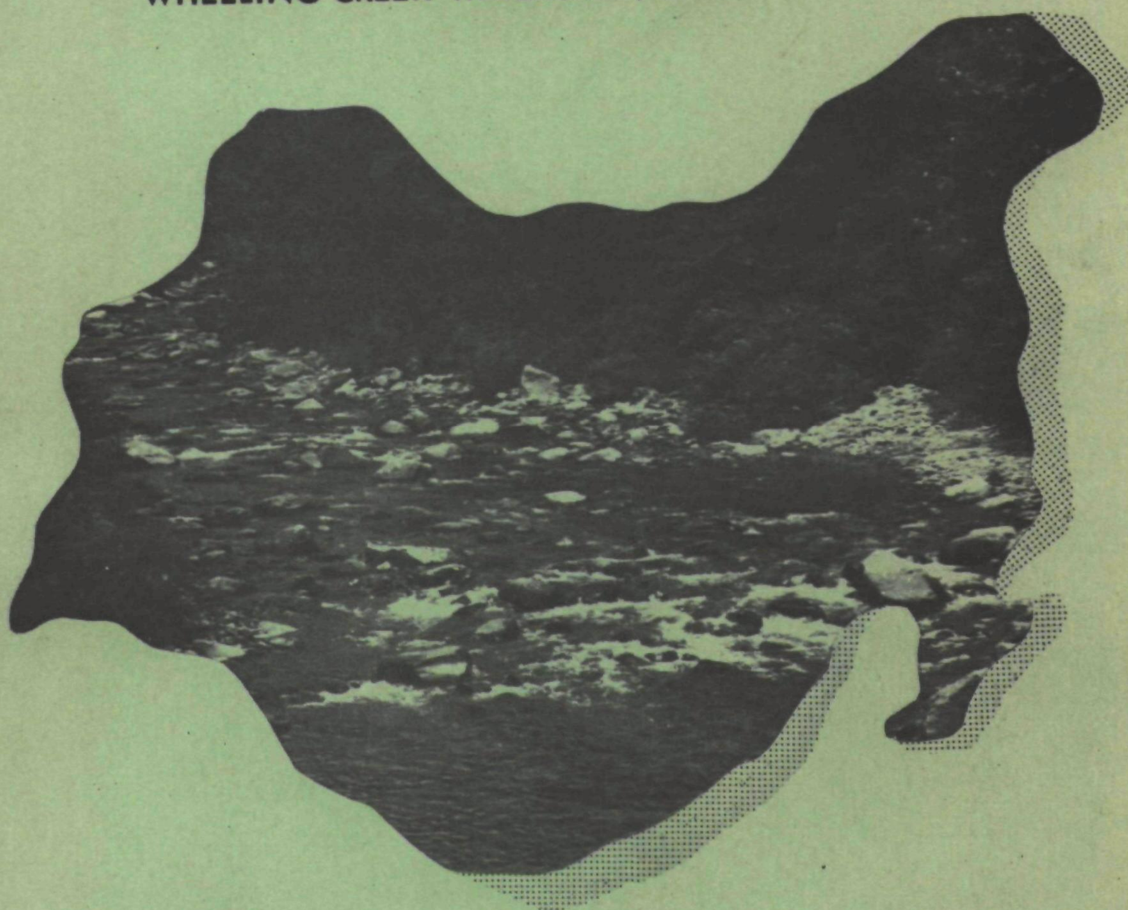
SOURCES OF COAL MINE DRAINAGE POLLUTION

WHEELING CREEK WATERSHED, OHIO



UNITED STATES DEPARTMENT OF THE INTERIOR

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

OHIO BASIN REGION

OHIO RIVER BASIN PROJECT

JUNE 1968

Work Document No. 25

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This document has been prepared to record a specific water pollution control activity carried out to date in furtherance of the water pollution control program being developed in the Ohio River Basin. The information contained herein will serve as a ready reference to aid in the planning and development of the program in the Basin, for appropriate in-service training of participating personnel, and facilitating program activities with other cooperating groups.

Questions or comments relative to this material should be directed to:

Mine Drainage Unit
Planning and Evaluation Section
Wheeling Field Station

UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
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INTRODUCTION

In August 1966, the Wheeling Field Station, Ohio Basin Region, Federal Water Pollution Control Administration, was contacted by Washington, D. C. Headquarters concerning the matter of pollution of Wheeling Creek, Belmont County, Ohio. Interest in the stream pollution problem at this time was in response to a telephone contact to Headquarters from a representative of the Lansing Valley Citizens Improvement Association. Subsequently, field studies of stream quality and sources of mine drainage were conducted by personnel of the Wheeling Field Station. The mine drainage source investigations were completed in February 1967. In December 1967, a preliminary outline of survey findings was forwarded to the Association for immediate use.

This document contains the field observations and chemical data obtained in the Wheeling Creek drainage basin. The conclusions and recommendations herein are subject to refinement as the water pollution control program progresses in the Ohio River Basin.

SUMMARY AND CONCLUSIONS

1. The Wheeling Creek watershed, draining 108 square miles of southeastern Ohio, has been extensively mined for the extraction of bituminous coal over the past 150 years. These activities have left hundreds of underground voids and large surface-mined acreages capable of producing acidic and mineralized drainage.

2. At the request of the Lansing Valley Citizens Improvement Association, the Wheeling Field Station, Federal Water Pollution Control Administration, United States Department of the Interior, conducted a study of stream water quality conditions and sources of mine drainage pollution in the Wheeling Creek watershed.

3. The water quality of Wheeling Creek is seriously degraded over nearly its entire length as a result of coal mine drainage. A portion of nearly every tributary to the main stream is affected by mine discharges. The water quality effects of mine drainage over the basin are generally those of excessive iron, sulfate, hardness, and total mineralization in the streams. Precipitation of iron compounds, particularly in Wheeling Creek, causes the additional problems of high turbidity and unsightly stream conditions.

4. Some 160 mine sites and an estimated 12,000 acres of strip mined area were investigated during this study. Samples were collected from 120 drainage sources, 72 of which were discharging at the time of the survey. Discharges from the coal mine sources ranged from one to 306 gallons per minute and totalled 2.1 million gallons per day. The pH values ranged from 2.3 to 8.4 and acidity concentrations from 0 milligrams per liter (mg/l) to 20,950 mg/l were found. The mine discharges consistently carried high hardness, sulfate, and iron loadings.

5. Nine active mining operations were examined during the course of the field study. Active mining operations contributed only a small percentage of the total discharge volume and chemical loadings found. Strip mines and mine refuse areas contributed equally small percentages of the total. Inactive or abandoned underground (drift) mines are the principal mine drainage pollution sources in the Wheeling Creek watershed.

6. Fifteen principal mine drainage sources were found to contribute 72 percent of the sulfate loading and nearly 40 percent of the iron loading discharged to the watershed streams. It is estimated that physical abatement of these principal sources would produce significant water quality improvement in Wheeling Creek, however, at least one-half of the total number of sources would have to be abated to improve stream water quality to a tolerable level.

7. Recommendations for further study and an action program leading to abatement of the mine drainage problem are included in this document.

RECOMMENDATIONS

Various measures are needed to control existing and potential water pollution of Wheeling Creek and its tributaries by coal mine drainage. These measures are needed to reduce concentrations of hardness, sulfate, and iron, reduce excessive salinity, control sedimentation and high turbidity, and improve aesthetic conditions for the protection of legitimate water uses.

The watershed has the widespread problem of serious coal mine drainage pollution. The following recommended actions to deal with this problem are based on water quality and mine drainage source investigations performed by the FWPCA in 1966-67:

Immediate Pollution Abatement

1. The State of Ohio should adopt the necessary standards and regulations to prevent pollution of streams by drainage from active coal mines and related operations.

The standards should include values for pH, sulfate, and total iron. Regulatory controls should include provisions pertaining to the inactivation or abandonment of mines so that the amounts of harmful drainage produced after abandonment will be minimal.

