I. INTRODUCTION

A. Description of Study

I. The Department of Mines and Mineral Industries of Pennsylvania authorized engineering surveys of a number of major watersheds in the Commonwealth. The purpose of these surveys was to locate the sources of pollution stemming from abandoned deep and strip mines, to recommend measures of correction, and to estimate the costs of abatement.

2. One of the major watersheds is Chartiers Creek Basin located in Allegheny and Washington Counties. The Basin is an important part of the Greater Pittsburgh industrial complex, with approximately 50 major and minor industries located in Chartiers Valley.

3. In April, 1968, the Chartiers Creek Basin Pollution Survey began with the identification of the polluted streams and the location of the sources. Two hundred thirty-three sources of pollution were measured and catalogued. Of that number, it was calculated that forty-five sources contribute approximately 84% of the total acid pollution into Chartiers Creek. Two of the forty-five sources are discharges from active mining operations. Treatment plants are now in operation at these sources.

4. The survey has been divided into three phases:

a. Phase I	The location and identification of pollution sources
b. Phase II	Periodic measurements of pollution sources for three months.
c. Phase III	Periodic measurements of pollution sources for an additional 10 months and abatement recommendations.

5. The report covering the Phases I and II study was submitted in August, 1968. The Phase III survey of Chartiers Creek has been predominantly involved with the forty-three major sources which result from abandoned mining operations - their behavior during different seasons of the year and their relationship to the abandoned strip and deep mines in the Basin. This report includes the data obtained from all three phases of the survey and it also includes recommendations for methods of abatement and an estimate of costs for complete or proportional reduction of pollution from the major sources.

B. Purpose

I. The purpose of Phase III has been to:

a. Periodically measure discharges of acid water at the established major sources of pollution and gauging stations and to collect samples.

b. Perform laboratory analysis on the collected samples of acid mine water.

c. Calculate and analyze the field and laboratory data in order to recommend methods for reducing or eliminating the pollution.

d. Prepare recommendations for methods to reduce or eliminate acid mine drainage in Chartiers Creek Drainage Basin on a priority basis.

e. Estimate costs for complete elimination or proportional reduction of pollution from the major sources of pollution.

C. Definition of Terms

I. Major Source: a discharge of acid mine drainage during maximum flow which results in at least a 1,000 lbs. acid load/day. The major sources were selected on the basis of the results of the initial readings for the Phase I Study on Acid Mine Drainage Pollution.

2. Minor Source: a discharge of acid mine water which results in less than 1,000 lbs. acid load/day.

3. Hydrologic Year: a 13-month period of time.

4. Slugger: a source which produces a large acid load in a short period of time.

5. Slugging Index: an indication of the potential of a source to contribute a large acid load within a short period of time. A slugging index of 4 would mean that the reading taken at a source during maximum flow was approximately four times greater than the average reading for that source during the hydrologic year.

6. Acid Load: the acid concentration as determined by laboratory tests multiplied by the flow at the time.

7. Pollution (in this report): refers only to acid mine water discharged into Chartiers Creek or a tributary of Chartiers Creek.

8. Priority Number: the relative order for recommended abatement of the major sources. The priority number is based on the average total acid load/day contributed by the source during the hydrologic year.

9. RND (random): indicates a strip mine area in which more than one type of reclamation has been performed.

10. DTH (drainage toward the highwall): indicates a strip mine in which the backfilling and grading operations have left portions of the coal seam exposed in the highwall. The drainage pattern is toward the highwall. Many ponding areas for water are present, and the natural drainage through the strip mine is blocked by backfill materials. Spoil banks are present.

11. URC (unreclaimed): indicates strip mines in which little or no attempt has been made to regrade the spoil piles or cover the coal outcrop in the highwall.

12. DAH (drainage away from highwall): indicates a strip mine which has been so backfilled and graded that the coal seam is usually covered and drainage is away from the highwall. The highwall may still be present.

