SECTION III

SHAMOKIN CREEK WATERSHED: RESULTS OF INVESTIGATIONS

GENERAL DESCRIPTION

The Shamokin Creek watershed drains approximately 137 square miles, situated principally in southeastern Northumberland County but extending into southwestern Columbia and southern Montour Counties, Pennsylvania. Shamokin Creek rises near Aristes Village and Centralia Borough, from where it flows westward through a mountainous wooded area into the City of Shamokin. Shamokin Creek then flows northward through gaps in Big and Little Mountains, then westward through a valley to enter the Susquehanna River at Sunbury City.

The population of the watershed is currently estimated at 60,000. The largest concentration exists in Shamokin City and surrounding Coal Township, where approximately 23,500 persons reside. Other population centers in the watershed are Mount Carmel and Kulpmont Boroughs, a portion of Sunbury City, and Mount Carmel Township.

Food processing and manufacturing, principally of textiles, wearing apparel, furniture, and fixtures, provide over half of the watershed income. These industries are located primarily in Shamokin and Sunbury Cities and in Centralia, Mount Carmel, and Kulpmont Boroughs. The production of chickens, eggs, and. hogs in the downstream valley adds to its economy.

Anthracite coal mining, once the mainstay of watershed economy, continues at a severely reduced rate. The watershed headwaters area of about 50.5 square miles situated south of the crest of Big Mountain is underlaid by a portion of the Western Middle Field. Discovery of anthracite in this field is credited to Isaac Tomlinson, who in 1790 discovered coal in the bed of Quaker Run. The first commercial shipment was made by John Thompson from a quarried deposit in the Quaker Run area. The first major mining was started at Cameron Colliery, which began operations in 1836. Completion of the Danville and Pottsville Railroad in 1838 opened the area for developing markets to the west. As demands for fuel escalated, mining increased. The Department of Environmental Resources' earliest records, begun in 1870, indicate a rapid rise in productivity as major collieries were developed. At peak production in 1917, the watershed contributed approximately 6,200,000 tons of coal through the efforts of 4,400 men.

Watershed strip (surface) mining became a significant contributor to anthracite tonnage during the thirties. Early strip mining was confined primarily to surface reservation pillars, geologically complex areas, and marginal quality coal veins. As underground mining costs increased and competing fuels captured large market segments, strip mining expanded. During 1932, when the Department of Environmental Resources first maintained records of strip mining tonnage, about 3.5 million tons, or approximately seven percent of total anthracite production, were stripped. Strip mining increased in the anthracite field until 1948, when about 13.5 million tons, or approximately 23 percent of total anthracite production, were stripped. Since 1948, however, all anthracite production has declined. During 1970 approximately 4.6

million tons, or a bout 50 percent of total anthracite production, were strip mined. Anthracite deep mine production has declined from a peak of about 100 million tons in 1917 to approximately 1.7 million tons in 1970. Active watershed mining is currently limited to small independent deep and strip mining operations. During 1970 fewer than 300 men were engaged in watershed coal production; deep mines accounted for 60,000 tons; strip mines accounted for 510,000 tons; and 270,000 tons were reclaimed from banks.

Although significant watershed anthracite reserves remain, mining is not expected to increase substantially in the near future. Past deep mining has left huge pools of water overlying remaining coal in now inactive major underground mines. Past strip mining has removed much of the most readily accessible reserves. The coal mining industry will be hard pressed to maintain production at the last few years' levels in the watershed, unless new mining techniques are developed or the demand for coal increases dramatically.

More than 100 years of intensive mining in the watershed headwaters area underlaid by coal has caused severe acid mine drainage pollution of streams draining that area. These streams include its North Branch, Locust Creek, Quaker Run, Buck Run, Coal Run, and Carbon Run, as well as Shamokin Creek. Several acid mine drainage discharges enter these streams from mine drainage discharge points, some of which drain extensively mined areas. Extensive past mining underneath and adjacent to these streams has interrupted surface-water and ground-water flow to the extent that portions of these streams do not ordinarily have flows. In addition, such municipalities as Mount Carmel and Kulpmont Boroughs, Shamokin City, as well as Mount Carmel and Coal Townships discharge untreated sanitary wastewaters into the watershed headwaters area. Therefore, the streams draining this area are grossly polluted and are not suitable for public use. These communities, except for Kulpmont Borough, are currently developing sewerage projects leading toward the abatement of this gross pollution. Relatively good quality water is contributed to the downstream portion of Shamokin Creek from several tributary streams. Although no significant pollution enters the downstream portion of Shamokin Creek, it remains quite adversely affected throughout its length by the above discharges.

Little or no aquatic life associated with unpolluted streams exists in the watershed headwaters area. Such aquatic life does exist in several tributary streams in Shamokin Creek's middle and lower reaches, including Trout Run, Buddys Run, Millers Run, Lick Creek, and those locally known as Kulps Run, Sunnyside Run, and Elysburg Run. Shamokin Creek's main stem does not support such aquatic life.

State Game Land No. 165 is located primarily on the south side but extends onto the north side of Little Mountain a few miles west of Shamokin. The area on the north side of Little Mountain is located within the watershed, while the remainder lies in the Zerbe Run Drainage Area. This 3,3l4-acre tract provides considerable hunting for both small and large game.

The locations of the watershed, cities, boroughs, villages, and other geographical features referred to in this section are shown on Plate I.

GEOLOGIC CONSIDERATIONS

Acid mine drainage in the watershed is caused by numerous man-made subsurface and surface conditions. These conditions and their interrelationship must be defined to determine the causes of acid mine drainage and to develop abatement plans. Therefore, geochemical considerations are discussed in this section.

Current watershed water quality is the result of the types of rocks laid down in the watershed millions of years ago and the conditions then existing under which deposited vegetable matter decayed. Sediments were deposited in either an oxidizing or reducing environment. Vegetable matter accumulating on the land surface or in well-aerated water was oxidized. In this environment the organic matter was converted by aerobic bacteria to water and carbon dioxide, and iron present reached the ferric state. Conversely, vegetable matter deposited in stagnant water decayed after quickly depleting available dissolved oxygen by a slow process of destructive distillation. In this oxygen-poor reducing environment, facultative and anaerobic bacteria obtained oxygen from sulfates and other available ions, with hydrogen sulfide being produced. Hydrogen sulfide reacted with soluble compounds to form disulfide, which precipitated as pyrite. This production of pyrite in sedimentary deposits was directly related to the presence of organic matter in a reducing environment. Where enough organic matter was deposited, coal was eventually formed with the pyrite. With subsequent mining of the coal, the pyrite was uncovered, broken, and much of its surfaces exposed. These exposed surfaces oxidized to form ferrous sulfate and sulfuric acid in the presence of water. Water flowing over these surfaces eventually carried these oxidation products as acid mine drainage discharges into watershed streams.

Conglomerates, sandstones, and shales comprise the major watershed rock types, and significant amounts of coal in 15 persistent mineable beds are also found. Streams draining the watershed headwaters area usually have (1) a very low solids content, (2) a pH of less than 7.0, and (3) trace amounts of various metals including iron. These streams have a low buffering capacity. Atmospheric carbon dioxide and organic acids from decaying vegetable matter depress the pH of these streams. Small iron concentrations in these streams are derived from the rocks from which these streams originated.

MAJOR SUBSURFACE CONDITIONS BEARING UPON THE FORMATION OF ACID MINE DRAINAGE

The major watershed subsurface conditions causing acid mine drainage are set forth in this section. The information used in defining these conditions was obtained from geologic maps, aerial photographs, available mine maps, individuals knowledgeable about the watershed, and field investigations. Geologic maps were obtained from the United States Geological Survey (USGS). Aerial photographs and mine maps were made available by the Department of Environmental Resources. Department personnel, coal operators, and other knowledgeable individuals provided information. Field investigations were made by Gannett Fleming Corddry and Carpenter, Inc., to verify information and data obtained from other sources and to secure supplementary information and data.

The watershed headwaters area of approximately 50.5 square miles located south of the crest of Big Mountain is underlaid with coal comprising a portion of the Western Middle Anthracite Field. Fifteen persistent and 19 locally occurring veins of coal have been discovered in this area. Virtually all these 34 coal veins have been deep or strip mined to some extent. These veins are identified in Exhibit A by name, number (or letter), and by the geologic formation in which they are found.

These coal measures were originally deposited over a much larger surface area than they now underlie. Subsequent severe folding of the earth's crust displaced these measures so that the coal veins pitch steeply as deep as 2,600 feet beneath the ground surface from their outcrops along watershed ridges. This displacement formed alternate ridges, or anticlines, and depressions, or synclines, generally trending northeast to southwest. During this displacement, faults were created as the coal-bearing rocks broke and adjacent broken surfaces were forced past each other. Hence, these coalbearing strata contain a series of ridges and valleys interspersed with faults occurring at odd angles.

This natural inclination of coal veins dictated the manner in which deep mining was undertaken. Slope entries were driven down the steeply pitching veins for a few hundred feet where tunnels were driven through intervening rock to intercept other coal veins. Several veins were mined from that level to the ground surface through those tunnels and slopes. Where mining was extended too close to the ground surface, subsidence of the ground surface into the underlying voids occurred. When the minable coal had been removed from that area, the slopes were extended to deeper levels where the same procedures were repeated. In some instances shafts were constructed at strategic places throughout the coal-bearing strata. As deep mining was extended throughout the area, an intricate system of interconnected slopes, shafts, and rock tunnels was formed. Barriers of unmined coal were left between mines being developed by different owners. Thus, under this original development each mine had its own system of shafts, slopes, and rock tunnels connecting the veins being mined.

As deep mining developed and continued in the various mines, surface and ground water were encountered. This water flowed down the mined veins to the levels being worked. From these levels it was necessary to pump the water to the surface for discharge to the nearest watercourse. As mining progressed to even deeper levels, more water was intercepted. Eventually the mine operators established pump relay stations to remove water in stages from the deepest levels. Naturally, costs of mining and mine dewatering increased as mining progressed to deeper levels. Some mine operators eventually decided to discontinue mining because of increased costs, the depressed market for coal, and other reasons. These discontinued mines then began to fill with water.

As the large mine operators discontinued mining, independent miners opened small operations within the large mines to recover remaining available coal. In some instances, coal left in barrier pillars was removed, thus creating communications between mines. In addition, coal left as ground support by the large mine operators was removed, causing more surface subsidence and creating additional locations through which surface water could enter the mine workings. The major mining companies have ceased mining and pumping operations in the watershed. The mines have partially filled with water. Vast underground pools have formed in contiguous mines since water could flow from one mine to another through various interconnections. These pools have found relief to surface streams through openings in the ground surface. Independent miners continue to extract coal above established pool levels.

Acid-producing materials are associated in varying degrees with all the watershed mined veins. As surface and ground water encounter these materials in the presence of air, ferrous sulfate and sulfuric acid are formed. Ferrous sulfate is very soluble in water. Acid mine drainage has been formed through this interaction between the acid-producing materials, air, and water since mining began. Acid mine drainage will continue to be created as long as these three substances remain in contact with each other. Additional acid mine drainage will continue to be formed in watershed mined areas for many years. The extent of deep mined areas and other related features are shown on Plate II.

MAJOR SURFACE CONDITIONS BEARING UPON THE FORMATION OF ACID MINE DRAINAGE

The major surface conditions causing acid mine drainage are discussed in this section. The same sources of information used to define subsurface conditions causing acid mine drainage are also employed in this section.

Approximately 25.3 percent, or 12.8 square miles, of the watershed has been affected by active and inactive strip mines. Most of this strip mining has been or is being conducted in certain of the Post-Pottsville coal veins, specifically the Buck Mountain, Seven Foot, Skidmore, the three major splits of the Mammoth, Four Foot, Holmes, Rough, Primrose, Orchard, Little Orchard, Diamond, and Little Diamond. The other veins occurring in the watershed have been stripped to a lesser extent. At the end of 1971 twenty-two active strip mines were noted, principally within the confines of areas previously stripped.