Long Term Pollution Abatement and Control

The State of Ohio, possibly in cooperation with a legally constituted body in the Wheeling Creek area, should proceed to eliminate or significantly reduce mine drainage from inactive or abandoned coal mines. It is realized that there are a number of difficult, lengthy, and expensive tasks involved in any program to abate pollutant discharges from inactive underground sites. A very major problem in this realm is the less than complete technical knowledge available of physical abatement methods. However, the following recommendations are made for the establishment of an abandoned mine drainage abatement program in the Wheeling Creek watershed:

(1) A mine drainage source priority listing should be established for the drainage sources outlined in this document. The priority listing should be based upon the relative contribution of each source to the total watershed problem. For example, a mine discharging high iron and acid or mineral loadings would be of a higher priority than one discharging a lesser loading located downstream from the first mine.

(2) The priority list should then be evaluated to determine that number of sources whose combined pollutant effect must be reduced or eliminated to achieve desired water quality goals at some downstream point. The priority listing should begin with the sources described in Table 4.

(3) Using the established source priorities, an engineering feasibility and cost study should be made for each site to design individual abatement techniques.

(4) Installation of physical measures deemed feasible by adequate study should then be carried out. Monitoring of discharge changes with time at the altered sites and in the receiving streams would be an integral part of physical abatement. Routine maintenance at the controlled sources would also be essential. Easements to or outright purchase of land may be necessary for the State of Ohio to obtain control over pollutant sources on private property. Institutional changes

also may need to be sought to enable the state government to achieve site control by the expenditure of public monies on private property. The acquisition of mineral rights in the areas of source abatement projects will be necessary to prevent future mining activity from destroying the physical controls.

(5) It is further recommended that, in all phases of the described abatement program, the State of Ohio seek technical and financial assistance from all pertinent agencies of the Federal government.

DESCRIPTION OF AREA

Wheeling Creek rises in north-central Belmont County, Ohio and flows east some 30 miles to the Ohio River at Bridgeport, Ohio. The drainage area is 108 square miles and the average fall of the main stream is 19 feet per mile. The basin is elongate in shape, measuring about 19 miles long in its east-west dimension, and is about ten miles wide at its maximum north-south dimension. The principal tributary to Wheeling Creek is Crabapple Creek with a drainage area of 20 square miles.

The Wheeling Creek basin is bounded on the north by Short Creek and on the south by McMahon Creek, both minor tributaries to the Ohio River. The Muskingum River basin forms the western boundary and the Ohio River forms the eastern boundary.

This area is part of the Appalachian Plateaus physiographic province which is a broad dissected upland underlain by essentially horizontal sedimentary rocks. Streams have dissected the area so that most of its plateau surface is no longer evident. The present surface consists mainly of broad, rounded ridges and intervening valleys. The valleys are deep and narrow near the Ohio River but are shallower and broader headward near the drainage divides.

The principal communities in the watershed are St. Clairsville and Bridgeport with populations of 3865 and 3824, respectively, in 1960.

GEOLOGY

The exposed strata of Belmont County were deposited during the Pennsylvanian and Permian periods in an uninterrupted sequence with an aggregate thickness of 1,100 feet. They consist of interbedded sheets of sandstone, siltstone, clay,mudstone, limestone, and coal.

The lithologic types comprise the upper 350 feet of the Conemaugh formation, the Monongahela formation (Pennsylvanian age), and the lower 470 feet of the Dunkard group of Pennsylvanian and Permian age. Within these formations, 56 members and coal beds are recognized and named.

The strata dip to the southeast at an average rate of 18 feet per mile over the county. Small local deformations cause slight variations in the dip, which in a few places is as much as 60 to 70 feet per mile.

COAL MINING

History

The mining of coal in Belmont County probably did not begin until about 1804 when coal was mined from an exposure along Pipe Creek. However, the presence of coal must have been known to the earliest settlers from the numerous outcrops throughout the county.

Early mining was limited to small openings and stripping operations along the coal outcrops and was mainly for local home consumption. Belmont County coal was used largely for domestic purposes until 183[illegible]. In that year a commercial underground mine was opened on the south bank of McMahon Creek at Bellaire. Between 1835 and 1840 other mines were opened along the Ohio River in the county and by 1845, shipment of coal along the river was an active enterprise. The construction of railroads through the area after 1858 caused a rapid expansion of the coal mining industry.

The Wheeling Creek field developed rapidly after the extension of a rail line from Dennison, Ohio to Bridgeport, Bellaire, and Martins Ferry. Extensive mines were in operation soon thereafter at Bridgeport, Wheeling Creek, Maynard, Crescent, Barton, and places between.

By 1888 the distribution of underground commercial mines throughout the county was in about the same pattern that exists today. Most of the large mines were in the northeastern quarter of Belmont County but several were operating elsewhere. A mine at Flushing and another a mile west of Flushing produced coal for rail shipment. A mine six miles southwest of Barnesville produced coal for use in locomotives. Mines were also in operation at Warnock, Badgertown, and Belmont.

After 1888 the coal mining industry grew steadily and in 1905, Belmont County led the State in production. The county has led coal production in Ohio almost continuously since 1905. The rapid increase in strip mining since World War II has added greatly to annual tonnages produced in recent years.

In the Wheeling Creek watershed, mining records show the existence of at least 83 underground mine locations and a very large strip mined acreage.

Coal Production

Total reported production in Belmont County over the period of record is about 500 million tons. Total production for 1965 was 7.7 million tons from 35 reporting mines. Production was divided between surface and underground mining operations in the ratio of 3.4 million tons to 4.3 million tons, respectively.

Total coal production for those townships comprising the Wheeling Creek drainage basin was 2.9 million tons. Most of the production was from strip mine operations.

Coal Reserves

There are 15 coal beds exposed in Belmont County. The Pittsburgh and Sewickley beds are the only two currently being mined commercially. Seven of the 15 beds contain mineable reserves. The other eight beds are not considered mineable because of erratic occurrence, poor quality, and insufficient thickness.

In the Wheeling Creek watershed, five of the seven coal beds considered mineable in Belmont County contain mineable reserves. The largest reserves, about three-fourths of the estimated watershed total, are contained in the Pittsburgh (#8) and Sewickley (#9) remaining beds. Recoverable coal reserves in the Wheeling Creek watershed are estimated at about 600 million tons.

STREAM WATER QUALITY

The water quality of Wheeling Creek is seriously degraded over nearly its entire length as a result of coal mine drainage. A portion of almost every tributary to the main stream is affected by mine discharges. The water quality effects of mine drainage over the basin are generally those of excessive iron, sulfate, hardness and total mineralization in the streams. Although there are many acid mine discharges in the watershed and certain streams are acidic, the acidity is rapidly neutralized by Wheeling Creek. Wheeling Creek was found to be alkaline over its entire length during the study period.

A sampling station on Wheeling Creek was maintained during the period June-August 1966 for repetitive sampling and flow measurement. The station was located at Stop 10 Bridge in Bridgeport near the stream mouth (Station No. 1684). Six samples were collected for chemical analysis during the study period. A statistical summary of the data from this station is shown in Table 1.

The data presented in Table 1 is probably representative of the worst conditions because of low streamflow at time of sampling. The maximum flow measured was 29 cubic feet per second (cfs). During low streamflow conditions the ratio of mine drainage in the stream to total streamflow is greatest and mine drainage effects on stream water quality are most pronounced.

At Station No. 1684 the stream was strongly alkaline on each sampling occasion. The pH level did not go below 7.3. The sulfate and hardness concentrations were consistently very high. The sulfate content of the stream at this location is excessive and is a residual component of the quantities of sulfate salts and sulfuric acid received upstream in mine drainage. The magnitude of sulfate concentration indicates the amount of acidic compounds neutralized by the alkalinity contained in Wheeling Creek. Wheeling Creek is extremely hard at this point, over 1000 milligrams per liter (mg/l) total hardness in four of six analyses. The hardness content of Wheeling Creek is derived primarily from components of mine drainage. The high specific conductance values exhibited, in excess of 2000 micromhos per centimeter, indicate the high total mineralization imparted to the stream by mine drainage.

The total iron concentrations were quite high ranging from 2.4 mg/l to 7.2 mg/l. Because of the alkaline condition of Wheeling Creek, dissolved iron discharged to it from mine drainage readily precipitates to form a thick orange suspension in the stream. This unsightly condition is evident in varying degrees throughout Wheeling Creek but is most pronounced in the stream reach from near the community of Bannock to the Ohio River. This discoloration is also evident downstream from the confluence of Wheeling Creek in the back channel of the Ohio River. Although coal mining activity may not be evident at a given vantage point in the watershed, the orange-colored stream is a vivid reminder of such activity upstream.

