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Environmental Protection Technology Series

Control of Mine Drainage from Coal Mine Mineral Wastes

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EPA-R2-73-230
May 1973

CONTROL OF MINE DRAINAGE FROM COAL MINE MINERAL WASTES

PHASE II

POLLUTION ABATEMENT AND MONITORING

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ABSTRACT

Acid runoff from refuse piles can be controlled by covering the mineral wastes with soil, establishing a vegetative cover, and providing adequate drainage to minimize erosion. The average acid formation rate for the entire restored refuse pile was estimated at 16 lb acid as $CaCO_3$/acre/day, or a reduction of 91+% when compared to the original unrestored pile. No significant differences were observed in acid formation rates from the three individual test plots covered with a nominal 1 foot, 2 feet, or 3 feet of soil. However, it was more difficult to uniformly place 1 foot of soil on the steeper slopes.

Slurry lagoons containing the fine coal rejects can be stabilized and the air pollution problem controlled by either a vegetative cover established directly on the mineral wastes without soil or by the application of a chemical stabilizer. Chemical stabilization is only a temporary measure, and vegetative covers should be the permanent solution to slurry lagoons.

Cost data from this project indicate that it would cost a Federal Agency approximately $6,100, $8,000, and $9,800 per acre to establish a grass cover on an abandoned refuse pile using one, two, and three feet of soil respectively. The magnitude of these costs can be attributed to the bidding procedures used in contracting the work, as required by Federal law.

This report was submitted in fulfillment of Project 14010 DDH, under the sponsorship of the Environmental Protection Agency, Office of Research and Monitoring, and Midwestern Division, Consolidation Coal Company, Pinckneyville, Illinois.

Key words: Mine drainage, refuse piles, slurry lagoons, New Kathleen Mine, vegetative covers, mineral wastes, acid formation rate, Illinois, grasses, reclamation.

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1. Acid runoff from refuse piles can be controlled by covering the mineral wastes with soil, establishing a vegetative cover, and providing adequate drainage to minimize erosion.

2. The average acid formation rate for the entire restored refuse pile was estimated at 16 lb acid as $CaCO_3$/acre/day, or a reduction of 91+% when compared to the original unrestored pile.

3. No significant differences were observed in acid formation rates from the three individual test plots covered with a nominal 1 foot, 2 feet, or 3 feet of soil. However, it was more difficult to uniformly place 1 foot of soil on the steeper slopes.

4. Slurry lagoons containing the fine coal rejects can be stabilized and the air pollution problem controlled by either a vegetative cover established directly on the mineral wastes without soil or by the application of a chemical stabilizer. Chemical stabilization is only a temporary measure, and vegetative covers should be the permanent solution to slurry lagoons.

5. Cost data from this project indicate that it would cost a Federal Agency approximately $6,100, $8,000 and $9,800 per acre to establish a grass cover on an abandoned refuse pile using one, two, and three feet of soil respectively. The magnitude of these costs can be attributed to the bidding procedures used in contracting the work, as required by Federal law.

II. RECOMMENDATIONS

One technique that was developed during Phase I appears to have merit and should be further explored and tested on a large scale. Several small test plots of grass were established directly on the coarse refuse without the use of a soil cover. This was accomplished by first treating the surface of the test plot to a depth of 8 inches with 40 T/A of agricultural limestone, followed by normal applications of fertilizer, grass seed, and straw mulch. An excellent stand of grass was established that lasted for over one year until the test plots were destroyed during the Phase II restoration activities. Whether a single application of limestone was sufficient or whether the treatment would have to be repeated at some frequency was never determined. The economic incentive appears to be substantial even at these large rates of limestone when compared to one foot of soil cover.

III. INTRODUCTION

A substantial amount of coal mined in this country undergoes a beneficiation or a cleaning operation. This is done to remove some of the dirt and impurities present in the coal. These impurities form the rejects or unmarketable portion of the coal mining operations and are usually referred to as "refuse" or "gob".

Disposal of the refuse varies with the type of mining operations conducted, i.e., surface or underground. When coal from a surface mine is cleaned, modern practice frequently consists of trucking the refuse back to the strip pits to be buried in the spoil bank under an adequate thickness of overburden material. The land is then graded and planted with a suitable cover of grass, shrubs, or trees.

When a coal cleaning operation is practiced in conjunction with an underground mine, the disposal of refuse becomes a more complex problem. Since strip pits are not normally available to an underground mine, disposal of the larger pieces of refuse, up to 8 inches in diameter, is to the nearest open field or valley. Fine reject material, usually 20 mesh and smaller, is transported in slurry form, by pipeline, to diked enclosures, slurry lagoons, or surface impoundments.

The coarse refuse portion of a coal cleaning operation consists largely of coal intermixed with pyrites, sandstone, clays, and shales of a carbonaceous character. When stored outdoors in piles or heaps and exposed to the elements, chemical reactions take place on the surface of the refuse pile. Rainfall, oxygen in the air, and the pyrite in the refuse provide an ideal environment for the formation of an acidic drainage containing dissolved iron and other compounds which enters the streams and rivers from runoff and seepage through the pile. Additional problems follow in that the clays, shales, and sandstones are continuously decomposed and erosion constantly washes away the silt, exposing new material for oxidation and acid formation. Acid drainage and siltation occur during mining operations, and can continue for decades after operations cease.

Slurry lagoons associated with coal mining operations present a different type of environmental problem. The lagoons contain the fine reject material from a cleaning plant and can analyze as much as 50% coal with the balance ash and some pyrite. Rainfall on these lagoons percolates into the beds, seeps through the dikes, or is returned to the atmosphere via evaporation, with little surface runoff. The dikes are usually well built and compacted from clean earth, but occasionally are built from refuse and covered with a layer of earth. In many instances, a grass cover or trees are planted on the slopes to prevent erosion, or vegetation can develop from volunteer growth. During active operations, a pool of water exists on the surface and only minor problems are experienced involving repairs to a leaking dike. When mining operations cease, maintenance often ceases and the dikes can wash out during heavy rainstorms. In addition, during extended periods of dry weather, blowing winds entrain the surface material and create a dust problem in the vicinity of the site.

Scores of these types of refuse piles and slurry lagoons, from underground and surface mining operations, exist in both the Appalachian and Midwestern coal fields. To date, only a limited number of options are available to effectively handle this problem. Topography tends to make each situation unique. In a large number of instances, the refuse piles have been abandoned.

In some instances, covering the pile with a thick layer of clean earth and planting a vegetative cover has been effective but very expensive. As an example, current regulations in Illinois[1] require a four-foot thickness of clean earth to be applied to a new refuse pile, followed by a vegetative cover to prevent erosion and exposure of the refuse pile to the elements. In certain cases such as in the Appalachian areas earth cover may not be available or it may be so expensive as to make the covering operation very costly. Chemical treatment of the runoff and seepage, using hydrated lime or limestone, may be an interim measure during active operations but is obviously not the long-term solution since the formation of acid can continue for decades.

In the latter part of 1968, Truax-Traer Coal Company (now the Midwestern Division), a Division of Consolidation Coal Company, entered into a cooperative grant with the Federal Water Pollution Control Administration (now Environmental Protection Agency) to demonstrate effective and practical means of abating air and water pollution from coal mining refuse piles and slurry lagoons. The intention of this demonstration project was to provide engineering data and design parameters that could be applied to minimize or prevent this type of environmental problem. The project would thus allow the knowledge on this subject to be advanced a stage further by providing design data and field experience for which there was and is an industrywide need.

This report is the second and final report of two phases, and describes the implementation of specific pollution abatement measures for the entire demonstration site. In addition, details of the monitoring program designed to evaluate the effectiveness of the remedial measures chosen are included.

IV. SUMMARY OF PHASE I

The New Kathleen Mine site is located approximately five miles southwest of DuQuoin, Illinois, on typical midwestern flatlands, surrounded by agricultural operations. Surface mining activities, both active and abandoned, are in close proximity (Figure 1).

The site formed a part of an abandoned coal mining operation, active from 1943-1955, that included a coal cleaning plant operated by Union Collieries Company in conjunction with the New Kathleen Mine. This was a slope mine in the Herrin (No. 6) Seam at a depth of approximately 110 feet.

The site contained an irregularly shaped refuse pile approximately 40 acres in area, standing 65 feet at its highest point, and containing about 2,000,000 cubic yards of coarse refuse. In addition to the refuse pile, the site contained a complex of six slurry lagoons, standing approximately 15 feet high, essentially flat, and occupying some 50 acres in area. The lagoons were completely enclosed by earthen dikes and contained the fine coal rejects transported thereto by hydraulic means. At the west end of the slurry lagoons, six small lakes remained from the abandoned mining operations that were used to collect the runoff from the slurry lagoons, and so arranged as to eventually overflow into the nearest stream, Walker Creek.

Phase I described the characteristics, hydrology, and acid formation rate of the refuse pile. The average rate of acid formation for this refuse pile was 198 pounds of acidity, as $CaCO_3$ per acre per day. Acid contribution from the slurry lagoons was not determined but appeared to be negligible. The methodology developed and used for estimating acid formation rates was described in detail.

As potential abatement measures, a number of experimental vegetative covers were tested. Grass was successfully established with and without the use of topsoil, using conventional agricultural equipment and techniques.

The final report covering Phase I was issued by the Environmental Protection Agency under Water Pollution Control Research Series, 14010 DDH 08/71, "Control of Mine Drainage from Coal Mine Mineral Wastes - Phase I, Hydrology and Related Experiments."

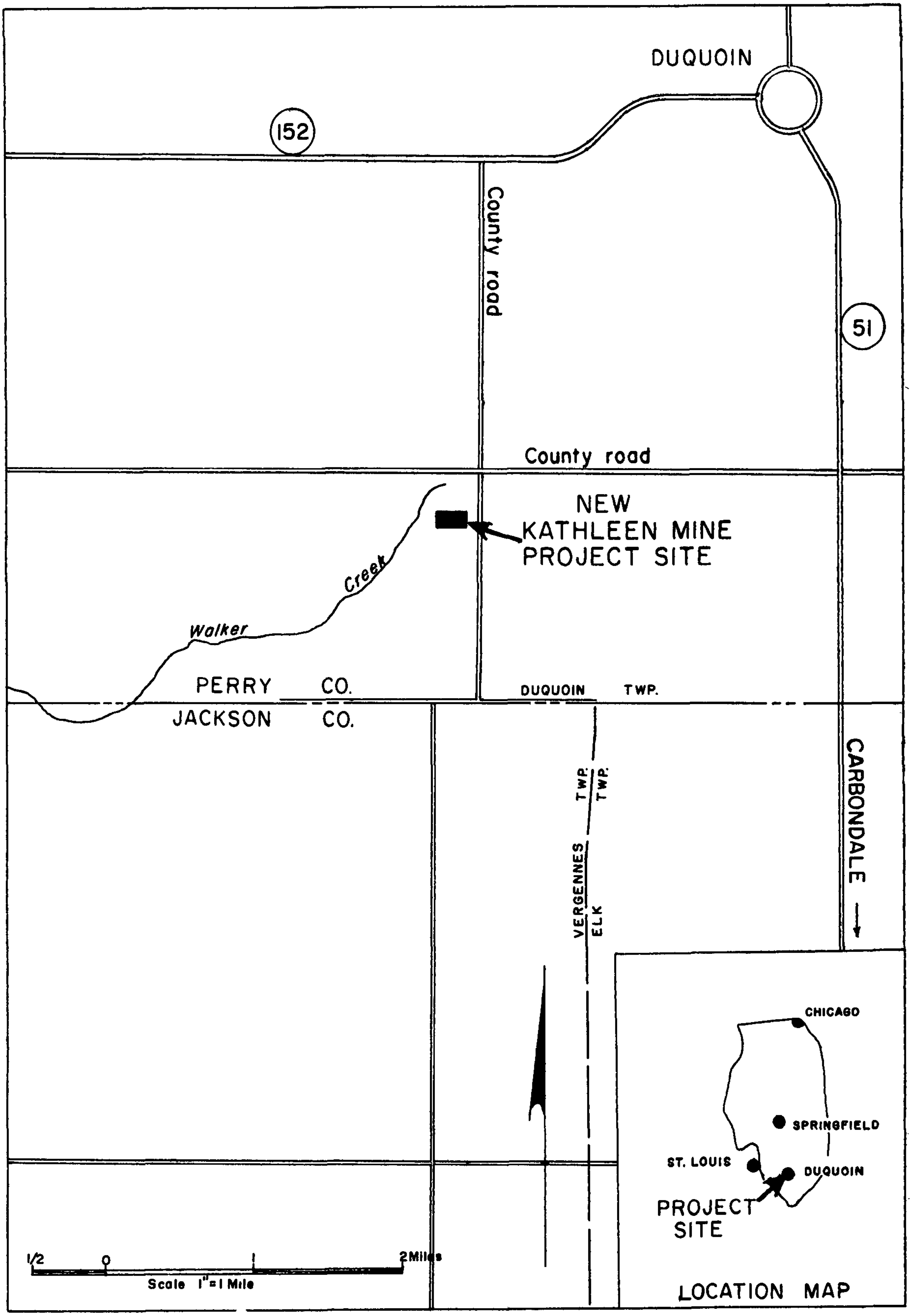

FIG. 1 NEW KATHLEEN MINE DUQUOIN, ILLINOIS

V. RESTORATION OF PROJECT SITE

Engineering and Construction

With the completion of Phase I in the spring of 1970, engineering plans and specifications were prepared for a pollution abatement program to restore the New Kathleen Mine site. The basic plan consisted of grading and covering the refuse pile with clean earth and establishing a permanent vegetative cover of grass. The slurry lagoon complex was stabilized by establishing a grass cover on approximately one-half of the area and treating the other half with a chemical stabilizer. In addition, the impounded water remaining in four lagoons was neutralized and drained into Walker Creek by opening the dikes. The inside areas of the drained lagoons were stabilized and the dikes left open to permit any future surface water to drain rather than be impounded. Monitoring stations were strategically located around the site to determine the effectiveness of the abatement measures.