Because of past inadequate restoration, many inactive watershed strip mines serve as catch basins, which collect direct precipitation, surface runoff, and ground water. Considerable volumes of water so collected enter underlying deep mine workings into which the strip mines have cut, or through fissures in the intervening rock. Partial restoration and sedimentation within portions of some strip mines allow some water to collect in the pits from which overflows to adjacent surface streams sometimes occur. In certain watershed areas virtually all former stream water has been intercepted by strip mines and interconnected deep mines. Water so collected comes in contact with acid-producing materials in either the strip or deep mines before being discharged as acid mine drainage to streams.

Acid mine drainage discharges, primarily during wet weather, have been caused by the discarding of acid-producing material on the ground surface. Large piles of this material have accumulated at past major underground mining operations and at coal-processing operations throughout the watershed. At these operations, process water is obtained from either adjacent surface streams or underlying deep mine water pools. This water is retained in sedimentation basins within closed systems or is directed into underlying deep mine pools. A few small active breakers are located downstream along Shamokin Creek, north of the watershed headwaters area. No pollutional discharges from these downstream breakers were noted during the field investigations.

The extent of watershed strip mining, both inactive and active, as well as the locations of large refuse areas and other geographic features are shown on Plate II.

WATER FLOW ROUTES INTO AND THROUGH DEEP MINE WORKINGS

After the major subsurface and surface conditions causing acid mine drainage within the watershed were established, water flow routes into and through deep mine workings were determined. Specific points at which surface and ground water enter deep mine workings had to be located before effective acid mine drainage abatement measures could be developed. Water flow routes also had to be traced through underground workings before mine drainage design volumes and quality could be established and before estimates could be made of acid mine drainage reductions attributable to the construction of preventive measures. The major points of connection between the ground surface and deep mine workings, and water flow routes through the deep mine workings are summarized below:

1. Deep Mine Entries:

   Numerous deep mine entries are located within the watershed, including drifts, slopes, and shafts. More than half of such entries were subsequently obliterated by strip mining along outcrops of the coal veins and by the filling of shafts to eliminate potentially dangerous holes. Currently existing deep mine entries are not significant points of entry for surface and ground water into deep mine workings. The locations of deep mine entries are shown on Plate II.

2. Subsidence Areas:

   Many areas exist where the ground surface has subsided into underlying deep mine workings. Most of these areas are associated with the Buck Mountain, Seven Foot, Skidmore, the three major splits of the Mammoth, Four Foot, Holmes, Rough, and Primrose veins. Minor amounts of subsidence areas are associated with the other mined veins. Many such areas were subsequently strip mined. Consequently, the subsidence areas shown on Plate II include only those areas not subsequently obliterated by strip mining.

3. Stream Infiltration Areas:

   Past deep mining extended under significant stretches of stream beds within the watershed. The streams so affected include virtually the entire lengths of the North Branch of Shamokin Creek, Locust Creek, Quaker Run, Coal Run, and Buck Run, as well as significant portions of Carbon Run, and Shamokin Creek upstream from Shamokin City. In addition, numerous unnamed tributaries of these streams have been undermined. As a result of this extensive mining under stream beds, many infiltration areas have been created. During other than heavy rainfall and runoff conditions, stream flow diminishes or ceases in these streams. The extent of mining underneath watershed streams is shown on Plate II.

4. Strip Mines:

Approximately 25 percent of the watershed headwaters area has been strip mined, primarily in the Buck Mountain, Seven Foot, Skidmore, the three major splits of the Mammoth, Four Foot, Holmes, Rough, Primrose, Orchard, Little Orchard, Diamond, and Little Diamond veins. Many stripmined areas encompass several veins, and most of these strip mines have cut into the underlying deep mines. Surface waters are intercepted by these strip mines, through which large volumes of such waters flow to underground pools present in the deep mines. The locations of all watershed strip mines are noted on Plate II.

5. Interconnected Deep Mines, Pools, and Pool Overflows:

The extensive deep mine workings have become connected to a considerable degree. Barrier pillars between collieries were required by law; however, where one owner was mining adjacent collieries he was granted permission to mine across the barrier pillars between those collieries. Independent miners also received permission to mine some of these barrier pillars after major mining had ceased in the adjacent collieries. Surface and ground waters have filled these collieries to levels at which these waters find relief to near by surface streams through overflows. The subsurface areas through which the current pool overflows drain are color coded on Plate III. Flows from Midvalley Colliery are drained by Discharge Point No.5. Discharge Point Nos. 19 and 20, located over Maysville Colliery but known as the Scott overflows, drain water from Morris Ridge, Sayre, Stuartsville, Sioux, Richards, Greenough, Pennsylvania, and Scott Collieries, as well as a small portion of Natalie Colliery. Reliance, Alaska, and major portions of Enterprise and Excelsior-Corbin are relieved by Discharge Point No. 12. Flows from the remaining portion of Excelsior-Corbin Colliery drain through Discharge Point No. 15. Discharge Point No. 21, located over Buck Ridge No.1 Colliery, drains flows from Maysville Colliery. Mine waters from Big Mountain and small parts of Burnside and Enterprise Collieries overflow through Discharge Point No. 23. Flows from Henry Clay, Stirling, Neilson, and Bear Valley, as well as major portions of Burnside and Royal Oak, and a minor portion of Buck Ridge drain through Discharge Point No. 49. Additional relief for Royal Oak mine water is provided by Discharge Point No. 29. A major portion of overflows from Buck Ridge Colliery pass through Discharge Point Nos. 24, 25, 26, and 27. Overflows from Buck Ridge No.1 Colliery and a minor portion of Luke Fidler Colliery drain to Discharge Point No. 36. Discharge Point Nos. 50, 51,52, and 53 drain flows from Hickory Ridge, Colbert, Hickory Swamp, Cameron, Glen Burn, and major portions of Natalie and Luke Fidler Collieries. Some colliery mining extended under adjacent colliery surface areas.

The information and data shown in this section relative to water flow routes through deep mine workings are based on investigations described in this report. However, gobbing practices, pulling of pillars, interconnecting strip mines, and roof falls that have occurred since major deep mining ceased may have blocked, restricted, or altered water flow routes through deep mine workings. The extent to which this may have occurred is extremely difficult to determine, but apparently huge volumes of water are being conveyed through the major underground flow routes 15 to 20 years after major deep mining operations were discontinued.

Much of the watershed surface area underlaid by deep mines has been extensively fissured. Surface and ground waters, therefore, have access to deep mine workings through these fissured areas in addition to the specific interconnections located during the investigations.

EXTENT OF SURFACE AND SUBSURFACE AREAS DRAINING INTO OR OUT OF THE WATERSHED

In certain areas along the perimeter of the watershed headwaters area, precipitation becoming part of the ground water is conveyed both into and out of the watershed. This condition results from deep mine workings extending under the watershed divide.

The Bear Valley Colliery extends westward under the watershed divide onto the Mahanoy Creek watershed, where it abuts the North Franklin Colliery. An effective barrier pillar presently exists between these two collieries. Approximately 160 acres have been mined beneath the Mahanoy Creek watershed within the Bear' Valley Colliery. Surface and ground waters from 330 acres of the Mahanoy Creek watershed flow into and through these mine workings to become a part of the overflow from Discharge Point No. 49.

The Locust Gap and Locust Spring Collieries extend under approximately 2,110 acres of the Shamokin Creek headwaters area along its southern limits. An additional estimated 660 acres, or 2,770 acres in all, of watershed surface area contribute surface and ground waters to these underground workings. These waters drain through Douteyville, Helfenstein, Locust Gap, and Centralia Tunnels to Mahanoy Creek.

The Logan and Centralia Collieries extend under approximately 714 acres of the watershed headwaters area near its eastern limits. In addition, an estimated 178 acres, or 892 acres in all, of watershed surface area contribute surface and ground waters to these underground workings. These waters flow underground through interconnected deep mine workings, from which they are discharged to Mahanoy Creek through the Centralia Tunnel.

The extent of the surface and subsurface areas contributing to, or taking from, watershed mine drainage discharges is shown on Plate III.

MINE DRAINAGE DISCHARGE POINTS

Locating mine drainage discharge points was also essential in defining the current extent of mine drainage pollution as well as the kind and extent of abatement measures applicable to the watershed. Before the investigations described in this report were started and during their early stages, the Department of Environmental Resources marked known mine drainage discharge points. The Department constructed weirs at the major known discharges and on several watershed streams. The Department obtained instantaneous flow measurements at these locations from September 1969 through December 1970 on a twice-a-week basis, except during periods when these sites were inaccessible. In addition, mine drainage discharge flow and quality data were extracted from the United States Environmental Protection Agency and the Department's files. These data had limited utility because of their age and change of status, in some instances from active pump discharges to pool overflows. The small amount of these data considered usable tended to corroborate the results of the gauging, sampling, and analytical program.

As part of the field investigations, 54 mine drainage discharge points were located, identified., and marked. These mine drainage discharges were located during field investigations conducted from December 1969 through November 1970. These 54 mine drainage discharges are distributed throughout the watershed headwaters area down to and including the overflows from the Cameron Colliery and tributary area, just north of Shamokin City. No mine drainage discharges drain to Shamokin Creek downstream from the vicinity of the Glen Burn Breaker. Additional mine drainage discharges probably exist in the watershed headwaters area under certain weather conditions not encountered during the field investigations. The findings, conclusions, and recommendations contained in this report are based solely upon discharge points observed from December 1969 through November 1970.

The mine drainage discharge points located during the field investigations are summarized as follows:

1. Underground Mine Water Pool Discharges:

    Eighteen mine drainage discharge points relieving underground mine water pools exist within the watershed. These discharges flow to surface streams through permeable ground surface, as well as drifts, slopes, shafts, drainage tunnels, relief boreholes, and strip pits, from or close to the tops of the pools.

2. Strip Mines:

    Mine drainage from eight strip mines drains through eight discharge points. These discharge points pass mine drainage resulting from direct precipitation, as well as surface runoff and ground water intercepted by those strip mines. These strip mines have apparently not cut into underlying deep mine workings. Much of the strip mining throughout the watershed has cut into underlying deep mines, thus explaining why so few mine drainage discharges are associated with the extensive strip-mined areas. The above discharge points do not include two within strip mines' through which major mine water pool overflows occur.

3. Refuse Areas:

Sixty-two refuse areas are located in the watershed headwaters area. All these refuse areas apparently discharge mine drainage to some extent during and for a short period following wet weather. However, fairly continuous discharges were noted from 14 refuse areas. These discharges originate from precipitation being trapped in, and bleeding from, these extensive refuse areas, as well as from spring water originating beneath these refuse areas. In four instances, portions of stream flows contribute to these discharges.

4. Deep Mine Entries:

Nine deep mine entries provide gravity drainage from portions of deep mine workings not parts of large underground mine water pools. Another four entries, comprised of a drift opening, a drainage tunnel, a slope entry, and an air shaft, provide outlets for major mine water pools.

5. Deep Mine Workings:

Two other mine drainage discharge points consist of mine drainage flowing from isolated deep mine workings through permeable ground surface. One of these appears to discharge flows continuously while the other is intermittent.

6. Miscellaneous Mine Drainage Discharge Points:

Three mine drainage discharge points not covered previously are comprised of ground-water and surface-water flows off unmined coal measures. Two of these are intermittent while the third appears to discharge flows continuously.

Exhibit B describes the nature and condition of the 54 mine drainage discharge points. The locations of all mine drainage discharge points are shown on Plate II.