In conjunction with sampling and flow measurement activities at selected stream locations, pH and specific conductance determinations were made at a number of additional stream locations in the watershed during the mine drainage source investigations. On the basis of these determinations and visual observations, water quality over the length of Wheeling Creek and most of its tributaries is considered degraded by coal mine drainage. These readings are shown on Figure 1.

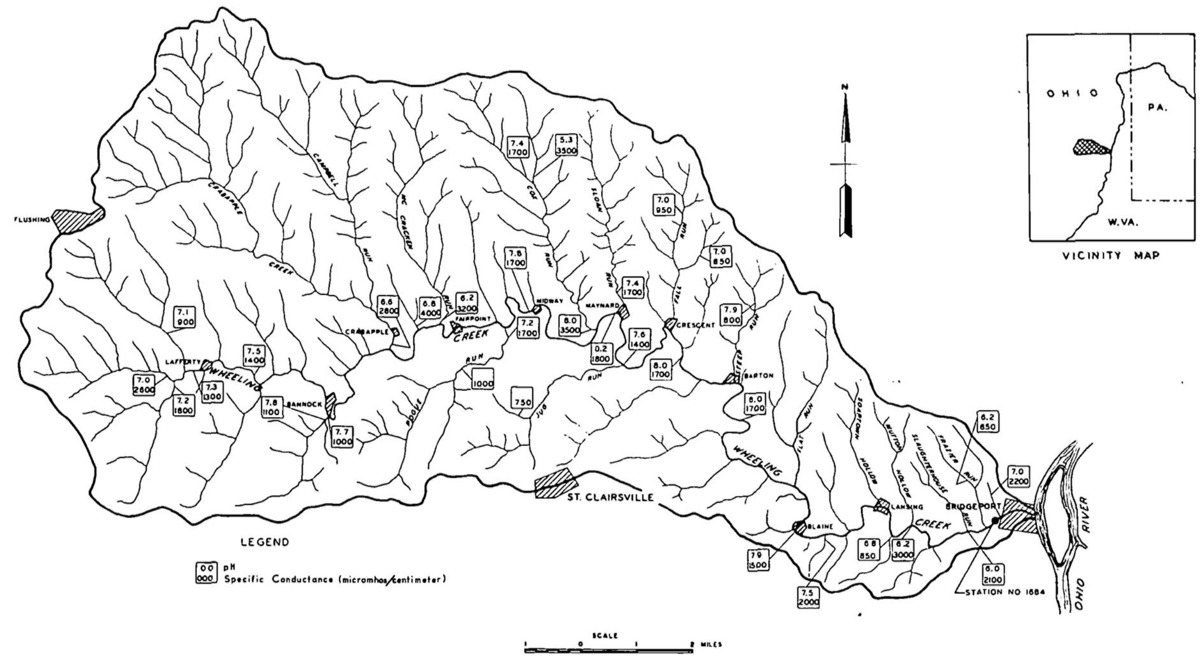

FIGURE I. STREAM WATER QUALITY, WHEELING CREEK AND TRIBUTARIES

Table 1
Surface water quality
physical and chemical data
Wheeling Creek, Ohio watershed

Station No. 1684 - Wheeling Creek near mouth

PHYSICAL OBSERVATIONS

PARAMETER	NUMBER OF SAMPLES	MAXIMUM VALUE	MINIMUM VALUE	AVERAGE VALUE
Temperature	6	25	19.0	22.8
pH	6	8.0	7.3	7.6
Specific Conductance*	6	2500	2000	2243
Flow (cfs)**	6	29	14	22.4

CHEMICAL OBSERVATIONS

PARAMETER	NUMBER OF SAMPLES	MAXIMUM VALUE (mg/l)	MINIMUM VALUE (mg/l)	AVERAGE VALUE (mg/l)	MAXIMUM VALUE (lb /day)	MINIMUM VALUE (lb /day)	AVERAGE VALUE (lb /day)
Dissolved Oxygen	6	8.9	6.4	7.4	1104	558	894
Acidity	6	11	0.0	2.0	830	0	159
Alkalinity	6	147	82.0	121.5	22,993	7853	15,026
Hardness	6	1363.0	366.0	1001.8	206,470	45,404	120,121
Sulfate	6	950	345.0	460.0	112,728	29,449	55,105
Total Iron	6	7.2	2.4	3.4	951	181	424
Manganese	6	1.1	0.2	0.4	130	22	52
Aluminum	6	21.8	0.0	8.3	2880	0	1013
Chloride	6	40.0	17.0	23.3	4962	1963	2786

*Micromhos/Centimeter
**Cubic Feet Per Second

Biology

A biological evaluation of Wheeling Creek at Station No. 1684 was made during the study to determine the effect of pollution conditions upon normal aquatic fauna. The benthic fauna found at this location consisted of the pollution-tolerant midge fly larvae. Minnows were observed in the stream. The substrate was heavily silted with an orange precipitate. The presence of fish indicates an acceptable acidity concentration, but the turbidity and precipitate associated with coal mine drainage pollution limits the production of fish and other aquatic life.

SOURCES OF MINE DRAINAGE

Some 160 mine sites and an estimated 12,000 acres of strip-mined area were investigated during this study. Samples were collected from 120 drainage sources, 72 of which were discharging at the time of the survey. All but one of the non-discharging sources are strip mine ponds. Discharges from the coal mine sources ranged from one to 306 gallons per minute (gpm). The pH values ranged from 2.3 to 8.4 and acidity concentrations from 0.0 mg/l to 20,950 mg/l were reported. The net (total acidity less alkalinity) acid loading of the 72 discharging sources totalled 13,962 pounds per day (lb/day).

A detailed description of the mine drainage sources in the Wheeling Creek watershed follows.

Headwaters

The headwaters of Wheeling Creek arise near the community of Flushing, flow southeast toward Lafferty, and are joined by an unnamed tributary which drains the area southwest of Lafferty. Strip mine operations, active and inactive, are loacted along both of these headwater streams (Figure 2). Below these headwater tributaries Wheeling Creek exhibited pH and specific conductance values of 7.5 and 1400, respectively.

Below Lafferty, Wheeling Creek receives drainage from a number of tributaries on either side of the main stream. All of these tributary watersheds have experienced varying amounts of strip mining activity. The streams are characterized by pH values in the range of 7.0 to 7.5 and specific conductance values in the range of 1000 to 3000 micromhos. Seven strip mine ponds were sampled in this area of the basin; two ponds were overflowing at time of sampling. All seven of the pond waters were alkaline and highly mineralized.

Between the communities of Lafferty and Bannock, Wheeling Creek is joined by several tributaries draining strip-mined areas. No pond discharges were found in this portion of the basin. The pH level of these streams remained above 7.0 and specific conductance values averaged about 1000 micromhos. At Bannock, Wheeling Creek had a pH of 7.7 and a specific conductance of 1000 micromhos.

Wheeling Creek

The first significant amounts of measurable mine drainage enters Wheeling Creek just downstream of Bannock. On Belmont County Highway No. 10 northeast of Bannock (Figure 2), five discharges from old underground mining activity were located. These discharges are located at road level, drain directly to Wheeling Creek, and appear to result from old drainways or portals which have been completely slumped over by the hillside material. The area immediately above these discharges has been strip-mined and intersection with the older underground workings may have occurred. Below these discharges is the approximate location where Wheeling Creek becomes noticeably discolored from precipitated iron compounds. (Figure 2, Mine Nos. 2086-2090).

Crabapple Creek

Crabapple Creek enters the main stream near the community of Crabapple and is the largest tributary to Wheeling Creek. This sub-watershed has been extensively strip-mined. No discharges were found in this area during the survey but samples were collected from 35 strip mine ponds. The pH value of the ponds ranged from 3.5 to 8.4 and specific conductance values ranged from 230 to 3500 micromhos. Thirty of the 34 pond water samples were alkaline, four were acid. Crabapple Creek exhibited a pH of 6.6 and a specific conductance of 2800 micromhos.

McCracken Run

Continuing downstream, McCracken Run is the next principal tributary to the main stream. Eight strip mine ponds and one borehole discharge from an active mine were sampled in this sub-watershed. The pH and specific conductance values of the pond samples ranged from 7.3 to 8.1 and 900 to 4300 micromhos. The borehole discharge is from the nearby Franklin No. 25 Mine (slope) of Hanna Coal Company.

