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SITE SELECTION AND DESIGN FOR MINIMIZING POLLUTION FROM UNDERGROUND COAL MINING OPERATIONS

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SITE SELECTION AND DESIGN FOR MINIMIZING POLLUTION FROM UNDERGROUND COAL MINING OPERATIONS

by

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report deals with selection of a site, the manner of mine development, the method of extraction of coal, and the proper closure of underground coal mines to insure the minimum pollution of the mine area both during the life of the mine and after abandonment. It is hoped that those planning mining operations or studying environmental effects of such operations may find this report useful.

Further information on this subject may be obtained from the Extraction Technology Branch.

David G. Stephan
Director
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Cincinnati

ABSTRACT

The objectives of this study were to determine how best to select a layout and mining system and also to develop and operate an underground coal mine while at the same time minimizing pollution of the environment. Study and data collection were begun in September 1974 at two pre-selected sites. After six months, work was shifted to a third more suitable site, Republic Steel Corporation's North River No. 1 mine.

The pre-mining environment was assessed by sampling Cedar Creek above site 3 and other streams to the east and west of the site. Analyses of samples of groundwater into the mine from "dripper" joints, of the water pumped from the mine sump, and of water from Cedar Creek below the mine at various distances, made possible the assessment of the area with regard to water quality. Principal factors associated with mining which affected downstream water quality were sulfide oxidation and acid formation in the mine, the quality of the groundwater seeping into the mine, the limestone used for rock dusting, and the quality of the resettled but not treated mine and washing plant water carried to the continuous miners for dust suppression. A sample was also taken toward the end of the miners' holiday when the continuous miners were idle and rock dusting was not being done.

Pollution downstream from the mine proved to be slight, even when untreated mine effluent flowed directly into the creek. The quantities of heavy metal ions contained in the mine influent and effluent were small. Geological and hydrologic conditions observed along with the analytical results suggest that water pollution should be minimal during the life of the mine. If openings are sealed after closure, environmental integrity for the area should exist indefinitely. At depths of 152-213 m below the surface subsidence should be minimal also.

Deep mines in Alabama's synclinal coalfields, if entered some distance from the outcrop, or mined down-dip if started on the outcrop, should produce little surface pollution. Sealing of all openings should insure minimum pollution far beyond the life of the mines.

This report was submitted in fulfillment of Contract No. 68-03-2015 by the Civil and Mineral Engineering Department and the Mineral Resources Institute of the University of Alabama, and the Geological Survey of Alabama, under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period June 19, 1974, to December 31, 1976, and work was completed on December 31, 1976.

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The final report was prepared by Reynold Q. Shotts, Professor of Mineral Engineering and by Eric Sterett, graduate assistant in Civil Engineering, Department of Civil and Mineral Engineering. The section on the hydrology of site 3 was written by Thomas A. Simpson, former Assistant State Geologist, Geological Survey of Alabama, and now Associate Professor of Mineral Engineering in The Department of Civil and Mineral Engineering. Written contributions on the geology of the three sites by Dr. Stephen Stow, Professor of Geology, were incorporated in the report.

All water analyses were made by Mr. Sterett, and Jack Davis, former graduate assistant, Department of Civil and Mineral Engineering, except for five analyses made by the Geological Survey of Alabama. At various times, graduate assistants employed on the project were David Sutley and Edgar Hirschberg, Department of Geology, and David Ramsey, Department of Civil and Mineral Engineering. Undergraduate assistants were James M. Patterson, Jr., and Lawson M. Cannon, Department of Civil and Mineral Engineering.

The EPA project officer during the first few months was Eugene F. Harris and, during the remainder of the project, was S. Jackson Hubbard.

Invaluable contributions to the study of site 3 were made by the Republic Steel Corporation, particularly August F. Hilleke, General Superintendent, Southern Coal Mines, and John Matthews, Mining Engineer. Valuable information concerning acid mine water in conventional and longwall mining sections was contributed by G. L. Barthauer, Vice President, Environmental Affairs, Consolidation Coal Company, Willard E. Ward and George W. Wood, Land Department, University of Alabama, and Calvin Jones, land owner and former mine operator in the Cahaba coalfield, also contributed data and opinion, as did Alice S. Allen, U. S. Bureau of Mines, Washington.

SECTION 1

INTRODUCTION

OBJECTIVES OF THE RESEARCH

The broad objectives of this research were stated in the Project Proposal as follows:

> The objective of this investigation will be (1) to select two coal mining sites that will be developed in the near future, (2) to evaluate state-of-the-art techniques to be applied to these sites which will minimize pollution from underground coal mining operations, and (3) to design mining programs prior to mining that will utilize the most favorable technology available to prevent pollution. This investigation will encompass studies in physiography, water quality, geology, hydrology, and other pertinent factors that will influence the pollution potential of the sites during and after mining.
>
> In order to evaluate and design alternative mining techniques for minimizing pollution, it will be necessary to critically evaluate the state-of-the-art as applied to these techniques, and to use this information as a foundation upon which to build additional environmental safeguards.

It became evident that a project as described would be one of studying every aspect of the <u>mining operation itself</u> and that measures to minimize or eliminate pollution sources would actually be a by-product of this study and of a study of the natural conditions that surround the mine in three dimensions.

In this study, <u>minimum</u> emphasis was placed on the internal environment of the mine itself as it affects the work force on the job (miner health and safety) and <u>maximum</u> emphasis on the effects of the mining operation on the environment external to the mine. The time frame of concern with the external environmental extends beyond that of the life of the mine. Inasmuch as the environment outside the mine may be affected by both the underground and surface operations, the latter cannot be altogether neglected; however, pollution contributed by the surface operation and that from underground operations must be evaluated separately. Operations at, and beyond the surface outside the mine have been investigated extensively by others and are not within the scope of this research.

CRITERIA FOR SITE SELECTION

In the project proposal two possible sites for the research were suggested. The reasons for selecting the two sites were:

(1) Both sites were partly or wholly on land owned, in fee, by the University of Alabama. This would mean ready access to the land and to all existing data on the land.

(2) The two sites presented greatly dissimilar mining conditions. Site 1 is in the long, narrow, synclinal Cahaba coalfield with steep coalbed dips near the margins and coalbeds of variable thickness. Site 2 is in the larger Warrior coalfield, where the coalbeds dip only slightly and are more uniform in thickness.

(3) The sites were selected at the height of the "coal boom" and were believed to be the two on University-owned land most likely to be mined soon.

As the project proceeded with no increase in the prospects for the immediate start of mining at either proposed site, it was decided to direct the project efforts to a mine already under construction or with construction scheduled immediately. Two companies were approached. Within a short time one of these, Republic Steel Corporation, agreed to cooperate with the project at a mine that had just started coal production near Berry, Alabama, only about 35 miles from the campus. On completion of a verbal agreement with Republic Steel Corporation, work on the two original sites was dropped and attention turned to site 3.

Site 3 is, geologically, more like site 2 than site 1. The coalbed is a member of the Pratt group of coalbeds, the group next above the Mary Lee group, which occurs at site 2. The Corona (Pratt) coalbed at site 3 is 1.25 - 1.50 meters (4 - 5 feet) thick, and is only slightly dipping. It does not crop out on or near the site and its depth of about 152 meters (500 feet) is greater than the coalbed at site 2 and shallower than most of the coalbed area at site 1. Its prime advantage was, however, that it was being mined.

Ideally, the pre-mining environment should have been studied prior to the construction of the mine so that later studies could have more precisely evaluated any environmental changes produced by mining. The mine was constructed and had begun production, however, before this could be done. Normally, this would mean no opportunity to detect deterioration in the environment that might be produced by the mining operation. Observation indicated that effect on the environment at this stage was minimal.

North River Mine was opened in a very thinly inhabited area. The topographic map, field-checked in 1967, shows a density of houses of fewer than 5 per land section (259 hectares or 640 acres). Section 32, T16S, R10W, in which the surface plant of the mine is located, had only four houses. The area is heavily wooded. There is some cleared and partly cultivated farm land in the alluvial flood plains of the streams.

To the west and north of the mined area, most of the cleared land is on the interstream divides, and in the other directions there is little cleared land at all. For this reason and because of the total absence of industry, the characteristics of the air, water, and natural habitat are as nearly natural as in any nonwilderness area.

Until 1975, the closest mining activity was at some small surface mines northeast of North River Mine about 11.3 km (7 miles) from the site. This year one small surface mine started about 5.5 km (3 1/2 miles) southwest and another, about 10 km (6 miles) southwest. It is doubtful if these small operations affect the environment in the vicinity of North River No. 1. Samples have been collected from Cedar Creek upstream from the mine; from North River northwest and southwest; and from Tyro Creek, to the southeast. It is believed that these samples yielded water quality very similar to that existing before the mine started. Samples collected downstream from the mine, on Cedar Creek, are the only ones likely to be affected by the mining operation to date. For these reasons, it is believed that no serious handicap is inherent in the late start made in data collection.

Figure 1 is a map of the coalfields showing the location of sites 1, 2, and 3.

SECTION 2

CONCLUSIONS

(1) Only Site 3, the North River No. 1 mine, was investigated fully. In the present early stages of mining the site is not being seriously polluted by mining operations. Only Cedar Creek, a small stream no more than 19.3 km (12 miles) long, which flows past the mine, is affected, downstream from the mine. Increases in alkalinity, pH, suspended solids, specific conductance, Fe, Mg and Cl were noted. pH may decrease slightly after 10 or 12 mining units are activated rather than the 5 to 6 operating at the time of sampling.

(2) The depth of the coalbed below the surface, the absence of any outcrop, and the moderate relief and intermediate regional slopes of the topography insure that the only way mine water will reach the surface during the life of the mine, will be by pumping. As long as the effluent is delivered to one or a few points, any required treatment would be easy.

(3) Examination of table 14 suggests that the bulk of the Al, Fe, Mg, K, and much of the Na in the mine effluent was in the suspended solids (clay, etc.) and not as dissolved ions. All the Cr, Cu, Pb, and Ni was in suspended matter. Concentrations of suspended solids were high in all water sampled as it was pumped from the mine.

(4) Suspended solids content and turbidity were low in all samples of water collected from Cedar Creek below the mine, indicating either that (a) the volume of water pumped from the mine is only a relatively small fraction of the flow in Cedar Creek, below the mine,

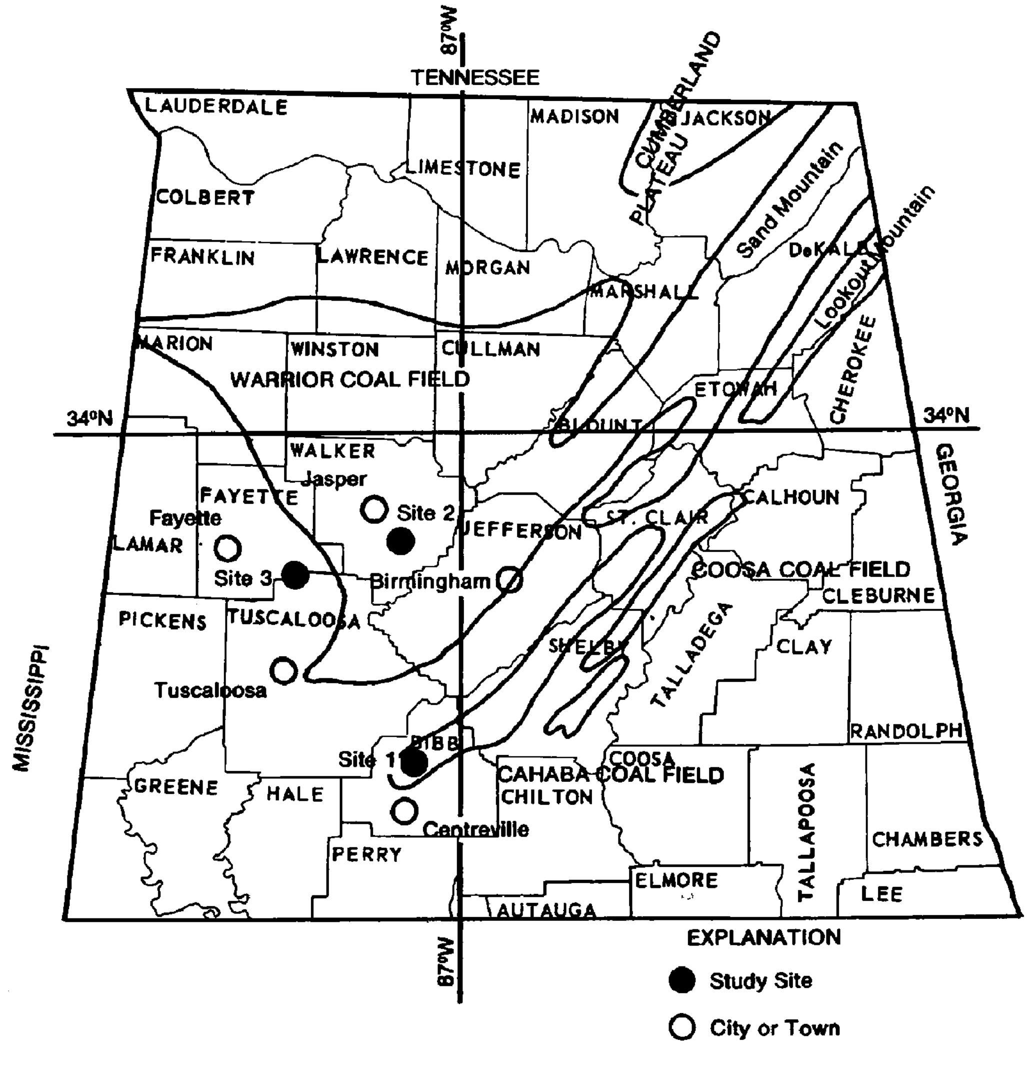

Figure 1. Principal productive coalfields of Alabama showing the location of sites 1, 2, and 3.

or (b) the suspended solids pumped from the mine settle readily. If it had been possible to make a water volume balance of the mine, or to estimate the flow of Cedar Creek, the proper alternative explanation would have been deducible. No stream gauging stations have ever been located on Cedar Creek.

(5) When the time comes for permanent closure of the mine, sealing the slope and two shafts should insure that the surrounding environment is not polluted by mine drainage. Any post-sealing outflow should be intermittent and should come only from the slope. Effluent would thus be convenient for treatment, should that procedure prove necessary.

(6) Although no observations could be made regarding future subsidence, some inferences can be made regarding the problem. At a mining depth of 150 - 200 m (490 - 650 feet) and with thick, competent sandstones in the roof strata, areas where pillars are left should have no subsidence. Present mining plans call for complete pillar removal in most of the mine. In such areas, subsidence should be slight, but uniform, and cracks or surface damage minimal. Only if the relatively sparsely settled area were to be extensively developed in the next 30 years, would there likely be significant surface damage and probably not then.

(7) The two incompletely investigated sites (sites 1 and 2) were in areas where mining had been done previously. At site 1, one large underground mine has been abandoned, and more recently strip mining has been done farther up streams flowing through the site. At site 2 some small-scale underground mining and some surface mining has been done upstream. Yet the flowing waters in both areas are relatively uncontaminated, including waters from the abandoned underground mine at site 1. These facts, coupled with the relatively low pollution from early mining at site 3, suggest the possibility that: (a) because of climatic conditions in the Alabama coal fields, high rainfall, little freezing or snow, and high mean temperatures, mining may contribute only minimal pollution when all other factors are equal, and (b) down-dip mining, as practiced in Alabama's synclinal basins, even shallow ones, via drift, slope, or shaft, may also contribute to less pollution.

SECTION 3

RECOMMENDATIONS

(1) There is the strong possibility that mine acid formation and drainage may be proportional to the sulfur content or form, in the coal or in the superadjacent strata. Certainly, if all other factors are equal, this should be true. Investigation of this factor is warranted.

(2) Room-and-pillar mining, with complete pillar extraction, and long-wall mining are both high-recovery methods. It would be interesting to determine which of these two methods produces the least pollution. At least one large eastern mining company has observed a possible water pollution advantage for longwall mining.

(3) Weather and climate should be investigated as factors in acid mine water pollution. The rather high annual rainfall of 132-142 cm (52-56 inches), the lack of appreciable precipitation as snow which soaks in on melting, perhaps the distribution of rainfall throughout the year, and high mean temperatures, may all be partly responsible for the apparent lack of severity of acid mine drainage in Alabama as compared to that in Northern Appalachian areas in which chemically and geologically similar coals are mined. Obviously, if there is a climatic effect, it probably will be more pronounced in surface and shallow drift mines, than in deeper underground mines.

(4) In the future, it may be found that if coal is to be recovered in areas that are more than sparsely inhabited and industrially or residentially developed, subsidence may prove to be as serious a problem as will acid mine drainage. Trouble may be avoided by sacrificing much marginally recoverable coal. Studies of this problem have been made for many years in Europe where it has been an environmental as well as a mine safety problem. As underground coal mining increases, especially in less primitive areas, environmental effects of subsidence will become increasingly important.

(5) There may be a connection between geological structure in the form of faults and joints and sulfides in the strata overlying the coal-bed which may combine to produce flows of polluted water into the mine and hence out of it. Although jointing was pronounced in the North River No. 1 mine, inflow of sulfur and iron-bearing water was minimal. This may have resulted from the absence of pyrite-bearing strata above the coalbed or from the location of the inflow water sources with respect to the joints. Investigation of joint systems and overlying strata in a number of places might result in determination of the extent to which acid formation is limited to the coalbed itself.

SECTION 4

DATA COLLECTION AND ANALYSIS

GEOLOGY, GEOLOGIC STRUCTURE, AND PRE-MINING ENVIRONMENT DATA AT SITE 1

Geology and Geologic Structure

Site 1 was chosen because it presented mining problems of a variably dipping coalbed that would be substantially different from those of a nearly horizontal one. Presumably, mining methods and steps required to achieve maximum freedom from pollution might differ also from those of a nearly level coalbed.

Site 1 is located in Sections 8, 9, 16, and 17 T24N R10E. The land in Section 8 belongs to the University of Alabama and the United States Steel Corporation; that in Section 9 and 17 to the First National Bank of Birmingham (1961). It was assumed that the land could all be leased for a mining unit in case some company became interested.

Figure 2 shows the site, the principal streams, the nearest abandoned coal mine, and the two principal folds that cause the relatively complex geologic structure.

From the orientation of streams in the northern part of site 1 the Tocoa anticlinal axis can be constructed generally perpendicular to the creek direction. The Cahaba River roughly parallels the axis and the principal creeks cut across it, so that smaller creeks generally furnish the criteria. The axis as shown in figure 2 follows closely the alignment of Butts[1] that has been used previously. With reference to the axis of the anticline, joints and faults at site 1 are generally aligned from N40°W to N45°W. Thrust faults have directions between N40°E and N45°E. Coal cleat has the same orientation as the joints and faults of the surrounding beds and therefore should show the same directions underground.

In order to lay out working areas in the mine and accurately calculate coal resources and recoverable product, it is necessary to have isopach maps of the coalbed and a contour map of the top or bottom of the coalbed. A drilling program would be necessary to verify the indicated configuration, where direct data are missing.

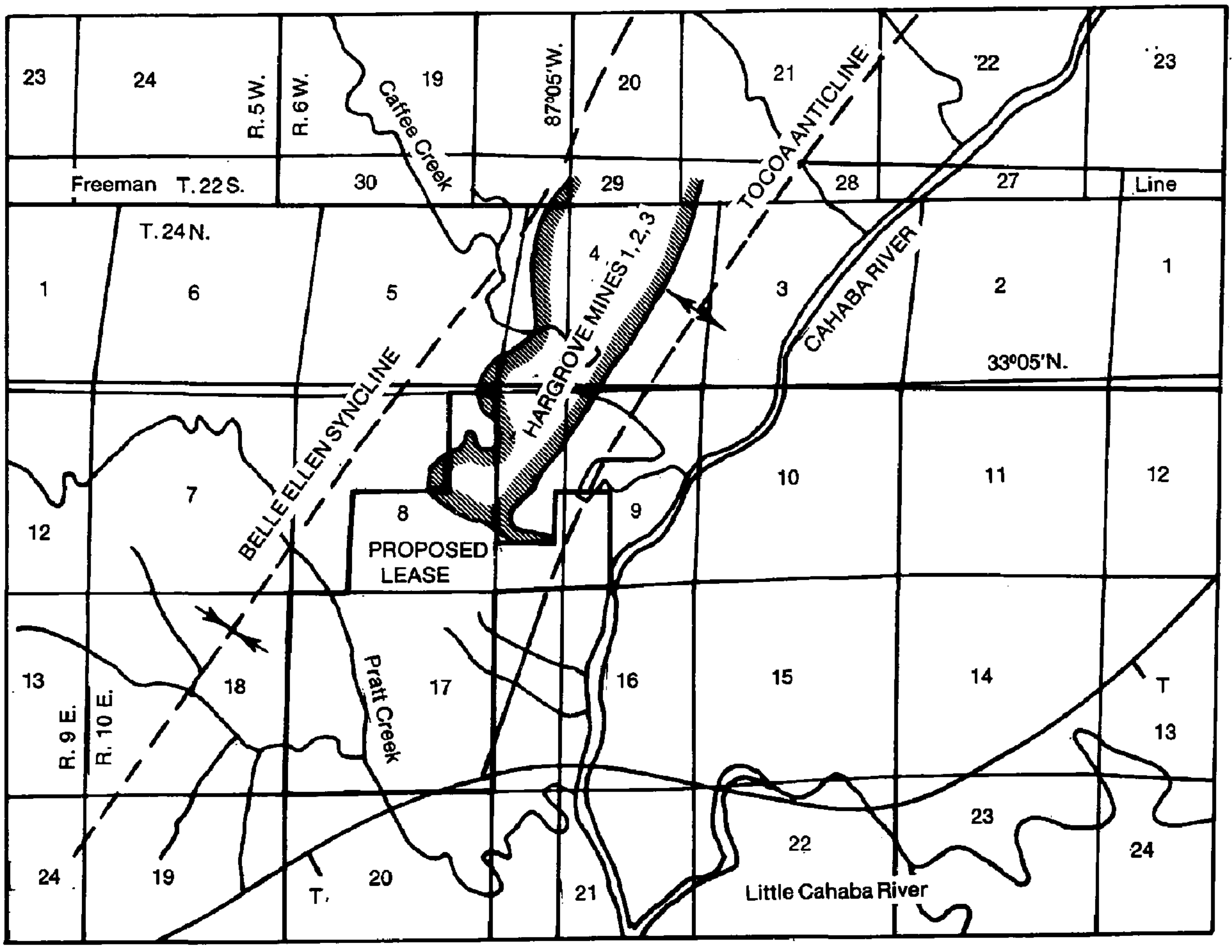

Figure 2. Sketch map, site 1, showing principal streams, geological structural features, and land ownership.

Such drilling of site 1 would be expensive and time consuming. Massive sandstone beds appear to make up a large proportion of the strata over the Thompson coalbed at this site, and drill holes as deep as 150 to 470 m (492 to 1,542 feet) would be required. More holes would be needed because of the rapid dips that prevail in some areas. In one known drill hole, (M 443), for example, the depth to the top of the Thompson coalbed is 473 meters (1,500 feet).

Because there are insufficient data on site 1 from which to construct a verifiable contour map of the top of the coalbed or an isopach map of the Thompson coalbed, some assumptions were made:

(1) The plunge of the axis of the Belle Ellen Syncline, as traced on the top of the Thompson coalbed, can be determined from drill holes M 427 and M 443, figure 3. The plunge is 72 m per km or 381 feet per mile. The same rate of plunge is assumed for the Tocoa anticline from the outcrop in SE 1/4 of the SW 1/4 Section 9 T24N R10E to a hypothetical drillhole near the SE corner of the NE 1/4 of the SW 1/4 Section 17 T24N R10E. The plunge, at the assumed rate, is 120 m (395 feet). The sea level elevation at the intersection of the Tocoa axial plane and the Thompson coalbed is estimated from the topographic map to be about 152 m (500 feet). When the plunge is subtracted, a sea level elevation of 32.6 m (107 feet) is indicated. The surface elevation is estimated to be only about 79 m (260 feet) where the axis crosses into section 17 T24N R10W so that the depth of a hole to verify the plunge of anticline axis at the top of the Thompson coalbed is a shallow 46.6 m (153 feet). Of course, the plunge of the coalbed on top of the anticline may be more or less. This figure is used, however, as the basis for a coal-surface contour map.

Butts[1] gives a general section for the Thompson coalbed in the abandoned Hargrove No. 2 mine. For the purpose of an isopach map, it is assumed that this is the section at the Hargrove No. 2 portal.

(2) The section at a point where the anticlinal axis enters Section 17 is assumed. It is the general section for the abandoned Coleanor mine, given by Butts[1]. The Coleanor mine opening lies about 6.45 km (4 miles) northeast of this point. Between the two points lies abandoned Piper Nos. 1 and 2 mines. From descriptions, these two mines carried Thompson coal of about the same thickness and quality as did Coleanor but no typical or specific sections have been found. The westermost works of Piper No. 2 are within a mile of Section 17. Extrapolation of this section to Section 17 thus is based upon indirect assumptions.

The sections at drill holes M 427 and M 443 are from holes drilled by a coal mining company (figure 3). They indicate the condition and depth below the surface of the Thompson coalbed. Over much of Bibb and Shelby counties the Thompson coalbed is split into the Upper and Lower Thompson. In the upper part of the Blocton Basin, Sections 4, 5, and 6 T24N R10E northward, the bed is not badly split into two beds although there are partings present. The same is true of the area east of the Tocoa anticline and south of T22N where Coleanor and the two Piper mines are located.

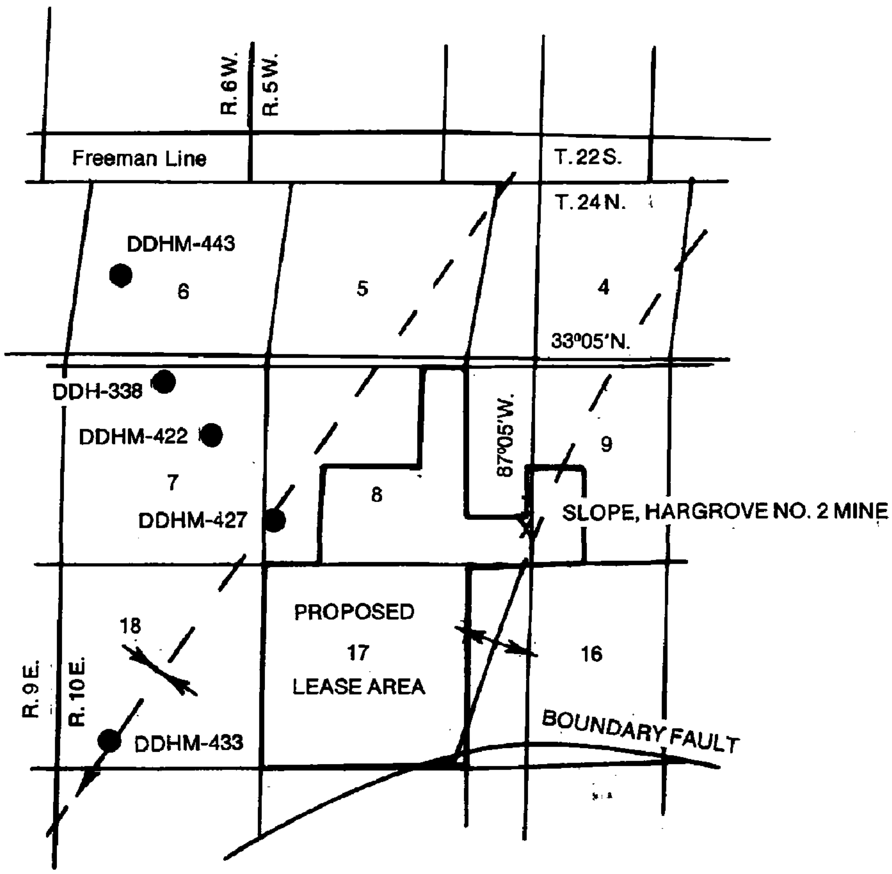

Figure 3. Map showing the location of diamond drill holes and the abandoned Hargrove No. 2 slope, site 1.

Along the same outcrop, northeastward, beginning just north of the Garnsey mine in Section 12 T22S R5W, the split widens and the two beds become too far apart to mine together. Drill hole M 427 is in the split zone which seems to run northeast across T24N R9E, the Tocoa anticline in T22S R5W where the Thompson coalbed has been removed by erosion, and into T22N R4W and, thence, to T21N. Drill hole M 443 either is south of the split zone or the hole was drilled only through the upper Thompson coalbed, which at that point carries 81 cm (32 inches) of coal and 12.7 cm (5 inches) of parting.

Figure 4 shows bed sections at the three points and the assumed section on the east side of Section 17. It is evident that if there are no other local changes between the four points, some assumptions must also be made concerning the changes in thickness of the usually lenticular partings.

One assumption could be that the thickness of the principal parting decreases uniformly from its considerable thickness at drill hole M 427 (figure 4) eastward to only 14 cm at Hargrove No. 2 and southwestward to drill hole M 443 where it is only 13 cm. Such a concept is plausible but generally such partings are lens-like and not wedge-like. Therefore, in the absence of any drill data between points to settle the question, an arbitrary thickness rate change was assumed.

On the basis of the meager data collected and the assumptions made, maps were prepared of coalbed thickness (isopach map), thickness of principal parting, and elevation of the top of the coal. These maps are not shown but were used to approximate the quantity of coal available for mining on the property. Total area to be mined is 376.6 hectares (930.6 acres). Of this total, both benches of the coalbed would be mined under 275.4 hectares (680.5 acres) and only the top bench will be mined under an additional 101.3 hectares (250.3 acres). Coal available in the full seam area is 5,181,000 metric tons (5,711,000 short tons) and in the top bench area, 990,000 metric tons (1,091,000 short tons), for a total of 6,171,000 metric tons (6,802,000 short tons). The average quantity of coal is 16,386 metric tons per hectare or 7,310 short tons per acre. This gives an approximate average coalbed thickness of 1.237 meters (4.06 feet). The average thickness in the full-bed mining area is 1.566 meters (5.14 feet) and in the upper-bench area, less than one meter (3.2 feet).