MINE DRAINAGE GAUGING, SAMPLIN(;, AND ANALYTICAL PROGRAM

To define the current extent of watershed mine drainage pollution, the current volume and quality of mine drainage discharges had to be established. Therefore, discharges from all 54 discharge points located by the Department of Environmental Resources and during the field investigations were gauged, sampled, and analyzed from December 1969 through November 1970. In addition, mine drainage flow measurements taken by the Department from September 1969 through December 1970 were utilized. As part of Gannett Fleming Corddry and Carpenter, Inc.'s field investigations, 11 instantaneous flow measurements and grab samples were obtained at most of these discharge points during dry, normal, and wet weather. The Department's twice-a-week flow measurements at major mine drainage pool overflows were also used. All samples collected were analyzed for pH, iron, acidity, and sulfate. In addition, some samples were analyzed for aluminum, manganese, and dissolved solids concentrations. The sporadic nature of mine drainage discharges from refuse areas prevented gauging and sampling of mine drainage discharged from refuse areas to the same extent as other mine drainage discharges.

Of the 54 discharge points located during the field investigations, 35 appear to continuously discharge mine drainage. The remaining 19 discharge points appear to intermittently discharge mine drainage. At all discharge points that appear to intermittently pass mine drainage, discharges were observed at some time during the field investigations. Based on discharge conditions encountered during low, average, and high ground-water levels, combined mine drainage volumes, as well as major constituents and characteristics, approximated the following:

	Ground-Water Levels		
	Low	**Average**	**High**
Volume - mgd	27.7	42.0	62.7
pH Range	2.5-7.6	2.5-8.2	2.5-8.2
Total Iron			
mg/l	50.8	51.1	50.4
tons per day	5.87	9.05	13.2
Acid (as $CaCO_3$)			
mg/l	220.0	216.0	211.0
tons per day	25.5	37.9	55.1

During the period covered by this program, yearly precipitation in the watershed was approximately five percent less than the average yearly precipitation over the period of record. Likewise, total precipitation during the period affecting spring high flows (December 1969 through April 1970) was approximately five percent less than the December through April average over the period of record. Total watershed precipitation during dry weather (August through October 1970) was approximately 17 percent less than average precipitation during these months over the period of record.

MINE DRAINAGE DESIGN VOLUMES AND QUALITY

In addition to establishing water flow routes into, through, and out of deep mine workings, mine drainage discharge design conditions at each discharge point had to be established before abatement measures could be planned and their effectiveness estimated. This section describes the mine drainage design volumes, constituents, and characteristics used in planning and evaluating the effectiveness of watershed abatement measures.

The following three conditions of discharge were established at each mine drainage discharge point to determine the necessity for abatement measures, to design abatement measures, and to estimate their effectiveness:

Design Average

> Average daily mine drainage volumes, constituents, and characteristics during a year of normal precipitation;

Design Wet Weather

> Average daily mine drainage volumes" constituents, and characteristics during spring high ground-water level periods caused by normal precipitation from December through April;

Design Maximum

> Maximum daily mine drainage volumes, constituents, and characteristics resulting from the maximum 24-hour accumulation of rainfall occurring, on the average, no more often than once every 10 years..

Design maximum conditions could have been selected from a wide range of precipitation conditions. Maximum mine drainage discharges resulting from as little as the 72-hour accumulation of rainfall occurring no more often than once a year to as much as the 30..minute accumulation of rainfall occurring no more often than once every 1,000 years could have been adopted. Following discussions with Department of Environmental Resources and federal personnel, these design maximum conditions were selected to provide reasonable protection to receiving streams. Excess mine drainage over design maximum loads could be absorbed by receiving streams whose flows would have been significantly increased by excess precipitation.

Design average, wet-weather, and maximum mine drainage volumes were calculated using precipitation records, and assumed surface-water runoff coefficients and evaporation-transpiration losses, as well as other information developed during the investigations. Mine drainage constituents and characteristics for design average as well as wet-weather conditions were based upon the previously noted sampling and analytical program results obtained during normal and high ground-water level periods, respectively. Design maximum constituents and characteristics were estimated from sampling and analytical results as well as previous experience.

For design average conditions, mine drainage volumes at discharge points range from 0 to 7.76 mgd, iron concentrations from 0.1 to 115 mg/l, and acid concentrations from 0 to 1,140 mg/I. Combined mine drainage volumes as well as major constituents and characteristics used for design purposes are summarized as follows:

	Design Average	**Design Wet Weather**	**Design Maximum**
Volume - mgd	44.2	65.8	1,500.0
pH Range	2.5-7.6	2.5-8.2	2.5-8.2
Total Iron			
mg/l	52.0	50.5	56.9
tons per day	9.58	13.9	356.0
Acid (as $CaCO_3$)			
mg/l	218.0	210.0	225.0
tons per day	40.1	57.7	1,410.0

Exhibit C presents the assumptions and calculations used to establish combined design mine drainage volumes. Exhibit D shows the mine drainage design volumes, major constituents, and characteristics of discharges for each of the 54 discharge points.

MINE DRAINAGE DESIGN
POLLUTION LOADS TO WATERSHED STREAMS

Another factor must be considered in evaluating abatement measures and their effectiveness. Certain mine drainage discharges percolate through permeable stream beds that have been undermined. Others are intercepted by inadequately restored strip mines that had cut into underlying deep mine workings. These mine drainage discharges may therefore be eliminated from consideration in the development of abatement plans unless such plans retain these discharges in watershed streams.

In all, 13 mine drainage discharges are so affected. Twelve completely disappear into, and the thirteenth loses an estimated 50 percent of its flow to underlying deep mine workings through permeable stream beds or interconnected strip mines. These waters then flow through extensive deep mine workings to become part of major mine water pool overflows. The mine drainage discharges so affected, as well as their volumes, iron, and acid loads, are listed in the following:

Reductions

Discharge Point		Design Average			Design Wet Weather			Design Maximum		
Eliminated	Reduced	Flow (mgd)	Iron (lbs/ day)	Acid (lbs/ day)	Flow (mgd)	Iron (lbs/ day)	Acid (lbs/ day)	Flow (mgd)	Iron (lbs/ day)	Acid (lbs/ day)
1, 2, 3, 4, 6, 13, 14, 31, 32, 33, 34, 35		0.506	22.4	1,180.3	1.030	26.7	1,734.4	18.123	415.5	31,885.9
	5	3.615	1,245.0	7,850.0	4.860	1,360.0	8,900.0	74.500	18,650.0	121,000.0
Totals		4.121	1,267.4	9,030.3	5.890	1,386.7	10,634.4	92.623	19,065.5	152,885.9

After the above listed reductions are subtracted from the mine drainage design volumes and quality, the following mine drainage design pollution loads remain:

	Design Average	Design Wet Weather	Design Maximum
Volume - mgd	40.1	60.0	1,410.0
pH Range	2.5-7.6	2.5-8.2	2.5-8.2
Total Iron			
mg/I	53.5	52.6	59.1
tons per day	8.95	13.2	346.0
Acid (as $CaCO_3$)			
mg/I	213.0	209.0	227.0
tons per day	35.5	52.4	1,330.0

The mine drainage design pollution loads to watershed streams are tabulated in Exhibit E.

EVAPORATION- TRANSPIRATION
LOSSES AND RUNOFF COEFFICIENTS

Precipitation data collected at the United States Weather Bureau's permanent Shamokin precipitation station for the period of November 1969 through October 1970 were used. During this period, precipitation equal to 41.74 inches of rain fell at the Shamokin station. Over the period of record for this station, annual precipitation has averaged 43.83 inches of rain. Design average and design wet-weather mine drainage flows were obtained by adjusting gauging results obtained during this same time to compensate for this five percent deficiency in precipitation.

Design maximum mine drainage flows were estimated using assumed values for evaporation-transpiration losses and runoff coefficients. These assumed values used were based on past experience. They are shown in Exhibit C.

PRESENT MINE DRAINAGE DISCHARGE LIMITATIONS OF THE DEPARTMENT OF ENVIRONMENTAL RESOURCES

One set of conditions used in the development of abatement plans for the watershed was that of bringing various mine drainage discharges under design average, wet-weather, and maximum conditions into compliance with present Department of Environmental Resources limitations. These discharge limitations are as follows:

pH not less than six or greater than nine

Iron concentration not in excess of seven mg/l

No acid

No additional mine drainage discharge limitations have at present been established for the watershed.

MINE DRAINAGE DISCHARGES IN COMPLIANCE WITH PRESENT DISCHARGE LIMITATIONS OF THE DEPARTMENT OF ENVIRONMENTAL RESOURCES

Only three existing mine drainage discharges meet all current Department of Environmental Resources limitations for the design average, design wet-weather, and design maximum conditions. For design average, design wet-weather, and design maximum conditions, three, four, and four mine drainage discharges, respectively, meet all current Department limitations. Discharges meeting all current Department limitations account for less than one-tenth of one percent of watershed pollution loads.

Distributed throughout the watershed are an additional seven discharges that are of marginal quality when compared to Department of Environmental Resources limitations. These discharges are of generally good quality but do not meet all Department discharge limitations. Under design average conditions these seven discharges account for less than one-tenth of one percent of total watershed pollution loads.

The number of mine drainage discharges meeting the Department of Environmental Resources' pH, iron, and acid limitations are listed below:

	Design Average	Design Wet Weather	Design Maximum
pH	4	5	5
Total Iron	26	29	30
Acid (as $CaCO_3$)	5	5	5

EXTENT AND EFFECTIVENESS OF PAST MINE DRAINAGE PREVENTIVE MEASURES

Mostly in connection with past major deep mining, an extensive amount of watershed surface-water diversion, as well as stream relocation and reconstruction work, was accomplished. The remains of numerous surface-water diversion ditches constructed uphill from deep mined coal outcrops are visible throughout the watershed. Later extensive strip mining has rendered these diversion ditches almost entirely ineffective. A considerable stretch of the upper reaches of Shamokin Creek and the lower reaches of its North Branch were reconstructed or relocated and reconstructed. This stream channel relocation and reconstruction appear to have remained effective. No appreciable reductions in stream flows appeared to occur throughout these reaches.

In addition, a surface improvement project over the Glen Burn Colliery was constructed during 1957 and 1958 with 50 percent Department of Environmental Resources funds and 50 percent federal funds. The project cost of approximately $183,000 was provided by the joint Federal-State Anthracite Mine Water Control Program, authorized by 1955 legislation that made $17,000,000 available for such purposes. This project consisted of moving 188,000 cubic yards of earth to restore strip pits; constructing 8,000 feet of surface-water diversion ditches; and laying 6,650 feet of pipe and flume to prevent an estimated 185,000,000 gallons of water per year from entering the underlying mine workings. Removal of one length of the flume by a strip mine operator and blockage of the other have caused complete failure of this system.

MAJOR MINE DRAINAGE VOLUME, IRON, AND ACID CONTRIBUTORS

During the investigations considerable variation was observed in the volume as well as in the tons of iron and acid contributed by mine drainage discharge points. The major contributors to iron and acid loads are the underground mine water pool overflows. The design average loads attributable to these pool overflows are summarized below in decreasing order of magnitude of acid contributions.

