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Tioga River Mine Drainage Abatement Project

Interagency Energy/Environment R&D Program Report

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TIOGA RIVER MINE DRAINAGE ABATEMENT PROJECT

by

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PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL RESOURCES

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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 project demonstrated effective techniques for mine drainage abatement, reduced a specific mine drainage problem, and restored portions of a strip mined area to their approximate original surface grades. Techniques demonstrated included: restoration of strip pits utilizing agricultural limestone and wastewater sludge as soil conditioners; burial of acid-forming materials within strip mines that were restored; and reconstruction and lining of a stream channel. Effectiveness of these preventive measures and their costs were determined. The data presented in this study will aid government and private companies to evaluate mine drainage abatement measures. The Extraction Technology Branch, Resource Extraction and Handling Division, may be contacted for further information.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

The Tioga River Demonstration Project in southeastern Tioga County, Pennsylvania, is located in an area essentially defined by an isolated pocket of coal that has been extensively deep and strip mined within the Pennsylvania Bituminous Coal Field. Acid mine drainage from abandoned mines is discharged into Morris Run, and Coal and Bear Creeks before they enter the Tioga River near Blossburg Borough. Water in these three streams generally has a pH of about 3.0 with a net acidity ranging from 200 to 1,000 milligrams per liter.

This project demonstrated effective techniques for mine drainage abatement, reduced a specific mine drainage problem, and restored portions of a strip mined area to their approximate original surface grades. Techniques demonstrated included restoration of strip pits utilizing agricultural limestone and wastewater sludge as soil conditioners, burial of acid-forming materials within strip mines that were restored, and reconstruction and lining of a stream channel. Effectiveness of these proventive measures and their costs were determined.

Project implementation resulted in an estimated acid reduction of 862 kilograms per day under average groundwater conditions from one of the two project sites. Reductions in flows and loadings from the other project site could not be confirmed because of gaps in the monitoring data and the relatively small size of the site when compared to the total mined area contributing to the discharges. However, large volumes of surface water now flow off the restored area to Fall Brook during and following significant rainfalls, rather than continuing to enter the underground mine workings. In addition, 16 and 13 percent reductions in acidity concentrations from the associated mine drainage discharges were documented.

This report was submitted in fulfillment of the requirements for Grant No. 14010 HIN by Gannett Fleming Corddry and Carpenter, Inc., under the sponsorship of the U. S. Environmental Protection Agency. This report covers the period November 1971 to October 1977, and work was completed as of August 1978.

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The helpful suggestions and comments of Henry R. Thacker, Ernst P. Hall, Ronald D. Hill, and Eugene F. Harris, of the U. S. Environmental Protection Agency were greatly appreciated.

The technical and administrative assistance provided during this project by Messrs. A. W. Bartlett, Robert Buhrman, John J. Buscavage, John J. Demchalk, Michael R. Ferko, Donald E. Fowler, Andrew E. Friedrich, Karl Hoover, C. H. McConnell, A. E. Molinski, D. W. Perrego, A. A. Ranieri, George Single, and Andrew Wasko of the Pennsylvania Department of Environmental Resources is gratefully acknowledged. Special recognition is given for the significant direction provided to the project by Edward R. Bates, who was employed by the Department but subsequently joined the Environmental Protection Agency staff.

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Richard W. Condon, Chairman of the Department of History, Mansfield State College, Mansfield, Pennsylvania, provided material aid by loaning study area deep mine maps.

Recognition is given for the significant contribution to success of the project made by Allegheny Mountain Company's Jerome J. Eckert, who installed the monitoring station weirs, hauled the wastewater sludge, and constructed the abatement measures on the two demonstration sites.

Acknowledgement is also made of the information and advice provided by W. W. Hinish of The Pennsylvania State University and Ralph Donald Lindsey of the Soil Conservation Service relative to seeding and soil supplements for the project.

The support and assistance given by Jerrald R. Hollowell of the Susquehanna River Basin Commission and Janice R. Ward of the United States Geological Survey in connection with the project monitoring program were greatly appreciated.

Finally, special recognition is gratefully given for the outstanding effort provided by Larry Haynes in maintaining the flow recorders, securing precipitation data, and collecting grab samples at the monitoring stations in all kinds of weather.

CONVERSION TABLE

	Metric Equivalents			English Equivalents	
	Divide		By	To Obtain	
Measurement	Unit	Symbol		Unit	Symbol
Length	centimeter	cm	2.54	inch	in
	meter	m	0.3048	foot	ft
	kilometer	km	1.61	mile	mi
Area	square meter	m^2	0.836	square yard	sy
	hectare	ha	0.405	acre	ac
	square kilometer	km^2	2.59	square mile	-
Volume	cubic meter	m^3	0.0283	cubic foot	cf
	cubic meter	m^3	0.7645	cubic yard	cy
	liter	l	3.785	gallon	gal
Mass	kilogram	kg	0.4536	pound	lb
	tonne	t	0.9074	ton	-
Flow	liter per second	l/s	0.06309	gallons per minute	gpm
	cubic meter per second	m^3/s	0.02832	cubic foot per second	cfs
	cubic meter per second	m^3/s	0.0438	million gallons per day	mgd

SECTION 1

INTRODUCTION

BACKGROUND

This report evaluates the information and data derived from implementation of a mine drainage abatement demonstration project consisting of two small portions of a mined area in the vicinity of Morris Run Village, Tioga County, Pennsylvania.

The Morris Run Study Area (Figure 1) constitutes a portion of the Pennsylvania Bituminous Coal Field in the upper reaches of the Tioga River Watershed. Although coal was mined in local areas within this watershed, the 35-square-kilometer study area is the prime source of significant acid mine drainage in the watershed. This mined area was further described in a 1968 report prepared by Gannett Fleming Corddry and Carpenter, Inc., entitled "Acid Mine Drainage Abatement Measures for Selected Areas Within the Susquehanna River Basin," referred to hereafter as the FWPCA Report.[1]

In May 1971, an application was submitted by the Pennsylvania Department of Environmental Resources to the U. S. Environmental Protection Agency requesting a demonstration grant in the amount of $450,000 to construct preventive measures as part of the recommended abatement plan described in the FWPCA Report. This approved grant, together with $226,500 from the Department, made $676,500 available for the project. The Department then entered into a service contract with Gannett Fleming Corddry and Carpenter, Inc., effective November 30, 1971, to perform engineering work and services related to the project.

The initial phase of the project culminated in a report[2] establishing the feasibility of the proposed demonstration project. Feasibility was established by:

1. Reviewing the history of mining, mine drainage problems, and potentially effective mine drainage abatement measures in the study area.

2. Determining the jurisdictional framework (legal authority) through which the demonstration project could be carried out.

3. Inventorying the interrelationship of geology, topography and geomorphology, hydrology, water quality, social and economic factors, and environmental features that would affect

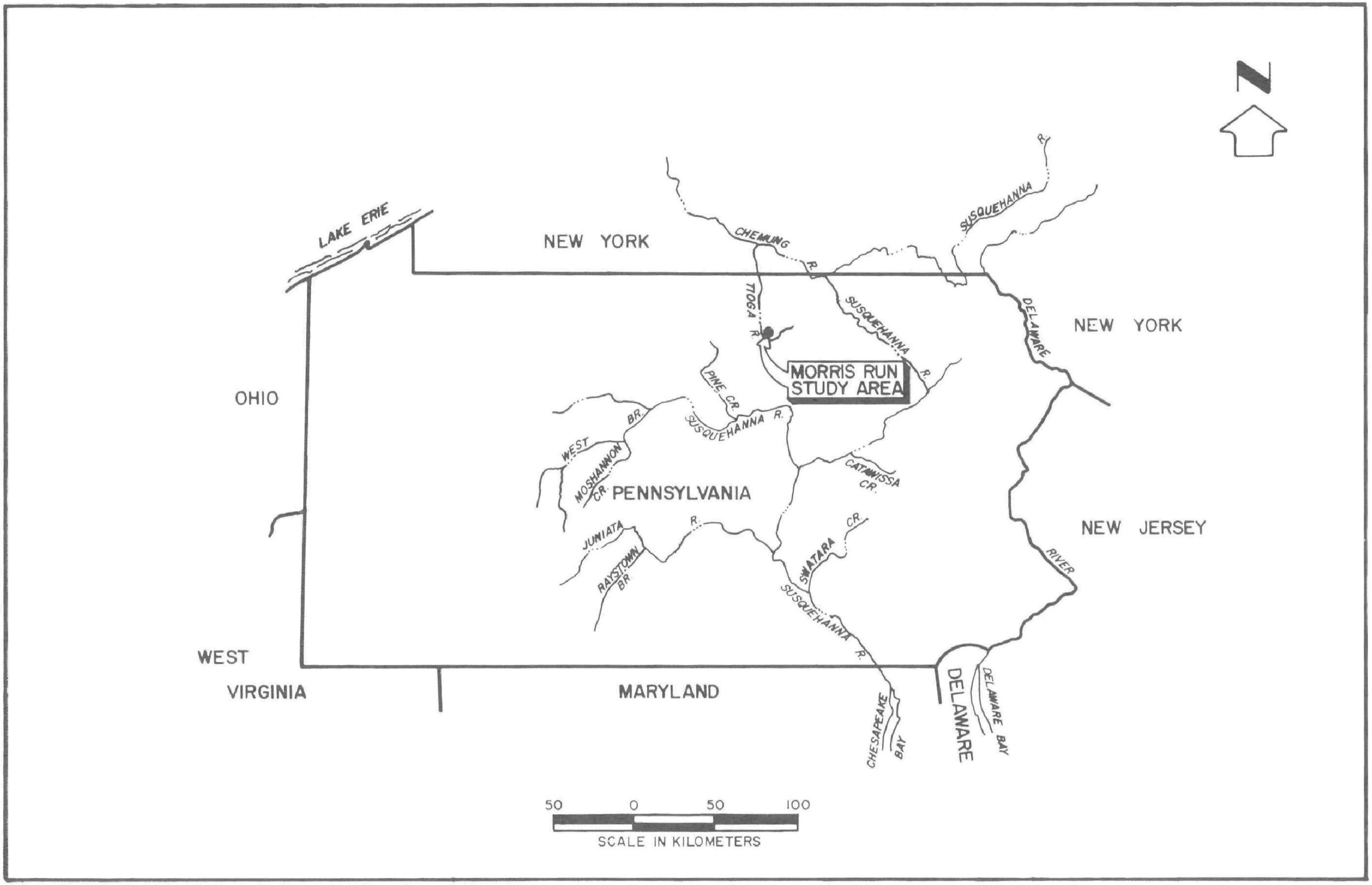


Figure 1. Location of Morris Run study area.

the value of a demonstration project in the study area.

4. Developing in sufficient detail a possible abatement program.

5. Assessing the potential effectiveness and stream quality improvement resulting from construction of the proposed project.

6. Determining possible benefits resulting from construction of the proposed project.

7. Developing proposed schedule and budget to assure satisfactory completion of the proposed project.

8. Recommending a surveillance program for the project area to enable assessment of actual versus estimated effectiveness.

GENERAL DESCRIPTION OF THE PROJECT

Abatement measures at the following sites were determined to be feasible and the following were recommended for construction (See Figure 2):

Site I.

Replace and line approximately 358 meters of stream channel. Restore strip mine S-26, consisting of approximately 5.7 hectares and 128,000 cubic meters of fill. Place agricultural limestone, fertilizer, and grass seed on the restored area. Construct monitoring station MS-1 and MS-2 upstream and downstream, respectively, of S-26. Construct monitoring station MS-3 on an underground mine drainage discharge.

These measures would (1) prevent a stream from flowing directly into underground mine workings, (2) limit water flow into underground mine workings with a comparable reduction in pollution from mine watercourse MS-3, and (3) restore the watercourse as one of the headwaters of Morris Run.

Site II.

Restore portions of improperly restored strip mines S-37 and S-39, consisting of approximately 24.3 hectares and 323,000 cubic meters of fill. Establish a 1.74 hectare test plot on the restored site and place sewage sludge and seed on the test plot to demonstrate effectiveness in establishing and maintaining vegetative growth. Place agricultural limestone, fertilizer, and grass seed on the remainder of the restored site. Construct monitoring stations MS-4, MS-5, and MS-6 on the affected deep mine discharges.