13. Symbol OAK 60: used to identify strip mines. The three letters are an abbreviation of the 7-1/2 minute U.S.G.S. quadrangle on which the strip mine is located. The numbers are used to differentiate the mines. In the case of the deep mine dumps, the letter D follows the number. The numbers do not indicate size, location, or type of reclamation for that area. The abbreviations used are as follows:

CLN	Clinton
OAK	Oakdale
PGW	Pittsburgh West
MID	Midway
CAN	Canonsburg
BRG	Bridgeville

14. Formation: a large and persistent stratum of one kind of rock.

15. Syncline: a fold in rocks in which the strata dip inward from both sides towards the axis.

D. Description of Chartiers Creek Drainage Basin

I. Topography:

a. The Chartiers Creek Drainage Basin lies within the Allegheny Plateau. The area is a maturely dissected region in which the principal streams have eroded their broad valleys to a fairly uniform gradient. The tributary streams have cut the uplands into numerous narrow ridges with steep hillsides rising from generally narrow valley bottoms.

b. The source of Chartiers Creek is about 6 miles south of Washington, Pennsylvania, and the Creek flows in a generally northeast direction to the Ohio River. The relief of the main valley varies from an approximate elevation of 710 ft at the Ohio River to an approximate elevation of 1520 ft at the headwaters.

c. Dissection of the uplands by the numerous streams has exposed the coal-bearing measures of the Monongahela Formation, mainly the valuable Pittsburgh seam. As a result of the topography and the level attitude of the rocks, the coal bed has been readily found and mined along the valley sides by various methods, but generally by drift mining and strip mining.

2. Surface Drainage:

a. The Chartiers Creek Drainage Basin is roughly rectangular in shape with a length of approximately 24 miles and an average width of approximately 12 miles. The drainage area above the mouth is about 276 sq. miles. Although the stream pattern of the basin is considered dendritic, it has some rectangular characteristics with a predominant number of minor tributaries flowing into the main channels from a northwesterly direction. (See Plate I.)

b. Chartiers Creek has several principal tributaries. The largest of these is Little Chartiers Creek with a drainage area of approximately 50 sq. miles. Other principal tributaries are Robinson Run with a drainage area of approximately 40 sq. miles and Millers Run which drains approximately 30 sq. miles.

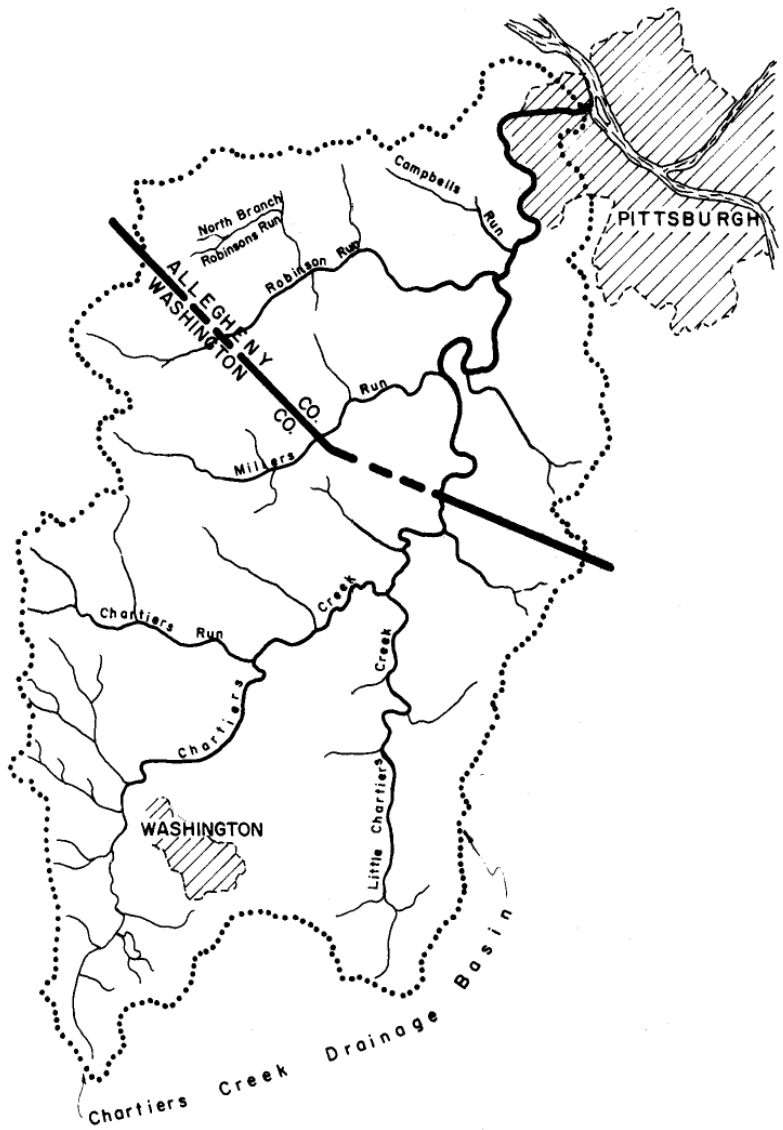
c. The Chartiers Creek region is well drained due to the hilly topography which is conducive to rapid runoff of the surface waters. This is indicated by the very few swampy or standing water areas within the basin. The slope of the main channel of Chartiers Creek varies from about 7 ft. per mile near the mouth to about 50 ft. per mile in the extreme headwaters. The channels of the tributaries generally vary in slope from about 30 ft. per mile to 100 ft. per mile.