Wheeling Creek

Evidence of underground mining activity increases noticeably downstream of McCracken Run. An unnamed tributary enters the main stream (from the north) near the community of Midway. This small drainage contains a number of discharges from underground mining activity. The sum of these discharges equalled 45 gpm and contributed a net alkaline load to the receiving stream during the sampling period.

Cox Run

Cox Run is the next principal tributary to Wheeling Creek continuing in the downstream direction. Active strip mines were located near the headwaters of Cox Run during the survey and several abandoned drift mines were located along the middle and lower reach of the stream. The largest discharge measured in the Wheeling Creek watershed was from an abandoned drift mine on Cox Run, Mine No. 1807 (Figure 2). This discharge was 306 gpm and alkaline in nature with a pH level of 7.0. The discharge was highly discolored and carried about 100 pounds per day of iron.

Cox Run was alkaline at its mouth and highly mineralized. The specific conductance at this point was 3500 micromhos.

Sloan Run

At the community of Maynard, Sloan Run enters the main stream from the north. The headwaters area of Sloan Run in Harrison and Jefferson Counties is free of mining activity but both underground and surface mining have occurred in the lower portion of the subwatershed. Three alkaline discharges from abandoned drift mines totalling 22 gpm were measured along Sloan Run. Below Sloan Run, Wheeling Creek exhibited a pH of 8.2 and a specific conductance of 1800 micromhos.

Jug Run

Jug Run enters the main stream from the southwest about midway between Maynard and Crescent. A number of small drift mines were located along Jug Run but only one had a measurable discharge at the time of inspection. Small amounts of seepage were emanating from the other openings inspected. There is a large mine refuse area in the upper portion of the stream valley (No. 1780, Figure 2) and other refuse areas along the lower portion of the stream. Measured acid loads from No. 1780 and the discharging drift mine totalled 150 lb/day. Jug Run was alkaline at its juncture with Wheeling Creek. Chemical data from Jug Run at mouth (Station No. 1789) is included in the Appendix.

Near the mouth of Jug Run, an abandoned drift mine (No. 1782) was discharging a daily acid load of 285 pounds to Wheeling Creek. On the downstream side of Jug Run, an operating drift mine was discharging a total net acid load of 310 lb/day from three of five openings. These discharges are also to Wheeling Creek.

Fall Run

Fall Run, tributary to Wheeling Creek at Crescent, carries an appreciable amount of acidity to the main stream. A net acid load of 585 lb/day was measured discharging from eight inactive drift mines and two inactive strip mines in this sub-watershed.

Although mining has occurred along both banks of the main stem and its tributaries, no significant amounts of mine drainage were found in that portion of the basin lying between the communities of Crescent and Barton. At a point midway between these two communities, Wheeling Creek had a pH value of 8.0 and a specific conductance of 1700 micromhos.

Steep Run

At Barton, Steep Run enters the main stem. During the survey, Steep Run carried the highest acid load of any tributary to the basin. Six abandoned drift mine effluents were found discharging a daily net acid load of 3000 lb/day to Steep Run. Specific conductance values as high as 8600 micromhos and pH values as low as 2.3 were measured in these effluents. At the time of the survey, mining activity in the Steep Run watershed was limited to underground mines. Mine No. 1774 (Figure 2) discharged an acid load of 1476 lb/day to Steep Run. This acid loading was one of the four highest encountered in the Wheeling Creek watershed. At its mouth, Steep Run exhibited a pH value of 4.0, a specific conductance of 5,000 micromhos, and discharged an acid load of 2500 lb/day to Wheeling Creek. Chemical data from Steep Run at mouth (Station No. 1788) is included in the Appendix.

In the stream reach between the community of Barton and the confluence of Flat Run with the main stream, Wheeling Creek receives mine drainage from three tributaries entering from the southwest. Surface and underground coal mining in this area has occurred near the mouths of the tributaries or along the banks of Wheeling Creek.

Flat Run

Flat Run has experienced both drift mining and strip mining in the lower one mile portion of its valley. Near the upper end of the stripped area (Figure 2), numerous "red water" seepage areas were observed at the base of the highwall. The cumulative discharge from eight separate seepage areas carried a net acidity loading of 35 lb/day discharged to Flat Run. Immediately below this point of measurement, a discharge of 36 gpm was measured emanating from the base of the highwall (No. 1796). This discharge may result from the intersection of the strip mine with a drift mine opening. From this point a daily acid load of 2000 pounds was being discharged to Flat Run. This acid loading was the second highest found in the Wheeling Creek watershed.

Wheeling Creek

A large mine waste dump is located along the main stream on the bank opposite Flat Run. An underground mine discharge of eight gpm was located near the waste dump. The discharge flows from the slumped mine opening, through part of the waste dump, and enters an unnamed tributary to Wheeling Creek. The discharge had a specific conductance exceeding 10,000 units, a pH level of 3.0, and carried an acid loading of 1690 lb/day. This load is one of the four highest encountered in the watershed. A second discharge of two gpm was measured at the base of the waste dump. It contained a very high acidity concentration of 20,950 mg/l.

Approximately one mile downstream, near the community of Blaine, a source was found which contributes the highest acid load in the watershed. This consisted of a 30 gpm discharge from a strip pit (Mine No. 1795). The pit acts as a collecting basin for underground mine and auger hole discharges. The discharge then flows over a gob pile from an old deep mine at Blaine before finally entering an unnamed tributary to Wheeling Creek. This discharge had a specific conductance exceeding 10,000 micromhos, a pH value of 3.5, and carried a daily acid load of 3,060 pounds. The mine dump at Blaine is located immediately adjacent to Wheeling Creek and the stream is in continual contact with the waste material.

About 0.6 mile below Blaine, an unnamed tributary enters the main stem. The area drained by this tributary has been drift-mined and later stripped for a distance of about 0.5 mile above its mouth. At the upper end of the stripping a 30 gpm discharge was found which carried an acid load of 980 lb/day to the unnamed tributary. At the time of the survey, this area was being restripped and augered.

Soaptown Hollow, Mutton Hollow

Soaptown Hollow and Mutton Hollow enter Wheeling Creek from the north in the vicinity of Lansing. One abandoned drift mine discharged an acid load of 60 lb/day to Soaptown Hollow. Two abandoned drift mines discharged a total of 11 gpm of highly mineralized drainage to Mutton Hollow.

Slaughterhouse Run, Frazier Run

Slaughterhouse and Frazier Runs are the remaining tributaries on the north bank of Wheeling Creek that are influenced by mine drainage. A drift mine drainage of eight gpm was measured discharging to Slaughterhouse Run and drift mine discharges totalling 44 gpm were measured discharging to Frazier Run. Chemical data from Frazier Run at mouth (Station No. 1799) is included in the Appendix.

Wheeling Creek

On the south bank of Wheeling Creek there has been a limited amount of both surface and underground mining between Blaine and the Ohio River. Several dry strip mines and two drift mine discharges were located on an unnamed tributary in this reach. The two discharges contributed a daily net acid load of 238 pounds discharged to the receiving stream.

At the time of the survey there were at least six active strip mines in the watershed area above the community of Midway. Active underground mines at that time included the large Franklin No. 25 Mine of Hanna Coal Company (over 400 employees) and two small drift mines (less than 10 employees).

The coal mines investigated in the Wheeling Creek watershed are nearly all located in the Pittsburgh (No. 8) and Sewickley (No. 9) coal seams. Generally, the underground mines are in the No. 8 seam and the strip mines in the upper portion of the watershed are in the No. 9 seam. However, a relatively small amount of underground and surface mining has taken place in the No. 9 and No. 8 seams, respectively.

A tabular listing of chemical data, source type, and receiving stream for the coal mine drainage sources investigated is presented in the Appendix.

DISCUSSION

The water quality of Wheeling Creek is seriously degraded by coal mine drainage. Specific water quality problems are excessive concentrations of alkalinity, hardness, sulfate, and iron. Precipitation of iron compounds in the stream causes the additional problems of high turbidity and unsightly stream conditions.