Restoration of the Refuse Pile

The plans consisted of grading and shaping the refuse pile into three major subareas or bowls, thus creating three giant-size test plots varying in size from 3 to 6 acres each. During the grading operation, approximately 134,000 yd^3 of refuse material was moved to shape the pile into the surrounding landscape with slopes not exceeding 1:3. The very steep sloped area at the western end of the pile required the moving of approximately 38,000 yd^3 of refuse to a relatively flat, low spot at the northwestern end of the site and away from the refuse pile proper. This material covered approximately 6 acres to a depth of 4 feet. The entire pile, including the aforementioned 6 acres, was then covered with a barrier of agricultural limestone applied to the surface at 15 T/acre. The bowls or test plots were then covered with clean earth, with thicknesses of 1 foot, 2 feet, and 3 feet, respectively. All sloped areas and the 6-acre flat area were covered with a 1-foot thickness of clean earth. Total earth cover amounted to approximately 94,000 yd^3.

The earth cover was then analyzed for nutrient requirements, using conventional soil testing techniques. Based on these tests, agricultural limestone was disked into the soil at a rate of 6 T/acre. This was followed by spreading and disking lightly a 11-17-23 fertilizer applied at 800 lb/acre. A grass seed mixture consisting of 37% perennial rye and 63% Kentucky fescue was applied at 80 lb/acre. The area was planted in the fall of 1970. The entire area was then covered with a straw mulch, applied pneumatically at 2½ T/acre on the sloped sides and 1½ T/acre on the "test" plots.

Clean earth used to cover the refuse pile was taken from a 6-acre plot of undisturbed land located at the southeast corner of the site. The area was drilled prior to selection as a borrow pit to determine the suitability of the soil for use as the earth cover. This area was eventually converted to a fresh water lake approximately 12 feet deep. The maximum haul distance was approximately 3,500 feet.

During the grading and covering of the refuse pile, a water quality monitoring system was included in the restoration program. A graded earthen peripheral ditch was constructed around the entire refuse pile to collect all the runoff and direct it to a single monitoring station at a point near Walker Creek. Monitoring systems were also constructed near each bowl or test plot to collect and direct the runoff from the test plot into the monitoring station. Each system included a concrete-paved ditch leading from the test plot and sloping downward into the monitoring station. Each monitoring station consisted of a concrete collection box, a stainless steel flume, stage recorder, and a recording conductivity meter (Figure 2). The objective was to provide an automated system for collecting runoff data to be used in evaluating the effectiveness of the abatement measures.

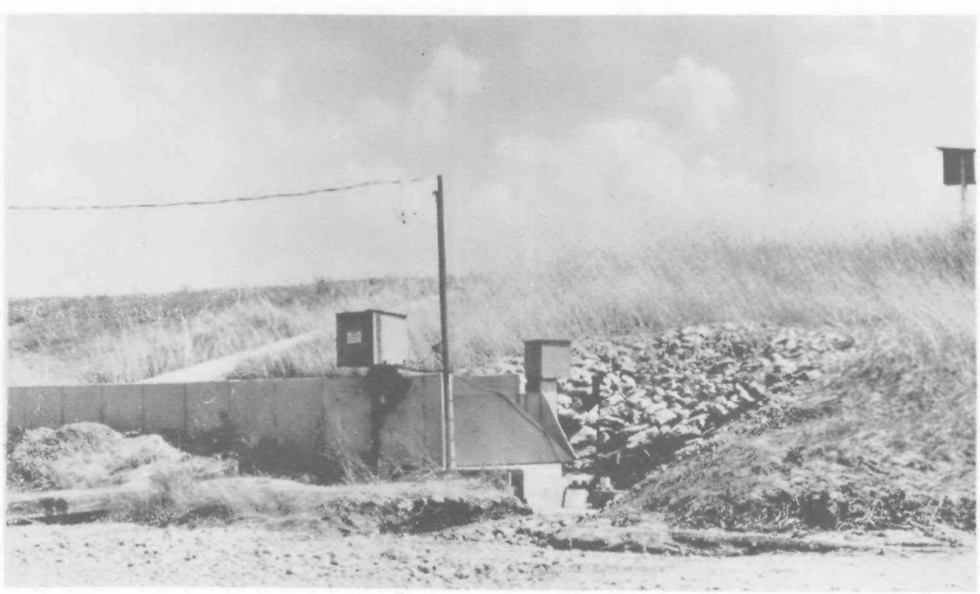

FIG. 2, MONITORING STATION AT FLOW POINT 1

In addition to the surface drainage monitoring facilities, subsurface drainage pipes were installed in seven locations around the refuse pile to monitor underground flow. These consisted of 8"D perforated plastic pipe placed on a bed and covered with washed and graded silica gravel. These pipes discharged into the graded peripheral ditch. Monitoring was conducted by measuring the flow at the individual pipes with bucket-stopwatch and obtaining periodic grab samples for water quality.

Figure 3 is a contour map of the restored refuse pile at the completion of the project including acreage of specific areas.

Stabilization of Slurry Lagoons

The slurry lagoons were treated somewhat differently. Soil testing of the slurry lagoon material and Test Plot 16, established during Phase I, indicated the possibility of establishing a grass cover directly on the slurry lagoons without the addition of any earth cover. Accordingly, approximately 19 acres were treated with agricultural limestone applied at a rate of 15 T/acre and disked in to a depth of 6 inches. This was followed by the application of 11-17-23 fertilizer at 800 lb/acre and lightly disked into the surface material. A grass mixture consisting of 15% perennial rye, 30% Kentucky fescue, 15% Reed canary grass, 5% Ladino clover, and 35% Balboa rye was sowed over the area at 130 lb/acre. Straw mulch applied at 1½ T/acre completed this operation.

The remainder of the slurry lagoons, occupying approximately 13 acres, was treated with a commercially available chemical stabilizer, "Coherex".* Test Plot 17, established during Phase I, provided encouraging data to justify a trial on a much larger scale. This material, a petroleum-based, non-toxic, emulsion-type liquid, was delivered to a siding near the project site in a railroad tank car. It was then transferred into small tank trucks and hauled to the site. Next, it was diluted by mixing with water, 1 part Coherex and 6 parts water, transferred into a smaller tank truck equipped with spray bars and applied to the surface at a rate of approximately 5,000 gallons of mixture per acre. The tank truck was equipped with oversized tires in order to traverse the slurry lagoon area. Its normal function was to apply liquid fertilizer on low, swampy farmlands (Figure 4).

Two additional nonautomated monitoring points were installed on the slurry lagoon complex. The dikes separating the

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*Golden Bear Oil Company, Bakersfield, California

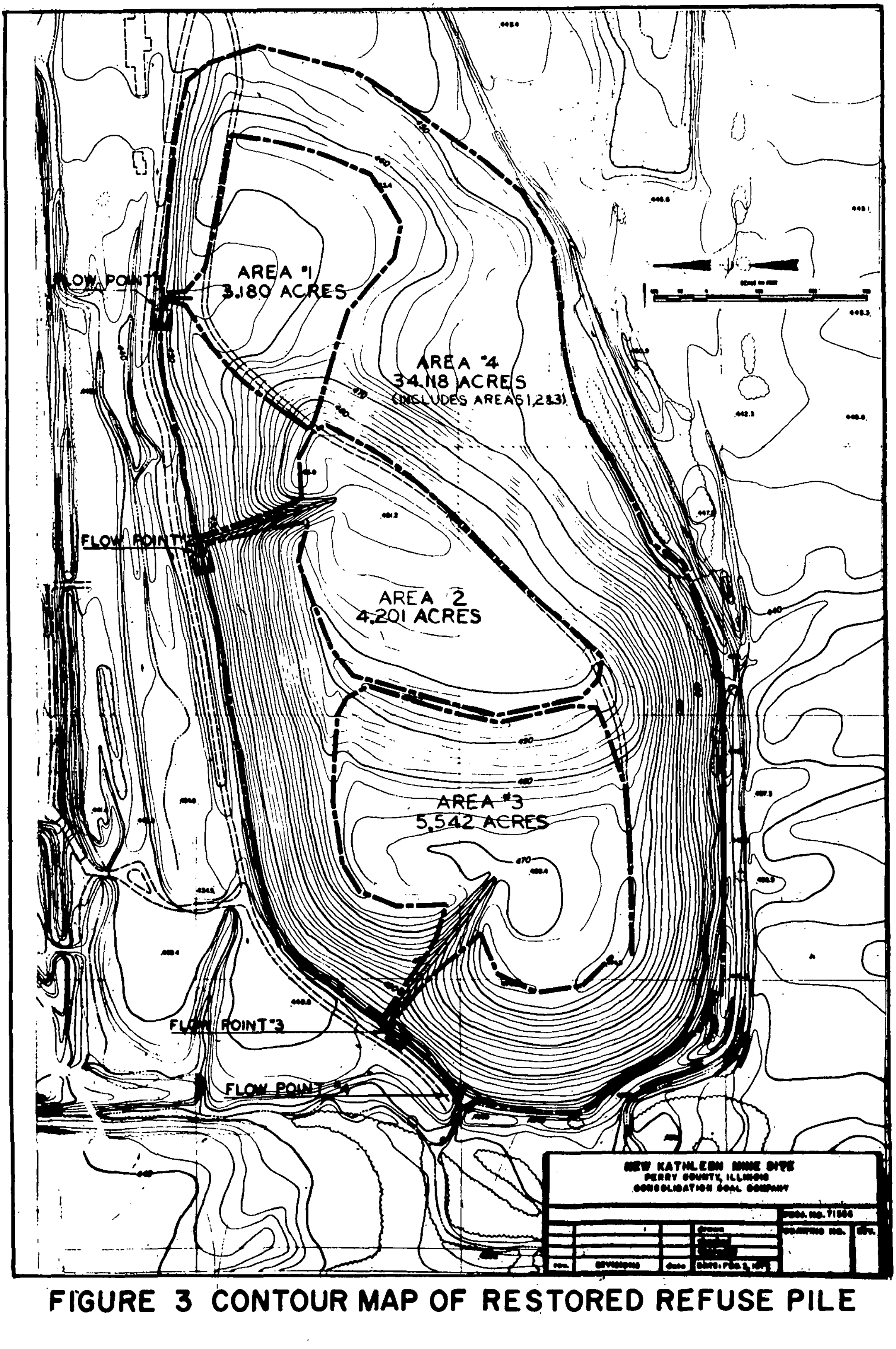

FIGURE 3 CONTOUR MAP OF RESTORED REFUSE PILE

FIG. 4 TREATING SLURRY LAGOONS WITH COHEREX

individual slurry lagoons were opened at selected points to allow all the runoff from the grassed area to exit at the monitoring point and all the runoff from the chemically stabilized (Coherex) areas to exit at another point.

Before completing the restoration, the impounded water in three of the slurry lagoons located at the western side of the site was neutralized with hydrated lime. The treated water was then drained into Walker Creek by opening the dikes. The inside areas of the drained lagoons were stabilized with the Coherex mixture and the dikes left open to allow any future surface runoff to drain rather than be impounded.

The entire operation was conducted with conventional earth-moving equipment and standard farm machinery with a minimum of innovation or adaptation. Figure 5 shows a contour map of the restored slurry lagoons including acreage for the individual slurry lagoons and drainage paths for the two test areas.