3. Geology:

a. General:

I) Bedrock in the Chartiers Creek Drainage Basin consists of gently dipping sedimentary beds of shale, sandstone, limestone, indurated clay, and coal. The outcropping beds belong to the Carboniferous system which includes in this area a large part of the Conemaugh, all of the Monongahela and Washington, and a small part of the Greene formations. The total thickness of the rocks exposed on the surface of the drainage basin is about 1100 ft.

2) Chartiers Creek originates in the rocks of the Greene Formation in Washington County and immediately flows on the rocks of the Washington Formation. Beginning north of Washington, Pennsylvania, and extending north of Woodville, the stream traverses the rocks of the Monongahela Formation, except around Midland where the stream flows on the rocks of the Conemaugh Formation. South of Woodville the stream valley is underlain by the Conemaugh Formation.



CHARTIERS CREEK DRAINAGE BASIN

LOCATION MAP

Plate No. I

b. Structure of the Basin

I) The regional dip of the Pittsburgh Coal is to the southeast. Three minor geological structures which locally modify the regional dip are present within the Chartiers Creek Drainage Basin. These are: the Nineveh Syncline which trends north - south; the Cross Creek Syncline which trends east - west; and the east - west trending Panhandle Trench.

2) The deepest portion of the Nineveh synclincal trough is near Morganza. The Nineveh Syncline locally modifies the southeast regional dip in the vicinity of Morganza to a north - south trend from Morganza to Bridgeville. Therefore, the acid mine drainage begins to collect at this low point which acts as a natural reservoir.

3) The minor local variations of the Pittsburgh Coal within a mine complex are most critical in determining the possible course of the acid mine drainage. In order to prepare abatement recommendations, detailed structure contours were prepared on the base of the Pittsburgh Coal on all mine maps made available to us for this survey.

4) The structure contour of the coal also indicates that a certain amount of acid mine drainage discharged into the Chartiers Creek Drainage Basin results from surface water entering outside the topographic boundaries of the basin. This is particularly true of the areas in North Fayette Township.