Some 120 mine drainage sources were sampled for chemical analysis. Seventy-two of these were discharging to streams of the Wheeling Creek watershed at the time of inspection. The total measured discharge volume was nearly 1500 gpm, or about 2.1 million gallons per day emanating from coal mines within the watershed. Approximately 65 percent of the total effluent volume was being discharged along Wheeling Creek or unnamed tributaries to the main stream, and in the Cox Run sub-watershed. Table 2 presents an area breakdown of mine drainage in terms of the total flow and total loadings (lb/day) of polluting constituents discharged to receiving streams in the Wheeling Creek watershed.

Acidity, Alkalinity

Although the survey found a net acid loading of about seven tons per day being discharged to Wheeling Creek and its tributaries, Wheeling Creek is strongly alkaline at its mouth. The majority of the tributaries to the main stream that drain mined areas are also alkaline. The alkalinity content of Wheeling Creek at Station No. 1684, plus the amount of alkalinity required to neutralize the mine effluent acidity (Table 2), indicate that about 12 tons per day of alkalinity are added to the watershed from sources other than those quantified during the survey. The principal sources of this large quantity of alkalinity are believed to be:

1. High natural stream alkalinity derived from limestone exposures in many areas of the watershed.

2. Streamflow augmentation by surface and subsurface seepage from strip-mined acreage.

The strip-mined areas in the upper portion of the study area contain hundreds of acres of ponded water. These ponds are permanent reservoirs which contribute streamflow increments by occasional overflow and continual seepage through permeable spoil material to ground and surface water. Although it was beyond the scope of this study to measure this hydrologic factor, the streamflow influence of delayed runoff and subsurface percolation from surface mining areas is well known.

Table 2
Mine drainage loadings
Wheeling Creek, Ohio watershed

Receiving Stream	Stream Mile 1/	Drainage Area (sq. mi.)	No. of Mine Discharges	Total Discharges (gpm)	Total Net Acidity (lb/day)	Total Net Alkalinity (lb/day)	Total Hardness (lb/day)	Total Sulfate (lb/day)	Total Iron (lb/day)
Wheeling Creek	-	-	15	215	917	210	3196	7520	1168
Unnamed Tribs. to Wheeling Cr.	-	-	17	415	6794	922	4540	20,009	1860
Frazier Run	1.1	1.4	1	3	19	-	40	122	29
Slaughter-house Run	1.3	.7	1	8	-	17	42	50	5
Mutton Hollow	2.6	1.4	2	11	6	44	53	165	25
Soaptown Hollow	3.7	2.0	1	6	59	-	74	410	86
Flat Run	6.7	3.4	3	100	2021	12	636	2570	724
McMonies Run	8.4	1.8	1	6	-	13	42	50	-
Steep Run	9.9	2.4	7	78	3102	-	1124	5161	1359
Town Run	10.8	2.5	-	-	-	-	-	-	-

Table 2 (continued)
Mine drainage loadings
Wheeling Creek, Ohio watershed

Receiving Stream	Stream Mile[1/]	Drainage Area (sq. mi.)	No. of Mine Dis-charges	Total Dis-charges (gpm)	Total Net Acidity (lb/day)	Total Net Alka-linity (lb/day)	Total Hard-ness (lb/day)	Total Sul-fate (lb/day)	Total Iron (lb/day)
Fall Run	12.1	3.9	10	95	631	46	1271	4244	568
Jug Run	13.7	3.8	2	26	148	-	178	292	23
Sloan Run	14.8	3.9	3	22	-	99	199	615	25
Cox Run	15.4	7.3	4	327	3	2532	484	4247	110
McCracken Run	20.0	4.7	-	-	-	-	-	-	-
Crabapple Creek	21.5	11.7[2/]	2	8	54	3	122	252	26
Campbell Run	-	7.3	-	-	-	-	-	-	-
Ross Run	-	1.8	3	150	208	224	1320	3519	3
TOTALS			72	1470	13,962	4,122	13,321	49,226	6,011

1/ Distance above mouth of Wheeling Creek
2/ Drainage area exclusive of Campbell and Ross Runs

During this study, 47 of the larges strip mine ponds (not overflowing) were sampled to determine their chemical character. Forty-one of these ponds were strongly alkaline.

From Table 2, the greatest demands on Wheeling Creek's alkaline reserve are presented by the acidic contributions of Steep Run, Flat Run, and the unnamed tributaries to Wheeling Creek. These subwatersheds contain six of the seven tons of daily net acidity measured in the mine discharges within the watershed.

Hardness

Over 50 percent of the hardness contained in the mine effluents comes from the sources discharging directly to Wheeling Creek and those discharging to unnamed tributaries to the main stream. The largest single source of hardness was Mine No. 1811 with a discharge of 75 gpm carrying a total hardness loading of 1566 lb/day.

Ions in mine drainage contributing to hardness in significant amounts are calcium, magnesium, iron, manganese, and aluminum.

Sulfate

Acidic and alkaline mine waters both commonly contain high concentrations of sulfate ion. The sources of sulfate in these effluents are free sulfuric acid and dissolved sulfate salts. The sulfate content of receiving streams in coal mining areas is indicative of the amount of total acidity that has been discharged to them through mine drainage. This sulfate content is the residual component of neutralized acidity as well as a component of acidity not yet subjected to neutralization.

A comparison of the total sulfate loading in mine effluents (Table 2) and the average sulfate loading measured in Wheeling Creek (Table 1) indicates that some 90 percent of the stream loading results from mine drainage. About 40 percent of the total sulfate load in the mine discharges comes from the area drained by 12 small unnamed tributaries to Wheeling Creek (Table 2).

Fifteen sources contributed over 1000 pounds per day each of sulfate ion to Wheeling Creek. The maximum sulfate discharge was 5670 pounds per day.

Total Iron

As pointed out, Wheeling Creek contains a high concentration of dissolved and suspended iron. An average daily loading of 424 pounds of iron was measured in Wheeling Creek at Station No. 1684 near the mouth (Table 1). Three tons per day of iron were measured discharging from 72 mine sources. Thus, some 2500 pounds per day of iron is precipitated and deposited on stream bottoms or is in intermittent stream transit. During high streamflow conditions the iron sediment is flushed from stream channels into the Ohio River.

One mine source (Mine No. 1795) discharged a daily iron loading of 1080 pounds, the largest source of iron found.

Table 3 presents a summary of flow volumes and chemical loadings, by type of source, for the 72 discharging sources inventoried.

Active mining operations contributed only a small percentage of the total discharge volume and chemical loadings found. Strip mines (including combination strip mines) and a mine refuse area contributed an equally small percentage of the total. Inactive drift mines (including combination drift mines) are the principal mine drainage pollution source type in the study area. This category discharged the following percentages of each parameter: flow (gpm) - 69 percent; net acidity - 91 percent; net alkalinity - 90 percent; hardness - 64 percent; sulfate - 78 percent; iron - 83 percent.

POLLUTION ABATEMENT

From the foregoing discussion it is apparent that primary concern for mine drainage pollution abatement should be with the inactive drift mine sources. Abatement within this source category would effect greater water quality improvement in the lower reaches of Wheeling Creek than control of the other types of pollution sources. This is particularly true if adequate regulation of active mining operations is maintained.

In order to predict the stream effect of an expected efficiency level of source abatement, it is necessary to center on the most reliable chemical parameter on which to base calculations. As discussed previously, mine acid entering Wheeling Creek is readily neutralized and is therefore unusable in estimating stream quality improvement. Hardness content is unreliable for this purpose because there are many varied sources of hardness in streams including natural sources. Iron is also unreliable because of the ease with which it precipitates from solution under conditions such as described in Wheeling Creek. In the absence of major industrial sources, sulfate is the most reliable indicator constituent for predicting water quality improvement in terms of abatement reduction of mine drainage. Natural sulfate concentrations in streams of the Appalachian coal fields generally do not exceed 20 mg/l.

Table 3

Mine drainage loadings by
source type
Wheeling Creek, Ohio watershed

Source Type	No.	Total Discharge (gpm)	Total Net Acidity (lb/day)	Total Net Alkalinity (lb/day)	Total Hardness (lb/day)	Total Sulfate (lb/day)	Total Iron (lb/day)
Drift mines (inactive)	41	764	5,333	3,170	6,199	22,757	2,717
Strip mines (inactive)	12	245	771	158	2,447	4,081	262
Combination drift mines * (inactive)	13	256	7,425	555	2,288	15,528	2,301
Combination strip mines** (inactive)	3	26	165	15	229	611	81
Mine refuse areas	1	24	131	0	138	201	0
Active mines	2	155	137	224	2,020	6,048	650
TOTALS	72	1,470	13,962	4,122	13,321	49,226	6,011

*Drift and strip mines together with principal portion of discharge from the drift mine.
**Strip and drift mines together with principal portion of discharge from the strip mine.

