012	2,624	150
	July 1984	269	Low	104,611	3,487	2,179	2,615	131
Drury Run	1971	23.4	Year Avg.	4,720	286			
	May 1984	34	High	18,181	40	569	422	28
	July 1984	30	Low	29,167	32	972	567	36
	1990	21	Year Avg.	12,543	11	331	270	15.5
Tangascootac Creek	1984	22	Year Avg.	11,012	32	262	131	
Pine Creek (Contribution from Babb Creek)	1975-1976	192	Year Avg.	113,497	288			
(Contribution from Little Pine Creek)	1970-1971		Year Avg.	19,382	169			
Loyalsock Creek (in-stream downstream	1975		Year Avg.	14,999	450			
from all AMD sources)								
Tioga River (in-stream near Tioga Junction)	1992	444	Year Avg.	92,785	547	1,224	598	101
	1994	544	Year Avg.	97,649	1,516	1,913	1,958	181

in-stream loads of 159,447 ppd sulfates and 400 ppd iron were contributed in the West Branch headwater area; 14,999 ppd sulfates and 450 ppd were contributed from the Loyalsock Creek downstream from all AMD sources; 11,012 ppd sulfate, 32 ppd iron, 262 ppd manganese and 131 ppd aluminum were contributed by Tangascootac Creek; and 132,879 ppd sulfate and 457 ppd iron were contributed by Pine Creek from its acid impacted tributaries, Babb Creek and Little Pine Creek.

Bituminous Coal Fields - North Branch Potomac River Drainage

Northwest Allegany County and Lower Georges Creek Complex

The Complex extends from the Pennsylvania-Maryland border, between Big Savage Mountain and Dans and Piney mountains southwesterly to Westernport, MD. Almost the entire Complex is underlain by bituminous coal reserves. The complex is drained by Georges Creek, Jennings Run and Braddock Run. All three streams are tributary to the North Branch of the Potomac River. A comprehensive mine drainage study conducted by Green Associates, Inc. and Gannett Fleming Corddry and Carpenter, Inc. (1974) identified 360 mine drainage discharges in the Complex in 1972-1973. Georges Creek watershed contained 290 discharge points while Jennings Run and Braddock Run accounted for 64 and 6 discharges, respectively. A total of 235 discharge points appeared to discharge continuously; the others were intermittent. Of the 360 Complex mine drainage discharge points, 157 did not appear to contribute significantly to pollution. During average groundwater conditions, these 157 discharges contributed a combined 69 ppd total iron with a discharge flow of 13.5 cfs, representing 1.7% and 23%, respectively, of the total iron load and flow of all 360 discharge points. Also, 133 of the 157 were alkaline or had no flow. The remaining 24 discharges contributed 42.6 ppd of acid, or about 0.1% of the entire load. In total, 203 discharges were considered to have a significant impact on stream water quality. These significant discharges had a combined flow during average groundwater conditions of 44.4 cfs with corresponding loads of 39,000 ppd acid and 3,900 ppd total iron. Based on sampling during low, average and high groundwater levels over the course of the one-year evaluation, the combined mine drainage flows ranged from 19.6-95.9 cfs. The loads of mine drainage indicators associated with the discharges were 14,280-45,400 ppd acid during low and high flow conditions and 39,000 ppd acid during average flow. During low and high flow, the combined total iron load ranged from 1,676 ppd-4,700 ppd and contributed 3,960 ppd total iron during average discharge flow conditions.

Sixty-four mine drainage discharge sites were identified in Jennings Run. The combined average flow rate and loads contributed during low ground water conditions were 1.83 cfs and 1,692 ppd acid and 141 ppd total iron. During high groundwater conditions, the combined average flow rate was 8.4 cfs with associated loads of 5,428 ppd acid and 310 ppd total iron. During average groundwater conditions, the flow rate of all mine drainage discharges was 5.5 cfs which contributed 4,438 ppd acid and 260 ppd total iron to Jennings Run.

Braddock Run had far fewer discharges with only six identified. However, the largest single source of mine drainage in the Complex, the Hoffman Drainage Tunnel, is located in this watershed. The Hoffman Drainage Tunnel had a flow rate of 10.9-44.4 cfs during low and high groundwater conditions and discharged 583-1,700 ppd total iron. During average groundwater conditions the flow rate was 24.8 cfs and contributed 1,320 ppd total iron to Braddock Run. Although it is the largest discharge, there is no acid contribution from the Hoffman Tunnel. The combined discharges in Braddock Run had flow rates of 11-44.8 cfs and acid and total iron loads of 174-634 ppd and 614-1,773 ppd, respectively, during low and high groundwater levels. During average groundwater conditions, the combined discharge flow rate was 24.9 cfs with an acid load of 433 ppd and a total iron load of 1,381 ppd.

Georges Creek watershed contained 290 mine drainage sources. During low groundwater conditions, the combined sources contributed 12,409 ppd acid and 921 ppd total iron at which time the average flow rate was 6.83 cfs. Samples collected during average groundwater conditions indicated the combined mine drainage flow rate was 27.36 cfs and contributed 34,143 ppd acid and 2,329 ppd total iron. During high flow conditions, the average rate was 42.78 cfs and 39,415 ppd acid and 2,618 ppd total iron were contributed to Georges Creek.

In-stream measurements of acidity, sulfate, total iron, manganese and aluminum provided information regarding the water quality and cumulative pollution loads from all sources in Jennings Run, Braddock Run and Georges Creek. In Georges Creek, samples obtained near the mouth downstream from all mine discharges but upstream from Westernport indicated the cumulative flow during average groundwater conditions was 95.5 cfs. The cumulative loads of mine drainage indicators associated with this flow were 22,699 ppd acid, 143,913 ppd sulfate, 1,444 ppd total iron, 1,135 ppd total manganese and 1,702 ppd total aluminum. In Jennings Run, the flow during average groundwater conditions at a site downstream from the mine discharges was 42.7 cfs and had associated loads of 692 ppd acid, 28,137 ppd sulfate, 115 ppd total iron, 46 ppd total manganese and 185 ppd total aluminum. The average flow in Braddock Run, downstream from the identified sources of mine drainage, was 34.4 cfs with pollution loads of 372 ppd acid, 54,254 ppd sulfate, 650 ppd total iron, 372 ppd total manganese and 112 ppd total aluminum.

In July 1990 through August 1991, Pegg (1995) monitored biological and chemical parameters in Mill Run (Georges Creek tributary) and its headwater tributary, Michaels Run, to evaluate impacts from mine drainage. Michaels Run was severely impacted by mine drainage from an abandoned deep mine. The combined total iron load contributed by the mine drainage averaged 8.56 ppd which accounted for 10.6% of the total iron load in Michaels Run. In addition to iron, Michaels Run discharged an average 0.77 ppd total manganese and 6.6 ppd total aluminum to Mill Run. Four major sources of AMD were identified in Mill Creek with two of them severely impacting the lower segment of Mill Run to its confluence with Georges Creek. Downstream from the confluence, the discharge from Mill Run had increased the total iron (88%) and total aluminum (28%) in the mainstream of Georges Creek. Mill Creek did not contribute any acid to Georges Creek, but did lower the alkalinity (12%). The major AMD sources contributed an average 1.2 cfs to the discharge of Mill Run. The cumulative manganese and aluminum loading from the four AMD discharges in Mill Creek was 20.8 ppd and 64.3 ppd, respectively. The net loads of AMD chemical constituents were monitored near the mouth of Georges Creek near Westernport from in-stream measurements. The pH values ranged from 7.07-7.66, indicating slightly alkaline buffered water. The ranges in the metals loads were 316-

1,157 ppd total iron, 348-1,008 ppd total manganese and 266-1,135 ppd total aluminum based on an average discharge of 70 cfs during three samplings in 1990-1991.

In another recent study of mine drainage impacts in the Georges Creek watershed, Pegg (undated) identified ten tributary or seep sources of AMD as well as an alkaline discharge from a deep mine as contributing to the chemical pollution from mine drainage. Samples collected monthly from November 1988 to November 1989 near the mouth of Georges Creek indicated that the pollution loads from all sources in the Georges Creek watershed upstream from Westernport averaged 8,350 ppd acid, 161,754 ppd sulfate, 1,011 ppd total iron, 847 ppd total manganese and 1,065 ppd total aluminum with an average flow of 96.9 cfs. Samples were analyzed less frequently for an additional suite of metals during the mine drainage study. Data from six sampling events indicated the loads associated with the additional metals analyzed averaged 10.6 ppd total chromium, 15.6 ppd total copper, 29.8 ppd total lead 46.4 ppd total nickel and 76.8 ppd total zinc during an averaged flow rate of 110.8 cfs.

North Branch Potomac River Watersheds - Upstream from Jennings Randolph Lake

Using water quality sampling data and simulated flows of 70 subwatersheds of the North Branch Potomac River upstream from the Randolph Jennings Lake, Morgan Mining and Environmental Consultants (1994) determined the contribution of each subwatershed to the total acidity, sulfates, iron, manganese and aluminum in the region. Under low flow conditions, the cumulative acid loading was 11,306 ppd with Laurel Run, Three Forks Run, Abram Creek, Kitzmiller discharges and Shallmar discharges as the major contributors (94% of total acid load). Subwatersheds in Maryland accounted for 8,445 ppd total acid loading while West Virginia subwatersheds contributed 2,862 ppd.

The total iron loading for all subwatersheds was 550 ppd with 454 ppd contributed by Maryland subwatersheds and 96 ppd contributed by West Virginia subwatersheds. The major sources of total iron loading were identified as Laurel Run, Three Forks Run, Kitzmiller discharge, Deakin Run, Shields Run and Glade Run (83% of total contribution).

The total contribution of manganese loading during low flow conditions was 678 ppd with 139 ppd and 539 ppd attributed to subwatersheds in Maryland and West Virginia, respectively. The major sources of manganese loading were Abram Creek and Laurel Run which accounted for 81% of the total.

Total aluminum loading for the study area was 1,370 ppd with subwatersheds in Maryland contributing 908 ppd and subwatersheds in West Virginia contributing 461 ppd. The subwatersheds that contributed the largest total aluminum loads (87%) were Abram Creek, Laurel Run, Three Forks Run, one Kitzmiller discharge and two Shallmar discharges.

The cumulative sulfate load for the study area was 93,352 ppd with 31,910 ppd from subwatersheds in Maryland and 61,442 ppd from subwatersheds in West Virginia. The greatest sources of total sulfate loading were Abram Creek, Stony River, Deakin Run, Sand Run, Three Forks Run, Howell Run, Laurel Run and Buffalo Run which combined for 77% of the entire study area load.

Water quality data collected during high flow conditions indicated that the combined loading of AMD indicators for the entire study area were 34,999 ppd acid, 3,472 ppd total iron, 2,474 ppd total manganese, 5,226 ppd total aluminum and 412,115 ppd sulfates. The acid contribution from Maryland and West Virginia subwatersheds were 18,664 ppd and 16,335 ppd, respectively. The major sources of acid loading were Abram Creek, Laurel Run, Three Forks Run, two Kitzmiller discharges, Stony River, an unnamed West Virginia tributary and Lostland Run. These eight sources contributed 91% of the entire acid load.

Maryland subwatersheds contributed 2,022 ppd total iron and West Virginia subwatersheds discharged 1,450 ppd iron to the study area. The subwatersheds identified as contributing the most iron were Three Forks Run, Abram Creek, Laurel Run, Stony River, an unnamed West Virginia tributary, Nydegger Run, Deakin Run and Buffalo Creek.

The total manganese load in discharged by Maryland subwatersheds only 450 ppd while West Virginia subwatersheds contributed 2,024 ppd. Four subwatersheds that discharged the most total manganese were Abram Creek, Stony River, Laurel Run and an unnamed West Virginia tributary.

Of the total aluminum loading for the entire area, 2,065 ppd were contributed by Maryland subwatersheds while West Virginia subwatersheds discharged 3,161 ppd. Abram Creek, Laurel Run, Three Forks Run, two Kitzmiller discharges, Stony River and an unnamed West Virginia tributary were major contributors of total aluminum accounting for 80% of the entire load.

Maryland and West Virginia subwatersheds contributed 126,974 ppd and 285,141 ppd sulfates, respectively, with the most substantial contributions from Abram Creek, Stony River, Deakin Run, Sand Run, Lostland Run and Three Forks Run accounting for 74% of the entire loading during high flow conditions.

Many of the mine drainage sources identified in the study contributed to the cumulative loading of AMD indicators in the North Branch Potomac River study area; however, the main load-producing subwatersheds were Laurel Run, Stony River, Abram Creek, Three Forks Run, and the Kitzmiller and Shallmar direct discharges.

Laurel Run is impacted by continuous discharge through two abandoned shafts from the Kempton Mine. During low and high flow conditions, estimated at 7 and 22.9 cfs, respectively, Laurel Run contributed 2,925-6,433 ppd acid, 146-505 ppd total iron, 72-131 ppd total manganese, 290-552 ppd total aluminum and 3,077-11,382 ppd sulfates.

The Stony River discharge was estimated as 6.5 and 234.3 cfs during low and high flow conditions, respectively. The pollutant loads associated with these flows were 139-2,528 ppd acid, 4-253 ppd total iron, 14-253 ppd total manganese, 5-367 ppd total aluminum and 12,324-78,365 ppd sulfates. An alkaline discharge from a power plant located on the west shore of Mount Storm Lake neutralizes acidity in Stony River to some degree.

Abram Creek is the largest subwatershed and has the highest density of abandoned mines and AMD discharges in the study area. During low and high flow conditions, estimated as 14.1 and

197.3 cfs, respectively, the AMD indicator loads were 2,357-10,645 ppd acid, 5-511 ppd total iron, 471-1,512 ppd total manganese, 383-2,086 ppd total aluminum and 28,203-100,063 ppd sulfates.

The Shallmar discharges originate from an underground mine situated about 0.5 mi west of the town of Kitzmiller, MD. Discharges emanating from the mine during low and high flow conditions contributed 441-1,319 ppd acid, 10-21 ppd total iron, 2-10 ppd total manganese, 54-161 ppd total aluminum, and 1,161-4,348 ppd sulfates to the North Branch Potomac watershed. It should be noted that during high flow sampling at the Shallmar discharges only one station was sampled.

The Kitzmiller direct discharges emanate from an underground mine located north of the town of Kitzmiller. Mine drainage is discharged through several mine entries and contributes during low and high flow 1,418-4,777 ppd acid, 67-269 ppd total iron, 6-18 ppd total manganese, 149-532 ppd total aluminum and 2,537-10,900 ppd sulfates to the watershed.

Both the left and right prongs of Three Forks Run are impacted by underground mine drainage. Mine discharges in this subwatershed form a substantial portion of the base flow of Three Forks Run. Pollution loads associated with low and high flows (estimated as 2.2 and 30.6 cfs, respectively) were 2,632-4,454 ppd acid, 143-566 ppd total iron, 20-51 ppd total manganese, 247-401 ppd total aluminum and 5,435-14,187 ppd sulfates.

Summary of Mine Drainage Loads in the Bituminous Coal Fields - North Branch Potomac River

Estimated cumulative loads of mine drainage chemical constituents were derived from recent comprehensive studies of the tributary subwatersheds to the North Branch Potomac River upstream from Jennings Randolph Lake and Georges Creek watersheds as well as data from an earlier investigation of Georges Creek watershed and northwest Allegany County (Table 4). During low flow conditions, the combined mine drainage indicator loads from 54 sources throughout 70 subwatersheds sampled upstream from Jennings Randolph Lake were 93,352 ppd sulfates, 550 ppd total iron, 678 ppd manganese and 1,370 ppd aluminum. During high flow conditions, the cumulative loads were 412,115 ppd sulfates, 3,472 ppd total iron, 2,474 ppd manganese and 5,226 ppd aluminum.

The estimated average cumulative loading of mine drainage indicators in Georges Creek Complex, based on in-stream measurements near the confluence with the North Branch, were 161,754 ppd sulfates, 1,011 ppd total iron, 847 ppd manganese, 1,065 ppd aluminum and 111 ppd zinc. The average cumulative mine drainage constituent loads contributed by Braddock Run was 54,254 ppd sulfates, 650 ppd total iron, 372 ppd manganese and 112 ppd aluminum. Average cumulative loads contributed by Jennings Run were 28,137 ppd sulfates, 115 ppd total iron, 46 ppd manganese and 185 ppd aluminum. The loads contributed by Braddock Run and Jennings Run were determined from in-stream measurements near their confluences with Wills Creek.

Table 4. Summary of cumulative acid mine drainage chemical constituent loads in the North Branch Potomac River tributaries draining the bituminous coal fields in Maryland and West Virginia. Loads are estimated as pounds per day (ppd) based on chemical concentration and flow (cfs).

Tributary	Date	Flow	Condition	Sulfates	Iron	Manganese	Aluminum	Zinc
Georges Creek	1972-1973	95.5	Year Avg.	143,913	1,444	1,135	1,702	
	1990-1991	96.9	Year Avg.	161,754	1,011	847	1,065	111
Braddock Run	1972-1973	34.4	Year Avg.	54,254	650	372	112	
Jennings Run	1972-1973	42.7	Year Avg.	28,137	115	46	185	
North Branch upstream from Jennings	1988-1989	73.1	Low	93,352	550	678	1,370	
Randolph Lake	1988-1989	974.3	High	412,115	3,472	2,474	5,226	

METHODS FOR CONTROLLING, REDUCING OR ELIMINATING THE LOADINGS OF CONTAMINANTS FROM ACID MINE DRAINAGE

Programs for Addressing Acid Mine Drainage Pollution

In 1967, a $500 million Land and Water Conservation and Reclamation Fund was created for prevention, control, and elimination of stream pollution from abandoned mining areas by construction of AMD treatment plants, reclamation of strip mined areas, sealing of deep mines, and other available measures. A series of evaluations conducted in the early to middle 1970s to determine the extent of AMD problems in Pennsylvania streams with proposed abatement measures resulted in the Operation Scarlift reports. For the period ending January 1990, 553 contracts with a total cost of about $78 million in 35 counties were initiated for AMD abatement (Frey, Kime and Spandenberg, 1996). In 1970 the State of Maryland enacted the Abandoned Mine Drainage Act. The Maryland General Assembly authorized $5 million to be expended to prevent, control and abate pollution from abandoned mines and to acquire land occupied or degraded by abandoned mines. Implementation of the Act resulted in the comprehensive investigation of mine drainage in the Northwest Allegany County and Lower Georges Creek Complex.

On February 9, 1995 the Office of Surface Mining (OSM) and the U.S. Environmental Protection Agency (EPA) signed an agreement for cooperative efforts to address water quality problems associated with AMD in Maryland, Ohio, Pennsylvania and West Virginia. The Statement of Mutual Intent and its Strategic plan are the results of the agreement of cooperation between the OSM's Appalachian Clean Streams Initiative and the EPA's Mine Drainage Initiative to clean up streams impacted by AMD. In addition to the OSM and EPA, other federal and state environmental agencies and local watershed associations have joined as signatories to the Statement of Mutual Intent. The Strategic Plan provides a framework for all signatories to collectively direct attention to the AMD problem and encourage clean up efforts. The objectives are summarized as follows:

- Cooperate to share and exchange data and information related to identifying mine drainage sites and establish abatement technologies to improve water quality in AMD impacted watersheds.

- Increase the level of awareness among government agencies, private organizations and the general public on environmental problems associated with AMD.