5) The main tributaries within the basin, such as Robinson Run and North Branch Robinson's Run, flow perpendicular to the regional dip. The tributaries to these streams run parallel to the regional dip. In some sense, therefore, the basin has been divided into a number of nearly isolated pockets, with a major source usually at the low end of the pocket. This combination of the regional dip and tributary streams being at right angles to the regional dip would offer the ideal case for sealing of the mines, if strip mining had not taken place along the outcrop of each of the individual valleys.

c. Pittsburgh Coal Seam:

I) The area of outcrop of the Monongahela Formation is more extensive than that of any other formation in the Chartiers Creek Drainage Basin. The Pittsburgh Coal seam is the lowest member of the Monongahela Formation. The base of the Monongahela Formation rests on the eroded surface of the Conemaugh Formation. Below the Pittsburgh Coal there is generally a few inches to a foot impervious gray underclay, then about 2 ft. of dark to light-gray brecciated limestone. The main coal seam is approximately 5 to 6 ft. thick with some thickening and thinning in various areas. The upper part of the Pittsburgh Coal consists of alternating bands of black carbonaceous shales and bony coal 6 inches to 2 feet in thickness for about 7 or 8 ft. above the main seam. The interval between the Pittsburgh Coal and the Redstone Coal, which is not persistent in this area, averages about 50 to 65 ft. and is occupied by a light to dark-gray shale interbedded with sandy. The character of this rock stratum changes rapidly in lateral direction. The low permeable shales grade into permeable sandstones in distances of a few hundreds of feet or Generally associated with the coal and shale overlying the main seam and the black carbonaceous shales and the sandstone overlying the coal bed are iron sulfide minerals (pyrite and marcasite). These minerals represent the principal source of coal mine acid upon oxidation. .

2) Iron sulfide minerals are also found in the main coal seam as horizontal shaly partings and as concretions known as sulfur balls. The iron-sulfide minerals in these partings are generally in the form of flaky crystals and the concretions occur as black to brassy spheres of various sizes. The sulfur balls are irregular in distribution in the Pittsburgh Coal and their composition is largely pyritic. These are sources of acid in the main coal seam, as is the natural sulfur content of the coal.

4. Mining Methods:

a. The three methods which have been employed to extract the Pittsburgh Coal in the Chartiers Creek Drainage Basin are: drift mining, shaft or inclined-slope mining, and contour strip mining.

b. Drift Mining:

I) In the Chartiers Creek Drainage Basin the combination of nearly flat lying coal beds plus a hill - valley type of topography results in the coal outcropping in the valley walls. These areas were mined by driving a drift, entry, directly into the hillsides.

2) The drift opening in the outcropping of coal is generally 8 to 12 ft. wide.

3) In most cases a second drift entry parallel to the and approximately 40 to 100 ft. from the first is driven.

4) Generally when the two entries are approximately 500 ft. deep, the first cross entries are started. This procedure is continued every 30 to 40 feet with the main entries extending in their original direction to the property line.

5) At the cross entries, rooms are driven at various angles to the main entry, depending on the face cleat of the coal, and the coal is extracted. The rooms are about 20 to 30 ft. wide in the mined area of the Chartiers Creek Drainage Basin.

6) Room pillars (ribs) are left between each pair of rooms, and cuts are made through these for ventilating and access purposes. The size of these pillars is about 10 to 20 ft. wide and approximately 100 feet in length.

7) On retreating, the room pillars are sometimes mined and the roof of the mine generally collapses.

c. <u>Shaft of Inclined Slope Mining</u>

1) The general southward dip of the Pittsburgh Coal puts the mineable coal beneath the valley bottoms in the southern portion of the drainage basin. In these areas the coal is mined through vertical shafts or inclined slopes. This method of mining follows the same procedures outlined under Drift Mining.

2) The newer method of long-wall mining is no being used in the active mine south of the basin area.

d. <u>Strip Mining</u>

1) Due to the outcropping of the Pittsburgh Coal on the valley walls, extensive contour strip mining has been utilized in the Chartiers Creek Drainage Basin to extract coal. This method consists of removing the overburden from the coal bed, starting a the outcrop and proceeding around the hill.

2) After the uncovered coal bed is removed, successive cuts are made until the depth of the overburden becomes too great for the equipment and the coal is uneconomical to mine.