Principal Sources

There are 15 mine drainage sources discharging more than 1000 lb/day of sulfate. These consist of 12 inactive drift mines, one active drift mine, one active shaft mine, and one inactive strip mine (Table 4).

Their combined sulfate discharge is 35,643 lb/day, about 72 percent of the total measured sulfate load to Wheeling Creek. The total flow of these 15 sources is 869 gpm, about 60 percent of the total discharges measured.

Physical abatement of these principal sources would significantly improve water quality in the lower reach of Wheeling Creek. The resultant water quality can be predicted on the basis of anticipated pollution reduction efficiencies from physical abatement of the 15 sources.

In view of the technical difficulties involved, mine drainage abatement through control of drift mine sources cannot be expected to reach a high degree of effectiveness. An overall 50 percent reduction of polluting constituents from these sources is a reasonable expectation. It may also be reasonably expected that at least a 90 percent reduction of pollution capability is achievable with the inactive strip mine. Assuming the 50 and 90 percent reductions for drift mine and strip mine sources, and a 50 percent reduction through regulation for the two active underground mine sources, the values shown in Table 4 would result.

The reduction in sulfate loading from the principal sources (Table 4) from 35 thousand to 17 thousand pounds per day would effect a similar sulfate reduction in Wheeling Creek at Station No. 1684. Based on the average sulfate values in Wheeling Creek (Table 1), the resultant concentration would be about 300 mg/l. Corresponding reductions in iron loading from the sources would reduce the total iron received by Wheeling Creek by nearly 40 percent. The turbidity and water quality problems produced by the precipitated iron would be expected to be reduced by this amount.

If an overall 75 percent reduction were to be achieved at the drift mine sources, the resultant sulfate concentration in Wheeling Creek would be in the order of 235 mg/l. Reductions in hardness and iron content would also be expected, but of lesser magnitude.

The expected sulfate and related constituent concentrations would be incrementally reduced to more desirable levels with physical abatement of additional mine drainage sources.

Table 4

Principal mine drainage sources
Wheeling Creek, Ohio watershed

Mine No.	Discharge (gpm)	Present Sulfate Load (lb/day)	Expected Sulfate Load (lb/day)*	Type of Source	Receiving Stream
1758	41	3050	1525	Drift Mine	Unnamed trib. to Wheeling Creek
1764	30	1620	810	Drift Mine	Unnamed trib. to Wheeling Creek
1767	8	1219	610	Drift Mine	Unnamed trib. to Wheeling Creek
1774	30	2196	1098	Drift Mine	Steep Run
1782	27	1069	535	Drift Mine	Wheeling Creek
1786	30	1080	108	Strip Mine	Fall Run
1790	26	2184	1092	Drift Mine	Fall Run
1791	65	2418	1209	Drift Mine	Unnamed trib. to Wheeling Creek
1792	60	2232	1116	Drift Mine	Unnamed trib. to Wheeling Creek
1795	30	5670	2835	Drift Mine	Unnamed trib. to Wheeling Creek
1796	36	1900	950	Drift Mine	Flat Run
1811	75	3600	1800	Drift Mine(active)	Wheeling Creek
1807	306	3855	1928	Drift Mine	Cox Run
2041	80	2448	1224	Shaft Mine(active)	Ross Run
2089	25	1102	551	Drift Mine	Unnamed trib. to Wheeling Creek
TOTALS	869	35,643	17,391		

*After abatement

APPENDIX

CODES FOR TABULAR DATA - PAGES A-1 THROUGH A-6

TYPE

A - Stream
C - Drift Mine
D - Strip Mine
E - Combination Drift Mine
F - Combination Strip Mine
H - Shaft or Slope Mine
I - Refuse Pile
J - Active Operation

RECEIVING STREAM

1 - Wheeling Creek
2 - Unnamed tributary to Wheeling Creek
3 - Crabapple Creek
4 - Unnamed tributary to Crabapple Creek
5 - Fall Run
6 - Unnamed tributary to Fall Run
7 - Campbell Run
8 - Unnamed tributary to Campbell Run
9 - Steep Run
10 - Unnamed tributary to Steep Run
11 - Slaughterhouse Run
12 - Frazier Run
13 - Mutton Hollow
14 - Soaptown Hollow
15 - Flat Run
16 - McMonies Run
17 - Jug Run
18 - Town Run
19 - Sloan Run
20 - Cox Run
21 - McCracken Run
22 - Ross Run

WHEELING CREEK, OHIO

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L	ACIDITY LB/DAY	ALKALINITY MG/L	ALKALINITY LB/DAY	HARDNESS MG/L	HARDNESS LB/DAY	SULFATES MG/L	SULFATES LB/DAY	TOT. IRON MG/L	TOT. IRON LB/DAY	MANGANESE MG/L	MANGANESE LB/DAY	FLOW GPM
381757*	E	12	2.9	5000	554	19	0	0	1135	40	3400	122	816.	29.4	4.4	0.16	3
381758	C	12	5.8	8000	63	30	832	409	1113	547	6200	3050	192.	94.5	1.3	0.64	41
381759	C	11	6.7	1900	2	0	182	17	440	42	525	50	55.	5.3	0.3	0.03	8
381760	C	1	3.0	4000	289	20	0	0	1047	75	1350	97	276.	19.9	2.3	0.17	6
381761	C	13	5.8	5000	242	8	80	2	970	34	2600	93	672.	24.2	4.2	0.15	3
381762	C	13	6.2	2800	0	0	460	44	200	19	750	72	6.	0.6	0.3	0.03	8
381763	D	14	3.7	8000	830	59	0	0	1032	74	5700	410	1200.	86.4	5.3	0.38	6
381764	C	2	5.7	2600	2725	981	0	0	1308	470	4500	1620	48.	17.3	4.2	1.51	30
381765	C	1	3.1	5000	55	0	0	0	875	10	850	10	312.	3.7	4.9	0.06	1
381766	C	15	6.2	1900	54	38	6	4	750	540	875	630	84.	60.5	1.9	1.37	60
381767	E	2	3.0	9999	17600	1689	0	0	2250	216	12700	1219	3000.	288.0	54.3	5.21	8
381768	E	2	3.1	9999	20950	502	0	0	810	19	13500	324	2281.	54.7	48.4	1.16	2
381769	E	2	6.4	2000	56	6	152	18	1260	151	1900	228	29.	3.5	8.0	0.96	10
381770	F	16	7.5	1500	63	4	240	17	592	42	700	50	2.	0.1	0.3	0.02	6
381771	C	10	6.5	6500	315	22	12	0	2400	172	4000	288	780.	56.2	5.2	0.37	6
381772	C	9	4.7	3500	2000	96	0	0	710	34	2450	117	216.	10.4	2.7	0.13	4
381773	C	9	3.0	5000	1310	125	0	0	1108	106	5200	499	42.	4.0	19.6	1.88	8
381774	C	9	3.6	8600	4100	1476	0	0	1050	378	6100	2196	1920.	691.2	4.9	1.76	30
381775	C	9	2.3	7400	7950	954	0	0	1070	128	7100	852	1680.	201.6	8.8	1.06	10
381776	C	9	3.8	7140	1650	297	0	0	1280	230	4800	864	1680.	302.4	2.8	0.50	15
381777	C	9	3.3	8600	2200	132	0	0	1280	76	5750	345	1560.	93.6	3.8	0.23	5
381778	C	6	7.0	2200	26	0	152	5	700	25	1000	36	0.	0.0	1.5	0.05	3
381779	C	6	6.8	1600	110	1	355	4	178	2	450	5	10.	0.1	0.5	0.01	1
381780	I	17	4.5	1200	458	131	0	0	482	138	700	201	0.	0.0	2.1	0.60	24

* The prefix '38' in the mine number designates the State of Ohio.