		Volume		Iron		Acid	
			Percent of Total Pollution		Percent of Total Pollution		Percent of Total
Pollution Discharge Point	Collieries Drained	(mgd)	Load	(lbs/day)	Load	(lbs/day)	Load
50, 51, 52, 53	Cameron, et al	5.520	13.8	4,081.4	22.8	25,073.0	35.3
19, 20	Scott, et al	9.810	24.4	4,358.0	24.4	13,160.0	18.5
12	Excelsior-Corbin, et al	7.040	17.5	3,460.0	19.3	10,900.0	15.3
5	Midvalley	3.615	9.0	1,245.0	7.0	7,850.0	11.1
49	Stirling, et al	6.340	15.8	2,530.0	14.2	7,670.0	10.8
23	Big Mountain, et al	1.110	2.7	184.0	1.0	1,570.0	2.2
15	Excelsior-Corbin	0.625	1.6	394.0	2.2	1,510.0	2.1
21	Maysville	2.050	5.1	1,060.0	5.9	770.0	1.1
24, 25, 26, 27	Buck Ridge	0.232	0.6	1.9	0.0	295.9	0.4
29	Royal Oak	0.382	1.0	43.4	0.2	223.0	0.3
36	Buck Ridge No. I, et al	1.570	3.9	280.0	1.6	65.5	0.1
Total 18		38.294	95.4	17,637.7	98.6	69,087.4	97.2

In all, there are 11 established pools from which 18 mine drainage discharges occur by overflow. These 18 pool overflows are shown on Plate III, together with their tributary deep mined areas in color code.

All these pool overflows except No.5 lie within the watershed headwaters area extending from the western edge of Shamokin City eastward to the western limits of Kulpmont Borough. Pool Overflow No.5, located near the eastern end of the watershed headwaters area, actually loses about 50 percent of its flow through the permeable stream bed of the North Branch of Shamokin Creek. This lost volume contributes directly to discharges measured at Pool Overflow Nos. 19 and 20.

The other 25 mine drainage discharges contribute 4.6, 1.4, and 2.8 percent of the total watershed design average volume, iron, and acid loads, respectively. Eleven of these are discharges from refuse areas providing 1.0, 0.2, and 2.1 percent of the volume, iron, and acid loads, respectively.

The number of discharge points contributing various percentages of total watershed design average mine drainage volume, iron, and acid loads are summarized below:

	Approximate Percentage of Total Watershed Mine Drainage Volume, Iron, and Acid Loads			
	50	85	95	100
Volume				
mgd	21.1	34.2	38.1	40.1
number of discharges	3	8	12	43
Total Iron				
tons per day	4.79	7.92	8.50	8.95
number of discharges	3	7	9	43
Acid				
tons per day	17.7	30.4	33.9	35.5
number of discharges	3	6	10	43

Exhibits F, G, and H present tabulations in descending order of magnitude of all discharge points and percentages of total watershed volume, iron, and acid loads represented by each under design average conditions.

STREAM QUALITY CRITERIA

In addition to the mine drainage discharge limitations previously presented, the Department of Environmental Resources has adopted general and specific stream quality criteria for the Susquehanna River Basin, of which Shamokin Creek is a part. The stream quality criteria are based upon the anticipated use of Susquehanna River Basin surface streams for (1) the maintenance and propagation of cold-water and warm-water fish; (2) water supply for domestic, industrial, livestock, wildlife, and irrigation purposes; (3) boating, fishing; and water contact sports; (4) power; and (5) treated waste assimilation.

The Department of Environmental Resources' general stream quality criteria apply to all streams in the watershed and are as follows:

> The water shall not contain substances attributable to municipal, industrial, or other waste discharges in concentration or amount sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant, or aquatic life. Specific substances to be controlled include, but are not limited to, floating debris, oil, scum, and other floating materials; toxic substances; and substances that produce color, tastes, odors or settle to form sludge deposits.

The specific stream quality criteria adopted by the Department of Environmental Resources are as follows:

pH	Not less than 6.0 or greater than 8.5.
Dissolved Oxygen	Minimum daily average 5.0 mg/l; no value less than 4.0 mg/I.
Total Iron	Not to exceed 1.5 mg/l.
Total Manganese	Not to exceed 1.0 mg/l.
Temperature	Not to exceed 5° F. rise above ambient temperature or a maximum of 87° F., whichever is less; not to be changed by more than 2° F. during anyone-hour period.
Dissolved Solids	Not to exceed 500 mg/l as a monthly average value; not to exceed 750 mg/l at any time.
Bacteria (coliforms/100 ml)	For the period 5/15 to 9/15 of any year - not to exceed 1,000/100 ml as an arithmetic average value; not to exceed 1,000/100 ml in more than two consecutive samples; not to exceed 2,400/100 ml in more than one sample. For the period 9/16 to 5/14 of any year - not to

exceed 5,000/100 ml as a monthly average value, or to exceed this number in more than 20 percent of the samples collected during any month; not to exceed 20,000/100 ml in more than five percent of the samples.

The specific stream quality limitations represent maximum or minimum values that can be reached in the receiving stream only during critical stream flow conditions. The critical flow is considered as the average minimum stream flow that occurs during seven consecutive days of anyone year and has a recurrence interval of 10 years, whether the flow is regulated or not. For stream flows lower than critical flow, the general stream quality criteria would apply.

The Department of Environmental Resources realized that mine drainage from abandoned mines must be abated throughout the watershed headwaters area to effect an improvement in watershed stream quality. Based on discussions with Department personnel, treatment of all mine drainage discharges from abandoned workings would not be required to the extent necessary to meet Department limitations. The basic intent of the Department appears to be that of initially protecting the major watershed streams. To achieve this end, the Department would apparently require the elimination, reduction, and/or treatment of mine drainage discharges to the extent necessary to remove mine drainage pollutants primarily responsible for degradation of major streams. If the removal of additional mine drainage pollutants appeared warranted, the Department would so indicate.

STREAM SAMPLING AND ANALYTICAL PROGRAM

An important aspect of the investigations was that of determining the existing quality of watershed streams. Knowledge of current stream quality was considered essential for evaluating abatement plans.

Available stream quality data were extracted from files of the United States Environmental Protection Agency and the Department of Environmental Resources. These data, although limited, tended to corroborate those collected during the stream sampling and analytical program. It was recognized that some individual watershed stream flow and quality have changed drastically within the past 20 years as individual collieries ceased operations and protective pumping stopped, thereby creating additional pool overflows.

Before authorizing these investigations, the Department of Environmental Resources installed weirs at a number of locations on streams. On other streams, Department personnel used a flow meter to obtain flow measurements. Some of the weirs were washed out by high stream flows. Department personnel obtained flow information on these sites, either by weir measurements or by flow meter, twice a week for about 18 months. The Department of Environmental Resources' stream flow information from October 1969 through December 1970 was provided to Gannett Fleming Corddry and Carpenter, Inc.

As part of the field investigations conducted by Gannett Fleming Corddry and Carpenter, Inc., five additional stream sampling stations were established. These included stations near the mouths of Locust Creek and Quaker Run, as well as three on the lower reaches of Shamokin Creek. In all, 30 stream quality sampling stations were established, with stream flow measurements taken at 17 of these stations. Fourteen of these stations were located along Shamokin Creek, while the remaining 16 were on its tributaries. Samples were collected for analysis at each station from December 1969 until November 1970. At most stations 11 grab samples were obtained under dry, average, and wet-weather runoff conditions. The locations of all stream sampling stations are shown on Plate I.

Specific stream quality criteria such as pH, total iron, total manganese, and dissolved solids are applicable to watershed streams when considering mine drainage discharges. All stream samples collected were analyzed for pH, total iron, acidity, and sulfate, whereas some were also analyzed for aluminum, manganese, and total solids concentrations. No effort was made during the investigations to determine the dissolved oxygen, temperature, or coliform bacteria content of streams. Dissolved oxygen was not considered to be a critical criterion since ferrous iron in mine drainage discharges was found to be relatively insignificant. This is particularly evident when the heavy flows of raw sewage into watershed headwaters streams are considered. Temperature was not regarded as a critical consideration, since the presence or absence of mining would have little effect on stream temperatures. Any coliform bacterial population in watershed streams would not be attributable to mine drainage discharges.

For purposes of this report, only pH and iron and acid concentrations have been used in evaluating stream quality and for determining the effectiveness of abatement plans.

CURRENT QUALITY OF WATERSHED STREAMS

The average quality of waters observed at Shamokin Creek headwaters area tributary stream sampling stations from December 1969 through November 1970 is summarized below:

	Shamokin Creek Headwaters Area Tributaries
pH	3.1 to 6.9
Total Iron - mg/l	1.8 to 43.8
Acid (as $CaCO_3$) - mg/l	(1) -54 to 203

(1) Represents a negative acidity, or alkalinity.

These ranges represent average quality of the North Branch of Shamokin Creek, Locust Creek, Quaker Run, Coal Run, Carbon Run, and Furnace Run. Few rather insignificant mine drainage discharges remain as parts of Coal Run stream flow. Some discharges of raw sewage also enter Coal and Furnace Runs. The average quality of waters observed in the headwaters tributaries is shown below:

	Coal Run and Furnace Run	**Other Shamokin Creek Headwaters Area Tributaries**
pH	6.5 to 6.9	3.1 to 3.6
Total Iron - mg/l	2.5 to 10.2	1.8 to 43.8
Acid (as $CaCO_3$) mg/l	(1) -54 to 0	81 to 203

(1) Represents a negative acidity, or alkalinity.

Based on analytical data, Coal Run and Furnace Run on the average meet the Department of Environmental Resources' pH criterion and are neutral to alkaline. The Department's iron criterion is not met on the average in either. Coal Run is sometimes acidic, and pH values as low as 4.8 were recorded on this tributary. Furnace Run is consistently alkaline, with its pH ranging between 6.6 and 7.5.

On the other hand, the remaining headwaters tributaries consistently do not meet the Department of Environmental Resources' pH and iron criteria and are acidic at all times.

Conversely, the average quality of waters observed at Shamokin Creek down stream tributary stream sampling stations during this same time is as follows:

	Shamokin Creek Downstream Tributaries
pH	6.4 to 6.8
Total Iron - mg/l	0.3 to 1.1
Acid (as $CaCO_3$) - mg/l	(1) -11 to 16

(1) Represents a negative acidity, or alkalinity.

These tributary streams consistently meet the Department of Environmental Resources' pH and iron criteria and are either slightly alkaline or slightly acidic.

The average quality of waters observed at Shamokin Creek stream sampling stations from December 1969 through November 1970 is summarized below:

	Shamokin Creek Near Mount Carmel	All Other Shamokin Creek Stations
pH	6.9	3.1 to 4.3
Total Iron - mg/l	2.7	8.0 to 42.4
Acid(as$CaCO_3$)-mg/1	(1) -38	86to 178

(1) Represents a negative acidity, or alkalinity.

Shamokin Creek near Mount Carmel on the average meets the Department of Environmental Resources' pH criterion and is consistently alkaline. This alkalinity is directly attributable to the large volume of raw sewage, which comprises most of the stream flow, from Mount Carmel Borough. The Department's iron criterion is not met at this station.

Shamokin Creek at all other stations consistently does not meet the Department of Environmental Resources' pH and iron criteria and is acidic.

A brief discussion of information and data on the quality of watershed streams follows. All sampling stations discussed were located near the mouths of tributaries.

1. Tributaries not seriously affected by mine drainage discharges, specifically Coal Run and Furnace Run.

   Coal Run is of generally fair quality from a mine drainage aspect. Coal Run had an average pH of 6.5, with values ranging from 4.8 to 7.5. Its iron concentration averaged 10.2 mg/l, with a high of 20.9 mg/l recorded. Coal Run, although neutral on the average, has varied from 40 mg/l alkalinity to

56 mg/l acidity. The higher pH and alkalinity values are contributed by raw sewage discharges in its lower reaches. Based on available information and additional limited analytical data, manganese and dissolved solids concentrations could be of sanitary significance.

Furnace Run is of generally good quality from a mine drainage aspect. Furnace Run had an average pH of 6.9, with values ranging from 6.6 to 7.5. Its iron concentration averaged 2.5 mg/l, with a high of 4.7 mg/l recorded. Furnace Run, although having 54 mg/l alkalinity on the average, varied from an alkalinity of 100 mg/l to an acidity of 16 mg/l. The higher pH and alkalinity values were the result of raw sewage discharges into its lower reaches. Based on available information and limited analytical data, other constituents and characteristics do not appear at present to be of major sanitary significance from a mine drainage aspect.