- Work with government agencies, watershed organizations, mining organizations and environmental groups to focus efforts on watersheds degraded by AMD.

- Increase knowledge and application of best available technologies for remediating and preventing AMD and support development of new technology.

- Support efforts to establish a remining program for reclaiming abandoned mines.

- Periodically report the extent and severity of AMD problems and the status of efforts to improve and restore impacted watersheds

Pennsylvania receives about $19 million annually from the Federal Office of Surface Mining (OSM) to correct abandoned mine problems. By law, these funds must be applied to correct abandoned mine problems associated with health and safety and generally be used for any sites mined after 1977. However, an amendment to the Federal Surface Mining Conservation and Reclamation Act allows 10% of the annual Abandoned Mine Land grants to be used for AMD abatement. As of September 1995, Pennsylvania had $7.8 million for addressing AMD problems. It is estimated that clean up of all AMD problems in Pennsylvania will cost approximately $5 billion.

In West Virginia, the governor's Stream Restoration Program is targeted at controlling AMD from abandoned sites. This program, initiated in 1992, directs funds for limestone treatment of AMD impacted streams. This effort, funded mostly by the state's Abandoned Mine Lands Program, has led to improvements in water quality in streams such as the Middle Fork and Blackwater Rivers (Ohio River Drainage)

In 1979, coal mine problems in Maryland were inventoried by the Natural Resources Conservation Service (formerly known as the US Department of Agriculture's Soil Conservation Service) and approximately 450 abandoned mine sites were identified with an estimated reclamation/abatement cost of $100 million. The goal of Maryland Abandoned Mine Reclamation Program of the Department of the Environment's Bureau of Mines is to promote reclamation of all abandoned mine sites that endanger the health or safety of the public or adversely impact the quality of the environment. In addition to the federal funds provided through the Federal Surface Mining Control Act of 1977, the Maryland Department of the Environment's Bureau of Mines administers State special funds from the Bituminous Coal Open-Pit Mining Reclamation Fund and the Deep Mining Fund. Maryland's Abandoned Mine Reclamation Program has reclaimed 1180 acres at a cost of $13.66 million. In most of the reclamation projects, mine drainage was improved or controlled through abatement measures.

Abatement Measures for Mitigating the Effects of Mine Drainage

Measures utilized for mitigating the adverse impact of mine drainage include treatment of AMD discharges and affected streams, reclamation of abandoned mine lands, regrading and revegetation of mine refuse piles, and sealing of abandoned mines. Treatment of AMD by the addition of an acid neutralizing agent (e.g., lime) increases pH and alkalinity, reduces acidity, and precipitates iron and other metals for subsequent removal. Remediation and mitigation techniques which show the greatest potential for success include fly ash injection, constructed wetlands and anoxic limestone drains. Fly ash injection is an emerging technology designed to prevent AMD from forming. Fly ash in the form of pressurized grout is injected into mine spoils to encapsulate the iron pyrite-rich material and effectively isolates potential AMD-forming material from oxygen and water infiltration to prevent the formation of AMD. Fly ash injection methods have been initiated at Bark Camp abandoned mining site along Bark Camp Run, a tributary to Bennetts Branch of Sinnemahoning Creek (West Branch Susquehanna River Basin).

In addition to surface injections, the use of fly ash injection into deep mines is also being investigated as a method to displace acidic mine water and abate the discharge. Anoxic limestone drains are a form of passive treatment in which acid discharge water is diverted into a trench that has been filled with limestone and covered with plastic or clay to prevent the infiltration of oxygen. The limestone dissolves, adding alkalinity and raising the pH of the discharge water. In-stream treatment for neutralizing AMD is accomplished by continuous or pulsed discharges of lime from a doser to an impacted stream. Actively dosing with lime has increased pH in impacted streams for miles downstream of the liming device.

Constructed wetlands have been evaluated for use in AMD abatement (Dietz and Stidinger, 1993). Monitoring of three wetland treatment sites, Canoe Creek, Jennings Environmental Education Center and Cucumber Run, has indicated that the wetland systems improved mine drainage water quality. Iron concentrations were reduced by all wetland treatment systems, with removal ranging from 50% to 90% of influent concentrations. The wetland systems reduced average acidity of AMD by greater than 40%. The benefits of wetlands were initially observed at naturally-occurring wetland sites that were receiving AMD. A naturally-occurring peat wetland was effective at removing metals from AMD. Iron and aluminum were concentrated in the wetland as organically bound and oxide precipitates. Sulfur had also accumulated in the peat. Suspected mechanisms of iron removal by wetland systems include plant uptake, microbial oxidation and precipitation, absorption by organic deposits, and sulfide precipitation.

A measure for preventing future AMD pollution involves the permitting programs for active mining. Permitting programs are concentrating on improving methods of predicting AMD, and in special mining techniques. One of the most useful predictive methods is acid-base accounting. The accounting method analyzes the potential for AMD production by evaluating the overburden material (above the coal which is to be removed) and the likelihood of acidic or alkaline discharge following removal of the coal. Acid-base accounting can identify sites that will clearly produce acidic or alkaline drainage; however, many sites are not clearly identified as acidic or alkaline. These sites that fall between the two extremes require special handling to prevent future AMD pollution. Two methods commonly utilized involve segregation of the overburden strata and its placement above the post mining watertable. One of the methods involves the subsequent placement of a clay cap over the material to reduce groundwater infiltration and contact with the material. The other method uses alkaline material as a cover to neutralize or inhibit acid formation. Permit applicants must demonstrate that the chances of successful AMD prevention greatly outweigh the risk of failure.

Additional methods currently being evaluated for abating AMD include the use of anhydrous ammonia as a treatment chemical, paper mill waste material to create artificial soils for land reclamation, and deep mine aeration. Soil consisting of paper mill waste has been used to provide cover for back-filled surface mines and is performing better than natural soils. A deep mine aeration project was initiated on the Brinkerton site on Sewickley Creek in Westmoreland County (Ohio River drainage). The proposed treatment system uses a compressor and static mixer in combination as a mechanical aerator to precipitate iron hydroxide sludge within the mine prior to discharge to surface waters. This treatment method is expected to remove 99% of the dissolved iron from the mine discharge. Due to the low operating and maintenance costs, the system is expected to be a long-term operation funded with the assistance of non-profit organizations.

Remediation Efforts

Nonpoint source coal mine drainage projects have been initiated with funding grants provided through Section 319(h) of the Clean Water Act enacted by Congress in 1987. Section 319 provides for EPA to award grants to states to assist them in implementing programs addressing nonpoint source pollution problems. State governments have taken the lead in identifying, planning and completing projects to eliminate AMD and improve watersheds. The projects undertaken include reclaiming abandoned surface mines, sealing underground mines, construction and operation of treatment plants, design and construction of passive treatment systems, removing or reclaiming coal cleaning refuse piles and providing technical assistance to local watershed groups. As of 1995 (USEPA, 1995), 25 state AMD remediation projects were in the development, design, construction or completion stage in Pennsylvania. Six of those 25 remediation projects are located in the Chesapeake Bay drainage. The projects and corresponding watersheds are as follows:

Project	Watershed
Rocky Ridge	Roaring Run/Sideling/Juniata River
Brookwood Shaft	Whiteside Run/Moshannon Cr./W. Br. Susquehanna R.
Babb Creek	Babb Cr./Pine Cr./W. Br. Susquehanna R.
Rausch Creek	Rausch Cr./Pine Cr./Mahantango Cr./Susquehanna R.
Aylesworth Creek	Aylesworth Cr./Lackawanna R./Susquehanna R.
Lackawanna River	Lackawanna R.

The Pennsylvania Department of Environmental Protection has undertaken reclamation of abandoned mine sites to reduce or eliminate impacts of abandoned sites on the environment. Due to long-term treatment, low cost and low maintenance, DEP has identified wetland treatment as the most appropriate treatment to reduce the impact of AMD on surface waters. Wetlands are most effective on small flows and seepages and are currently utilized in combination with anoxic limestone drains to treat discharges from active mining sites.

A funding grant has been awarded for the construction of limestone drains designed to increase pH and remove dissolved metals from acid discharges from abandoned deep mines in the headwaters of Swatara Creek (Susquehanna River Basin). The goal of the project is to evaluate the performance of anoxic limestone drains under field conditions for neutralizing acid conditions and precipitating metals for removal from the acid discharges.

Twenty-three AMD remediation projects are also in various stages of development in West Virginia, Maryland and Virginia. Of the 23 projects, 4 are located in the Chesapeake Bay drainage.

Project	Watershed
Bismark Strip Drainage	Little Cr./Abram Cr./N. Br. Potomac R.
Abram Creek IAF&WA Project	North Branch Potomac River
North Branch Dosers	North Branch Potomac River
North Branch IAF&WA Project	North Branch Potomac River

Since December 1992, two stream dosers (addition of limestone to neutralize acidic waters) have operated on the North Branch Potomac River Watershed at Kitzmiller and on Lostland Run. Two additional dosers were constructed on the North Branch Potomac River at Gorman and on Laurel Run. These dosers have helped to increase pH levels to at least 6.5 in the 26 mi of mainstem and tributaries upstream from the Jennings Randolph Reservoir.

As an alternative to expensive abandoned mine reclamation projects, remining has been encouraged. Remining allows for the recovery of coal resources while reducing or eliminating sources of AMD. The Pennsylvania Surface Mining, Conservation and Reclamation Act (SMCRA) provides regulatory and economic incentives to encourage remining. Remining is the surface mining of abandoned surface and/or deep mines that originally created and continue to discharge effluent water that fail to meet effluent standards for acidity and iron. Under an approved remining program, mine operators can remine abandoned coal mines without assuming legal responsibility for treatment of the preexisting degraded water provided the water discharged is not further degraded and regulatory requirements are satisfied. A slight water quality improvement may be required to obtain a remining permit. A mine operator must collect premining water quality measurements and discharge flow measurements to determine preexisting (baseline) loads of contaminants. The strength of the pollution abatement plan and the economics of conventional treatment of the discharge are also factored into a final baseline loading rate. To obtain a permit to remine, an operator must indicate proposed pollution abatement measures for preexisting contaminant loads. The Pennsylvania remining program has eight discrete abatement technique categories: regrading of abandoned surface mine spoils, surface mining of remaining coal in underground mines by removal of the overburden (referred to as underground mine daylighting), revegetation, addition of alkaline material (limestone or dolostone) brought in from offsite, special handling of acid-producing spoil material, hydrologic control of ground and surface water, sewage sludge application, and all other abatement measures. The majority of remined sites (90%) include more than one abatement technique. The most common forms of abatement are spoil regrading, backfilling surface water impoundments, sealing exposed mine entries, mine daylighting, and revegetation.

Remining permits have been issued on 21 coal seems in the bituminous coal fields of Pennsylvania. Abandoned mine areas within the permitted boundary range from 1 to 395 acres with an average of 67 acres. The average abandoned area designated for reclamation is approximately 35 acres for either underground or surface mines. Without the relief under the remining program, most mine operators would be unwilling to risk continuous mine drainage treatment to mine remaining coal reserves.

SUMMARY

Acid mine drainage from abandoned coal mines is the single greatest source of pollution in the Susquehanna River Basin, West Branch Susquehanna River Subbasin and North Branch Potomac River Subbasin. Most of the mines that once produced coal are now abandoned, but continue to produce and discharge acid drainage. Acid mine drainage is characterized by low pH and elevated levels of sulfates, acidity and metals such as iron, manganese and aluminum. Although severe stream degradation from acid occurs within subwatersheds and segments of the Susquehanna River, West Branch Susquehanna River and North Branch Potomac River, natural alkaline reserves are capable of neutralizing all acid downstream from the coal regions.

The Anthracite Coal Region in Pennsylvania is composed of the Northern, Eastern Middle, Western Middle and Southern Coal fields. In addition to the Susquehanna River reach between Pittston and Shickshinny, the major tributaries impacted by mine drainage in the Northern Coal Field are the Lackawanna River, Solomons Creek and Nanticoke Creek. Large mine drainage discharges emanate from the Klondike, Coalbrook, Jermyn, Gravity Slope, Lackawanna, Old Forge and Seneca mines in the Lackawanna River watershed. Discharges from Number 9 Mine, Plainsville outlet, Number 7 Mine and West End Mine are the principal sources of mine drainage discharging to the main stem Susquehanna River. The largest discharges to Solomons Creek are from the South Wilkes-Barre Mine and the Nottingham-Buttonwood Mine. The Truesdale Mine is the single largest source of AMD in the Nanticoke Creek.

Major tributary streams receiving significant contributions of mine drainage in the Eastern Middle Coal Field include Nescopeck and Catawissa creeks. The Truesdale Mine and Jeddo Mine are the largest sources of mine drainage in Nanticoke and Nescopeck creeks, respectively. Additional large discharges to Nescopeck Creek originate from the Dainty Slope, Tomhicken, Black Ridge, Stony Creek, Gowen and Derringer Mines. Catawissa Creek is impacted by mine drainage primarily from Green Mountain water level tunnels, with Audenreid Tunnel as the largest.

Mine drainage in the Western Middle Coal Field impacts the Shamokin and Mahanoy Creek watersheds. Twelve large discharges impact in the Shamokin Creek watershed, and the Mahanoy Creek watershed receives mine drainage from 17 large discharges.

Significant contributions of mine drainage impact Rausch Creek, Wiconisco Creek and Swatara Creek in the Southern Coal Field.

Based on water quality and discharge flow data from the large discharges, ranges in the cumulative loads of mine drainage indicator chemical constituents from the large discharges in the Anthracite Coal Fields were 661,457-2,6037,68 ppd sulfates and 31,006-143,707 ppd dissolved iron during low and high flow conditions. Combined net in-stream loadings measured at the mouth of the major tributaries draining the anthracite coal fields plus averaged discharge measurements from the large mine drainage sources discharging directly to the Susquehanna River and Rausch Creek were 952,531 ppd sulfates and 35,226 ppd iron. Estimates on the cumulative loading of other metals associated with mine drainage in the Anthracite Coal Fields

could not be calculated due to an insufficient number of samples. Although deep mine discharges contribute the greatest amount of mine drainage, estimated loads determined from the large discharges do not account for loads contributed by surface mining activity and associated sources of AMD. In-stream measurements at the mouth of the major tributaries provide an estimate of the loads of mine drainage indicators from all upstream mine drainage sources discharged to the Susquehanna River; however these values also include loads not attributed solely to mine drainage. Other point and non-point sources also contribute to the loading.

Tributaries contributing the greatest mine drainage loads in the West Branch Susquehanna River Subbasin are Anderson Creek, Clearfield Creek, Moshannon Creek, Sinnemahoning Creek, Kettle Creek and Pine Creek. Eight deep mines and refuse piles were the largest sources of AMD in the headwater area. Clearfield Creek enters the West Branch east of the town of Clearfield. Clearfield Creek's largest source of AMD is from the Middle Penn No.4 Mine in the Japling Run tributary and the Brookwood Shaft Mine in the Muddy Run subwatershed. Nearly all tributaries to Moshannon Creek are impacted by AMD discharges, and the entire length of Moshannon Creek, except in the extreme headwaters, is polluted by mine discharges. A single deep mining complex discharges into all Moshannon Creek western tributaries from Hawk Run north to Webber Run. Most of the coal deposits within the Sinnemahoning Creek watershed are located in the Bennett Branch subwatershed. Abandoned deep mines were the greatest source of AMD to the watershed with coal mine refuse and strip mines contributing to a lesser extent. Kettle Creek is degraded by mine drainage for approximately 4 mi upstream from its mouth. A total of 11 deep mine discharges accounted for all the major sources of mine drainage in the watershed. Pine Creek is affected by the contribution of AMD from two tributaries that drain two coal field extensions of the main Bituminous Coal Field. Babb Creek drains the northern field and is degraded by discharges from deep mines as well as surface mining above deep mine complexes. Little Pine Creek drains the southern coal field and receives AMD from shallow drift mines located in the English Run and Otter Run subwatersheds. The West Branch, downriver from Pine Creek, receives additional mine drainage from Loyalsock Creek. Loyalsock Creek is the farthest downriver tributary that drains an area underlain by coal.

Estimates of the cumulative mine drainage chemical constituent loads from the Bituminous Coal Fields drained by the West Branch Susquehanna River and its tributaries were derived from in-stream loadings, downstream from sources of mine drainage. Estimated loads are based on net cumulative loads calculated from in-stream measurements at the mouth of tributaries impacted by mine drainage during low and high flow conditions. Additional data from in-stream water quality measurements from the Pennsylvania Stream Monitoring Network and Operation Scarlift reports were used in calculating cumulative loads in the West Branch tributaries downstream from AMD sources, but were not sampled by Hainly and Barker (1993). The average in-stream loads of AMD chemical constituents in the headwater area (Bower to Curwensville) of the West Branch were 159,447 ppd sulfates and 400 ppd iron. The ranges in the loads of mine drainage indicators during low and high flow conditions from Anderson Creek to Brewery Run were 1,367,478- 3,561,572 ppd sulfate, 12,549-88,394 ppd total iron, 21,936-53,614 ppd manganese, 37,967-70,590 ppd aluminum and 1,040-4,087 ppd zinc. In addition, added contributions of average in-stream loads of 14,999 ppd sulfates and 450 ppd were measured in the Loyalsock Creek downstream from all AMD sources; 11,012 ppd sulfate, 32 ppd iron, 262 ppd manganese and 131 ppd aluminum were measured in the Tangascootac Creek; and 132,879 ppd sulfate and 457 ppd iron were contributed to Pine Creek from Babb Creek and Little Pine Creek.

The Tioga River watershed is impacted by discharges from numerous entries to deep mines and strip mining activity. Tributary streams degraded by AMD include Morris Run, Coal Creek and Bear Creek. Recent water quality data from the Pennsylvania Stream Monitoring Network, indicates average (based on two 12-month sampling periods) in-stream loadings of mine drainage indicators in the Tioga River downstream from all AMD sources were 92,785-97,649 ppd sulfate, 547-1,516 ppd total iron, 1,224-1,913 ppd total manganese, 598-1,958 ppd total aluminum and 101-181 ppd total zinc.

The Juniata River watershed is affected by mine drainage in its headwaters. The headwater areas drain to four major tributaries. The Raystown Branch and Augwick Creek drain a small part of the main Bituminous Coal Field and the Broad Top Coal Field. The Little Juniata River and Frankstown Branch drain a small portion of the main Bituminous Coal Field. Deep mining was conducted above and below local surface drainage, therefore both gravity discharges and mine pool overflows contribute AMD to the watershed. In-stream measurements from the Pennsylvania Stream Monitoring Network indicate net loads in the Beaver Dam Branch tributary to the Juniata River were 52,451 ppd sulfates, 1,281 ppd total iron, 375 ppd total manganese and 1,253 ppd total aluminum. Additional mine drainage data were requested from the Army Corps of Engineers; however the data were not available.