WHEELING CREEK, OHIO

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L	ACIDITY LB/DAY	ALKALINITY MG/L	ALKALINITY LB/DAY	HARDNESS MG/L	HARDNESS LB/DAY	SULFATES MG/L	SULFATES LB/DAY	TOT. IRON MG/L	TOT. IRON LB/DAY	MANGANESE MG/L	MANGANESE LB/DAY	FLOW GPM
381781	C	17	6.1	6000	720	17	0	0	1670	40	3800	91	960.	23.0	2.3	0.06	2
381782	C	1	4.1	5000	880	285	0	0	1630	528	3300	1069	528.	171.1	2.4	0.78	27
381783	C	6	7.0	2000	63	3	206	9	490	23	850	40	22.	1.0	0.6	0.03	4
381784	E	5	3.4	2000	892	10	0	0	496	5	1175	14	0.	0.0	3.4	0.04	1
381785	D	5	6.4	5000	44	0	96	1	1676	20	2800	33	144.	1.7	4.6	0.06	1
381786	D	5	3.1	5500	775	279	0	0	1355	487	3000	1080	264.	95.0	3.9	1.40	30
381787	C	5	6.9	5000	190	6	372	13	848	30	3250	117	744.	26.8	4.9	0.18	3
381788	A	0	4.0	5000	1290	2507	0	0	1380	2682	3400	6609	432.	839.8	5.3	10.30	162
381789	A	0	7.4	1350	18	13	88	66	597	451	700	529	2.	1.7	0.5	0.38	63
381790	C	5	2.9	8680	570	177	0	0	1310	408	7000	2184	1140.	355.7	8.2	2.56	26
381791	E	2	7.5	6000	112	87	580	452	796	620	3100	2418	47.	36.5	0.8	0.62	65
381792	E	2	6.9	6000	145	104	250	180	966	695	3100	2232	46.	32.8	1.6	1.15	60
381793	C	2	6.5	1900	4	0	365	4	560	6	475	5	17.	0.2	0.2	0.00	1
381795	E	2	3.5	9999	8500	3060	0	0	186	66	15750	5670	3000.	1080.0	19.5	7.02	30
381796	E	15	3.9	8000	4600	1987	0	0	120	51	4400	1900	1536.	663.6	8.8	3.80	36
381797	D	15	1.2	2000	12	0	268	12	940	45	850	40	4.	0.2	0.5	0.02	4
381798	A	0	8.1	9999	325	175	335	180	1139	615	5250	2835	55.	29.8	2.4	1.30	45
381799	A	0	7.8	1600	14	0	210	0	522	0	525	0	0.	0.0	0.0	0.00	0
381800	A	0	7.2	3000	6	0	170	0	980	0	1300	0	0.	0.0	0.0	0.00	0
381801	A	0	6.9	3000	10	0	178	0	1180	0	1800	0	13.	0.0	6.4	0.00	0
381802	D	5	6.7	5000	18	1	266	25	1140	109	2150	206	84.	8.1	2.8	0.27	8
381803	C	19	6.7	6000	17	0	504	6	620	7	2050	24	86.	1.0	0.5	0.01	1
381804	C	19	7.1	6500	20	0	282	3	1260	15	2300	27	6.	0.1	0.8	0.01	1
381805	E	19	6.2	6000	18	4	392	94	740	177	2350	564	98.	23.6	0.8	0.19	20

WHEELING CREEK, OHIO

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L	ACIDITY LB/DAY	ALKALINITY MG/L	ALKALINITY LB/DAY	HARDNESS MG/L	HARDNESS LB/DAY	SULFATES MG/L	SULFATES LB/DAY	TOT. IRON MG/L	TOT. IRON LB/DAY	MANGANESE MG/L	MANGANESE LB/DAY	FLOW GPM
381808	C	20	6.7	2106	155	22	356	51	164	23	2200	316	43.	6.2	0.5	0.07	12
381809	D	20	7.4	2380	95	9	508	48	118	11	625	60	0.	0.0	0.2	0.02	8
381810	C	1	3.2	3300	1280	30	0	0	320	7	1800	43	384.	9.2	2.9	0.07	2
381811	CJ	1	6.8	8720	400	360	248	223	1740	1566	4000	3600	720.	648.0	2.3	2.07	75
381812	C	1	6.3	6580	930	133	0	0	820	118	2900	417	960.	138.2	2.9	0.42	12
381813	C	1	3.7	7000	1700	40	0	0	174	4	2900	69	648.	15.6	3.7	0.09	2
381814	C	1	6.4	3000	116	62	460	248	300	162	1500	810	37.	20.1	9.8	5.29	45
381815	C	1	6.7	5000	202	12	321	19	708	42	2775	166	46.	2.8	0.6	0.04	5
381820	C	1	6.5	5000	410	68	0	0	1400	235	1900	319	312.	52.4	1.9	0.32	14
381821	C	1	6.7	5000	76	1	244	5	1392	33	1600	38	168.	4.0	2.1	0.05	2
381822	C	20	6.7	2800	250	3	0	0	1480	17	1400	16	134.	1.6	2.4	0.03	1
381842	HJ	21	7.3	4300	0	0	469	0	215	0	1575	0	7.	0.0	0.1	0.00	0
381843	D	21	7.6	1600	44	0	46	0	896	0	1100	0	0.	0.0	0.1	0.00	0
381807	C	20	7.0	3580	17	62	688	2526	118	433	1050	3855	28.	102.1	0.2	0.73	306
382006	D	21	7.5	1900	131	0	256	0	1052	0	1125	0	1.	0.0	0.2	0.00	0
382007	D	21	7.4	2400	366	0	203	0	1260	0	1600	0	1.	0.0	0.0	0.00	0
382008	D	21	7.3	3500	146	0	270	0	1045	0	1850	0	2.	0.0	0.7	0.00	0
382009	D	21	7.8	1300	104	0	265	0	285	0	425	0	1.	0.0	0.4	0.00	0
382017	D	21	7.4	3500	250	0	66	0	1835	0	2100	0	3.	0.0	1.6	0.00	0
382018	A	0	7.4	2400	30	0	108	0	1250	0	1320	0	0.	0.0	0.0	0.00	0
382019	D	21	7.8	3000	54	0	135	0	1715	0	1800	0	1.	0.0	1.0	0.00	0
382020	D	21	8.1	2000	30	0	95	0	1150	0	1150	0	0.	0.0	0.1	0.00	0
382028	D	22	7.7	950	15	0	45	0	350	0	450	0	1.	0.0	0.0	0.00	0
382029	D	22	7.5	2800	146	0	150	0	1300	0	1350	0	1.	0.0	0.1	0.00	0

WHEELING CREEK, OHIO

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L	ACIDITY LB/DAY	ALKALINITY MG/L	ALKALINITY LB/DAY	HARDNESS MG/L	HARDNESS LB/DAY	SULFATES MG/L	SULFATES LB/DAY	TOT. IRON MG/L	TOT. IRON LB/DAY	MANGANESE MG/L	MANGANESE LB/DAY	FLOW GPM
382030	D	22	7.9	950	17	0	32	0	480	0	540	0	0.	0.0	0.0	0.00	0
382031	D	7	8.0	1100	68	0	73	0	605	0	600	0	1.	0.0	1.0	0.00	0
382032	D	7	7.2	2100	46	0	96	0	1280	0	1290	0	1.	0.0	2.0	0.00	0
382033	D	4	7.2	450	0	0	25	0	248	0	230	0	1.	0.0	0.1	0.00	0
382034	D	4	5.6	3500	414	0	0	0	2600	0	2550	0	3.	0.0	26.0	0.00	0
382035	D	4	6.7	2200	13	0	113	0	1235	0	1300	0	1.	0.0	0.0	0.00	0
382036	D	22	8.4	350	0	0	58	0	140	0	80	0	1.	0.0	0.0	0.00	0
382037	D	22	7.4	1400	53	0	146	0	660	0	725	0	18.	0.0	0.1	0.00	0
382038	D	22	7.8	2800	193	0	201	0	1800	0	1650	0	4.	0.0	0.1	0.00	0
382039	D	22	7.5	3000	277	99	164	59	1940	698	1750	630	1.	0.3	0.4	0.14	30
382040	D	22	6.0	1400	350	168	0	0	350	168	920	441	2.	0.7	12.0	5.76	40
382041	HJ	22	7.3	5500	146	140	380	364	473	454	2550	2448	2.	1.6	0.8	0.77	80
382043	D	22	6.1	3000	170	0	3	0	2260	0	1850	0	1.	0.0	3.6	0.00	0
382044	D	22	7.7	850	11	0	61	0	380	0	380	0	0.	0.0	0.0	0.00	0
382045	D	4	8.0	320	6	0	48	0	140	0	90	0	0.	0.0	0.1	0.00	0
382046	D	4	7.4	950	8	0	130	0	328	0	420	0	1.	0.0	0.2	0.00	0
382047	D	4	7.8	1000	16	0	166	0	180	0	450	0	3.	0.0	0.2	0.00	0
382048	D	4	8.1	230	0	0	47	0	106	0	45	0	0.	0.0	0.0	0.00	0
382049	D	4	7.6	1700	0	0	78	0	996	0	1100	0	3.	0.0	0.0	0.00	0
382050	D	4	7.5	1700	10	0	43	0	985	0	975	0	1.	0.0	1.0	0.00	0
382060	D	4	5.7	1200	74	0	6	0	600	0	630	0	1.	0.0	6.6	0.00	0
382061	D	4	7.7	450	0	0	86	0	156	0	100	0	0.	0.0	0.1	0.00	0
382062	D	4	7.8	450	0	0	87	0	188	0	110	0	1.	0.0	0.1	0.00	0
382063	D	4	7.7	500	0	0	51	0	244	0	200	0	1.	0.0	0.0	0.00	0