3) The highwalls on the inside of the strip mine range in height from a few feet to about 100 ft.

4) The spoil material consisting of soil and rock is placed on the downward side of the hill.

5) Some of the contour strip mining has been used to recover coal pillars and barriers left by former underground operations.

6) In many areas the strip mining broke into the abandoned deep mines. Many of the major and minor sources of the Chartiers Creek Drainage Basin are a result of this condition.

E. Surface-Subsurface Water Complex

Strip mining and deep mining have changed the effect of the normal hydrological cycle on the Chartiers Creek Drainage Basin. In addition, the streams have become polluted with acid mine water. The deep mining and strip mining have caused pollution in the following ways:

1) Deep Mining:

a. In the Chartiers Creek Drainage Basin the majority of the deep mining was done by drifting. Generally with the deep mining, subsidence occurs and causes fracturing of the less permeable strata overlying the coal, with the following results:

i. The groundwater flows into the deep mine through the fractures created by subsidence in the strata overlying the mine.

ii. These fractures expose the acid-forming iron sulfide minerals, which are associated with the shales and coal, to oxidation.

iii. The ground water flows over the oxidized iron-sulfide minerals to form acid mine water.

iv. The acid mine water generally flows along the impermeable underclay and/or limestone at mine bottom and discharges at the point of lowest elevation.

b. Sink holes have developed in the bottoms of a number of the small tributary valleys, causing a loss of surface water into the mine. This has the two-fold effect of eliminating clean water, which would dilute the pollution of the streams, and adding a greater volume of acid water which must be treated in order to abate the pollution.

2) <u>Strip Mining:</u>

a. The largest single factor to affect the surface ground water complex is the strip mine, particularly the unreclaimed or poorly reclaimed strip mines throughout the Chartiers Creek Drainage Basin. The strip mines have affected the acid mine drainage problem in the following way:

I) Acid-forming materials have been left exposed over large areas of land. They oxidize in normal atmosphere and produce the sulfate minerals. Rapid runoff from the rainfall dissolves these minerals and carries them in the form of acid and impurities into the streams.

2) Ponds, lakes and other depressions left along the base of the highwalls accumulate surface water, and this water usually percolates back into the deep mine through the soil or through entries into the deep mine which have been uncovered by the strip mining operation.

3) Blockage of natural valleys or drainage channels by strip mine materials causes surface water to be diverted or lost into the deep mine.

4) The vast acres of unvegetated spoil banks causes. rapid runoff of water from the spoil piles into the deep mines and is believed to be the major cause of slugging at some of the major and minor sources.

F. <u>Methods of Study:</u>

I. <u>Sample Collection:</u>

a. The field survey was carried out by a two-man team during the months of June, 1968 through July, 1969.

b. The pH, dissolved solids, temperature, and flow of the discharge were recorded in the field.

c. Samples of the acid mine discharge were collected at the source in 300 ml BOD bottles and labeled accordingly. The samples were returned to our water laboratory for analysis.

2. Laboratory Analysis:

a. The samples collected from each source were analyzed in the laboratory for the following ions: total iron, manganese, sulfate and total hardness. Each sample was also tested for acidity and/or alkalinity. ,

b. The analysis for acidity is performed in accordance with ASTM standards as modified by FWPCA. A 50-m1. sample is boiled for two minutes. The sample is titrated with a .02 (N/50) normal sodium hydroxide solution using a phenothalien indicator to a permanent pink color and an end point of pH 8.3, as measured continuously by a temperature-compensated pH meter. The results are expressed as mg/l (milligrams per liter) of calcium carbonate as acidity.

c. The alkalinity is determined in the laboratory by titrating a 50 ml. sample with .02 normal sulfuric acid down to an end point of pH 4.5. The results are expressed in mg/l of calcium carbonate.