The North Branch Potomac River drains the Bituminous Coal Fields of western Maryland and eastern West Virginia. Mine drainage from abandoned mines significantly contributes to the deteriorated water quality in the North Branch and its tributaries. The headwater area, upstream from Jennings Randolph Lake, has a long history of coal mining utilizing both deep and surface mining techniques. Underground mines were constructed to allow for drainage from the inner workings to surface streams. Surface mining activities have resulted in highwalls, pits with standing water and spoil piles. Fifty-two AMD producing sites have been identified in the headwater area. These sites consisted of 19 underground mines, 17 surface mines, 13 underground/surface mines and 3 loadouts not associated with mining activity. The majority of the sites was located in the Abram Creek, Stony River, Lostland Run and Three Forks Run subwatersheds. The majority (90%) of the mine drainage discharged to the North Branch in the headwater area originates from 15 sites in 4 subwatersheds and 2 direct discharges (Shallmar and Kitzmiller). Downriver from the Jennings Randolph Lake, the Bituminous Coal Field is drained by the Northwest Allegany County and Georges Creek Complex. Almost the entire Complex is underlain by coal reserves and is drained by Georges Creek, Jennings Run and Braddock Run. Georges Creek joins the West Branch Potomac River near Westernport. Jennings Run and Braddock Run are tributary to Wills Creek which confluences with the North Branch near Cumberland. Sources of mine drainage include deep mines, surface strip mines and refuse. Extensive deep mines workings comprise 34 mi^2 of the Complex. Within the Georges Creek watershed, 290 mine drainage discharge points have been identified, while Jennings Run and Braddock Run contained 64 and 6 discharge points, respectively.

Estimated cumulative loads of mine drainage chemical constituents were derived from recent comprehensive studies of the tributary subwatersheds to the North Branch Potomac River upstream from Jennings Randolph Lake and Georges Creek watersheds as well as data from an earlier investigation of Georges Creek watershed and northwest Allegany County (Table 4). During low flow conditions, the combined mine drainage indicator loads from 54 sources throughout 70 subwatersheds sampled upstream from Jennings Randolph Lake were 93,352 ppd sulfates, 550 ppd total iron, 678 ppd manganese and 1,370 ppd aluminum. During high flow conditions, the cumulative loads were 412,115 ppd sulfates, 3,472 ppd total iron, 2,474 ppd manganese and 5,226 ppd aluminum. The estimated average cumulative loading of mine drainage indicators in Georges Creek Complex, based on in-stream measurements near the confluence with the North Branch, was 161,754 ppd sulfates, 1,011 ppd total iron, 847 ppd manganese, 1,065 ppd. aluminum and 111 ppd zinc. The average cumulative mine drainage constituent loads contributed by Braddock Run was 54,254 ppd sulfates, 650 ppd total iron, 372 ppd manganese and 112 ppd aluminum. Average cumulative loads contributed by Jennings Run were 28,137 ppd sulfates, 115 ppd total iron, 46 ppd manganese and 185 ppd aluminum. The loads contributed by Braddock Run and Jennings Run were determined from in-stream measurements near their confluences with Wills Creek. Data regarding the loading of mine drainage in the Savage River watershed was not obtained.

Estimating AMD loads from in-stream measurements downstream from all sources leads to uncertainties as to what is attributable to mine discharges versus other point and non-point sources of the chemical constituents. On the other hand, estimating loads by addition of individual discharges also has uncertainties as to what proportion of the load is ultimately delivered downstream. Biological and chemical processes in receiving streams alter chemical concentrations in mine drainage subsequent to discharge from the AMD source. Iron and aluminum, as well as other trace metals in mine drainage, commonly precipitate and coat stream beds and through oxidative-reductive reactions sorb and desorb from particles in the receiving stream. These processes alter the delivery of mine drainage constituents downstream. Data correlating AMD loads in upper reaches of the Chesapeake Bay watershed with loadings of contaminants entering the Bay are lacking. The buffering capacity of the region is sufficient to neutralize all of the acid from AMD resulting in circumneutral pH conditions in the lower reaches of tributaries entering the Bay. At these pH levels, metals discharged in mine drainage are likely transported into the Bay predominantly in particulate and colloidal forms (suspended sediments) rather than in the dissolved form. Additional studies are needed to evaluate the transport of AMD chemical constituents (metals) from the upper reaches of the watershed to the Bay.

Much of the available data related to mine drainage was generated during early comprehensive investigations (Scarlift Reports and Northwest Allegany County and Lower Georges Creek Complex) to identify impacted watersheds and sources of mine acid for the purpose of determining appropriate AMD abatement measures. These investigations, for the most part, are limited to acid, iron and sulfate loading estimates and do not contain information on additional pollutants. Consequently, there are insufficient data on other metals directly associated with mine drainage discharges to estimate loads from data in these reports. Although these previous investigations thoroughly identified sources of AMD and associated loads 25-30 years ago, there is some uncertainty as to whether the historical data are currently applicable. Mitigation efforts in recent years have likely altered both the sources of AMD (e.g., spoil piles, refuse and drainage pits) and the concentrations of the chemical constituents. Hawkins (1995) analyzed AMD chemical characteristics and loads of discharges before and after remining operations. Analysis of contaminant concentrations, loading rates and flow rates before and after remining operations and reclamation efforts indicated that remining is successful in terms of preventing further degradation of surface and groundwater. The majority of post-remining operations had contaminant loads of acidity and iron equivalent to or less than pre-remining levels. Wood (1996) evaluated the concentrations of mine drainage constituents from large discharges in the Anthracite Coal Region over time and indicated water quality has changed at some mines, likely resulting from altered mine water residence time, path length, or depth of circulation subsequent to borehole drilling, mine sealing, and construction or failure of mine water diversion systems. A comparison of historical (1960s-early 1970s) measurements with recent data indicated that sulfate concentrations at 62 mines decreased while concentrations increased at 15 mines. Manganese concentrations in water discharged from most mines had decreased over time. Manganese concentrations had decreased at 23 of 27 mines evaluated between 1970-1975 and 1991. A comparison of iron concentrations indicated a decrease in iron levels in 57 mine discharges while an increase was detected in 24 mine discharges.

Current water quality and discharge flow data are needed to support or revise the estimated loads presented. Recent mine drainage discharge data for the Anthracite Coal Fields were limited to a single sampling sweep of large discharges. Recent data for discharges in the West Branch Susquehanna River were not available during the preparation of this literature synthesis; however new data are being collected by watershed groups. The Wildlands Conservancy is collecting information regarding discharges from the Jeddo Tunnel in the Nescopeck Creek. Additional data has been collected in the Lackawanna River watershed and is currently being analyzed by Parr Government Systems. The U.S. Geological Survey is currently collecting water quality data from Swatara Creek to evaluate the efficacy of mine drainage remediation measures implemented at upstream sources. The Southern Allegany Resource Conservation and Development watershed association is currently sampling the largest 100 mine drainage discharges in western Pennsylvania with approximately 25 of the sites located in the Chesapeake Bay watershed. Mine drainage data have also been collected for the Cambria and Clearfield County Conservation Districts. When they become available, these new data will provide improved estimates of contaminant loading from coal mine drainage.

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APPENDIX I

SOURCES OF MINE DRAINAGE AND ASSOCIATED CONTAMINANT LOADS FROM THE ANTHRACITE COAL FIELDS IN THE SUSQUEHANNA RIVER DRAINAGE

Estimates of acid mine drainage loads in the Susquehanna River tributaries draining the Anthracite Coal Fields, based on water quality data from large discharges (Wood, 1996).

ID numbers correspond to figures 2 - 5 in text.

ID	MINE	AMD DISCHARGE SOURCE	COORDINATES (Lat/Long)	DATE	DISCHARGE (cfs)	Sulfate (mg/L)	Sulfate (ppd)	Fe (mg/L)	Fe (ppd)	Mn (mg/L)
Lackawanna River										
3	Klondike Mine	Vandling Drift	41 38 15	4/15/75	4	92	1979.6			
			75 27 35	10/28/91	0		0.0			
5	Coalbrook Mine	Upper Wilson Creek	41 36 11	4/15/75	2.6	190	2657.3			
		(Simpson) Drift	75 29 09	10/28/91	0.81	150	653.6	0.05	0.2	0.14
6	Coalbrook Mine	Lower Wilson Creek	41 36 02	4/15/75	16	150	12910.1			
		(Simpson) Shaft	75 29 13	10/28/91	4.2	140	3163.0	0.09	2.0	0.05
7	Jermyn Mine	Jermyn Slope	41 31 16	4/16/75	39	220	46153.7	1.5	314.7	1.5
			75 32 49	10/30/91	12	190	12264.6	0.32	20.7	0.76
9	Gravity Slope Mine	slope (Peckville Shaft)	41 28 52	4/16/75	23	170	21032.8	0.32	39.6	1.5
			75 33 48	10/29/91	5.1	150	4115.1	0.48	13.2	0.87
11	Lackawanna Mine	Jerome Shaft	41 28 44	4/16/75	2.4	150	1936.5	20	258.2	
			75 35 48	10/29/91	0		0.0		0.0	
13	Old Forge Mine	Old Forge borehole	41 21 36	4/24/75	97	780	406991.8	40	20871.4	5.6
			75 45 04	10/29/91	68	420	153630.5	25	9144.7	3.2
14	Seneca Mine	Duryea breech	41 20 51	4/17/75	34	700	128025.4	48	8778.9	7.3
			75 46 42	11/1/86	31			35	5836.5	
				4/1/87	47			35	8848.8	
				10/31/89	37			31	6170.0	3.8
				2/20/90	28			30	4518.5	3.5
				10/30/91	5.6	310	9338.3	26	783.2	3.4
Susquehanna River										
16	Number 9 Mine	Pittston (Butler) Water Tunnel	41 19 36	4/15/75	8.7	265	12401.8	2.5	117.0	
			75 47 25	10/30/91	2.5	320	4303.4	3.4	45.7	3.7
17	Plainsville outlet		41 17 03	4/15/75	9.2	1100	54437.7	85	4206.6	
			75 51 20	10/30/91	0		0.0		0.0	
21	Number 7 Mine	seepage	41 12 33	4/14/75	3.5	1400	26358.2	40	753.1	
			76 00 07	10/31/91	0.22	420	497.0	1	1.2	4.5
22	Number 7 Mine	Susquehanna Number 2 Shaft	41 12 27	4/14/75	8.5	2800	128025.4	100	4572.3	
			76 00 22	10/31/91	5.8	980	30575.5	43	1341.6	7.2
24	West End Mine	Mocanaqua Tunnel	41 09 01	4/14/75	5.8	680	21215.6	60	1872.0	12
			76 08 40	11/1/91	2.4	690	8908.0	75	968.3	9.7
Solomons Creek										
18	South Wilkes-Barre Mine	Solomon Creek boreholes	41 13 50	4/14/75	39	1800	377621.2	190	39860.0	17
			75 55 20	10/31/91	20	640	68854.0			5.2
19	Nottingham-Buttonwood	Airshaft Number 22	41 13 34	4/15/75	27	760	110381.6	95	13797.7	
			75 56 13	10/31/91	5	760	20441.0	53	1425.5	6.6
				11/1/86	24					
				4/1/87	43					
				11/1/89	26					
				2/20/90	29					
Nanticoke Creek										
20	Truesdale Mine	Askam Shaft borehole	41 11 58	4/14/75	11	2000	118342.8	100	5917.1	
			75 57 52	10/31/91	0		0.0			
Little Nescopeck Creek										
38	Jeddo Mine	Jeddo Tunnel	41 00 19	4/16/75	65	430	150349.2	6	2097.9	
			75 59 38	11/5/91	24	600	77460.8	2.8	361.5	8.4

Estimates of acid mine drainage loads in the Susquehanna River tributaries draining the Anthracite Coal Fields, based on water quality data from large discharges (Wood, 1996).

ID numbers correspond to figures 2 - 5 in text.

ID	MINE	Mn (ppd)	Al (mg/L)	Al (ppd)	As (mg/L)	As (ppd)	Cd (mg/L)	Cd (ppd)	Cr (mg/L)	Cr (ppd)	Cobalt (mg/L)	Cobalt (ppd)	Cu (mg/L)
Lackawanna River													
3	Klondike Mine												
5	Coalbrook Mine												
		0.6											
6	Coalbrook Mine												
		1.1											
7	Jermyn Mine	314.7											
		49.1											
9	Gravity Slope Mine	185.6	1.4	173.2							0.06	7.4	0.015
		23.9											
11	Lackawanna Mine												
13	Old Forge Mine	2922.0	0.12	62.6							0.11	57.4	
		1170.5											
14	Seneca Mine	1335.1	0.4	73.2	0.002	0.4					0.15	27.4	
					0.01	1.7	0.005	0.8					0.01
							0.007	1.8					
		756.3	0.1	19.9	0.002	0.4			0.06	11.9	0.05	10.0	0.035
		527.2	0.21	31.6	0.005	0.8	0.006	0.9	0.03	4.5	0.05	7.5	0.035
		102.4											
Susquehanna River													
16	Number 9 Mine												
		49.8											
17	Plainsville outlet												
21	Number 7 Mine												
		5.3											
22	Number 7 Mine												
		224.6											
24	West End Mine	374.4	6	187.2	0.001	0.0					0.37	11.5	0.013
		125.2											
Solomons Creek													
18	South Wilkes-Barre Mine	3566.4	1	209.8	0.027	5.7					0.22	46.2	
		559.4											
19	Nottingham-Buttonwood												
		177.5											
					0.012	1.5	0.01	1.3					0.01
					0.009	2.1	0.012	2.8					
			0.1	14.0	0.005	0.7	0.006	0.8	0.02	2.8	0.06	8.4	0.01
			0.19	29.6	0.006	0.9	0.006	0.9	0.02	3.1	0.07	10.9	0.008
Nanticoke Creek													
20	Truesdale Mine												
Little Nescopeck Creek													
38	Jeddo Mine												
		1084.5											

Estimates of acid mine drainage loads in the Susquehanna River tributaries draining the Anthracite Coal Fields, based on water quality data from large discharges (Wood, 1996).

ID numbers correspond to figures 2 - 5 in text.

ID	MINE	Cu (ppd)	Pb (mg/L)	Pb (ppd)	Li (mg/L)	Li (ppd)	Hg (mg/L)	Hg (ppd)	Ni (mg/L)	Ni (ppd)	Sr (mg/L)
Lackawanna River											
3	Klondike Mine										
5	Coalbrook Mine										
6	Coalbrook Mine										
7	Jermyn Mine										
9	Gravity Slope Mine	1.9	0.011	1.4	0.03	3.7			0.11	13.6	0.22
11	Lackawanna Mine										
13	Old Forge Mine				0.12	62.6	0.0006	0.3	0.22	114.8	1.8
14	Seneca Mine				0.1	18.3			0.18	32.9	0.99
		1.7	0.018	3.0					0.1	16.7	
			0.092	23.3					0.07	17.7	
		7.0							0.097	19.3	
		5.3							0.065	9.8	
Susquehanna River											
16	Number 9 Mine										
17	Plainsville outlet										
21	Number 7 Mine										
22	Number 7 Mine										
24	West End Mine	0.4	0.01	0.3	0.12	3.7			0.34	10.6	0.36
Solomons Creek											
18	South Wilkes-Barre Mine		0.014	2.9	0.18	37.8	0.0005	0.1	0.56	117.5	3.7
19	Nottingham-Buttonwood										
		1.3	0.024	3.1					0.17	21.9	
			0.092	21.3					0.08	18.5	
		1.4							0.077	10.8	
		1.2							0.075	11.7	
Nanticoke Creek											
20	Truesdale Mine										
Little Nescopeck Creek											
38	Jeddo Mine										

Estimates of acid mine drainage loads in the Susquehanna River tributaries draining the Anthracite Coal Fields, based on water quality data from large discharges (Wood, 1996).

ID numbers correspond to figures 2 - 5 in text.

ID	MINE	Sr (ppd)	Zn (mg/L)	Zn (ppd)
Lackawanna River				
3	Klondike Mine			
5	Coalbrook Mine			
6	Coalbrook Mine			
7	Jermyn Mine			
9	Gravity Slope Mine	27.2	0.18	22.3
11	Lackawanna Mine			
13	Old Forge Mine	939.2	0.04	20.9
14	Seneca Mine	181.1	0.09	16.5
			0.05	8.3
			0.047	11.9
			0.11	21.9
			0.058	8.7
Susquehanna River				
16	Number 9 Mine			
17	Plainsville outlet			
21	Number 7 Mine			
22	Number 7 Mine			
24	West End Mine	11.2	0.53	16.5
Solomons Creek				
18	South Wilkes-Barre Mine	776.2	0.14	29.4
19	Nottingham-Buttonwood			
			0.1	12.9
			0.045	10.4
			0.031	4.3
			0.034	5.3
Nanticoke Creek				
20	Truesdale Mine			
Little Nescopeck Creek				
38	Jeddo Mine			

ID	MINE	AMD DISCHARGE SOURCE	COORDINATES (Lat/Long)	DATE	DISCHARGE (cfs)	Sulfate (mg/L)	Sulfate (ppd)	Fe (mg/L)	Fe (ppd)	Mn (mg/L)
Black Creek/Nescopeck Creek										
39	Dainty Slope Mine	collapsed slope	40 58 12	4/14/75	1.6	8	68.9			
			76 06 30	11/7/91	0		0.0			
40	Tomhicken Mine	strip pool overflow	40 57 55	4/15/75	2.7	66	958.6	12	174.3	1.5
			76 05 30	11/5/91	0.16	60	51.6	0.36	0.3	1.1
41	Black Ridge Mine	strip pool overflow	40 58 21	4/15/75	1.2	30	193.7			
			76 02 54	11/7/91	0		0.0			
42	Stony Creek Mine	Stony Creek and seepage	40 57 39	4/15/75	4	9	193.7	1	21.5	
			76 02 19	11/5/91	0.27	7.2	10.5	0.28	0.4	0.15
52	Gowen Mine	Gowen Tunnel	40 56 54	4/15/75	6.6	110	3905.3	2	71.0	
			75 10 47	11/5/91	0.27	250	363.1	3	4.4	4.5
53	Derringer Mine	Derringer Tunnel	40 56 48	4/15/75	8.8	280	13254.4	1	47.3	
			76 10 43	11/5/91	1.5	93	750.4	0.08	0.6	1.3
Catawissa Creek										
45	Oneida Mine	Oneida Tunnel 1	40 55 32	4/15/75	6.4	69	2375.5	1	34.4	
			76 07 25	11/6/91	0.88	170	804.7	1.2	5.7	1.8
48	Green Mountain Mine	Green Mountain Tunnel	40 53 52	4/15/75	2.1	76	858.5	1	11.3	
			76 04 03	11/7/91	0.5	95	255.5	0.51	1.4	1.3
49	Audenreid Mine	Audenreid Tunnel	40 53 52	4/15/75	19	280	28617.5	2	204.4	
			76 03 59	11/7/91	5.9	300	9521.2	1.6	50.8	3.8
50	Oneida Mine	Oneida Tunnel 3	40 55 06	4/16/75	9.1	53	2594.4	0.22	10.8	0.57
			75 08 50	11/4/91	1.4	74	557.3	0.1	0.8	0.73
Mahanoy Creek										
57	Vulcan Buck Mountain Mine	Vulcan Buck borehole	40 48 55	4/16/75	9.8	160	8434.6	10	527.2	
			76 07 35	11/1/91	0.86	140	647.7	11	50.9	1.5
58	Gilberton Mine	pump discharge	40 48 01	4/18/75	23	1000	123722.1	54	6681.0	16
			76 12 34	10/30/91	7.8	640	26853.1	51	2139.9	9.4
59	Weston Mine	seepage	40 48 30	4/16/75	3.7	1200	23883.7	20	398.1	
			76 14 49	11/1/91	0.03	670	108.1	9.5	1.5	8.4
60	Weston mine	Lost Creek borehole	40 48 25	4/16/75	1	1300	6993.0	20	107.6	
			76 14 49							
61	Hammond Mine	boreholes	40 48 06	4/16/75	1.7	1200	10973.6	40	365.8	
			76 16 04	10/10/91	0		0.0		0.0	
63	Girard Mine	seepage	40 47 30	4/16/75	8	460	19795.5	20	860.7	
			76 16 06	10/30/91	2	230	2474.4	19	204.4	4.2
64	Packer No. 5 Mine	breach and boreholes	40 47 41	4/18/75	45	1300	314684.4	40	9682.6	
			76 16 48	10/30/91	25	700	94136.4	23	3093.1	9.8
64B	Packer No. 5 Mine	breach	40 47 39	10/30/91	3.2	760	13082.3	21	361.5	9.8
			76 16 28							
66	Preston mine	tunnel	40 47 25	4/17/75	2.2	200	2366.9	20	236.7	
			76 17 34	10/30/91	0.36	110	213.0	12	23.2	1.5
68	Centrailia Mine	Tunnel	40 47 27	4/16/75	11	580	34319.4	10	591.7	
			76 19 26	10/30/91	2.7	660	9585.8	6.8	98.8	6.1
70	Bast Mine	Oakland Tunnel	40 47 06	4/17/75	6.6	660	23431.9	20	710.1	
			76 19 54	10/30/91	6.4	520	17902.0	17	585.3	3.6
71	Tunnel Mine 2	drain pool area and seepage	40 46 45	4/17/75	1.3	640	4475.5	30	209.8	
			76 20 12							
73	Potts Mine	east breach	40 46 24	4/17/75	3.2	960	16525.0	40	688.5	
			76 22 15	10/10/91	0		0.0		0.0	
75	Locust Gap Mine	Helfenstein Tunnel	40 45 04	4/17/75	3.9	670	14055.9	10	209.8	
			76 26 12	10/29/91	2.5	860	11565.3	22	295.9	6.6