The restoration of the New Kathleen Mine site was not completed without a number of problems. Periods of wet weather caused heavy earth-moving machinery to bog down in the soft refuse. The dry slurry lagoons can be very deceiving to the inexperienced, especially near pools of water. Large diameter rubber tires on the spray-equipped tank truck used for

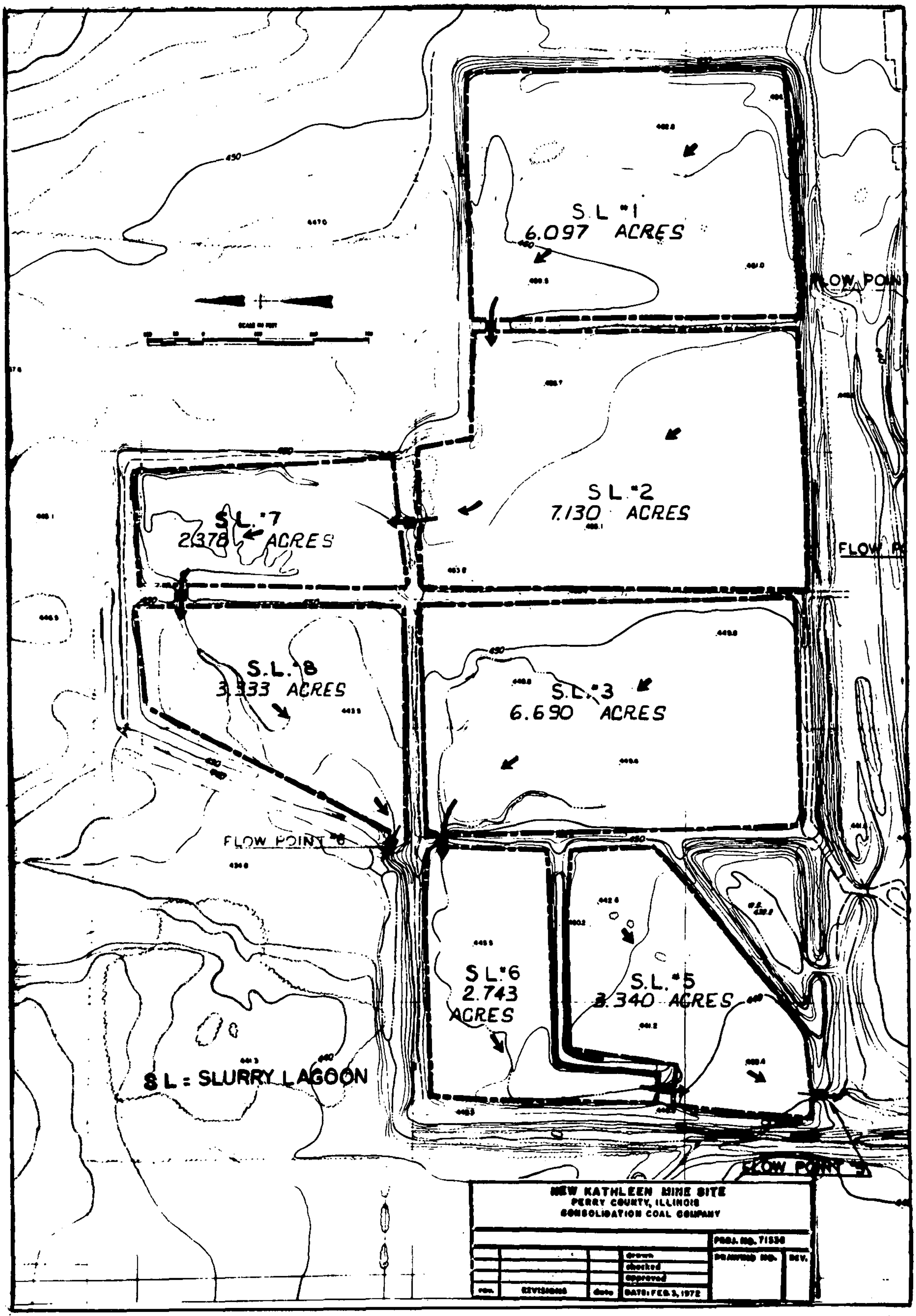

FIGURE 5 CONTOUR MAP OF RESTORED SLURRY LAGOONS

treating the slurry lagoons measured 64 inches diameter and 42 inches wide. This vehicle had no difficulty traversing the slurry lagoons with its contents. Vehicles with smaller tires didn't make it.

The schedule for reviewing plans, advertising for bids, awarding the contract, commencement and payment for work, and completion were all in accordance with guidelines established by the Environmental Protection Agency.

Cost Data

The costs of restoring the New Kathleen Mine site were $381,023. These costs are summarized in Table I. The cost data presented here represent only the direct costs in restoring the refuse pile and slurry lagoons. It does not include the research activities conducted at the site prior to the restoration, and it does not include the costs of the monitoring program conducted at the site after the restoration. Further, many people provided input to the project in the form of ideas, thoughts, suggestions, expertise, and indirect supervision which are not reflected in these costs.

To arrive at a unit cost estimate in terms of $/acre for restoring the refuse pile and slurry lagoons, the "Services" were arbitrarily prorated at 75:25 for the refuse pile and slurry lagoons respectively. This procedure resulted in total costs of $347,510 for restoring 40 acres of refuse pile or ∿$8700/acre. Similarly, prorating the slurry lagoon portion of "Services" 50:50, the total cost of seeding 20.5 acres of slurry lagoons was $16,023 or $782/acre. The total costs of stabilizing 14.5 acres of slurry lagoons with "Coherex" was $17,389 or $1199/acre.

Union labor was used in the entire restoration program.

Table II shows the estimated cost of reclaiming and vegetating a hypothetical abandoned refuse pile at various thicknesses of earth cover without the research aspects, using selective unit costs. Cost data from this project indicate that it would cost a Federal Agency approximately $6,100, $8,000, and $9,800 per acre to establish a vegetative cover on an abandoned refuse pile using nominal thicknesses of one, two, and three feet of soil, respectively. The magnitude of these costs can be attributed to the bidding procedures used in contracting the work, as required by Federal law. Care should be exercised in extrapolating these data, with the most sensitive parameter being the grading costs.

TABLE I

COST DATA

	Quantity	Unit Cost	Total $
Refuse Pile - 40 Acres			
1. Grading and Shaping Refuse Pile	133,900 yd^3	Lump Sum	$120,510
2. Earth Cover	94,140 yd^3	$1.05/$yd^3$	98,847
3. Peripheral Channel Around Pile	7,000 yd^3	Lump Sum	12,250
4. Concrete Paved Ditches	660 ft	$ 12/ft	7,920
5. Flow Monitoring Stations	3	$3,500/ea	10,500
	1	$6,500/ea	6,500
6. Perforated Pipe Seepage Drains	3,610 ft	$ 9/ft	32,490
7. Seeding and Fertilizer	40 Acres	$ 650/A	26,000
8. Agricultural Limestone	685 Tons	$ 12/T	8,220
	Total Refuse Pile		$323,237
Slurry Lagoon Areas - 35 Acres			
9. Neutralize and Drain #4 Pond		Lump Sum	$ 1,080
10. Seed and Fertilize 20.5 Acres		Lump Sum	11,538
11. Apply "Coherex" on 14.5 Acres		Lump Sum	12,804
	Total Slurry Lagoons		$ 25,422
Services			
12. R. A. Nack & Associates			$ 30,837
13. A & H Corporation			1,527
	Total Services		$ 32,364
	Total New Kathleen Site		$381,023

TABLE II

ESTIMATED COST OF RECLAIMING A REFUSE PILE WITHOUT RESEARCH ASPECTS

$/ACRE

	Depth of Cover		
	1 ft	2 ft	3 ft
Grading & Shaping*	$3,000	$3,000	$3,000
Limestone Barrier			
15 T/A @ $12/T	180	180	180
Earth Cover**	1,700	3,400	5,100
Lime, Seed & Fertilizer			
@ $650/A	650	650	650
	$5,530	$7,230	$8,930
Adm. Engineering, etc.			
@ 10%	553	723	893
	$6,083	$7,953	$9,823
Say	$6,100	$8,000	$9,800

*$120,510 ÷ 40A = $3,013/A, say $3,000/A
**1610 yd^3/A-ft x $1.05/$yd^3$ = $1,690/A-ft, say $1,700/A-ft

VI. OBSERVATIONS OF ABATEMENT MEASURES

The restoration of the New Kathleen Mine site commenced in July, 1970 and was essentially complete in December, 1970. A small area at the western end of the refuse pile was not completed due to inclement weather toward the end of the year. This work was postponed until spring, 1971 when it was completed.

In the spring of 1971, the road between the refuse pile and the slurry lagoons was scraped and covered with a 6-inch layer of 2" x 1" crushed limestone rock to provide ready access to the monitoring stations and the slurry lagoon complex.

In March, 1971, the three test bowls or plots on the refuse pile were seeded by hand with an equal mixture of hulled sweet clover, Cody alfalfa, and Korean lespedeza at the rate of 12 lb/acre since no legumes were included in the original mixture applied in the fall of 1970.

During the spring and summer of 1971, some twenty bare spots totaling approximately 2 acres were repaired by either adding more soil and/or reseeding. Many of these areas were on the steeper western and southern side of the refuse pile and although it was more difficult to apply the required soil thickness on the steeper slopes, the problems were not insurmountable. Eroded areas were filled with clean earth, reseeded, and mulched.

In July, 1971, nitrogen fertilizer, 46-0-0 at 300 lb/acre, was applied to the entire refuse pile. During this time, the grass cover was mowed to 6 inches to provide additional mulch and to allow the grass cover to reseed itself. At the end of the summer, an excellent stand of grass had been established on the refuse pile.

In September, 1971, two test plots were seeded to crownvetch, one on the south side of the No. 3 test plot and one on the south end of the No. 3 slurry lagoon. Both areas were treated with 500 lb limestone, 50 lb superphosphate, 50 lb potash, and 20 lb ammonium nitrate. This was rototilled into the soil or slurry material to a depth of 6 inches. Both areas were seeded with inoculated crownvetch seed, by hand, applied at 10 lb/acre, and covered with straw mulch. One year later, there was no visible evidence that the crownvetch germinated.

The slurry lagoons presented only one problem. Approximately one-half acre of the No. 8 slurry lagoon adjacent to Flow Point 6 slipped and was washed out into Walker Creek. The cause of this failure can be attributed to inadequate drainage on that part of the slurry lagoon complex. This lagoon was the last in the series of four lagoons seeded to grasses. The drainage pattern for this area consisted of collecting all the surface runoff from No. 1 and No. 2 lagoons, directing the flow across No. 7 and No. 8, finally exiting at Flow Point 6. An erosion ditch, 6 feet wide and 24 inches deep, eventually developed at the outlet of the No. 8 slurry lagoon. Six wooden ditch checks, each backed with 12 bales of straw, were installed on No. 8 slurry lagoon in August, 1971. The area adjacent to the flume was then reseeded and mulched. No further problems were experienced, and one year later, June, 1972, that portion of the slurry lagoon complex seeded to grass appeared to be well stabilized with a grass cover. Figure 6 illustrates the dense stand of grass established on the slurry lagoons without the use of any topsoil approximately nine months after seeding.

No problems were experienced on the slurry lagoons treated with the chemical stabilizer "Coherex." Visual examination of the surface during the summer of 1971 indicated only a slight deterioration, with flaking of the crust taking place at the surface. Blowing dust during periods of high winds had been significantly reduced. The stabilization of this portion of the slurry lagoons appeared satisfactory after the first year. However, chemical stabilization does not appear to be a permanent solution and vegetative covers should be the ultimate treatment.

The restoration of this site was approved by the EPA, with final acceptance taking place in October, 1971. At approximately the same time, the restored site was sold with rights of access and sampling privilege for EPA extending to June, 1976.

Figure 7 and Figure 8 are aerial photographs of the New Kathleen Mine site showing the refuse pile before and after restoration.

FIG. 6 GRASS COVER ON SLURRY LAGOONS
NEW KATHLEEN MINE

FIG. 7 REFUSE PILE – BEFORE RESTORATION
NEW KATHLEEN MINE – MAY, 1969

FIG. 8 REFUSE PILE – AFTER RESTORATION
NEW KATHLEEN MINE – MAY, 1972

VII. MONITORING PROGRAM

The monitoring program conducted at the restored site was essentially the same as that used in determining the acid formation rates at the beginning of the program and previously reported. A comparison of "before" and "after" values thus provided information on the effectiveness of the abatement measures incorporated onto the refuse pile. In addition, acid formation rates were determined for the three test plots to determine any significant differences in the effectiveness of the 1-foot, 2-foot, and 3-foot soil covers.

Since a "before" estimate of acid formation rates on the slurry lagoons was never determined, an "after" estimate would only be of academic interest. However, a single storm was monitored on the chemically stabilized slurry lagoons and this result is included in this report.

During the first year after restoration, i.e., 1971, a number of problems were experienced with the automated monitoring stations. The western end of the pile was completed and additional repair work was done on a number of bare spots that developed during the winter and spring season. The runoff during this period contained large amounts of sediment carried from the test plots and refuse pile where the grass cover had not been fully established. This sediment filled the concrete flumes with mud which had to be shoveled out by hand after every major storm. At the same time, the flow recorders and conductivity meters failed to function when the critical components of the instruments were packed solidly with mud. As the grass covers became more firmly and uniformly established, the sedimentation problem decreased substantially, especially at the monitoring stations associated with the test plots, and reliable flow data were obtained from the flow recorders.