Deep mine maps for the Lower Kittanning seam were secured for the general area encompassing Site II as well as monitoring stations MS-4, MS-5, and MS-6. A review of these maps revealed that the three mines involved, which are drained by these three discharges, have been interconnected so extensively

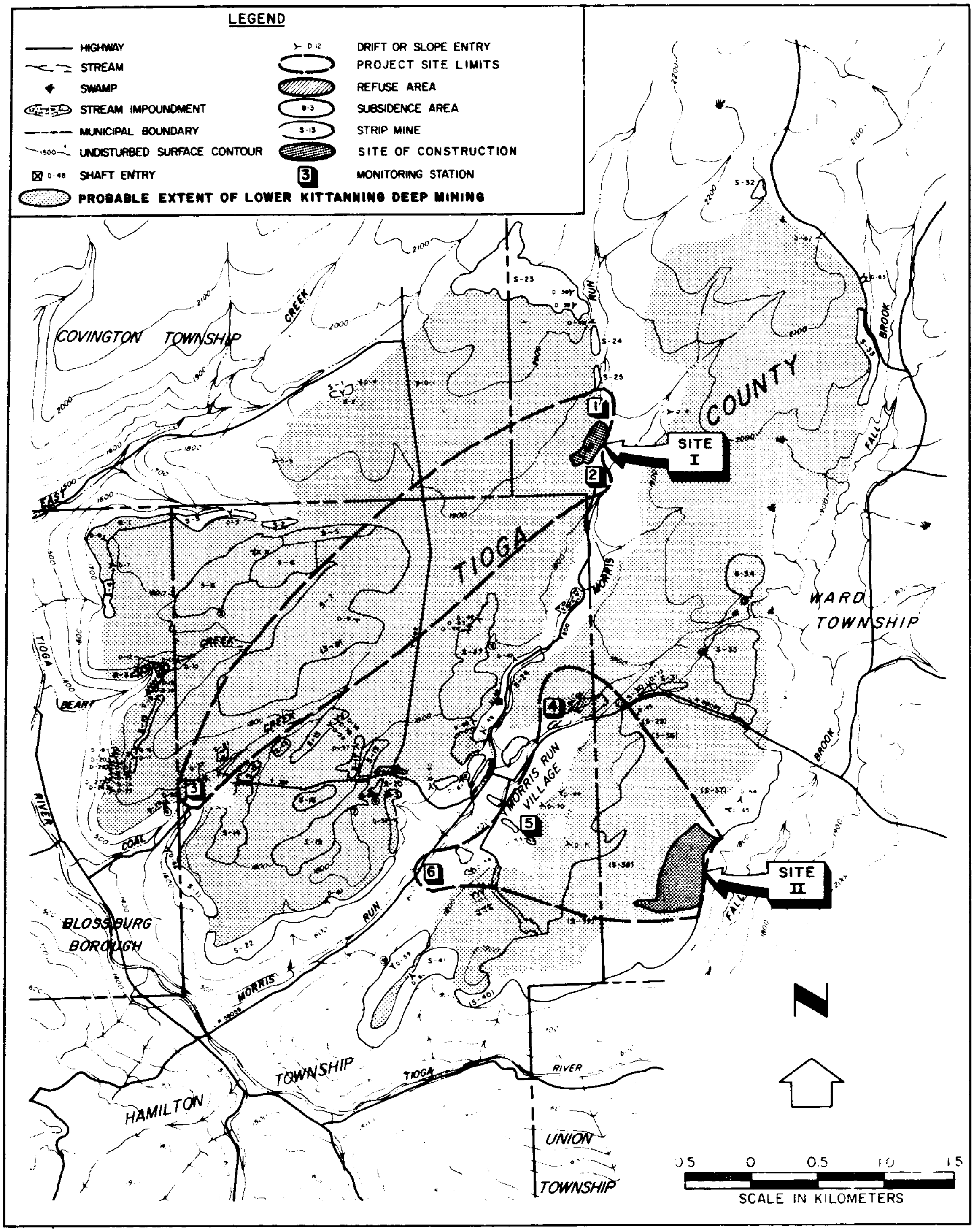


Figure 2. Mine - related features of Morris Run study area.

that the entire mined area can be considered as having one mine drainage pattern. Very little specific coal pavement elevation information was available for two of these three mines. Therefore, it was not possible to delineate where the water presently entering the mines via Site II actually emerges at specific discharge points. From these maps and available geologic information, it was estimated that 90 percent of the water infiltration via Site II flows to monitoring station MS-5 and 10 percent flows to monitoring station MS-4. Because of the lack of this specific information, monitoring station MS-6 was also monitored.

The proposed construction at the two sites shown on Figure 2 would prevent considerable volumes of surface water from entering deep mine workings, via interconnected strip mines in the Lower Kittanning seam, and contributing to deep mine discharges.

PURPOSE OF THE PROJECT

The primary objective of this project was to demonstrate the effectiveness of replacing a stream channel, restoring strip mines, and using wastewater sludge as a soil amendment in eliminating or reducing acid mine drainage discharges. In order to demonstrate the effectiveness of the project, it was necessary to (1) monitor acid mine drainage sources before, during, and after construction, and (2) maintain complete cost records relative to construction and maintenance of the preventive measures implemented.

EFFECTIVENESS OF THE PROJECT

Implementation of this demonstration project reduced acid mine drainage at two or more discharge points. Effectiveness of the demonstration project was determined by a gauging, sampling, and analytical program carried out at the six monitoring stations. Monitoring of these acid mine drainage discharges and the affected stream before, during, and after construction confirmed mine drainage flow reductions resulting from construction. The accurate construction cost records compiled will enable estimation of abatement costs on similar areas in the future.

SECTION 2

CONCLUSIONS

The strip mine restoration and stream channel reconstruction at Site I has proved to be effective in achieving project objectives.

The monitoring program demonstrated that before construction a loss of flow occurred in the tributary of Morris Run as it passed through Site I. This loss contributed to the discharge draining the underlying deep mine workings (MS-3). This water loss (and its subsequent contribution to MS-3) was as follows:

Seasonal Conditions	Preconstruction MS-1 To MS-2 Channel Loss In Stream Flow (m^3/s)	Preconstruction MS-1 To MS-2 Channel Stream Flow Contribution To MS-3 (Percent)
High Groundwater	0.018	10.5
Low Groundwater	0.012	19.3
Yearly Average	0.014	11.8

After construction, there was no measurable loss in stream flow between MS-1 and MS-2. Furthermore, when monitoring data were adjusted for normal annual rainfall, flow from MS-3 had been reduced approximately 15 percent. Although there was no measurable change in acidity at MS-3, the postconstruction reduction in flow has resulted in a daily reduction of approximately 862 kilograms of acid at MS-3.

Based upon a two-year site evaluation, a successful vegetative growth had been established on the restored strip mine acreage, and the stream channel had been successfully restored to handle design flows. No maintenance of the site appeared to be required.

Site I construction was accomplished at a total cost of $156,565. This amounted to approximately $166/meter for channel reconstruction and $14,789/hectare for strip mine restoration.

Results of construction at Site II were not as clear-cut as demonstrated at Site I. No permanent flow reduction could be confirmed because of gaps in the monitoring data and because construction at Site II reaffected only a very small portion of the mined area contributing to the discharges draining the underground mine complex. Flows at MS-4 and MS-5 when adjusted to normal precipitation appeared to be slightly reduced during the first postconstruction year but appeared to be slightly increased during the second postconstruction year. However, it was apparent that large volumes of surface runoff flowed off the restored area whenever significant rainfall occurred. In addition, after Site II construction, acidity concentrations gradually and consistently decreased at the two discharges draining the reaffected area. By the end of the second postconstruction year, there were 16 percent and 13 percent reductions in acidity, respectively at MS-4 and MS-5. The causes of this water quality improvement were not clear.

Excellent results were achieved in demonstrating the use of municipal wastewater sludge as a soil conditioner. Grasses grown on the sludge plot were thicker and more luxurious than grasses grown on the remainder of the restored area. The average air-dried weight of grasses cut from random 1-square-meter areas within the test plot was about three times that from adjacent 1-square-meter areas where the grasses were growing the best. Furthermore, based on bacteriological analyses of samples obtained from the infiltration ditch below the sludge plot, no significant health hazard existed.

As in the case of Site I, it appeared that restoration at Site II was successful and no maintenance would be required. This restoration was accomplished at a total cost of $303,577 or $9,370/hectare. Several factors, such as surface slope, volume of earth, and surface area affected, enter into the cost of restoring an abandoned strip mine. The Pennsylvania Department of Environmental Resources' recent experience indicated that such restoration construction costs have ranged from $7,400 to $14,800/hectare in the Bituminous Field, and from $7,400 to $24,700/hectare in the Anthracite Field. The construction costs at Sites I and II, therefore, can be considered as top-of-the-range and mid-range, respectively. One contribution to the higher unit cost at Site I was the greater volume of earth moved per hectare when compared to Site II. However, in the final analysis, the responsible person must weigh the costs against the benefits in deciding whether to restore abandoned strip mines.

During construction, Hurricane Eloise dropped more than 12.7 centimeters of rain as it passed through the project area. The runoff from this significant rainfall caused damage at both Sites I and II. Some $20,967 of the total construction cost of $460,142 was spent to repair this storm-related damage. It is believed, however, that no significant future maintenance will be required on this project.

SECTION 3

RECOMMENDATIONS

Based on the information developed during this project, the following recommendations are made:

1. Since both technical and economic feasibility of using strip mine restoration to the approximate original contour, burial of acid-forming material, replacement of a stream channel, and use of clay as an impermeable membrane in the restored stream channel for mine drainage abatement have been successfully demonstrated, these methods should be utilized, where applicable, to reduce or eliminate acid mine drainage.

2. Where mine drainage abatement projects are being undertaken, monitoring programs should be established on the affected mine drainage discharges and receiving streams to:

    a. Determine site-specific effectiveness of these abatement measures;

    b. Document acid load reductions;

    c. Verify resultant stream quality improvements; and

    d. Establish priorities for additional abatement, if needed to achieve water quality objectives.

3. The validity of conclusions drawn from a monitoring program is primarily based on the reliability of the data collected. Therefore, in establishing such programs, care must be exercised to provide:

    a. Proper quality control over analytical results; and

    b. Sufficient back-up monitoring equipment to minimize information gaps.

4. The use of wastewater sludge as a soil conditioner is a viable means of disposing of wastewater sludge, which is being produced at an ever increasing rate. Therefore, additional such demonstration projects should be performed. Sufficient funds should be made available to determine methods of transporting, storing, and applying various types of wastewater sludge and their optimum application rates.

SECTION 4

SITE RESTORATION

ABATEMENT METHOD DESCRIPTION

Site I

This site included strip mine S-26; monitoring stations MS-1 and MS-2 located on Morris Run upstream and downstream, respectively, from S-26; the underlying deep mine workings cut into by S-26 lying west of Morris Run; and monitoring station MS-3 established on the discharge draining these deep mine workings. Site I is delineated on Figure 2 (Page 4).

Two abatement methods were utilized on this project site: restoration of a strip mine, and replacement and lining of a stream channel. Both of these measures served the same purpose - to minimize the volume of water coming in contact with acid-forming material. Two advantages resulted: the water prevented from contacting the acid-forming material did not become acid, and that water was available to augment a downstream public water supply and to dilute any remaining acid mine drainage discharges.

In addition, agricultural limestone and fertilizer were applied to the restored strip mine. The effectiveness of these soil conditioners in establishing and maintaining vegetation on the restored strip mine was demonstrated.

Site II

This site included a portion of an extensive inadequately restored strip mine along the outcrop of the Lower Kittanning seam overlooking Fall Brook; the down dip deep mine workings in this same coal seam extending under the crest of the ridge and extending toward Morris Run; and monitoring stations MS-4, MS-5, and MS-6 established on the discharges draining these deep mine workings. Site II is shown on Figure 2 (Page 4).

Similar to the one abatement method proposed for Site I, a portion of a strip mine interconnected with deep mine workings was restored in order to reduce the volume of acid mine drainage being discharged. In addition, municipal wastewater sludge was applied to a test plot on the regraded strip mine to demonstrate the effectiveness of the sludge as a soil conditioner in establishing and maintaining vegetative growth.

PREDESIGN CONDITIONS

Site I

The 5.7 hectare strip mine portion of Site I cuts essentially perpendicularly across a tributary of Morris Run. During the active stripping operation, this stream was diverted by cutting into the underlying Lower Kittanning seam deep mine workings. The stripping operations ceased after the operations had intercepted the deep mine workings. Figure 3 depicts the condition of the strip pit before restoration.

Site II

Approximately 3,660 meters of the outcrop of the Lower Kittanning coal seam overlooking Fall Brook was strip mined. The strip mining intercepted the deep mine workings and, as a result of poor restoration, allowed surface runoff to flow into the deep mine workings and emerge down dip along Morris Run as part of the acid mine drainage at monitoring stations MS-4, MS-5, and MS-6. A typical portion of the 24.3 hectares selected for restoration is pictured in Figure 4.

DESIGN PHASE

The locations and outlines of the two project sites are shown on Figure 2. Photogrammetric maps had been previously obtained for both sites on an approximate horizontal scale of one centimeter equals 24 meters with a contour interval of approximately 1.5 meters. These maps were used for both preliminary and final design. As design was finalized, the areas to be restored were expanded: Site I was increased from 5.7 to 6.5 hectares to accommodate reclamation of the entire affected area; and Site II was increased from 24.3 to 28.8 hectares to allow reclamation of a portion of the unrestored strip mine lying immediately adjacent to, and considered as a unit with, a previously reclaimed strip mined area.

Site I

Strip Mine Restoration

The 6.5 hectare strip mine as it appeared in its unrestored state is shown in Figure 5, with the heavy dashed line indicating the extent of the area that was reaffected. Figure 6 shows the final restoration plan. This plan consisted of regrading the strip mine to near original contour using approximately 108,000 cubic meters of spoil material to meet partial fill requirements. As a final step, fill obtained from within the affected area from specific spoil piles that contained a minimum amount of acid-forming material was spread to a 0.3 meter depth over specific portions of the graded area containing excessive acid-forming material. Approximately 9,400 cubic meters of this select fill was used. Selected typical project cross sections depicting the unrestored and restored ground elevations are shown on Figures 7, 8, 9, and 10.

Based upon analyses of soil samples obtained from the site, the

Figure 3. Site I strip mine before restoration, looking southwest (1967).

Figure 4. Site II strip mine before restoration (1974). Picture was taken looking northward. Vehicle parked near southern end of area that was later restored.