Pre-Mining Environment

The pre-mining environment of the proposed mine site was easily determined. The area is uninhabited, rather rugged, part of it plateau-like and heavily wooded. It is doubtful whether there is an inhabited house within 3.22 km (2 miles) of the site. The West Blocton area is 4.8 to 6.4 km (3 to 4 miles) from the site, but there is little industry in West Blocton; nor have any mine or gob pile fires been observed in the area. One coal washing plant and a coal loading facility are unlikely to produce airborne dusts that would be carried that far to the southeast. Thus, the air is as pure as is ordinarily found in any rural area.

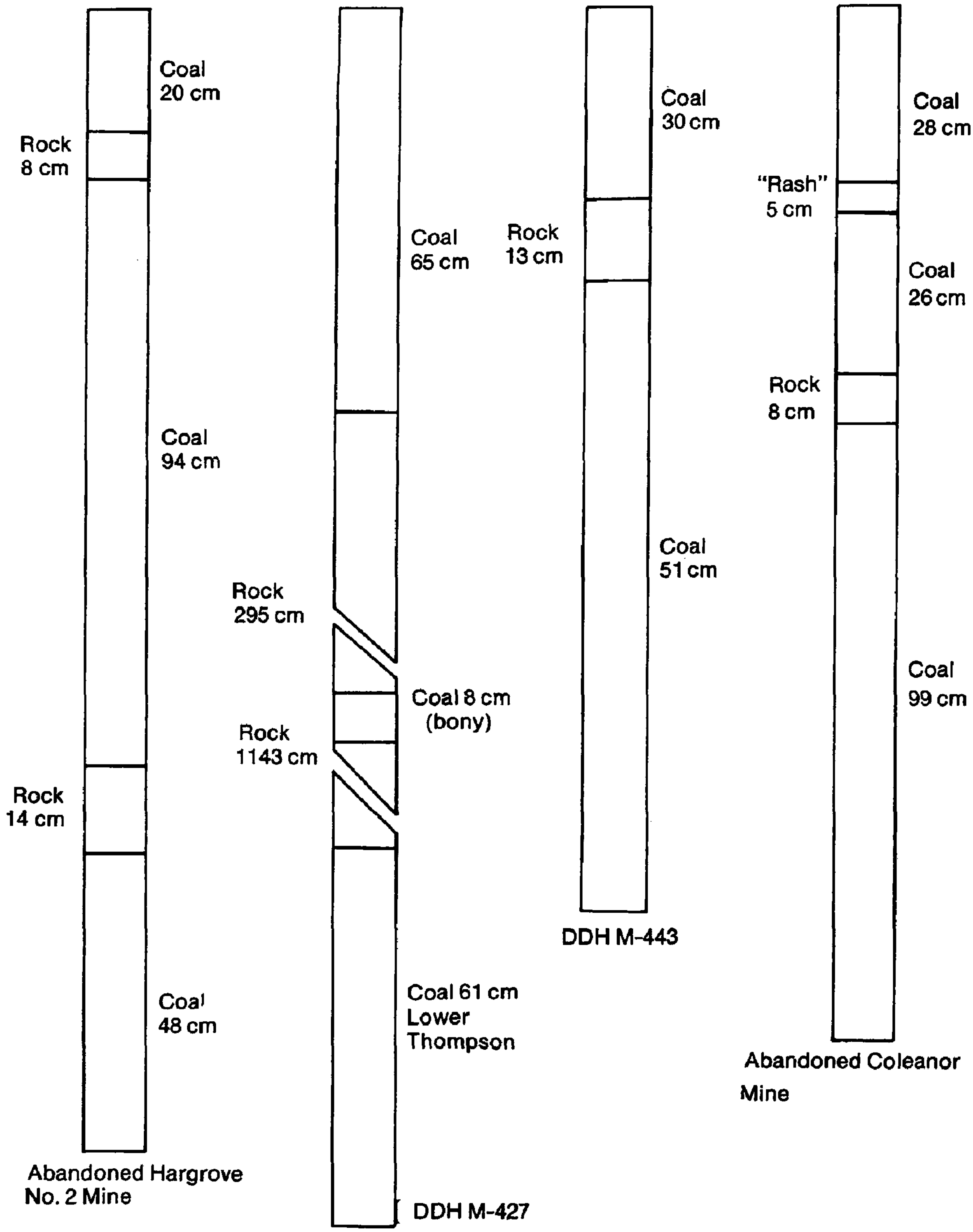

Figure 4. Sections of the Thompson coalbed on, or near, the proposed lease area, site 1.

There are several possible sources of water pollution in the area:

(1) The old Hargrove No. 2 rock slope is but two or three hundred feet (61 to 91 meters) from a proposed rock slope opening site and not much farther from another possible shaft site. It is filled with water and, except in dry weather, overflows into the Cahaba River, about 0.4 km (0.25 mile) to the southeast.

(2) Strip mining operations, a coal preparation plant, and a coal loading facility are situated within the Cahaba River drainage, 4.8 to 16 km (3 to 10 miles) north and northwest of the site. Any pollution from these sources will be greatly diluted by the time it reaches the proposed mining area.

(3) Numerous abandoned underground mines drain and overflow into Caffee, Big Ugly, Little Ugly, and Cain creeks and into Bear Branch, all of which are tributaries of the Cahaba River above the proposed site.

(4) A few abandoned strip pits and abandoned underground mines may drain into the headwaters of Pratt Creek, which flows across the western part of the proposed mine site and into the Cahaba River south of the site.

In order to determine pre-mining water quality on, and near, the proposed mining property, 12 water samples were collected. The first six were collected during a generally dry fall season (November 22, 1974) when there was no visible drainage from the Hargrove No. 2 slope. A rain, one or two days previously, however, had made the Cahaba River so muddy that no sample was collected. There was no outflow from the Hargrove No. 1 slope, and Pratt and Caffee creeks carried only moderate flows.

Flow rates were generally higher when samples 7 - 12 were taken. An intermittent stream was flowing from the Hargrove No. 2 slope.

Figure 5 shows the 12 sampling locations, and table 1 gives brief descriptions. Analyses of the first six samples are given in table 2 and of the last six, in table 3.

None of the 12 analyses indicates serious pollution. pH was in the acid range for only one sample, that obtained in the high flow period from the Hargrove No. 2 slope (pH 6.2). All other samples had a pH of seven or above. The Cahaba River carried the highest pH, while Pratt and Caffee creeks were not far behind. All these streams probably carry some mine drainage and flow over no calcareous beds until outside the coalfield. Samples 4 and 12 were taken after the streams reached possible limestones. No known limestones or dolomites are present in the Pennsylvanian strata of the Cahaba coalfield; however, since the boundary (Helena) fault probably thrust carbonate rocks over the Pennsylvanian strata, carbonates would have been carried into Pennsylvanian strata by circulating ground water as the previously overlying rocks were being eroded. It has been reported that ash from commercial coals from the Piper No. 1 and No. 2 mines had an appreciable lime content. A published ash analysis of a Thompson coalbed at Garnsey mine, which is about 3.5

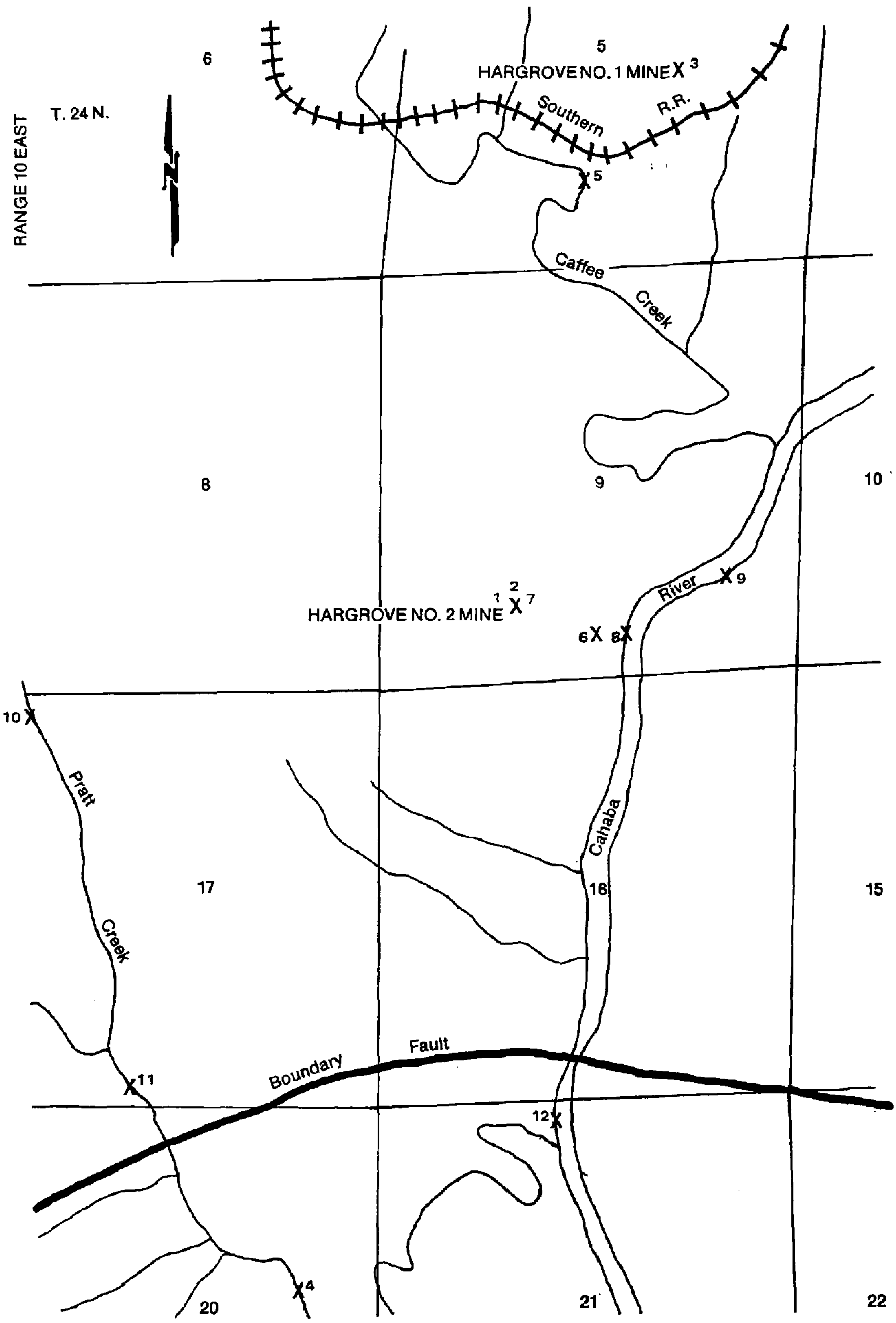

Figure 5. Map showing the location of the 12 water samples collected at site 1.

TABLE 1 - WATER SAMPLING LOCATIONS, SITE 1[ab]

Sample Number	Site Location
1	Hargrove No. 2 air shaft
2	Hargrove No. 2 mine slope
3	Hargrove No. 1
4	Pratt Creek
5	Caffee Creek located about 250 yards from Hargrove No. 1
6	Small pool in wet weather stream supporting aquatic life (fish) that drained from Hargrove No. 2 area to Cahaba River, approximately 200 yards from the Cahaba River
7	Hargrove No. 2 slope opening
8	Cahaba River at mouth of small intermittent stream flowing from Hargrove No. 2 slope
9	Cahaba River, SW 1/4 Section 9 T24N R10E, upstream from Hargrove No. 2 slope
10	Pratt Creek just south of its entry into proposed mine area (Section 17 T24N R10E)
11	Pratt Creek upstream from where it flows off proposed mine area (Section 17 T24N R10E)
12	Cahaba River near where it flows south of proposed mine area, SW 1/4 of SW 1/4 Section 16 T24N R10E

a Samples were taken after a big rain up the river

b Arsenic and BOD results omitted. BOD sample bottles were accidentally emptied before analysis. The analytic procedure for As was suspect so the results were omitted.

TABLE 2 - TEST RESULTS: SITE NO. 1, SAMPLED NOVEMBER 22, 1974

Parameter	1	2	3	4	5	6
			Sample Point			
ACIDITY as mg/l $CaCO_3$	31.2	31.7	82.41	5.03	4.5	7.04
ALKALINITY as mg/l $CaCO_3$	58.6	56.5	134.2	44.7	53.3	97.8
AMMONIA as mg/l N	0.26	0.18	0.22	0.23	0.21	0.21
BIOCHEMICAL OXYGEN DEMAND, mg/l (5 days @ 20°C)	2.1	3.1	1.0	3.2	3.2	2.3
CHLORIDE as mg/l Cl	1.07	1.6	1.07	1.6	4.29	17.18
DISSOLVED OXYGEN, mg/l	11.1	4.7	7.8	8.6	7.8	8.5
HARDNESS as mg/l $CaCO_3$	50.9	50.9	127.2	67.8	3.3	38.2
pH	7.3	7.0	7.17	7.67	7.75	7.7
SPECIFIC CONDUCTANCE, µmhos/cm	92.8	91.5	265	122	234	188
SULFATE as mg/l SO_4	3.0	2.0	26	24	40	3.5
TURBIDITY, JTU	13.0	3.7	108	7.6	9.1	1.5
ALUMINUM as mg/l Al	ND[a]	ND	ND	ND	ND	ND
ANTIMONY as mg/l Sb	ND	ND	ND	ND	ND	ND
ARSENIC as mg/l As	--	--	--	--	--	--
CADMIUM as mg/l CA	ND	ND	ND	ND	ND	ND

[a] None detectable

TABLE 2 (Continued)

Parameter	1	2	3	4	5	6
			Sample Point			
CALCIUM as mg/l Ca	9	8	23	10	25	2.5
CHROMIUM as mg/l Cr	ND	ND	ND	ND	ND	ND
COPPER as mg/l Cu	ND	ND	ND	ND	ND	ND
IRON as mg/l Fe	ND	ND	1 ppm	ND	1 ppm	ND
LEAD as mg/l Pb	ND	ND	ND	ND	ND	ND
MAGNESIUM as mg/l Mg	2.5	2.5	10	7	13	2.5
MANGANESE as mg/l Mn	ND	ND	0.5	ND	0.2	ND
MERCURY as mg/l Hg	ND	ND	ND	ND	ND	ND
NICKEL as mg/l Ni	ND	ND	ND	ND	ND	ND
POTASSIUM as mg/l K	1.3	1.5	4.9	1	2.5	2.0
SODIUM as mg/l Na	6	6.5	11	4	5.5	15
TIN as mg/l Sn	ND	ND	ND	ND	ND	ND
ZINC as mg/l Zn	ND	ND	0.1	ND	ND	0.1
SUSPENDED SOLIDS, as mg/l	13.2	4.0	67.5	2.0	4.4	1.6

TABLE 3 - TEST RESULTS: SITE NO. 1, SAMPLED FEBRUARY 14, 1975

Parameter	7	8	9	10	11	12
				Sample Point		
ACIDITY as mg/1 $CaCO_3$	2.57	2.06	1.57	2.57	1.57	1.02
ALKALINITY as mg/1 $CaCO_3$	5.25	42.5	40.9	12.2	9.45	16.15
AMMONIA as mg/1 N	0.32	0.16	0.22	0.44	0.48	0.20
BIOCHEMICAL OXYGEN DEMAND, mg/1 (5 days @ 20°C)	--	--	--	--	--	--
CHLORIDE as mg/1 Cl	1.43	2.43	2.62	1.207	1.43	1.92
DISSOLVED OXYGEN, mg/1	9.2	10.6	10.8	10.9	10.5	10.5
HARDNESS as mg/1 $CaCO_3$	14.38	68.2	76.3	37.7	24.4	76.3
pH	6.2	7.6	7.9	7.66	7.6	7.92
SPECIFIC CONDUCTANCE, μmhos/cm	27.1	144	139	72	56.5	120.5
SULFATE as mg/1 SO_4	2.7	22.9	25.6	18.8	12.9	21.2
TURBIDITY JTU	11	12	10	7.5	9.2	13
ALUMINUM as mg/1 Al	ND[a]	ND	ND	ND	ND	ND
ANTIMONY as mg/1 Sb	ND	ND	ND	ND	ND	ND
ARSENIC as mg/1 As	--	--	--	--	--	--
CADMIUM as mg/1 Cd	ND	ND	ND	ND	ND	ND

[a] None detectable

TABLE 3 (Continued)

Parameter	7	8	9	10	11	12
	Sample Point					
CALCIUM as mg/l Ca	1.0	24.0	22.0	8.0	6.5	14.5
CHROMIUM as mg/l Cr	ND	ND	ND	ND	ND	ND
COPPER as mg/l Cu	ND	ND	ND	ND	ND	ND
IRON as mg/l Fe	0.5	0.375	0.3	0.35	0.85	0.5
LEAD as mg/l Pb	ND	ND	ND	ND	ND	ND
MAGNESIUM as mg/l Mg	1.8	10	10	4.5	5	10
MANGANESE as mg/l Mn	0.045	0.126	0.189	0.099	0.068	0.189
MERCURY as mg/l Hg	ND	ND	ND	ND	ND	ND
NICKEL as mg/l Ni	ND	ND	ND	ND	ND	ND
POTASSIUM as mg/l K	0.6	1.2	1.4	1.5	0.7	0.8
SODIUM as mg/l Na	1.7	5	5.2	1.9	1.6	2.2
TIN as mg/l Sn	ND	ND	ND	ND	ND	ND
ZINC as mg/l Zn	ND	ND	ND	ND	ND	ND
SUSPENDED SOLIDS as mg/l	4.66	20.5	22.6	7.0	5.32	24.6
TEMPERATURE AT SITE °F	57.5°	52°	52°	52°	52°	52°

miles (5.6 km) from the boundary fault, contained 4.3 percent CaO and 1.7 percent MgO. These were the highest CaO and the second highest MgO content of 16 analyses reported for Alabama coals.[4]

The Hargrove No. 2 air shaft and slope are connected not far underground, and the abandoned works of Hargrove No. 1 and 2 are physically connected, although the principal openings are separated by about 2.4 km (1.5 miles). It would be no surprise, therefore, if the analyses of all three samples were similar. Analyses 1, 2, and 7 were indeed similar. Differences in the rate of outflow (flushing) could have caused the difference between samples 1 and 7. As expected, differences between water samples from the slope and air course at Hargrove No. 2 were insignificant. The water at Hargrove No. 1 was visibly turbid the day the sample was collected. This was verified by greater acidity and alkalinity expressed as mg/ℓ of $CaCO_3$, greater turbidity, greater hardness, greater specific conductance, and more suspended material. It is assumed that the water in Hargrove No. 1 slope had been locally stirred in some way, perhaps by a rock fall not far inside the slope or by an inflow of surface water.

Most heavy metal ions were not present or the content was low. If pyrite oxidation is occurring in these flooded mines (presence of dissolved oxygen indicates the possibility) then it must be precipitated as fast as formed or oxygen circulates very slowly from inflow. Both mines are full of water. Sulfates and iron ions are moderate to scarce.

Sulfates were highest in the Caffee Creek and Hargrove No. 1 slope samples. Caffee Creek carries effluent from both strip pits and abandoned underground mines.

Proposed Mining Plan and Layout

Historically, all underground mines in the Cahaba coalfield have been developed down the dip. Consideration of Site 1 did not proceed far enough to consider mine layout but it is likely that downdip development would have been chosen. A comparatively short rock slope to the coal and a ventilation shaft, or two or three vertical shafts of moderate depths, probably represent the choices. In order to develop the mine updip, it would be necessary to sink two or more shafts near the southwest corner of the property. The required depth would be about 470 m (1,542 feet) deep, which would make it a very expensive development. Further, these shafts would tap the coalbed in an area where it is not very thick, whereas a downdip opening would be in an area of maximum thickness.

It has been demonstrated that downdip mining generally produces on the order of 10-fold less acidity than does updip mining.[5] Drainage is minimal, and after abandonment, the water-filled mine produces a minimum of oxidation of iron sulfides as indicated by the water analyses from Hargrove No. 1 and 2 mines.

Mining in all Alabama underground coal mines is done by the room and pillar system. Longwall methods are not used, but a so-called "modified longwall" was once used at Boothton and perhaps at other Cahaba field mines.[6] Boothton was closed in 1952. Longwall retreat mining would require developing entries to the boundaries of the property before mining begins, whereas longwall advancing would not. Longwall advancing and room and pillar mining could be laid out so that all water in the mine, except that in downdip rooms, would flow to the main entries for pumping. This layout is possible not only because the area to be mined dips southwestward toward the axis of the Belle Ellen syncline (figure 3) but also because the axis of both folds plunge south-southwest.

Figures 6 and 7, from a recent publication[7] show schematically how a downdip mining system may be developed.

Quality and Control of Mine Effluent

Development, operation, and maintenance of the abandoned mine should produce no more than minimal pollution of air and water. Surface subsidence also should be minimal because of the thick, competent sandstones in the strata overlying the Thompson coalbed and the depth of most of the mined area below the surface.

GEOLOGY, GEOLOGIC STRUCTURE, AND PRE-MINING ENVIRONMENT DATA AT SITE 2

Geology and Geologic Structure

Site 2 is located in Walker County and in the Warrior coalfield. The land outlined heavily in figure 8 is owned in fee or by mineral rights only by the University of Alabama. Three other areas of unknown ownership in sections 1, 10, and 11 T16N R6,7W were included in the logical mining unit because they can best be mined from openings on University of Alabama land:

(a) The area west of the coal outcrop north of the river, in the NW 1/4 of Section 10 and bounded on the west by a fault. To mine this area, which is too small for a separate mine, would require entry from University land, mining across the fault from Section 9 and part of Section 10 west of the fault, or mining under the river from the south half of Section 10.

(b) The area west of the river in Section 1. This area must be mined from University land or from the east side of the river. The long-abandoned Colta Mine lies east of the river in this area.

(c) The non-University land inside the Shepherd Bend loop lies in Sections 11 and 12. Any mining from other areas would require a drift under the river because this land tract hardly seems large enough for a separate deep mine.

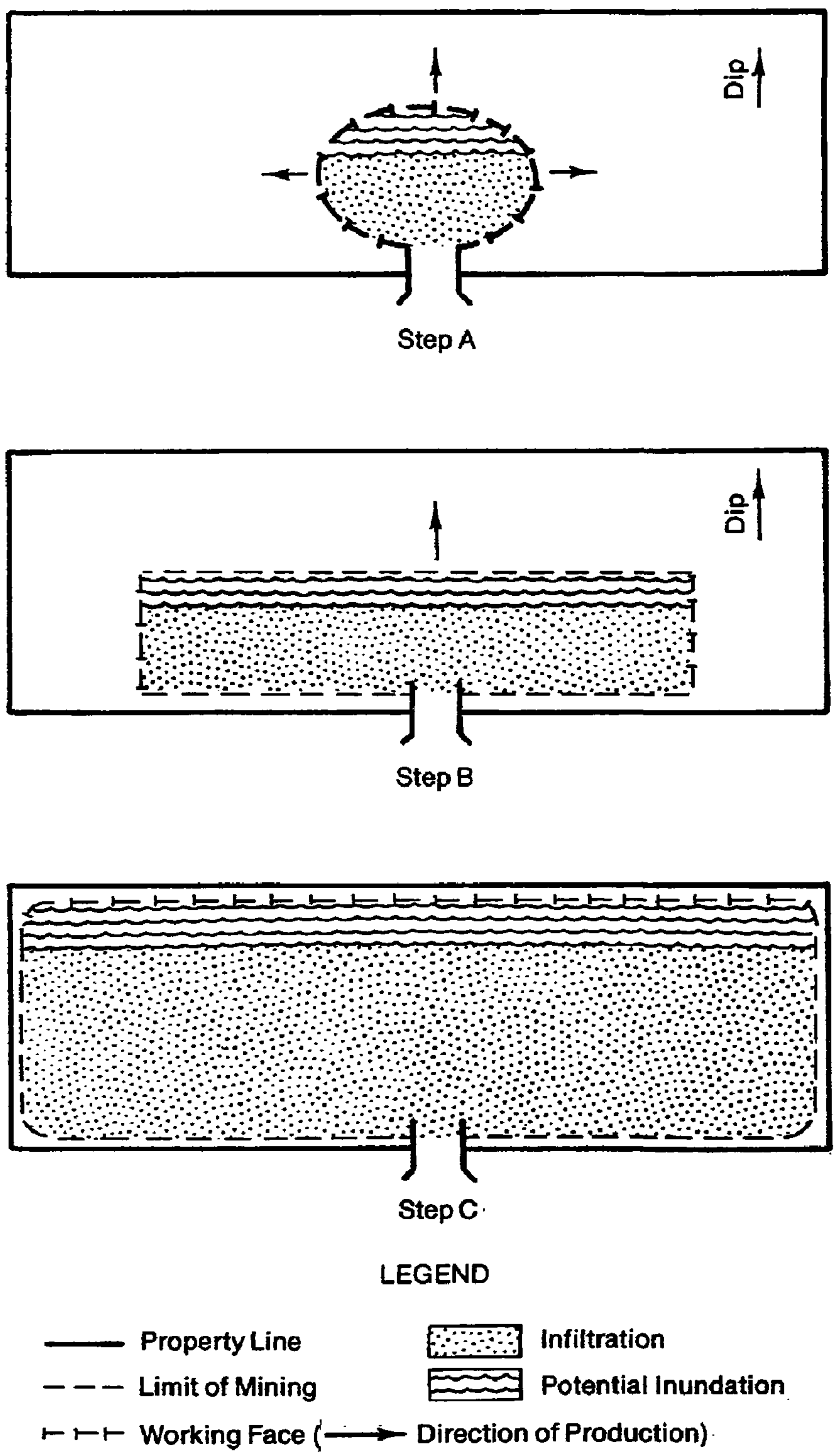

Figure 6. Normal down-dip mining procedure.

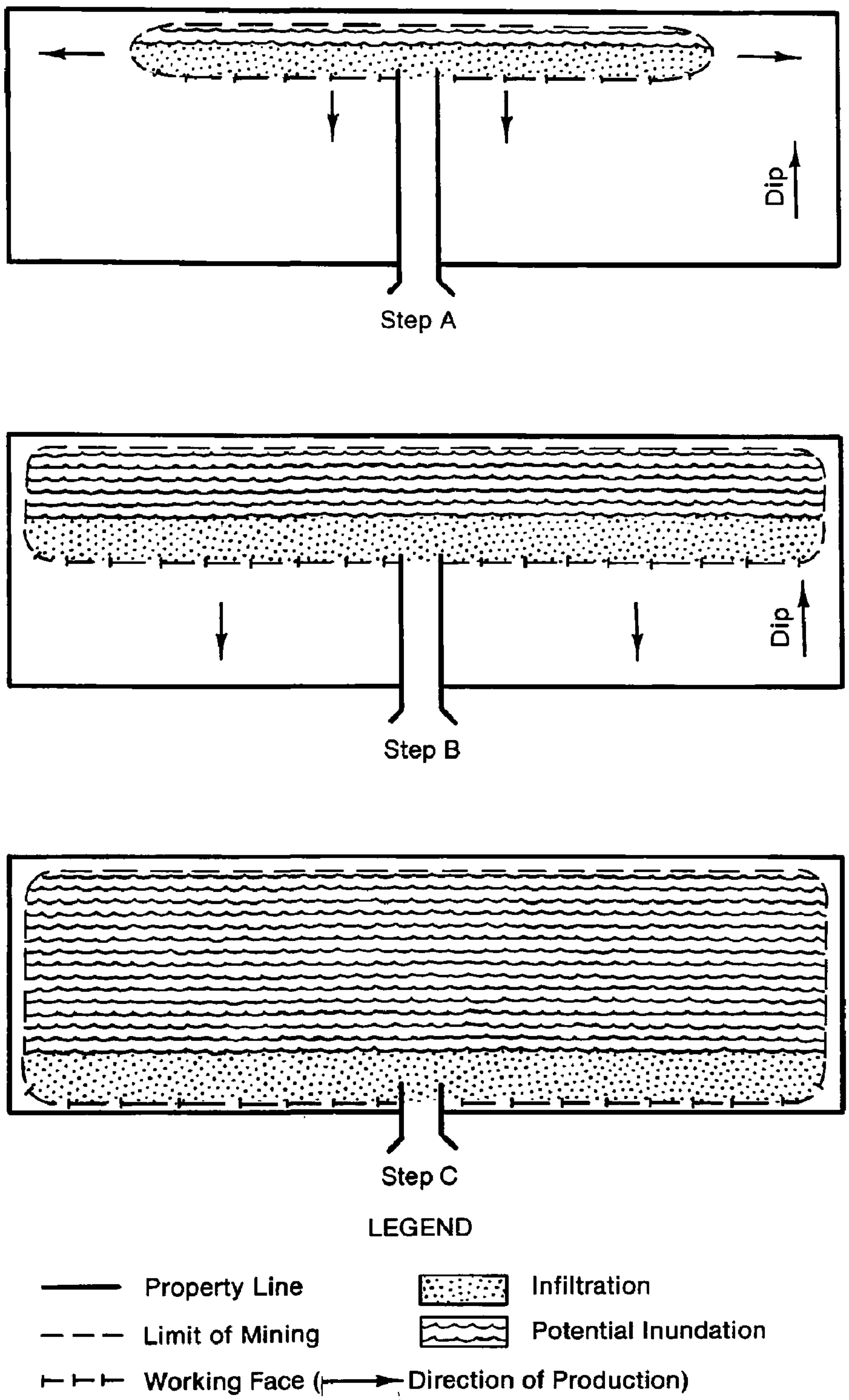

Figure 7. Alternate (retreat) down-dip mining procedure.