d. Total hardness of water is defined as concentration of calcium and magnesium ions and is expressed as parts per million calcium carbonate. The complexometric hardness titration method was used to obtain the results by the following procedure: to a 50 ml. sample of water a buffer and an indicator solution are added; a small quantity of sodium cyanide is added to eliminate interference due to iron and copper; and the sample is titrated with a .02N solution of the disodium salt of ethylenediaminetetracetic acid. The end point is when the solution changes from wine red to pale blue. The result is total hardness in parts per million calcium carbonate.

e. The barium sulfate turbidimetric method is used to measure the concentration of sulfate ions in the acid mine water. This method involves the precipitation of barium sulfate under controlled conditions which stabilize the suspension. The suspension is placed in a light-cell and the results are read as parts per million sulfate on a photometer.

f. The total iron content is measured by using the 1,10-phenanthroline method. An orange color develops in the presence of iron. The concentration of iron is measured in parts per million iron by use of a photometer.

g. The concentration of manganese in the water samples is obtained by the use of the cold periodate oxidation method. In this method the manganese is oxidized to permanganate which has a characteristic pink to pink-purple color. The results are read as parts per million manganese on the photometer.

3. Engineering Investigation:

a. Deep mine maps were obtained where possible for the areas which contained the major pollution sources. Structure contours were constructed on the base of the coal to determine the direction of subsurface flow for the deep mines. The W.P.A. coal maps were used to establish the over-all subsurface drainage trend of the basin.

b. The locations of mine openings and air shafts were transferred from the deep mine maps to an aerial mosaic map and were checked by our personnel in the field.

c. The majority of the major sources were investigated in the field to determine the condition of the associated strip mines and other areas where surface waters were lost into the deep mines. The other areas included tributaries, valleys and portions above the deep mine.

d. Aerial photographs were used to locate strip mines and to calculate the area occupied by the strip mines. Most of the strip mines were examined by our personnel to verify the conditions noted on the aerial photographs.

e. Cost estimates were made for each source, based on our analysis of the conditions of the strip mine, extent of disrupted surface drainage, amount of clearing and grubbing required and accessibility to the properties.

f. The primary abatement methods are based on restoration of natural drainage to prevent unpolluted surface water from entering the deep mines. These corrective measures are considered to be a permanent type of corrective measure but result in only partial abatement of the source.

4. Sources of Information

a. The information pertinent to the acid mine drainage of Chartiers Creek Drainage Basin was obtained from various sources. We wish to express our appreciation to all who have contributed to this survey.

b. Information pertaining to the areal extent of the drainage basin and the sub-watersheds, population, and the number of industries was obtained from the U. S. Army Corps of Engineers Review of Reports on Chartiers Creek Basin, Pa., Parts I and II. Information dealing with climatology and precipitation was obtained from publications of the U. S. Weather Bureau. The geological description of the area was found in publications of the U. S. Geological Survey and Topographic and Geologic Survey of the Commonwealth of Pennsylvania.

c. Deep mine maps were obtained from the owners of the various deep mines. Some deep mine maps could not be located, others were not made available by their owners. Some deep mine maps were supplied to us by the Bureau of Bituminous Mine Subsidence with permission of the owners. Pittsburgh Coal Company supplied deep mine maps of property currently owned by them in the northern portion of the basin.

d. Coal mine information was obtained from maps in the library of Ackenheil & Associates, Inc. The maps originally came from the U.S. Bureau of Mines and were up-dated by the firm.

e. The discharge for Chartiers Creek at the Ohio River was obtained from Ground Water Branch, U.S.G.S. in Pittsburgh.

f. Aerial photographs for Allegheny County were supplied by Aerial Map Service and the photographs for Washington County were supplied by American Air Survey Corporation.

g. Aerial maps for Allegheny County were supplied by the Southwestern Pennsylvania Regional Planning Commission.

h. Data pertaining to the acid mine drainage pollution in the Washington County portion of the Chartiers Creek Drainage Basin was received from the Washington County Planning Commission.

i. Invaluable assistance was given by American Air Surveys who took part in an experiment to identify types of pollution by infra-red and false color photographs. The analysis of this experiment is still in progress.