The conductivity meters never reached predictable or reliable performance because of the intermittent nature of the runoff and the basic design of the conductivity meter probe. In spite of numerous configurations, solids always entered the probe cell, resulting in erroneous readings or no readings at all. Eventually, grab samples were taken of the runoff at all monitoring stations. These were analyzed for acidity, to be ultimately used in estimating the acid formation rates.

Because of the difficulties encountered in attempting to correlate conductivity with acidity, a new technique was developed in order to estimate acidity values over the wide range of flow rates. It was observed that a relationship appeared to exist between the instantaneous flow rates measured by the recording flow meter and corresponding acidity values obtained from the grab samples. When these matched parameters were plotted on log-log paper, a straight line could be drawn between the points.

Although the slope remained essentially constant from storm to storm for all monitoring stations, the line shifted from side to side. Thus, all flow rates were correlated with acidity by a series of parallel lines of relatively constant slopes (Figure 9). These data were then used in constructing the acid load hydrographs from which the acid formation rates were estimated.

The following fundamental hypothesis developed during Phase I[2] was used to calculate the average acid formation rate for the restored refuse pile:

1. The oxidation of pyrite is primarily confined to a relatively narrow zone at or near the surface of the pile with the products of the reaction accumulating in this zone and flushed out during periods of precipitation and appearing in the runoff, and

2. The acid load from the refuse pile is directly proportional to the acid load from the runoff and inversely proportional to the ratio of total storm runoff to the total rainfall.

This hypothesis can then be expressed mathematically using the following relationship:

$$P = \frac{\Sigma R}{A \times \Sigma t \times f}$$

where

P = Average acid formation rate, lb/acre/day.
ΣR = Total weight of acidity from all monitored storms in a given drainage area, in lb acidity as $CaCO_3$.
A = Surface drainage area in acres.
Σt = Total period of acid formation corresponding to the time between storms, in days.
f = Ratio of total storm runoff volume to total rainfall volume for storms of record.

The average acid formation rate from the restored refuse pile, as measured at Flow Point 4, was estimated at 16 lb acid as

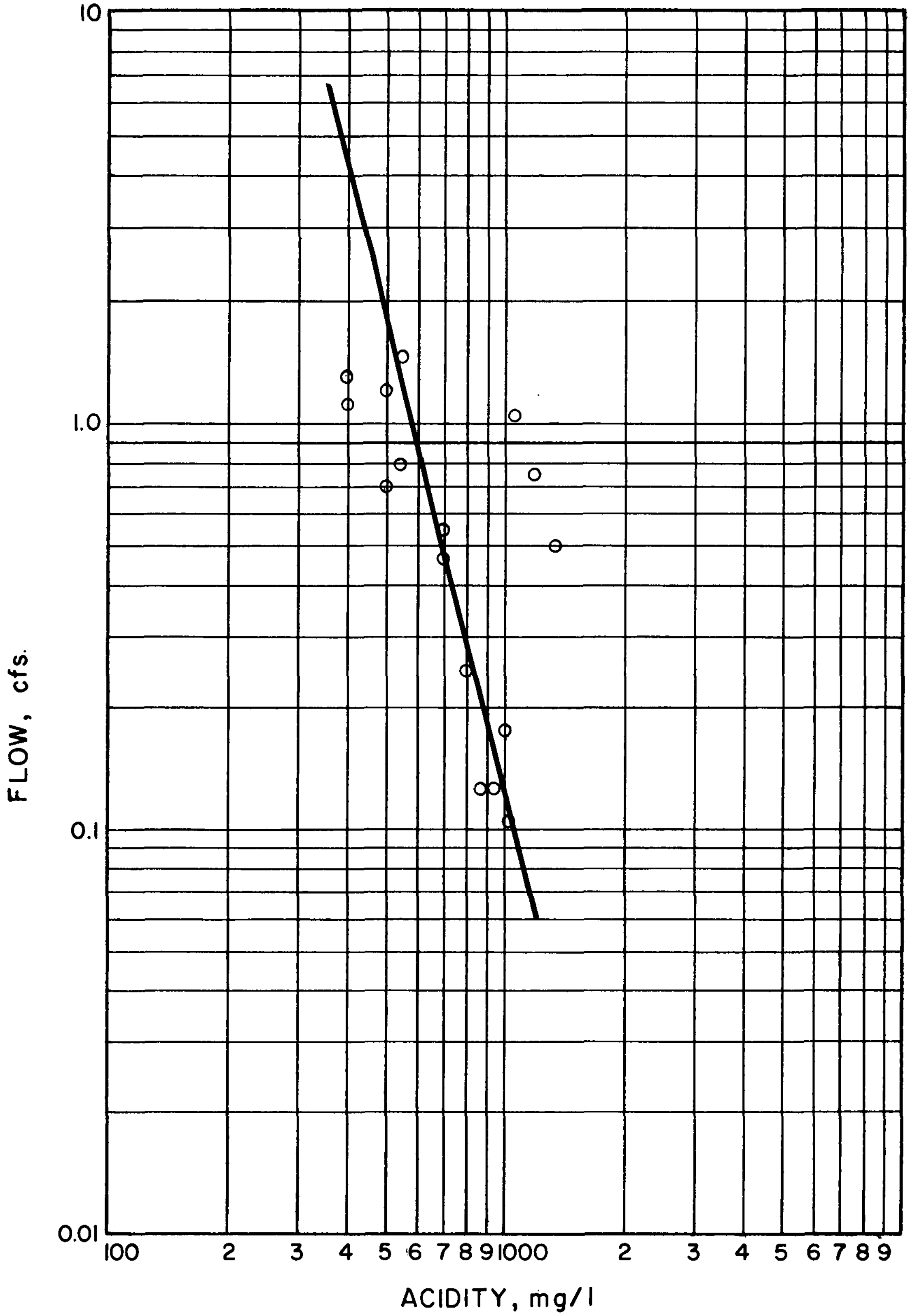

FIG. 9 ACIDITY VS. FLOW CHART

$CaCO_3$ equivalent/acre/day. This can be compared to 198 lb/acre/day reported for the pile in the "before" condition. This corresponds to a 91+% reduction in the acid formation rate. A total of eight separate storms were monitored to obtain the above estimate. Total measured rainfall per storm varied from a low of 0.08 inches to a high of 2.35 inches. The summary of acid formation rates measured at Flow Point 4 is shown in Table III.

Acid formation rates were also determined for the individual test plots on the refuse pile to determine if any significant differences existed between the 1-foot, 2-foot, and 3-foot soil covers. The average acid formation rates at Flow Points 1, 2, and 3 were 0.9, 2.0, and 0.9 lb acid/acre/day, respectively, or a weighted average, by number of storms, of 1.3 lb/acre/day. Thus, no significant differences were observed in acid formation rates from the individual test plots on the refuse pile. Contrary to many unsupported statements that more soil is better, the monitoring program at this site did not confirm that surface runoff was better from the deeper soil covers. For all practical purposes, one foot of soil, properly graded and well vegetated, produces essentially identical results as three feet of soil. It should be noted that the runoff flowing through the monitoring stations at Flow Points 1, 2, and 3 came only from the bowl-shaped test plots and excluded all the runoff from the sloped sections of the pile and any seepage through the pile. Five storms were monitored at Flow Point 1, six storms at Flow Point 2, and eight storms at Flow Point 3. A summary of acid formation rates measured at Flow Points 1, 2, and 3 after restoration is shown in Tables IV, V, and VI.

The difference between the 16 lb acid/acre/day obtained from the entire refuse pile and the 1.3 lb acid/acre/day weighted average from the individual test plots can be attributed to exposed refuse remaining in or adjacent to the peripheral ditch around the pile and to seepage through the pile.

Although concerted efforts were repeatedly made during and after the restoration phase to bury and/or cover all exposed refuse, approximately 2000 ft of the peripheral ditch and the areas immediately adjacent to the ditch on the south and southwest side of the pile remained either uncovered or covered only with a thin layer of soil. Inevitably, rainfall washed away this thin mantle of soil almost as fast as it was applied, reexposing the refuse to the elements. Topography and site boundaries on this end of the refuse pile made earth-moving conditions extremely difficult.

TABLE III

ACID FORMATION RATES FROM FLOW POINT 4*

Date	Rainfall in.	Applied Water ft^3	Measured Runoff ft^3	Time Since Last Storm days	Acid Load lb
2/23/72	1.10	139,135	120,288	9	4,500
3/1/72	0.30	37,977	21,637	5	965
3/15/72	0.80	101,271	31,342	13	936
3/21/72	0.15	18,988	67	5	5
3/27/72	0.35	44,306	2,755	6	108
4/7/72	0.08	10,127	1,218	4	180
4/14/72	2.35	297,432	161,584	7	4,451
4/20/72	2.05	259,456	169,711	5	5,192
Σ8		Σ908,692	Σ508,602	Σ54	Σ16,337

Area of Refuse Pile = 34.1 Acres

f = 508,602 ÷ 908,692 = 0.55

$$\text{Acid Formation Rate} = \frac{16{,}337}{34.1 \text{ Acres} \times 54 \times 0.55}$$

$$= 16 \text{ lb acid as } CaCO_3\text{/acre/day}$$

*Entire refuse pile, including peripheral channel

TABLE IV

ACID FORMATION RATES FROM FLOW POINT 1*

Date	Rainfall in.	Applied Water ft^3	Measured Runoff ft^3	Time Since Last Storm days	Acid Load lb
3/21/72	0.15	1,732	7	5	<1
4/14/72	2.35	27,120	19,629	7	28
4/20/72	2.05	23,657	15,895	5	20
5/1/72	0.50	5,771	38	10	<1
5/29/72	1.00	11,543	61	7	<1
Σ5		Σ69,823	Σ35,630	Σ34	Σ49

Area of test plot = 3.18 acres

f = 36,630 ÷ 69,823 = 0.51

$$\text{Acid Formation Rate} = \frac{49}{3.18 \text{ Acres} \times 34 \times 0.51}$$

$$= 0.9 \text{ lb acid as } CaCO_3\text{/acre/day}$$

*Test plot covered with 3 ft soil and planted to grasses

TABLE V

ACID FORMATION RATES FROM FLOW POINT 2*

Date	Rainfall in.	Applied Water ft^3	Measured Runoff ft^3	Time Since Last Storm days	Acid Load lb
3/23/72	1.10	23,637	17,338	9	76
3/15/72	0.80	12,200	6,273	13	36
3/21/72	0.15	2,287	56	5	1
4/7/72	0.08	1,220	63	4	1
4/14/72	2.35	35,828	25,701	7	78
4/20/72	2.05	31,254	29,417	5	81
Σ6		Σ106,426	Σ78,848	Σ43	Σ273

Area of test plot = 4.20 acres

f = 78,848 ÷ 106,426 = 0.74

$$\text{Acid Formation Rate} = \frac{273}{4.20 \text{ Acres} \times 43 \times 0.74}$$

$$= 2.0 \text{ lb acid as } CaCO_3\text{/acre/day}$$

*Test plot covered with 2 ft soil and planted to grasses.

TABLE VI

ACID FORMATION RATES FROM FLOW POINT 3*

Date	Rainfall in.	Applied Water ft^3	Measured Runoff ft^3	Time Since Last Storm days	Acid Load lb
2/23/72	1.10	31,182	27,364	9	48
3/1/72	0.30	6,035	4,746	5	16
3/15/72	0.80	16,094	6,956	13	17
3/21/72	0.15	3,018	54	5	<1
3/27/72	0.35	7,041	218	6	1
4/7/72	0.08	1,609	92	4	<1
4/14/72	2.35	47,267	23,841	7	48
4/20/72	2.05	41,230	34,710	5	39
Σ8		Σ153,476	Σ97,981	Σ54	Σ170

Area of test plot = 5.54 acres

f = 97,981 ÷ 153,476 = 0.64

$$\text{Acid Formation Rate} = \frac{170}{5.54 \text{ Acres} \times 54 \times 0.64}$$

$$= 0.9 \text{ lb acid as } caCO_3/\text{acre/day}$$

*Test plot covered with 1 ft soil and planted to grasses.

Seepage did not appear to be a major contributor. Although seven perforated pipelines were carefully installed and covered with silica gravel well below the earth cover, seepage flows were observed at only two pipes and this only for a short period of time before the vegetative cover was established. During the latter part of 1971 and well into 1972, no flows were observed at any of the seepage points.

The single determination of acid formation rate on the chemically stabilized slurry lagoon produced a value of 17 lb acid/acre/day. No storms were monitored at the grassed portion of the slurry lagoon complex. A detailed example of the methodology used in developing the storm data from which acid formation rates were subsequently estimated follows. The storm of March 1-2, 1972, monitored at Flow Point 4, was selected for this example.