ID	MINE	Mn (ppd)	Al (mg/L)	Al (ppd)	As (mg/L)	As (ppd)	Cd (mg/L)	Cd (ppd)	Cr (mg/L)	Cr (ppd)	Cobalt (mg/L)	Cobalt (ppd)	Cu (mg/L)
Black Creek/Nescopeck Creek													
39	Dainty Slope Mine												
40	Tomhicken Mine	21.8	0.2	2.9			0.002	0.0			0.04	0.6	0.005
		0.9											
41	Black Ridge Mine												
42	Stony Creek Mine												
		0.2											
52	Gowen Mine												
		6.5											
53	Derringer Mine												
		10.5											
Catawissa Creek													
45	Oneida Mine												
		8.5											
48	Green Mountain Mine												
		3.5											
49	Audenreid Mine												
		120.6											
50	Oneida Mine	27.9	2.7	132.2	0.001	0.0	0.002	0.1			0.04	2.0	0.035
		5.5											
Mahanoy Creek													
57	Vulcan Buck Mountain Mine												
		6.9											
58	Gilberton Mine	1979.6	0.7	86.6	0.008	1.0					0.32	39.6	
		394.4											
59	Weston Mine												
		1.4											
60	Weston mine												
61	Hammond Mine												
63	Girard Mine												
		45.2											
64	Packer No. 5 Mine												
		1317.9											
64B	Packer No. 5 Mine	168.7											
66	Preston mine												
		2.9											
68	Centrallia Mine												
		88.6											
70	Bast Mine												
		123.9											
71	Tunnel Mine 2												
73	Potts Mine												
75	Locust Gap												
	Mine	88.8											

ID	MINE	Cu (ppd)	Pb (mg/L)	Pb (ppd)	Li (mg/L)	Li (ppd)	Hg (mg/L)	Hg (ppd)	Ni (mg/L)	Ni (ppd)	Sr (mg/L)
Black Creek/Nescopeck Creek											
39	Dainty Slope Mine										
40	Tomhicken Mine	0.1	0.003	0.0	0.015	0.2	0.0006	0.0	0.05	0.7	0.05
41	Black Ridge Mine										
42	Stony Creek Mine										
52	Gowen Mine										
53	Derringer Mine										
Catawissa Creek											
45	Oneida Mine										
48	Green Mountain Mine										
49	Audenreid Mine										
50	Oneida Mine	1.7	0.005	0.2	0.014	0.7			0.065	3.2	0.031
Mahanoy Creek											
57	Vulcan Buck Mountain Mine										
58	Gilberton Mine				0.07	8.7	0.0005	0.1	0.38	47.0	1.5
59	Weston Mine										
60	Weston mine										
61	Hammond Mine										
63	Girard Mine										
64	Packer No. 5 Mine										
64B	Packer No. 5 Mine										
66	Preston mine										
68	Centrailia Mine										
70	Bast Mine										
71	Tunnel Mine 2										
73	Potts Mine										
75	Locust Gap Mine										

ID	MINE	Sr (ppd)	Zn (mg/L)	Zn (ppd)							
Black Creek/Nescopeck Creek											
39	Dainty Slope Mine										
40	Tomhicken Mine	0.7									
41	Black Ridge Mine										
42	Stony Creek Mine										
52	Gowen Mine										
53	Derringer Mine										
Catawissa Creek											
45	Oneida Mine										
48	Green Mountain Mine										
49	Audenreid Mine										
50	Oneida Mine	1.5	0.24	11.7							
Mahanoy Creek											
57	Vulcan Buck Mountain Mine										
58	Gilberton Mine	185.6	0.51	63.1							
59	Weston Mine										
60	Weston mine										
61	Hammond Mine										
63	Girard Mine										
64	Packer No. 5 Mine										
64B	Packer No. 5 Mine										
66	Preston mine										
68	Centrailia Mine										
70	Bast Mine										
71	Tunnel Mine 2										
73	Potts Mine										
75	Locust Gap Mine										

ID	MINE	AMD DISCHARGE SOURCE	COORDINATES (Lat/Long)	DATE	DISCHARGE (cfs)	Sulfate (mg/L)	Sulfate (ppd)	Fe (mg/L)	Fe (ppd)	Mn (mg/L)
77	Locust Gap	Doutyville Tunnel	40 44 35	4/18/75	13	700	48950.9	12	839.2	6.4
	Mine		76 28 38	10/29/92	1.5	620	5002.7	15	121.0	4.5
Zerbe Run/Mahanoy Cr.										
103	North Franklin Mine	drift and borehole	40 46 17	4/18/75	7.3	580	22775.6	25	981.7	6
			76 40 44	10/31/91	1.6	360	3098.4	18	154.9	3
103A	North Franklin Mine	includes site 103 and seepage	40 46 36	4/18/75	8.3	560	25002.6	22	982.2	
			76 40 58	10/31/91	2.2	410	4852.1	17	201.2	3.1
Shamokin Creek										
80	Mid-Valley	Tunnel	40 48 48	4/17/75	5.9	280	8886.5	15	476.1	
	Mine		76 24 24	11/1/91	3.7	190	3781.6	19	378.2	2.8
84	Scott Ridge	breach	40 47 30	4/17/75	2.8	1190	17923.6	50	753.1	
	Mine		76 29 26	11/1/91	4.8	360	9295.3	29	748.8	4.3
85	Scott Ridge	rock tunnel	40 47 39	4/17/75	15	490	39537.3	45	3631.0	6.8
	Mine3		76 29 19							
86	Colbert Mine	breach	40 47 26	4/17/75	0.9	510	2469.1	40	193.7	
			76 29 47	11/1/91	1.7	350	3200.6	28	256.1	4.2
87	Excelsior Mine	strip pool overflow	40 46 25	4/18/75	13	400	27971.9	44	3076.9	5.4
			76 29 37	11/1/91	6.3	310	10505.6	31	1050.6	3.6
88	Maysville Mine	borehole	40 47 03	4/16/75	3.3	460	8165.7	50	887.6	
	Numbers l and 2		76 30 52	10/31/91	2.2	440	5207.1	29	343.2	4.3
89	Corbin Mine	Corbin Water-level	40 46 46	4/16/75	1	490	2635.8	40	215.2	
		Drift	76 30 53	10/31/91	0.49	410	1080.7	43	113.3	5.5
91	Big Mountain	Number l Slope	40 46 19	4/16/75	2	300	3227.5	20	215.2	
	Mine		76 32 19	10/31/91	0.01	360	19.4	30	1.6	4
92	Cameron Mine	air shaft	40 47 44	4/16/75	4	790	16998.3	60	1291.0	
			76 33 59	10/31/91	3.1	700	11672.9	66	1100.6	7.3
93	Cameron Mine	drift	40 47 37	4/16/75	4.7	1100	27810.6	150	3792.4	
			76 33 55	10/31/91	0.32	870	1497.6	20	34.4	4.9
96	Cameron Mine	drift and tunnel	40 47 31	4/16/75	1.1	920	5443.8	60	355.0	
			76 33 46	10/31/91	0		0.0		0.0	
97	Henry Clay	pump slope	40 46 37	4/16/75	11	470	27810.6	50	2958.6	
	Stirling Mine		76 34 07	10/31/91	3	490	7907.5	34	548.7	4.1
Swatara Creek										
202	Blackwood	Blackwood Water-	40 38 23	4/25/75	2.6	170	2377.6	1.1	15.4	1.6
	Mine	level Tunnel	76 19 36	10/30/91	0.45	120	290.5	0.34	0.8	1.2
215	Middle Creek	strip pool overflow	40 38 20	4/23/75	9.8	180	9488.9	0.28	14.8	2.4
	Mine		76 22 45	10/30/91	2	150	1613.8	4.7	50.6	0.35
218	Eureka Mine	drift	40 38 41	4/22/75	1.1	170	1005.9	3	17.8	
			76 24 30	10/30/91	0.11	29	17.2	0.88	0.5	0.95
238	East Franklin	Lower Paoli Tunnel	40 36 40	4/21/75	1.4	310	2334.6	35	263.6	
			76 25 30	10/29/91	0.01	460	24.7	9.6	0.5	1.4
244	Lincoln Mine	Rowe Drainage	40 35 42	4/21/75	6.4	130	4475.5	10	344.3	
		Tunnel	76 26 32	10/31/91	0.84	110	497.0	9.9	44.7	4.3
Wiconisco Creek										
252	Tower City	Tunnel	40 36 43	4/25/75	1.5	210	1694.5	8	64.6	
	Number l Mine		76 31 04	10/2/91	0		0.0			
253	Erdman Coal	pump discharge	40 37 13	4/25/75	2.1	880	9940.8			
	Company		76 31 26	10/29/91	0.34	150	274.3	17	31.1	2.8
253A	Erdman Coal	seeps and borehole	40 37 06	1975						
	Company		76 31 42	10/29/91	0.3	140	225.9	5.7	9.2	2.3

ID	MINE	Mn (ppd)	Al (mg/L)	Al (ppd)	As (mg/L)	As (ppd)	Cd (mg/L)	Cd (ppd)	Cr (mg/L)	Cr (ppd)	Cobalt (mg/L)	Cobalt (ppd)	Cu (mg/L)
77	Locust Gap	447.6	0.77	53.8	0.002	0.1					0.18	12.6	0.025
	Mine	36.3											
Zerbe Run/Mahanoy Cr.													
103	North Franklin Mine	235.6	3.4	133.5	0.002	0.1					0.32	12.6	0.02
		25.8											
103A	North Franklin Mine												
		36.7											
Shamokin Creek													
80	Mid-Valley												
	Mine	55.7											
84	Scott Ridge												
	Mine	111.0											
85	Scott Ridge	548.7	0.9	72.6	0.002	0.2					0.28	22.6	0.002
	Mine3												
86	Colbert Mine												
		38.4											
87	Excelsior Mine	377.6	0.95	66.4	0.001	0.1					0.14	9.8	
		122.0											
88	Maysville Mine												
	Numbers I and 2	50.9											
89	Corbin Mine												
		14.5											
91	Big Mountain												
	Mine	0.2											
92	Cameron Mine												
		121.7											
93	Cameron Mine												
		8.4											
96	Cameron Mine												
97	Henry Clay												
	Stirling Mine	66.2											
Swatara Creek													
202	Blackwood	22.4	0.29	4.1							0.06	0.8	0.007
	Mine	2.9											
215	Middle Creek	126.5	2.2	116.0							0.09	4.7	0.03
	Mine	3.8											
218	Eureka Mine												
		0.6											
238	East Franklin												
		0.1											
244	Lincoln Mine												
		19.4											
Wiconisco Creek													
252	Tower City												
	Number I Mine												
253	Erdman Coal												
	Company	5.1											
253A	Erdman Coal												
	Company	3.7											

ID	MINE	Cu (ppd)	Pb (mg/L)	Pb (ppd)	Li (mg/L)	Li (ppd)	Hg (mg/L)	Hg (ppd)	Ni (mg/L)	Ni (ppd)	Sr (mg/L)
77	Locust Gap	1.7			0.08	5.6			0.34	23.8	0.59
	Mine										
	Zerbe Run/Mahanoy Cr.										
103	North Franklin Mine	0.8			0.04	1.6			0.52	20.4	0.15
103A	North Franklin Mine										
Shamokin Creek											
80	Mid-Valley										
	Mine										
84	Scott Ridge										
	Mine										
85	Scott Ridge	0.2			0.09	7.3	0.007	0.6	0.32	25.8	0.32
	Mine3										
86	Colbert Mine										
87	Excelsior Mine				0.06	4.2			0.24	16.8	0.3
88	Maysville Mine										
	Numbers I and 2										
89	Corbin Mine										
91	Big Mountain										
	Mine										
92	Cameron Mine										
93	Cameron Mine										
96	Cameron Mine										
97	Henry Clay										
	Stirling Mine										
Swatara Creek											
202	Blackwood	0.1			0.021	0.3					0.12
	Mine										
215	Middle Creek	1.6	0.003	0.2	0.017	0.9			0.13	6.9	0.14
	Mine										
218	Eureka Mine										
238	East Franklin										
244	Lincoln Mine										
Wiconisco Creek											
252	Tower City										
	Number I Mine										
253	Erdman Coal										
	Company										
253A	Erdman Coal										
	Company										

ID	MINE	Sr (ppd)	Zn (mg/L)	Zn (ppd)							
77	Locust Gap	41.3	0.55	38.5							
	Mine										
	Zerbe Run/Mahanoy Cr.										
103	North Franklin Mine	5.9	0.65	25.5							
103A	North Franklin Mine										
Shamokin Creek											
80	Mid-Valley										
	Mine										
84	Scott Ridge										
	Mine										
85	Scott Ridge	25.8	0.25	20.2							
	Mine3										
86	Colbert Mine										
87	Excelsior Mine	21.0	0.33	23.1							
88	Maysville Mine										
	Numbers I and 2										
89	Corbin Mine										
91	Big Mountain										
	Mine										
92	Cameron Mine										
93	Cameron Mine										
96	Cameron Mine										
97	Henry Clay										
	Stirling Mine										
Swatara Creek											
202	Blackwood	1.7	0.21	2.9							
	Mine										
215	Middle Creek	7.4	0.6	31.6							
	Mine										
218	Eureka Mine										
238	East Franklin										
244	Lincoln Mine										
Wiconisco Creek											
252	Tower City										
	Number I Mine										
253	Erdman Coal										
	Company										
253A	Erdman Coal										
	Company										

ID	MINE	AMD DISCHARGE SOURCE	COORDINATES (Lat/Long)	DATE	DISCHARGE (cfs)	Sulfate (mg/L)	Sulfate (ppd)	Fe (mg/L)	Fe (ppd)	Mn (mg/L)
266	Lykens-	Big Lick Tunnel	40 34 59	4/17/75	6.7	160	5766.5	15	540.6	
	Williamstown		76 39 03	10/29/91	0		0.0		0.0	
267	Lykens-	Lykens Water-level	40 35 07	4/17/75	2.1	110	1242.6	15	169.4	
	Williamstown	Drift	76 41 58	10/29/91	0.39	120	251.7	17	35.7	1.2
269	Lykens-	airshaft and pump	40 34 51	4/17/75	6	200	6455.1	30	968.3	
	Williamstown	station	76 41 59	10/29/91	1.1	110	650.9	18	106.5	2.4
270	Lykens-	seepage	40 34 48	4/17/75	2.2	210	2485.2	20	236.7	
	Williamstown		76 42 00	10/29/91	0.61	110	360.9	20	65.6	2.6
Rausch Creek										
255	Good Spring	buried borehole	40 37 16	4/23/75	1	230	1237.2	22	118.3	
	Number I Mine		76 31 33	10/2/91	0		0.0		0.0	
257	Valley View	intermittent pump	40 36 47	4/24/75	2.4	470	6067.8	40	516.4	
	Mine		76 33 12	10/2/91	0		0.0		0.0	
258	Valley View	Valley View Tunnel	40 36 50	4/24/75	7.2	110	4260.3	22	852.1	
	Mine		76 33 07	10/29/91	1.4	100	753.1	16	120.5	2
259	Markson Mine	Markson Columnway	40 37 09	4/23/75	2.4	410	5293.2	32	413.1	
			76 33 02	10/29/91	2.2	540	6390.5	39	461.5	8.8
272	Rausch Creek	above East Branch	40 30 16	4/21/81	3.3	12	213.0	0.02	0.4	
			76 36 13	10/28/91	0.05	9.8	2.6	0.06	0.0	0.14
273	East Branch Rausch Cr.	at Horseshoe Trail	40 30 18	4/21/81	1.6	8.7	74.9	0.01	0.1	
			76 36 05	10/28/91	0.09	13	6.3	0.05	0.0	0.49
274	Rausch Creek	at Horseshoe Trail	40 29 54	4/21/81	5.4	13	377.6	0.04	1.2	
		"(includes 291, 292)"	76 35 52	10/28/91	0.26	19	26.6	0.02	0.0	0.31
Rattling Run/Stony Creek										
278	Rattling Run	at Stony Creek Road	40 26 09	4/9/91	2.7	8.4	122.0	0.04	0.6	
		"(includes 295, 296)"	76 43 01	10/28/91	0.14	7.5	5.6	0.04	0.0	0.34

ID	MINE	Mn (ppd)	Al (mg/L)	Al (ppd)	As (mg/L)	As (ppd)	Cd (mg/L)	Cd (ppd)	Cr (mg/L)	Cr (ppd)	Cobalt (mg/L)	Cobalt (ppd)	Cu (mg/L)
266	Lykens-												
	Williamstown												
267	Lykens-												
	Williamstown	2.5											
269	Lykens-												
	Williamstown	14.2											
270	Lykens-												
	Williamstown	8.5											
Rausch Creek													
255	Good Spring												
	Number I Mine												
257	Valley View												
	Mine												
258	Valley View												
	Mine	15.1											
259	Markson Mine												
		104.1											
272	Rausch Creek												
		0.0											
273	East Branch Rausch Cr.												
		0.2											
274	Rausch Creek												
		0.4											
Rattling Run/Stony Creek													
278	Rattling Run												
		0.3											