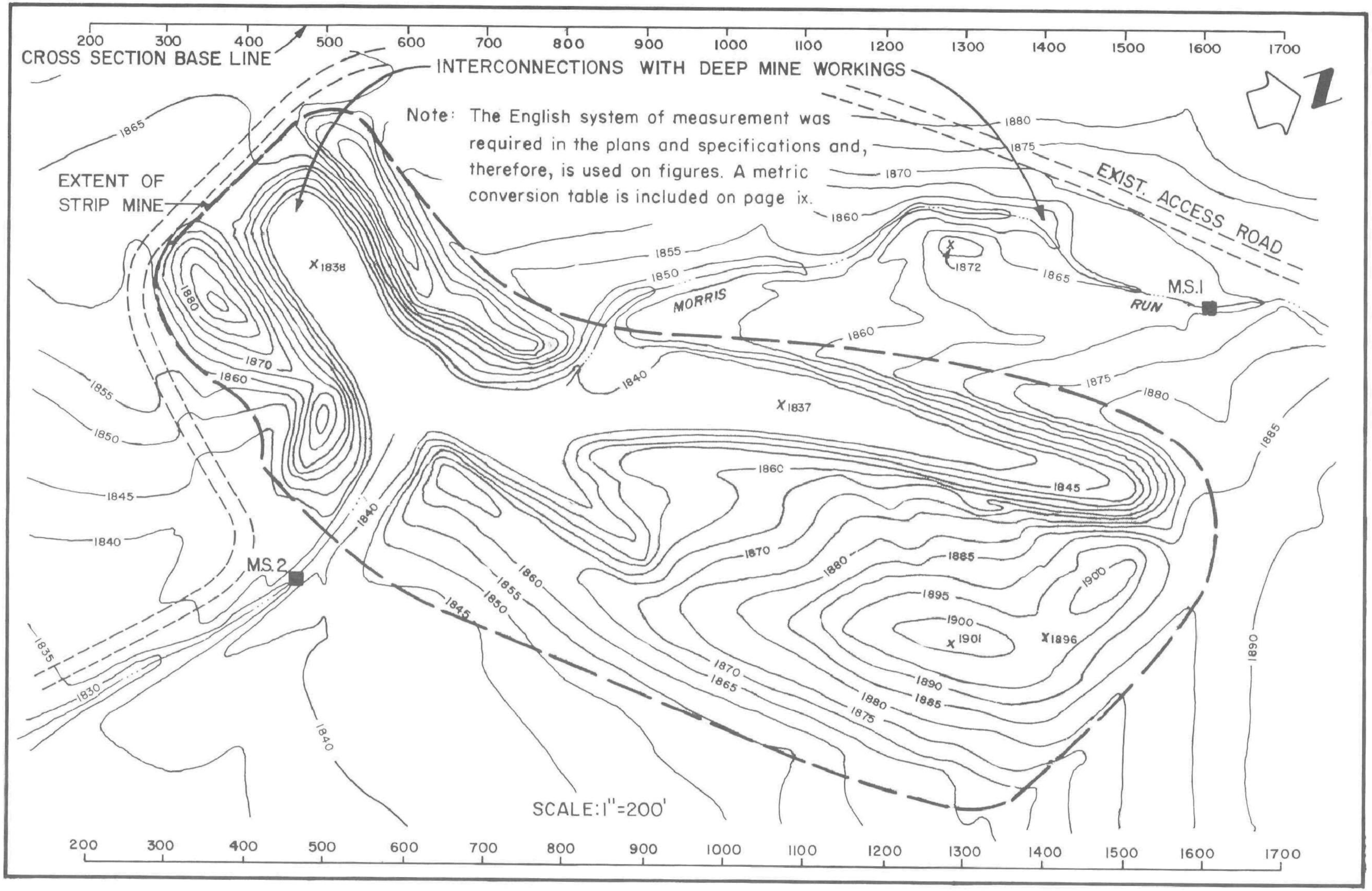


Figure 5. Site I unrestored strip mine

(From construction plans, Department of Environmental Resources).

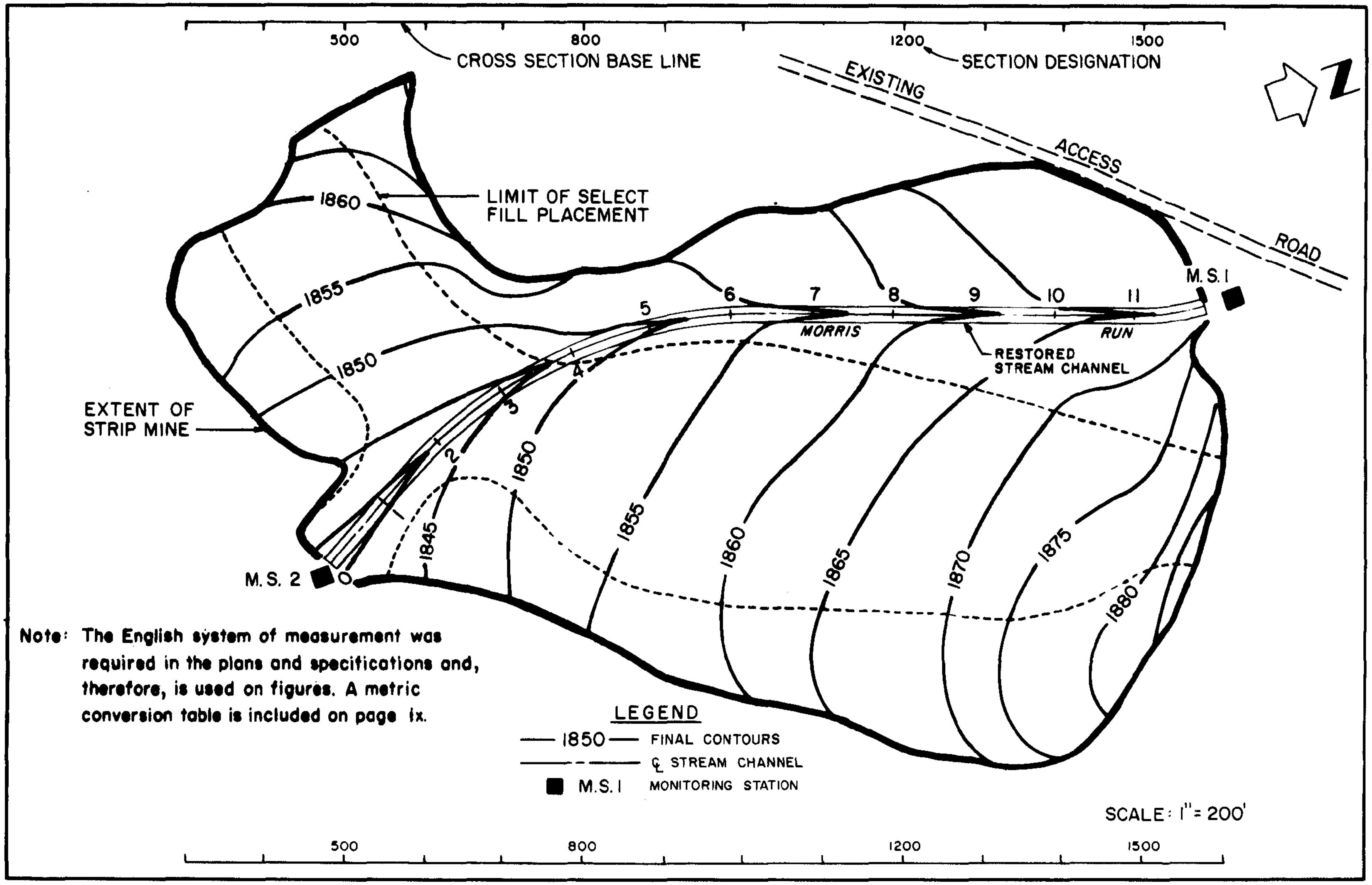
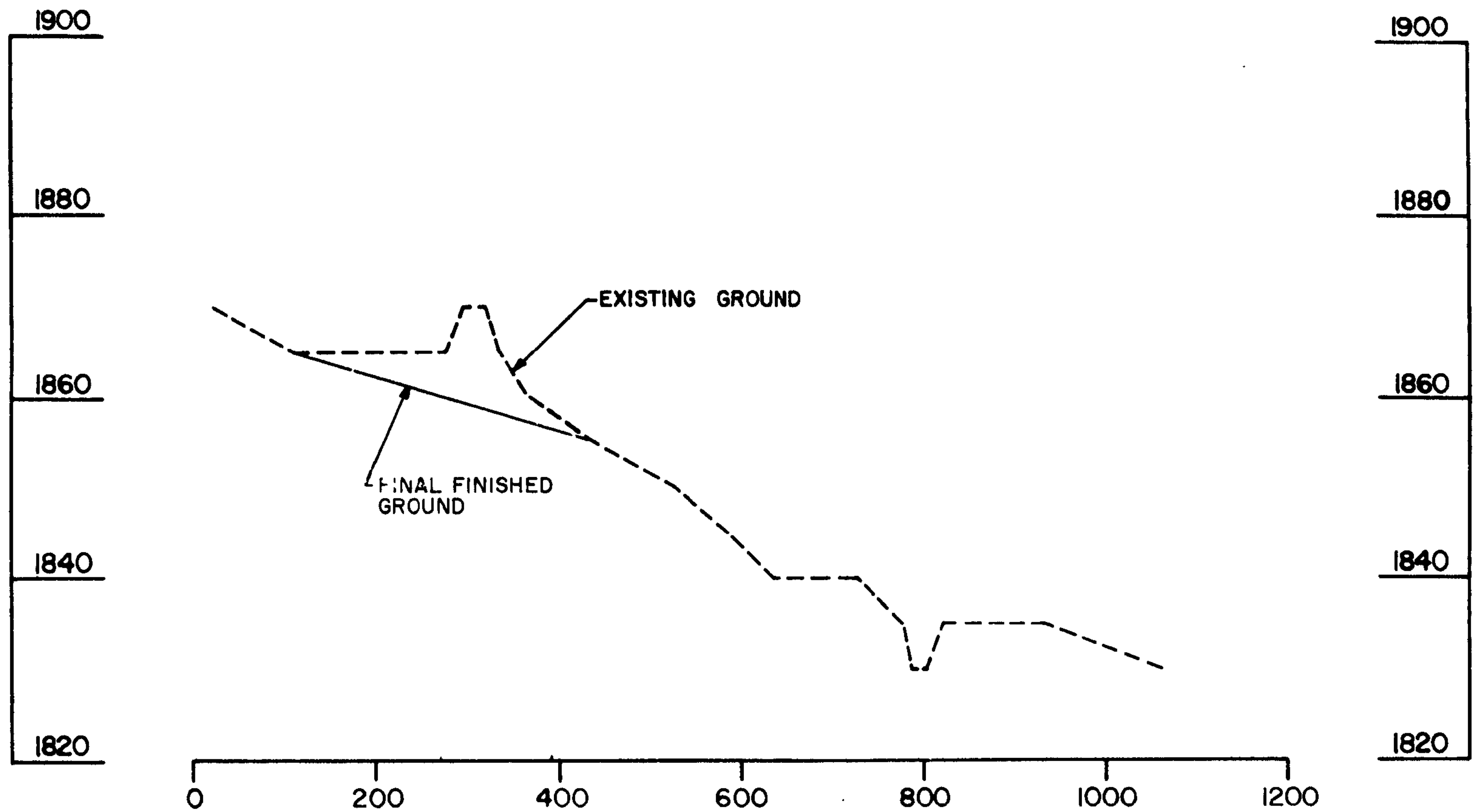


Figure 6. Site I strip mine final restoration plan.

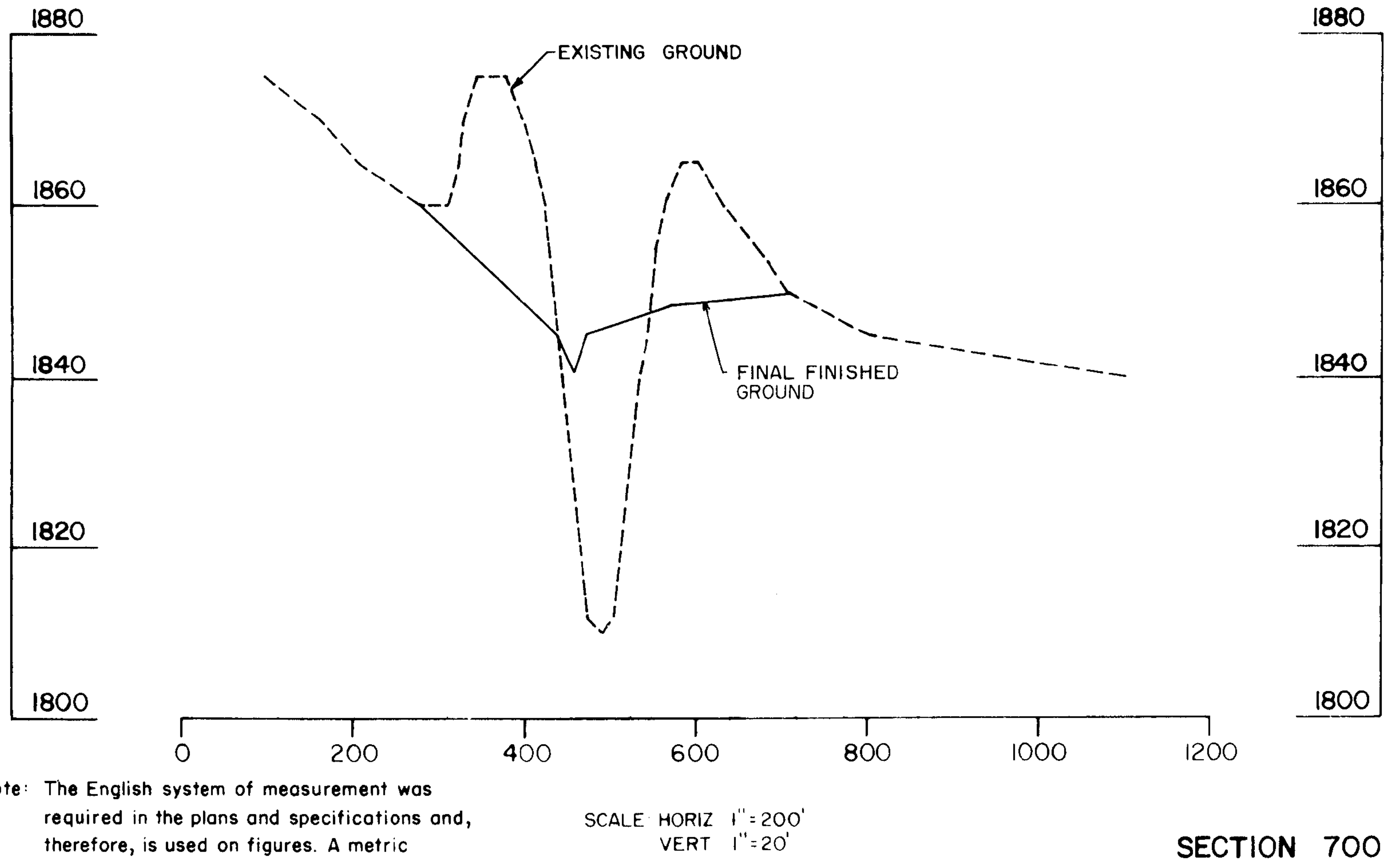


Note: The English system of measurement was required in the plans and specifications and, therefore, is used on figures. A metric conversion table is included on page ix.