At the first sign of the storm, personnel with sample bottles was deployed to Flow Point 4 monitoring station. When the rain began to fall, samples of the runoff were taken at the discharge of the flume at periodic intervals. At the completion of the storm, samples were returned to the laboratory and analyzed for total acidity. The following day, charts were removed from the rain gage and the stage recorder, necessary notations completed, and these, together with the acidity data obtained from the grab samples taken during the storm, were tabulated, correlated, and an acid load calculated. A tabulation of data for the storm of March 1, 1972 at the Flow Point 4 is presented in Table VII.

Rainfall for this storm was estimated from the rain gage chart to be 0.30 inch. The area occupied by the refuse pile and associated with the Flow Point 4 monitoring station was surveyed at the completion of restoration and measured 34.87 acres. The total "Applied Water" to the restored refuse pile during the storm period was:

$$0.30 \text{ inch} \times \frac{1 \text{ ft}}{12 \text{ inches}} \times 34.87 \text{ acres} \times \frac{43{,}560 \text{ ft}^3}{\text{acre}}$$

$$= 37{,}977 \text{ ft}^3$$

The flow in cfs (Column II), as recorded by the stage recorder, was then plotted against time of day (Column I), and the points connected with a smooth curve to produce Figure 10A, Runoff Volume Hydrograph. The area under the curve was planimetered to obtain the total runoff, 21,637 ft^3, measured at the flume during the storm period.

TABLE VII

TABULATED DATA - FLOW POINT 4

Date	I Time of Day hrs	II Flow cfs	III Acidity mg/l	IV Acid Rate lb/day
3/1/72	0620	0.0	-	-
	0640	0.039	(2000)*	421
	0652	0.075	(1500)	608
	0700	0.062	(1700)	569
	0720	0.119	(1300)	835
	0745	0.497	1450	3892
	0755	0.780	1200	5054
	0805	1.22	1100	7247
	0825	1.64	550	4871
	0845	1.42	400	3067
	0855	1.32	500	3564
	0905	1.12	400	2419
	0925	0.820	550	2435
	0945	0.705	500	1903
	1005	0.565	700	2136
	1025	0.497	700	1879
	1045	0.255	800	1102
	1105	0.170	1000	918
	1115	0.135	950	693
	1120	0.135	900	656
	1125	0.119	1050	675
	1200	0.089	(1400)	673
	1300	0.050	(1850)	500
	1400	0.020	(2500)	270
	1640	0.0	-	0
	2240	0.0	-	0
	2300	0.029	(2150)	337
	2320	0.029	(2150)	337
	2400	0.012	-	-
3/2/72	0020	0.062	(1600)	536
	0032	0.119	(1250)	803
	0040	0.119	(1250)	803
	0100	0.232	(1000)	1253
	0104	0.900	(550)	2673
	0108	0.635	(650)	2229
	0120	0.860	(550)	2554
	0140	1.42	(450)	3451
	0200	1.17	(500)	3159
	0240	0.635	(650)	2229
	0300	0.497	(750)	2013
	0340	0.211	(1000)	1139
	0400	0.152	(1200)	985
	0500	0.062	(1650)	552
	0600	0.029	(2350)	368
	0700	0.005	-	-
	1100	0.0	-	0

*Data reported in parentheses are estimates taken from Fig. 9 Acidity vs. Flow Chart.

As mentioned earlier, a new technique was developed to correlate acidity values obtained from the grab samples with recorded flow rates. Matched pairs of acidity values and flow rates were plotted on log-log paper and a straight line drawn through the points. Acidity values were thus estimated over the full range of recorded flows to be used in constructing the acid load hydrograph. However, actual acidity values were used whenever available in computing the instantaneous mass flows of acid in lb acid/day. Estimated values from the acidity flow chart were used only to complete the hydrographs. Figure 9, Acidity vs. Flow Chart represents the correlation used for the storm of March 1, 1972. A separate correlation was used for each storm.

Using the flow data and acidity values, instantaneous mass flows of acid were then calculated. As an example, at 0825 hours, the flow at the flume was determined from the stage recorder to be 1.64 cfs. The acidity of the sample taken at the corresponding time was 550 mg/l acidity. The instantaneous mass flow of acid was calculated as:

$$\frac{1.64\ ft^3}{sec} \times \frac{60\ sec}{min} \times \frac{1440\ min}{day} \times \frac{62.4\ lb}{ft^3} \times \frac{.000550}{}$$

$$= 4871\ lb/day\ acid$$

Next, the instantaneous mass flow of acid, in lb/day (Column IV), was plotted against time of day (Column I) and the points connected with a smooth curve to form Figure 10B, Acid Load Hydrograph. The area under the curve was then planimetered to obtain 965 lb acid, the total acid load measured at the flume during the storm period.

The elapsed time from the previous storm was determined to be five days, from the daily rainfall records.

A total of eight storms were monitored at Flow Point 4 and the data condensed and compiled in a similar manner. A summation technique was then used in estimating an average acid formation rate for the entire refuse pile. Table III, Acid Formation Rates from Flow Point 4, presents data for the individual storms together with the final calculation used in making the estimate

Data from the three test plots monitored at Flow Points 1, 2, and 3, and from the single storm monitored at the chemically treated slurry lagoons, were treated in an identical manner.

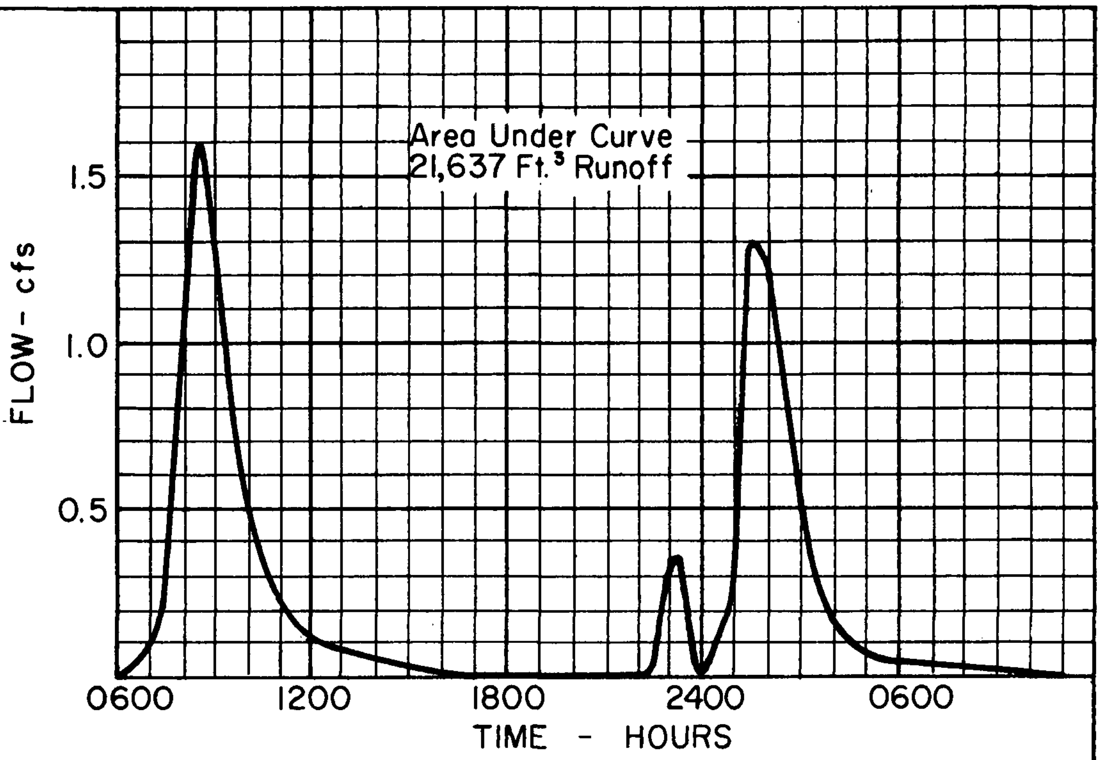

FIG. 10A RUNOFF VOLUME

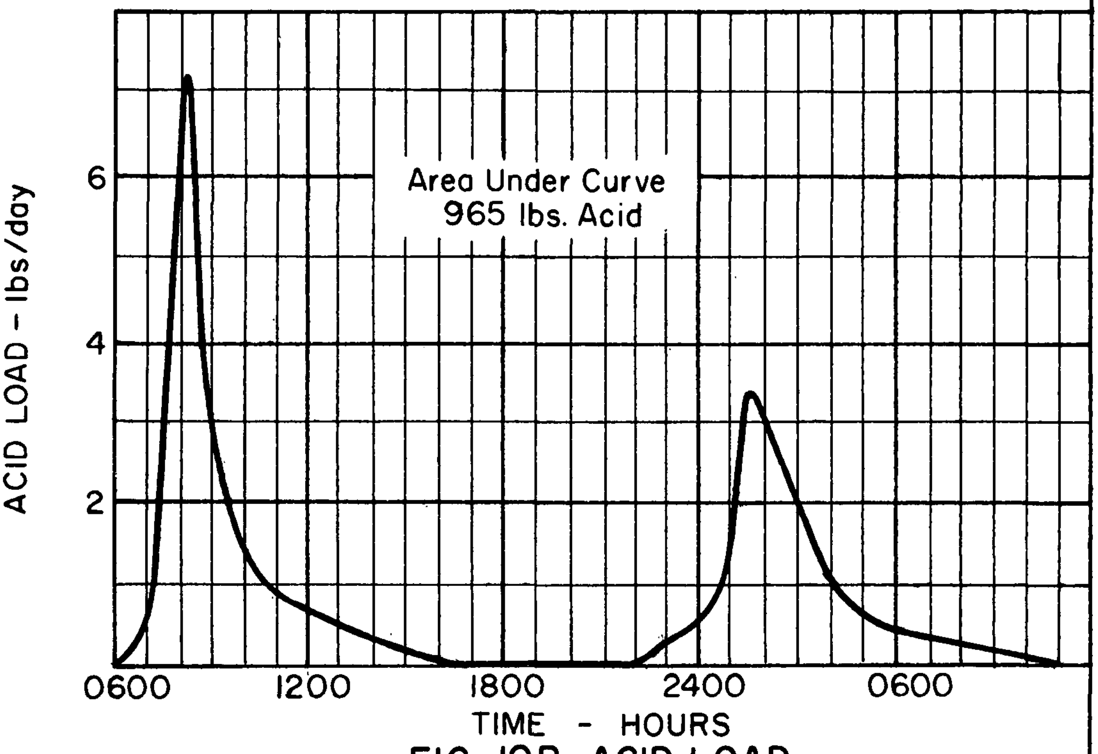

FIG. 10B ACID LOAD

FIG. 10 HYDROGRAPHS, MAR. 1-2, 1972, FLOW POINT 4

VIII. EPILOGUE

It would seem appropriate at this point to reflect on the experience gained in the course of this project and to offer for consideration some very broad guidelines that may be useful in future projects of this kind. This report described what was done at one site, in one location, under a given set of conditions, and should not be construed as applicable to every single situation. However, with proper planning and diligent attention to details, relatively basic and simple technology can be applied to the stabilization of most coal mine mineral wastes and the subsequent control of pollution with a minimum impact on the environment.

The primary objective of this project was to demonstrate water and air pollution abatement techniques that would be essentially permanent, require a minimum of maintenance, and present a pleasing appearance. The basic principle adopted consisted of sealing the mineral wastes with a suitable cover to minimize the movement of water and/or air into the pyrite-containing refuse, thus reducing or eliminating the subsequent formation of acid, siltation, erosion, and dust entrainment.

Attention was directed largely toward vegetative covers that could be established and maintained with conventional agriculture techniques and machinery. Since the surface of the refuse pile was highly acidic ($pH < 3$), it could not by itself support a vegetative cover. Therefore, a suitable thickness of clean earth was first placed on the graded refuse pile and a vegetative cover established thereon.

The mechanism of control postulated at the time the cover technique was selected was as follows:

1. The cover should be sufficiently impermeable to decrease or stop water movement into the pile. When this occurs, the products of oxidized pyrite will not be washed away during periods of rainfall, and fresh pyrite surfaces will not be exposed. Further, a vegetative cover can function as a water-consuming layer through the principles of evapotranspiration, thus further reducing the quantity of water entering the interior of the pile.

2. The cover should be sufficiently impermeable to oxygen to act as an efficient diffusion barrier. Since oxygen (and water) must be continuously present to support the pyrite oxidation reaction, any material effectively separating the pyrite from the atmosphere will cause the

oxidation reaction to either slow down or cease completely. The characteristics of the cover then control the oxidation reaction. In addition, the cover can function as an oxygen-consuming layer. A vegetative cover such as grass may build up enough organic matter in the soil to support high rates of aerobic bacterial activity. Such a layer can be effective in removing oxygen from the soil atmosphere before it reaches the zone of pyrite oxidation.

The above phenomena, either singly or in combination, should reduce the acid formation over a period of time to negligible quantities.