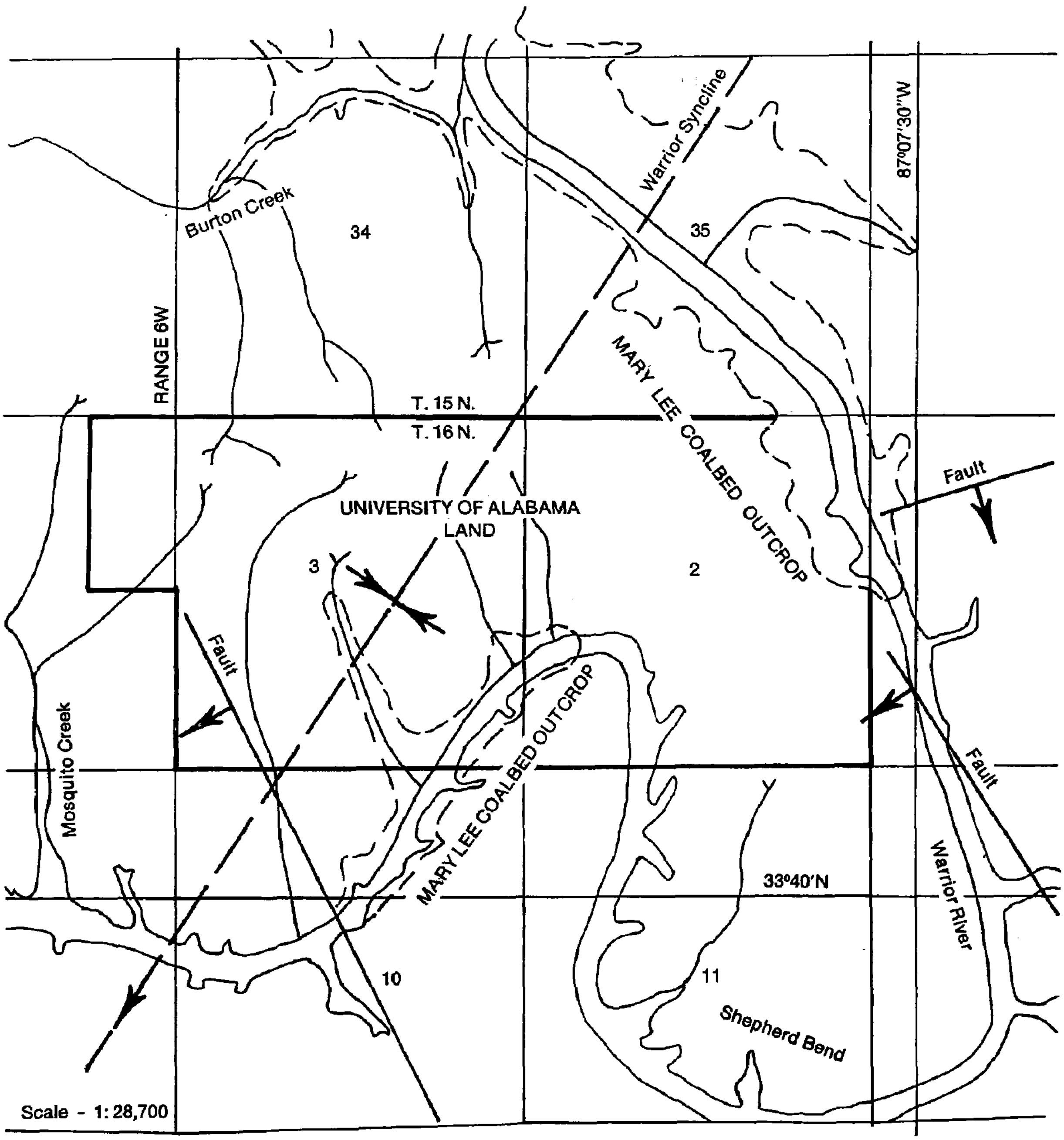

Figure 8. Map of site 2, showing University-owned land, Mary Lee coalbed outcrop, principal streams, and faults.

Coalbeds available for underground mining in the area are the Mary Lee and the Blue Creek. The Mary Lee coalbed can be entered through a drift at an elevation of 91.5 - 94.5 m. The fault shown in the southwest part of the site precludes mining of about 30.5 hectares of reserves unless a rock slope is driven downward from the main portion of the property. The vertical displacement of this fault is about 61 m (200 feet). The entire site is drained by short streams that flow into the Mulberry Fork of the Warrior River, which is at an elevation of 76 m (250 feet) in the area. If the Mary Lee coalbed is entered at 91.5 m elevation, the mine will drain into the river, since the dip is toward the river.

Known coalbed thickness averages about 80 cm (31.5 inches). The coal has a volatile matter content of about 32.7 percent and an ash content of 10 percent.

The Blue Creek coalbed, lying about 3.5 - 7.5 meters below the Mary Lee, is similar, but the bed is only about 56 cm thick.

The New Castle coalbed is about 7.5 meters above the Mary Lee. Average ash content is about 12 percent, and sulfur content, 1.7 percent. The bed is about 33 cm thick.

The total Mary Lee coal available for mining, including the areas not owned by the University of Alabama, has been estimated for site 2. The areas inside the outcrop and the property boundaries were measured carefully, several times, with a planimeter. About 14.2 hectares (35 acres) of the tract were excluded because it is on the downthrown side of a fault with enough displacement to make it impractical to mine from an opening located on the upthrown side. Another 41.4 hectares (102.5 acres) were deducted for a 30.5 m (100 foot) barrier pillar around the property. The law requires a 61 m (200 foot) pillar but it was assumed that adjoining, unmined properties will furnish the other half. The net mineable area is 676.2 hectares (1,670 acres).

The average thickness of the Mary Lee coalbed in the area is only 79.76 cm (31.4 inches). The standard United States Geological Survey and United States Bureau of Mines figure used in calculating the bulk density of bituminous coal in place is 1,800 tons per acre-foot, or in metric units 132.4 X 10^5 kg/hectare-meter. Using 0.8 meter for averag- coalbed thickness gives 4.08 X 10^5 kg/hectare. Calculations based on the USBM average of 57 percent recovery for modern underground mining[8] and a measured area of 676 hectares (1,670 acres), give 4.08 X 10^6 kg (45 X 10^5 tons) recoverable coal. Any second mining of pillars or longwall mining should increase this figure. It would appear that a small-to-medium sized mine, designed for a maximum annual production rate of 4.08 X 10^5 metric tons (4.5 X 10^5 short tons), would have a life of about 10 years from construction to sealing.

Analysis and mapping of the data reveal that site 2 has a more complex structure than was originally thought. Figure 9 is one interpretation of the structure on top of the Mary Lee coalbed, based upon maps and other information from the Alabama By-Products Corporation, which has done the only known exploration in the area. The presence of

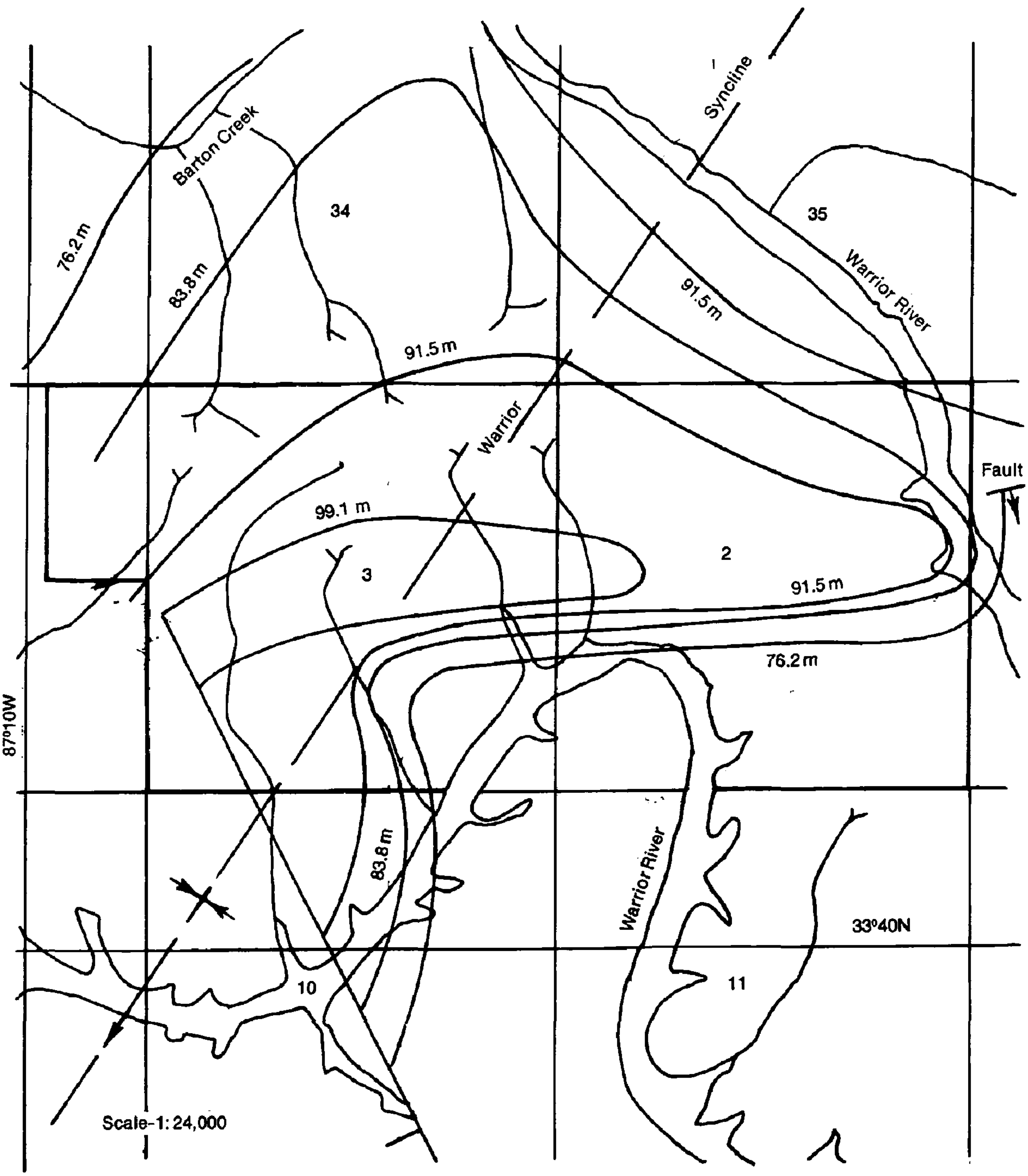

Figure 9. Elevation contours drawn on top of the Mary Lee coalbed, site 2.

the "high" through the center of the tract would have considerable influence on a mine layout. If the high-angle fault across Sections 10, 3, and 4 does not continue as indicated, the east-west ridge still is partly faulted. If the fault is continuous, as suggested, the structure should be similar to that shown. In the Warrior coalfield, the numerous NW-SE trending normal faults have maximum displacement near the center rather than at one end. Blair[9] states that maximum displacement is about 200 feet. The length of the fault is roughly proportional to the amount of displacement, a fault of 100 feet displacement having a length of about 2 miles (3.2 km). The faults occur in echelon and are commonly parallel to each other. "Graben" faults are common. Faults usually occur near folding axes and often are roughly perpendicular to them. The axis of the asymmetric Warrior syncline lies across the property, as shown. Blair's map does not show this fault. As added support for the interpretation shown in the figure, Blair also says: "The structure produced by faulting of this type resembles closely....a short slit or tear in a horizontal sheet of paper on which, if lateral pressure is applied, there is a movement along the tear, producing a bisected dome on the high side with a corresponding basin on the low side, the axes of the fold corresponding with the point of greatest displacement on the break."[9] Direct confirmation of the northward extension of the fault was sought in the field and on the aerial photographs. The search was not completed.

Overburden is generally thin, and much of the coal on the proposed mining property is strippable. Stripping would allow mining of the Pratt and America coalbeds, which occur in a ridge across Sections 2, 3, and 4, and also of the Mary Lee, Blue Creek, and New Castle coalbeds nearer the river. If strip mining is possible up to the 30.5 m cover line, the property would be almost cut in two. It would be narrowed drastically also in the southwest quarter of Section 2. In view of the quantity of coal that could be strip-mined, the size of an underground mine on the remaining area would be much smaller than indicated by the reserves unless it were found practical to extend mining to the west of the fault in Sections 3 and 4.

Pre-Mining Environment

Field visits were made and water samples taken in order to evaluate the pre-mining environment.

The area is rural. The nearest industry is at Cordova, over 8 km (5 miles) to the north. The Alabama Power Company has a large coal-fired electric generating plant located at Gorgas, also about 8 km southwest of site 2. Prevailing westerly winds could carry any effluent from the stacks toward site 2. The coal burned in the Gorgas steam plant contains about 1.5 percent sulfur and releases about 552 gm (1.20 lb) of sulfur or 1,104 gm (2.40 lb) SO_2 per million btu of heat produced. Because the stacks are equipped with mechanical or electrostatic precipitators, the quantity of particulate matter deposited 8 km distant should be low and particle size very fine. Several abandoned and active strip mines lie near High Level about 3.2 km (2 miles) directly to the west of site 2 and others lie northwest at slightly greater distances. One large underground mine and three coal preparation plants are in the vicinity of

Gorgas. It is doubtful that dust produced by these operations would affect site 2.

There are no local sources of air pollution. The 1971 topographic map indicates 19 structures on the 676.2 hectares (1,670 acres), and most of these may be camp houses or summer houses on the Warrior River in the northwest 1/4 of Section 10. One structure is shown in Section 2 and one in Section 3.

Possible sources of water pollution are fairly numerous. The small industries in Cordova about 8 km (5 miles) up-river from site 2 may discharge effluents into the river. There are numerous abandoned mines, most of them small, on both sides of the river as far as Cordova. There are others on the river 14.5 - 16 km above Cordova in the Empire-Sipsey area. Some of the strip-mines north of High Level drain into streams that empty into the Warrior River north of site 2. Oxidation of coal in the natural outcrops of the Pratt, America, New Castle, Mary Lee and Blue Creek coalbeds, of course, also pollutes the river and tributary streams.

In order to check the condition of the local waters, six samples were taken on October 22, 1974. None of these were on the site itself because no running streams were found at that time.

All samples were taken by boat on the Warrior River. The sampling locations are shown in figure 10. Sample 1 was taken where the river reaches the proposed mining tract. It should characterize the river water quality, at fairly low flow rates, as it reaches the mining property.

Samples 2, 3, 4, and 5 were taken from the north side of the river opposite drainage from site 2. Note that 2, 3, and 4 are on the upthrown side of the fault that re-exposes the Mary Lee coalbed outcrop for nearly a mile along the river in Sections 2, 3, and 10. Sample 5 was taken at the mouth of the largest drain on the property but on the down-thrown side of the fault where the Mary Lee coalbed is well below drainage. These four localities should measure any pollution flowing into the river from site 2.

Sample 6 was taken from the mouth of Mosquito Creek. The eastern tributaries of this creek partly drain the west end of site 2 while the remainder of its watershed drains the America and Pratt coalbed strip mines at High Level. The quality of the river water here should characterize the quality of the river just past site 2 and differences between samples 1 and 5 or 6 should reflect any pollution from site 2.

Table 4 shows the analyses of the 6 samples. The figures indicate that for the large number of potential pollution sources, the Warrior River water is fairly pure and flow past site 2 produces little or no detectable changes. All pH values are between 7 and 8, except that value from sample 6; sample 6 contained drainage from some strip mines and had a pH of 8.05. Sulfates are low. The more common metal ions, Al, Fe, Ca, and Mg, apparently were not determined and rarer ions, like Sb, As, Cd, Cu, Pb, Mn, Ni, Sn, and Zn were not detected. Turbidity was low. Specific conductance was quite uniformly low.

TABLE 4 - TEST RESULTS: SITE NO. 2, SAMPLED OCTOBER 22, 1974

Parameter	Sample Point 1	2	3	4	5	6
ACIDITY as mg/l $CaCO_3$	2.31	2.51	2.05	3.08	2.56	2.26
ALKALINITY as mg/l $CaCO_3$	21.83	18.10	17.25	17.25	15.98	15.44
AMMONIA as mg/l N	0.35	0.35	0.20	0.20	0.22	0.20
BIOCHEMICAL OXYGEN DEMAND, mg/l (5 days @ 20°C)	2.18	1.18	1.64	2.00	1.27	1.64
CHLORIDE as mg/l Cl	4.30	3.76	6.44	4.30	3.76	4.30
DISSOLVED OXYGEN, as mg/l	8.40	8.0	7.70	7.30	7.50	8.10
HARDNESS as mg/l $CaCO_3$	20.72	24.68	21.55	24.68	22.79	29.0
pH	7.72	7.15	7.40	7.11	7.23	8.05
SPECIFIC CONDUCTANCE, µmhos/cm	59.0	66.0	65.0	65.0	64.8	65.0
SULFATE as mg/l SO_4	11.2	12.0	11.6	13.0	13.0	12.0
TURBIDITY JTU	3.10	2.30	3.50	2.90	3.30	2.25
ALUMINUM as mg/l Al	--	--	--	--	--	--
ANTIMONY as mg/l Sb	ND[a]	ND	ND	ND	ND	ND
ARSENIC as mg/l As	ND	ND	ND	ND	ND	ND
CADMIUM as mg/l Cd	ND	ND	ND	ND	ND	ND

[a] None detectable

TABLE 4 (Continued)

Parameter	1	2	3	4	5	6
	Sample Point					
CALCIUM as mg/l Ca	--	--	--	--	--	--
CHROMIUM as mg/l Cr	--	--	--	--	--	--
COPPER as mg/l Cu	ND	ND	ND	ND	ND	ND
IRON as mg/l Fe	--	--	--	--	--	--
LEAD as mg/l Pb	ND	ND	ND	ND	ND	ND
MAGNESIUM as mg/l Mg	--	--	--	--	--	--
MANGANESE as mg/l Mn	ND	ND	ND	ND	ND	ND
MERCURY as mg/l Hg	--	--	--	--	--	--
NICKEL as mg/l Ni	ND	ND	ND	ND	ND	ND
POTASSIUM as mg/l K	0.95	0.975	0.95	1.0	0.95	--
SODIUM as mg/l Na	1.95	1.80	1.80	1.80	1.80	1.80
TIN as mg/l Sn	ND	ND	ND	ND	ND	ND
ZINC as mg/l Zn	ND	ND	ND	ND	ND	ND

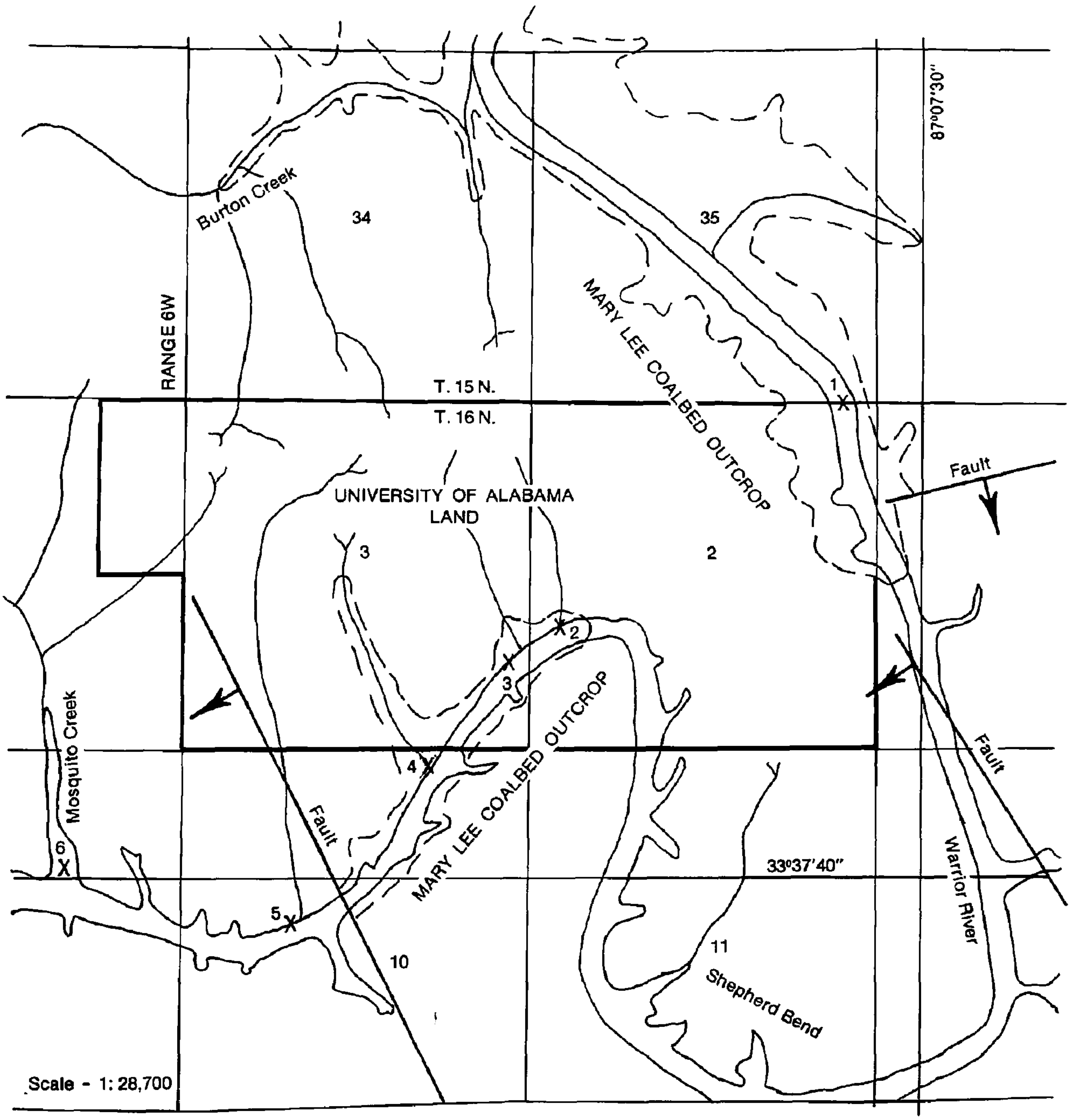

Figure 10. Location of the six water samples collected, site 2.

Proposed Mining Plant and Layout

Work on site 2 did not proceed far enough for consideration of details of mine lay-out. It was assumed that the mine would be opened by a drift from the outcrop, probably in the northwest 1/4 of the southwest 1/4 of Section 2 T16S R6W. The main slope would be driven approximately north, or up the dip. If, however, all the coalbeds were first strip-mined with a 30.5 m (100 foot) highwall, the underground opening could be as far north as the northeast 1/4 of the northeast 1/4 of Section 3. Left entries would mine the accessible areas in Sections 3 and 4 and right entries, those in Sections 1, 2, 11, and 12. Because these entries would be so near the north line of the property, most of the area would be mined south and down dip. Strip-mining of the shallower coal would produce acid drainage which would all flow into the Warrior River. By properly channeling and treating this drainage, the river would probably be protected from excessive pollution until the restored spoilbanks were revegetated and most of the acidity flushed away. The average sulfur percent in the Mary Lee coalbed is about 0.7, in the Blue Creek, about 0.8, and in the New Castle, about 1.7, so that acid pollution may not be a serious problem at any time. The quality of the Warrior River water, with the many abandoned mines upstream, lends support to this possibility.

A possible alternative to conventional stripmining, at least where cover is greater than 25 - 40 feet (7.6 - 12.2 m), might be "longwall stripping", which has been used to some extent in West Virginia.[11] By this method the mining face, under shallow cover, is advanced and the roof is supported, near the face, as in the longwall advancing system. On advancing the mechanical roof supports, the roof settles to the floor behind them with minimum breaking. The resulting terrain would then not differ from its original condition except for some slight subsidence. An objection to this method, from the standpoint of resource conservation, is that the underlying Blue Creek coalbed and the overlying New Castle coalbed would be lost. The fairly-high-sulfur New Castle coal would be left in the partly fractured ground where it could more readily reached by oxygen-bearing surface water than it was before mining.

Quality and Control of Mine Effluent

If acid mine water proves to be a problem, the effluent from the underground mine should be easy to handle. Some drainage probably would issue from the drift entries and from the small mining area where updip mining is done, but the greater part of the mining area would be mined downdip. Any drainage collecting along the face could be pumped updip and across to the main entries, but it would be simpler to pump the water to the surface through shallow drill holes. All underground drainage could be collected and treated, if necessary. After the mine is exhausted, a seal on the entries should hold easily because the slight southward dip of the narrow strip north of the entries would insure a very low head of trapped water.

GEOLOGY, GEOLOGIC STRUCTURE, AND PRE-MINING ENVIRONMENT DATA AT SITE 3

Geology and Geologic Structure

The topography of the area that encompasses the North River mining district is one of relatively low relief, with rather sluggish larger streams meandering across broad alluvium-covered valleys. The hills which rise from 30.5 km to 61 km (100 to 200 feet) above the principal streams are deeply dissected. The elevations of the larger hills range from 152 km to 183 km (500 to 600 feet), and are usually capped by Cretaceous sands and gravels of the Coker formation, a member of the Tuscaloosa group.

The Cretaceous age Coker formation lies unconformably over the massive coal-bearing Pottsville formation of Pennsylvanian age. The formation consists of sands and gravels and is a member of the Tuscaloosa group. Within the Coker formation are two members, only one of which is of concern. This is the Eoline member which is divided into a lower sand unit and an upper clay-rich unit. The Eoline sands consist of white to light gray to tan, fine to coarse gravel, and cross-bedded, micaceous sands. These sands generally weather to a dark red color. Interbedded with the sands are clay balls which vary in color from light to dark gray and may be as large as 12.5 cm (6 inches) in diameter. The thickness of these sands varies, but the maximum noted was about 25 m (82 feet).

The Eoline sands grade upward into the Eoline clays. These clays are illitic, thinly laminated, and range in color from green to purple to gray. They are interbedded with fine, cross-bedded glauconitic sands. Thin ironstone layers are common throughout the Eoline clay.

The coalbeds and their enclosing rocks are of Pennsylvanian age. The U. S. Geological Survey[12] and the Alabama Geological Survey[13] have termed the Alabama Pennsylvanian rocks the "Pottsville formation" and have divided this formation into upper, middle and lower. Figure 11, from Shotts[14], as modified only slightly from Butts, shows these divisions. The exact point of separation is somewhat indefinite but generally the limit of the lower Pottsville is just under the Black Creek coal in the Warrior coalfield and near the Gould coalbed in the Cahaba coalfield. With this division, there is no upper Pottsville in the Warrior coalfield.

Stearns[15], on the basis of sections and well logs from Eastern Kentucky to Mississippi, also divided the Pottsville into three parts and introduced the division names of Pocahontas, New River, and Kanawha, currently used in Kentucky. Stearns places the Pocahontas-New River division at the Rosa coal and the New River-Kanawha division just above the Pratt coal. Thus, the Warrior coalfield has four coalbed groups in the Kanawha: the Gwin, Cobb, Utley and Brookwood. See Culbertson and Shotts[12,16] for the Utley group, not recognized earlier by McCalley[17].

The coalbed mined at North River No. 1 Mine is in the Pratt group.

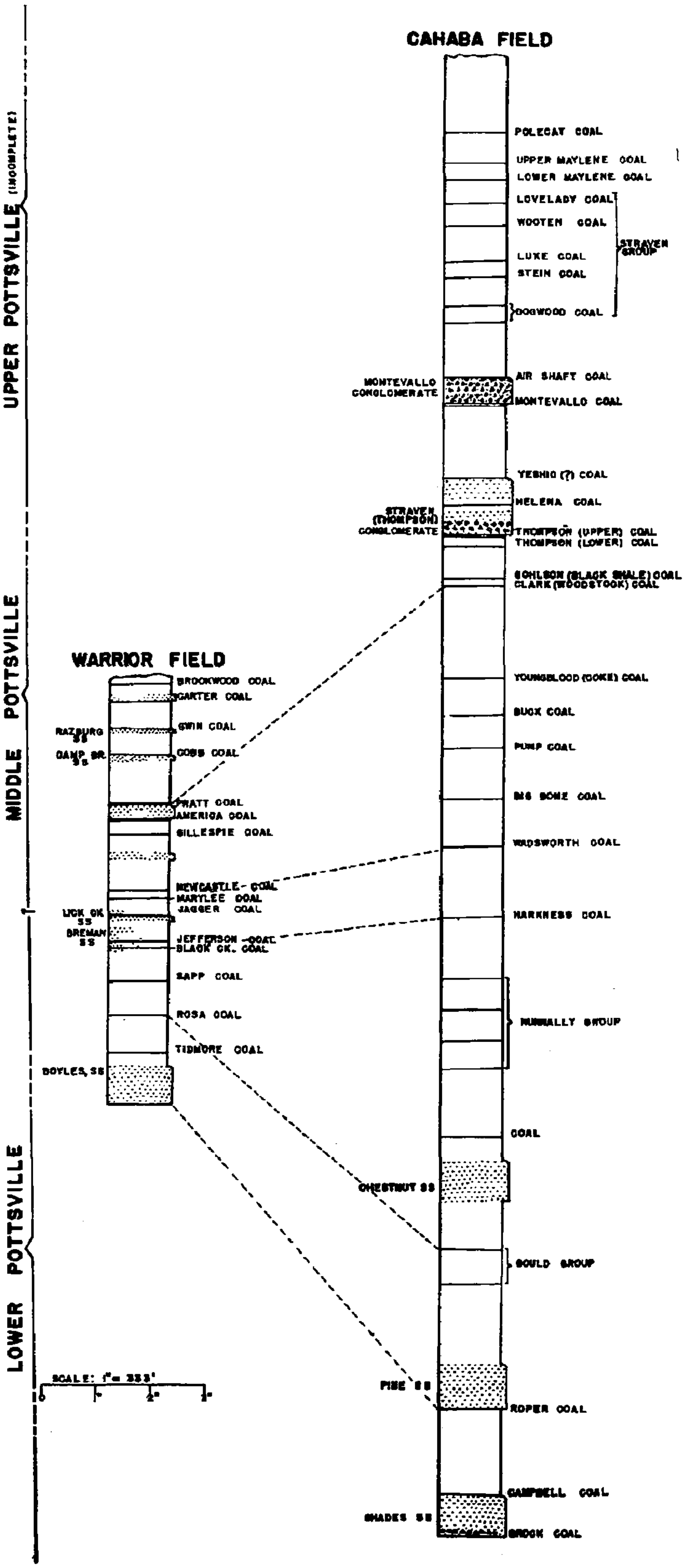

Figure 11. Age of the coalbeds, Warrior and Cahaba coalfields.