SCALE: HORIZ.: 1" = 200'
VERT.: 1" = 20'

SECTION 300

Figure 7. Site I cross section 300.



Note: The English system of measurement was required in the plans and specifications and, therefore, is used on figures. A metric conversion table is included on page ix.

Figure 8. Site I cross section 700.

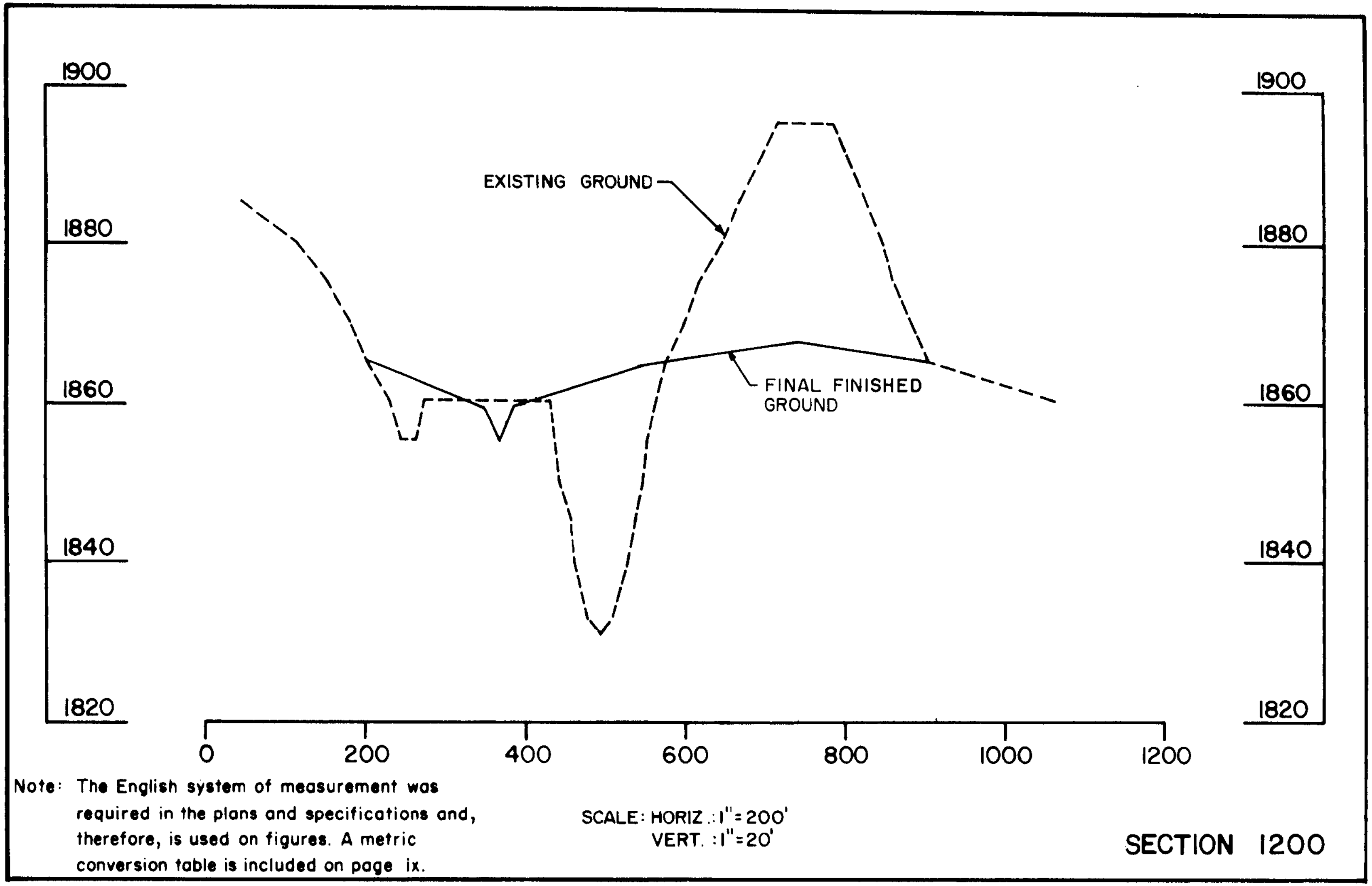


Figure 9. Site I cross section 1200.

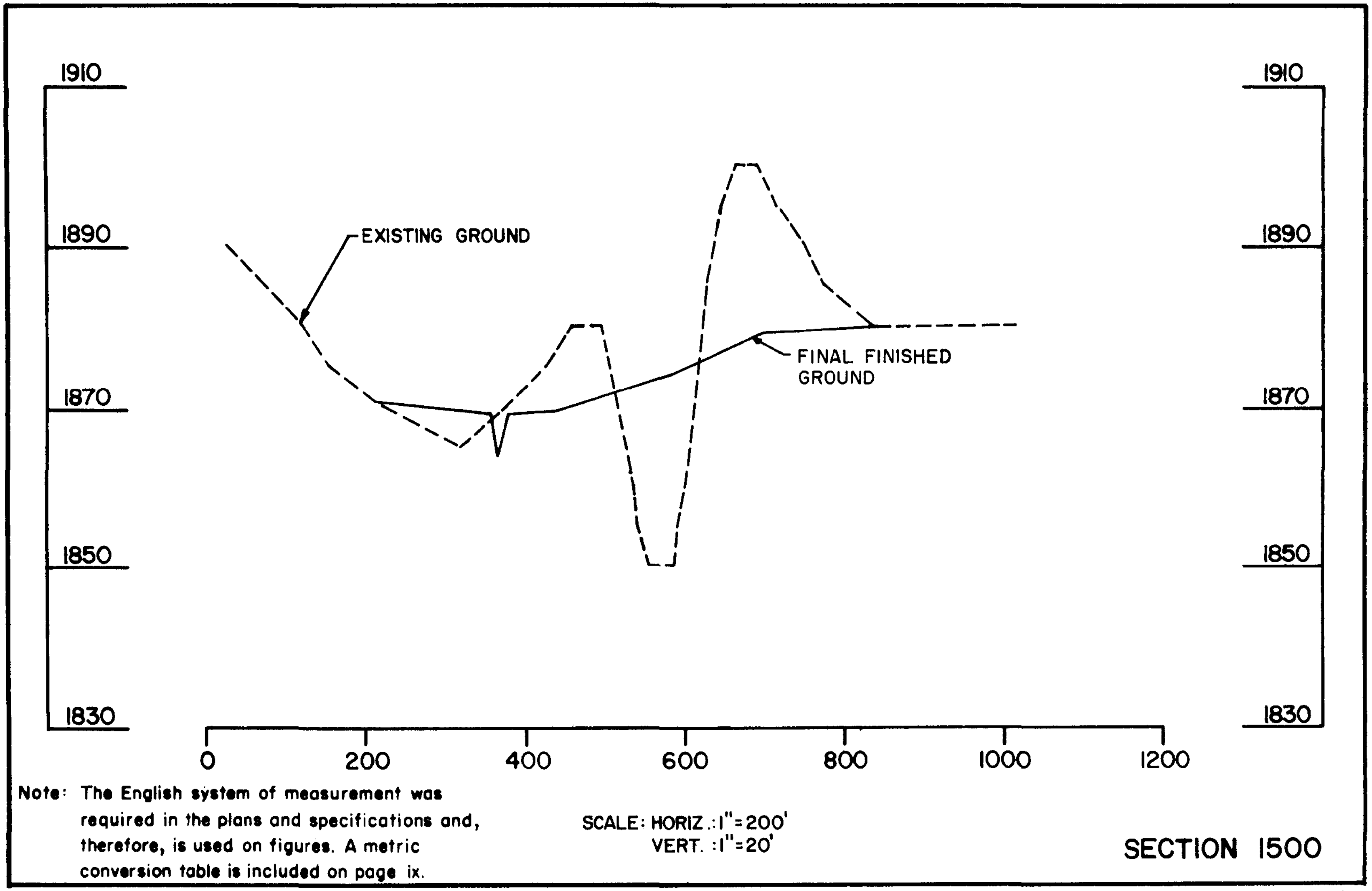


Figure 10. Site I cross section 1500.

soil cover on the restored project site was conditioned with agricultural limestone and fertilizer prior to seeding and mulching. Specified materials and application rates were as follows:

Material	Application Rate
Agricultural ground limestone (minimum of 4 percent MgO)	4.48 tonnes per hectare worked into a depth of 10 centimeters or less
Fertilizer ($N - P_2O_5 - K_2O$)	134-224-224 kilograms per hectare (112 kilograms of nitrogen to be supplied from a slow release source, such as ureaform)
Seed (pre-mixed)	
Kentucky 31 Tall Fescue	39 kilograms per hectare
Birdsfoot Trefoil (Empire Type)	8 kilograms per hectare
Common Rye Grass	6 kilograms per hectare
Mulch (old straw or hay)	4.48 tonnes per hectare

Channel Reconstruction

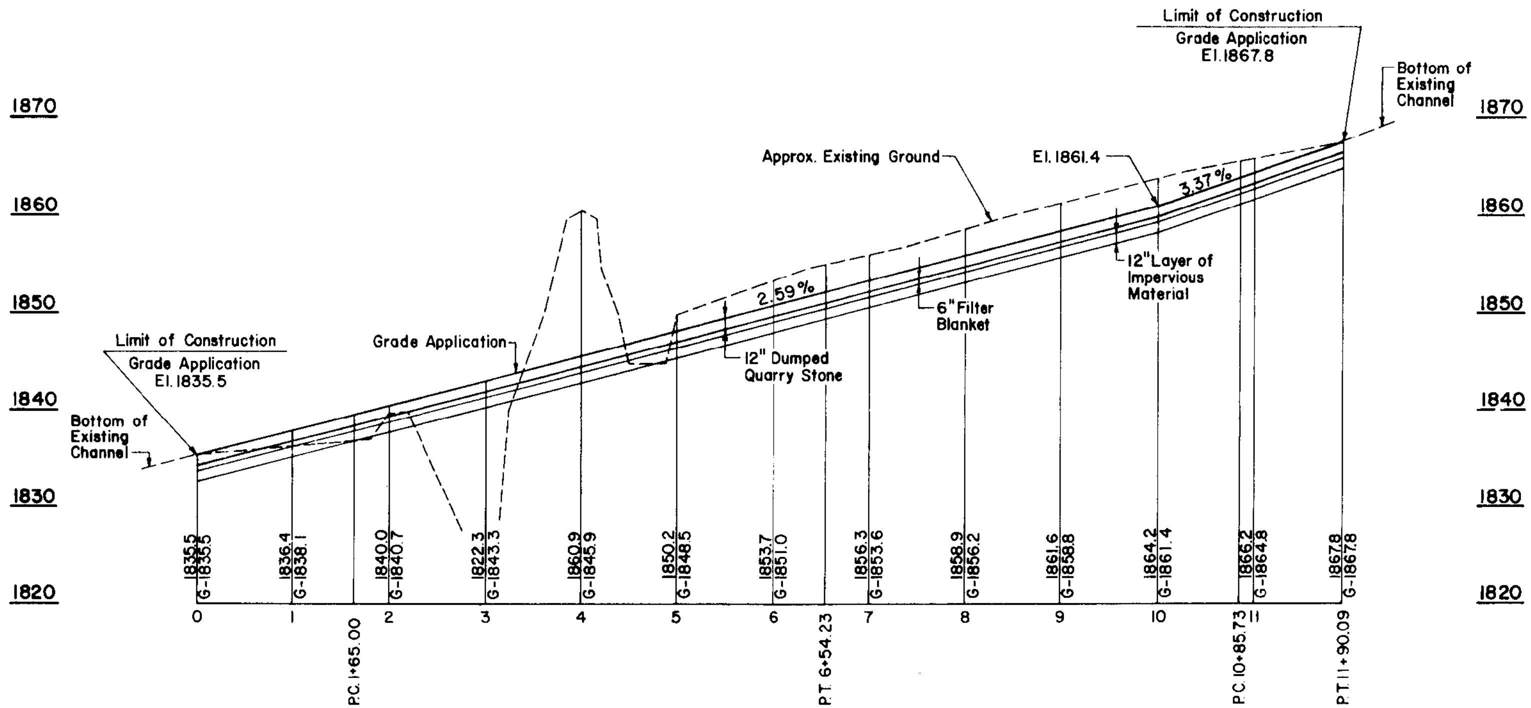
This part of the project consisted of designing and constructing 363 meters of new stream channel across the restored strip pit to connect the headwaters channel to the existing downstream Morris Run channel (see Figures 6 and 11). The specifications required placing a 30.5-centimeter layer of nonrigid impervious material in the channel bottom, topped by a 15.2-centimeter layer of filter blanket and a 30.5-centimeter protective cover of quarry stone. A typical cross section of the restored stream channel is shown on Figure 12.