ID	MINE	Cu (ppd)	Pb (mg/L)	Pb (ppd)	Li (mg/L)	Li (ppd)	Hg (mg/L)	Hg (ppd)	Ni (mg/L)	Ni (ppd)	Sr (mg/L)
266	Lykens-										
	Williamstown										
267	Lykens-										
	Williamstown										
269	Lykens-										
	Williamstown										
270	Lykens-										
	Williamstown										
Rausch Creek											
255	Good Spring										
	Number I Mine										
257	Valley View										
	Mine										
258	Valley View										
	Mine										
259	Markson Mine										
272	Rausch Creek										
273	East Branch Rausch Cr.										
274	Rausch Creek										
Rattling Run/Stony Creek											
278	Rattling Run										

ID	MINE	Sr (ppd)	Zn (mg/L)	Zn (ppd)							
266	Lykens-										
	Williamstown										
267	Lykens-										
	Williamstown										
269	Lykens-										
	Williamstown										
270	Lykens-										
	Williamstown										
Rausch Creek											
255	Good Spring										
	Number I Mine										
257	Valley View										
	Mine										
258	Valley View										
	Mine										
259	Markson Mine										
272	Rausch Creek										
273	East Branch Rausch Cr.										
274	Rausch Creek										
Rattling Run/Stony Creek											
278	Rattling Run										

APPENDIX II

SOURCES OF MINE DRAINAGE AND ASSOCIATED CONTAMINANT LOADS IN THE BITUMINOUS COAL FIELDS OF PENNSYLVANIA WEST BRANCH SUSQUEHANNA RIVER DRAINAGE

Estimates of acid mine drainage loads in the West Branch Susquehanna River tributaries in 1984, based on Hainly and Barker (1993).					
TRIBUTARY	DATE	FLOW (cfs)	SULFATE (mg/L)	SULFATE (ppd)	Total Fe (mg/L)
Anderson Creek	May 1984	247	57	76044	0.95
Unnamed Tributary at Curwensville	May 1984	0.58	41	128	0.39
Hartshorn Run	May 1984	11	39	2317	0.41
Unnamed Tributary at Susquehanna Bridge	May 1984	5.5	270	8021	0.68
Montgomery Creek	May 1984	52	130	36512	0.59
Moose Creek	May 1984	39	79	16641	0.61
Wolf Run	May 1984	3.7	780	15588	56
Clearfield Creek	May 1984	1670	140	1262805	4.4
Abes Run	May 1984	4.8	720	18667	2.8
Unnamed tributary at Bishtown	May 1984	0.86	730	3391	1.9
Lick Run	May 1984	86	54	25083	0.39
Unnamed Tributary near Shawville	May 1984	0.76	50	205	1.1
Devils Run	May 1984	1.9	300	3079	0.6
Unnamed Tributary at Shawville	May 1984	0.73	74	292	0.76
Bloody Run	May 1984	2.1	700	7940	0.41
Trout Run	May 1984	152	20	16420	0.27
Millstone Run	May 1984	15	280	22685	1.4
Surveyor Run	May 1984	18	350	34028	2.2
Bear Run	May 1984	2.2	600	7130	8.6
Unnamed Tributary at Lecontes Mills	May 1984	1.5	1100	8912	8
Unnamed Tributary near Lecontes Mills	May 1984	1.5	210	1701	0.49
Unnamed Tributary near Gallows Harbor	May 1984	0.99	120	642	0.29
Unnamed Tributary at Gallows Harbor (below RR Bridge)	May 1984	0.14	170	129	0.47
Unnamed Tributary at Gallows Harbor	May 1984	4.2	73	1656	0.29
Moravian Run	May 1984	61	52	17133	0.73
Unnamed Tributary at Gallows Harbor	May 1984	0.85	31	142	0.27
Unnamed Tributary at Coudley	May 1984	0.12	22	14	0.24
Deer Creek	May 1984	77	150	62384	0.98
Unnamed Tributary at Coudley	May 1984	2.3	540	6708	3.2
Unnamed Tributary near Fairview	May 1984	1.9	270	2771	0.66
Unnamed Tributary near Rolling Stone	May 1984	1	150	810	0.34
Big Run	May 1984	8.5	26	1194	0.46
Willholm Run	May 1984	2.5	19	257	0.34
Sandy Creek	May 1984	49	110	29113	1.6
Alder Run	May 1984	64	260	89876	10
Rolling Stone Run	May 1984	4.8	400	10370	6.2
Mowry Run	May 1984	3.9	110	2317	0.54
Basin Run	May 1984	11	290	17230	2.5
Rock Run	May 1984	7	710	26844	8.4
Potter Run	May 1984	6.4	1300	44938	20
Unnamed Tributary near Keewaydin	May 1984	0.76	1000	4105	17
Rupley Run	May 1984	2.8	260	3932	3
Moshannon Creek	May 1984	1160	150	939812	4.5
Redlick Run	May 1984	7.5	30	1215	1.8
Unnamed Tributary at Karthaus	May 1984	1.5	840	6806	8.1
Mosquito Creek	May 1984	251	36	48805	0.37
Laurel Run	May 1984	7.9	140	5974	3.6
Unnamed tributary near Karthaus	May 1984	0.72	290	1128	2.3
Saltlick Run	May 1984	12	610	39537	3.7
Unnamed Tributary at Belford	May 1984	2.2		0	2.1
Upper three Runs	May 1984	52	68	19099	0.36
Lower Three Runs	May 1984	27	54	7875	0.34
Sterling Run	May 1984	43		0	0.3
Loop Run	May 1984	10	490	26466	1.7
Grove Run	May 1984	13	44	3089	0.2
Unnamed tributary near Birch	May 1984	2	11	119	0.17
Sinnemahoning Creek	May 1984	3370	24	436851	0.32
Cooks Run	May 1984	48	80	20741	3.7
Milligan Run	May 1984	3.3	740	13190	
Smith Run	May 1984	6.1	21	692	0.26
North Smith Run	May 1984	1.3	71	499	0.44
Kettle Creek	May 1984	694	21	78717	0.66
Dry Run at Westport	May 1984	2.2	89	1058	0.39
Dry Run at Shintown	May 1984	0.56	12	36	0.35
Shintown Run	May 1984	13	13	913	0.19
Drury Run	May 1984	34	99	18181	0.22

Estimates of acid mine drainage loads in the West Branch Susquehanna River tributaries in 1984, based on Hainly and Barker (1993).					
TRIBUTARY	Fe Load (ppd)	Total Mn (mg/L)	Mn Load	Total Al (mg/L)	Al Load (ppd)
Anderson Creek	1267	1.2	1601	1.2	1601
Unnamed Tributary at Curwensville	1	0.03	0	0.2	1
Hartshorn Run	24	0.41	24	0.5	30
Unnamed Tributary at Susquehanna Bridge	20	4.6	137	2	59
Montgomery Creek	166	3.5	983	2.2	618
Moose Creek	128	2.3	484	1.2	253
Wolf Run	1119	37	739	10	200
Clearfield Creek	39688	1.7	15334	2.3	20746
Abes Run	73	27	700	21	544
Unnamed tributary at Bishtown	9	23	107	12	56
Lick Run	181	6.8	3159	0.6	279
Unnamed Tributary near Shawville	5	0.18	1	0.5	2
Devils Run	6	8.9	91	3	31
Unnamed Tributary at Shawville	3	0.07	0	0.1	0
Bloody Run	5	0.11	1	0.1	1
Trout Run	222	0.16	131	0.3	246
Millstone Run	113	4.9	397	3.6	292
Surveyor Run	214	7	681	6.4	622
Bear Run	102	23	273	13	154
Unnamed Tributary at Lecontes Mills	65	33	267	21	170
Unnamed Tributary near Lecontes Mills	4	3.6	29	2.8	23
Unnamed Tributary near Gallows Harbor	2	2.2	12	1	5
Unnamed Tributary at Gallows Harbor (below RR Bridge)	0	3.8	3	5.3	4
Unnamed Tributary at Gallows Harbor	7	3.1	70	2	45
Moravian Run	241	1	329	0.7	231
Unnamed Tributary at Gallows Harbor	1	0.29	1	0.5	2
Unnamed Tributary at Coudley	0	0.03	0		0
Deer Creek	408	3.4	1414	1.8	749
Unnamed Tributary at Coudley	40	20	248	21	261
Unnamed Tributary near Fairview	7	16	164	6.2	64
Unnamed Tributary near Rolling Stone	2	6	32	1.4	8
Big Run	21		0	0.1	5
Willholm Run	5	0.05	1	0.1	1
Sandy Creek	423	2.8	741	1.8	476
Alder Run	3457	4.6	1590	8.1	2800
Rolling Stone Run	161	9.3	241	10	259
Mowry Run	11	3.1	65	3.1	65
Basin Run	149	6.4	380	6.8	404
Rock Run	318	18	681	13	492
Potter Run	691	20	691	23	795
Unnamed Tributary near Keewaydin	70	14	57	18	74
Rupley Run	45	7.3	110	17	257
Moshannon Creek	28194	2.2	13784	3.5	21929
Redlick Run	73	0.34	14	0.3	12
Unnamed Tributary at Karthaus	66	4.9	40	8.6	70
Mosquito Creek	502	0.45	610	0.4	542
Laurel Run	154	4.9	209	2.9	124
Unnamed tributary near Karthaus	9	3	12	7.2	28
Saltlick Run	240	9.4	609	4.6	298
Unnamed Tributary at Belford	25	16	190	14	166
Upper three Runs	101	0.24	67	0.3	84
Lower Three Runs	50	0.65	95	0.5	73
Sterling Run	70	1.3	302	1	232
Loop Run	92	16	864	6.1	329
Grove Run	14	0.73	51	0.2	14
Unnamed tributary near Birch	2	0.05	1		0
Sinnemahoning Creek	5825	0.15	2730	0.5	9101
Cooks Run	959	0.92	239	4	1037
Milligan Run	0	12	214	29	517
Smith Run	9	0.01	0	0.5	16
North Smith Run	3	1.1	8	2	14
Kettle Creek	2474	0.27	1012	0.7	2624
Dry Run at Westport	5	1.5	18	2	24
Dry Run at Shintown	1	0.01	0	0.1	0
Shintown Run	13	0.02	1	0.1	7
Drury Run	40	3.1	569	2.3	422

Estimates of acid mine drainage loads in the West Branch Susquehanna River tributaries in 1984, based on Hainly and Barker (1993).

TRIBUTARY	Total Zn (mg/L)	Zn Load (ppd)			
Anderson Creek	0.08	107			
Unnamed Tributary at Curwensville	0.03	0			
Hartshorn Run	0.06	4			
Unnamed Tributary at Susquehanna Bridge	0.21	6			
Montgomery Creek	0.19	53			
Moose Creek	0.11	23			
Wolf Run	1.3	26			
Clearfield Creek	0.11	992			
Abes Run	1	26			
Unnamed tributary at Bishtown	9.3	43			
Lick Run	0.86	399			
Unnamed Tributary near Shawville	0.06	0			
Devils Run	0.29	3			
Unnamed Tributary at Shawville	0.03	0			
Bloody Run	0.05	1			
Trout Run	0.06	49			
Millstone Run	0.28	23			
Surveyor Run	0.41	40			
Bear Run	1	12			
Unnamed Tributary at Lecontes Mills	1.3	11			
Unnamed Tributary near Lecontes Mills	0.23	2			
Unnamed Tributary near Gallows Harbor	0.19	1			
Unnamed Tributary at Gallows Harbor (below RR Bridge)	0.52	0			
Unnamed Tributary at Gallows Harbor	0.26	6			
Moravian Run	0.12	40			
Unnamed Tributary at Gallows Harbor	0.16	1			
Unnamed Tributary at Coudley	0.06	0			
Deer Creek	0.17	71			
Unnamed Tributary at Coudley	0.88	11			
Unnamed Tributary near Fairview	0.52	5			
Unnamed Tributary near Rolling Stone	0.2	1			
Big Run	0.05	2			
Willholm Run	0.05	1			
Sandy Creek	0.15	40			
Alder Run	0.29	100			
Rolling Stone Run	0.79	20			
Mowry Run		0			
Basin Run	0.43	26			
Rock Run	0.78	29			
Potter Run	0.84	29			
Unnamed Tributary near Keewaydin	0.67	3			
Rupley Run	0.68	10			
Moshannon Creek	0.14	877			
Redlick Run	0.07	3			
Unnamed Tributary at Karthaus	0.31	3			
Mosquito Creek	0.08	108			
Laurel Run	0.2	9			
Unnamed tributary near Karthaus	0.22	1			
Saltlick Run	0.44	29			
Unnamed Tributary at Belford	0.65	8			
Upper three Runs	0.05	14			
Lower Three Runs	0.11	16			
Sterling Run	0.09	21			
Loop Run	0.61	33			
Grove Run		0			
Unnamed tributary near Birch	0.06	1			
Sinnemahoning Creek	0.02	364			
Cooks Run	0.11	29			
Milligan Run	9.6	171			
Smith Run	0.06	2			
North Smith Run	0.1	1			
Kettle Creek	0.04	150			
Dry Run at Westport	0.13	2			
Dry Run at Shintown	0.03	0			
Shintown Run	0.05	4			
Drury Run	0.15	28			

TRIBUTARY	DATE	FLOW (cfs)	SULFATE (mg/L)	SULFATE (ppd)	Total Fe (mg/L)
Brewery Run	May 1984	4.4	26	618	0.09
Cummulative loads from Anderson to Clearfield		358.78		155251	
Cumulative loads from Clearfild to Moshannon Creeks		597.51		472096	
Cumulative loads from Moshannon to Sinnemahoning Creeks		429.82		160113	
Cumulative loads from Sinnemahoning Cr. to Brewery Run		806.86		134643	
Cumulative loads from Anderson Creek to Brewery Run		8392.97		3561572	

TRIBUTARY	DATE	FLOW	SULFATE (mg/L)	SULFATE (ppd)	Total Fe (mg/L)
Anderson Creek	July 1984	48	87	22555	0.29
Unnamed Tributary at Curwensville	July 1984	0.01	36	2	0.54
Hartshorn Run	July 1984	2.3	56	696	0.22
Unnamed Tributary at Susquehanna Bridge	July 1984	1.4	630	4764	0.23
Montgomery Creek	July 1984	16	410	35432	0.59
Moose Creek	July 1984	6.5	170	5968	0.69
Wolf Run	July 1984	1.2	2100	13611	110
Clearfield Creek	July 1984	230	270	335416	0.86
Abes Run	July 1984	1.4	1300	9830	2.2
Unnamed tributary at Bishtown	July 1984	0.34	1300	2387	2.8
Lick Run	July 1984	20	84	9074	0.29
Unnamed Tributary near Shawville	July 1984	0.06	57	18	0.76
Devils Run	July 1984	0.22	340	404	0.54
Unnamed Tributary at Shawville	July 1984	0.16	140	121	0.48
Bloody Run	July 1984	0.6	390	1264	0.21
Trout Run	July 1984	26	38	5336	0.13
Millstone Run	July 1984	3.6	960	18667	1.4
Surveyor Run	July 1984	3.9	810	17062	2.8
Bear Run	July 1984	0.68	2300	8448	19
Unnamed Tributary at Lecontes Mills	July 1984	0.61	2100	6919	7.4
Unnamed Tributary near Lecontes Mills	July 1984	0.09	540	262	0.7
Unnamed Tributary near Gallows Harbor	July 1984	0.12	760	493	2.1
Unnamed Tributary at Gallows Harbor (below RR Bridge)	July 1984	0.18	360	350	0.39
Unnamed Tributary at Gallows Harbor	July 1984	0.24	350	454	0.1
Moravian Run	July 1984	6.2	120	4019	0.29
Unnamed Tributary at Gallows Harbor	July 1984	0.04	29	6	0.82
Unnamed Tributary at Coudley	July 1984			0	
Deer Creek	July 1984	14	380	28734	1.6
Unnamed Tributary at Coudley	July 1984	0.27	1500	2187	14
Unnamed Tributary near Fairview	July 1984	0.13	1200	843	0.49
Unnamed Tributary near Rolling Stone	July 1984	0.3	340	551	0.17
Big Run	July 1984	0.73	45	177	0.16
Willholm Run	July 1984	0.17	21	19	0.64
Sandy Creek	July 1984	8.7	490	23025	3.1
Alder Run	July 1984	7.7	850	35351	25
Rolling Stone Run	July 1984	1	970	5239	11
Mowry Run	July 1984	0.11	360	214	0.43
Basin Run	July 1984	1.9	770	7902	
Rock Run	July 1984	1.6	1800	15556	10
Potter Run	July 1984	2.3	2400	29815	20
Unnamed Tributary near Keewaydin	July 1984	0.16	2100	1815	16
Rupley Run	July 1984	0.35	670	1267	3
Moshannon Creek	July 1984	192	360	373332	3.1
Redlick Run	July 1984	0.77	110	457	8.5
Unnamed Tributary at Karthaus	July 1984	0.57	1500	4618	8.4
Mosquito Creek	July 1984	38	93	19088	0.17
Laurel Run	July 1984	0.74	590	2358	5.6
Unnamed tributary near Karthaus	July 1984	0.3	1400	2269	0.57
Saltlick Run	July 1984	3.8	1400	28734	3.7
Unnamed Tributary at Belford	July 1984	0.26	740	1039	1.1
Upper Three Runs	July 1984	9.5	160	8210	0.12
Lower Three Runs	July 1984	4.9	140	3705	0.13

TRIBUTARY	Fe Load (ppd)	Total Mn (mg/L)	Mn Load	Total Al (mg/L)	Al Load (ppd)
Brewery Run	2	0.03	1		0
Cumulative loads from Anderson to Clearfield	2727		3969		2761
Cumulative loads from Clearfild to Moshannon Creeks	7058		12671		9418
Cumulative loads from Moshannon to Sinnemahoning Creeks	1396		3064		1973
Cumulative loads from Sinnemahoning Cr. to Brewery Run	3506		2062		4662
Cumulative loads from Anderson Creek to Brewery Run	88394		53614		70590

TRIBUTARY	Fe Load (ppd)	Total Mn (mg/L)	Mn Load	Total Al (mg/L)	Al Load (ppd)
Anderson Creek	75	2.1	544	1.8	467
Unnamed Tributary at Curwensville	0	0.01	0		0
Hartshorn Run	3	0.75	9	0.3	4
Unnamed Tributary at Susquehanna Bridge	2	8.9	67	0.2	2
Montgomery Creek	51	10	864	5.1	441
Moose Creek	24	5.5	193	2.6	91
Wolf Run	713	79	512	22	143
Clearfield Creek	1068	3.7	4596	2.4	2981
Abes Run	17	34	257	24	181
Unnamed tributary at Bishtown	5	42	77	25	46
Lick Run	31	1.5	162	1	108
Unnamed Tributary near Shawville	0	0.08	0		0
Devils Run	1	11	13	2.1	2
Unnamed Tributary at Shawville	0	0.03	0	0.2	0
Bloody Run	1	0.03	0	0.3	1
Trout Run	18	0.31	44	0.5	70
Millstone Run	27	14	272	5.9	115
Surveyor Run	59	15	316	21	442
Bear Run	70	72	264	38	140
Unnamed Tributary at Lecontes Mills	24	48	158	30	99
Unnamed Tributary near Lecontes Mills	0	9	4	5.7	3
Unnamed Tributary near Gallows Harbor	1	25	16	22	14
Unnamed Tributary at Gallows Harbor (below RR Bridge)	0	8.7	8	12	12
Unnamed Tributary at Gallows Harbor	0	20	26	13	17
Moravian Run	10	2.7	90	1.4	47
Unnamed Tributary at Gallows Harbor	0	0.25	0	0.6	0
Unnamed Tributary at Coudley	0		0		0
Deer Creek	121	9.1	688	3.3	250
Unnamed Tributary at Coudley	20	53	77	49	71
Unnamed Tributary near Fairview	0	60	42	14	10
Unnamed Tributary near Rolling Stone	0	15	24	6	10
Big Run	1		0	0.2	1
Willholm Run	1	0.06	0	0.2	0
Sandy Creek	146	11	517		0
Alder Run	1040	13	541	18	749
Rolling Stone Run	59	19	103	22	119
Mowry Run	0	15	9	13	8
Basin Run	0	13	133	12	123
Rock Run	86	36	311	22	190
Potter Run	248	28	348	30	373
Unnamed Tributary near Keewaydin	14	23	20	25	22
Rupley Run	6	15	28	36	68
Moshannon Creek	3215	5.3	5496	25	25926
Redlick Run	35	2.2	9	0.4	2
Unnamed Tributary at Karthaus	26	5.9	18	13	40
Mosquito Creek	35	1.3	267	0.3	62
Laurel Run	22	27	108	6.3	25
Unnamed tributary near Karthaus	1	6.5	11	11	18
Saltlick Run	76	22	452	6.4	131
Unnamed Tributary at Belford	2	27	38	24	34
Upper Three Runs	6	0.46	24		0
Lower Three Runs	3	2.3	61	1.2	32