WHEELING CREEK, OHIO

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L	ACIDITY LB/DAY	ALKALINITY MG/L	ALKALINITY LB/DAY	HARDNESS MG/L	HARDNESS LB/DAY	SULFATES MG/L	SULFATES LB/DAY	TOT. IRON MG/L	TOT. IRON LB/DAY	MANGANESE MG/L	MANGANESE LB/DAY	FLOW GPM
382064	D	4	7.5	1500	36	0	98	0	708	0	825	0	1.	0.0	0.4	0.00	0
382065	D	4	7.6	1400	0	0	120	0	680	0	725	0	1.	0.0	0.8	0.00	0
382066	D	4	3.5	2400	1130	0	0	0	432	0	1830	0	18.	0.0	15.4	0.00	0
382067	D	4	6.2	1100	8	0	85	3	572	20	645	23	1.	0.0	0.5	0.02	3
382068	D	3	7.1	1200	21	0	50	0	636	0	660	0	1.	0.0	3.4	0.00	0
382069	D	3	7.1	1400	2	0	69	0	774	0	900	0	2.	0.0	1.8	0.00	0
382070	D	3	7.3	2400	42	0	244	0	1236	0	1350	0	1.	0.0	0.4	0.00	0
382071	D	4	7.6	950	25	0	153	0	3500	0	405	0	0.	0.0	0.2	0.00	0
382075	D	2	8.0	1300	29	17	70	42	774	464	860	516	1.	0.6	0.2	0.12	50
382076	D	2	8.0	560	20	12	110	66	440	264	380	228	1.	0.6	0.8	0.48	50
382077	D	2	7.9	1000	19	0	76	0	370	0	165	0	1.	0.0	0.2	0.00	0
382078	D	2	7.5	1300	0	0	129	0	608	0	560	0	1.	0.0	0.2	0.00	0
382079	D	2	7.3	1600	12	0	71	0	940	0	940	0	1.	0.0	0.0	0.00	0
382080	D	2	6.3	950	0	0	92	0	504	0	450	0	1.	0.0	0.4	0.00	0
382081	D	2	5.5	2800	550	0	900	0	1284	0	2200	0	1.	0.0	19.7	0.00	0
382082	D	3	8.4	2600	0	0	141	0	1830	0	1760	0	4.	0.0	0.4	0.00	0
382083	D	3	8.4	1100	0	0	137	0	506	0	570	0	1.	0.0	0.3	0.00	0
382084	D	3	8.4	800	0	0	120	0	360	0	330	0	1.	0.0	0.2	0.00	0
382085	D	3	8.4	2400	0	0	120	0	1680	0	1680	0	2.	0.0	0.0	0.00	0
382086	C	3	6.2	5500	900	54	0	0	1710	102	3825	229	430.	25.8	5.6	0.34	5
382087	C	1	7.0	2800	57	3	156	9	1550	93	1720	103	71.	4.2	0.6	0.04	5
382088	C	1	5.7	6500	1455	174	0	0	1640	196	4600	552	550.	66.0	6.0	0.72	10
382089	C	2	6.2	5000	365	109	0	0	2050	615	3675	1102	270.	81.0	4.8	1.44	25
382090	C	1	6.0	6000	645	30	0	0	1880	90	2925	140	250.	12.0	4.2	0.20	4

WHEELING CREEK, OHIO

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382091	F	5	6.2	4000	780	168	14	3	750	162	2450	529	370.	79.9	2.3	0.50	18
382092	E	1	7.4	3000	21	1	148	8	622	37	1450	87	11.	0.7	1.0	0.06	5
382093	F	2	7.7	2200	74	1	273	6	384	9	1200	28	1.	0.0	0.2	0.00	2
382094	F	2	7.4	2200	14	0	106	2	1068	25	1350	32	24.	0.6	0.8	0.02	2
382095	C	2	3.2	2800	590	70	0	0	700	84	1680	201	105.	12.6	1.6	0.19	10
382096	D	2	5.3	3000	1250	225	0	0	488	87	2300	414	380.	68.4	1.8	0.32	15
382097	E	2	6.9	8000	945	158	0	0	1205	202	4300	722	530.	89.0	3.0	0.50	14

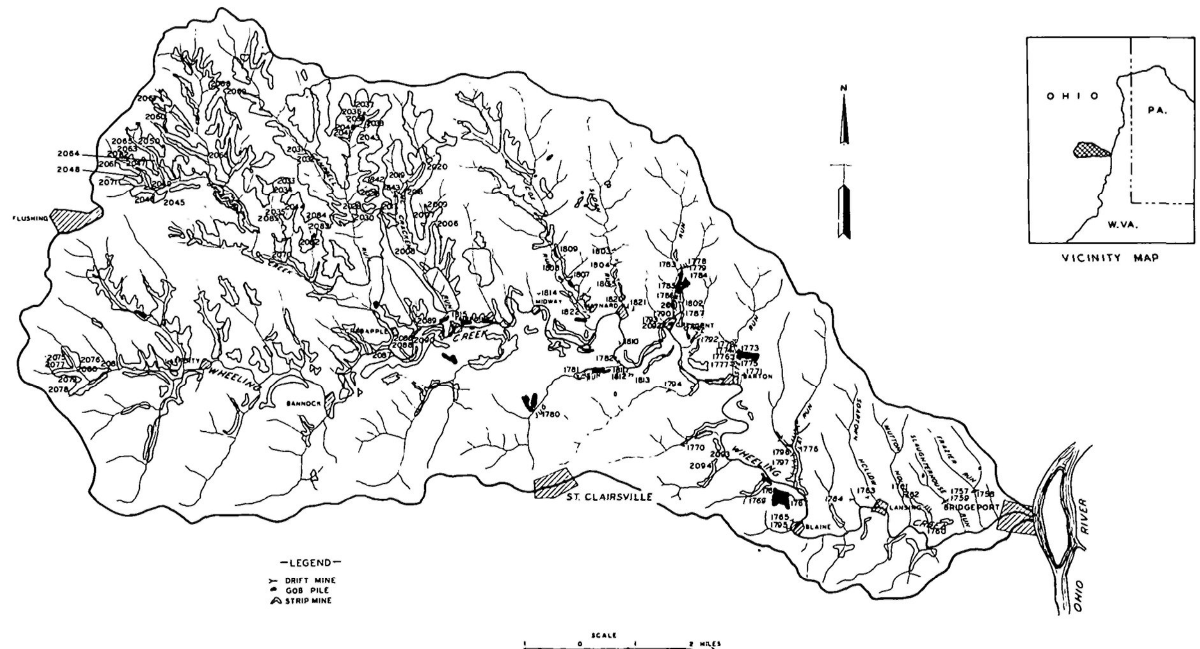

FIGURE 2. SOURCES OF MINE DRAINAGE POLLUTION, WHEELING CREEK, OHIO WATERSHED