It is the equivalent of the Pratt coalbed itself, but in the western Warrior coalfield, it is usually referred to as the Corona coalbed. McCalley[18] says: "The Cardiff (Fire Clay) and Pratt seams come together and form the Corona...". The "coming together" occurs near Oakman, Alabama. Just west of Oakman, the Pratt, Cardiff (Fire Clay, Nickel Plate) and America are present south of the Southern Railroad, but north of it, only the Corona is found. The Corona is the only coalbed of the Pratt group that is of any importance in the North River area.

Figure 12 is a log of a hole drilled approximately one mile south-southeast of the slope of the North River No. 1 mine. Apparently one other coalbed overlies the Corona coalbed at this point. The Cobb Upper coalbed was mapped by McCalley as cropping out in Cedar Creek valley, a few feet above the stream[19]. This thin bed does not appear in figure 12 although the drill hole apparently was started well above the horizon. The 74-cm (29-inch) coalbed at 130 m (428 feet) is the one mapped by McCalley[20] as the Cobb Lower. For that reason, the thick sandstone immediately underlying the coalbed is the Camp Branch sandstone of Butts[21]. See also figure 11. The Camp Branch sandstone is distributed widely in the western Warrior coalfield[22].

The Corona coalbed lies 75 m (245 feet) below the Cobb Lower. The intervening strata are largely shale. Much of it is sandy or contains sandstone bands. The immediately overlying "sandstone with shale bands" is giving roof control problems in the new mine.

All strata apparently were deposited in freshwater under rather rapidly shifting environmental conditions and at varying distances from sediment sources. There are no limestone beds, and apparently no distinctive fossil zones were encountered except for the fossil plant matter of the coalbeds themselves. Alternating bands of "fire clay", coal and bone coal in the Corona coalbed itself indicated a fluctuating depositional environment.

The Mary Lee and Black Creek coal groups underlie the Corona coalbed in this area and there may also be coal in the pre-Black Creek zones (Rosa or Bear Creek zone). The logs of the two nearby Bessemer Coal, Iron, and Land (Sinclair Oil) holes shown in figure 13[23] indicate mineable coal at the Black Creek and possibly at the Mary Lee horizons. The horizon labeled "Black Creek" could be the underlying Bear Creek zone instead, depending on the completeness of the Pocahontas section in the area.

From subsurface data obtained from diamond drill exploration by the Joy Manufacturing Company for Republic Steel Corporation, two cross-sections were drawn. These cross-sections are wholly within the property limits for the Republic Steel Corporation and represent the general subsurface stratigraphy of the North River mining district. The exact location of both cross-sections can be found on the aerial map of the North River No. 1 mine property, figure 14.

The east-west cross-section was drawn to best represent the stratigraphy perpendicular to the general dip of the region. The north-south cross-section, therefore, best represents the stratigraphy parallel to the general dip of the region, which is slightly west of south. The

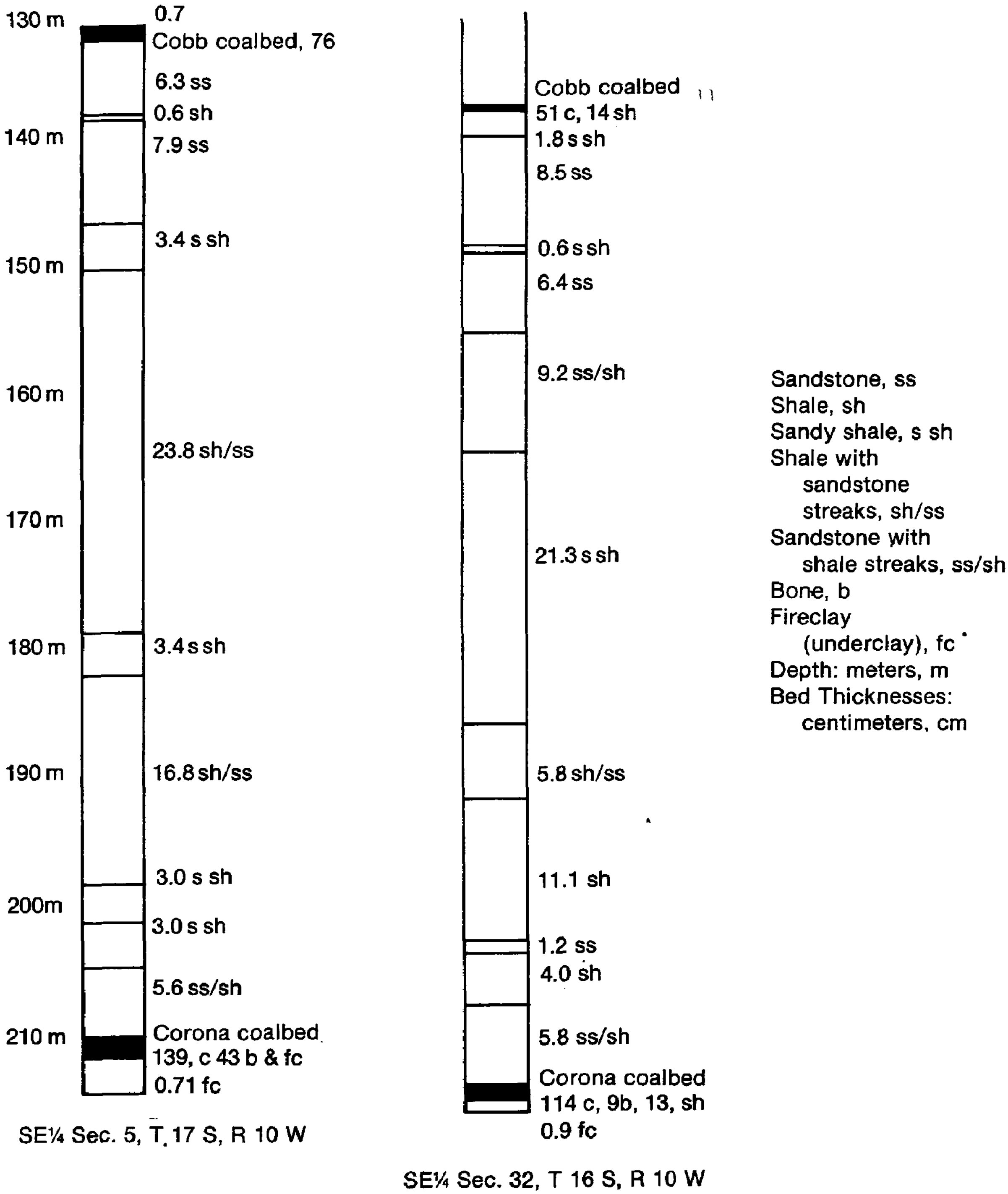

Figure 12. Graphic logs, lower part, of two drill holes near North River No. 1 mine.

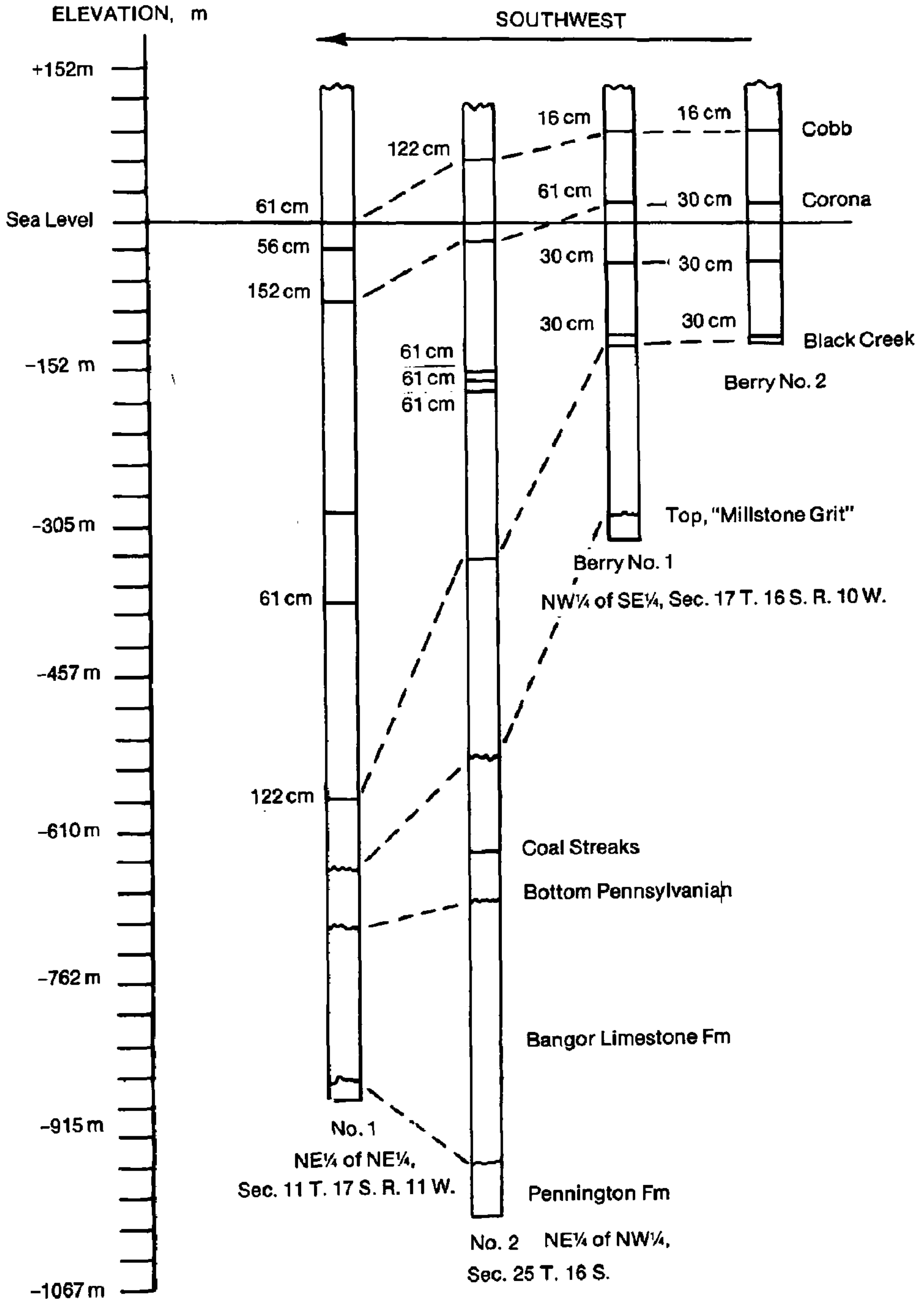

Figure 13. Published logs of four drill holes north, northwest, and west of North River No. 1 mine.

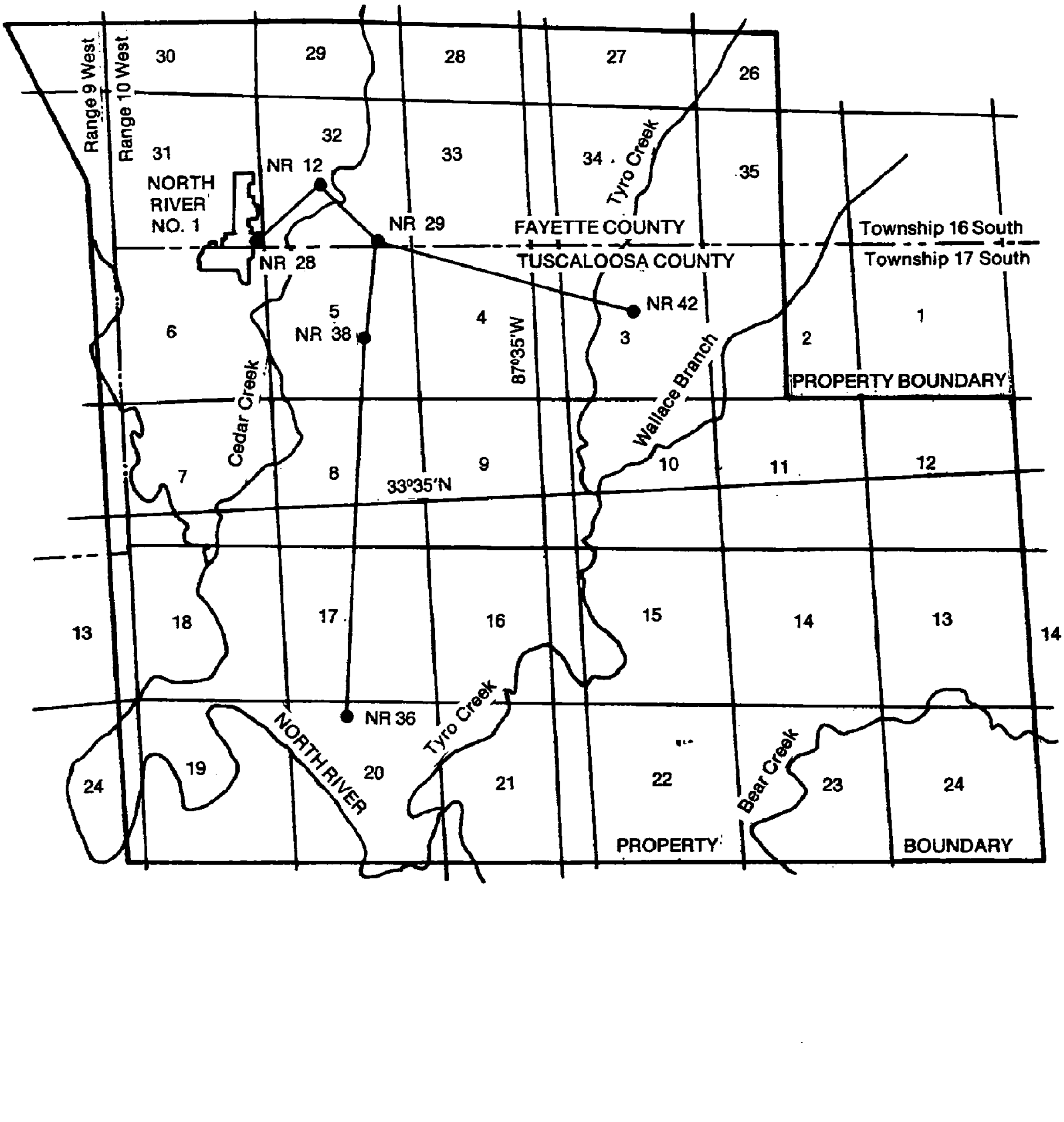

Figure 14. Map showing North River No. 1 mining area, principal streams, and location of drill holes used to construct stratigraphic sections.

cross-sections are not shown, but they reveal general stratigraphic trends in the area.

The Pottsville formation generally consists of alternate beds of shale and sandstone with two coalbeds. In the northern part of Fayette County the thickness of the Pottsville is about 305 m (1,000 feet). The thickness increases southward; in the Sinclair No. 1 well, Section 11 T17S R11W (figure 13), the base of the Pottsville was encountered at a depth of 843 m (2,765 feet). The basal 30.5 m (100 feet) of the Pottsville is a coarse conglomeratic sandstone containing white quartz pebbles 0.5 to 1.0 cm in diameter[24].

In the east-west cross-section, perpendicular to the general regional dip, there is a repeated pattern of sandstone and sandy shale. This pattern repeats itself about three times within this cross-section. On the surface there are a couple of hills that are capped with the Eoline member of the Cretaceous Coker formation. These are typical sands and clays, weathered to a red color. Except for these sands and clays of the Coker formation, the remainder of the cross-section is made of the sandstones and shales of the Pottsville formation with its two prominent coalbeds.

Both cross-sections shown that the Cobb coalbed is based on the very persistent Camp Branch sandstone of Butts[25] throughout the section. It has a projected thickness in the east of 9.1 to 12.2 m (30 to 40 feet) and follows a lensoid pattern to the west that reaches maximum thickness of 24.4 to 27.4 m (80 to 90 feet). Above the Cobb coalbed there is a shale member of the Pottsville formation that keeps a uniform thickness of about 10.7 to 12.2 m (35 to 40 feet).

The Pratt coalbed has a sandstone member of the Pottsville formation forming its roof-rock. This sandstone ranges in thickness from a moderately thin 3 m (10 feet) in the east to about 7.6 to 9.1 m (25 to 30 feet) in the west. In general, the east-west cross-section shows a very uniform succession of the various members of the Pottsville formation, as one would expect from a section parallel to the strike of the beds.

In the north-south cross-section, the beds of sandstone and shales are not so uniform as in the east-west section. This cross-section was drawn parallel to the dip direction, and the general trend is for each of the individual lithologic units to have gradual increase in thickness in the downdip direction to the southwest.

Again in this cross-section, the sandstone unit underlying the Cobb coalbed decreases in thickness to the south. As in the first cross-section discussed, a sandstone unit forms the roof-rock above the Pratt coalbed. The sandstone forming the roof of the Pratt coalbed pinches out to the south where the Pratt is overlain by a bed of shale with a thickness of 30.5 to 36.6 m (100 to 120 feet).

Several small units of sandstone and shale disappear in the north-south cross-section and do not persist from drill hole to drill hole.

If a closer spacing of drill-hole information had been available, local disappearances such as these could have been mapped more precisely. It appears highly probable that stratigraphic unit thicknesses fluctuate considerably throughout the area.

Structure

The structure of the North River area is not believed to be complex. A structure map was made by the Sinclair Oil Company and was published by Semmes[26]. Structure was mapped on top of the Utley No. 1 coalbed which is a thin, generally uneconomic, but persistent, coal horizon higher than the Cobb coalbeds. The two notable features of the map are: (a) a gentle but slightly varying dip to the south or southwest and (b) two parallel NW-SE faults with a graben between them, lying about 1.2 km (2 miles) west of North River No. 1 mine. Exploratory drilling has been done near the faults in order to delineate them and to determine their effect on future mining.

The company is already encountering the principal joints in the area. Because of the depth of weathering, it would be almost impossible to map the jointing system on the surface. The principal joints are often filled with water and drain rather rapidly when encountered. After the stored water drains, inflow is modest. Signs of biological contamination of the inflowing water have been noticed in the mine.

Figure 15 shows the principal set of joints mapped to date. They trend east, about 30^{o}N, although they are obviously not all parallel. The dip of the beds appears to be more nearly south than are the joint directions.

The Corona coalbed at the North River mine does not yield coal of coking quality (the Pratt coalbed makes excellent coke in Jefferson County). The entire output is under contract to the Southern Electric Generating Company for utility fuel. The reported production of coal for the Alabama State fiscal year 1975 was 307,072 tons (278,574 metric tons). Part of this may have been unwashed coal because the preparation plant was finished late. Thus 1975 finds the mine just getting into production. Five or six mining units are now working out of a planned ten to twelve, toward a 1 1/2 to 2 million ton (1,361,000 to 1,814,000 metric tons) annual production rate.

The coal mine was developed with a belt slope 565 m (1,852 feet) long, a man shaft and a ventilation shaft. The surface elevation of the slope mouth is about 110 m (360 feet), and the hoist and air shafts are at 129 m (423 feet) and 128 m (420 feet), respectively. The coal is roughly 28 m (92 feet) below sea level. The depth of the coalbed increases toward the south and west.

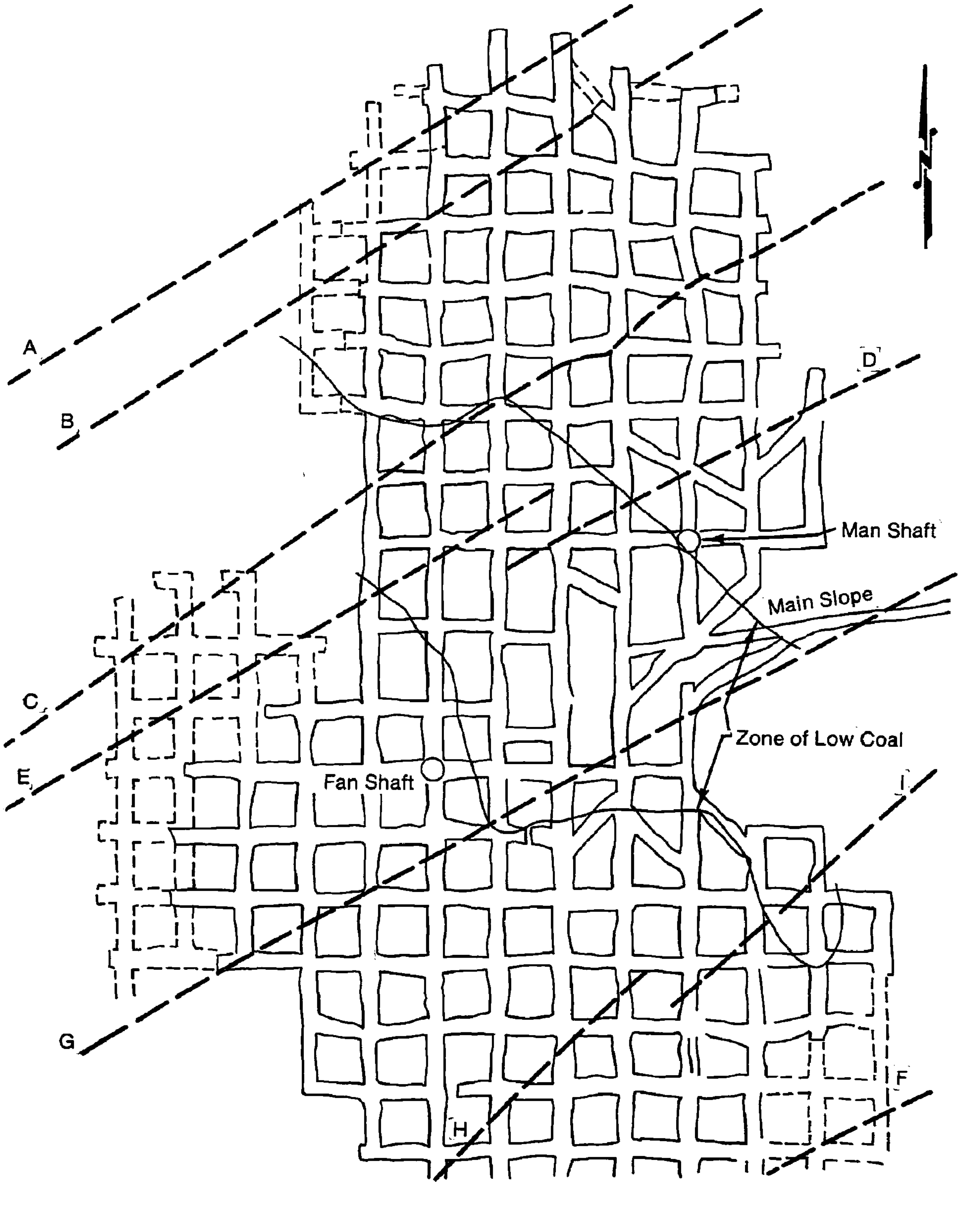

Figure 15. An early map of North River No. 1 mine, showing the direction of the dominant joint system in roof rock.

HYDROLOGY OF THE NORTH RIVER NO. 1 MINE, REPUBLIC STEEL CORPORATION, BERRY, ALABAMA, SITE 3*

Introduction

The Republic Steel Corporation, North River No. 1 mine near Berry, Fayette County, Alabama, is mining coal from the Pratt coalbed under about 120 to 150 m (400 to 500 feet) of cover. The mine, when in full production, will produce 1.8 million metric tons (2 million tons) annually for steam power generation.

The purpose of this report is to provide basic water data for the mine area. These data are on the occurrence and movement of surface and ground water as well as on the quality of these waters so that plans for pollution abatement and control can be formulated to minimize pollution effects from underground mining operations.

Water Availability

Ground Water

The quantity and movement of ground water is controlled by the subsurface rocks. The physical characteristics and chemical composition of the geologic formations are major factors that affect the quantity of water available, and the quality and the vertical areal distribution of ground water.

The data collected on the availability of water for the area have been taken from reports of the Geological Survey of Alabama and from field studies.

In the mine area, ground water occurs in openings along fractures, bedding planes, rock contacts in sandstone units of the Pottsville Formation, in sand and gravel of the Coker Formation, terrace deposits, and in the alluvium. In the mine area, deposits of sand and gravel cap only some of the higher points of elevation and are therefore limited in areal extent, thickness and water availability. The Pottsville Formation is the principal water-bearing geologic unit. See table 5.

The Pottsville in the mine area consists of sandstone, shale, siltstone, conglomerate, clay, limestone, and coal, and ranges in thickness from 300 to 920 m (1,000 to 3,000 feet). The most productive water-bearing openings generally occur in the sandstone beds. Some solution openings may occur in the limestone beds, but the beds are thin and non-persistent.

The nature of the occurrence of the different rock units of the Pottsville as an alternating sequence of beds of shale, sandstone, limestone, siltstone, conglomerate, clay, and coal beds place impermeable beds of shale and clay above or below permeable beds of sandstone, thereby

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*Prepared by Thomas A. Simpson, Assistant State Geologist, Geological Survey of Alabama, University of Alabama. Publication authorized by the State Geologist.

TABLE 5 - GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS[a]

System Series	Geologic Unit	Thickness (feet)	Lithology	Water-Bearing Properties	Quality of water
Quatemary Holocene and Pleistocene	Terrace deposits and alluvium	0 - 25	Lenticular poorly sorted beds of sand, gravel, and clay.	Wells generally produce less than 5 gpm (19 l/min).	Water generally reported to be soft and low in mineral content.
Cretaceous Upper Cretaceous	Coker Formation	0 - 80	Varicolored, unconsolidated lenticular beds of clay, sand, and gravel. The coarser sand beds and beds of gravel are near the base of the formation.	Aquifier probably will yeild less than 5 gpm (19 l/min) in western edge of county. Cretaceous eroded over much of Tuscaloosa County.	Water is reported to be soft and low in mineral content.
Pennsylvanian Lower and Middle Pennsylvanian	Pottsville Formation	1,000 - 3,000	Sandstone, brown to red, dark gray micaceous, conglo-meratic, shale, and coal.	Sandstone generally yields less than 10 gpm (38 l/min) to individual wells. Weathered sandstone may yield up to 50 gpm (190 l/min).	Water is soft to hard and locally may contain ob-jectionable amounts of iron.

[a] After O'Rear, et al., 1972.

limiting the vertical movement of water. However, where these beds have been fractured by faulting, folding, and jointing the vertical and lateral movement of ground water is affected. Ground water also moves laterally along bedding planes and at the contact between different rock types.

The Pottsville does not provide high yields to wells; generally, a flow of 5 gpm (19 l/min) is considered to constitute a good well. However, yields of 50 to 125 gpm (189 to 473 l/min) have been developed in some areas. The amount of water available depends upon the number and size of water-bearing openings penetrated. Generally the number and size of openings decrease with depth, and below 100 m (330 feet) little additional water can be expected.

Ground water in sand and gravel in the Coker Formation is very limited and shallow wells yield less than 5 gpm (19 l/sec).

The alluvium and terrace deposits are not important sources of ground water because of their limited areal extent and thickness. The flood plains of major streams may be suitable for a domestic source.

Most of the springs in the area flow less than a liter per second, but they may be adequate for a domestic source.

Mine Water Sources

The major source of ground water in the mine is from water-bearing fractures and joints. The workings are dry except when occasional water-bearing "slips" or joints are penetrated by the mine openings. The water "make" for the mine is probably no more than 100 to 200 gpm (6 to 13 l/sec).

The initial penetration of a water-bearing opening usually releases a large inflow of 200 to 300 gpm (13 to 19 l/sec), but after draining over a period of time, flow decreases to a trickle. This indicates that the fracture system is serving as a storage reservoir and that movement through the system both vertically and laterally is very restricted. Much of the jointing observed in the back was "healed" or filled in with a cementing material of some kind.

The structure of the rocks in the mine area is relatively simple, and rocks dip generally southward a few feet per mile. However, faulting, folding, and jointing exist in some areas and near large-scale structural features water flows of greater magnitude can be expected.

Ground Water Quality

The chemical character of ground water depends on several variables, such as the composition of the aquifer, distance from recharge areas, time the water has been in contact with the aquifer, and the overall pattern of ground water circulation. Ground water collected from water wells in the Coker Formation generally contains less than 100 mg/l dissolved solids, less than 40 mg/l chloride, and is soft. Ground water collected from water wells in the Pottsville Formation generally contains more than 100 mg/l dissolved solids, less than 40 mg/l chloride, and ranges from soft to very hard. Locally, ground water contains iron in excess of 0.3 mg/l and objectionable amounts of silica.

In contrast to the chemical quality of ground water from wells, water samples collected underground at four different points show the water to be a sodium bicarbonate type. The results are shown in table 6. One sample from a "slip" at Northwest Main was very turbid. The results indicate storage over a long period of time in the fracture system.

Surface Water

The major drainage system in the mine area is the North River, and the nearest recording station with the longest period of record is at Samantha, Tuscaloosa County. The records for 1974 are given in table 7 that follows.

Environmental Considerations

One of the most serious water pollution problems associated with coal mining is acid mine water. Ground water in the mines, on coming in contact with coal or rocks containing a high sulfide content and in the presence of oxygen, becomes acid. On hydrolysis of oxygenated metal salts, a gelatinous mass of red, brown, and yellow iron oxides and hydroxides, termed "yellow boy", is precipitated.

This situation can also occur when rainfall runs off waste piles on the surface.

Preventive measures should be undertaken to channel mine water effluent and runoff from waste piles to tailings ponds where the water can be held and treated before being allowed to flow into the surface drainage system in the area.

See appendix A for special references for this section of the report.

Mine Plan and Layout

The mining plan and layout of North River No. 1 was prepared long before the present project was shifted to site 3; therefore, it is impossible to know the extent to which potential environmental impact was considered in selecting a mining system. Because the mining system is similar to that used in most underground mines in Alabama, it is suspected that experience factors were used. It is not believed that in the past, environmental considerations have weighed very much in decisions regarding mining method. If this is a fact, it does not reflect an anti-environmental bias but simply the fact that it was not known how, or to what extent, potential pollution from mining operations is affected by choice of mining method or layout.