TRIBUTARY	Total Zn (mg/L)	Zn Load (ppd)			
Brewery Run	0.03	1			
Cumulative Loads from Anderson to Clearfield Creeks		219			
Cumulative loads from Clearfild to Moshannon Creeks		1005			
Cumulative loads from Moshannon to Sinnemahoning Creeks		244			
Cumulative loads from Sinnemahoning Cr. to Brewery Run		386			
Cumulative loads from Anderson Creek to Brewery Run		4087			
TRIBUTARY	Total Zn (mg/L)	Zn Load (ppd)			
Anderson Creek	0.12	31			
Unnamed Tributary at Curwensville	0.08	0			
Hartshorn Run	0.08	1			
Unnamed Tributary at Susquehanna Bridge	0.3	2			
Montgomery Creek	0.3	26			
Moose Creek	0.17	6			
Wolf Run	2.6	17			
Clearfield Creek	0.15	186			
Abes Run	1.3	10			
Unnamed tributary at Bishtown	1.4	3			
Lick Run	0.06	6			
Unnamed Tributary near Shawville	0.03	0			
Devils Run	0.13	0			
Unnamed Tributary at Shawville	0.03	0			
Bloody Run	0.05	0			
Trout Run		0			
Millstone Run	0.61	12			
Surveyor Run	0.6	13			
Bear Run	2.8	10			
Unnamed Tributary at Lecontes Mills	1.9	6			
Unnamed Tributary near Lecontes Mills	0.43	0			
Unnamed Tributary near Gallows Harbor	1.1	1			
Unnamed Tributary at Gallows Harbor (below RR Bridge)	0.88	1			
Unnamed Tributary at Gallows Harbor	1.3	2			
Moravian Run	0.11	4			
Unnamed Tributary at Gallows Harbor	0.09	0			
Unnamed Tributary at Coudley		0			
Deer Creek	0.31	23			
Unnamed Tributary at Coudley	1.8	3			
Unnamed Tributary near Fairview	1.3	1			
Unnamed Tributary near Rolling Stone	0.43	1			
Big Run	0.02	0			
Willholm Run	0.04	0			
Sandy Creek	0.32	15			
Alder Run	0.67	28			
Rolling Stone Run	0.94	5			
Mowry Run	0.41	0			
Basin Run	0.65	7			
Rock Run	1.2	10			
Potter Run	1	12			
Unnamed Tributary near Keewaydin	0.85	1			
Rupley Run	1.3	2			
Moshannon Creek	0.28	290			
Redlick Run	0.06	0			
Unnamed Tributary at Karthaus	0.37	1			
Mosquito Creek	0.07	14			
Laurel Run	0.63	3			
Unnamed tributary near Karthaus	0.32	1			
Saltlick Run	0.89	18			
Unnamed Tributary at Belford	0.91	1			
Upper Three Runs	0.04	2			
Lower Three Runs	0.17	4			

TRIBUTARY	DATE	FLOW	SULFATE (mg/L)	SULFATE (ppd)	Total Fe (mg/L)
Sterling Run	July 1984	8	90	3889	0.14
Loop Run	July 1984	1.9	1900	19498	1.2
Grove Run	July 1984	0.23	110	137	0.08
Unnamed tributary near Birch	July 1984			0	
Sinnemahoning Creek	July 1984	331	49	87602	0.18
Cooks Run	July 1984	36	160	31111	6.3
Milligan Run	July 1984	3.7	930	18586	6.3
Smith Run	July 1984	3.7	7	140	0.14
North Smith Run	July 1984	0.61	360	1186	0.42
Kettle Creek	July 1984	269	72	104611	2.4
Dry Run at Westport	July 1984	0.71	170	652	0.09
Dry Run at Shintown	July 1984	0.02	13	1	0.27
Shintown Run	July 1984	7.4	16	640	0.16
Drury Run	July 1984	30	180	29167	0.2
Brewery Run	July 1984	1.6	30	259	0.08
Cumulative loads from Anderson to Clearfield Creeks		27.41		60473	
Cumulative loads from Clearfield to Moshannon Creeks		103.86		237810	
Cumulative loads from Moshannon to Sinnemahoning Creeks		68.97		94003	
Cumulative loads from Sinnemahoning Cr. to Brewery Run		352.74		186352	
Cumulative loads from Anderson Creek to Brewery Run		1353.98		1367478	

TRIBUTARY	Fe Load (ppd)	Total Mn (mg/L)	Mn Load	Total Al (mg/L)	Al Load (ppd)
Sterling Run	6	3.1	134	1.7	73
Loop Run	12	55	564	22	226
Grove Run	0	0.71	1	0.2	0
Unnamed tributary near Birch	0		0		0
Sinnemahoning Creek	322	0.27	483	0.1	179
Cooks Run	1225	2.1	408	5	972
Milligan Run	126	16	320	9	180
Smith Run	3	0.01	0		0
North Smith Run	1	5	16	8	26
Kettle Creek	3487	1.5	2179	1.8	2615
Dry Run at Westport	0	2.5	10	2.1	8
Dry Run at Shintown	0	0.02	0		0
Shintown Run	6	0.02	1		0
Drury Run	32	6	972	3.5	567
Brewery Run	1	0.01	0		0
Cumulative loads from Anderson to Clearfield Creeks	868		1646		680
Cumulative loads from Clearfield to Moshannon Creeks	2009		4551		3290
Cumulative loads from Moshannon to Sinnemahoning Creeks	225		1686		643
Cumulative loads from Sinnemahoning Cr. to Brewery Run	4882		3907		4369
Cumulative loads from Anderson Creek to Breweru Run	12549		21936		37967

TRIBUTARY	Total Zn (mg/L)	Zn Load (ppd)			
Sterling Run	0.16	7			
Loop Run	2.2	23			
Grove Run	0.14	0			
Unnamed tributary near Birch		0			
Sinnemahoning Creek	0.02	36			
Cooks Run	0.21	41			
Milligan Run	1	20			
Smith Run	0.02	0			
North Smith Run	0.32	1			
Kettle Creek	0.09	131			
Dry Run at Westport	0.18	1			
Dry Run at Shintown	0.02	0			
Shintown Run	0.03	1			
Drury Run	0.22	36			
Brewery Run	0.034	0			
Cumulative loads from Anderson to Clearfield Creeks		52			
Cumulative loads from Clearfield to Moshannon Creeks		176			
Cumulative loads from Moshannon to Sinnemahoning Creeks		75			
Cumulative loads from Sinnemahoning Cr. to Brewery Run		231			
Cumulative loads from Anderson Creek to Brewery Run		1040			

APPENDIX III

SOURCES OF MINE DRAINAGE AND ASSOCIATED CONTAMINANT LOADS IN THE BITUMINOUS COAL FIELDS OF WEST VIRGINIA AND MARYLAND NORTH BRANCH POTOMAC RIVER DRAINAGE

Sources of mine drainage in the North Branch Potomac River watershed upstream from Jennings Randolph Lake, based on study conducted by Morgan Mining and Environmental Consultants, LTD (1994). Site numbers refer to figure 7 in text

Site Number	Source of Mine Drainage	Sub-watershed Affected	Latitude Coordinates			Longitude Coordinates		
301	underground mine refuse piles	Unnamed	39	12	36	79	28	38
302	surface mine	Fairfax Run	39	11	37	79	29	5
303	Davis Coal and Coke No. 42 mine	Laurel Run	39	13	156	79	28	51
304	surface mine	Laurel Run	39	13	37	79	28	52
305		Laurel Run						
306	reclaimed surface mine	Shields Run	39	18	38	79	23	42
307	two surface mines	Shields Run	39	17	25	79	25	12
308	underground mine	Glade Run	39	18	30	79	19	51
309	underground mine	Steyer Run	39	19	2	79	18	29
310		Stony River						
311	surface mine	Stony River	39	7	33	79	16	56
312	two surface mines	Stony River	39	12	13	79	17	11
313		Stony River						
314	loading facility/refuse piles	Stony River	39	12	57	79	18	55
315	underground mine	Stony River	39	17	29	79	14	40
316	underground mine	Laurel Run	39	22	5	79	18	8
317	underground mine(reclamed)	Lostland Run	39	23	5	79	16	48
318	underground mine collapsed draining entry	Lostland Run	39	22	50	79	15	59
319	surface mine reclamation project	Lostland Run/Wolfton Run	39	25	4	79	15	12
320	surface mine	Lostland Run	39	24	12	79	16	15
321	surface mine	Lostland Run	39	23	16	79	15	35
322	surface mine	Abram Cr.	39	11	58	79	13	24
323	surface mine	Abram Cr.	39	13	53	79	13	46
324	refuse pile	Abram Cr	39	12	39	79	13	17
325	surface mine	Abram Cr.	39	15	20	79	13	20
326		Abram Cr						
327	remined abandoned surface mine	Abram Cr.	39	16	33	79	11	3
328	surface mine	Abram Cr.	39	18	14	79	9	51
329	underground mine	Abram Cr.	39	18	33	79	11	3
330	underground mine complex	Abram Cr.	39	18	15	79	11	39
331	surface and underground mines	Abram Cr	39	18	34	79	11	48
332	underground mine	Abram Cr.	39	18	15	79	11	39
333	underground mines and refuse piles	Abram Cr	39	19	17	79	8	25
334	underground mines and refuse piles	Abram Cr.	39	19	17	79	8	25
335	Surface and underground mines	Abram Cr	39	21	12	79	9	49
336	Shallmar Mines	Shallmar Disch.	39	22	49	79	12	20
337	surface mine	Wolfden Run	39	23	37	79	12	0
338	Hammil Mines (underground)	Kitzmiller Disch.	39	23	57	79	10	50
339		Unnamed						
340	underground mine	Disch. to River	39	23	43	79	10	7
341	underground and surface mine	Three Forks Run	39	25	29	79	11	48
342	underground mine	Three Forks Run	39	26	12	79	11	57
343	surface and deep mines linked to #45	Three Forks Run	39	24	55	79	11	35
344	underground mine	Three Forks Run	39	24	49	79	13	1
345	surface and deep mines linked to #43	Three Forks Run	39	24	55	79	11	35
346	underground mine	Three Forks Run	39	24	55	79	10	33
347	surface mine	Deep Run	39	23	8	79	8	0

Sources of mine drainage in the North Branch Potomac River watershed upstream from Jennings Randolph Lake, based on study conducted by Morgan Mining and Environmental Consultants, LTD (1994). Site numbers refer to figure 7 in text

Site Number	Source of Mine Drainage	Sub-watershed Affected	Latitude Coordinates			Longitude Coordinates		
348	underground mines	Deep Run	39	23	37	79	7	43
349	underground/surface mine	Deep Run	39	23	49	79	8	27
350	surface and underground mine	Elklick Run	39	26	53	79	11	5
351	surface and underground mine	Elklick Run	39	26	37	79	10	17
352	surface and underground mine	Elklick Run	39	26	27	79	9	16

Sources of acid mine drainage and associated pollution loads during low flow conditions in the North Branch Potomac River watershed upstream from Jennings Randolph Lake.

Site number refers to figure 7 in text.

Site Number	Watershed	Flow Condition	Date of Sampling	Flow (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
301	Unnamed	Low Flow	JUNE-OCT. 1988	0.701	4	181	3	4	1
302	Fairfax Run	Low Flow	JUNE-OCT. 1988	0.236	19	323	0	3	1
	Fairfax Run	Low Flow	JUNE-OCT. 1988	0.057	0	41	0	0	0
303	Laurel Run	Low Flow	JUNE-OCT. 1988	1.234	2702	2809	457	28	149
	Laurel Run	Low Flow	JUNE-OCT. 1988	0.75	566	854	114	10	39
304	Laurel Run	Low Flow	JUNE-OCT. 1988						
305	Laurel Run	Low Flow	JUNE-OCT. 1988	0.44	50	406	0	10	5
306	Shields Run	Low Flow	JUNE-OCT. 1988	0.007	1	8	0	0	0
307	Shields Run	Low Flow	JUNE-OCT. 1988	0.579	47	272	8	4	2
308	Glade Run	Low Flow	JUNE-OCT. 1988	0.005	1	8	0	0	0
309	Steyer Run	Low Flow	JUNE-OCT. 1988	0.005	1	4	0	0	0
310	Stony River	Low Flow	JUNE-OCT. 1988	0.01	10	35	1	2	1
311	Stony River	Low Flow	JUNE-OCT. 1988	0.463	40	100	1	2	2
312	Stony River	Low Flow	JUNE-OCT. 1988						
313	Stony River	Low Flow	JUNE-OCT. 1988	0.132	308	692	66	17	24
314	Stony River	Low Flow	JUNE-OCT. 1988						
315	Stony River	Low Flow	JUNE-OCT. 1988						
316	Laurel Run	Low Flow	JUNE-OCT. 1988	0.03	1	23	0	0	0
316	Lostland Run	Low Flow	JUNE-OCT. 1988	0.04	2	133	0	0	0
	Lostland Run	Low Flow	JUNE-OCT. 1988	0.01	1	35	0	0	0
318	Lostland Run	Low Flow	JUNE-OCT. 1988	0.035	0	48	1	0	0
319	Lostland Run	Low Flow	JUNE-OCT. 1988	0.044	21	16	1	0	1
	Wolfden Run	Low Flow	JUNE-OCT. 1988	0.173	15	18	0	1	2
320	Lostland Run	Low Flow	JUNE-OCT. 1988	0.002	0	1	0	0	0
321	Lostland Run	Low Flow	JUNE-OCT. 1988						
322	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.406	361	2321	51	36	12
	Abram Cr	Low Flow	JUNE-OCT. 1988	0.258	156	404	5	12	12
	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.007	0	35	1	0	0
	Stony River	Low Flow	JUNE-OCT. 1988	0.22	148	399	5	7	14
323	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.076	425	951	12	24	66
324	Abram Cr	Low Flow	JUNE-OCT. 1988						
325	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.243	460	1520	32	37	56
326	Abram Cr	Low Flow	JUNE-OCT. 1988						
327	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.031	87	644	0	28	15
	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.031	29	269	0	8	4
	Abram Cr	Low Flow	JUNE-OCT. 1988						
328	Abram Cr.	Low Flow	JUNE-OCT. 1988						
	Abram Cr	Low Flow	JUNE-OCT. 1988	0.13	194	778	66	14	0
	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.86	5	580	7	2	1

Sources of acid mine drainage and associated pollution loads during low flow conditions in the North Branch Potomac River watershed upstream from Jennings Randolph Lake.

Site Number	Watershed	Flow Condition	Date of Sampling	Flow (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
329	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.067	37	150	2	1	2
	Abram Cr	Low Flow	JUNE-OCT. 1988	0.175	162	982	26	11	10
330	Abram Cr.	Low Flow	JUNE-OCT. 1988						
	Abram Cr	Low Flow	JUNE-OCT. 1988						
	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.013	18	82	4	0	1
332	Abram Cr.	Low Flow	JUNE-OCT. 1988						
333	Abram Cr	Low Flow	JUNE-OCT. 1988						
334	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.02	55	120	20	2	2
335	Abram Cr	Low Flow	JUNE-OCT. 1988	0.045	13	154	0	2	1
	Abram Cr.	Low Flow	JUNE-OCT. 1988	0.22	61	1305	0	21	8
	Abram Cr.	Low Flow	JUNE-OCT. 1988						
336	Shallmar Disch.	Low Flow	JUNE-OCT. 1988	0.8	682	2529	6	6	100
	Shallmar Disch.	Low Flow	JUNE-OCT. 1988	0.6	638	1819	4	5	61
337	Wolfden Run	Low Flow	JUNE-OCT. 1988	1.087	59	41	0	1	2
	Wolfden Run	Low Flow	JUNE-OCT. 1988	0.147	8	13	2	0	1
	Wolfden Run	Low Flow	JUNE-OCT. 1988	0.308	7	17	0	0	0
	Wolfden Run	Low Flow	JUNE-OCT. 1988	0.1	24	156	0	0	3
338	Kitzmiller Disch.	Low Flow	JUNE-OCT. 1988	0.486	1054	1751	56	4	111
	Kitzmiller Disch.	Low Flow	JUNE-OCT. 1988	0.09	195	500	6	1	23
339	Unnamed	Low Flow	JUNE-OCT. 1988	0.146	150	657	0	23	20
340	Disch. to River	Low Flow	JUNE-OCT. 1988	0.2	1	523	0	0	0
341	Three Forks Run	Low Flow	JUNE-OCT. 1988						
342	Three Forks Run	Low Flow	JUNE-OCT. 1988	0.15	66	472	63	2	0
343	Three Forks Run	Low Flow	JUNE-OCT. 1988						
	Three Forks Run	Low Flow	JUNE-OCT. 1988	0.316	97	280	0	3	11
344	Three Forks Run	Low Flow	JUNE-OCT. 1988	0.026	28	62	1	0	3
345	Three Forks Run	Low Flow	JUNE-OCT. 1988						
	Three Forks Run	Low Flow	JUNE-OCT. 1988	0.52	6852	3702	595	7	196
346	Three Forks Run	Low Flow	JUNE-OCT. 1988	0.31	2	676	13	2	20
	Three Forks Run	Low Flow	JUNE-OCT. 1988	0.067	0	59	0	0	0
347	Deep Run	Low Flow	JUNE-OCT. 1988						
	Deep Run	Low Flow	JUNE-OCT. 1988						
348	Deep Run	Low Flow	JUNE-OCT. 1988						
349	Deep Run	Low Flow	JUNE-OCT. 1988						
	Deep Run	Low Flow	JUNE-OCT. 1988						
350	Elklick Run	Low Flow	JUNE-OCT. 1988						
	Elklick Run	Low Flow	JUNE-OCT. 1988						
351	Elklick Run	Low Flow	JUNE-OCT. 1988						
352	Elklick Run	Low Flow	JUNE-OCT. 1988						

Sources of acid mine drainage and associated pollution loads during high flow conditions in the North Branch Potomac River watershed upstream from Jennings Randolph Lake.