Since the refuse pile continues to generate acid, several years may be required until acid formation ceases completely. To accomplish this, it may be necessary to assist nature to do its job by adopting a routine maintenance, inspection, and monitoring program and follow the progress of this reduction. As the site has now been transferred into private ownership, this may provide some economic problems for the new owner. Financial subsidies or services through federal and/or state agencies may be all that is required to provide the necessary incentives. Part of the sales agreement does provide the Federal EPA rights of access, egress, and sampling privileges until June 30, 1976.

From the standpoint of any future activities involving refuse piles, perhaps the most important parameter that should be given the highest priority and attention is erosion and drainage control. Everything else is secondary. Uncontrolled runoff damages everything. Reducing the velocity and controlling the flow of runoff can make the greatest single contribution in ultimately abating pollution from refuse piles. A variety of measures are available to control runoff. These include proper grading, subsurface drains, diversion ditches, terraces, and vegetative covers.

It is not possible to lay down any hard and fast rules as to a specific slope for the grading operations. Every situation is different. Slopes greater than 1:2 are more difficult but not impossible to construct and maintain with conventional earth-moving equipment. Techniques developed in the interstate highway program and in major construction projects can be directly applicable to refuse pile grading. Equipment such as graders, tractors, bulldozers, and earth-carrying vehicles is readily available, and improvements in capacity, reliability, and efficiency are continuously being made by the manufacturers. When the slopes exceed the capability of conventional earth-moving equipment, a variety of other equipment is available such as draglines and shovels, and under extreme conditions, manual labor. Bench terracing is another practical alternative that can be adopted for extremely steep and/or long slopes.

The top of the pile should be formed into a dished plateau or bowl. All peaks and ridges should be graded toward the low point in the bowl since this helps to reduce the amount of runoff and surface water draining along the sides of the pile with a corresponding reduction of erosion and gullying. Adequate drainage from the bottom of the dished area is a must and can best be accomplished by open ditches made and maintained out of a variety of inexpensive materials--wood troughs, concrete-lined channels, or large-diameter metal or plastic pipe cut lengthwise and firmly anchored into the ground. Grass sod should not be overlooked as an effective alternative. The total cost of grass sod may not be as high as other alternatives.

The benefits of surface treatment with an alkali such as limestone, lime, fly ash, or waste alkaline products (prior to covering with earth) have not been adequately demonstrated in this project. Although 15 T/acre of agricultural limestone was spread on the graded refuse pile before covering with earth, the cost benefit of this treatment has not been determined. Suffice to say, it did not appear to be detrimental in the restoration of this refuse pile.

The question of soil thickness in covering refuse piles appears to be a controversial one. From a technical standpoint, it is difficult to justify topsoil cover greater than 1 foot thickness on a properly graded refuse pile with adequate drainage control. Anything greater than 1 foot can be regarded as safety factor to camouflage improper grading and inadequate drainage. Of course, as the graded slope increases beyond the aforementioned, the difficulty of applying a nominal 1 foot of soil cover increases correspondingly. Thicknesses less than 1 foot have been explored on the test plots reported in Phase I, but difficulties were experienced in trying to place a 4-inch thickness of soil with even the smallest machinery without exposing the refuse.

When clean earth is to be used to cover a refuse pile as a prelude to establishing a permanent vegetative cover, a sufficient number of soil samples should be taken from the borrow area and analyzed for soil nutrients. If a substantial depth of soil is to be moved from the borrow area, core samples to the ultimate depth of the borrow area should be taken and analyzed. Submitting samples from surface scrapings can lead to erroneous results since rarely will the soil from the surface of a borrow area find its way on the surface of the covered refuse pile. Arrangements should also be made to have available at the site, and protected from the elements, the required supplies of limestone, fertilizer, grass seed, and mulch before the earth-covering operations commence.

The areas to be seeded should be divided into smaller segments that can be limed, fertilized, seeded, and mulched promptly (e.g., within 1-2 days) after the earth cover has been applied. Otherwise heavy rains inevitably occur that lead to erosion and gulleys and the necessity of redoing what has already been done.

Regarding specifics of fertilizers, lime requirements, and seed mixtures for grass covers, it is almost impossible to recommend any specifics because soils, climatology, and ultimate land use will vary so widely. Drainage and pH control of the soil are basic to the establishment of most vegetative covers. Native grasses with a good past performance record should be favored. Fertilizer application should be made on the basis of the grass seed selected. It is good practice to include in the grass seed mixture at least one species of native legumes. A complete and comprehensive listing of grass seed mixtures with recommended fertilizer requirements and other valuable information is available in the Department of Agriculture "Grass, The Yearbook of Agriculture, 1948,"[3] available from the Superintendent of Documents. We would not hesitate to double or even triple the quantities of grass seed suggested in the above publication when seeding soil that has never been seeded before.

In establishing a permanent vegetative cover on a refuse pile, the optimum time for planting in most areas of the East and Midwest appears to be early fall. Thus, the earth covering, drainage control, and grading should be started in late spring or summer. This should be followed by a thorough inspection of the newly seeded area the following spring with reseeding and/or repairing, as necessary, of any bare spots.

A newly covered and seeded refuse pile is a sensitive entity and should be given "tender loving care" at least for the first year or two. Unless this is done, the land can deteriorate into its original condition. Bare spots should be covered, seeded, and mulched as soon as they are observed or no later than the following planting season. Regular soil testing and application of lime and fertilizer is recommended to maintain the grass cover. Gulleys and rills should be promptly filled with clean earth, seeded, and mulched.

Livestock should not be pastured on the covered refuse pile because they tend to form paths that are subject to erosion and acid-producing material will be exposed.

In certain instances, it may be desirable to dispose of the land to someone who can develop the necessary incentives to put it back into productive use such as land developers or farmers. In other instances, land can be donated or sold for a nominal amount to a community or municipality to be used as a recreational area, wildlife resort, or park. Borrow areas can be conveniently converted into fresh water lakes and eventually stocked with fish. The lakes can be filled with either groundwater or the runoff from the covered refuse pile, collected and diverted into the lake.

Slurry lagoons, because of their unique physical and chemical characteristics, were treated differently. Grading was neither required nor desired. However, drainage control is important because of the unstable nature of the slurry material. Adequate drainage facilities and erosion control should be provided to reduce the velocity and control the flow of runoff. Where gulleys already exist, these can be filled with bales of straw, slurry, clean earth, or other inert fill. When a permanent vegetative cover is planned, careful attention to opening the dikes at strategic points must be provided since most slurry lagoons are completely enclosed during active operations. This will require the construction and maintenance of permanent, stable structures at the outlet of the lagoons to control the runoff and direct it into the nearest stream. Otherwise, channeling and gullying will take place and slurry will be deposited in the nearest stream.

The establishment of a permanent grass cover directly on the slurry lagoons, without the use of topsoil, was a relatively simple procedure once a vehicle was obtained that could traverse the lagoons with a load. The procedure consisted of soil testing, limestone application, fertilizer addition, grass seed sowing, and mulching with straw. For purposes of establishing grass covers, slurry lagoons can be classified as free-draining, very poor-grade soils. Drought-resistant species and legumes native to the area should be considered for use in any grass seed mixture for slurry lagoons. Straw was the preferred mulch for both the refuse pile and the slurry lagoons since the soils were essentially barren of any humus.

Chemical stabilization of slurry lagoons is only a temporary measure because of solubility, abradability, and nonrenewable nature of the chemical agent. But because it does provide almost instantaneous stabilization and dust suppression, it does present an attractive temporary option. Permanent vegetative covers should be the ultimate solution for slurry lagoons.

Finally, there continues to be an interest in recovering any potentially valuable and/or useful materials from abandoned refuse piles and slurry lagoons. Extensive studies promoting the uses of refuse material from coal mining operations have been underway in Great Britain for years, and for lesser periods in this country. Some of these studies have resulted in the use of refuse material in the construction of highways, dams, dikes, industrial sites, and recreational areas. The recovery of the coal present in the slurry lagoons and its subsequent use as fuel in power plant boilers has not received the attention it deserves.

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The primary objective of this large-scale project was to demonstrate practical methods of abating pollution from coal mine refuse piles. The demonstration of at-source control methods such as this is an important element of the total Environmental Protection Agency Mine Drainage Pollution Control Program. This project was conducted under the direction of the Pollution Control Analysis Section, Ernst P. Hall, Chief, and Donald J. O'Bryan, Project Manager, with Eugene E. Chaudoir of the EPA Indiana District Office serving as Project Officer. Technical assistance was provided by Ronald D. Hill, Chief, Mine Drainage Pollution Control Activities, EPA, National Environmental Research Center, Cincinnati, Ohio.

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XII. APPENDICES

STORM DATA - 2/23/72 - FLOW POINT 2

Date	Time of Day hrs	Flow cfs	Acidity mg/l
2/23/72	0800	0	-
	0850	0.006	-
	0905	0.006	80
	0925	0.006	100
	0945	0.006	90
	1000	0.006	190
	1100	0.006	70
	1135	0.016	80
	1200	0.016	-
	1300	0.016	-
	1400	0.012	-
	1500	0.009	-
	1545	0.006	90
	1700	0.006	-
	1800	0.006	-
	1900	0.006	-
	2000	0.025	-
	2100	0.099	-
	2200	0.328	-
	2300	0.904	-
	2330	1.19	-
	2400	0.904	-
2/24/72	0030	0.564	-
	0100	0.236	-
	0200	0.099	-
	0300	0.060	-
	0400	0.041	-
	0500	0.030	-
	0600	0.030	-
	0700	0.025	-
	0800	0.041	-
	0815	0.128	150
	0835	0.236	90
	0855	0.328	70
	0910	0.437	-
	0940	0.345	50
	1000	0.296	50
	1020	0.250	80
	1040	0.222	70
	1100	0.209	70
	1200	0.250	-
	1300	0.280	-
	1400	0.171	90
	1420	0.138	90
	1440	0.108	90
	1500	0.099	100
	1600	0.060	-
	1640	0.047	130
	1650	0.047	150
	1700	0.041	150
	1800	0.025	-
	1900	0.016	-
	2000	0.008	-
	2100	0	-

STORM DATA - 2/23/72 - FLOW POINT 3

Date	Time of Day hrs	Flow cfs	Acidity mg/l
2/23/72	0720	0	-
	0740	0.004	-
	0800	0.009	-
	0900	0.009	150
	0920	0.004	110
	0940	0.006	120
	1035	0.006	140
	1105	0.016	110
	1130	0.025	130
	1200	0.035	-
	1300	0.030	-
	1400	0.025	-
	1500	0.020	-
	1550	0.016	140
	1700	0.016	-
	1800	0.020	-
	1900	0.020	-
	1940	0.041	-
	2000	0.060	-
	2020	0.082	-
	2040	0.128	-
	2100	0.236	-
	2120	0.328	-
	2140	0.328	-
	2200	0.564	-
	2220	1.34	-
	2240	1.49	-
	2300	1.30	-
	2320	1.92	-
	2330	2.06	-
	2340	1.61	-
	2400	0.818	-
2/24/72	0020	0.437	-
	0040	0.265	-
	0100	0.196	-
	0120	0.149	-
	0220	0.108	-
	0320	0.060	-
	0420	0.047	-
	0520	0.041	-
	0620	0.035	-
	0720	0.035	-
	0825	0.611	40
	0845	0.763	40
	0905	0.763	20
	0945	0.399	20
	1005	0.312	30
	1025	0.328	30
	1105	0.312	30
	1200	0.399	-
	1240	0.520	-
	1300	0.399	-
	1340	0.236	-
	1405	0.183	30
	1425	0.138	30
	1445	0.128	30
	1505	0.118	40
	1643	0.053	40

STORM DATA - 2/23/72 - FLOW POINT 3 (cont'd)

Date	Time of Day hrs	Flow cfs	Acidity mg/l
2/24/72 (cont'd)	1705	0.047	50
	1805	0.030	-
	1905	0.020	-
	2005	0.009	-
	2105	0.004	-
	2200	0	-

STORM DATA - 2/23/72 - FLOW POINT 4

Date	Time of Day hrs	Flow cfs	Acidity mg/l
2/23/72	0700	0	-
	0900	0.020	1500
	0920	0.037	1350
	0940	0.039	1150
	1035	0.043	1000
	1105	0.039	950
	1130	0.089	1100
	1550	0.039	1450
	2000	0.152	-
	2100	0.705	-
	2200	2.01	-
	2220	4.90	-
	2240	7.67	-
	2300	6.28	-
	2320	8.65	-
	2330	10.2	-
	2340	8.95	-
	2400	4.08	-
2/24/72	0100	0.860	-
	0200	0.497	-
	0300	0.405	-
	0400	0.352	-
	0500	0.278	-
	0600	0.232	-
	0700	0.190	-
	0800	0.278	-
	0820	1.88	850
	0840	3.36	600
	0900	3.36	-
	0945	1.82	550
	1000	1.37	-
	1005	1.22	600
	1020	1.17	-
	1040	1.27	-
	1045	1.27	800
	1100	1.27	-
	1105	1.27	800
	1200	1.70	-
	1300	1.88	-
	1400	0.74	-
	1405	0.705	1050
	1425	0.565	1100
	1445	0.405	1200
	1500	0.352	-
	1505	0.327	1250
	1600	0.190	-
	1700	0.152	-
	1703	0.152	1850
	1800	0.013	-
	1900	0.075	-
	2000	0.050	-
	2100	0.029	-
	2200	0.012	-
	2400	0	-