The restored streambed was designed to accommodate flows up to approximately 9.4 m^3/s. Based upon rainfall frequency and duration tables for the area, together with measurements obtained at MS-1, this design flow is approximately 20 percent greater than the flow anticipated from a one-in-ten-year, 24-hour duration rainfall. Rainfall and flow data are discussed in Section 6, Project Evaluation.

Site II

The unrestored 28.8 hectare strip mine is shown on Figure 13, and Figure 14 shows the final restoration plan. The plan consisted of grading the strip mine to near original contour using approximately 478,000 cubic meters of fill.

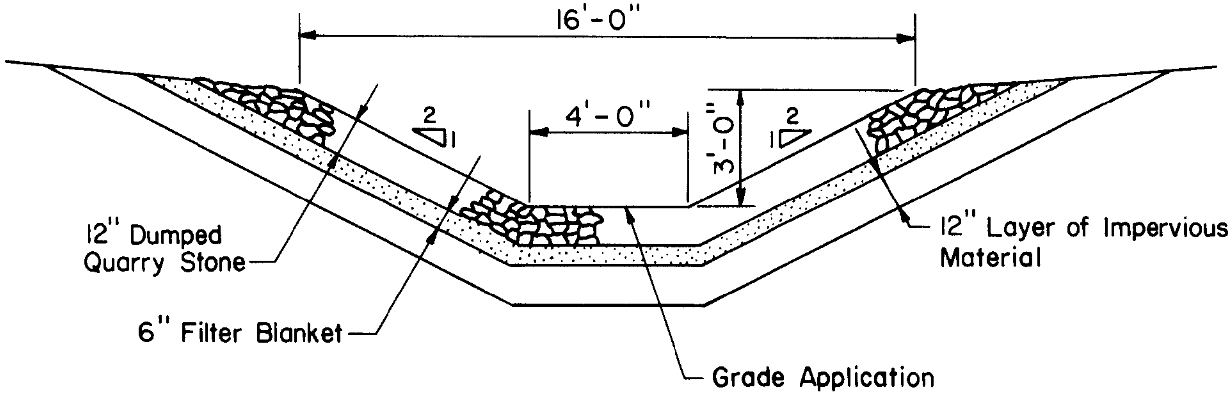
The graded site was divided into demonstration areas. One was a



Note: The English system of measurement was required in the plans and specifications and, therefore, is used on figures. A metric conversion table is included on page ix.

SCALE: Horiz. 1" = 200'
Vert. 1" = 20'

Figure 11. Site I reconstructed stream channel profile.



SCALE: HORIZ. 1"=5'
VERT. 1"=5'

Note: The English system of measurement was required in the plans and specifications and, therefore, is used on figures. A metric conversion table is included on page ix.

Figure 12. Site I reconstructed stream channel cross section.

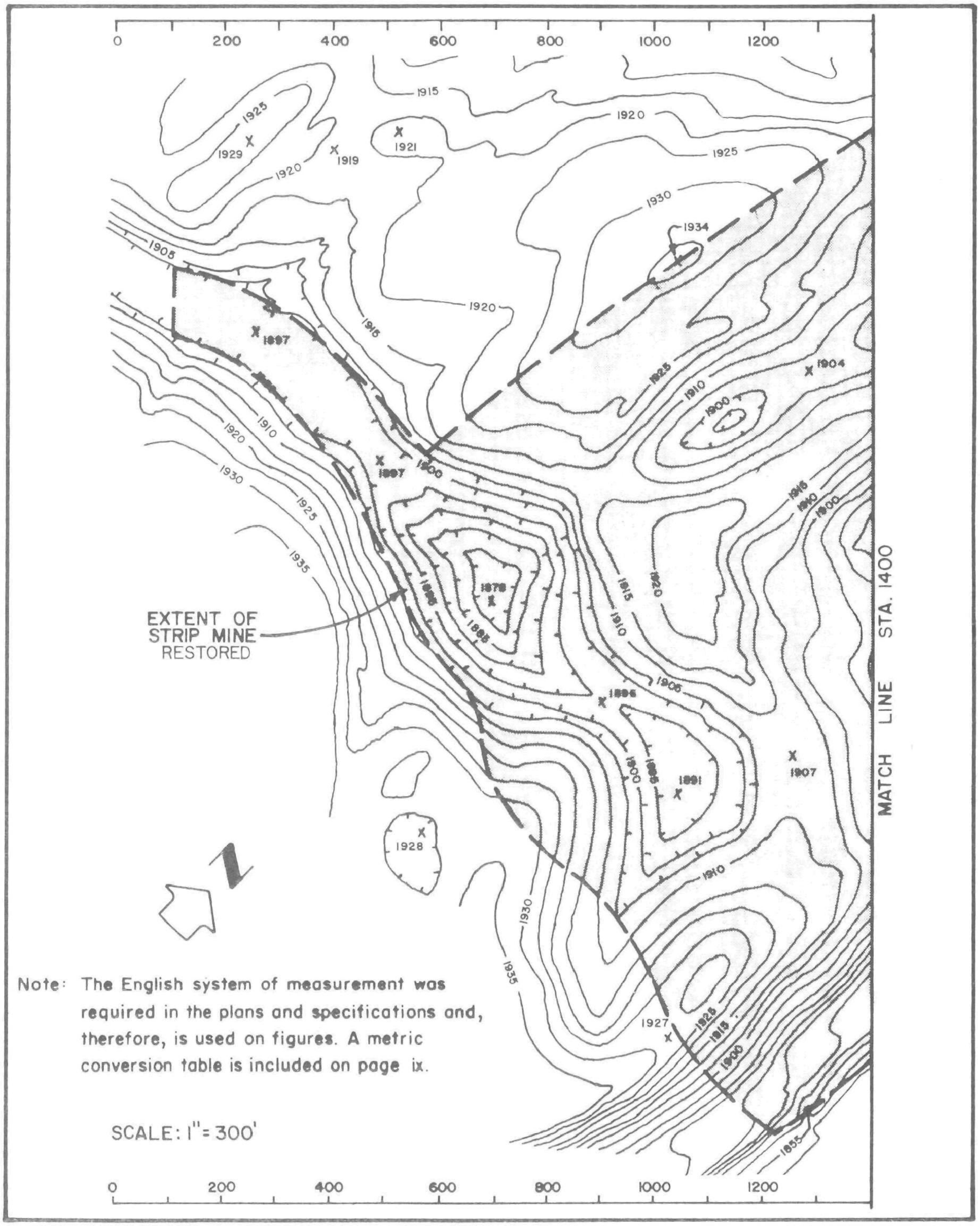


Figure 13. Site II unrestored strip mine.

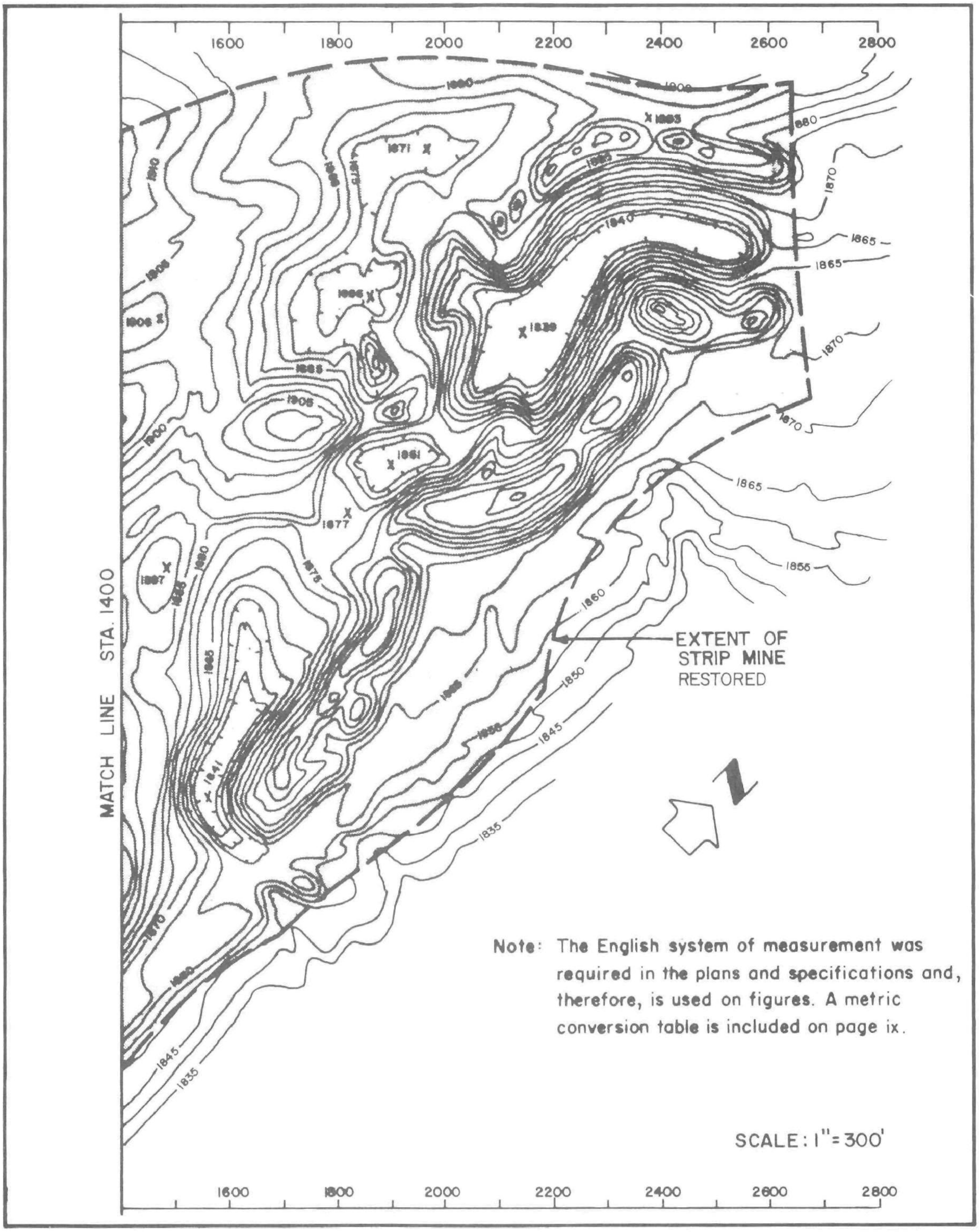
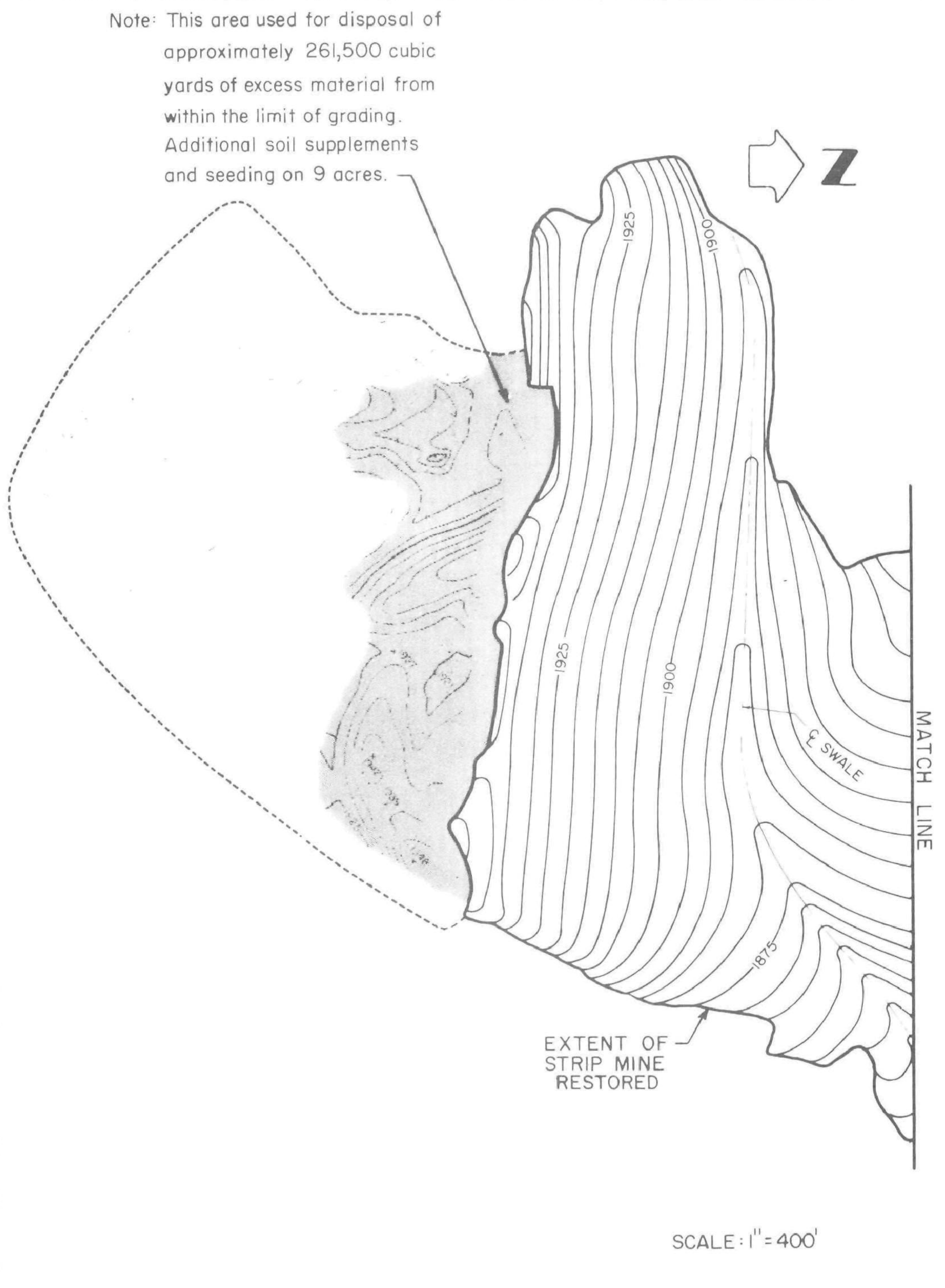
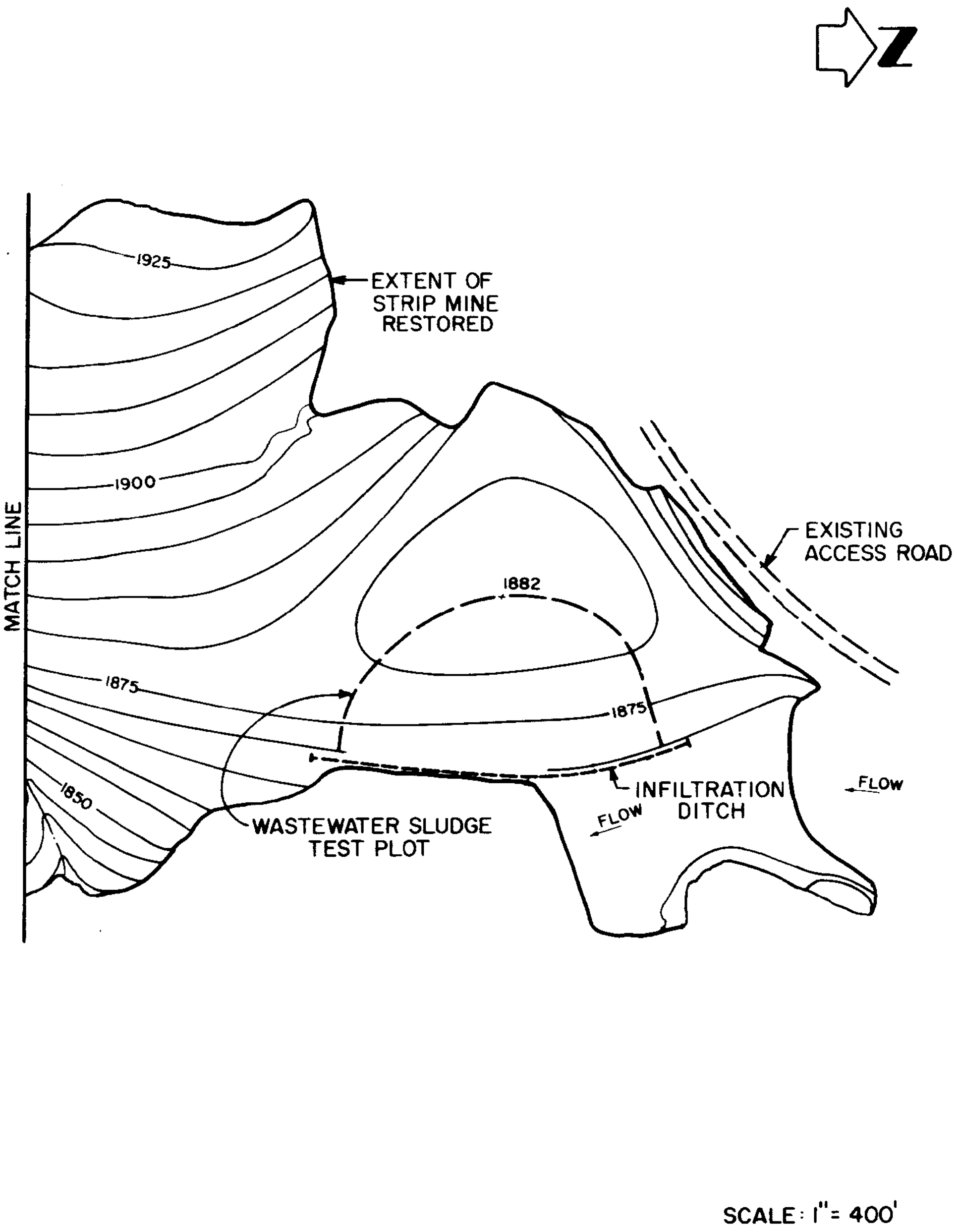