Site Number	Watershed	Flow Condition	Date	Flow (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
301	Unnamed	High Flow	MARCH-APR. 1989	5.707	0	739	6	8	12
302	Fairfax Run	High Flow	MARCH-APR. 1989						
	Fairfax Run	High Flow	MARCH-APR. 1989	0.135	10	25	0	0	1
303	Laurel Run	High Flow	MARCH-APR. 1989	6.969	4548	6015	455	86	387
	Laurel Run	High Flow	MARCH-APR. 1989						
304	Laurel Run	High Flow	MARCH-APR. 1989	1.316	64	64	9	1	5
305	Laurel Run	High Flow	MARCH-APR. 1989	1.583	60	862	10	21	21

Sources of acid mine drainage and associated pollution loads during high flow conditions in the North Branch Potomac River watershed upstream from Jennings Randolph Lake.

Site Number	Watershed	Flow Condition	Date	Flow (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
306	Shields Run	High Flow	MARCH-APR. 1989						
307	Shields Run	High Flow	MARCH-APR. 1989	2.096	113	57	4	4	5
308	Glade Run	High Flow	MARCH-APR. 1989	0.245	9	98	0	1	1
309	Steyer Run	High Flow	MARCH-APR. 1989	1.284	0	90	2	0	1
310	Stony River	High Flow	MARCH-APR. 1989	0.057	75	232	9	11	5
311	Stony River	High Flow	MARCH-APR. 1989	15.238	1069	1726	28	36	61
312	Stony River	High Flow	MARCH-APR. 1989	1.793	271	1267	6	9	33
313	Stony River	High Flow	MARCH-APR. 1989	4.33	1615	4400	283	80	172
314	Stony River	High Flow	MARCH-APR. 1989	0.645	2689	3044	623	4	109
315	Stony River	High Flow	MARCH-APR. 1989	0.625	7	233	1	1	1
316	Laurel Run	High Flow	MARCH-APR. 1989	0.081	0	37	0	0	0
317	Lostland Run	High Flow	MARCH-APR. 1989						
	Lostland Run	High Flow	MARCH-APR. 1989						
318	Lostland Run	High Flow	MARCH-APR. 1989	0.139	0	246	1	1	0
319	Lostland Run	High Flow	MARCH-APR. 1989						
	Wolfden Run	High Flow	MARCH-APR. 1989	1.162	75	150	0	4	9
320	Lostland Run	High Flow	MARCH-APR. 1989	0.007	0	3	0	0	0
321	Lostland Run	High Flow	MARCH-APR. 1989	0.005	2	4	0	0	0
322	Abram Cr.	High Flow	MARCH-APR. 1989	5.69	859	7151	229	103	52
	Abram Cr	High Flow	MARCH-APR. 1989						
	Abram Cr.	High Flow	MARCH-APR. 1989	0.009	5	11	0	0	0
	Stony River	High Flow	MARCH-APR. 1989	7.243	4415	5391	750	91	582
323	Abram Cr.	High Flow	MARCH-APR. 1989	2.257	3859	9545	59	226	623
324	Abram Cr	High Flow	MARCH-APR. 1989						
325	Abram Cr.	High Flow	MARCH-APR. 1989	3.44	1744	4249	126	109	249
326	Abram Cr	High Flow	MARCH-APR. 1989						
327	Abram Cr.	High Flow	MARCH-APR. 1989	0.915	1283	8356	0	278	175
	Abram Cr.	High Flow	MARCH-APR. 1989	0.115	1302	4348	6	189	234
	Abram Cr	High Flow	MARCH-APR. 1989	1.455	16	1099	1	19	11
328	Abram Cr.	High Flow	MARCH-APR. 1989	12.205	1185	4016	273	53	11
	Abram Cr	High Flow	MARCH-APR. 1989						
	Abram Cr.	High Flow	MARCH-APR. 1989						
329	Abram Cr.	High Flow	MARCH-APR. 1989	0.366	120	367	29	4	8
	Abram Cr	High Flow	MARCH-APR. 1989	0.453	303	1266	50	13	15
330	Abram Cr.	High Flow	MARCH-APR. 1989						
331	Abram Cr	High Flow	MARCH-APR. 1989						
	Abram Cr.	High Flow	MARCH-APR. 1989						
332	Abram Cr.	High Flow	MARCH-APR. 1989						
333	Abram Cr	High Flow	MARCH-APR. 1989	8.601	371	2320	6	25	19
334	Abram Cr.	High Flow	MARCH-APR. 1989						
335	Abram Cr	High Flow	MARCH-APR. 1989	0.96	114	445	10	8	10
	Abram Cr.	High Flow	MARCH-APR. 1989	3.088	200	2199	4	33	16
	Abram Cr.	High Flow	MARCH-APR. 1989	0.159	14	85	1	0	2
336	Shallmar Disch.	High Flow	MARCH-APR. 1989	0.851	441	1161	21	2	54
	Shallmar Disch.	High Flow	MARCH-APR. 1989						
337	Wolfden Run	High Flow	MARCH-APR. 1989	7.25	156	274	0	5	13
	Wolfden Run	High Flow	MARCH-APR. 1989						
	Wolfden Run	High Flow	MARCH-APR. 1989	1.402	23	98	8	2	3
	Wolfden Run	High Flow	MARCH-APR. 1989	0.158	4	207	0	0	2

Sources of acid mine drainage and associated pollution loads during high flow conditions in the North Branch Potomac River watershed upstream from Jennings Randolph Lake.

Site Number	Watershed	Flow Condition	Date	Flow (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
338	Kitzmiller Disch.	High Flow	MARCH-APR. 1989	2.716	3706	7574	214	13	374
	Kitzmiller Disch.	High Flow	MARCH-APR. 1989	0.42	881	2401	37	3	109
339	Unnamed	High Flow	MARCH-APR. 1989	2.246	2072	4894	223	126	250
340	Disch. to River	High Flow	MARCH-APR. 1989	0.361	0	621	1	0	1
341	Three Forks Run	High Flow	MARCH-APR. 1989	5.962	1319	3827	7	31	196
342	Three Forks Run	High Flow	MARCH-APR. 1989	1	475	3150	387	15	2
343	Three Forks Run	High Flow	MARCH-APR. 1989	3.359	91	580	39	2	28
	Three Forks Run	High Flow	MARCH-APR. 1989	4.286	254	902	7	5	36
344	Three Forks Run	High Flow	MARCH-APR. 1989	0.349	157	298	14	1	11
345	Three Forks Run	High Flow	MARCH-APR. 1989	0.298	56	68	4	0	2
	Three Forks Run	High Flow	MARCH-APR. 1989	1.161	2254	3570	302	6	204
346	Three Forks Run	High Flow	MARCH-APR. 1989	0.33	61	393	1	2	8
	Three Forks Run	High Flow	MARCH-APR. 1989						
347	Deep Run	High Flow	MARCH-APR. 1989	10.152	55	4983	21	8	47
	Deep Run	High Flow	MARCH-APR. 1989	0.583	0	299	7	0	3
348	Deep Run	High Flow	MARCH-APR. 1989	0.587	73	516	1	2	8
349	Deep Run	High Flow	MARCH-APR. 1989	0.01	0	2	0	0	0
	Deep Run	High Flow	MARCH-APR. 1989	0.937	5	2421	2	1	1
350	Elklick Run	High Flow	MARCH-APR. 1989	3.982	387	2083	9	26	31
	Elklick Run	High Flow	MARCH-APR. 1989	1.557	101	109	1	2	6
351	Elklick Run	High Flow	MARCH-APR. 1989	0.006	2	6	0	0	0
352	Elklick Run	High Flow	MARCH-APR. 1989	0.36	1004	1303	127	3	55

Tributaries and associated mine drainage loads in the North Branch Potomac River upstream from Jennings Randolph Lake, based on Morgan Mining and Environmental Consultants (1994).

WSID Number	Tributary	Flow Condition	Date	Discharge (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
1	Unnamed Trib WV	Low Flow	JUNE-OCT. 1988	0.52	2.8	89.76	1.54	0.79	0.53
		High Flow	MARCH-APR. 1989	4.242	160.17	640.68	9.38	10.53	22.19
2	Unnamed Trib.	Low Flow	JUNE-OCT. 1988	0.105	0.57	9.63	0.1	0.01	0.11
		High Flow	MARCH-APR. 1989	0.858	0	78.68	0.65	0.09	0
3	Fairfax Run WV	Low Flow	JUNE-OCT. 1988	0.539	2.91	26.17	0.35	0.03	0.44
		High Flow	MARCH-APR. 1989	7.373	39.77	2187.35	21.48	19.09	4.77
4	Unnamed Trib.	Low Flow	JUNE-OCT. 1988	0.174	1.88	33.79	0.61	0.21	0.15
		High Flow	MARCH-APR. 1989	1.414	15.25	45.76	1.98	0.15	0
5	Unnamed Trib.	Low Flow	JUNE-OCT. 1988	0.105	0.57	11.33	0.39	0.08	0.17
		High Flow	MARCH-APR. 1989	0.859	0	27.8	0.65	0.05	0
6	Unnamed Trib.	Low Flow	JUNE-OCT. 1988	0.074	0.4	8.38	0.51	0.07	0.11
		High Flow	MARCH-APR. 1989	0.606	6.54	19.61	0.46	0.07	0.78
7	Wilsonia Run	Low Flow	JUNE-OCT. 1988	0.961	5.18	77.75	1.09	0.1	0.57
		High Flow	MARCH-APR. 1989	7.827	0	295.53	5.07	0.84	0
8	Unnamed Trib.	Low Flow	JUNE-OCT. 1988	0.465	22.57	102.84	1.86	2.43	0.53
		High Flow	MARCH-APR. 1989	1.673	27.07	72.19	1.9	0.63	0
9	Deakin Run	Low Flow	JUNE-OCT. 1988	2.778	134.86	11328.31	52.15	10.79	8.39
		High Flow	MARCH-APR. 1989	22.624	0	62725.4	146.44	15.86	84.2
10	Elk Run	Low Flow	JUNE-OCT. 1988	0.682	3.68	643.77	2.1	2.76	4.12
		High Flow	MARCH-APR. 1989	5.555	119.85	1348.37	30.86	8.99	21.57
11	Unnamed Trib.	Low Flow	JUNE-OCT. 1988	0.136	1.47	24.21	0.05	0.01	0.07
		High Flow	MARCH-APR. 1989	1.111	0	53.93	0	0	0
12	Unnamed Trib.	Low Flow	JUNE-OCT. 1988	0.173	0.93	23.33	0.16	0.01	0.12
		High Flow	MARCH-APR. 1989	1.414	0	160.17	9.99	0.15	7.86
13	Dobbin Run	Low Flow	JUNE-OCT. 1988	0.62	3.34	133.77	0.33	0.03	0.33
		High Flow	MARCH-APR. 1989	5.05	0	408.6	3.27	0.27	4.9
14	Laurel Run MD	Low Flow	JUNE-OCT. 1988	7.043	2925.23	3077.19	145.5	71.8	289.86
		High Flow	MARCH-APR. 1989	22.936	6433.27	11381.94	504.76	131.14	551.78
15	Unnamed	Low Flow	JUNE-OCT. 1988	0.087	1.88	6.1	0.02	0	0.05
		High Flow	MARCH-APR. 1989	0.312	3.37	15.15	0.2	0.02	0
16	Unnamed	Low Flow	JUNE-OCT. 1988	0.099	0.53	28.3	0.03	0.01	0.12
		High Flow	MARCH-APR. 1989	0.808	4.36	82.81	1.35	0.04	0.83
17	Sand Run MD	Low Flow	JUNE-OCT. 1988	2.313	12.48	6125.87	5.36	17.47	3.37
		High Flow	MARCH-APR. 1989	18.837	0	37797.72	25.4	70.11	27.43
18	Red Oak Cr.	Low Flow	JUNE-OCT. 1988	2.077	11.2	425.73	0.9	0.11	1.12
		High Flow	MARCH-APR. 1989	16.917	0	2098.76	22.81	1.83	20.08
19	Unnamed	Low Flow	JUNE-OCT. 1988	0.434	2.34	37.46	14.49	0.19	10.65
		High Flow	MARCH-APR. 1989	3.535	19.07	133.47	6.67	0.19	6.48
20	Unnamed	Low Flow	JUNE-OCT. 1988	0.242	1.31	15.66	0.6	0.03	0.39
		High Flow	MARCH-APR. 1989	0.87	0	61.01	1.55	0.19	0.99
21	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	1.01	0	65.38	3.43	0.16	1.91
22	Shields	Low Flow	JUNE-OCT. 1988	3.001	16.19	809.37	38.69	3.08	11.33
		High Flow	MARCH-APR. 1989	10.793	116.43	989.7	25.62	5.82	13.39
23	Unnamed	Low Flow	JUNE-OCT. 1988	0.763	4.12	135.82	1.61	0.08	0.78
		High Flow	MARCH-APR. 1989	6.212	0	301.57	5.03	0.34	3.69
24	Buffalo Cr. WV	Low Flow	JUNE-OCT. 1988	4.086	22.04	2865.18	9.92	10.58	20.5
		High Flow	MARCH-APR. 1989	52.428	565.59	4524.75	124.43	19.8	144.23

Tributaries and associated mine drainage loads in the North Branch Potomac River upstream from Jennings Randolph Lake, based on Morgan Mining and Environmental Consultants (1994).

WSID Number	Tributary	Flow Condition	Date	Discharge (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
25	Unnamed	Low Flow	JUNE-OCT. 1988	0.177	0.95	33.42	0.53	0.02	0.34
		High Flow	MARCH-APR. 1989	1.436	0	92.95	1.55	0.08	1.16
26	Discharge to River	Low Flow	JUNE-OCT. 1988	0.005	0.03	1.83	0	0	0
		High Flow	MARCH-APR. 1989	0.169	0	14.59	0.13	0.01	0.09
27	Unnameed	Low Flow	JUNE-OCT. 1988	0.254	1.37	56.17	0.88	0.34	2.53
		High Flow	MARCH-APR. 1989	2.067	0	44.6	2.01	0.45	2.12
28	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	1.556	16.79	58.75	0.5	0	0
29	Nydegger Run	Low Flow	JUNE-OCT. 1988	3.193	17.22	1308.95	4.48	1.03	3.27
		High Flow	MARCH-APR. 1989	26.007	0	4208.45	185.17	22.45	29.46
30	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	0.836	0	31.57	2.07	0.09	1.13
31	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	1.039	28.02	190.55	0.9	0.39	0
32	Glade Run	Low Flow	JUNE-OCT. 1988	3.686	19.88	1033.88	19.48	2.39	9.15
		High Flow	MARCH-APR. 1989	42.182	0	4779.14	97.86	15.93	88.76
33	Steyer Run	Low Flow	JUNE-OCT. 1988	0.887	4.78	310.99	1.72	0.05	1.15
		High Flow	MARCH-APR. 1989	7.221	0	934.8	31.16	1.17	19.86
34	Difficult Cr.	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	32.275	0	4874.56	24.37	1.74	19.15
35	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	1.117	0	789.29	2.77	1.27	1.45
36	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	0.559	3.02	60.3	0.6	0	0.51
37	Unnamed	Low Flow	JUNE-OCT. 1988	0.147	0.79	6.34	0.06	0.01	0.11
		High Flow	MARCH-APR. 1989	1.197	6.46	45.2	0.45	0	0
38	Unnamed	Low Flow	JUNE-OCT. 1988	0.372	2.02	16.05	1.14	0.02	0.74
		High Flow	MARCH-APR. 1989	3.032	0	130.84	1.47	0.16	0
39	Stony River	Low Flow	JUNE-OCT. 1988	6.454	139.25	12323.76	3.83	13.98	4.87
		High Flow	MARCH-APR. 1989	234.325	2527.9	78364.84	252.79	252.79	366.55
40	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	0.174	0.94	11.26	0	0	0
41	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	1.864	0	80.44	2.21	0	1.41
42	Laurel Run	Low Flow	JUNE-OCT. 1988	1.309	7.06	1186.21	0.35	0.07	0.71
		High Flow	MARCH-APR. 1989	38.898	0	9022.08	104.91	20.98	86.02
43	Crooked Run	Low Flow	JUNE-OCT. 1988	0.63	3.4	1532.6	0.17	0.03	0.37
		High Flow	MARCH-APR. 1989	5.134	0	4043.15	13.85	11.35	19.11
44	Maple Run	Low Flow	JUNE-OCT. 1988	0.853	4.6	46.01	1.84	0.14	0.69
		High Flow	MARCH-APR. 1989	12.267	132.34	397.01	7.94	0	6.62
45	Lostland Run	Low Flow	JUNE-OCT. 1988	1.403	7.57	1574.1	0.38	0.3	0.76
		High Flow	MARCH-APR. 1989	41.668	1123.79	14833.97	51.69	53.94	89.9
46	Unnamed	Low Flow	JUNE-OCT. 1988	0.122	0.66	138.85	0.72	0.13	0.36
		High Flow	MARCH-APR. 1989	0.99	0	587.41	0.48	0.05	0.59
47	Unnamed	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	1.721	0	120.68	0.74	0	0
48	Short Run	Low Flow	JUNE-OCT. 1988	0.333	1.8	193.99	0.18	0.5	0.41
		High Flow	MARCH-APR. 1989	9.899	373.77	2189.2	26.16	4.81	26.7

Tributaries and associated mine drainage loads in the North Branch Potomac River upstream from Jennings Randolph Lake, based on Morgan Mining and Environmental Consultants (1994).