TABLE 6 - TEST RESULTS: WATER SAMPLES COLLECTED BY THE GEOLOGICAL SURVEY OF ALABAMA

REPUBLIC STEEL BERRY MINE AT BERRY, ALABAMA

Constituent	Main south track dripper, No. 1 8/7/75 1000 hr.	North 75° 1 flat North, No. 2 8/7/75 1100 hr.	Northwest main, No. 3 8/7/75 1045 hr.	Northeast of elevator shaft No. 4, 8/7/75 1140 hr.	North River at Samantha 6/26/75 1300 hr.
Specific Conductance (μmhos/cm)	1330	--[a]	1870	1290	50
Iron, total (μg/l)	80	--	400	60	--
Aluminum (μg/l)	60	--	10	30	--
pH	9	--	8.7	8.9	6.2
Antimony (mg/l)	0[b]	--	0[b]	0[b]	--
Cadmium (μg/l)	<1.0	<1.0	<1.0	1.0	0[b]
Chromium, dissolved (μg/l)	0[b]	--	0[b]	0[b]	--
Cobalt (mg/l)	--	1.0	--	--	--
Copper (μg/l)	1	--	2	5	--
Lead (μg/l)	2	2.0	2	3	0[b]
Manganese (μg/l)	0[b]	--	0[b]	0[b]	100
Mercury (μg/l)	<0.2	--	<0.2	<0.2	0.2
Nickel (μg/l)	1	--	1	2	--
Tin (mg/l)	0[b]	--	0[b]	<1.0	--
Zinc (μg/l)	18	--	24	13	8

TABLE 6 - (Continued)

Constituent	Main south track dripper, No. 1 8/7/75 1000 hr.	North 75° 1 flat North, No. 2 8/7/75 1100 hr.	Northwest main, No. 3 8/7/75 1045 hr.	Northeast of elevator shaft No. 4, 8/7/75 1140 hr.	North River at Samantha 6/26/75 1300 hr.
Calcium (mg/l)	1.1	--	1.7	1.0	3.3
Magnesium (μg/l)	0.3	--	0.5	0.3	2.6
Sodium (μg/l)	380	--	510	370	2.8
Potassium (μg/l)	2.0	--	2.5	1.7	1.3
Residue, total filterable at 180°C	890	--	1270	855	--
Bicarbonate (μg/l)	720	--	850	720	14
Carbonate (μg/l)	54	--	31	39	--
Sulfate (μg/l)	--	--	--	--	12
Chloride (μg/l)	78	--	240	82	2.2
Hardness, total (mg/l)	4	--	6	4	19
Ammonia NH_3 (mg/l)N	0.64	--	0.70	0.50	--
Turbidity JTU	5	--	55	2	--

[a] Not enough water for complete analysis

[b] Material specifically analyzed for, but not detected

TABLE 7 - MOBILE RIVER BASIN

02464000 North River Near Samantha, Alabama

Discharge, in Cubic Feet Per Second, Water Year October, 1973 to September, 1974

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	131	31	347	778	697	332	738	210	457	43	29	223
2	69	31	258	792	625	294	3,510	178	538	40	26	427
3	50	28	203	1,260	575	262	2,680	185	332	37	25	359
4	40	27	258	2,060	462	237	4,370	166	250	35	35	156
5	35	30	352	1,320	384	218	4,040	188	237	34	31	119
6	30	33	246	2,130	631	199	1,410	172	284	34	25	90
7	27	31	195	4,470	2,710	185	864	148	284	41	27	76
8	25	116	169	2,370	2,430	172	758	131	275	57	183	4,930
9	24	600	153	1,990	1,220	156	600	131	221	53	72	3.140
10	23	262	142	3,120	835	150	462	128	229	49	44	1,450
11	21	145	123	3,550	637	150	389	172	162	41	36	804
12	20	106	116	3,180	520	241	1,300	1,860	136	46	34	451
13	19	89	111	1,470	445	188	7,810	806	241	38	45	358
14	23	76	104	1,040	422	159	4,490	457	207	35	51	451
15	81	68	100	1,220	1,360	148	2,290	400	162	35	53	295
16	60	62	91	1,090	2,340	142	1,500	676	136	33	42	218
17	43	54	81	857	1,580	136	1,100	509	118	30	49	158
18	34	49	78	670	907	128	850	367	100	27	43	137
19	27	47	73	551	1,160	136	770	284	106	30	35	112
20	25	45	178	606	900	683	700	266	98	31	30	96
21	23	439	347	1,030	724	1,080	660	307	81	27	27	83
22	22	486	262	772	3,130	765	640	289	73	26	24	73
23	21	246	225	857	2,050	538	1,290	600	80	45	23	52
24	20	182	203	1,300	951	405	650	354	106	60	21	57
25	20	156	2,580	2,010	650	322	480	271	81	48	20	58

TABLE 7 - (Continued)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
26	19	145	12,500	1,590	515	289	394	4,160	66	38	19	69
27	19	606	8,220	1,690	433	254	332	4,500	59	47	20	78
28	22	2,780	1,720	2,150	378	233	284	1,510	53	72	32	74
29	30	914	974	3,300	---	3,150	250	857	47	53	33	68
30	31	491	772	1,520	---	2,130	233	613	46	40	35	60
31	31	---	765	929	---	951	---	457	---	33	152	---
Total[a]	1,065	8,375	31,946	51,672	29,671	14,433	45,844	21,382	5,235	1,258	1,321	14,842
Mean	34.4	279	1,031	1,667	1,060	466	1,528	690	175	40.6	42.6	495
Max	131	2,780	12,500	4,470	3,130	3,150	7,810	4,500	538	72	183	4,930
Min	19	27	73	551	378	128	233	128	46	26	19	57
Cfsm	0.16	1.27	4.71	7.61	4.84	2.13	6.98	3.15	0.80	0.19	0.19	2.26
In.	0.18	1.42	5.43	8.78	5.04	2.45	7.79	3.63	0.89	0.21	0.22	2.52

[a] Calendar Year 1973: total 219,520; mean 601; maximum 12,500; minimum 14; cubic feet per square mile 2.74; inches 37.29

Water Year 1974: total 227,044; mean 622; maximum 12,500; minimum 19; cubic feet per square mile 2.84; inches 38.57

Location: Lat 33°28'45", long 87°35'50", in SW 1/4 sec. 16, T18S, R10W, Tuscaloosa County, about 200 feet (61 m) downstream from bridge on county road, 1.2 miles (1.9 km) upstream from Cripple Creek, 4 miles (6 km) north of Samantha, and at mile 36.9 (59.4 km).

Drainage Area: 219 mi^2 (567 km^2)

Period of record: December, 1938 to September, 1954; October, 1968 to current year.

Gage: Water-stage recorder. Datum of gage is 232.39 ft. (70.832 m) above mean sea level. Prior to Jan. 25, 1939, nonrecording gage 40 ft. (12 m) downstream at same datum.

Average Discharge: 21 years (1939-1954, 1968-74), 366 ft^3/s (10.4 m^3/s), 22.70 in/yr (577 mm/yr).

TABLE 7 - (Continued)

Extremes: Current year: Maximum discharge, 13,400 ft^3/s (379 m^3/s) Dec. 26 (gage height, 24.85 ft. or 7.574 m); minimum, 19 ft^3/s (0.54 m^3/s) Oct. 26, 27, 28 (gage height, 1.66 ft. or 0.506 m).
Period of record: Maximum discharge, 25,000 ft^3/s (722 m^3/s) Mar. 20, 1970 (gage height, 35.08 ft. or 10.692 m); minimum, 0.1 ft^3/s (0.003 m^3/s) Sept. 5 - 8, 13 - 15, 1954.
Floods of July, 1916 and February, 1936 reached a stage of about 31 ft. (9.5 m), from information by local residents.

Remarks: Records good.

Revisions: (Water years) WSP 1304: 1939 (M); Drainage area.

TABLE 7a - PEAK DISCHARGE (BASE, 5,000 CFS)

Date	Time	G. H.[a]	Discharge Units	Date	Time	G. H.[a]	Discharge Units
12-26	0900	24.85	13,400	4-13	0900	17.94	8,750
1-07	0700	11.60	5,080	5-26	2100	17.07	8,190
4-04	1900	14.58	6,580	9-08	1600	15.85	7,390

Source Table 7 and Table 7a: Water Resources Data for Alabama, 1974.
Part 1, Surface Water Record, United States Geological Survey.

[a] Gage height

As in all Alabama mines, a room-and-pillar system is in use. It is designed as a full recovery system, using continuous mining machines.

Givan says:

The growing use of high-capacity loading and continuous mining units has resulted in increasing departure from the long line (pillar line) concept. Now the general practice is to work section by section extracting pillars, as a rule, as soon as places, or groups of places, are driven to their limit. Mining may be done on the retreat on one or both sides or on the advance on one side and retreat on the other -- seldom full advance.[27]

This apparently is descriptive of the basic method being used at North River No. 1. Figure 16, which is Givan's figure 12-33, closely resembles the North River No. 1 system.

At North River No. 1, the mains are nine entries driven north and south from the slope. Each entry is 6.1 m (20 feet) wide on 26 m (85 foot) centers (measured from map). East and west flats are turned off the mains, also as nine entries, about every 2,100 m (6,800 feet). Rights and lefts off the main entries are not opposite each other, however. Butt entries are turned off the flats for first mining. They are on 363 m (1,190 feet) centers and are separated by chain pillars 156 m (510 feet) wide. Since mining was begun, some dimensions have been changed to improve roof control. Experimentation with dimensions will probably be continued for some time, and with varying roof conditions in the mine, it is possible that room and other dimensions may differ.

After rooms are driven up and bleeder entries established, pillar mining in a finished room goes on simultaneously with first mining in the next one. Apparently, mining will be away from the main entries at North River No. 1, rather than toward them as in figure 16.

Figure 15 shows that in early driving of the mains northward, crosscuts between places were driven opposite each other. Since that time, they have been staggered in the hope that roof support will be improved.

As now laid out, at North River No. 1:

(a) Main entries and butt entries are almost parallel to coalbed dip and flat entries are parallel to strike;

(b) Mining will be both up-dip and down-dip. The location of the portal, relative to the reserves dedicated to Mine No. 1, indicates that most of the mining area lies east of the mains and that much more down-dip than up-dip mining will be done.

(c) Butt entries are all to be mined up-dip.

All entry haulage in North River No. 1 is by belt, with shuttle cars being used from the face to the nearest belt.

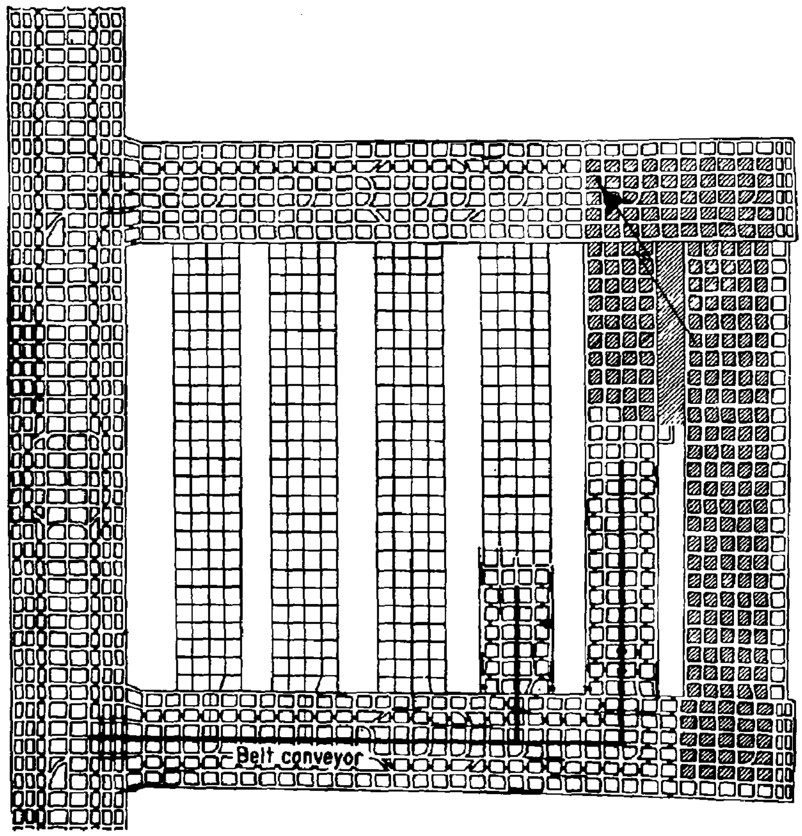

Figure 16. Example of room-and-pillar panel mining with pillar recovery (ref. 27).

Pre-Mining Environment

The quality of water in the locale of the North River Mine before mining operations began was determined by selecting specific sample points based upon the probability of influence on water quality by mining operations. Points on Cedar Creek upstream from the mine should be free from the influence of mine operations, as should those on North River upstream from its confluence with Cedar Creek.

Because of the geological characteristics of the area and the depth of the mine, the only possible samples that could have been influenced by mine operations were the samples taken downstream from the mine in Cedar Creek or North River. This assumption was made because at a mine depth of 152 m, the only possible way for polluting substances to reach the surface would be by pumping. Once these polluting substances reached the surface and were allowed to follow a natural drainage path, the only possible route of flow was into Cedar Creek, downstream from the mine. It should be noted that this is what actually occurred, because at the time each sample of mine effluent was taken, there was a break in the pipeline to the settling pond, and all of the mine effluent actually did drain directly into Cedar Creek.

Eight sample analyses represent pre-mining conditions. They are given below as reported in the monthly progress reports with respective dates and locations.

Sample 2 -- taken May 23 from Cedar Creek, approximately 3.3 river miles above the mine.

Sample 3 -- taken May 23 from Cedar Creek, approximately 4.2 river miles above the mine.

Sample 4 -- taken May 23 from North River below bridge where Highway 18 crosses North River.

Sample 8 -- taken June 20 from North River above its confluence with Cedar Creek.

Sample 13 -- taken August 7 from Tyro Creek, the principal drainage basin east of the mine.

Sample 15 -- taken August 25 from Cedar Creek, same location as sample 2.

Sample 17 -- taken September 11 from Cedar Creek, approximately 0.15 km above the mine.

North River at Samantha -- taken by USGS as reported in table 6 of Hydrology of the North River No. 1 Mine, Republic Steel Corporation, Berry, Alabama, Site 3.

The analyses are given in table 8.

TABLE 8 - TEST RESULTS: WATER SAMPLES REPRESENTING PRE-MINING ENVIRONMENT, SITE 3

Parameter	Sample Point 2	3	4	8	13	15	17	North River at Samantha
ACIDITY as mg/l $CaCO_3$	4.15	5.18	4.15	4.15	3.12	3.32	2.6	--
ALKALINITY as mg/l $CaCO_3$	23.9	22.9	15.6	86.3	19.8	32.2	41.1	14.0
BICARBONATE as mg/l $CaCO_3$	23.9	22.9	15.6	86.3	19.8	32.2	41.1	14.0
CARBONATE as mg/l $CaCO_3$	0	0	0	0	0	0	0	0
AMMONIA as mg/l N	0.1	0.2	0.16	0.23	1.3	0.04	0.7	--
BIOCHEMICAL OXYGEN DEMAND mg/l (5 days @ 20°C)	2.0	1.3	0.7	0.3	0.4	1.8	1.2	--
CHLORIDE as mg/l Cl	2.57	1.206	0.938	0.943	0.47	1.62	3.72	2.2
DISSOLVED OXYGEN, mg/l	--	--	--	8.0	8.7	8.2	8.6	--
HARDNESS as mg/l $CaCO_3$	23.2	21.2	16.2	5.94	14.8	31.4	4.8	19.0
pH	7.01	6.0	6.54	7.02	7.07	7.27	7.07	6.2
SUSPENDED SOLIDS, mg/l	--	--	--	8.5	3.2	9.6	21.0	--
SULFATE as mg/l SO_4	0.8	0.8	0.7	1.0	0.4	0.02	13.0	12.0
TURBIDITY, JTU	9.3	8.8	9.2	12.0	8.5	5.8	24.0	--
ALUMINUM as mg/l Al	ND[a]	ND	ND	ND	ND	0.25	0.3	--
ANTIMONY as mg/l Sb	ND	ND	ND	ND	ND	ND	ND	--
ARSENIC as mg/l As	ND	ND	ND	ND	ND	ND	ND	--

TABLE 8 - (Continued)

Parameter	Sample Point 2	3	4	8	13	15	17	North River at Samantha
CADMIUM as mg/l Cd	ND	ND	ND	ND	ND	ND	ND	0
CALCIUM as mg/l Ca	4.0	1.25	1.1	0.5	2.5	5.75	10.9	3.3
CHROMIUM as mg/l Cr	ND	ND	ND	ND	ND	ND	ND	--
COPPER as mg/l Cu	ND	ND	ND	ND	ND	ND	ND	--
IRON as mg/l Fe	0.8	0.75	0.85	0.6	0.5	0.61	0.6	--
SPECIFIC CONDUCTANCE, µmhos/cm	45.0	35.0	25.7	41.0	39.1	74.0	130.0	50.0
TEMPERATURE C°	22.0	22.5	22.0	24.0	22.0	28.2	31.0	0
LEAD as mg/l Pb	ND	ND	ND	ND	ND	ND	ND	--
MAGNESIUM as mg/l Mg	2.5	2.25	1.5	1.5	2.7	2.45	6.08	--
MANGANESE as mg/l Mn	ND	ND	ND	ND	0.1	0.17	0.15	0.1
MERCURY as mg/l Hg	ND	ND	ND	ND	ND	ND	ND	0.0002
NICKEL as mg/l Ni	ND	ND	ND	ND	ND	ND	ND	--
POTASSIUM as mg/l K	1.6	1.0	1.0	1.2	0.88	2.54	7.5	1.3
SODIUM as mg/l Na	5.5	3.0	0.7	1.8	2.02	7.2	1.6	2.8
TIN as mg/l Sn	ND	ND	ND	ND	ND	ND	ND	ND
ZINC as mg/l Zn	ND	ND	ND	0.05	ND	0.13	0.112	0.008

[a] None detectable

In table 9, approximate flow values for Cedar Creek at the bridge where Highway 63 crosses Cedar Creek are shown. This represents sample point No. 17 in the analyses. These values were obtained by taking the flow values from North River near Samantha, Alabama, from October, 1974 to September, 1975, as reported by the U. S. Geological Survey and shown in table 7. Each flow value was multiplied by (20 ÷ 219) or 0.0913. The value of 8.1 hectares (20 acres) represents the drainage area of Cedar Creek at the junction of Highway 63 and the value of 88.6 hectares (219 acres) represents the entire drainage area of North River above the gauging station at Samantha. The approximation was made on the assumption that the flow values at the Samantha station include the contribution of flow from Cedar Creek and that contribution is some definite portion of the recorded values at Samantha. The amount of actual contribution is left up to judgement, but because of the similar geological characteristics of the specific area, the amount of water added to Cedar Creek and North River by percolation and rainfall and removed by addition to underground water supply, evaporation, and transpiration, will yield similar flows for each basin on a unit volume/second/unit area basis.

The water sampled was relatively pure. In figure 17, sample No. 17, taken on September 23, was analyzed for milliequivalents per liter in solution as cations and anions and plotted to show the contribution of each ion. The plot shows that the principal anions are $SO_4^=$, Cl^-, $HCO_3^=$, and that the principal cations are Ca^{+2}, Mg^{+2}, K^+, Na^+, with trace amounts of NH_4^+, Fe^{+2}, Zn^{+2}, Al^{+3}, Mn^{+2}. This concentration represents a moderately low flow condition. From table 9, the September 11 flow is 3.38 ft^3/sec as opposed to a minimum low flow of 2.10 ft^3/sec for September, and a maximum low flow rate of 34.7 ft^3/sec for February.

Figure 17 represents only the dissolved ions in solution. The water also had the following characteristics (table 8):

(1) low acidity value, maximum of 5.18 mg/ℓ as $CaCO_3$;
(2) average BOD's for natural waters, range from 0.7 to 2.0 mg/ℓ;
(3) high concentration of dissolved oxygen;
(4) low chloride concentration, maximum of 3.72 mg/ℓ of Cl;
(5) neutral pH, ranges from 6.0 to 7.07;
(6) low suspended solids, maximum of 21.0 mg/ℓ.

Sources and Quality of Mine Influent

To evaluate the quality of the mine influent, six sets of data were analyzed. Three sets were collected and analyzed by Eric Sterret, graduate assistant, and three sets by the Geological Survey of Alabama Water Quality Resources division. Sample numbers and locations are given in table 10. The numbers are as they appear in table 6, in the section on Hydrology of North River No. 1 Mine, Republic Steel Corporation, Berry, Alabama. Results of analyses are given in table 11. A mean value was calculated for each parameter and is so designated.

TABLE 9 - CALCULATED FLOW VALUES, CEDAR CREEK
AT TUSCALOOSA COUNTY HIGHWAY NO. 63 BRIDGE, NEAR NORTH RIVER NO. 1 MINE.[a]
DISCHARGE IN CUBIC FEET PER SECOND; WATER YEAR RECORD OCTOBER, 1974 TO SEPTEMBER, 1975

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	4.84	2.65	9.59	102.28	34.70	44.11	59.54	14.25	7.76	10.32	277.63	4.11
2	4.29	2.65	9.95	63.74	41.00	40.55	47.49	11.05	7.12	5.94	231.05	3.74
3	3.65	2.65	8.95	52.05	134.25	36.35	44.84	10.50	6.03	5.39	105.02	3.47
4	3.47	2.65	8.13	52.60	223.74	33.79	33.97	10.50	5.30	4.66	67.95	3.29
5	3.29	4.66	7.58	42.28	196.35	31.42	28.40	11.32	4.75	4.20	63.01	3.11
6	3.29	5.48	7.21	36.80	145.21	29.22	24.93	11.60	10.78	4.57	56.53	3.38
7	3.29	4.02	11.96	31.78	91.05	28.49	22.37	24.38	11.60	20.55	42.19	3.47
8	3.20	3.29	38.45	47.76	66.58	26.48	20.55	38.81	10.05	66.12	30.78	3.47
9	3.01	2.92	27.21	78.54	56.26	23.65	27.12	30.14	7.67	20.55	24.75	3.20
10	2.92	2.83	19.82	322.37	47.03	25.66	42.74	66.39	8.68	12.42	22.01	2.92
11	2.74	3.56	16.62	762.56	41.19	27.95	30.59	38.08	22.10	11.69	22.83	3.38
12	2.74	5.84	15.53	439.27	60.09	26.39	24.95	25.02	32.97	12.97	17.81	2.83
13	2.65	4.84	13.33	223.74	47.67	193.61	21.64	18.54	13.42	10.78	13.70	2.56
14	2.65	3.74	11.51	130.59	39.73	610.05	69.50	14.98	8.86	8.13	11.23	2.28
15	2.92	3.56	10.87	88.22	35.34	276.71	127.85	208.22	23.93	6.94	9.95	2.10
16	13.70	3.38	11.05	66.85	254.79	113.24	69.59	273.06	18.17	6.03	13.97	2.10
17	10.78	3.65	9.95	54.70	269.41	77.99	50.96	107.76	10.78	5.30	19.18	2.37
18	6.76	4.84	8.95	47.21	294.98	155.25	39.09	63.01	8.04	12.51	19.91	2.92
19	5.30	5.11	8.95	48.49	463.93	313.24	31.60	42.74	6.58	10.41	16.26	3.20
20	4.47	21.74	9.59	65.48	179.91	151.60	25.84	31.23	7.03	7.95	17.53	3.01
21	4.11	23.20	8.95	54.52	103.20	87.12	20.37	24.29	23.20	8.95	13.24	2.65
22	3.84	14.70	8.31	47.58	74.98	62.10	18.26	19.18	36.44	11.51	10.41	3.01
23	3.56	11.23	8.40	41.83	129.68	49.41	16.44	15.71	16.53	7.95	8.95	21.46
24	3.38	9.41	275.80	40.09	206.39	115.07	15.71	13.52	10.41	6.48	8.31	65.48
25	3.20	9.13	323.29	265.75	110.50	90.05	14.98	11.51	7.76	14.06	7.95	23.93

TABLE 9 - (Continued)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
26	3.11	9.13	181.74	153.42	74.06	58.17	14.52	10.14	6.67	120.55	6.67	14.34
27	3.01	8.13	87.58	87.85	60.46	47.12	13.15	8.95	6.21	82.28	5.75	10.78
28	2.92	7.40	91.32	64.47	51.32	38.90	11.78	8.13	5.75	53.15	5.48	8.68
29	2.83	6.94	128.77	52.15	--	36.99	11.60	7.58	5.66	29.41	4.93	7.12
30	2.74	7.03	282.19	44.47	--	109.59	13.79	8.95	6.21	20.55	4.57	6.21
31	2.74	--	179.00	39.18	--	91.32	--	8.58	--	59.82	4.29	--
Mean	4.05	6.68	59.36	117.72	126.48	99.00	33.15	38.45	11.87	21.37	37.52	7.49
Max	13.70	23.20	323.29	762.56	463.93	628.31	127.85	261.84	36.44	120.55	277.63	65.48
Min	2.65	2.65	7.21	31.78	34.70	23.65	11.60	7.58	4.75	4.20	4.29	2.10

[a] Site: Township 16 South, Range 10 West, Section 32; Drainage area: 20 square miles

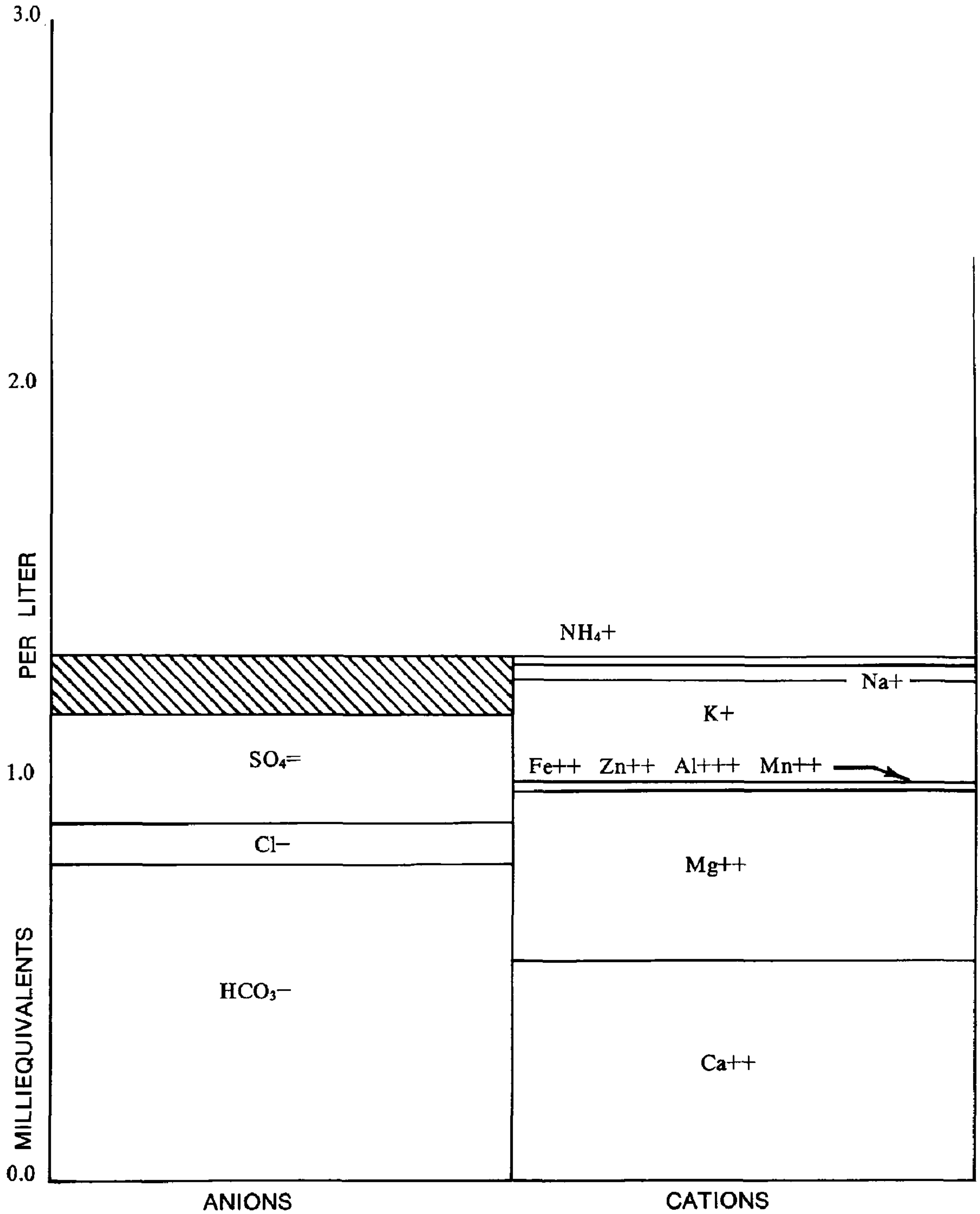

Figure 17. Graphical representation of water quality in a probable pre-mining environment.