2. Headwaters tributaries seriously affected by mine drainage discharges, specifically the North Branch of Shamokin Creek, Locust Creek, Quaker Run, and Carbon Run.

   The North Branch of Shamokin Creek, Quaker Run, and Carbon Run all receive major mine drainage discharges and are of comparably poor quality. Their average pH ranged between 3.1 and 3.5, with a low of 3.0 recorded. Their average iron concentration varied from 22.6 to 43.8 mg/l, with a high of 106.3 mg/l recorded. Acidity, on the average, of these three streams ranged from 81 to 203 mg/l, with a high of 288 mg/l recorded. Based on available information and limited analytical data, manganese and dissolved solids concentrations are of a magnitude sufficient to be of major sanitary significance.

   Locust Creek receives drainage from extensive refuse areas distributed over its surface area, and is therefore of generally poor quality. The average pH of Locust Creek was 3.6, with a low of 3,,2 recorded. Its iron concentration averaged 1.8 mg/l, with a high of 3.8 mg/l recorded. Acidity in Locust Creek averaged 135 mg/l, with a high of216 mg/l recorded. Based on available information and limited analytical data, manganese and dissolved solids are of a magnitude sufficient to be of sanitary significance.

3. Tributaries draining areas lying downstream from coal- bearing deposits, specifically Trout Run, an unnamed tributary locally known as Kulps Run, Buddys Run, Millers Run, Lick Creek, and an unnamed tributary sometimes called Elysburg Run.

   The tributaries draining areas downstream from coal-bearing deposits (headwaters area) are of generally good quality. Except for that from minor deposits of refuse distributed throughout some of these tributaries' drainage areas, no potential for acid mine drainage exists in these streams. The average pH of these tributaries ranged from 6.4 to 6.8, with occasional lows to 5.3 recorded. Iron concentrations on the average varied from 0.3 to 1.1 mg/l, with a high of 1.9 mg/l recorded. These streams on the average were near neutral, with alkalinities as high as 11 mg/l and acidities as high as 16 mg/l recorded. Extremes of 40 mg/l alkalinity and 32 mg/l acidity were recorded in these streams. Based on available information and additional limited analytical data, other stream constituents and characteristics do not appear to be of sanitary significance. In addition, normal aquatic life, including several species of minnows, was noted in these streams.

4. Shamokin Creek.

The farthest upstream sampling station on Shamokin Creek is just downstream from Mount Carmel Borough. At this point, the pH was 6.9 on the average, with a low of 6.7 recorded. Shamokin Creek's iron concentration averaged 2.7 mg/l, with a high of 3.8 mg/l recorded. Its average alkalinity was 38 mg/l, with a high of 108 mg/l recorded. These high pH and alkalinity values are actually the result of large volumes of raw sewage from Mount Carmel Borough and Atlas Village. Under conditions of little or no runoff, practically all the stream flow is comprised of this raw sewage. From a mine drainage pollution abatement aspect, other constituents do not appear to be of sanitary significance.

Shamokin Creek at all other sampling stations throughout its entire length is of poor quality. On the average, its pH ranged from 3.1 to 4.3, with a low of 2.9 recorded. Shamokin Creek's iron concentration on the average varied from 8.0 to 42.4 mg/l, with a high of 178.4 mg/l recorded. Its average acid concentrations ranged from 86 to 178 mg/l, with a high of 408 mg/l recorded.. Based on available information and additional limited analytical data, manganese and dissolved solids are of a sufficient magnitude to be of major sanitary significance.

Exhibit I lists the constituents and characteristics measured at each sampling station during the sampling and analytical program. The locations of all sampling stations are noted on Plate I. The locations of all streams are shown on Plates I, II-A, and II-B.

ACID MINE DRAINAGE ABATEMENT PLANS STUDIED IN DETAIL

Various abatement measures, separately or in combination, have the potential for eliminating mine drainage pollution in the watershed. All abatement measures considered applicable to problems and conditions of the watershed were reviewed separately and in combination to develop by inspection techniques alternative abatement plans. Plans developed by this procedure and considered of sufficient merit were studied in detail. This section describes such plans.

Preliminary consideration was given to developing abatement plans in each of three categories:

1. Abatement plans based solely on preventive measures

2. Abatement plans based solely on treatment measures

3. Abatement plans based on various combinations of preventive and treatment measures

Comments relative to these three categories and the individual abatement plans presented in this section are set forth in the following:

1. Based on investigations described in this report and previous experience, it would be prohibitively expensive and totally impractical to develop an abatement plan comprised solely of preventive measures in an area as large as and with the physical conditions of the watershed.

2. For abatement plans consisting of preventive measures supplemented by treatment measures, estimates of acid mine drainage reductions attributable to the preventive measures were made on the basis of estimated increases in runoff coefficients, volumes of surface water kept from deep mine workings, and similar factors. In the preliminary design of treatment measures, due allowance was made for acid mine drainage reductions attributable to preventive measures.

3. Treatment measures were designed to meet the present Department of Environmental Resources' mine drainage discharge limitations.

4. Based on investigations described in this report and previous experience, a number of preventive measures were considered uniquely applicable to watershed Conditions. These preventive measures were used in some of the abatement plans presented.

5. In the development of abatement plans, consideration was given in certain cases to abating all mine drainage discharges and in others only some

discharges. Plans were studied that would reduce watershed mine drainage by 90 to 100 percent. In the development of abatement plans in which somewhat less than a 100 percent reduction was to be attained, every effort was made to concentrate on those discharges contributing 90 percent of the watershed mine drainage iron and acid loads. Preventive measures designed toward this end eliminated some additional mine drainage discharges.

Each abatement plan studied in detail is described below:

ABATEMENT PLAN I

Basic Intent:	Collect and treat at five sites mine drainage from Discharge Points 5, 12, 15, 19, 20, 21, 23, 24, 25, 26, 27, 29, 36, 49, 50, 51, 52, and 53 comprising 18 major discharges not meeting current Department of Environmental Resources limitations.
Preventive Measures:	None.
Collection System and Treatment Measures:	a. 19 boreholes 50 to 296 feet deep with casings 12 to 26 inches in diameter; design wet-weather flow b.22 pumps 475 to 6,800 gpm in capacity; design wet weather flow c. 4,010 feet of PVC pressure pipe 10 to 18 inches in diameter; design wet-weather flow d. 13,570 feet of conveyance sewers 10 to 24 inches in diameter; design wet-weather flow e. 9,622 feet of lined channels; design wet-weather flow f. Five treatment plants - North Branch Shamokin Creek one mile downstream from Wilburton No.1 Village and 2,500 feet southwest of Strong Village, Shamokin Creek 500 feet upstream from Brady Village, Shamokin Creek 500 feet upstream from Shamokin, Shamokin Creek 500 feet downstream from Shamokin; design wet-weather flow

Estimated acid mine drainage volume affected and reductions in total watershed design average loads attributable to the abatement plan are as follows:

Volume - 96%; 38.3 mgd
Iron - 91 % (to 4 mg/l); 8.18 tons per day Acid -
97%; 34.5 tons per day

ABATEMENT PLAN II

Basic Intent: Collect and treat at four sites' mine drainage from the same 18 Discharge Points enumerated in Abatement Plan I, the drainage from which does not meet current Department of Environmental Resources limitations. Breach one barrier pillar to reduce five systems in Plan I to four systems in this plan.

Preventive Measures: None.

Collection System and Treatment Measures:

a. 20 boreholes 50 to 296 feet deep with casings 12 to 28 inches in diameter; design wet-weather flow

b.23 pumps 475 to 4,900 gpm in capacity; design wet weather flow

c. 6,360 feet of PVC pressure pipe 10 to 24 inches in diameter; design wet-weather flow

d. 13,570 feet of conveyance sewers 10 to 24 inches in diameter; design wet-weather flow

e. 340 feet of lined channels; design wet-weather flow

f. Four treatment plants - 2,500 feet southwest of Strong Village, Shamokin Creek 500 feet upstream from Brady Village; Shamokin Creek 500 feet upstream from Shamokin, Shamokin Creek 500 feet downstream from Shamokin; design wet-weather flow

Estimated acid mine drainage volume affected and reductions in total watershed design average loads attributable to the abatement plan are as follows:

Volume - 96%; 38.3 mgd
Iron - 91 % (to 4 mg/l); 8.18 tons per day
Acid - 97 % ; 34.5 tons per day

ABATEMENT PLAN III

Basic Intent:	Collect and treat at four sites mine drainage from Discharge Points 5, 8, 9, 10, 11, 12, 15, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 36, 37, 38, 39, 40, 42, 43,46,47,48,49,50,51,52,53, and 54 comprising 35 discharges not meeting current Department of Environmental Resources limitations. Mine drainage from Discharge Points 17, 41, and 45 meeting Department of Environmental Resources limitations, and mine drainage from Discharge Points 7, 16, 18, and 44 of marginal quality or minor pollutional loadings not collected and treated. These latter four discharges are located at considerable distances from collection and treatment systems.
Preventive Measures:	None.
Collection System and Treatment Measures:	a. 20 boreholes 50 to 296 feet deep with casings 12 to 28 inches in diameter; design wet-weather flow b.23 pumps 475 to 4,900 gpm in capacity; design wet weather flow c. 9,910 feet of PVC pressure pipe 4 to 24 inches in diameter; design wet-weather flow d. 72,630 feet of conveyance sewers 6 to 27 inches in diameter; design wet-weather flow e. 2,740 feet of lined channels; design wet-weather flow f. Nine flow equalization basins 0,,98 to 15.4 million gallon capacity; design maximum flow g. Two pump stations 0.06 to 0.178 mgd capacity; design wet-weather flow h. Four treatment plants - 2,500 feet southwest of Strong Village, Shamokin Creek 500 feet upstream from Brady Village, Shamokin Creek 500 feet upstream from Shamokin, Shamokin Creek 500 feet downstream from Shamokin; design wet-weather flow

Estimated acid mine drainage volume affected and reductions. in total watershed design average loads attributable to the abatement plan are as follows:

Volume	- 99.8%; 40.0 mgd
Iron	- 93% (to 4 mg/l); 8.28 tons per day
Acid	- 100%; 35.5 tons per day

ABATEMENT PLAN IV

Basic Intent: Control of mine drainage pollution by construction of preventive and treatment measures: eliminate mine drainage at Discharge Points 1,9, 10, 11, 30, 31, 43, 46, and 47, of which 1 and 31 presently infiltrate into underground pools; reduce mine drainage at Discharge Points 2,3,5, 12, 19,20,23,49,50,51,52, and 53, of which 2 and 3 presently infiltrate_ into underground pools; collect and treat in four systems the remaining mine drainage from Discharge Points 5, 12, 15, 19, 20, 21, 23, 24, 25, 26, 27, 29, 36, 49, 50, 51, 52, and 53; mine drainage from 17 Discharge Points not eliminated or treated is comprised of 17, 41, and 45 meeting Department of Environmental Resources limitations, 16, 18, 37, 38, 39, 44, and 48 of marginal quality, and 7, 8, 22, 28, 40, 42, and 54 of insignificant loadings.

Preventive Measures: Clear 19,500 feet of stream channels and construct 99,900 feet of lined stream channels including that length cleared; construct 73,500 feet of surface-water diversion ditches; restore 368 acres of improperly restored strip mines; excavate and restore 20 acres of subsidence areas; move 1,140,000 cubic: yards of refuse into strip mines; regrade, cover, and plant 176 acres of refuse areas.