WSID Number	Tributary	Flow Condition	Date	Discharge (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
49	Abram Run	Low Flow	JUNE-OCT. 1988	14.093	2356.55	28202.55	4.56	471.31	383.13
		High Flow	MARCH-APR. 1989	197.348	10644.95	100062.54	510.96	1511.58	2086.41
50	Discharge to River	Low Flow	JUNE-OCT. 1988	0.8	681.8	2528.71	5.52	5.74	100.11
		High Flow	MARCH-APR. 1989	0.851	440.67	1161.34	20.66	2.16	54.17
51	Discharge to River	Low Flow	JUNE-OCT. 1988	0.6	637.57	1818.86	4.01	4.73	61.17
		High Flow	MARCH-APR. 1989						
52	Wolfden Run	Low Flow	JUNE-OCT. 1988	2.64	14.24	555.37	2.85	0.85	4.13
		High Flow	MARCH-APR. 1989	17.778	287.68	2685.05	22.06	8.63	36.44
53	Discharge to River	Low Flow	JUNE-OCT. 1988	0.486	1053.84	1751.15	56.36	3.75	110.89
		High Flow	MARCH-APR. 1989	2.716	3706.48	7574.1	213.89	13.04	373.58
54	Unnamed	Low Flow	JUNE-OCT. 1988	0.13	364.63	785.37	10.24	2.5	38.36
		High Flow	MARCH-APR. 1989	0.968	1070.39	3326.03	54.82	5.38	158.21
55	Unnamed	Low Flow	JUNE-OCT. 1988	0.146	150.42	656.8	0.2	23.15	20
		High Flow	MARCH-APR. 1989	2.246	2071.65	4894.43	222.91	126	249.57
56	Discharge to River	Low Flow	JUNE-OCT. 1988	0.004	0.02	1.49	0.02	0	0.01
		High Flow	MARCH-APR. 1989						
57	Discharge to River	Low Flow	JUNE-OCT. 1988	0.004	0.02	11.18	0.01	0	0.01
		High Flow	MARCH-APR. 1989						
58	Unnamed	Low Flow	JUNE-OCT. 1988	0.027	0.15	45.73	0.33	3.64	3.17
		High Flow	MARCH-APR. 1989	0.921	0	427.24	5.61	0.99	3.38
59	Discharge to River	Low Flow	JUNE-OCT. 1988	0.2	1.08	523.22	0.15	0.11	0.28
		High Flow	MARCH-APR. 1989	0.361	0	621.17	1.27	0.29	0.97
60	Three Forks Run	Low Flow	JUNE-OCT. 1988	2.249	2632.45	5434.74	143.15	19.65	247.47
		High Flow	MARCH-APR. 1989	30.582	4453.9	14186.5	565.81	51.14	400.85
61	Stoney Hollow Run	Low Flow	JUNE-OCT. 1988	0.093	0.5	80.26	6.47	1.08	18.91
		High Flow	MARCH-APR. 1989	3.145	0	1034.81	10.52	1.19	7.63
62	Unnamed	Low Flow	JUNE-OCT. 1988	0.045	0.24	11.89	0.07	0	0.04
		High Flow	MARCH-APR. 1989	1.334	0	266.24	1.8	0.22	1.22
63	Discharge to River	Low Flow	JUNE-OCT. 1988						
		High Flow	MARCH-APR. 1989	0.661	3.57	1451.13	0.89	0.29	0.64
64	Unnamed	Low Flow	JUNE-OCT. 1988	0.792	4.27	286.23	0.21	0.04	0.43
		High Flow	MARCH-APR. 1989	0.762	0	143.86	0.53	0.08	0.62
65	Deep Run	Low Flow	JUNE-OCT. 1988	0.685	3.69	1023.48	0.37	0.04	0.55
		High Flow	MARCH-APR. 1989	22.671	0	11617.3	14.67	39.13	70.93
66	Unnamed	Low Flow	JUNE-OCT. 1988	0.037	0.2	15.37	0.06	0	0.04
		High Flow	MARCH-APR. 1989	1.086	0	322.18	0.35	0.06	0
67	Howell Run	Low Flow	JUNE-OCT. 1988	2.026	10.93	3092.69	1.2	1.31	1.09
		High Flow	MARCH-APR. 1989	16.934	0	6211.26	12.79	11.87	32.88
68	Discharge to River	Low Flow	JUNE-OCT. 1988	0.005	0.093	1.94	0.01	0	0.01
		High Flow	MARCH-APR. 1989						
69	Discharge to River	Low Flow	JUNE-OCT. 1988	0.002	0.01	3.41	0.05	0.01	0
		High Flow	MARCH-APR. 1989						

Tributaries and associated mine drainage loads in the North Branch Potomac River upstream from Jennings Randolph Lake, based on Morgan Mining and Environmental Consultants (1994).

WSID Number	Tributary	Flow Condition	Date	Discharge (cfs)	Acidity (ppd)	Sulfate (ppd)	Iron (ppd)	Manganese (ppd)	Aluminum (ppd)
70	Elklick Run	Low Flow	JUNE-OCT. 1988	0.72	3.88	718.48	0.43	0.85	0.58
		High Flow	MARCH-APR. 1989	11.048	595.93	4707.84	47.67	28.01	70.92
Combined Low Flow (cfs)				73.1					
Combined High Flow (cfs)				974.3					

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

WATERSHED	DESCRIPTION	DATE	DISCHARGE cfs	Total Acidity Load (lbs/day)	sulfate mg/L	Sulfate Load (lbs/day)	Total Fe mg/L	Fe Load (lbs/day)	Total Mn mg/L
Matthew Run	acid seep	12/19/88	0.02	53.64	1108.5	119.3	242	26.0	32
		1/20/89	0.03	61.89	1639.2	264.5	217	35.0	25
		2/25/89	0.02	41.04	1646.2	177.1	231	24.9	32
		3/23/89	0.1	152.76	1206.8	649.2	143	76.9	22
		4/21/89	0.01	29.92	2251.2	121.1	251	13.5	29
		9/5/89	0.03	158.4	3201.7	516.7	425	68.6	69
Neff Run	abandoned deep mine drainage	12/19/88	0.04	87.29	610.1	131.3	7.4	1.6	19
		1/20/89	0.24	289.24	381.1	492.0	14	18.1	13
		2/25/89	0.07	124.64	703	264.7	10	3.8	20
		3/23/89	1.31	1554.59	594.6	4190.0	5.91	41.6	12
		4/21/89	0.08	153.83	947.9	407.9	7	3.0	14
		9/5/89	0.04	82.82	834.2	179.5	9.89	2.1	21
Georges Creek	acid drainage culvert	12/19/88							
		1/20/89	0.94	622.56	525	2654.6	4.79	24.2	4.76
		2/25/89							
		3/23/89							
		4/21/89	0.05	29.4	517.6	139.2	4.55	1.2	4.55
		9/5/89							
Georges Creek	acid seep	12/19/88							
		1/20/89	0.7	4978.1	2011	7572.3	143	538.5	26
		2/25/89	0.21	1379.43	2304.2	2602.9	189	213.5	33
		3/23/89	0.45	3644.82	2065.7	5000.3	154	372.8	28
		4/21/89	0.1	812.02	2459.4	1323.0	190	102.2	26
		9/5/89	0.05	433.81	2309.1	621.1	199	53.5	32
Georges Creek	acid seep	12/19/88	0.07	74.48	762.3	287.0	3.77	1.4	5.76
		1/20/89	0.16	97.28	684.2	588.9	2.93	2.5	4.53
		2/25/89	0.19	134.09	1183.4	1209.5	3	3.1	5.43
		3/23/89	0.11	47.77	784.2	464.0	1.39	0.8	3.11
		4/21/89	0.17	88.23	958.2	876.2	2.06	1.9	4.18
		9/5/89	0.07	52.9	1104.5	415.9	3.45	1.3	6.99
Georges Creek	acidic drainage	12/19/88							
		1/20/89							
		2/25/89	8.95	1166.08	342.2	16474.9	1.83	88.1	4.1
		3/23/89							
		4/21/89							
		9/5/89	0.65	105.51	528.1	1846.5	0.44	1.5	6.24

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

WATERSHED	DESCRIPTION	Mn Load (lbs/day)	Total Al mg/L	Al Load (lbs/day)	Total Cr mg/L	Cr Load (lbs/day)	Total Cu mg/L	Cu Load (lbs/day)
Matthew Run	acid seep	3.4	0.23	0.0	0.01	0.0	0.01	0.0
		4.0	0.48	0.1	0.02	0.0	0.03	0.0
		3.4	0.21	0.0	0.02	0.0	0.02	0.0
		11.8	0.1	0.1	0.02	0.0	0.03	0.0
		1.6	0.16	0.0	0.02	0.0	0.03	0.0
		11.1	0.23	0.0	0.01	0.0	0.01	0.0
Neff Run	abandoned deep mine drainage	4.1	32.6	7.0	0.01	0.0	0.16	0.0
		16.8	27.05	34.9	0.02	0.0	0.11	0.1
		7.5	25.93	9.8	0.02	0.0	0.1	0.0
		84.6	15.7	110.6	0.02	0.1	0.07	0.5
		6.0	35.6	15.3	0.02	0.0	0.03	0.0
		4.5	28.46	6.1	0.03	0.0	0.11	0.0
Georges Creek	acid drainage culvert							
		24.1	13	65.7	0.02	0.1	0.07	0.4
		1.2	13.22	3.6	0.02	0.0	0.03	0.0
Georges Creek	acid seep							
		97.9	80.6	303.5	0.02	0.1	0.68	2.6
		37.3	70.04	79.1	0.02	0.0	0.6	0.7
		67.8	63.1	152.7	0.03	0.1	0.62	1.5
		14.0	86.68	46.6	0.04	0.0	0.03	0.0
		8.6	54.42	14.6	0.07	0.0	0.62	0.2
Georges Creek	acid seep	2.2	14.9	5.6	0.01	0.0	0.08	0.0
		3.9	11.7	10.1	0.02	0.0	0.03	0.0
		5.5	11.78	12.0	0.02	0.0	0.02	0.0
		1.8	7.8	4.6	0.02	0.0	0.04	0.0
		3.8	11.8	10.8	0.02	0.0	0.03	0.0
		2.6	11.7	4.4	0.01	0.0	0.06	0.0
Georges Creek	acidic drainage							
		197.4	5.64	271.5	0.02	1.0	0.03	1.4
		21.8	3.64	12.7	0.01	0.0	0.01	0.0

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

WATERSHED	DESCRIPTION	Total Pb mg/L	Pb Load (lbs/day)	Total Ni mg/L	Ni Load (lbs/day)	Total Zn mg/L	Zn Load (lbs/day)
Matthew Run	acid seep	0.01	0.0	0.6	0.1	0.24	0.0
		0.03	0.0	0.55	0.1	0.23	0.0
		0.02	0.0	0.5	0.1	0.24	0.0
		0.03	0.0	0.03	0.0	0.14	0.1
		0.03	0.0	0.03	0.0	0.26	0.0
		0.08	0.0	1.12	0.2	0.48	0.1
Neff Run	abandoned deep mine drainage	0.01	0.0	1.34	0.3	2.5	0.5
		0.03	0.0	1.05	1.4	4	5.2
		0.02	0.0	1.1	0.4	3	1.1
		0.03	0.2	0.93	6.6	5	35.2
		0.03	0.0	0.03	0.0	3	1.3
		0.26	0.1	1	0.2	2.31	0.5
Georges Creek	acid drainage culvert						
		0.03	0.2	0.5	2.5	1.2	6.1
		0.03	0.0	0.03	0.0	1.11	0.3
Georges Creek	acid seep						
		0.03	0.1	2.4	9.0		
		0.02	0.0	1	1.1		
		0.03	0.1	2.71	6.6		
		0.07	0.0	2.62	1.4		
		0.07	0.0	2.38	0.6		
Georges Creek	acid seep	0.01	0.0	0.62	0.2	1	0.4
		0.03	0.0	0.45	0.4	0.82	0.7
		0.02	0.0	0.4	0.4	0.8	0.8
		0.03	0.0	0.2	0.1	0.56	0.3
		0.03	0.0	0.03	0.0	0.81	0.7
		0.01	0.0	0.51	0.2	0.46	0.2
Georges Creek	acidic drainage						
		0.03	1.4	0.2	9.6	0.4	19.3
		0.12	0.4	0.3	1.0	0.66	2.3

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

WATERSHED	DESCRIPTION	DATE	DISCHARGE cfs	Total Acidity Load (lbs/day)	sulfate mg/L	Sulfate Load (lbs/day)	Total Fe mg/L	Fe Load (lbs/day)	Total Mn mg/L
Georges Creek	acid drainage (Mill Run)	12/19/88							
		1/20/89	2.7		285.5	4146.6	0.6	8.7	3.95
		2/25/89							
		3/23/89							
		4/21/89							
		9/5/89	0.32	223.92	1283	2208.5	0.8	1.4	21.8
Georges Creek	acid drainage (Mill Run)	12/19/88	4.76	1608.85	408.9	10469.9	3.81	97.6	0.94
		1/20/89	28.27	1534.69	126.6	19252.1	1.53	232.7	0.3
		2/25/89	18.26	2180.81	226.2	22218.4	2.5	245.6	0.6
		3/23/89	31.6	1509.61	167.8	28523.2	1.42	241.4	0.44
		4/21/89	8.23	822.08	319.2	14131.3	2.26	100.1	0.58
		9/5/89	1.09	805.93	839.3	4921.1	8.58	50.3	1.38
Georges Creek	acid seep opposite sewage plant	12/19/88							
		1/20/89	0.69	665.25	1706.3	6333.2	4	14.8	6.32
		2/25/89	0.65	803.12	1554.4	5434.9	2.5	8.7	6.96
		3/23/89	1.44	1830.81	1428.9	11068.4	16	123.9	9
		4/21/89							
		9/5/89							
Georges Creek	acid drainage (Franklin Run)	12/19/88	0.27	240.38	2117.5	3075.4	1.99	2.9	22
		1/20/89							
		2/25/89							
		3/23/89							
		4/21/89	0.15	65.23	1925.4	1553.6	2.14	1.7	14
		9/5/89	0.95	465.7	2321.2	11861.9	2.44	12.5	21
Georges Creek	alkaline drainage from deep mine	12/19/88	0.18		811.4	785.6	7.07	6.8	0.54
		1/20/89	1.14		947.3	5809.1	10	61.3	0.59
		2/25/89	1.62		1152.1	10039.8	4.18	36.4	0.63
		3/23/89	0.64		971.1	3343.2	1.74	6.0	0.77
		4/21/89	0.62		890.3	2969.3	3	10.0	0.47
		9/5/89	0.08		1007.6	433.6	9.36	4.0	0.55

WATERSHED	DESCRIPTION	Mn Load (lbs/day)	Total Al mg/L	Al Load (lbs/day)	Total Cr mg/L	Cr Load (lbs/day)	Total Cu mg/L	Cu Load (lbs/day)
Georges Creek	acid drainage (Mill Run)							
		57.4	1.16	16.8	0.02	0.3	0.03	0.4
		37.5	4.72	8.1	0.01	0.0	0.01	0.0
Georges Creek	acid drainage (Mill Run)	24.1	3.58	91.7	0.01	0.3	0.01	0.3
		45.6	1.21	184.0	0.01	1.5	0.03	4.6
		58.9	1.96	192.5	0.02	2.0	0.03	2.9
		74.8	1.1	187.0	0.02	3.4	0.03	5.1
		25.7	3.33	147.4	0.02	0.9	0.03	1.3
		8.1	6.2	36.4	0.01	0.1	0.01	0.1
Georges Creek	acid seep opposite sewage plant							
		23.5	11.3	41.9				
		24.3	11.42	39.9				
		69.7	22.9	177.4				
Georges Creek	acid drainage (Franklin Run)	32.0	11.1	16.1	0.01	0.0	0.01	0.0
		11.3	11.2	9.0	0.02	0.0	0.03	0.0
		107.3	7.06		0.01	0.1	0.01	0.1
Georges Creek	alkaline drainage from deep mine	0.5	0.01	0.0	0.01	0.0	0.01	0.0
		3.6	0.54	3.3	0.02	0.1	0.03	0.2
		5.5	0.41	3.6	0.02	0.2	0.03	0.3
		2.7	1.13	3.9	0.02	0.1	0.03	0.1
		1.6	0.68	2.3	0.02	0.1	0.03	0.1
		0.2	0.42	0.2	0.01	0.0	0.01	0.0

WATERSHED	DESCRIPTION	Total Pb mg/L	Pb Load (lbs/day)	Total Ni mg/L	Ni Load (lbs/day)	Total Zn mg/L	Zn Load (lbs/day)
Georges Creek	acid drainage (Mill Run)						
		0.03	0.4	0.12	1.7		
		0.14	0.2	0.73	1.3	4.7	8.1
Georges Creek	acid drainage (Mill Run)	0.01	0.3	0.01	0.3		
		0.03	4.6	0.03	4.6	0.03	4.6
		0.03	2.9	0.03	2.9	0.03	2.9
		0.03	5.1	0.03	5.1	0.06	10.2
		0.03	1.3	0.03	1.3	0.09	4.0
		0.14	0.8	0.1	0.6	0.2	1.2
Georges Creek	acid seep opposite sewage plant						
Georges Creek	acid drainage (Franklin Run)	0.01	0.0	0.4	0.6	0.69	1.0
		0.03	0.0	0.42	0.3	0.66	0.5
		0.11	0.6	0.48	2.5	0.82	4.2
Georges Creek	alkaline drainage from deep mine	0.01	0.0	0.05	0.0	0.02	0.0
		0.03	0.2	0.03	0.2	0.02	0.1
		0.03	0.3	0.03	0.3	0.02	0.2
		0.14	0.5	0.06	0.2	0.05	0.2
		0.03	0.1	0.42	1.4	0.66	2.2
		0.08	0.0	0.03	0.0	0.16	0.1

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

WATERSHED	DESCRIPTION	DATE	DISCHARGE cfs	Total Acidity Load (lbs/day)	sulfate mg/L	Sulfate Load (lbs/day)	Total Fe mg/L	Fe Load (lbs/day)	Total Mn mg/L
Georges Creek	totals at mouth of Georges Cr.	11/19/88	43.22	0	310.2	72118.4	1.46	339.4	1.61
		12/19/88	44.07	0	492.2	116682.0	2.09	495.5	2.19
		1/20/89	219.58	0	207.4	244974.5	1.74	2055.2	1.18
		2/25/89	78.24	10193.77	334.8	140907.3	2.16	909.1	1.97
		3/23/89	206.89	84235.54	234.3	260754.1	1.56	1736.1	1.41
		4/21/89	52.72	0	351.8	99767.8	1.97	558.7	1.6
		5/26/89	174.47	0	373.1	350159.0	2.45	2299.4	1.75
		6/29/89	43.52	6615.18	462.4	108249.5	2.12	496.3	2.23
		8/2/89	193.98	0	309.7	323159.9	1.81	1888.7	1.9
		9/5/89	19.94	0	788.3	84554.4	1.84	197.4	2.34
		9/26/90	46.12	0	459.5	113997.2	3.69	915.5	1.99
		10/24/89	74.43	4161.79	229.6	91926.2	1.64	656.6	1.05
		11/25/89	62.11	3338.04	286	95553.6	1.77	591.4	1.67
Average loads at mouth of Georges Creek (1988-1989)			96.9	8349.6		161754.1		1010.7	

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

WATERSHED	DESCRIPTION	Mn Load (lbs/day)	Total Al mg/L	Al Load (lbs/day)	Total Cr mg/L	Cr Load (lbs/day)	Total Cu mg/L	Cu Load (lbs/day)
Georges Creek	totals at mouth of Georges Cr.	374.3	1.55	360.4				
		519.2	2	474.1	0.01	2.4	0.01	2.4
		1393.8	1.89	2232.4	0.02	23.6	0.03	35.4
		829.1	2.78	1170.0	0.02	8.4	0.03	12.6
		1569.2	2	2225.8	0.02	22.3	0.03	33.4
		453.7	2.63	745.8	0.02	5.7	0.03	8.5
		1642.4	2.75	2580.9				
		522.1	2.06	482.3				
		1982.6	1.79	1867.8				
		251.0	2.33	249.9	0.01	1.1	0.01	1.1
		493.7	2.08	516.0				
		420.4	0.96	384.4				
		558.0	1.65	551.3				
Average loads at mouth of Georges Creek (1988-1989)		846.9		1064.7		10.6		15.6

Mine drainage sources and associated estimates of chemical loads in the Georges Creek watershed, based on water quality data collected by W.J.Pegg.

WATERSHED	DESCRIPTION	Total Pb mg/L	Pb Load (lbs/day)	Total Ni mg/L	Ni Load (lbs/day)	Total Zn mg/L	Zn Load (lbs/day)
Georges Creek	totals at mouth of Georges Cr.						
		0.01	2.4	0.12	28.4	0.2	47.4
		0.03	35.4	0.06	70.9	0.12	141.7
		0.03	12.6	0.1	42.1	0.2	84.2
		0.1	111.3	0.1	111.3	0.12	133.5
		0.03	8.5	0.05	14.2	0.14	39.7
		0.08	8.6	0.11	11.8	0.13	13.9
Average loads at mouth of Georges Creek (1988-1989)			29.8		46.4		76.8