TABLE 10 - NUMBER, ANALYTICAL LABORATORY, AND SAMPLE LOCATION, MINE INFLUENT, SITE 3

Sample Number	Lab Performing Analysis	Location
1	Geological Survey of Alabama	Main South Track Dripper
2	Geological Survey of Alabama	North Main West
3	Geological Survey of Alabama	Northeast of Elevator Shaft
6	University of Alabama	North Face Main Track
7	University of Alabama	Main Track Heading South, First Junction South of Slope Bottom
19	University of Alabama	North Flat Number 1 Right

TABLE 11 - TEST RESULTS: WATER SAMPLES, MINE INFLUENT, SITE 3

Parameter	Sample Number 1	3	4	6	7	19	Mean
ACIDITY as mg/l $CaCO_3$	--	--	--	--	--	--	--
ALKALINITY as mg/l $CaCO_3$	774.0	881.0	759.0	46.8	43.7	681.6	531.0
BICARBONATE as mg/l $CaCO_3$	720.0	850.0	720.0	38.2	34.8	600.59	493.9
CARBONATE as mg/l $CaCO_3$	54.0	31.0	39.0	3.6	3.5	74.42	34.25
AMMONIA as mg/l N	0.64	0.70	0.50	0.32	0.28	0.36	0.47
CHLORIDE as mg/l Cl	78.0	240.0	82.0	179.2	77.3	105.5	127.0
HARDNESS as mg/l $CaCO_3$	--	--	--	5.94	2.97	11.6	7.5
pH	9.0	8.7	8.9	9.0	9.03	9.12	8.96
SUSPENDED SOLIDS mg/l	890.0	1270.0	855.0	11.5	16.1	1.0	507.3
SPECIFIC CONDUCTANCE, µmhos/cm	1330.0	1870.0	1290.0	1550.0	110.0	1100.0	1208.3
TEMPERATURE, °C	--	--	20.5	24.0	--	--	22.5
SULFATE as mg/l SO_4	ND[a]	ND	ND	ND	ND	ND	--
TURBIDITY, JTU	5.0	55.0	2.0	17.0	7.1	3.9	15.0
ALUMINUM as mg/l Al	0.06	0.01	0.03	ND	ND	0.24	0.057
ANTIMONY as mg/l Sb	ND	ND	<0.001	ND	ND	ND	<0.00016
CADMIUM as mg/l Cd	<0.001	<0.001	<0.001	ND	ND	ND	<0.0005

TABLE 11 - (Continued)

Parameter	Sample Number						
	1	3	4	6	7	19	Mean
CALCIUM as mg/l Ca	1.1	1.7	1.0	1.75	0.25	2.27	1.35
CHROMIUM as mg/l Cr	ND	ND	ND	ND	ND	ND	--
COPPER as mg/l Cu	0.001	0.002	0.005	ND	ND	ND	0.0013
IRON as mg/l Fe	0.08	0.4	0.06	ND	ND	0.33	0.145
LEAD as mg/l Pb	0.002	0.002	0.003	ND	ND	ND	0.0012
MAGNESIUM as mg/l Mg	0.3	0.5	0.3	1.0	0.5	0.45	0.51
MANGANESE as mg/l Mn	ND	ND	ND	ND	ND	ND	--
MERCURY as mg/l Hg	<0.0002	<0.0002	<0.0002	ND	ND	ND	<0.0001
NICKEL as mg/l Ni	0.001	0.001	0.002	ND	ND	ND	0.0007
POTASSIUM as mg/l K	2.0	2.5	1.7	3.5	2.9	1.14	2.29
SODIUM as mg/l Na	380.0	510.0	370.0	192.0	180.0	104.4	289.4
TIN as mg/l Sn	ND	ND	<0.001	ND	ND	ND	<0.00016
ZINC as mg/l Zn	0.018	0.024	0.013	0.04	0.05	0.067	0.035

[a] None detectable

The analyses of the water indicated that it contained primarily Na^+, Cl^-, HCO_3^-, and $CO_3^=$ ions with trace amounts of Ca^{+2}, Mg^{+2}, Fe^{+2}, Zn^{+2}, NH_4^+, K^{+3}, Hg^{+2}, Cd^{+2}, Cu^{+2}, Pb^{+2}, Ni^{+2}, Sn^{+4}, Al^{+3}, and Mn^{+2} ions.

In figure 18, a graphical representation of ions in solution is given. The vertical scale represents mean milliequivalents per liter of anions or cations which are summed vertically to give a total concentration. The milliequivalent weight, per liter, of each constituent is given in table 12. In principle, the total of cations should equal the total of anions, but because of probable analytical error, a difference of 1.359 milliequivalents/liter was obtained. This difference is represented by the shaded area on the right side of the graph.

As taken from figure 18 and table 11, the water flowing into the mine shows the following characteristics:

(1) high pH: an average value of 8.96;
(2) high alkalinity: an average value of 531.0 mg/ℓ $CaCO_3$, primarily as HCO_3;
(3) high concentrations of Na^+ and Cl^- ions in solution;
(4) low hardness: an average value of 7.5 mg/ℓ as $CaCO_3$;
(5) high specific conductance: caused principally by high concentration of salts of Na^+ as indicated in figure 35;
(6) zero acidity; and
(7) trace concentrations of the metals Al, Cd, Ca, Cu, Fe, Pb, Mg, Hg, Ni, K, Sn, and Zn.

Sources and Quality of Mine Effluent

The effluent from the mine was sampled four times from May to August of 1975. All samples were taken at the same place, i.e., at the pump outlet on the surface near the ventilation shaft. The route of the water sampled is from the interior of the mine to a collection tank and then to a settling pond. At the sampling point chosen, the outflow had not yet had an opportunity to settle.

As given in the monthly reports, the dates and corresponding samples are:

May 23	Sample 1
July 25 (end of miner's holiday)	Sample 9
August 7	Sample 11
August 25	Sample 14

Samples 1, 11, and 14 represent effluent during operation of the mine whereas sample 9 represents effluent during an idle period. Sample 9 was taken at the end of the miner's holiday which represents a two-week period during which only maintenance was done. No water was pumped into the mine for dust suppression around the continuous miners.

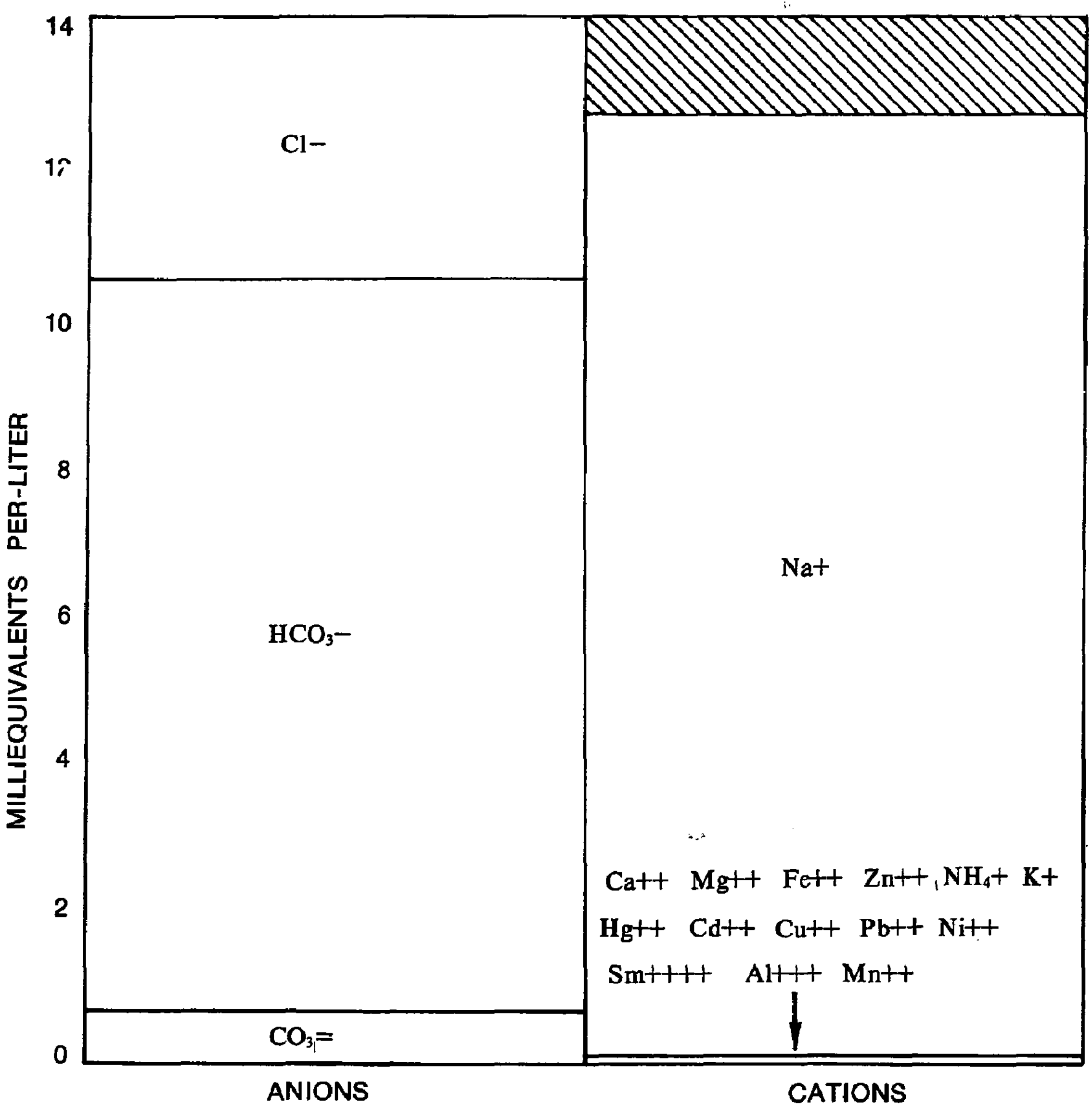

Figure 18. Graphical representation of water quality of mine influent.

TABLE 12 - MEAN MILLIEQUIVALENT WEIGHT, PER LITER, IONS IN SOLUTION, MINE INFLUENT SAMPLES, SITE 3

Cations and anions	meq/1
CATIONS:	
Na^{+}	12.588
Ca^{+2}	0.06593
K^{+}	0.05856
Mg^{+2}	0.0418
NH_4^{+}	0.0258
Fe^{+2}	0.0052
Zn^{+2}	0.0011
Hg^{+2}, Cd^{+2}, Cu^{+2}, Pb^{+2}, Ni^{+2}, Sn^{+4}, Al^{+3}	0.00019
Total	12.78700
ANIONS:	
HCO_3^{-}	9.878
$CO_3^{=}$	0.685
Cl^{-}	3.583
Total	14.146

A summary of results is reported in tables 13 and 14. Table 13 gives the specific tests done and mean values for each test, with the exception of the metal analyses, which are reported separately in table 14. The values of table 13 are confined to samples 1, 11, and 14. In table 14, the operating conditions are representative of samples 1, 11, and 14, and the idle conditions by sample 9. In figure 19, the data of table 14 are shown in bar graph representation to indicate how mine operation affects concentration of total metals.

The physical description of the water at the time of sampling was that of a gray sludge-like fluid. This was reflected in the experimental analysis by the high values for turbidity and suspended solids.

On analysis, the water proved to be a highly buffered system with a high concentration of dissolved salts and total metals.

The water had a total alkalinity of 559.3 and was slightly alkaline with a pH of 8.63. The high alkalinity value was caused primarily by HCO_3^- and to a lesser extent by $CO_3^=$.

The high salt content can be seen in the high concentrations, primarily, of Cl^-, Na^+, and K^+ and high specific conductances. The average conductance value was 1923.3 micromhos, and concentrations of Cl^-, Na^+, and K^+ in solution were respectively 336.1, 165.5, and 6.97 mg/ℓ.

Total metals, including material in suspension, are plotted in figure 19. The primary contributors are Al, Na, K, Fe, Mg, Ca, with trace amounts of Cu, Zn, Cr, Mn, Pb, and Ni. The following trends are noted:

(1) Of the 16 metals analyzed, all except Ca and Na showed substantial decreases when the mine was not operating.

(2) The idle condition yielded a sample with a lower ratio of total to dissolved metals. For example, in the case of Fe, during operation a ratio of total to dissolved metals was 109.4 / 3.3, or 33 to 1. When the mine was idle the ratio was much lower at 2.4 / 1.25, or approximately 2 to 1.

(3) In the operational mode, trace amounts of elements such as Cr, Cu, Pb, and Ni are noted. In the non-operational mode, these elements were absent with the exception of Sb which occurred in the dissolved state.

Post-Mining Environment

The effects of mine operation on water quality in the area were observed from the samples that were taken below the drainage area of the mine. As previously mentioned, all samples taken below the mine of Cedar Creek and North River were assumed to be affected by mining operations.

TABLE 13 - MEAN VALUES FOR CERTAIN PARAMETERS OF MINE WATER EFFLUENT, SITE 3

Parameters	Mean
ACIDITY, mg/l $CaCO_3$	0
ALKALINITY, mg/l $CaCO_3$	559.3
AMMONIA, as mg/l NH_3	.62
CHLORIDE, mg/l as Cl	336.1
HARDNESS, mg/l as $CaCO_3$	67.5
pH	8.63
SPECIFIC CONDUCTANCE, units	1923.3
SULFATE, units	14.4
TURBIDITY, JTU	7688.3
SUSPENDED SOLIDS, mg/l	3713.3
TEMPERATURE, ^{o}C	23.0

TABLE 14 - METAL ION CONCENTRATIONS OF MINE WATER EFFLUENT SAMPLES: MEAN VALUES FOR MINE IN OPERATION AND ONE VALUE FOR MINE IDLE

Parameter (mg/l)		Operating Conditions	Non-Operating Conditions
Al	total	360.0	28.0
	dissolved	2.19	4.8
Sb	total	ND[a]	ND
	dissolved	ND	0.8
Cd	total	ND	ND
	dissolved	ND	ND
Ca	total	9.25	8.5
	dissolved	16.1	12.5
Cr	total	1.33	ND
	dissolved	ND	ND
Cu	total	0.32	ND
	dissolved	ND	ND
Fe	total	109.4	2.4
	dissolved	3.3	1.25
Pb	total	0.42	ND
	dissolved	ND	ND
Mg	total	67.2	11.5
	dissolved	13.2	ND
Mn	total	0.2	ND
	dissolved	0.16	0.043
Hg	total	ND	ND
	dissolved	ND	ND
Ni	total	0.53	ND
	dissolved	ND	ND
K	total	234.3	12.5
	dissolved	6.87	3.83
Na	total	282.3	183.0
	dissolved	165.5	182.0
Sn	total	ND	ND
	dissolved	ND	ND
Zn	total	0.91	0.025
	dissolved	0.81	0.17

[a] None detectable

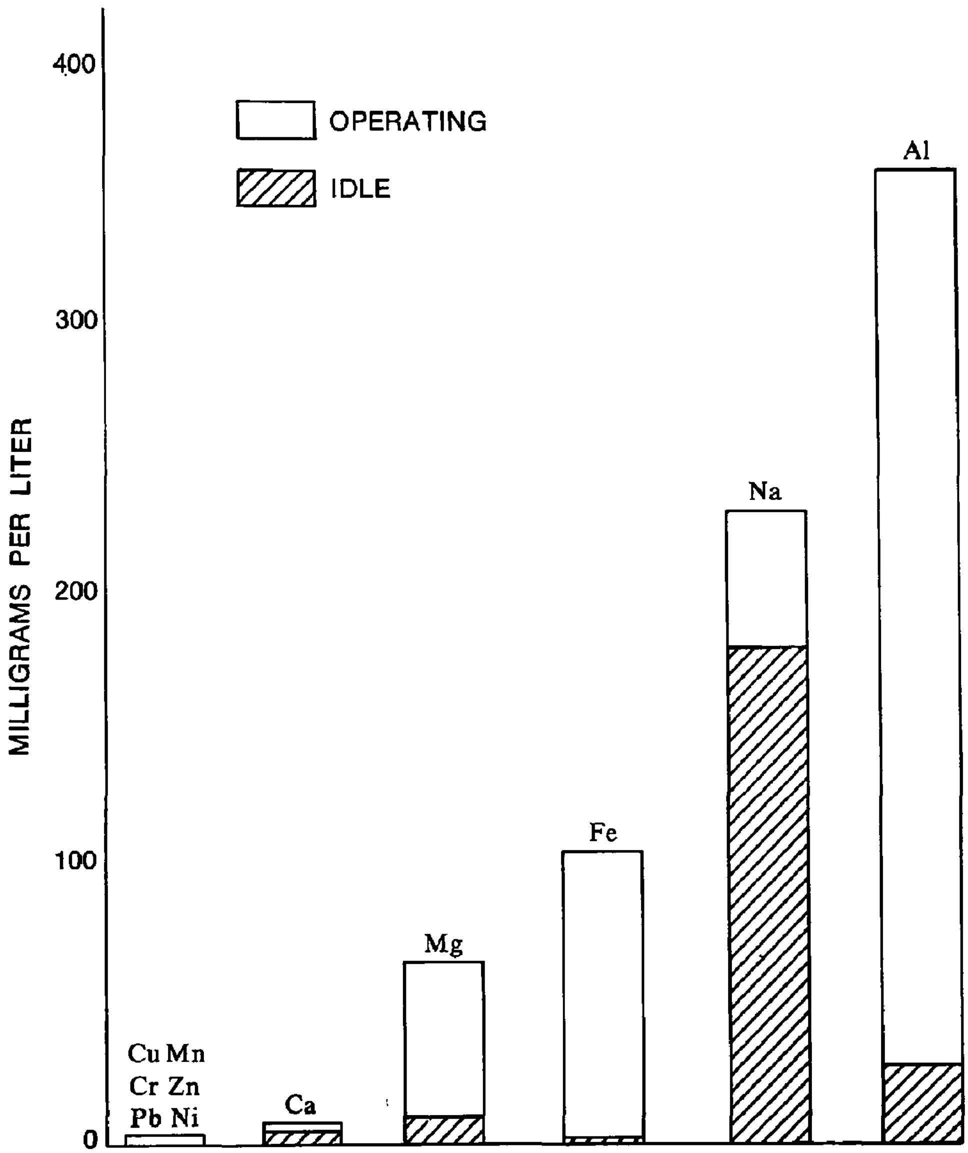

Figure 19.--Graphical representation, water quality, mine effluent, mine operating and mine idle.

In the experimental analysis, the samples that were affected and their respective sampling dates and location are:

Sample 5 -- taken May 23 from Cedar Creek, 3.1 miles below the mine and just above the confluence of North River and Cedar Creek.

Sample 10 -- taken July 16 from Cedar Creek, 1.9 miles below the mine. (This sample represents the down condition of the mine.)

Sample 12 -- taken August 7 from Cedar Creek, 2.8 miles below the mine.

Sample 16 -- taken August 25 from the same location as 12 and 18.

Sample 18 -- taken September 11 from the same location as 12 and 16.

The results are given in table 15.

A representative sample of the water, sample 18 taken on September 11, is plotted graphically, figure 20, to show the concentrations of ions in milliequivalents/liter of solution. The primary anions are HCO_3^-, Cl^-, and $SO_4^=$, and the primary cations are Na^+, Ca^{+2}, Mg^{+2}, Al^{+3} with trace amounts of Fe^{+2}, Mn^{+2}, K^+, and Sn^{+2}.

The water also has the following characteristics:

(1) low acidity value: maximum of 4.15 mg/ℓ as $CaCO_3$;
(2) average BOD for natural waters ranging from 0.5 to 1.45 mg/ℓ;
(3) high concentration of dissolved oxygen;
(4) low chloride concentration: maximum of 21.8 mg/ℓ;
(5) neutral pH, ranging from 6.32 to 7.14; and
(6) low dissolved solids: maximum of 36.5 mg/ℓ.

Influence of Mining Operations on Water Quality

During mine operation, the only potential polluting mechanism was the mine waste that was pumped to the surface. This assumption is made because at the depth of 500 feet, there should be no observable effects on subsurface ground water quality.

To examine the actual differences in mine effluent when the mine was operating or idle, a comparison was made. Table 16 shows average condition, range, and percent change of condition. The data in table 16 were derived by taking mean values of each parameter as reported in their respective sections.

TABLE 15 - TEST RESULTS: WATER SAMPLES COLLECTED FROM CEDAR CREEK DOWNSTREAM FROM MINE, SITE 3, POST-MINING ENVIRONMENT

Parameter	Sample Point				
	5	10	12	16	18
ACIDITY as mg/l $CaCO_3$	4.15	2.08	2.6	2.59	3.6
ALKALINITY as mg/l $CaCO_3$	26.0	53.8	34.3	28.2	80.0
BICARBONATE as mg/l $CaCO_3$	26.0	53.8	34.3	28.2	80.0
CARBONATE as mg/l $CaCO_3$	--	--	--	--	--
AMMONIA as mg/l N	0.12	ND[a]	0.7	0.06	0.88
BIOCHEMICAL OXYGEN DEMAND mg/l (5 days @ 20°C)	0.5	1.1	0.7	0.8	1.45
CHLORIDE as mg/l Cl	1.74	5.4	3.79	3.75	21.8
DISSOLVED OXYGEN, mg/l	--	8.0	8.5	7.8	7.1
HARDNESS mg/l $CaCO_3$	29.3	31.6	23.5	32.4	4.15
pH	6.32	7.14	7.14	7.12	7.0
SUSPENDED SOLIDS, mg/l	11.5	36.5	5.32	32.5	21.0
SPECIFIC CONDUCTANCE μmhos/cm	60.0	180.0	91.4	108.0	275.0
TEMPERATURE, °C	22.0	--	22.0	26.5	25.0
SULFATE as mg/l SO_4	1.5	ND	0.7	5.4	12.0
TURBIDITY JTU	13.0	33.0	17.0	13.0	24.0

TABLE 15 - (Continued)

Parameter	Sample Point 5	10	12	16	18
ALUMINUM as mg/l Al	ND	2.3	1.5	0.7	1.62
ANTIMONY as mg/l Sb	ND	ND	ND	ND	ND
CADMIUM as mg/l Cd	ND	ND	ND	ND	ND
CALCIUM as mg/l Ca	4.0	7.3	6.8	6.25	14.6
CHROMIUM as mg/l Cr	ND	ND	ND	ND	ND
COPPER as mg/l Cu	ND	ND	ND	ND	ND
IRON as mg/l Fe	1.0	ND	0.7	0.64	1.05
LEAD as mg/l Pb	ND	ND	ND	ND	ND
MAGNESIUM as mg/l Mg	2.5	3.8	3.1	2.5	6.38
MANGANESE as mg/l Mn	ND	ND	0.15	0.04	0.09
MERCURY as mg/l Hg	ND	ND	ND	ND	ND
NICKEL as mg/l Ni	ND	ND	ND	ND	ND
POTASSIUM as mg/l K	1.6	3.05	1.65	1.6	1.4
SODIUM as mg/l Na	5.5	14.2	9.14	9.3	33.7
TIN as mg/l Sn	ND	ND	ND	ND	ND
ZINC as mg/l Zn	ND	0.03	ND	0.4	1.3

a None detectable

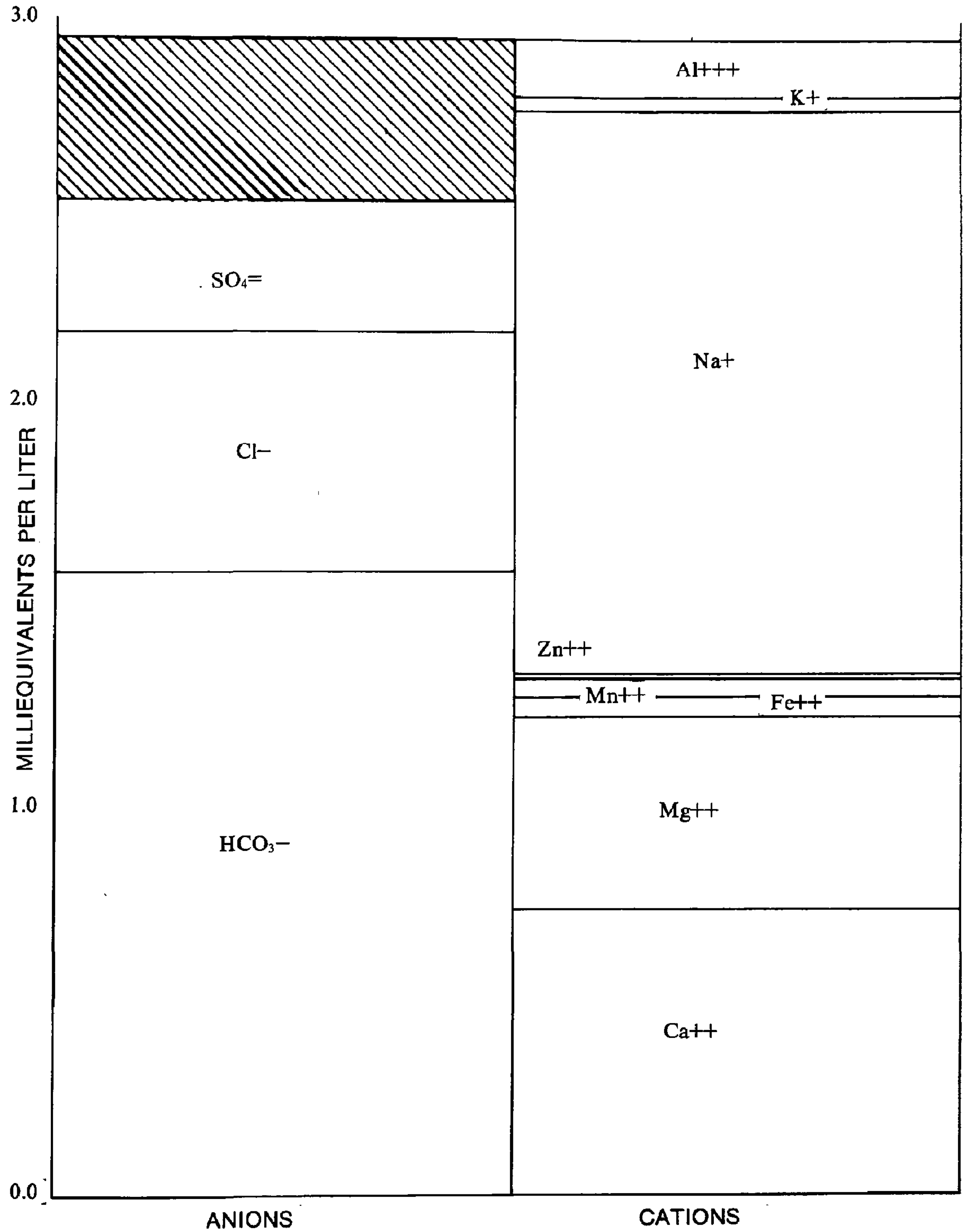

Figure 20. Graphical representation of water quality in post-mining environment (Cedar Creek watershed), site 3.

TABLE 16 - RANGE, MEAN VALUES AND PERCENTAGE CHANGE

OF WATER QUALITY PARAMETERS, MINE OPERATING AND MINE IDLE, SITE 3

Parameter	Mine Operating		Mine Idle		% increase idle
	Range	Mean	Range	Mean	
ACIDITY as mg/l $CaCO_3$	3.1 - 5.2	3.89	2.6 - 4.2	3.0	-22.9
ALKALINITY as mg/l $CaCO_3$	15.6 - 86.3	34.95	26.0 - 80.0	44.7	27.2
AMMONIA as mg/l $N:NH_3$	0.1 - 1.3	0.448	0.0 - 0.88	0.352	-21.5
BIOCHEMICAL OXYGEN DEMAND, mg/l	0.3 - 2.0	0.98	0.5 - 1.45	0.71	-27.8
DISSOLVED OXYGEN, mg/l	8.0 - 8.7	8.43	7.1 - 8.5	7.85	- 6.9
HARDNESS as mg/l $CaCO_3$	4.8 - 23.2	15.02	4.2 - 32.4	24.19	61.1
pH	6.0 - 7.07	6.7	6.3 - 7.14	6.94	3.6
SUSPENDED SOLIDS, mg/l	3.2 - 21.0	10.9	5.32 - 36.5	21.36	96.0
SPECIFIC CONDUCTANCE, μmhos/cm	25.7 - 130.0	52.3	60.0 - 180.0	141.04	169.8
SULFATE as mg/l SO_4	0.02 - 0.8	0.47	0.0 - 13.0	4.12	799.0
CHLORIDE as mg/l Cl	0.5 - 2.6	1.721	1.74 - 21.8	7.296	323.9
TURBIDITY, JTU	8.5 - 24.0	11.97	13.0 - 33.0	20.0	67.1
ALUMINUM as mg/l Al	0.0 - 0.3	0.05	0.0 - 2.3	1.53	2950.0
CALCIUM as mg/l Ca	0.5 - 10.9	3.38	4.0 - 14.6	7.8	130.8
IRON as mg/l Fe	0.5 - 0.85	0.68	0.0 - 1.05	0.85	24.1
MAGNESIUM as mg/l Mg	1.5 - 6.1	2.76	2.5 - 6.4	3.66	32.7
MANGANESE as mg/l Mn	0.0 - 0.15	0.05	0.0 - 0.15	0.056	12.0
POTASSIUM as mg/l K	0.88 - 7.5	2.07	1.4 - 3.1	1.86	-10.0
SODIUM as mg/l Na	0.7 - 5.5	2.489	5.5 33.7	14.37	477.3
ZINC as mg/l Zn	0.0 - 0.112	0.024	0.0 1.3	0.35	1323.0

Figures 21 through 35 are graphical representations of acidity, alkalinity, specific conductance, suspended solids, pH, Fe^{++}, Al^{+++}, Ca^{++}, Mg^{++}, K^{+}, Na^{+}, Mn^{++}, Zn^{++}, $SO_4^{=}$, Cl^{-} concentrations as functions of river miles. The ordinate represents river miles on Cedar Creek, with the positive values corresponding to sample points above the mine and negative values corresponding to sample points below the mine. The zero point, or point of discharge, represents the location of the mine. The actual distance represented is 4.2 miles above the mine and 3.1 miles below the mine or a total of 7.3 river miles. The abscissa represents concentration of parameter as specified on each graph. Actual water flow is from right to left on each graph. In figure 22, the rate at which a unit quantity of acidity as $CaCO_3$ flows past a given point is shown in mg/sec.

Combining the data in table 16 and figures 21 through 35 and relating this to the quality of mine effluent (tables 13 and 14), a direct influence of mining operations on Cedar Creek was observed. All parameters in figures 21 through 35 showed an increase with the exception of acidity, which decreased. The most pronounced increases were observed in Na^{+}, Cl^{-}, $SO_4^{=}$, Al^{+++}, Zn^{++}, and Ca^{++}, with mean increases of 477.3, 323.9, 799.0, 2950.0, 1323.0, and 130.8 percent, respectively. The value for acidity decreased 22.9 percent, and alkalinity increased 27.2 percent.