Estimated acid mine drainage volume affected and reductions. in total watershed design average loads attributable to the preventive measures are as follows:

Volume	- 9.7%
Iron	- 8.5%
Acid	- 10.7%

Collection System and Treatment Measures:

a. 20 boreholes 50 to 296 feet deep with casings 12 to 28 inches in diameter; design wet-weather flow

b. 23 pumps 475 to 4,500 gpm in capacity; design wet weather flow

c. 6,360 feet of PVC pressure pipe 10 to 24 inches in diameter; design wet-weather flow

d. 13,570 feet of conveyance sewers 10 to 24 inches in diameter; design wet-weather flow

e. 340 feet of lined channels; design wet-weather flow

f. Four treatment plants - 2,500 feet southwest of Strong Village, Shamokin Creek 500 feet upstream from Brady Village, Shamokin Creek 500 feet upstream from Shamokin, Shamokin Creek 500 feet downstream from Shamokin; design wet-weather flow

Estimated acid mine drainage volume affected and reductions in total watershed design average loads attributable to the treatment measures are as follows:

Volume	- 86.6%
Iron	- 83.7% (to 4 mg/l)
Acid	- 88.0%

Estimated acid mine drainage volume affected and reductions in total watershed design average loads attributable to the abatement plan are as follows:

Volume	- 96.3%; 38.6 mgd
Iron	- 92.2 % ; 8.25 tons per day
Acid	- 98.7%; 35.1 tons per day

ABATEMENT PLAN V

Basic Intent: Control of mine drainage pollution by construction of preventive and treatment measures: eliminate mine drainage at Discharge Points 9, 10, 11, 31, 43, 46, and 47, of which 31 presently infiltrates into an underground pool; reduce mine drainage at Discharge Points 5, 12, 19,20,49,50, 51,52, and 53; collect and treat in four systems the remaining mine drainage from Discharge Points 5, 12,15, 19,20,21,23,24,25,26,27,29,36, 49, 50, 51, 52, and 53; mine drainage from the remaining 18 Discharge Points not eliminated or treated is comprised of 17, 41, and 45 meeting Department of Environmental Resources limitations, 16, 18, 37, 38, 39, 44, and 48 of marginal quality, and 7, 8, 22, 28, 30, 40, 42, and 54 of insignificant loadings. .

Preventive Measures: Clear 19,500 feet of stream channels and construct 86,900 feet of lined stream channels including that length cleared; construct 68,000 feet of surface-water diversion ditches; restore 122 acres of improperly restored strip mines; excavate and restore 13 acres of subsidence areas; move 21,000 cubic yards of refuse into strip mines; regrade, cover, and plant 113 acres of refuse areas.

Estimated acid mine drainage volume affected and reductions in total watershed design average loads attributable to the preventive measures are as follows:

Volume - 8.5%
Iron - 7.8%
Acid - 9.4%

Collection System and Treatment Measures:

a. 20 boreholes 50 to 296 feet deep with casings 12 to 28 inches in diameter; design wet-weather flow

b.23 pumps 475 to 4,500 gpm in capacity; design wet weather flow

c. 6,360 feet of PVC pressure pipe 10 to 24 inches in diameter; design wet-weather flow

d. 13,570 feet of conveyance sewers 10 to 24 inches in diameter; design wet-weather flow

e. 340 feet of lined channels; design wet-weather flow

f. Four treatment plants - 2,500 feet southwest of Strong Village, Shamokin Creek 500 feet upstream from Brady Village, Shamokin Creek 500 feet upstream from Shamokin, Shamokin Creek 500 feet downstream from Shamokin; design wet-weather flow

Estimated acid mine drainage volume affected and reductions in total watershed design average loads attributable to the treatment measures are as follows:

Volume - 87.8%
Iron - 84.4% (to 4 mg/l)
Acid - 89.3%

Estimated acid mine drainage volume affected and reductions in total watershed design average loads attributable to the abatement plan are as follows:

Volume - 96.3%; 38.6 mgd
Iron - 92.2%; 8.25 tons per day
Acid - 98.7%; 35.1 tons per day

COST ESTIMATES I'OR ACID MINE DRAINAGE ABATEMENT PLANS STUDIED IN DETAIL

Various considerations associated with each abatement plan studied in detail were evaluated before selecting the plan to be recommended for construction. Cost was a major consideration. Accordingly, project and total annual costs were estimated and compared. These cost estimates, based on present price levels, are set forth in this section.

Costs associated with each plan studied in detail are summarized in the following:

		Total Annual Costs		
Abatement Plan	**Project Cost**	**Average Over Initial 30 Years**	**Average Over Next 270 Years**	**Average Over 300 Years**
I	$11,900,000	$2,040,000	$1,940,000	$1,950,000
II	$10,900,000	$1,840,000	$1,750,000	$1,760,000
III	$16,600,000	$2,380,000	$2,160,000	$2,190,000
IV	$18,100,000	$2,420,000	$1,730,000	$1,800,000
V	$13,400,000	$2,040,000	$1,730,000	$1,760,000

DISCUSSION OF ACID MINE DRAINAGE ABATEMENT PLANS STUDIED IN DETAIL

The principal factors considered in evaluating the abatement plans studied in detail are discussed below:

ABATEMENT PLANS I AND II

The basic intent of both these plans is the collection and treatment of the 18 significant mine drainage discharges, which are comprised of the major mine water pool overflows not meeting current Department of Environmental Resources limitations. Abatement Plan I achieves this through five collection and treatment systems, Abatement Plan II by four collection and treatment systems. In Abatement Plan II, one barrier pillar is breached to enable collection and treatment of AMD in four, rather than five, systems as proposed in Abatement Plan I. Both plans would achieve the same level of pollution load reduction. No preventive measures are included in these plans. These plans would give more positive control and more predictable results than subsequent plans incorporating preventive measures. Stage construction of each collection and treatment system would achieve an incremental reduction in acid mine drainage pollution.

The major reason for the relatively slight project and long-term cost differential between Abatement Plans I and II is the number of collection and treatment complexes as well as their operation and maintenance. In both these plans the collection facilities account for approximately 26 percent of the project cost.

ABATEMENT PLAN III

Nearly all mine drainage discharges not meeting current Department of Environmental Resources requirements are collected for treatment in Abatement Plan III. To this extent, the plan accomplishes slightly more than do Abatement Plans I and II. For all practical purposes, the entire pollution load is abated by this plan. Those mine drainage discharges not collected include three that meet Department of Environmental Resources limitations and four of marginal quality located at considerable distances from collection and treatment systems. Four collection and treatment systems are utilized as in Abatement Plan II, and no preventive measures are included. This plan would also give more positive control and more predictable results than subsequent plans incorporating preventive measures. Separate construction of each collection and treatment system would achieve an incremental reduction in acid mine drainage pollution.

The project and long-term costs of Abatement Plan III are greater than for Abatement Plans I and II. The differential in project cost of this plan versus Abatement Plans I and II is related to the more extensive collection systems required to convey the additional mine drainage discharges to the treatment plants. The higher long-term costs of this plan versus Abatement Plans I and II are also associated with operation and maintenance, and periodic replacement of the more extensive collection systems required. Approximately 47 percent of the project cost is attributable to the collection facilities in this plan versus approximately 26 percent in Abatement Plans I and II.

ABATEMENT PLANS IV AND V

The basic intent of Abatement Plans IV and V is to: (1) eliminate by treatment measures the 18 significant mine drainage discharges via major mine water pool overflows not meeting current Department of Environmental Resources limitations; (2) eliminate by preventive measures other mine drainage discharges not meeting current Department limitations; and (3) prevent wherever feasible and practical the infiltration of surface water into underlying major mine water pools to augment stream flows. Both these plans achieve the first objective through four collection and treatment systems as utilized in Abatement Plan II. The second and third objectives are achieved by the construction of preventive measures at selected locations. Abatement Plan IV includes more extensive preventive measures than does Abatement Plan V.

Both plans will achieve approximately the same pollution load reduction overall (approximately 95 percent), although Abatement Plan IV achieves a slightly higher reduction by the use of preventive measures than does Abatement Plan V (approximately 10 percent versus approximately 9 percent of the total pollution load). Abatement Plan V project cost for preventive measures to achieve a 9 percent reduction in pollution load is approximately $3.0 million. To achieve a 10 percent reduction in pollution load by the use of preventive measures under Abatement Plan IV, the project cost is $7.8 million. Additional potential preventive measures were not included in any of the plans studied in detail because additional significant sums of money would have to be expended to achieve additional minimal reductions in pollution load. The watershed headwaters area has been so extensively deep and strip mined that virtually its entire surface area has been seriously disrupted. Approximately half of the precipitation falling in this area is intercepted by the mine workings and becomes part of acid mine drainage discharges. This watershed is therefore significantly different in this respect from other watersheds throughout the Commonwealth, where reductions in pollution loads by 20 to 50 percent could be economically achieved by the construction of preventive measures. Hence, desirable stream quality cannot be economically attained by preventive measures in this watershed without the use of substantial treatment measures.

In Abatement Plan IV approximately 43 percent of the project cost is attributable to preventive measures, and 57 percent to treatment measures. In Abatement Plan V approximately 22 percent of the project cost is attributable to preventive measures, and 78 percent to treatment measures. Both plans provide the same overall design average pollution load reductions.

Through the use of preventive measures, Abatement Plans IV and V would both provide flows of relatively good quality in considerable stretches of watershed streams where these streams presently on the average have little or no flow. Watershed streams in which flows would be augmented include portions of Quaker, Coal, Carbon, and Furnace Runs as well as the North Branch of Shamokin Creek, an unnamed tributary of Shamokin Creek near Excelsior Village, and the headwaters area of Shamokin Creek.

Abatement Plans IV and V, in addition to reducing or eliminating watershed mine drainage discharges, will prevent an average of 0.1 million gallons per day containing 0.11 tons per day of acid and 0.01 tons per day of iron from entering Mahanoy Creek via established underground mine water flow routes through Douteyville, Locust Gap, and Centralia Drainage Tunnels.

The project cost for Abatement Plan V is considerably less than for Abatement Plan IV. There is, however, little difference between the long-term costs, with those for Abatement Plan V being slightly less than for Abatement Plan IV. Stage construction of preventive measures by sub-watershed would be equally applicable to both plans as would stage construction of treatment facilities.

RECOMMENDED ACID MINE DRAINAGE ABATEMENT PLAN

Based on long-term costs, Abatement Plans II and V are more attractive than the other plans. Abatement Plan II offers a project cost less than that for Abatement Plan V, although it achieves almost the same level of abatement. Both plans provide the flexibility to enable stage construction and an evaluation of abatement measures as well as resultant stream quality. In view of the Department of Environmental Resources' current philosophy of considering the construction of preventive measures wherever practical and feasible before considering the construction of treatment measures, Abatement Plan V is recommended for construction. Over the long term, this plan is as economical as Plan II even though project costs are $2.5 million greater. A slightly greater abatement will also be achieved through Plan V than through Plan II.

Abatement Plan V is comprised of the construction of preventive measures in seven watershed areas and treatment measures in four facilities. These preventive and treatment measures are shown on Plates IV-A and IV-B. The recommended order for implementing this plan is as follows:

1. Construct preventive measures in the headwaters area of Shamokin Creek.

   a. Reconstruct and line 5,020 feet of stream channel, and place 120 feet of reinforced concrete pipe to convey two sources of water and stream flow across a mined area.

   b. Reconstruct and line 1,050 feet of channel to convey two sources of water across a mined area into the existing stream channel.

2. Construct preventive measures on an unnamed tributary of Shamokin Creek near Excelsior Village

   a. Reconstruct and line 4,390 feet of stream channel, and place 140 feet of reinforced concrete pipe to convey surface and stream flow across a mined area.

   b. Reconstruct and line 2,220 feet of stream channel, and place 240 feet of reinforced concrete pipe to convey surface and stream flow across a mined area.

   c. Reconstruct and line 2,,315 feet of stream channel, place 25 feet of reinforced concrete pipe, and reopen culvert under a private road to convey surface and stream flow across a mined area.