Figure 13 (continued). Site II unrestored strip mine.



Note: The English system of measurement was required in the plans and specifications and, therefore, is used on figures. A metric conversion table is included on page ix.

Figure 14. Site II final restoration plan.



Note: The English system of measurement was required in the plans and specifications and, therefore, is used on figures. A metric conversion table is included on page ix.

Figure 14 (continued). Site II final restoration plan.

1.74 hectare plot on which 1,270 tonnes of municipal wastewater sludge were spread to a depth of 7.6 centimeters and worked into the top 10 centimeters of final soil cover. No other soil conditioner was used on the sludge test plot. The remaining graded area was conditioned with limestone and fertilizer at the same rates of application as those required for Site I. The entire strip was then revegetated using the same seed mixture and rate of application as specified for Site I (See page 18).

To minimize a potential health hazard, an infiltration ditch was constructed immediately downhill from the sludge test plot. This ditch prevented surface runoff from the test plot from entering Fall Brook until a vegetative cover was established. This ditch, the location of which is shown on Figure 14, was designed to hold the runoff from the sludge test plot that might occur from a one-in-ten-year, 24-hour duration rainfall.

PRECONSTRUCTION PHASE

Wastewater Sludge

In order to demonstrate the use of wastewater sludge as a soil conditioner in lieu of conventional liming and fertilizing, approvals were required from the Department, the Tioga County Commissioners, and the Ward Township Commissioners. Approval was granted by the Department after a review of the potential effects on both surface waters and groundwaters. The Tioga County Planning Commission was instrumental in securing permission for using the wastewater sludge from these two local governmental agencies.

Source and Associated Costs of the Sludge

Several potential sources of wastewater sludge were investigated. These included Blossburg, Wellsboro, Mansfield, Canton, and Williamsport, Pennsylvania, as well as Elmira, New York, wastewater treatment plants. All were willing to provide the sludge at no cost. After considering availability of adequate volumes of sludge, proximity and accessibility, the Williamsport plant was selected to provide the sludge.

Sludge Characteristics

The sludge transported to the project site had been vacuum filtered, and stored on the ground surface for some time adjacent to the wastewater treatment plant. Accordingly, this partially dewatered sludge contained about 38.8 percent total solids.

The sludge was subjected to laboratory analyses. These analyses were performed on supernatant obtained from leaching 250 grams of the sludge in 1,250 milliliters of distilled water at room temperature for 48 hours. Results of these analyses are shown in Appendix A.

Bidding and Awarding of Construction Contract

It was decided that all construction work at both sites should be accomplished under one contract. Accordingly, the construction work was advertised and 14 bids were opened on January 2, 1975. Bids ranged from a high of $1,466,067 to a low of $429,996. This low bid by Allegheny Mountain Company compared favorably with the engineer's estimate of $428,217. This company was awarded the contract on January 21, 1975 (See Appendix A).

CONSTRUCTION PHASE

The contractor started work at Site II in February 1975. Work at Site I was delayed until May 1975 due to problems in securing the necessary stream encroachment permits and approval of an erosion and sedimentation control plan. Work at both sites was completed in October 1975 with the final on-site inspection being held October 6.

Seven change orders in the contract were authorized which ultimately raised the total construction cost from $429,996 to $460,142. These change orders were as follows:

Change Order No. 1

Approved February 24, 1975, required an additional entity to be named as an insured party on the contractor's public liability and property damage insurance policy; no additional cost.

Change Order No. 2

Approved June 27, 1975, required the 3.6 hectare disposal site for Site II excess fill to be treated with soil amendments and seeded in accordance with the technical specifications; added $5,101.20 to the contract cost.

Change Order No. 3

Approved September 3, 1975, authorized the placing of jute matting on 366 meters of a swale on Site II to reduce continued soil erosion that resulted from heavy rainfall before a vegetative cover had been established; added $4,700 to the contract cost.

Change Order No. 4

Approved December 14, 1975, authorized increases from field measurements in the quantities of impervious material, filter blanket and quarry stone used in the channel lining on Site I; added $3,678 to the contract cost.

Change Order No. 5

Approved December 7, 1976, authorized the contractor to repair Hurricane Eloise flood damages; added $5,209.03 to the contract cost.

Change Order No. 6

Approved March 1, 1977, authorized placing 165 meters of mulch blanket and 91 meters of riprap in a Site II swale to control continuing erosion; added $11,058 to the contract cost.

Change Order No. 7

Approved July 27, 1977, this change order reflects authorized revegetation of 0.1 hectare following the completed repair work on the Site II swale; added $400 to the contract cost.

Total construction cost for the project is summarized in the following:

Original Contract	$429,996.00
Change Order No. 1	None
Change Order No. 2	5,101.20
Change Order No. 3	4,700.00
Change Order No. 4	3,678.00
Change Order No. 5	5,209.03
Change Order No. 6	11,058.00
Change Order No. 7	400.00
Total Construction Cost	$460,142.23

SECTION 5

MONITORING PROGRAM

PURPOSE

To demonstrate the effectiveness of the abatement work at Sites I and II, it was necessary to establish a monitoring program to determine mine drainage loadings before, during, and after construction.

To accomplish this, a gaging, sampling, and analytical program involving six monitoring stations was undertaken. Two of these six monitoring stations (MS-1 and 2) were located upstream and downstream, respectively, from the Site I strip mine to establish the water loss from the headwaters of Morris Run into underlying deep mine workings. The third monitoring station (MS-3) was established to monitor the mine drainage discharge that would be affected by the work accomplished at the Site I strip mine. The other three monitoring stations (MS-4, 5, and 6) were established to monitor the related mine drainage discharges, some or all of which would be affected by construction work at the Site II strip mine. These monitoring stations are shown on Figure 2 (See page 4).

A continuous recording rain gage was installed in the study area to provide supplementary precipitation data.

SCHEDULE

The monitoring program began on June 13, 1973 by taking grab samples for analysis and instantaneous flow measurements at all of the monitoring station sites. This method of monitoring was scheduled to continue through September 13, 1973, during which time it was planned to construct the monitoring stations and install continuous flow recorders. However, installation of the continuous flow recorders at MS-1 through MS-5 was not completed until March 18, 1974, and the continuous flow recorder at MS-6 was not placed into operation until May 14, 1974. Accordingly, during this interim period, grab samples and instantaneous flow measurements were obtained at two-week intervals.

After installation of the continuous flow recorders, sampling and analytical monitoring program schedules were established and continued through October 21, 1976. However, the Department in cooperation with other entities continued the monitoring program at MS-3, 4, and 5 with the final water sample collection occurring on October 6, 1977 and final flow data collection on October 15, 1977. These additional monitoring data have been integrated into the evaluation portion of this project.

ANALYTICAL DETERMINATIONS

Initial analyses of grab samples collected at the six monitoring stations included pH, acidity, alkalinity, total iron, manganese, aluminum, sulfate, and total solids. Once an initial data base was established, routine analyses for manganese, aluminum, and total solids were substantially reduced. Additional analyses of these constituents, along with zinc concentrations, were limited to once prior to, and after, construction at the two strip mine sites.

Following the spreading of the wastewater sludge on the test plot at Site II, samples from MS-4, 5, and 6 were analyzed for zinc, copper, and lead on a quarterly basis.

In addition, "complete" analyses were performed on samples collected at each monitoring station before and after construction at both strip mine sites. These "complete" analyses consisted: acidity, alkalinity, aluminum, arsenic, cadmium, calcium, chromium, copper, iron (total and ferrous), lead, magnesium, manganese, potassium, sodium, zinc, mercury, COD, chloride, cyanide, fluoride, hardness, nitrate, pH, specific conductivity, sulfate, temperature, turbidity, and residue (total and filterable). Results of these "complete" analyses before and after construction are reported in Appendix A.

The sampling and analytical schedule for all six monitoring stations for all phases of this project is summarized in Appendix A. Complete analytical results are shown in Appendix B.

RAINFALL

Published precipitation data were obtained for two National Oceanic and Atmospheric Administration stations located near the study area. These stations, namely, English Center and Towanda located 32 kilometers southeast and 47 kilometers east-northeast, respectively, from the study area, were selected as being the closest stations with sufficient years of record to establish a standard of comparison. Normal monthly rainfall for these stations from 1940 through 1970 are shown in Appendix A.

Rainfall duration and frequency data for the study area are also shown in Appendix A. These data, as well as actually recorded rainfall, were used in design and in evaluating the effectiveness of the project.

To supplement rainfall data from the selected stations, a continuous recording rain gage was installed in the study area. Actual monthly rainfall measured at this gage and at the two selected stations is summarized in Appendix A.

FLOW MONITORING

Each monitoring station site facilities consisted of an artificial impoundment and a weir over which the flow was continuously recorded by a Model 61R, Stevens Total Flow Meter equipped with a spring-wound clock. The measuring capacity of the continuous flow recorder installed at each monitoring station was based upon the following criteria:

1. Capability to measure wet weather flows related to spring high groundwater levels and substantiated by instantaneous flow measurements taken prior to monitoring station construction.

2. Sensitivity to water level changes throughout the required flow range.

3. Flexibility to permit the interchanging of component parts of the manufacturer's standardized equipment if required.

The impoundments at MS-1, 2, and 3 were constructed of concrete,, whereas those at MS-4 and 5 were constructed of timber made impermeable by an asphalt coating and polyethylene liner. Initial efforts to install a timber type impoundment at MS-6 were unsuccessful due to leakage through porous fill. Eventually, the monitoring site was moved about 15 meters downstream to a point where the discharge passed through a culvert under a public road. This flow was directed into a 6.1-meter long, 183-centimeter diameter, half-round, asphalt-coated corrugated steel tank with baffle plates to still current eddies. A V-notch weir was also installed in the downstream end of the tank.