The most important inference made from the data is that there appears to be a "freezing" of acid-producing reactions at the point of discharge. This is shown in the graphs for acidity, alkalinity, pH, Fe^{++}, and $SO_4^{=}$ (figures 21, 22, 23, 26, 27, and 34, respectively).

A simplified model for the production of acid mine drainage from pyritic sulfur is given by the following four reactions:

(1) $FeS_2(s) + 7/2\ O_2 + H_2O \rightarrow Fe^{+2} + 2SO_4^{-2} + 2H^{+}$

(2) $Fe^{+2} + 1/2\ O_2 + 2H^{+} \rightarrow Fe^{+3} + H_2O$

(3) $Fe^{+3} + 3H_2O \rightarrow Fe(OH)_3\ (s) + 3H^{+}$

(4) $Fe(s) + 14Fe^{+3} + 25^{=} + 8H_2O \rightarrow 15Fe^{+2} + 2SO_4^{-2} + 16H^{+}$

These reactions describe the oxidation of iron pyrite and show that the concentration of sulfate or acidity in the water is directly related to the amount of pyrite dissolved. For each mole of iron pyrite dissolved four equivalents of acidity are released.

The sequence with which the reactions occur is shown in figure 36.

The first reaction (a) is the oxidation of iron pyrite by air or the dissolving of iron pyrite followed by oxidation (a'). The Ferrous iron is then oxygenated slowly (b) and the resultant ferric iron is rapidly reduced by pyrite (c) releasing more acidity and seeding reaction (b) with more Fe(II). The end product is the production of $Fe(OH)_3$ (s)(d).

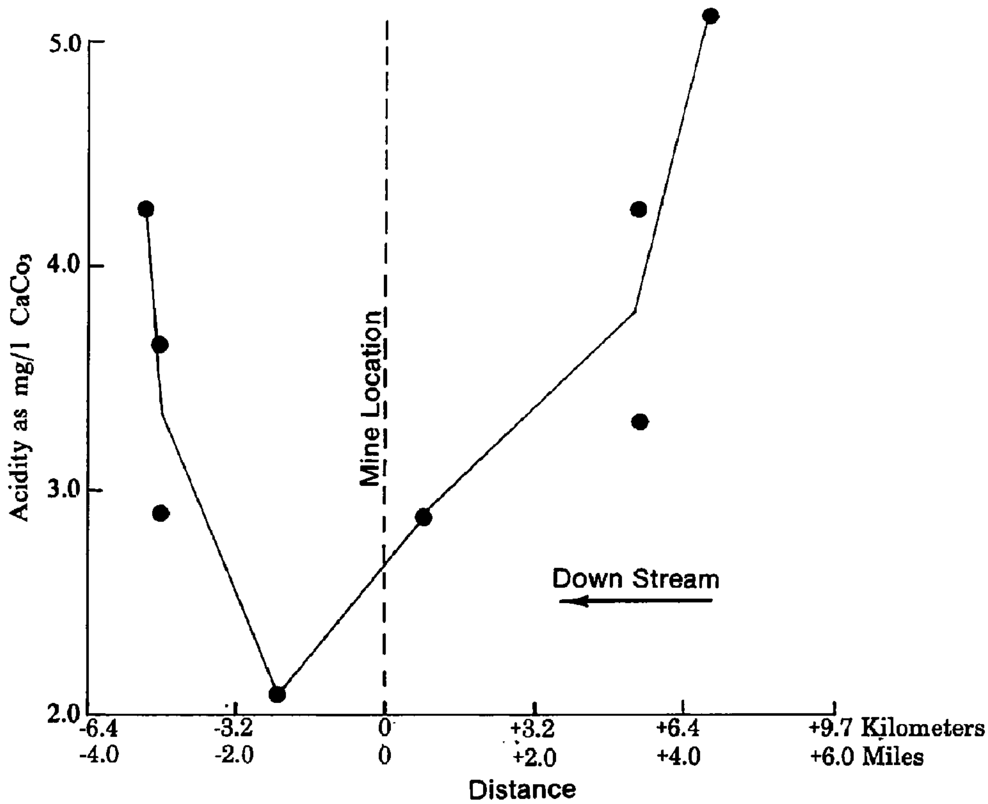

Figure 21.--Changes in acidity as $CaCO_3$ mg/liter, with direction and distance, Cedar Creek.

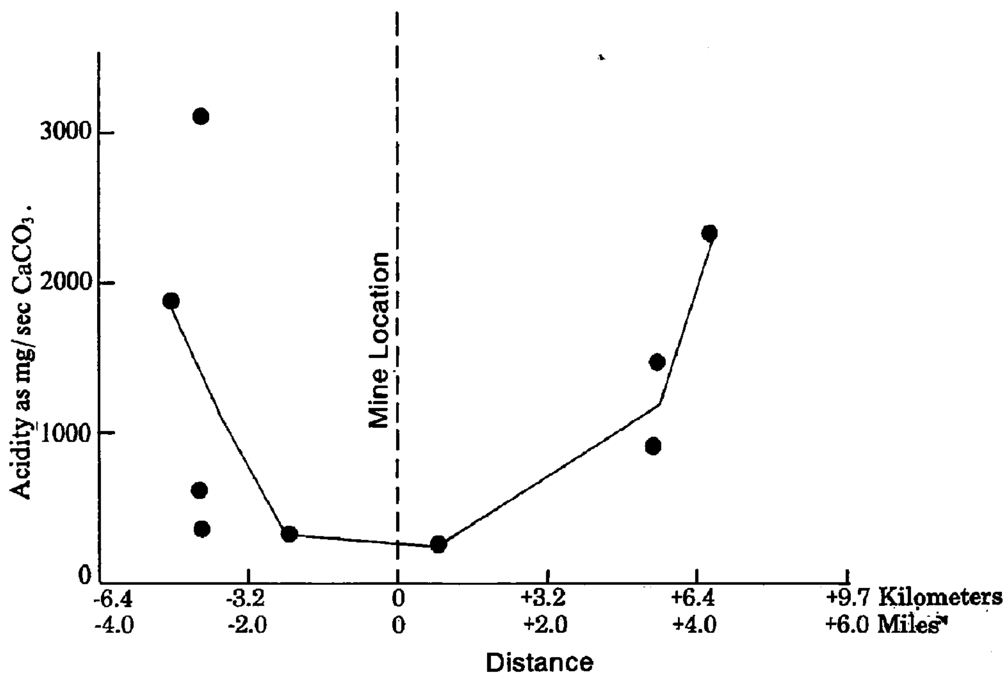

Figure 22. Changes in acidity (as mg/sec. $CaCO_3$) with direction and distance, Cedar Creek.

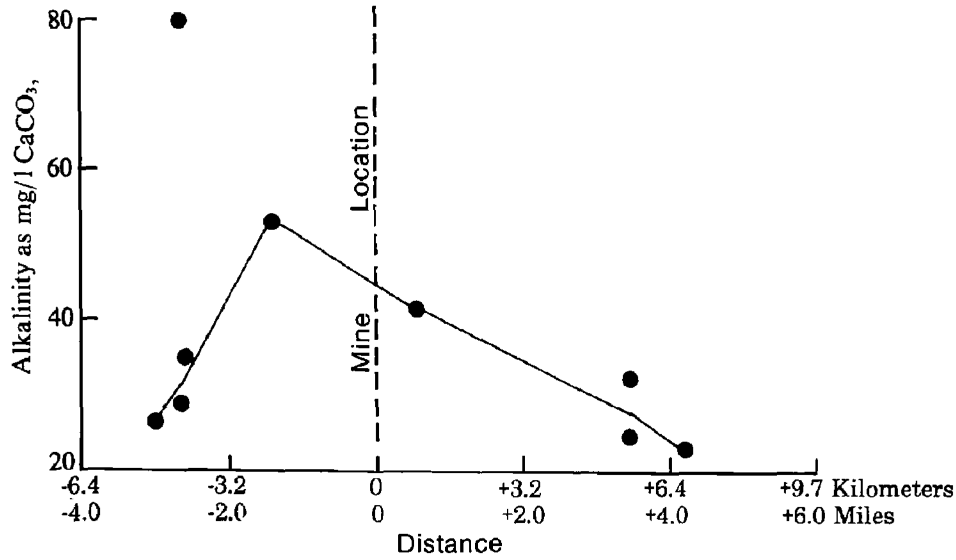

Figure 23. Changes in alkalinity (as mg/l $CaCO_3$) with direction and distance, Cedar Creek.

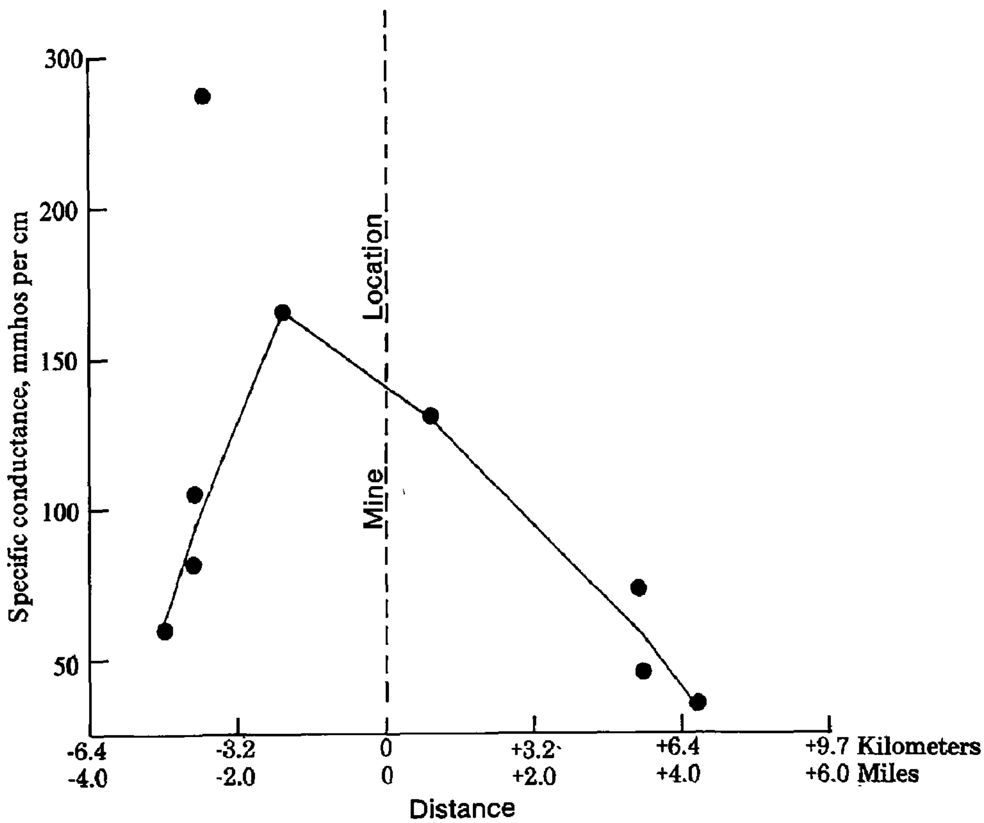

Figure 24. Changes in specific conductance (mmhos/cm) with direction and distance, Cedar Creek.

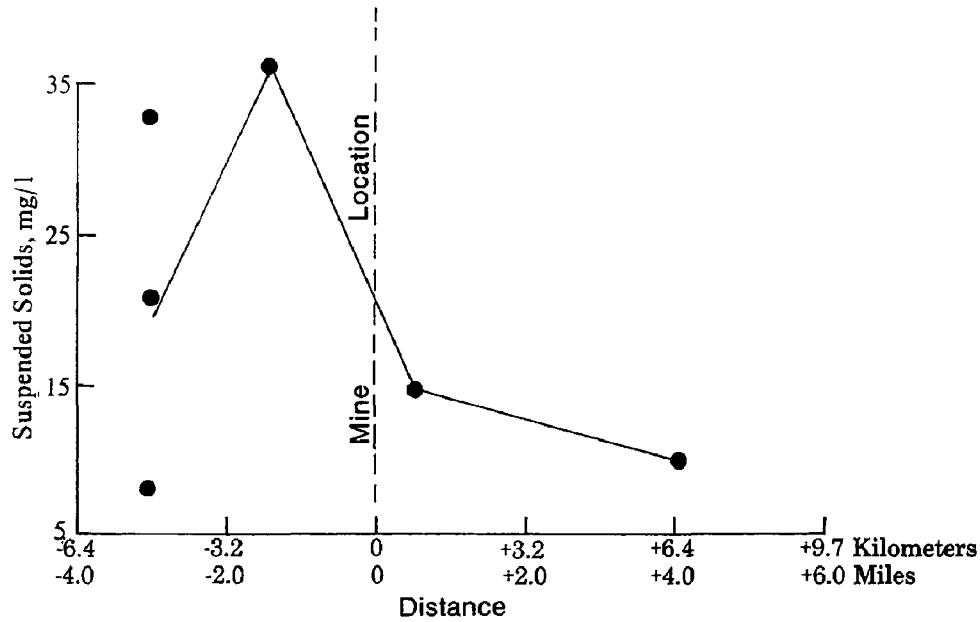

Figure 25. Changes in suspended solids (mg/l) with direction and distance, Cedar Creek.

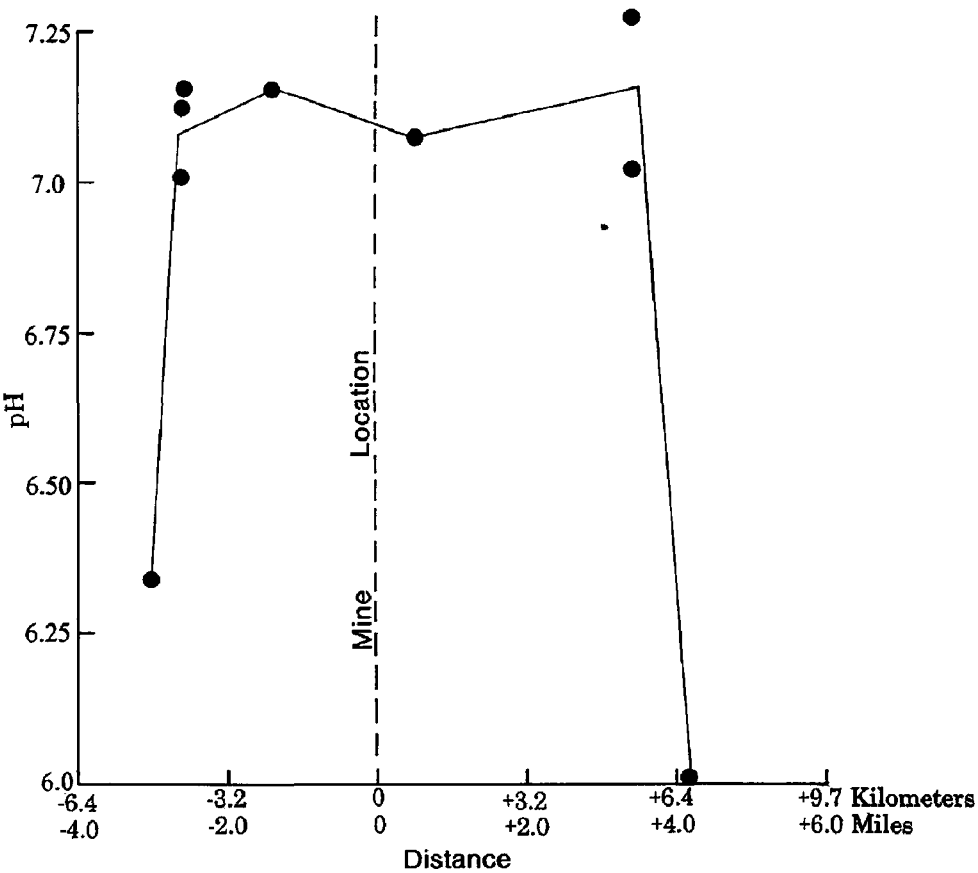

Figure 26. Changes in pH with direction and distance, Cedar Creek.

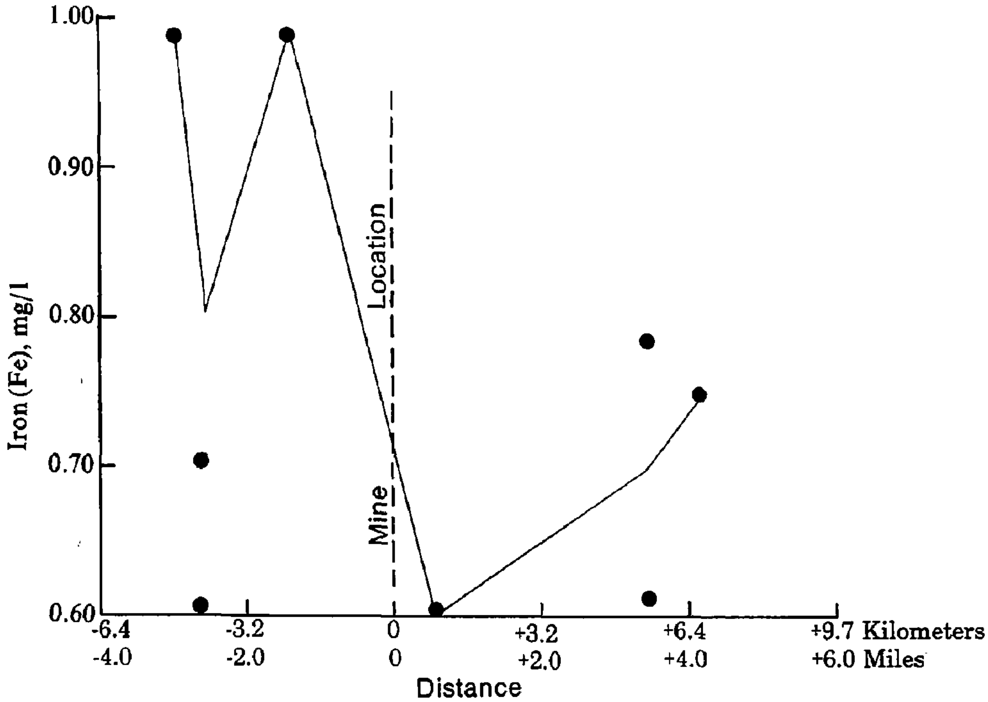

Figure 27. Changes in Fe ion concentration (mg/l) with direction and distance, Cedar Creek.

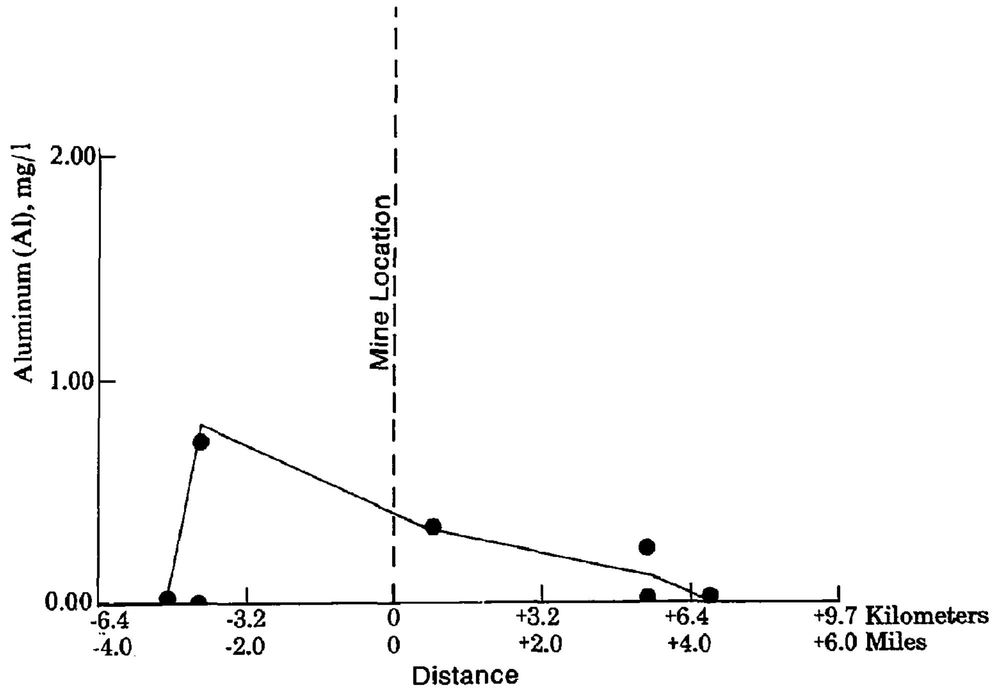

Figure 28. Changes in Al ion concentration (mg/l) with direction and distance, Cedar Creek.

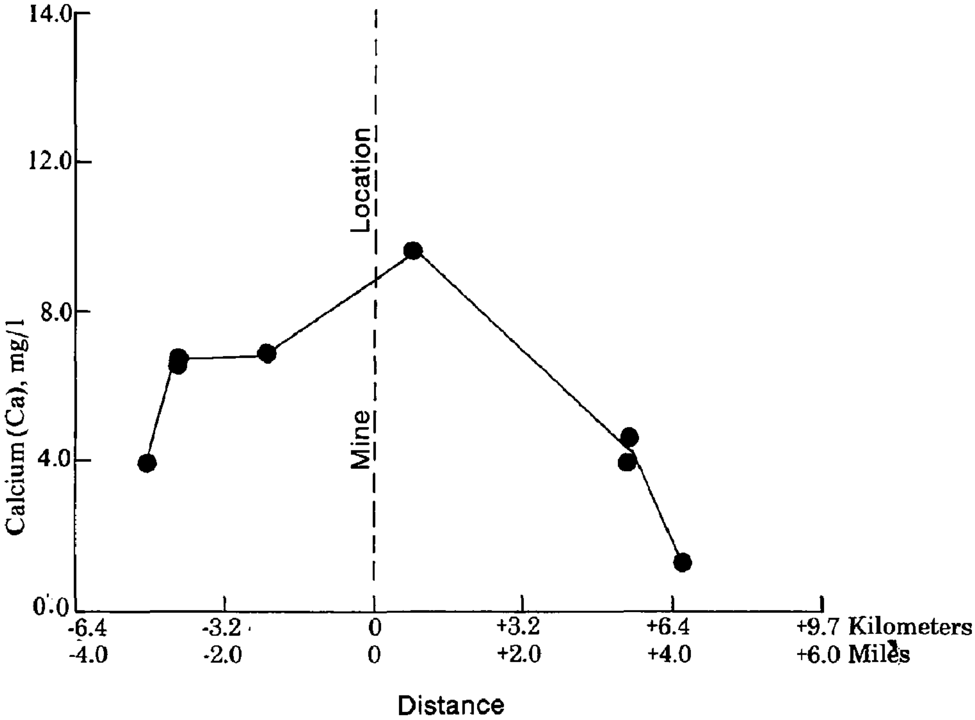

Figure 29. Changes in Ca ion concentration (mg/l) with direction and distance, Cedar Creek.

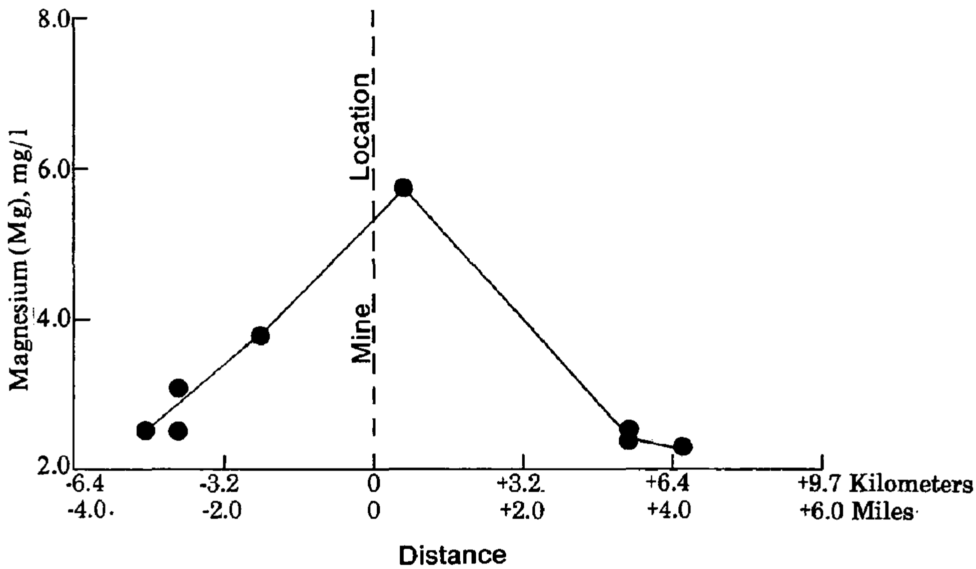

Figure 30. Changes in Mg ion concentration (mg/l) with direction and distance, Cedar Creek.

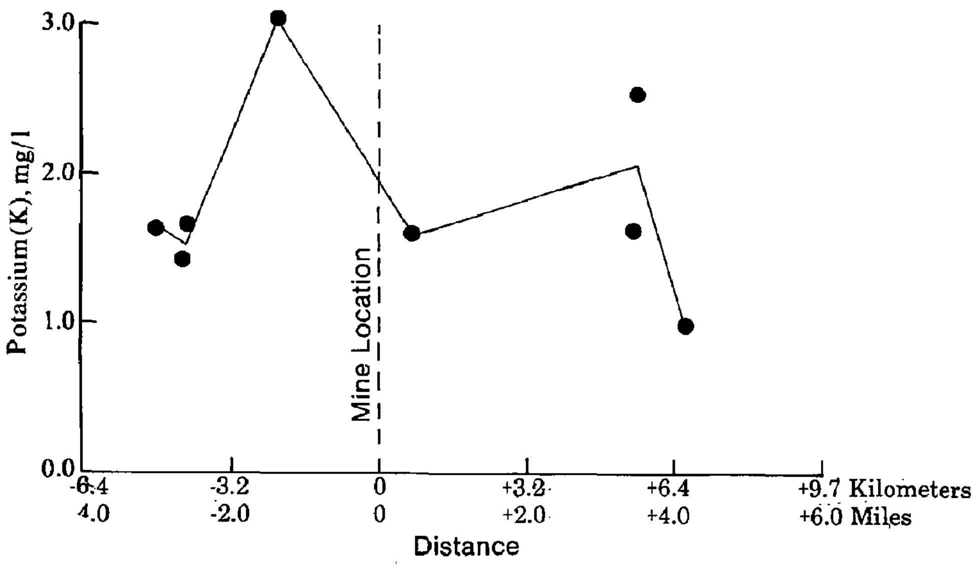

Figure 31. Changes in K ion concentration (mg/l) with direction and distance, Cedar Creek.

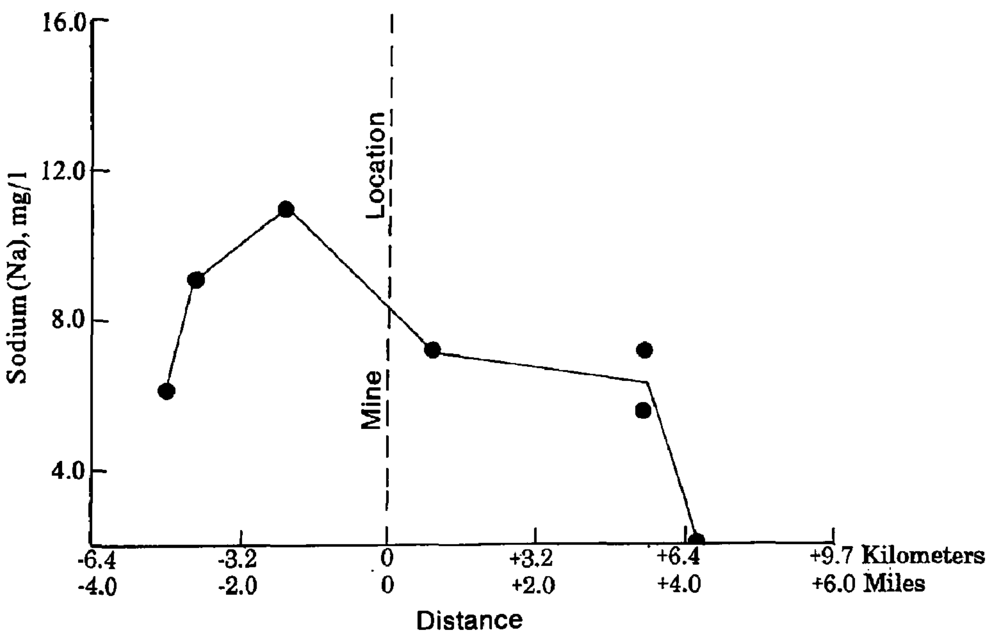

Figure 32. Changes in Na ion concentration (mg/l) with direction and distance, Cedar Creek.

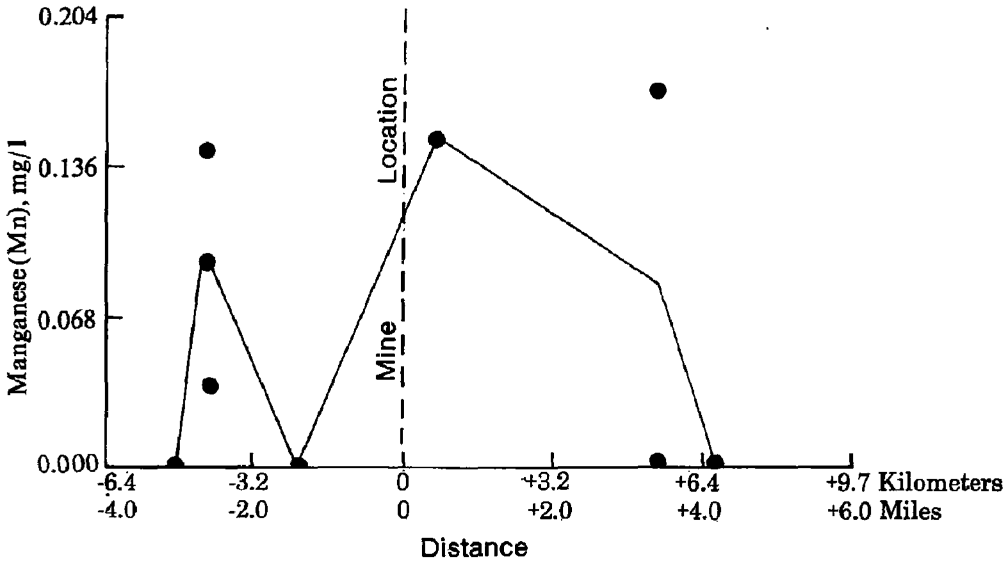

Figure 33. Changes in Mn ion concentration (mg/l) with direction and distance, Cedar Creek.