STORM DATA - 3/1/72 - FLOW POINT 3

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/1/72	0600	0	-
	0604	0.012	-
	0608	0.002	-
	0612	0.016	-
	0700	0.002	-
	0745	0.053	50
	0755	0.090	50
	0805	0.138	50
	0815	0.183	50
	0825	0.265	40
	0835	0.296	40
	0845	0.250	50
	0905	0.222	50
	0925	0.183	45
	0945	0.149	45
	1005	0.118	60
	1025	0.090	60
	1045	0.067	70
	1105	0.053	60
	1115	0.047	60
	1120	0.047	60
	1125	0.035	60
	1140	0.030	-
	1200	0.025	-
	1300	0.012	-
	1400	0.002	-
	1500	0	-
	2220	0	-
	2236	0.006	-
	2340	0.004	-
	2400	0.006	-
3/2/72	0020	0.030	-
	0040	0.053	-
	0100	0.138	-
	0120	0.265	-
	0140	0.280	-
	0200	0.236	-
	0240	0.149	-
	0340	0.082	-
	0440	0.041	-
	0540	0.025	-
	0640	0.020	-
	0740	0.016	-
	0840	0.016	-
	0940	0.016	-
	1040	0.016	-
	1140	0	-

STORM DATA - 3/1/72 - FLOW POINT 4

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/1/72	0620	0	-
	0640	0.039	-
	0652	0.075	-
	0700	0.062	-
	0720	0.119	-
	0745	0.497	1450
	0755	0.780	1200
	0805	1.22	1100
	0825	1.64	550
	0845	1.42	400
	0855	1.32	500
	0905	1.12	400
	0925	0.820	550
	0945	0.705	500
	1005	0.565	700
	1025	0.497	700
	1045	0.255	800
	1105	0.170	1000
	1115	0.135	950
	1120	0.135	900
	1125	0.119	1050
	1200	0.089	-
	1300	0.050	-
	1400	0.020	-
	1500	0.012	-
	1640	0	-
	2240	0	-
	2300	0.029	-
	2320	0.029	-
	2400	0.012	-
3/2/72	0020	0.062	-
	0032	0.119	-
	0040	0.119	-
	0100	0.232	-
	0104	0.900	-
	0108	0.635	-
	0120	0.860	-
	0140	1.42	-
	0200	1.17	-
	0240	0.635	-
	0300	0.497	-
	0340	0.211	-
	0400	0.152	-
	0500	0.062	-
	0600	0.029	-
	0700	0.005	-
	0800	0.003	-
	0900	0.003	-
	1000	0.003	-
	1100	0	-

STORM DATA - 3/15/72 - FLOW POINT 2

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/15/72	0500	0	-
	0515	0.009	-
	0600	0.002	-
	0700	0.002	-
	0745	0.006	-
	0830	0.067	-
	0955	0.478	50
	1015	0.381	50
	1035	0.312	50
	1050	0.250	50
	1115	0.183	70
	1135	0.138	70
	1155	0.108	70
	1215	0.082	110
	1235	0.066	120
	1325	0.047	130
	1355	0.035	160
	1440	0.020	200
	1635	0.009	280
	1700	0	-
	1745	0	-
	1800	0.004	-
	1900	0.020	-
	1930	0.047	-
	2000	0.067	-
	2030	0.067	-
	2100	0.067	-
	2130	0.060	-
	2230	0.041	-
	2330	0.030	-
3/16/72	0030	0.025	-
	0130	0.016	-
	0230	0.012	-
	0330	0.012	-
	0430	0.009	-
	0530	0.009	-
	0630	0.009	-
	0730	0.009	-
	0815	0.004	250
	0930	0.004	260
	1030	0.002	-
	1100	0	-
	1500	0	-
	1515	0.074	250
	1520	0.060	330
	1530	0.047	250
	1550	0.047	180
	1610	0.047	110
	1630	0.047	100
	1650	0.053	100
	1700	0.053	70
	1740	0.047	100
	1750	0.047	60
	1800	0.041	70
	1810	0.041	90
	1910	0.030	-
	2010	0.025	-
	2110	0.020	-
	2200	0	-

STORM DATA - 3/15/72 - FLOW POINT 3

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/15/72	0720	0	-
	0740	0.009	-
	0800	0.035	-
	0820	0.099	-
	0828	0.209	-
	0840	0.280	-
	0856	0.363	-
	0900	0.457	-
	0920	0.418	-
	0930	0.457	30
	0950	0.587	40
	1010	0.457	40
	1030	0.328	40
	1050	0.183	40
	1110	0.138	30
	1130	0.099	40
	1150	0.074	50
	1210	0.060	50
	1230	0.470	50
	1330	0.025	50
	1435	0.006	70
	1500	0.002	50
	1600	0	-
	1620	0	-
	1640	0.006	70
	1740	0.006	-
	1840	0.004	-
	1900	0.016	-
	1920	0.035	-
	1940	0.067	-
	2000	0.108	-
	2020	0.118	-
	2040	0.108	-
	2100	0.082	-
	2200	0.047	-
	2300	0.030	-
	2400	0.020	-
3/16/72	0100	0.016	-
	0200	0.012	-
	0300	0.012	-
	0400	0.009	-
	0500	0.009	-
	0600	0.006	-
	0700	0.006	-
	0800	0.006	-
	0830	0.006	40
	0935	0.004	50
	1000	0.004	-
	1100	0.002	-
	1200	0.002	-
	1300	0	-
	1440	0	-
	1510	0.067	30
	1515	0.118	50
	1520	0.108	40
	1530	0.118	30
	1550	0.183	30
	1610	0.138	30

STORM DATA - 3/15/72 - FLOW POINT 3 (cont'd)

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/16/72 (cont'd)	1630	0.099	40
	1650	0.0741	30
	1700	0.067	20
	1740	0.041	30
	1750	0.035	30
	1800	0.030	40
	1810	0.025	40
	1900	0.016	-
	2200	0.006	-

STORM DATA - 3/15/72 - FLOW POINT 4

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/15/72	0740	0	-
	0812	0.740	-
	0820	0.635	-
	0836	2.71	-
	0844	2.56	-
	0900	2.87	-
	0930	2.07	300
	0950	2.56	350
	1010	2.35	450
	1030	1.48	350
	1050	0.705	375
	1110	0.434	450
	1130	0.302	550
	1150	0.208	650
	1210	0.152	700
	1230	0.119	900
	1330	0.044	1300
	1430	0.008	1500
	1500	0.005	1550
	1640	0	-
	1900	0	-
	1910	0.005	-
	1920	0.089	-
	1940	0.232	-
	2000	0.434	-
	2020	0.510	-
	2040	0.434	-
	2120	0.232	-
	2220	0.119	-
	2240	0.089	-
	2320	0.062	-
	2400	0.043	-
3/16/72	0020	0.039	-
	0100	0.024	-
	0140	0.005	-
	0240	0.003	-
	0320	0.002	-
	0420	0.002	-
	0520	0.001	-
	0620	0.001	-
	0720	0	-
	1500	0	-
	1512	0.497	1150
	1517	0.860	800
	1522	0.880	1050
	1532	0.725	950
	1552	0.680	900
	1612	0.434	700
	1632	0.208	600
	1652	0.127	650
	1702	0.119	750
	1742	0.089	950
	1752	0.068	1050
	1802	0.066	1100
	1812	0.062	1200
	1840	0.026	-
	1940	0.020	-
	2020	0.005	-

STORM DATA - 3/15/72 - FLOW POINT 4 (cont'd)

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/16/72 (cont'd)	2040	0.004	-
	2100	0.001	-
	2140	0.001	-
	2200	0	-

STORM DATA - 3/21/72 - FLOW POINT 1

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/21/72	1520	0	-
	1525	0.009	15
	1535	0.004	20
	1545	0.002	20
	1600	0	-

STORM DATA - 3/21/72 - FLOW POINT 2

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/21/72	1510	0	-
	1530	0.074	140
	1540	0.006	510
	1550	0.004	380
	1600	0	-

STORM DATA - 3/21/72 - FLOW POINT 3

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/21/72	1500	0	-
	1530	0.041	50
	1540	0.009	50
	1550	0.009	65
	1600	0	-

STORM DATA - 3/21/72 - FLOW POINT 4

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/21/72	1505	0	-
	1532	0.012	550
	1542	0.050	1150
	1552	0.039	1400
	1602	0.002	2600
	1610	0	-

STORM DATA - 3/27/72 - FLOW POINT 3

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/27/72	0200	0	
	0215	0.030	(55)*
	0220	0.047	(48)
	0232	0.012	(75)
	0240	0.009	(75)
	0300	0.041	(50)
	0304	0.171	(35)
	0312	0.030	(55)
	0320	0.016	(70)
	0324	0.020	(60)
	0400	0.009	(75)
	0500	0.006	-
	0600	0	-

* Analytical data shown in parentheses estimated from previous correlations at this monitoring station.

STORM DATA - 3/27/72 - FLOW POINT 4

Date	Time of Day hrs	Flow cfs	Acidity mg/l
3/27/72	0300	0	-
	0304	0.119	(950)*
	0312	0.900	(425)
	0316	0.740	(450)
	0320	0.940	(425)
	0324	0.565	(500)
	0332	0.327	(610)
	0340	0.940	(425)
	0352	0.565	(500)
	0400	0.378	(600)
	0420	0.119	(950)
	0440	0.050	(1250)
	0540	0.039	(1350)
	0640	0.029	(1500)
	0740	0	-

* Analytical data shown in parentheses estimated from previous correlations at this monitoring station.

STORM DATA - 4/7/72 - FLOW POINT 2

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/7/72	1300	0	-
	1310	0.041	110
	1320	0.030	280
	1330	0.009	230
	1340	0.004	230
	1400	0.002	190
	1440	0.002	170
	1500	Trace	-
	1600	Trace	-
	1700	Trace	-
	1800	0	-

STORM DATA - 4/7/72 - FLOW POINT 3

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/7/72	1300	0	-
	1310	0.020	30
	1320	0.047	40
	1330	0.025	40
	1340	0.009	30
	1400	0.004	30
	1440	0.002	30
	1500	Trace	-
	1600	Trace	-
	1700	Trace	-
	1800	Trace	-
	1900	Trace	-
	2000	Trace	-
	2100	Trace	-

STORM DATA - 4/7/72 - FLOW POINT 4

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/7/72	1300	0	
	1315	0.062	600
	1325	0.211	1450
	1335	0.211	1300
	1345	0.135	2250
	1405	0.062	2200
	1425	0.039	3150
	1445	0.039	3300
	1505	0.039	3300
	1600	0.039	-
	1700	0.039	-
	1800	0.029	-
	1900	0.029	-
	2000	0.029	-
	2100	0	-

STORM DATA - 4/14/72 - FLOW POINT 1

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/14/72	0200	0	-
	0250	0.060	-
	0255	0.209	-
	0300	0.149	-
	0310	0.520	-
	0330	0.209	-
	0400	0.030	-
	0500	0.009	-
	0600	0.002	-
	0700	0	-
	0730	0	-
	0750	0.099	-
	0800	0.564	-
	0810	1.70	-
	0825	0.818	-
	0845	0.363	40
	0925	0.280	30
	1005	0.099	20
	1045	0.041	40
	1145	0.016	40
	1245	0.006	50
	1300	0.002	-
	1400	0	-
4/15/72	0100	0	-
	0135	0.020	-
	0140	0.328	-
	0200	1.47	-
	0220	0.564	-
	0240	0.209	-
	0300	0.149	-
	0320	0.457	-
	0340	0.363	-
	0400	0.183	-
	0500	0.099	-
	0600	0.074	-
	0700	0.041	-
	0720	0.035	40
	0815	0.030	50
	0910	0.025	55
	1000	0.030	-
	1100	0.060	-
	1130	0.564	-
	1140	1.57	-
	1150	1.13	-
	1200	0.564	-
	1225	0.520	20
	1305	0.250	10
	1345	0.099	20
	1430	0.053	20
	1500	0.030	-
	1600	0.020	-
	1720	0.012	30
	1900	0.030	-
	2000	0.047	-
	2100	0.060	-
	2200	0.149	-
	2230	0.381	-

STORM DATA - 4/14/72 - FLOW POINT 1 (cont'd)

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/15/72 (cont'd)	2250	0.564	-
	2300	0.457	-
	2400	0.099	-
4/16/72	0100	0.041	-
	0200	0.025	-
	0300	0.020	-
	0400	0.012	-
	0500	0.009	-
	0600	0.004	-
	0700	0	