The size and type of weir plate installed at each monitoring site were selected to provide sufficient fluctuation in water levels to meet the requirements of the continuous water-level recorders. Two types of weir plates were used: a sharp-edged rectangular weir was installed at MS-3; and 90^{o} V-notch weirs were placed in the other five monitoring stations. General design considerations for the monitoring stations are presented in Appendix A.

Average monthly flows measured at each of the monitoring stations are summarized in Appendix A.

Figures 15 through 20 show each monitoring station installation.

Figure 15. Monitoring Station MS-1.

Figure 16. Monitoring Station MS-3.

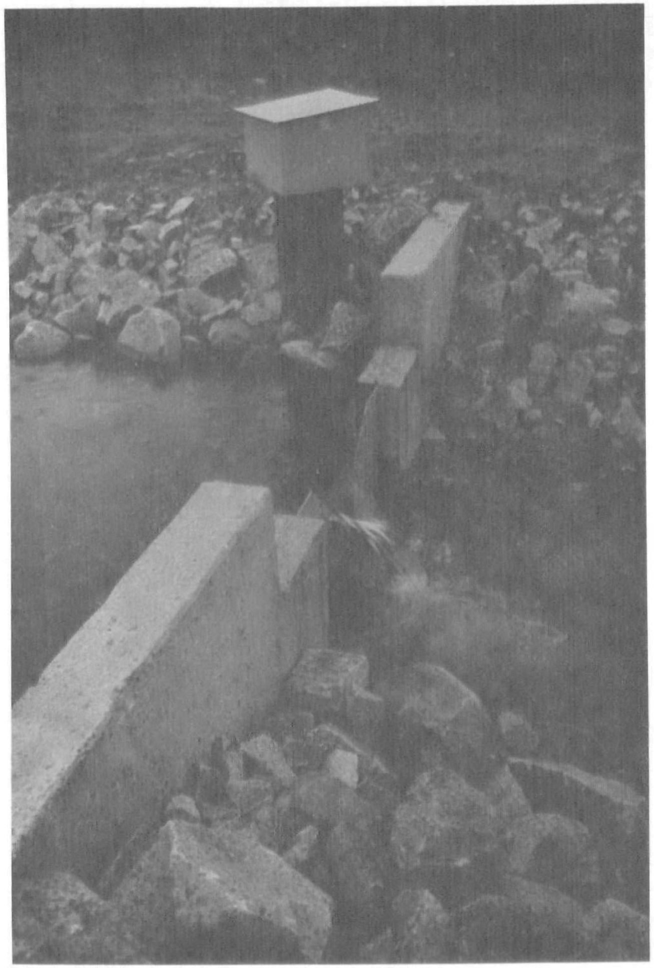


Figure 17. Monitoring Station MS-2.

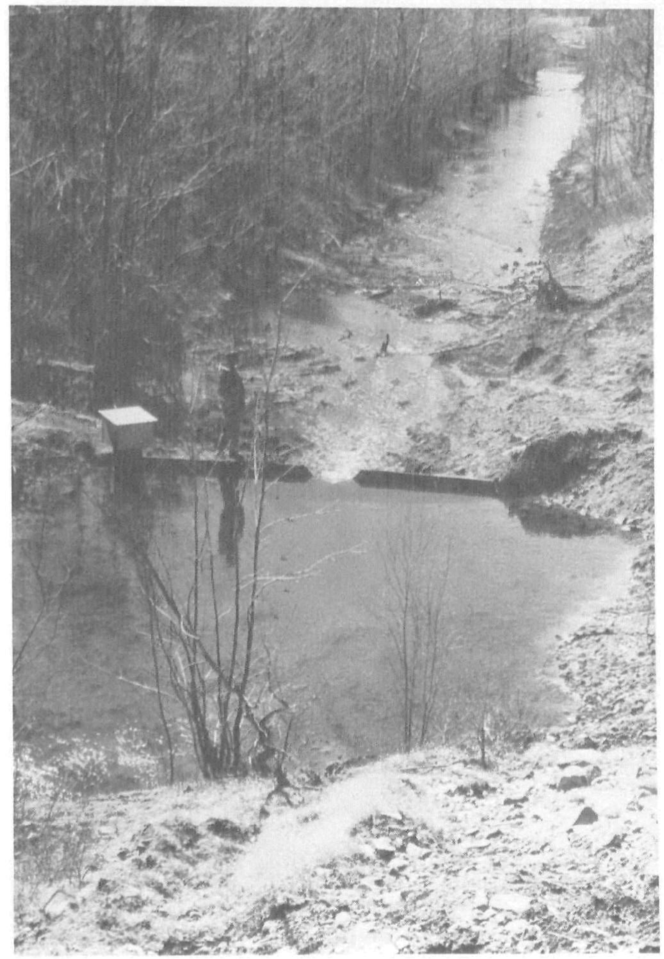


Figure 18. Monitoring Station MS-4.

Figure 19. Monitoring Station MS-5.

Figure 20. Monitoring Station MS-6.

SECTION 6

PROJECT EVALUATION

METHODOLOGY

Three criteria and their interrelationships were evaluated to determine project performance and to document achievement of project objectives:

1. The effectiveness of project site improvement in abating or reducing acid mine drainage discharges.

2. Effectiveness of design and construction methods for each project site.

3. Associated costs related to construction and maintenance of the abatement measures.

The effectiveness of project site improvement in reducing mine drainage discharges was determined using monitoring program data to compare associated flows and loadings during specific time periods before and after construction. These included average yearly conditions adjusted for normal rainfall, seasonal variations, and storm occurrences. Effectiveness of design and construction methods was documented through on-site inspections, precipitation and flow measurements, and photography during project evaluation. Finally, the abatement measures demonstrated were evaluated on the basis of economic feasibility.

SITE I EVALUATION

Abatement Effectiveness

The general relationships between MS-1, 2, and 3 at Site I were discussed in the Introduction. MS-1 and 2 were located immediately upstream and downstream, respectively, from the unrestored Site I strip mine. This strip mine underlaid Morris Run whose flow was diverted into the underground mine workings. MS-3 was located at the mine drainage discharge affected by Site I stream channel construction and open pit restoration work.

Flow data obtained from these stations before construction at the Site I strip mine were evaluated to determine:

1. The relative time response to precipitation events in order to compare flows in Morris Run with the mine drainage flows over comparable time periods.

2. The estimated stream flow loss to the underground mine workings.

3. The estimated contribution of stream flow to the mine drainage discharge.

A one-year period, from June 1974 through May 1975, was selected to determine preconstruction flow patterns. This period was selected because gaps in flow information were minimal. Furthermore, near-normal yearly precipitation for this period was recorded at the established weather stations near English Center and Towanda. Consequently, it was felt that the rainfall measured by the project area rain gage could be considered normal.

The relationship during this preconstruction period between MS-1 and MS-2 with rainfall measured at the rain gage installed in the project area is shown in Figure 21. The relationship during the same period between MS-3 and project area rainfall is shown in Figure 22. As can be seen in Figure 22, increased flow rates at MS-1 from rainfall during the warm seasons and vegetative growing periods were not significant until rainfall events of 2.54 centimeters or more occurred in a 24-hour period. During these same periods, there was noticeably less flow recorded at MS-2 than at MS-1. On several occasions, in fact, the rate of infiltration into the underground workings and the evaporation rate for the pool in the unrestored strip mine between MS-1 and MS-2 equalled or exceeded the flow entering the pit as recorded at MS-1. Consequently, no flow whatsoever was recorded at MS-2.

As might be expected, flows recorded at MS-3 were even less sensitive to rainfall events during the warm weather seasons. However, during early spring, similar rainfall events caused noticeable increases in flow from MS-3.

In comparing peak flow periods that were recorded at both MS-1 and MS-3 as a result of a significant rainfall event (2.54 centimeters or more in a 24-hour period) there appeared to be a lag of approximately 72 hours. Consequently, in comparing and evaluating flows as recorded at all three monitoring stations, time periods and their related flows were not used where flows were not recorded for all three stations. Despite this restriction, 333 out of 365 days of flow data from all three monitoring stations were used.

Average monthly flow rates at all three monitoring stations before and after construction are shown in Table 1. Based upon the data compiled before construction, there was an average loss over the year of 0.014 m^3/s between MS-1 and MS-2. Assuming that this loss was caused primarily by infiltration and seepage into the underground mine workings, approximately 11.8 percent of the average flow of 0.115 m^3/s at MS-3 was contributed by Morris Run, which flowed into the strip pit located between MS-1 and MS-2. During periods of high groundwater conditions, approximately 0.018 m^3/s was lost between MS-1 and MS-2. This was approximately 10.5 percent of the seasonal average flow of 0.171 m^3/s from MS-3. Flow contributions between MS-1 and MS-2 during low groundwater conditions averaged 0.012 m^3/s, or 19.3 percent of the seasonal average flow of 0.061 m^3/s at MS-3. These data are summarized in Table 2.

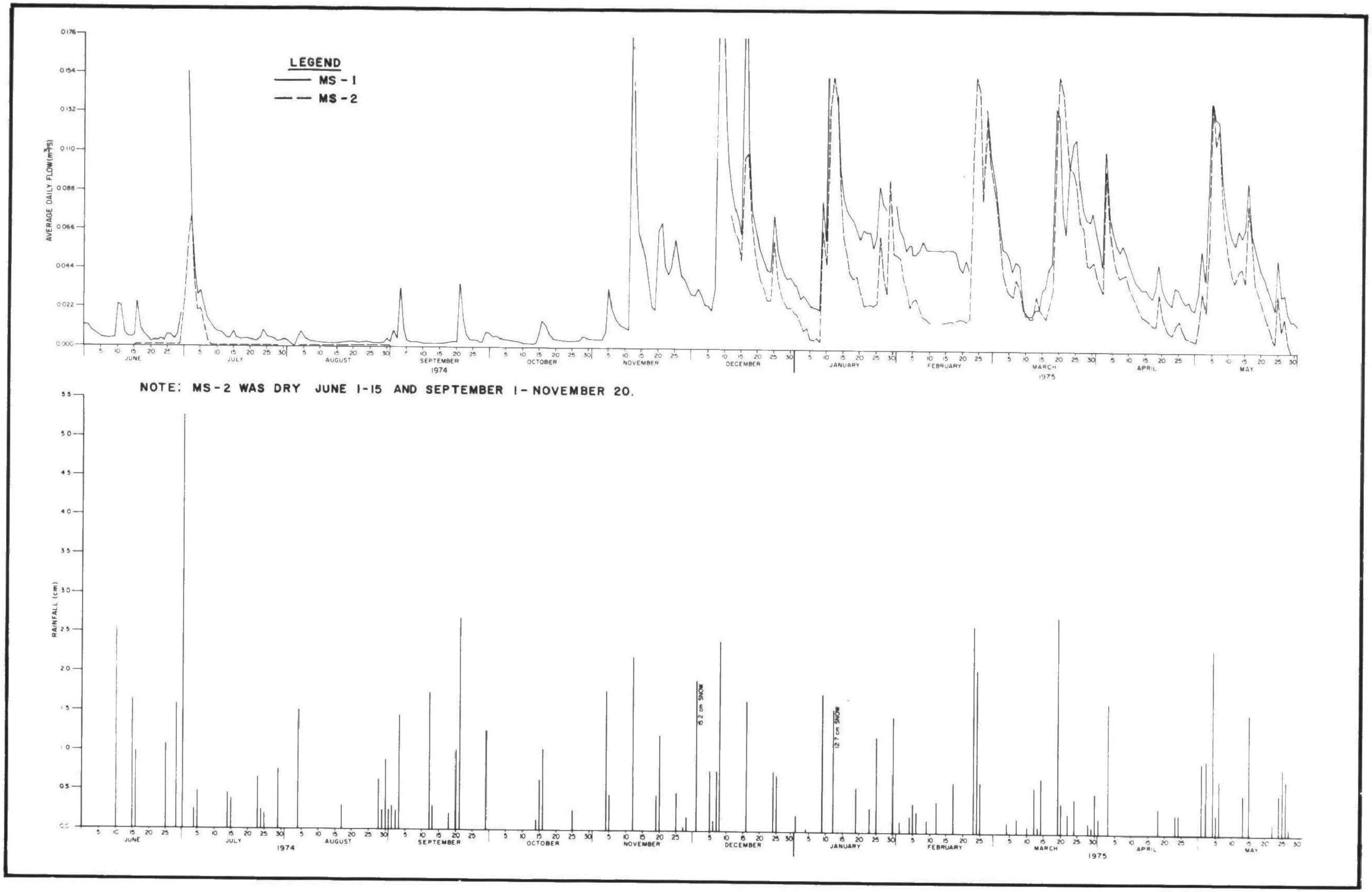


Figure 21. Comparison of daily flow at MS-1 and MS-2 vs. rainfall before construction.