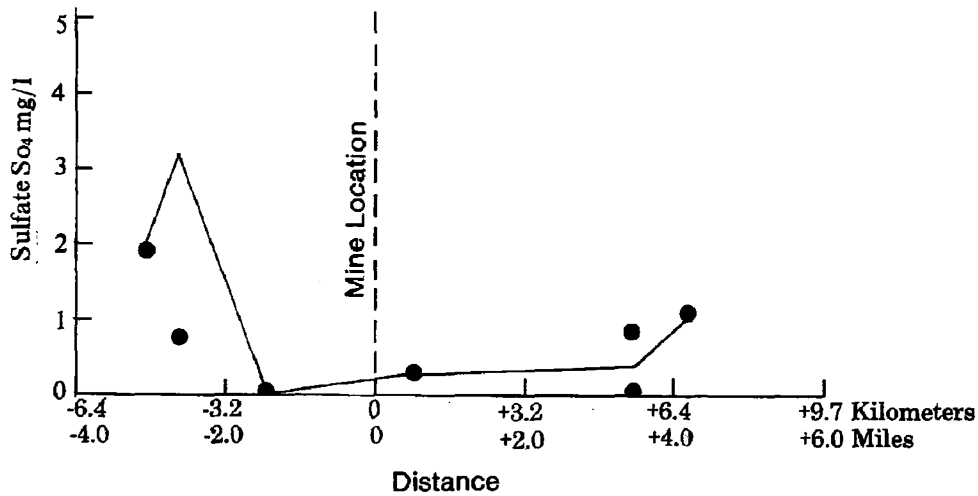

Figure 34. Changes in SO_4 ion concentration (mg/l) with direction and distance, Cedar Creek.

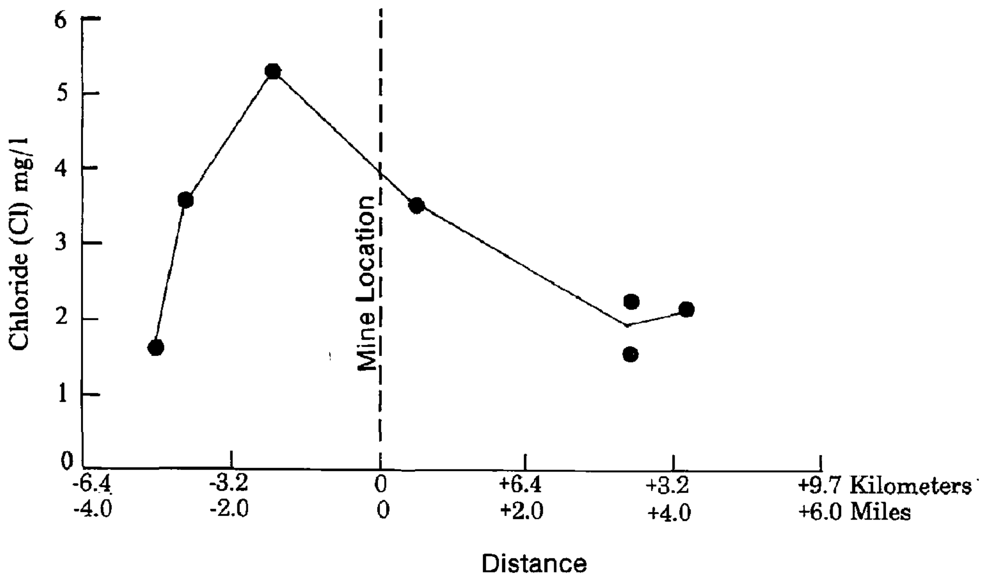

Figure 35. Changes in Cl ion concentration (mg/l) with direction and distance, Cedar Creek.

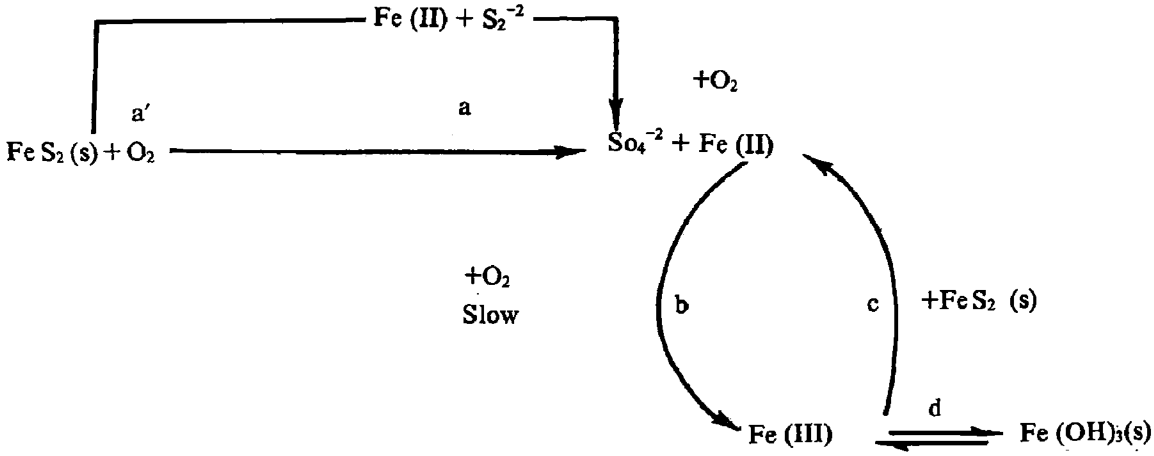

Figure 36. Sequence of reactions in the oxidation of pyrite.

Relating the process for the oxidation of pyrite to all the figures, and to the fact that the actual mine waste was alkaline with low sulfate (14.4 mg/l), high total Fe (109.4 mg/l), and low dissolved Fe (3.3 mg/l), the "freezing" effect can be explained.

The Fe and acidity graphs show an increase of concentration downstream. The alkalinity graph shows an increase and then a decrease, as does the SO_4^{-2} graph. What appears to be occurring is that the addition of lime from rock dusting to the mine water causes a stoppage of acid production by not allowing reaction (1) to occur. This is justified by the low concentration of SO_4^{-2} and dissolved Fe^{++} and high concentration of total Fe. The actual makeup to total Fe is not known, but the mining of a medium sulfur content coal probably contributes some FeS_2 to the mine wastewater. After the effluent is diluted and traveling downstream, reaction (1) begins to occur releasing H^+, SO_4^{-2}, and Fe^{+2}. This effect is noted in each graph.*

PREDICTED FUTURE ENVIRONMENTAL EFFECTS

Mine Water Effluent

The samples of mine effluent, reported herein, were taken relatively early in the history of mining at North River No. 1 and the effluent appears not to pollute the present hydrologic system of the area unduly. This is a favorable circumstance, but it leads to questions regarding probable environmental effects as the mine reaches full production, becomes a mature mine, then an old one, and finally an abandoned and sealed mine. None of the data really answer the question; therefore, an answer must come by deduction from available data and from the configuration of the abandoned mine.

The potential for acid mine water pollution is certainly present because Corona (Pratt) bed coal mined at North River No. 1 averages around 2.0 percent sulfur (medium sulfur coal).

Conditions at North River No. 1 during the life of the mine and probably after closing are:

(1) Probably no part of the mine will be under less than 130 m (430 feet) of cover, and 160 m (520 feet), on up, will be a much more common figure.

(2) The coal is being mined down-dip, up-dip and along strike. When abandoned, the mine will completely fill with water at the coalbed level, because the water table everywhere lies well above the Corona coalbed.

(3) The slope and two shafts should be the only openings to the surface unless one or more additional air shafts are sunk in the future, as the mined area increases.

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* See selected Bibliography B for special references used in this and other sections dealing with water quality.

Since the top of shafts and slope are at about 130 m (430 feet) above sea level, the coalbed is at 0 to -30 m (0 to -100 feet), the nearest hills around the openings go to no more than 170 m (560 feet) elevation and are about 0.4 km (1/4 mile) away, the water table should stand, in normal weather, everywhere below the top of the shafts, and probably below the top of the slope. There is a possibility that in wet weather the openings might overflow, so that for this reason, as well as for reasons of safety, all openings should be securely sealed.

With the mine effectively sealed and filled with water, little or no oxygen should enter. Surface waters slowly co-mingling with circulating ground water should provide a minor source of pyrite oxidation. Even if some acid is produced in the mine, as long as there is no surface outflow, the environment of the surface should be unaffected. If there is occasional outflow from a drain pipe in the sealed drift, the limited access of oxygen to the mine water should make any overflow harmless. If this proves not to be the case, neutralization of such overflow should prove easy and relatively inexpensive.

Mine Subsidence

North River No. 1 is not old enough for any data to be taken on the problem of possible surface subsidence and damage to the surface. Any projections regarding subsidence will not, therefore, be based upon field observation or model experiments, but upon deductions from the coalbed thickness, method of mining, depth below surface, and the nature of the overlying strata.

Stefanko[28] has recently summarized present theory and observation concerning subsidence and ground movement. A longer and more detailed review can be found in two reports by Braeuner[29,30].

Broken rock occupies a larger volume than the same mass of solid rock. The increase of volume, on breaking, is dependent upon the size distribution of broken rock. After abandonment and support removal from entries or narrow rooms, successive falls of rock result in filling of the voids and the broken rock eventually begins to support the mass above until, finally, if there is sufficient depth, further subsidence ceases. Subsidence may cease before completion of a full arch if a very strong and competent stratum, like a massive sandstone, is reached. As noted in discussions of the stratigraphy, at least two thick sandstones are present in the strata over North River No.1; therefore, it appears to be unlikely that any serious disturbance of the surface will occur over areas where no second mining (pillar removal) is done.

However, as indicated in the section on "Mining Plan and Layout," present plans for North River No. 1 are to remove pillars except from under certain areas overlain by important surface structures. If complete pillaring proves possible, it is likely that the entire area will subside some, but because of probable competent strata, differential settling should be minimal and damage at the surface minimal or absent.

Figure 37, from Stefanko[31], shows the relation between the percent of coalbed thickness that is settled and the ratio between mine opening width and depth below the surface. It is clear that the subsidence will never be equal to full coalbed thickness but at W/D of about 1.25, a maximum subsidence of about 90 percent is reached. At a depth of 160 m (520 feet), that opening width is about 190 m (625 feet). With complete extraction at North River No. 1, that width will be greatly exceeded in most areas.

If pillar mining proves difficult in certain areas but some, or all, pillars have to be left in other areas, removal cannot be complete and surface damage might occur from differential settling. As long as the area is as sparsely settled and as underdeveloped as at present, damage to surface structures is a most remote possibility. If, however, during the next 20 to 30 year life of the mine, considerable development and population increases occur, surface structure damage might occur. If such development does occur, it would be practical for Republic Steel Corporation and other surface owners to guide the development so that the areas undermined and settled early in mine history are developed first.

PLANS FOR FINAL CLOSURE

In final closure of underground openings, a choice may be made between complete filling of all openings or some kind of near-surface closure. It probably is not practical, from the standpoint of effectiveness to completely fill horizontal or near-horizontal openings. Vertical shafts can be filled rather effectively, although time must be allowed for settling. Sealing of all openings, including vertical shafts, can be done.

Seals will be different in style for the two vertical shafts and the slope. Effectiveness and costs of sealing methods have been studied[32,33]. The rocks at North River No. 1 are layered and vary from thick sandstones to soft shales and underclays. The opening is a rock slope, inclined at $16^{\circ}35'$, which cuts across the bedding planes of the dissimilar layers for its entire length. If it is to be sealed, as it must be, not too far down the slope, a double bulkhead as in figure 38 probably would be best. The bulkhead seal should be tight, but would not need to be unusually strong because the maximum head of water would be low. The rear bulkhead, and possibly both bulkheads, should be extended into a key, cut in the top, side, and bottom. If a drain pipe is to be used in any of the three openings, it should be in the slope which is lowest in elevation of the three.

The sealed slope will hold considerable water below the seals, if they are placed near the surface. Its arching cross-section of approximately 5 m (17 feet) width, 5 m height, and about 550 m (1800 feet) length below the seal has a volume of about 15,000 m^3 (19,000 $yards^3$). The figure would be reduced by the volume of the concrete lining for the first 40 m (130 feet) and by the section at coalbed level.

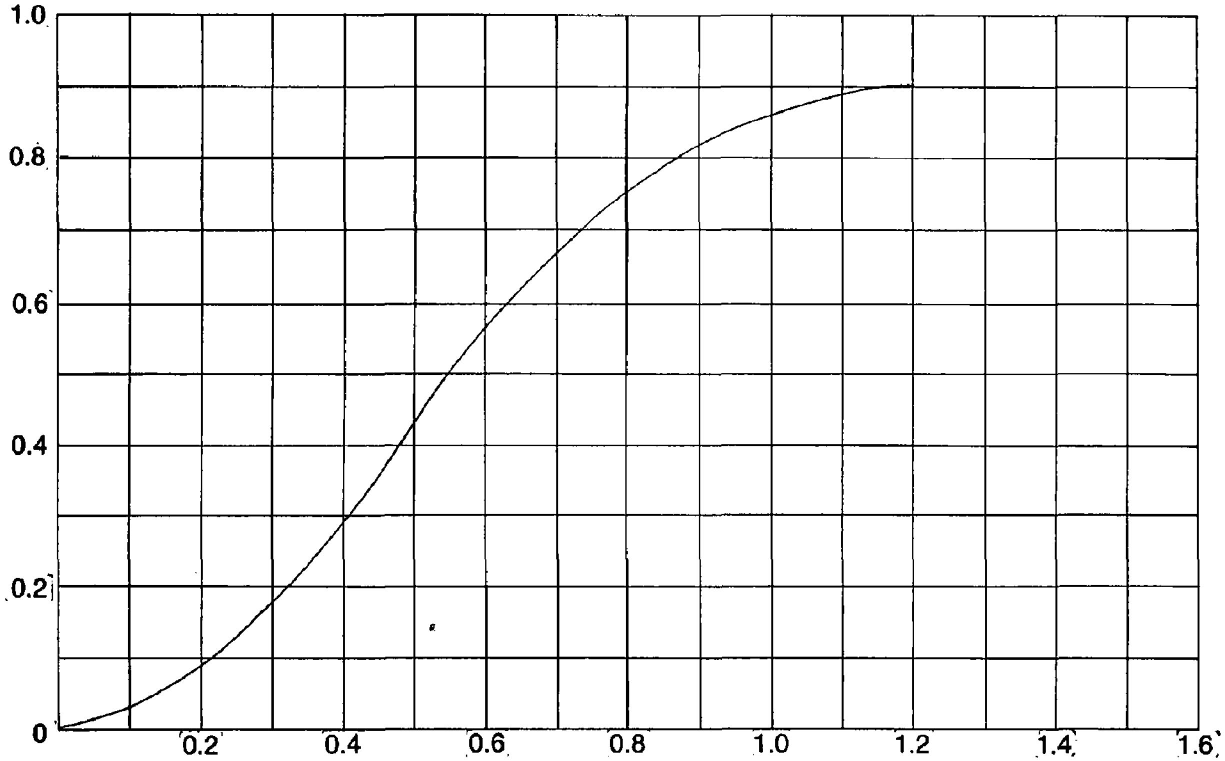

Figure 37. Subsidence as a function of the ratio, opening width to depth below the surface for full caving (ref. 28).

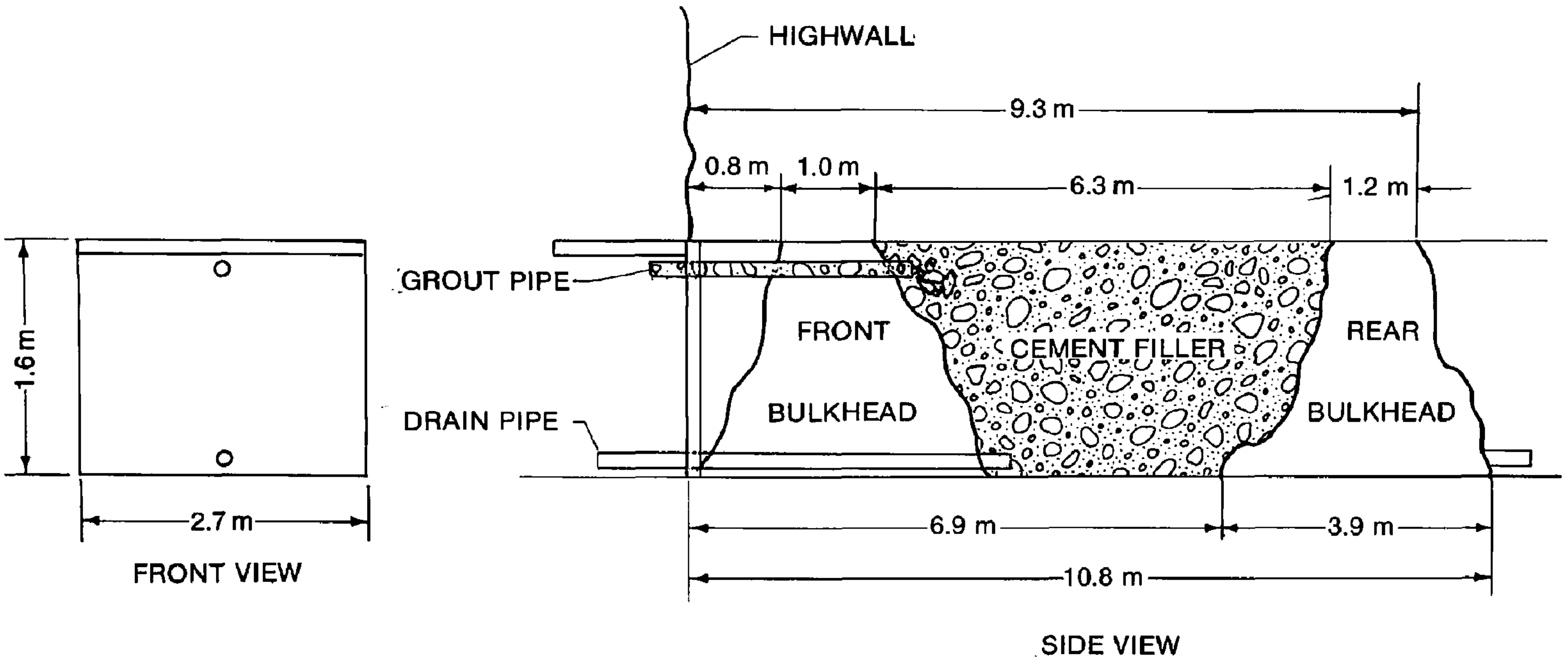

Figure 38. Quick setting double bulkhead seal, Clarksburg, W. Va. (ref. 32).

With complete circumferential keys, 30 cm (1 foot) deep and 61 cm (2 feet) long, a cross-sectional area of about 22 m^2 (230 $feet^2$) and bulkhead shapes as shown in figure 38, approximately 140 m^3 (200 $yards^3$) of cement would be required for the bulkheads and 150 m^3 (200 $yards^3$) of light cement, for the space between bulkheads. If the seal can be placed in the 120-foot concrete-lined section at the drift mouth, less than these quantities of cement will be needed, and the keys might be omitted.

The same sources (Scott and Hays, and Skelly and Loy) show two styles of seal for shafts. These are shown in figures 39 and 40. Figure 39, for a completely filled shaft, would be rather expensive to fill unless plenty of low cost material, such as washery waste, were available for the job. If the material is not well compacted immediately, settling might result in a surface depression to be filled later, possibly more than once. The shafts are 157 m (520 feet) and 156 m (512 feet) deep. They are 6.7 m (22 feet) in diameter, and together have a volume of about 11,100 m^3 (14,500 $yards^3$). For these reasons, the style of closure shown in figure 40 is to be preferred. The reinforced concrete slab should be far enough down the shaft to rest on firm, relatively unweathered rock, preferably a sandstone, and possibly just below the minimum height of the water table. There should be no danger of slab and backfill uplift by water pressure because of the small head at all openings.

The steps necessary for sealing the shafts would be:

(1) excavating to firm bedrock below the water table,
(2) pouring the concrete slab, and
(3) filling and compacting with soil of the space above the concrete slab to conform to the natural ground slope.

Each shaft has an excavated diameter of 22 feet so that the slab (figure 40) to cover the shaft should be well reinforced and not less than 25 X 25 feet in area and one to two feet thick. If a size even larger, of 30 X 30 feet, and 2 feet thick is assumed, 50 m^3 (67 $yards^3$) of reinforced concrete will be needed for the slab. If the slab can be placed at a depth of about 20 feet, or where the concrete lining now stops, about 2,290 m^3 (3,000 $yards^3$) of soil will be needed for filling to level ground.

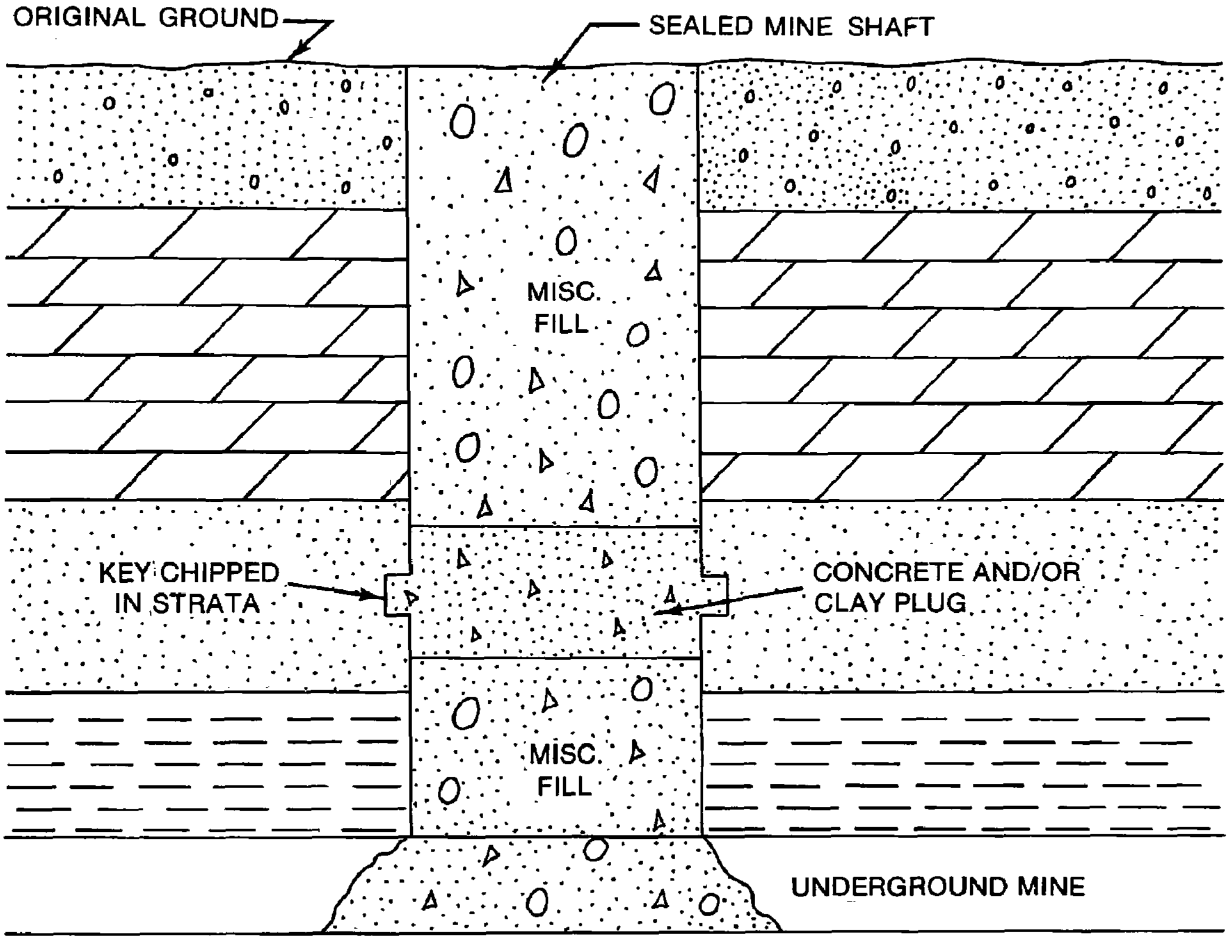

Figure 39. Cross section of typical shaft seal (ref. 32).

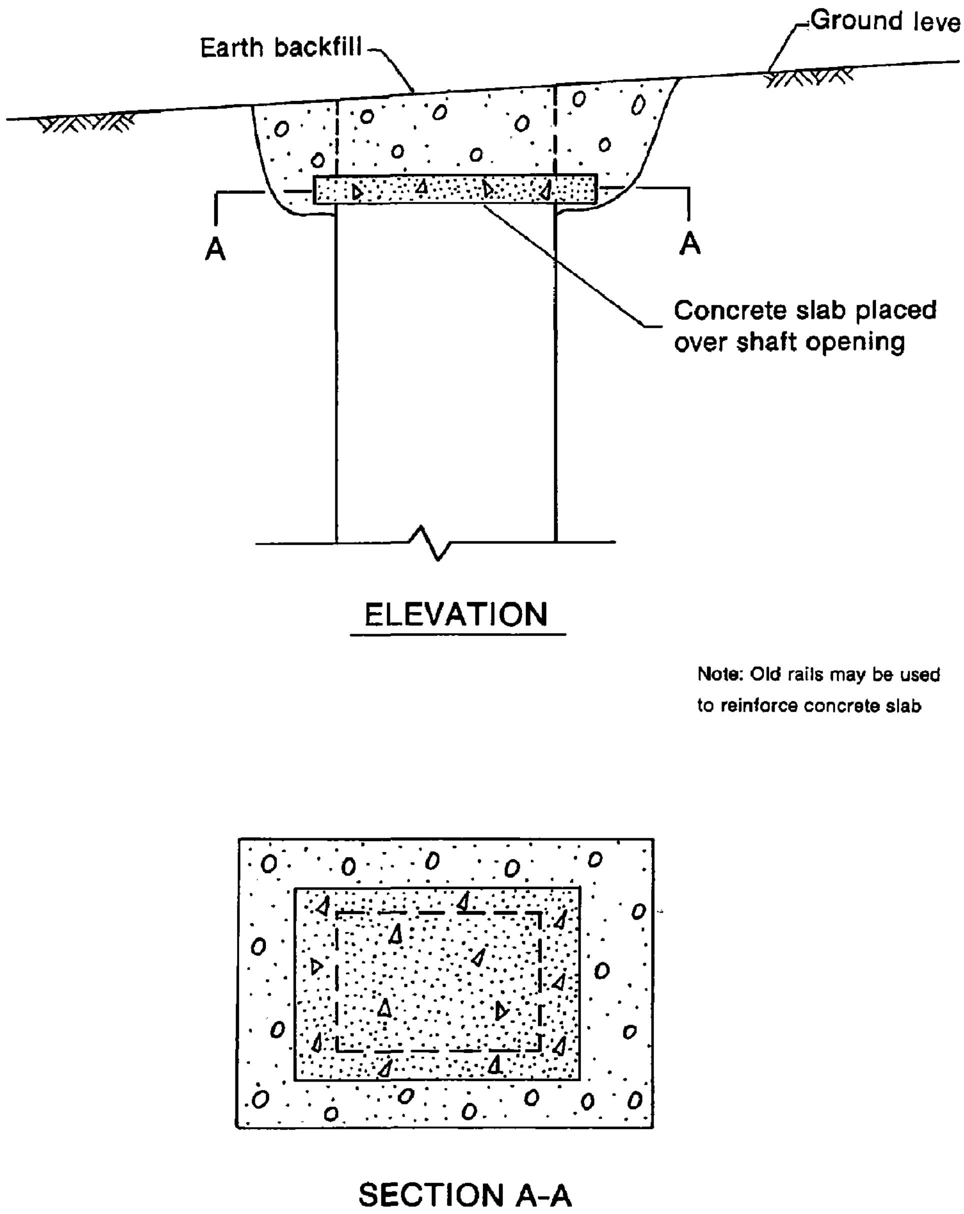

Figure 40. Shaft seal with concrete slab (ref. 32).

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16. ABSTRACT

The objectives of this study were to determine how best to select a layout and mining system and also to develop and operate an underground coal mine while at the same time minimizing pollution of the environment.

The pre-mining environment was assessed by sampling Cedar Creek 3 and other streams. Analyses of samples of groundwater into the mine, of the water pumped from the mine sump, and of water from Cedar Creek below the mine, made possible the assessment of the area with regard to water quality. Principal factors associated with mining which affected downstream water quality were sulfide oxidation and acid formation in the mine, the quality of the groundwater seeping into the mine, the limestone used for rock dusting, and the quality of the resettled but not treated mine and washing plant water carried to the continuous miners for dust suppression.

Pollution downstream from the mine proved to be slight, even when untreated mine effluent flowed directly into the creek. The quantities of heavy metal ions contained in the mine influent and effluent were small. If openings are sealed after closure, environmental integrity for the area should exist indefinitely.

Deep mines in Alabama's synclinal coalfields, if entered some distance from the outcrop, or mined down-dip if started on the outcrop, should produce little surface pollution.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Underground mining	Mining Methods	
Ground Water	Heavy Metals	
Surface Waters	Mine Seals	13 B
Water Pollution	Down-Dip Mining	
Water Quality	Sulfide Oxidation	
Mining Engineering	Acid Mine Drainage	
Coal Mining		

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