STORM DATA - 4/14/72 - FLOW POINT 2

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/14/72	0200	0	-
	0230	0.012	-
	0330	0.171	-
	0345	0.020	-
	0400	0.053	-
	0500	0.025	-
	0600	0.006	-
	0700	0.006	-
	0800	0.209	-
	0815	1.06	-
	0835	1.34	30
	0855	0.846	30
	0935	0.478	40
	1015	0.250	55
	1055	0.118	60
	1135	0.067	80
	1235	0.035	150
	1300	0.025	-
	1400	0.012	-
	1500	0	-
4/15/72	0100	0	-
	0130	0.060	-
	0200	0.659	-
	0230	0.846	-
	0300	0.328	-
	0330	0.478	-
	0400	0.328	-
	0500	0.138	-
	0600	0.082	-
	0700	0.053	-
	0720	0.041	100
	0800	0.035	-
	0910	0.020	120
	1000	0.025	-
	1100	0.053	-
	1130	0.564	-
	1200	0.934	-
	1225	0.846	40
	1305	0.542	30
	1345	0.265	50
	1430	0.090	55
	1530	0.035	-
	1630	0.012	-
	1720	0.012	140
	1900	0.025	-
	2000	0.030	-
	2100	0.041	-
	2200	0.138	-
	2230	0.381	-
	2330	0.280	-
	2400	0.171	-
4/16/72	0030	0.099	-
	0100	0.067	-
	0200	0.041	-
	0300	0.025	-

STORM DATA - 4/14/72 - FLOW POINT 2 (cont'd)

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/16/72 (cont'd)	0400	0.020	-
	0500	0.016	-
	0600	0.012	-
	0700	0.009	-
	0800	0.006	-
	0900	0	-

STORM DATA - 4/14/72 - FLOW POINT 3

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/14/72	0020	0	-
	0140	0.002	-
	0220	0.012	-
	0300	0.020	-
	0308	0.265	-
	0320	0.183	-
	0340	0.035	-
	0400	0.012	-
	0440	0.012	-
	0500	0.009	-
	0600	0.004	-
	0700	0.004	-
	0800	0.236	-
	0840	1.49	20
	0920	0.875	20
	1000	0.478	25
	1040	0.183	40
	1140	0.074	50
	1240	0.035	50
	1340	0.020	-
	1440	0.012	-
	1540	0.009	-
	1600	0.006	70
	1620	0	-
4/15/72	0120	0	-
	0140	0.041	-
	0200	1.06	-
	0216	2.01	-
	0220	1.92	-
	0230	1.41	-
	0240	0.875	-
	0300	0.437	-
	0320	0.763	-
	0340	0.904	-
	0400	0.542	-
	0420	0.312	-
	0440	0.222	-
	0500	0.171	-
	0600	0.149	-
	0700	0.082	-
	0730	0.060	35
	0810	0.053	30
	0905	0.041	30
	1005	0.053	-
	1100	0.060	-
	1120	0.128	-
	1140	1.06	-
	1200	2.01	-
	1220	1.09	-
	1250	1.06	10
	1330	0.457	20
	1400	0.209	-
	1430	0.128	25
	1530	0.060	-
	1630	0.035	-
	1700	0.030	-

STORM DATA - 4/14/72 - FLOW POINT 3 (cont'd)

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/15/72 (cont'd)	1725	0.025	25
	1800	0.020	-
	1900	0.041	-
	2000	0.060	-
	2100	0.060	-
	2200	0.196	-
	2300	0.763	-
	2400	0.209	-
4/16/72	0100	0.082	-
	0200	0.053	-
	0300	0.035	-
	0400	0.025	-
	0500	0.020	-
	0600	0.016	-
	0700	0.009	-
	0800	0.006	-
	1000	0.004	-
	1100	0	-

STORM DATA - 4/14/72 - FLOW POINT 4

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/14/72	0240	0	-
	0300	0.232	-
	0312	2.28	-
	0320	2.42	-
	0340	1.88	-
	0400	0.497	-
	0420	0.170	-
	0500	0.039	-
	0600	0.029	-
	0700	0.020	-
	0800	2.28	-
	0808	5.56	-
	0820	10.50	-
	0840	8.06	250
	0900	4.18	275
	0940	2.87	450
	1000	1.59	450
	1040	0.565	700
	1140	0.190	900
	1240	0.062	1300
	1340	0.050	-
	1440	0.050	-
	1540	0.050	-
	1600	0	-
4/15/72	0120	0	-
	0140	0.565	-
	0152	5.45	-
	0200	10.8	-
	0220	5.56	-
	0240	2.42	-
	0300	1.82	-
	0320	3.53	-
	0340	3.03	-
	0400	1.32	-
	0500	0.327	-
	0600	0.119	-
	0700	0.020	-
	0745	0	-
	0800	0	-
	0900	0.020	1900
	1000	0.075	-
	1100	0.075	-
	1120	0.378	-
	1140	5.56	-
	1200	10.20	-
	1220	7.02	-
	1230	7.02	325
	1250	4.48	350
	1300	3.53	-
	1330	1.42	575
	1400	0.565	-
	1420	0.278	950
	1500	0.152	-
	1600	0.050	-
	1700	0.020	-
	1800	0.005	-
	2400	0	-

STORM DATA - 4/20/72 - FLOW POINT 1

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/20/72	0000	0	-
	0100	0.002	-
	0130	0.149	-
	0145	0.790	-
	0200	0.363	-
	0230	0.099	-
	0300	0.041	-
	0400	0.009	-
	0500	0.002	-
	0600	0	-
4/21/72	0100	0	-
	0200	0.002	-
	0230	0.030	-
	0300	0.099	-
	0330	0.280	-
	0350	0.875	-
	0355	0.934	-
	0400	0.875	-
	0430	0.790	-
	0500	0.763	-
	0530	0.611	-
	0600	0.328	-
	0700	0.183	-
	0800	0.090	30
	0900	0.030	40
	0950	0.016	-
	1000	0.030	-
	1040	0.457	-
	1100	0.363	-
	1130	0.209	-
	1155	0.710	-
	1212	0.457	-
	1230	0.965	-
	1300	0.222	-
	1400	0.047	-
	1500	0.020	-
	1600	0.006	-
	1700	0.002	-
4/22/72	0400	0	-

STORM DATA - 4/20/72 - FLOW POINT 2

Date	Time of Day hrs	Flow cfs	Acidity mg/1
4/20/72	0000	0	-
	0100	0.002	-
	0200	0.250	-
	0230	0.345	-
	0300	0.250	-
	0400	0.099	-
	0500	0.047	-
	0600	0.035	-
	0700	0.025	-
	0800	0.020	-
	0830	0.017	80
	0900	0.016	-
	1100	0.012	-
	1300	0.009	-
	1400	0	-
4/21/72	0200	0	-
	0300	0.099	-
	0400	1.03	-
	0430	1.38	-
	0500	1.23	-
	0600	0.763	-
	0700	0.499	-
	0800	0.280	50
	0900	0.128	70
	0945	0.082	-
	1000	0.108	-
	1100	0.478	-
	1200	0.710	-
	1230	1.16	-
	1300	0.818	-
	1400	0.250	-
	1500	0.108	-
	1600	0.060	110
	1700	0.047	-
4/22/72	0400	0	-

STORM DATA - 4/20/72 - FLOW POINT 3

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/20/72	0000	0.012	-
	0100	0.047	-
	0200	0.196	-
	0228	0.296	-
	0300	0.209	-
	0400	0.082	-
	0500	0.053	-
	0600	0.030	-
	0700	0.020	-
	0835	0.002	30
	0900	0.006	-
	1000	0.004	-
	1400	0	-
4/21/72	0008	0	-
	0016	0.009	-
	0044	Trace	-
	0100	0.006	-
	0200	0.006	-
	0300	0.149	-
	0400	1.70	-
	0416	1.92	-
	0444	1.65	-
	0456	1.74	-
	0516	1.34	-
	0520	1.49	-
	0600	0.790	-
	0620	0.846	-
	0700	0.542	-
	0805	0.236	20
	0905	0.099	35
	0956	0.060	-
	1030	0.363	-
	1100	0.818	-
	1130	0.542	-
	1212	1.13	-
	1220	1.06	-
	1240	1.83	-
	1300	0.996	-
	1400	0.196	-
	1500	0.090	-
	1600	0.035	35
	1700	0.030	-
	2000	0.020	-
	2400	0.006	-
5/22/72	0100	0.002	-
	0300	0	-

STORM DATA - 4/20/72 - FLOW POINT 4

Date	Time of Day hrs	Flow cfs	Acidity mg/l
4/20/72	0100	0	-
	0124	1.17	-
	0152	4.68	-
	0230	1.42	-
	0300	0.670	-
	0400	0.170	-
	0500	0.062	-
	0600	0.020	-
	0900	0	-
4/21/72	0124	0	-
	0200	0.005	-
	0300	0.740	-
	0400	8.80	-
	0412	9.55	-
	0440	8.35	-
	0448	8.80	-
	0512	6.64	-
	0516	7.54	-
	0540	5.56	-
	0546	3.53	-
	0620	4.38	-
	0700	2.21	-
	0800	0.780	-
	0810	0.635	700
	0900	0.302	-
	0910	0.278	1000
	0952	0.119	-
	1000	0.211	-
	1048	4.28	-
	1124	2.28	-
	1200	5.80	-
	1230	9.25	-
	1300	3.44	-
	1400	0.635	-
	1500	0.232	-
	1600	0.119	-
	1615	0.103	1650
	1700	0.075	-
	1720	0.062	-
	1732	0.075	-
	1744	0.135	-
	1800	0.119	-
	1900	0.062	-
	2200	0.005	-
4/22/72	0200	0	-

STORM DATA - 5/1/72 - FLOW POINT 1

Date	Time of Day hrs	Flow cfs	Acidity mg/l
5/1/72	0650	0	-
	0655	0.004	50
	0700	0.030	-
	0705	0.025	-
	0710	0.012	-
	0715	0.004	-
	0720	0.002	50
	0730	0	-
	0800	0	-
	0810	0.006	-
	0815	0.009	40
	0835	0.002	30
	0900	0.002	30
	1000	0	-

STORM DATA - 5/1/72 - FLOW POINT 5*

Date	Time of Day hrs	Flow cfs	Acidity mg/l
5/1/72	0700	0	-
	0710	4.90	-
	0720	3.78	-
	0730	1.03	-
	0735	0.668	260
	0740	0.248	-
	0750	0.070	-
	0800	0.025	-
	0810	0.110	350
	0830	0.745	290
	0840	0.234	-
	0850	0.120	290
	0940	0.010	-
	0950	0.010	310
	1000	0.010	-
	1050	0	-

* Data for slurry lagoons treated with "Coherex".

STORM DATA - 5/29/72 - FLOW POINT 1

Date	Time of Day hrs	Flow cfs	Acidity mg/l
5/29/72	1420	0	-
	1425	0.004	40
	1428	0.090	-
	1430	0.047	-
	1435	0.009	-
	1440	0.030	-
	1445	0.035	40
	1450	0.030	-
	1455	0.016	-
	1500	0.004	-
	1505	Trace	45
	1510	0	-

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SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.	
2.	
3. Accession No.	**W**
4. Title	Control of Mine Drainage from Coal Mine Mineral Wastes - Phase II - Pollution Abatement and Monitoring
5. Report Date	
6.	
7. Author(s)	Z. V. Kosowski
8. Performing Organization Report No.	
9. Organization	Midwestern Division of Consolidation Coal Co.
10. Project No.	14010 DDH
11. Contract/Grant No.	
12. Sponsoring Organization	
13. Type of Report and Period Covered	
15. Supplementary Notes	Environmental Protection Agency Report No. EPA-R2-73-230, May 1973

16. Abstract

Acid runoff from refuse piles can be controlled by covering the mineral wastes with soil, establishing a vegetative cover, and providing adequate drainage to minimize erosion. The average acid formation rate for the entire restored refuse pile was estimated at 16 lb acid as $CaCO_3$/acre/day, or a reduction of 91+% when compared to the original unrestored pile. No significant differences were observed in acid formation rates from the 3 individual test plots covered with a nominal 1 foot, 2 feet, or 3 feet of soil. However, it was more difficult to physically place 1 foot of soil, especially on the steeper slopes.

Slurry lagoons containing the fine coal rejects can be stabilized and the air pollution problem controlled by either a vegetative cover established directly on the mineral wastes without soil or by the application of a chemical stabilizer. Chemical stabilization is only a temporary measure, and vegetative covers should be the permanent solution to slurry lagoons.

Cost data from this project indicate that it would cost approximately $6,100, $8,000, and $9,800 per acre to cover with grass a refuse pile with one, two, and three feet of soil respectively.

17a. Descriptors

Acid Mine Drainage*, Refuse Piles*, Slurry Ponds*, Reclamation, Coal Mine

17b. Identifiers

Illinois*, New Kathleen Mine*, Mineral Wastes*, Acid Formation Rate

17c. COWRR Field & Group

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