3. Construct preventive measures on Coal Run.

a. Clear and line 3,475 feet of Coal Run, and remove a portion of a refuse bank encroaching on Coal Run to convey stream flow across a mined area and to prevent stream water contact with the refuse.

b. Construct 2,870 feet of surface-water diversion ditches above strip mines, and reconstruct 2,720 feet of stream channel to convey surface and stream flow across a mined area.

c. Clear 1,700 feet of Coal Run, and line 3,030 feet of Coal Run to convey stream flow across a mined area.

d. Construct 5,940 feet of surface-water diversion ditches, restore a six acre strip mine, clear 2,777 feet of stream channel, and reconstruct and line 2,975 feet of stream channel to convey stream flow across a mined area.

e. Clear 4,200 feet of Coal Run to convey stream now through this area.

f. Construct 9,150 feet of surface-water diversion ditches, restore three strip mines comprising 17 acres, and reconstruct and line 2,960 feet of stream channel to convey surface and stream now across a mined area.

g. Construct 4,495 feet of surface-water diversion ditches, restore one strip mine and a portion of another comprising 16 acres, and reconstruct and line 1,770 feet of stream channel to convey surface water across a mined area.

4. Construct preventive measures on the North Branch of Shamokin Creek.

a. Construct 4,100 feet of surface-water diversion ditches, and reconstruct and line 3,610 feet of stream channel to convey surface and stream flow across a mined area.

b. Construct 4,500 feet of surface-water diversion ditches, and reconstruct and line 6,200 feet of stream channel to convey surface and stream flow across a mined area.

c. Reconstruct and line 2,460 feet of stream channel to convey stream flow across a mined area.

d. Shore one deep mine entry, construct 1,200 feet of surface-water diversion ditches, clear 3,100 feet of stream channel, and reconstruct and line 765 feet of stream channel to convey surface and mine flow across a mined area.

e. Construct 3,780 feet of surface-water diversion ditches, and reconstruct and line 2,315 feet of stream channel to convey surface and stream flow across a mined area.

f. Construct 1,240 feet of surface-water diversion ditches, clear 1,480 feet of stream channel, and reconstruct and line 4,,580 feet of stream channel to convey surface and stream flow across a mined area.

g. Construct 2,360 feet of surface-water diversion ditches, and reconstruct and line 650 feet of stream channel to convey surface and stream flow across a mined area.

h. Construct 4,300 feet of surface-water diversion ditches, restore 6.9 acres of a strip mine, and reconstruct and line 890 feet of stream channel to convey surface and stream flow across a mined area.

5. Construct preventive measures on Locust Creek.

a. Reconstruct and line 5,175 feet of Locust Creek to convey stream flow across a mined area.

b. Restore a 3.13-acre test area, and reconstruct: and line 8,625 feet of Locust Creek to convey stream flow across a mined area.

c. Construct 10,420 feet of surface-water diversion ditches, clear 8,925 feet of stream channel, and reconstruct and line 3,,720 feet of stream channel to convey surface and stream flow across a mined area.

d. Restore a 44-acre refuse area to prevent surface water contact with the refuse area.

6. Construct preventive measures on Quaker Run.

a. Restore two strip mines comprising 23 acres to prevent infiltration of surface water into an underlying deep mine.

b. Restore a one-acre portion of a subsidence area, and reconstruct and line 740 feet of stream channel to convey stream flow across a mined area.

7. Construct preventive measures on Carbon and Furnace Runs.

a. Reconstruct and line 6,550 feet of Carbon Run to convey stream flow across a mined area.

b. Restore a 69-acre refuse area to prevent surface water contact with the refuse area.

c. Reconstruct and line 5,280 feet of stream channel to convey stream flow across a mined area.

d. Clean and repair 3,200 feet of existing flumes, construct 12,920 feet of surface-water diversion ditches, reconstruct and line 1,610 feet of stream channel, restore two strip mines comprising 12.6 acres, and restore one 6.3-acre subsidence area to convey surface and stream flow across a mined area.

e. Restore 19 acres of a strip mine to prevent infiltration of surface water into an underlying deep mine.

f. Restore two strip mines comprising 32 acres to prevent infiltration of surface water into an underlying deep mine.

8. Breach the barrier pillar between two major underground mine water pools to create a single larger underground pool as well as eliminate one major mine water pool overflow.

9. Construct collection facilities and a treatment plant along Shamokin Creek at approximately 2,500 feet southwest of Strong Village..

10. Construct collection facilities and a treatment plant along Shamokin Creek at approximately 500 feet upstream from Brady Village.

11. Construct collection facilities and a treatment plant along Shamokin Creek southeast of and 500 feet upstream from Shamokin City.,

12. Construct collection facilities and a treatment plant along Shamokin Creek north of and 500 feet downstream from Shamokin City.

Assumptions have been made that two currently active strip mines will be restored upon their completion in a manner that will provide for the conveyance of surface and stream flows across the mined areas. These two strip mines are located a short distance west of Sagon Village along Coal Run, and along the southern slope of Big Mountain west of Shamokin City in the Carbon Run Drainage Area.

It is recommended that the Department of Environmental Resources require adequate restoration of surface drainage patterns upon completion of future strip mines in the watershed.

Project and unit cost information for the preventive and treatment measures comprising the recommended plan is summarized in the following:

		Total Annual Costs Per Ton of Acid Removed		
	Project Cost	**Average Over Initial 30 Years**	**Average Over Next 270 Years**	**Average Over 300 Years**
Preventive Measures	$ 2,970,000	$219	$ 44	$ 62
Treatment Measures	$10,450,000	$153	$145	$146

Exhibit J presents information by the above groupings on estimated acid mine drainage pollution abated as well as associated costs for the preventive and treatment measures comprising the recommended plan. Exhibit K shows by groupings the mine drainage discharge points affected by these preventive and treatment measures.

WATERSHED ACTIVE MINES

Active coal mining continues on a reduced scale in the watershed by the following means: strip mining, deep mining, and bank processing. At the end of 1971 there remained active 22 strip mines, which had produced 363,000 tons of coal; eight deep mines, which had produced 36,500 tons of coal; and six bank processing operations, which had produced 53,000 tons of coal during 1971. All these operations have a limited remaining life, which in most instances is less than five years. Each operation. is limited by the amount of coal remaining after earlier deep mining operations were completed, its accessibility, extent of underground mine water pools, extent and condition of past strip mining operations, percentage of coal remaining and its distribution in banks, and similar factors.

Based on available information and data, no active deep or strip mining operation in the watershed has found it necessary to collect and pump mine water to the surface for discharge to watershed streams. Any water developed by these active operations, which are all connected with past deep mining, follows established flow routes into abandoned underground mine workings from which discharges originate.

If these active deep and strip mine operators are required to collect and treat their mine drainage, these facilities would have only an insignificant effect on watershed mine drainage pollution. From an engineering standpoint, it would therefore be more practical to allow this water to flow into the underground mine workings for collection and treatment with the abandoned mine drainage discharges.

A reasonable and workable method by which active operators could bear their part of the responsibility for watershed mine drainage abatement would be to pay the Department of Environmental Resources on the basis of coal tonnage produced. The Department could then use this money most effectively to implement abatement measures designed to eliminate watershed mine drainage. The Department should therefore require the payment of a fixed amount per ton of coal mined from each active operator in the watershed. This amount per ton of coal should be consistent with that to be paid by active operators in other portions of the anthracite field.

ANTICIPATED QUALITY OF WATERSHED STREAMS AFTER IMPLEMENTATION OF RECOMMENDED ABATEMENT PLAN

Information and data on the anticipated quality of watershed streams follow:

1. Headwaters tributaries not seriously affected by mine drainage discharges, specifically Coal Run, Furnace Run, and an unnamed tributary at Excelsior Village:

   Coal Run will be improved in quality, from a mine drainage standpoint, by augmentation of flow in its upper and middle reaches" This augmentation will be accomplished by collecting and conveying considerable volumes of good quality water across mined areas to the stream. Through this procedure this water will be prevented from infiltrating into underlying deep mine workings and becoming part of underground pool overflows in other portions of the watershed. Coal Run throughout much of its length usually contains little or no flow, except during and immediately following rains. Of five minor acid mine drainage discharges located in its upper reaches, one will be eliminated and the other four will become part of the stream flow. One major underground pool overflow in its lower reaches will be eliminated by pumping via boreholes and a collection system to a treatment plant, and eventual discharge directly to Shamokin Creek. Relatively small volumes of raw sewage will continue to discharge into Coal Run from Sagon and Coal Run Villages as well as fair volumes into its lower reaches from portions of Shamokin City and adjacent Coal Township. An integral part of the recommended abatement plan is the assumed restoration by the operator of an active strip mine adjacent to Sagon Village to the extent necessary to restore the Coal Run stream bed where this strip mine has intercepted it. The average pH at the mouth of Coal Run is expected to be 7.0, with a low of 6.5 anticipated. Coal Run will retain approximately 40 mg/l alkalinity on the average. The maximum iron concentration is expected to be 1.5 mg/l. Other stream constituents and characteristics are not then expected to be of consequence. If current raw sewage discharges are collected, treated, and discharged to Coal Run, little change in stream quality would be anticipated.

   Furnace Run, from a mine drainage standpoint, will retain its present quality. A slight augmentation in flow will occur near its headwaters by collecting and conveying a relatively small volume of good quality water across a mined area to the stream. Through this procedure this water will be prevented from infiltrating into underlying deep mine workings and becoming part of an underground pool overflow directly to Shamokin Creek. No acid mine drainage discharges in Furnace Run will be reduced or eliminated, since none currently exist in this stream. Considerable volumes of raw sewage will continue to discharge into its middle and lower reaches from portions of Coal Township and Shamokin City. The average pH at the mouth of Furnace Run will continue to be about 6.9, with its range anticipated to be between 6.6 and 7.5. Furnace Run will retain on the average an alkalinity of approximately 50 mg/l. Its iron concentration will average 2.5 mg/l, with a high of 4.5 mg/l anticipated. Other stream constituents and characteristics are not then expected to be of significance. If current raw sewage discharges are collected, treated, and the effluent discharged directly to Shamokin Creek, it is anticipated that stream pH and alkalinity would be depressed.

The unnamed tributary of Shamokin Creek at Excelsior Village usually contains no stream flow because its flow normally is intercepted by past mining or infiltrates into underlying deep mine workings. Flow in this stream will be augmented by collecting and conveying considerable volumes of good quality water across these mined areas. Through this procedure this water will be prevented from entering underlying deep mine workings and becoming part of an underground pool overflow directly to Shamokin Creek. This tributary throughout its length usually contains little or no flow, except during and immediately following heavy rains. Two minor acid mine drainage discharges located in its upper reaches will become part of the stream flow. Small volumes of raw sewage from individual homes will continue to discharge into this tributary in its middle and lower reaches and will be retained as part of the stream flow. The average pH at the mouth of this stream is expected to be 6.5, with a low of 6.2 expected. This stream will retain on the average an alkalinity of approximately 5 mg/l. Its iron concentration will average 0.4 mg/l, with a high of 0.8 mg/l anticipated. Other stream constituents and characteristics are not then expected to be of significance. If current raw sewage discharges are collected, treated, and the effluent discharged directly to Shamokin Creek, it is anticipated that stream pH and alkalinity would be depressed.

2. Headwaters tributaries seriously affected by mine drainage discharges, specifically the North Branch of Shamokin Creek, Locust Creek, Quaker Run, and Carbon Run:

   The North Branch of Shamokin Creek, from a mine drainage standpoint, will be significantly improved in quality. Its flow will be augmented by collecting and conveying considerable volumes of good quality water across mined areas to the stream. Through this procedure this water will be prevented from entering underlying deep mine workings and becoming part of underground pool overflows in other portions of the watershed. Three
   acid mine drainage discharges originating from refuse piles, all of poor quality but relatively small volume, will continue to infiltrate into underlying deep mine workings and become part of an underground pool. This underground pool will flow into an adjacent downstream underground pool

through a breach in a barrier pillar, thereby eliminating a major acid mine drainage pool overflow into the North Branch of Shamokin Creek. A fifth acid mine drainage discharge of considerable volume and relatively low iron and acidity will be conveyed across a mined area and will become a part of stream flow in the North Branch of Shamokin Creek. No discharges of raw sewage will be conveyed into this stream, which has no such discharges at present. The net effect on this stream will be the elimination of a major pool overflow, but the addition of a lesser but considerable volume of good quality water and one mildly acid mine drainage discharge. The average pH at the mouth of this stream is expected to be 5.0, with a low of 4.4 expected. This stream will retain on the average an acidity of approximately 20 mg/l. Its iron concentration will average 1.2 mg/l, with a high of 2.5 mg/l anticipated. Other stream constituents and characteristics are not then expected to be of significance. An operator is currently removing a portion of a large refuse pile on the upper reaches of this stream, thereby reducing a continued potential source of acid mine drainage from two acid mine drainage discharge points.

Locust Creek, from a mine drainage standpoint, will be somewhat improved in quality. Its flow will be augmented by collecting and conveying considerable volumes of good quality water across mined areas to the stream. Through this procedure this water will be prevented from entering underlying deep mine workings and becoming part of underground pool overflows to other portions of the watershed as well as to Mahanoy Creek. These preventive measures will reduce acid mine drainage pollution not only in Shamokin Creek but in Mahanoy Creek as well. Locust Creek usually contains little or no flow throughout its length, except during and immediately following rains. Of four relatively minor acid mine drainage discharges from refuse piles into Locust Creek, three will be eliminated and the fourth will become part of the stream flow. Some acid and iron will be contributed to Locust Creek from the extensive refuse piles scattered along its course. Relatively small volumes of raw sewage will continue to discharge into Locust Creek from Locust Gap Village. The average pH at the mouth of Locust Creek is expected to be 4.0, with a low of 3.6 expected. Locust Creek will retain on the average an acidity of approximately 50 mg/l. Its iron concentration will average 3.2 mg/l, with a high of 5.5 mg/l expected. Other stream constituents and characteristics are not then expected to be of significance. If current raw sewage discharges are collected, treated, and the effluent discharged directly to Locust Creek or Shamokin Creek, it is anticipated that stream pH and acidity would remain essentially unchanged.

Quaker Run will be significantly improved in quality from a mine drainage standpoint. A minor augmentation of stream flow will be accomplished by restoring strip mines and by conveying stream flow across a mined area.

However, large volumes of acid mine drainage currently overflowing two underground pools via three acid mine drainage discharges will be prevented from entering Quaker Run by their collection, treatment, and discharge directly to Shamokin Creek. Quaker Run flow will be significantly reduced to an order of magnitude comparable to other headwaters area tributaries that have also been undermined, rather than continue to carry large volumes of acid mine drainage conveyed into Quaker Run via interconnected deep mine workings from other sub-watersheds. Three other minor acid mine drainage discharges, one meeting and the other two almost meeting the Department of Environmental Resources' discharge limitations, will continue to contribute flow to Quaker Run. Significant volumes of raw sewage from Kulpmont Borough and Brady Village will continue to discharge into Quaker Run. The average pH at the mouth of Quaker Run is expected to be 7.8, with a low of 7.4 anticipated. Quaker Run will contain on the average an alkalinity of approximately 70 mg/l, which will be directly attributable to the large proportionate volume of raw sewage contained in its flow. Its iron concentration will average 1.0 mg/l, with a high of 1.5 mg/l expected. Dissolved oxygen, dissolved solids, and bacteria concentrations in Quaker Run will be of significance, again because of the large proportionate volume of raw sewage contained in its flow. If current raw sewage discharges are collected, treated, and the effluent discharged directly to Shamokin Creek, it is anticipated that pH and alkalinity would be depressed in Quaker Run.

Carbon Run will be improved in quality from a mine drainage standpoint. Its flow will be augmented throughout its middle reaches by collecting and conveying considerable volumes of good quality water across mined areas to the stream. Through this procedure this water will be prevented from entering underlying deep mine workings and becoming part of underground pool overflows to the downstream portion of the watershed as well as directly to Shamokin Creek. Three minor acid mine drainage discharges on Car bon Run will be eliminated, while nine other minor acid mine drainage discharges will continue to exist in its watershed. Of these nine, two meet Department of Environmental Resources mine drainage discharge limitations and the other seven are marginal to mildly acid. However, a large volume of acid mine drainage currently overflowing one underground pool via one acid mine drainage discharge will be prevented from entering Carbon Run by its collection, treatment, and discharge directly to Shamokin Creek. Carbon Run flow will be reduced somewhat overall. Considerable volumes of raw sewage will continue to discharge into its lower reaches from portions of Coal Township and Shamokin City. The average pH at the mouth of Carbon Run is expected to be 7.0, with a low of 6.5 anticipated. Carbon Run will contain on the average an alkalinity of approximately 18 mg/l, principally attributable to relatively large volumes of raw sewage contained in its flow. Its iron concentration will average 7.5 mg/l, with a high of 12 mg/l expected. Dissolved oxygen, dissolved solids, and bacteria concentrations in Car bon Run could be of significance. If current raw sewage discharges are collected, treated, and the effluent discharged directly to Shamokin Creek, it is anticipated that pH and alkalinity would be depressed in Car bon Run.

3. Tributaries draining areas lying downstream from coal-bearing deposits, specifically Trout Run, an unnamed tributary locally known as Kulps Run, Buddys Run, Millers Run, Lick Creek, and an unnamed tributary sometimes called Elysburg Run:

   Stream quality will be unchanged in these tributaries that drain areas down-stream from coal-bearing deposits. These streams will on the average retain pH from 6.4 to 6.8, and iron concentrations ranging from 0.3 to 1.1 mg/l. These streams will remain on the average near neutral, with alkalinities as high as 11 mg/l and acidities as high as 16 mg/l. It is anticipated that other stream constituents and characteristics will remain of no sanitary significance. Normal aquatic life should continue to exist in these tributary streams.

4. Shamokin Creek:

   At the farthest upstream sampling station on Shamokin Creek (Station S14), just downstream from Mount Carmel Borough, stream quality will remain about the same. Its flow will be augmented by collecting and conveying relatively small volumes of good quality water across mined areas to the stream. Through this procedure this water will be prevented from entering underlying deep mine workings and becoming part of a downstream underground pool overflow. The pH is expected to average about 6.7, with a low of 6.5 anticipated. Shamokin Creek at this point will on the average retain an alkalinity of 30 mg/l. Its iron concentration will average 2.5 mg/l, with a high of 3.5 mg/l anticipated. Under conditions of average or lesser runoff, much of this stream flow will be comprised of raw sewage discharges from Mount Carmel Borough and Atlas Village. Dissolved oxygen, dissolved solids, and bacteria concentrations would continue to be of significance. If current raw sewage discharges are collected, treated, and the effluent discharged directly to this portion of Shamokin Creek, these constituents would then be of lesser significance.

   The next sampling station (Station S-13) is located on Shamokin Creek a relatively short distance downstream from the point where it receives its North Branch. Stream quality in Shamokin Creek will be dramatically improved, from a mine drainage aspect, at this location. Considerable volumes of good quality water will have been retained as stream flow by preventive measures, and a large volume of alkaline water with relatively low iron content will have been discharged into Shamokin Creek from the farthest upstream acid mine drainage treatment plant located 2,500 feet southwest of Strong Village. This treatment plant discharge on the average will comprise about three-fourths of Shamokin Creek flow at this station. The average pH at this station is expected to be 7.3, with a low of 6.8 anticipated. Shamokin Creek at this station will contain on the average an alkalinity of approximately 24 mg/l. Its iron concentration will average 3.4 mg/l, with a high of 5.0 mg/l expected. Dissolved solids in Shamokin Creek consisting of those contributed by raw sewage discharges from Mount Carmel Borough and Atlas Village as well as by the acid mine drainage treatment plant could be of significance.

Shamokin Creek at all 12 additional downstream sampling stations will retain its dramatically improved stream quality from a mine drainage aspect. Three additional significant volumes of treated acid mine drainage will be discharged into Shamokin Creek within its headwaters area. At Station S-4, which is the United States Geological Survey Gauging Station located a relatively short distance downstream from the headwaters area of Shamokin Creek, the four acid mine drainage treatment plant discharges will on the average comprise approximately two-thirds of Shamokin Creek flow. At Station S-I, near the mouth of Shamokin Creek, the four acid mine drainage treatment plant discharges will on the average comprise approximately one-fourth of Shamokin Creek flow. Shamokin Creek pH is expected to average between 6.9 and 7.3, with a low of 6.0 anticipated in its lower reaches. Shamokin Creek will contain on the average an alkalinity of 16 to 32 mg/l throughout its remaining length downstream from Station S-13. Its iron concentration will on the average throughout this remaining length range from 2.0 to 0.8 mg/l, with iron concentration generally decreasing downstream. Dissolved solids, both from significant contributions of raw sewage and acid mine drainage treatment plants, could continue to be of significance in this entire stretch of Shamokin Creek. If current raw sewage discharges are collected, treated, and discharged to Shamokin Creek, little change in stream dissolved solids concentrations would occur.

Exhibit L shows the anticipated constituents and characteristics of watershed streams at each sampling station after implementation of the recommended abatement plan.

OVERVIEW

Shamokin Creek throughout its entire length has been of very poor quality. The Department of Environmental Resources is concerned with acid mine drainage abatement in this watershed, as mandated in Pennsylvania's Clean Streams Act, as well as resultant stream quality improvement in the Susquehanna River. Based on results of investigations described in this report, Shamokin Creek stream quality will be dramatically improved upon implementation of the recommended abatement plan. Susquehanna River stream quality will be enhanced to a lesser degree. When the recommended plan is implemented, the entire length of Shamokin Creek is expected to meet the Department's pH stream quality criterion, and to virtually meet the Department's iron stream quality criterion. The downstream reaches of Shamokin Creek, at and downstream from Station S-4, will probably meet the Department's pH and iron criteria under nearly all flow conditions. Furthermore, for all of Shamokin Creek other constituents and characteristics associated with mine drainage except dissolved solids would not then appear to be of major sanitary significance. Some dissolved solids are also contributed to watershed streams via raw sewage discharges from major population centers in the Shamokin Creek headwaters area. The collection and treatment of these discharges will not cause a major reduction in this constituent. Relatively high dissolved solids concentrations in Shamokin Creek may not, however, adversely affect anticipated stream uses. Therefore, it appears that the recommended plan will accomplish the Department's objective.

In addition, the recommended plan will (1) remove 92.2 and 98.7 percent of total average watershed iron and acid loads, respectively, and (2) significantly improve the present stream quality of Shamokin Creek tributaries currently receiving the major acid mine drainage loads. Although under the recommended plan various headwaters tributaries would still not meet the Department of Environmental Resources' specific stream quality criteria, there would not appear to be any water usage problem associated with this fact. Considering the anticipated stream quality in Shamokin Creek, the Department's objective of controlling mine drainage from abandoned mines throughout its headwaters area would probably be met or, as a minimum, a significant step will have been made toward this end.

The recommended abatement plan is amenable to stage construction. Therefore, the anticipated effect of each stage on reductions in acid mine drainage loads and improvement in stream quality can be verified and evaluated. If, during the course of implementing the recommended plan, additional preventive or treatment measures (or both) are indicated, these could easily be accommodated.