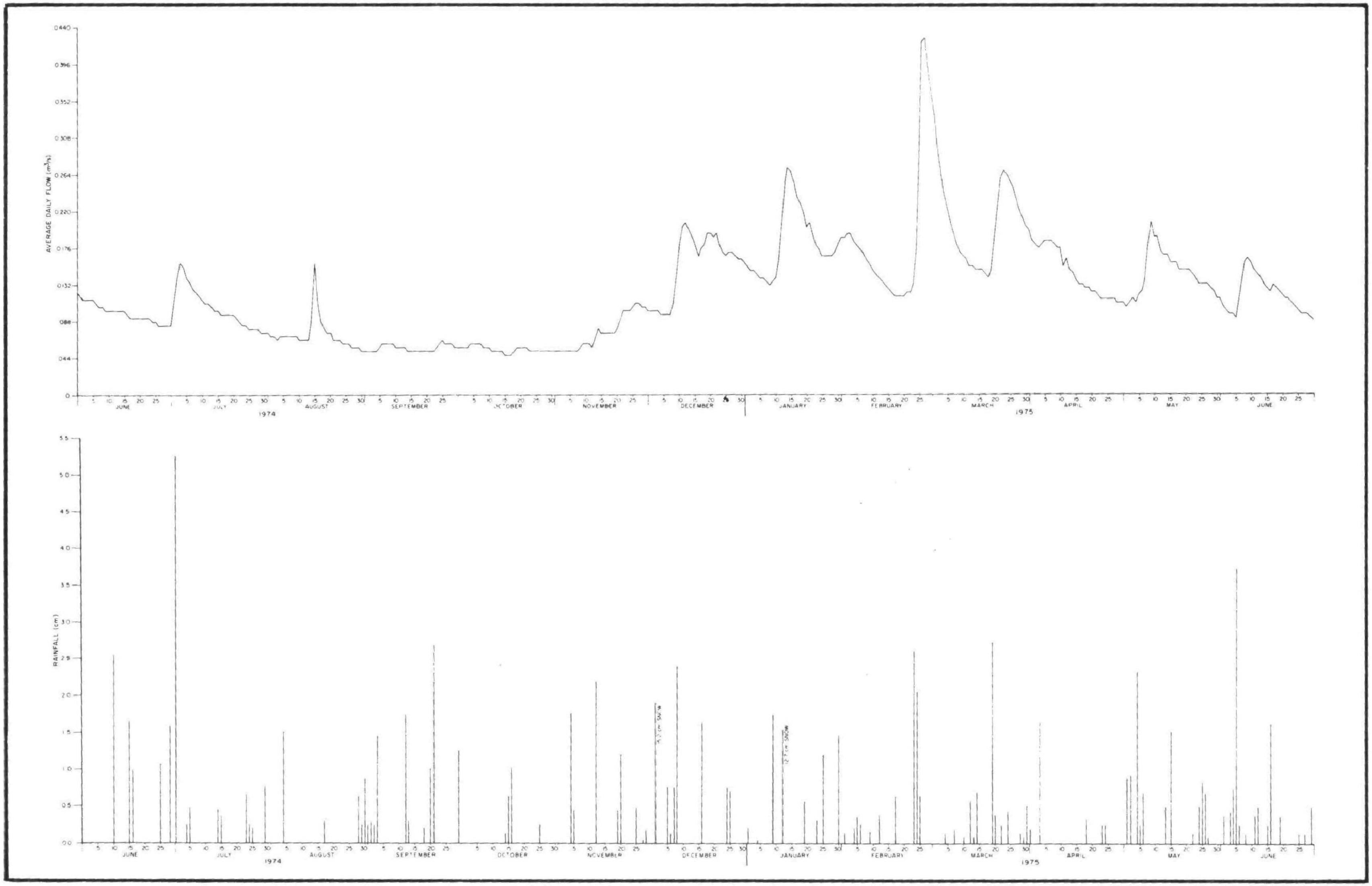


Figure 22. Comparison of daily flow at MS – 3 vs. rainfall before construction.

TABLE 1. AVERAGE MONTHLY FLOWS AT MS-1, MS-2, AND MS-3 BEFORE AND AFTER CONSTRUCTION

Before Construction		MS-1		MS-2		MS-3	
Month	Year	Average Flow (m^3/s)	Days of Record	Average Flow (m^3/s)	Days of Record	Average Flow (m^3/s)	Days of Record
June	1974	0.010	30	0.001	30	0.096	30
July		0.015	31	0.008	31	0.105	31
August		0.003	31	0.000	31	0.070	31
September		0.007	30	0.000	30	0.057	30
October		0.005	31	0.000	31	0.057	31
November		0.033	21	0.000	21	0.066	21
December		0.064	20	0.050	20	0.180	20
January	1975	0.069	29	0.045	29	0.184	29
February		0.062	21	0.032	21	0.175	21
March		0.064	31	0.057	31	0.206	31
April		0.043	30	0.027	30	0.145	30
May		0.064	28	0.046	28	0.149	28
After Construction							
June	1975	0.035	30	--*	0	0.118	30
July		0.013	31	--*	0	0.079	31
August		0.004	31	--*	0	0.061	31
September		0.010	15	0.012	15	0.114	30
October		0.059	11	0.065	11	0.171	31
November		0.046	30	0.048	30	0.127	30
December		0.044**	9	0.046**	9	0.127	31
January	1976	-- **	0	-- **	0	0.118	31
February		-- **	0	-- **	0	0.210	29
March		0.061	16	0.059	16	0.201	31
April		0.048	30	0.045	30	0.136	30
May		0.048	28	0.045	28	0.140	31
June		0.060	30	0.061	30	0.145	30
July		0.025	31	0.026	31	0.101	31
August		0.028	26	0.030	26	0.118	31
September		0.008	30	0.007	30	0.074	30
October		0.037	19	0.035	19	0.088	20

* Flow bypassed MS-2 during Site I strip mine reclamation.
** MS-1 and MS-2 frozen - few flows recorded as indicated before freeze.

TABLE 2. ESTIMATED SEASONAL FLOW CONTRIBUTION TO MS-3 FROM SITE I SEEPAGE BEFORE CONSTRUCTION

Seasonal Conditions	Average Flows (m^3/s)			Contribution to MS-3	
	MS-1	MS-2	MS-3	m^3/s	Percent
High Groundwater (Feb., Mar., Apr., and May)	1.33	0.92	0.171	0.018	10.5
Low Groundwater (Aug., Sept., Oct., and Nov.)	0.27	0.00	0.061	0.012	19.3
Average (June through May)	0.84	0.51	0.123	0.014	11.8

It was concluded, therefore, that if design and construction were properly accomplished, similar reductions in flow could be expected at MS-3, and no significant water loss would be recorded between MS-1 and MS-2.

On May 28, 1975, the contractor diverted stream flow around and back into the stream channel downstream from MS-2 so he could proceed with construction. Consequently, no flow was recorded at MS-2 until September 8, 1975, when the contractor returned stream flow into the newly restored stream channel. Only very limited data were available for comparison at these two monitoring stations until March 1976 because both monitoring stations were frozen due to the extremely cold winter months. However, subsequent flows recorded at these stations from March 1976 until the monitoring program ended on October 21, 1976 correlate excellently with little (if any) measurable loss between the two stations. Monthly average flows for this period are also summarized in Table 1.

To determine the estimated reduction in flow from the underground mine workings monitored at MS-3, a postconstruction period from June 1975 through May 1976 was selected. As described previously, a preconstruction monitoring period had been selected since near-normal amounts of rainfall had been recorded at nearby, long-established weather stations. An assumption was made that normal rainfall occurred in the project area as well. Annual rainfall during the selected postconstruction period averaged about 28 percent above normal for the project area gaging station. These data are summarized in Appendix A.

For purposes of estimating the differences in flow at MS-3 resulting from a departure from normal rainfall during the postconstruction period, it was assumed that the flow from MS-3 during the postconstruction period was 28 percent above normal. As shown in Table 1, actual average monthly flow at MS-3 during this postconstruction period was 0.134 m^3/s. Therefore, under normal rainfall conditions, it would be expected that the flow at MS-3 would be approximately 0.104 m^3/s. Based upon an average annual flow of 0.123 m^3/s prior to construction at Site I, there was an average annual flow reduction of approximately 15 percent.

To establish actual pollution load reductions, it was also necessary to determine if any noticeable changes in water quality had occurred as a result of construction at the Site I strip mine. The most common parameter found in acid mine drainage, and the most sensitive to changes, is acidity. Based upon a summary of the sampling and analytical data for MS-3 as shown in Table 3, seasonal fluctuation occurred as expected in both the preconstruction and postconstruction periods, but average acid concentrations remained essentially the same: 800 mg/l for the preconstruction period and 795 mg/l for the postconstruction period. However, it is estimated that, if average annual flow of 0.104 m^3/s had been measured at MS-3, average acid concentrations would have been in the order of 845 mg/l. Using this estimate, this acid load reduction amounted to approximately 862 kilograms per day and was attributable solely to construction at the Site I strip mine. A summary of flow and acid load reduction at MS-3 due to Site I improvement is shown in Table 4.

TABLE 3. AVERAGE ACID CONCENTRATIONS
AT MS-3 BEFORE AND AFTER CONSTRUCTION AT SITE I

Month	Preconstruction Period (June 1974 through May 1975)		Postconstruction Period (June 1975 through May 1976)	
	No. of Determinations	Avg. Acid as $CaCO_3$ (mg/1)	No. of Determinations	Avg. Acid as $CaCO_3$ (mg/1)
June	2	710	3	692
July	2	785	2	805
August	2	850	3	1,057
September	3	990	2	1,190
October	2	1,018	3	877
November	2	925	5	814
December	2	805	1	750
January	2	735	2	680
February	2	750	3	637
March	3	703	2	605
April	2	705	2	730
May	1	630	2	700
Average		800		795

TABLE 4. SUMMARY OF FLOW AND ACID LOAD REDUCTION AT MS-3 AFTER CONSTRUCTION

	Period	
	Preconstruction (June 1974 through May 1975)	Postconstruction (June 1975 through May 1976)
Average Annual Flow*, m^3/s	0.123	0.104
Percentage Flow Reduction	---	15.0
Average Acidity as $CaCO_3$, mg/l	800.0	845.0
Average Acid Load, Kg/day	8,480.0	7,620.0
Average Acid Load Reduction, Kg/day	---	862.0
Percentage Acid Load Reduction	---	10.0

* Adjusted to normal rainfall

Effectivess of Design and Construction

One of the key considerations in using preventive measures as a means of abating acid mine drainage is that little maintenance should be required after construction. Permanent improvement should result despite the vagaries of nature. In evaluating Site I, there were three critical tests applied to determine effectiveness of design and construction:

1. Initial performance to insure that there was little (if any) loss in streamflow between MS-1 and MS-2 as a result of stream channel restoration.

2. The effect of unusual rainfall events on stability of strip mine restoration and sizing and construction of the restored stream channel considering its ability to handle unusually high stream flow.

3. Determination of soil stability of the restored strip mine as indicated by vegetative growth, especially during the critical second growing season.

Initial performance very clearly met anticipated flow and acid reductions. It was estimated initially that with normal annual rainfall, stream infiltration and seepage at the Site I strip mine contributed approximately 11 percent of the flow and acid loading from the underground mine workings as measured at MS-3. Subsequent data collected after construction at Site I verified that reductions of that order of magnitude had, in fact, been realized.

During a 37-hour rain storm (Hurricane Eloise) occurring between 10:00 P.M. September 24, 1975 through 11:00 A.M. September 26, 1975, there were 13.8 centimeters of rainfall recorded on the project area rain gage. As verified by field observations after the storm, no damage resulted to the reconstructed stream channel, nor was there any evidence that streamflow exceeded channel design capacity. A minor amount of erosion in the newly regraded and seeded area had occurred. This eroded section was subsequently regraded, reseeded, and mulched. Figure 23 shows the Site I strip mine with its restored stream channel near MS-2 and the newly established vegetation on the regraded area.

The condition of the restored strip pit at Site I in October 1976 after the second growing season is shown in Figure 24. There was an excellent growth of vegetation on the regraded area and little evidence of further erosion. The restored area had been used extensively by wildlife, including deer and bear. Seedings from species indigenous to the surrounding area were encroaching upon, and had become reestablished on, the periphery of the restored area.

Figure 23. Site I after restoration (1975).

Figure 24. Site I after restoration (1976).

SITE II EVALUATION

Abatement Effectiveness

The general relationships between MS-4, 5, and 6 and the Site II strip mine were established as described in the Introduction (See page 3). All three monitoring stations draining interconnected portions of extensive underground mine workings were located on the Morris Run watershed. The Site II strip mine, located on the opposite side of the ridge on the Fall Brook watershed, intercepted uphill surface runoff and directed this runoff into these underground mine workings where it flowed downdip to the monitoring stations. Consequently, the monitoring program covering all three stations was geared to provide an initial data base on flow and water quality from each monitored discharge. This program would also provide additional data after construction at the Site II strip mine to determine flow and acid load reductions at each station.

Although Site II strip pit regrading started on February 25, 1975, it was not until the end of May 1975 that substantial regrading had been accomplished. Accordingly, the same one-year period from June 1974 through May 1975 was selected as a basis to determine preconstruction flows in accordance with the reasoning established for Site I evaluation (See page 35). The relationship during the preconstruction period between the three monitoring station flows and the rainfall as measured at the project area rain gage is shown in Figure 25. It was noted that increased flow rates from MS-5 and MS-6 during the warm seasons and vegetative growing periods were not significant until rainfall accumulations reached 2.54 centimeters or more in a 24-hour period, or an extended period of rainfall occurred. Peak flow rates measured at MS-6 as a result of a rainfall event of 2.54 centimeters or more exhibited a time lag of approximately 48 hours.

Flow rate increases measured at MS-4 were even less sensitive to these rainfall events. Peak flows that were recorded exhibited a time lag of 8 to 10 days. Consequently, in evaluating flows as recorded at the three monitoring stations, each flow was evaluated separately.

Average flows at all three monitoring stations are shown in Table 5. Based upon the data compiled during this period, average flows for MS-4, MS-5, and MS-6 were 0.050, 0.024, and 0.014 m^3/s, respectively. Data summarizing average, high groundwater, and low groundwater flows prior to construction from these three monitoring stations are as follows:

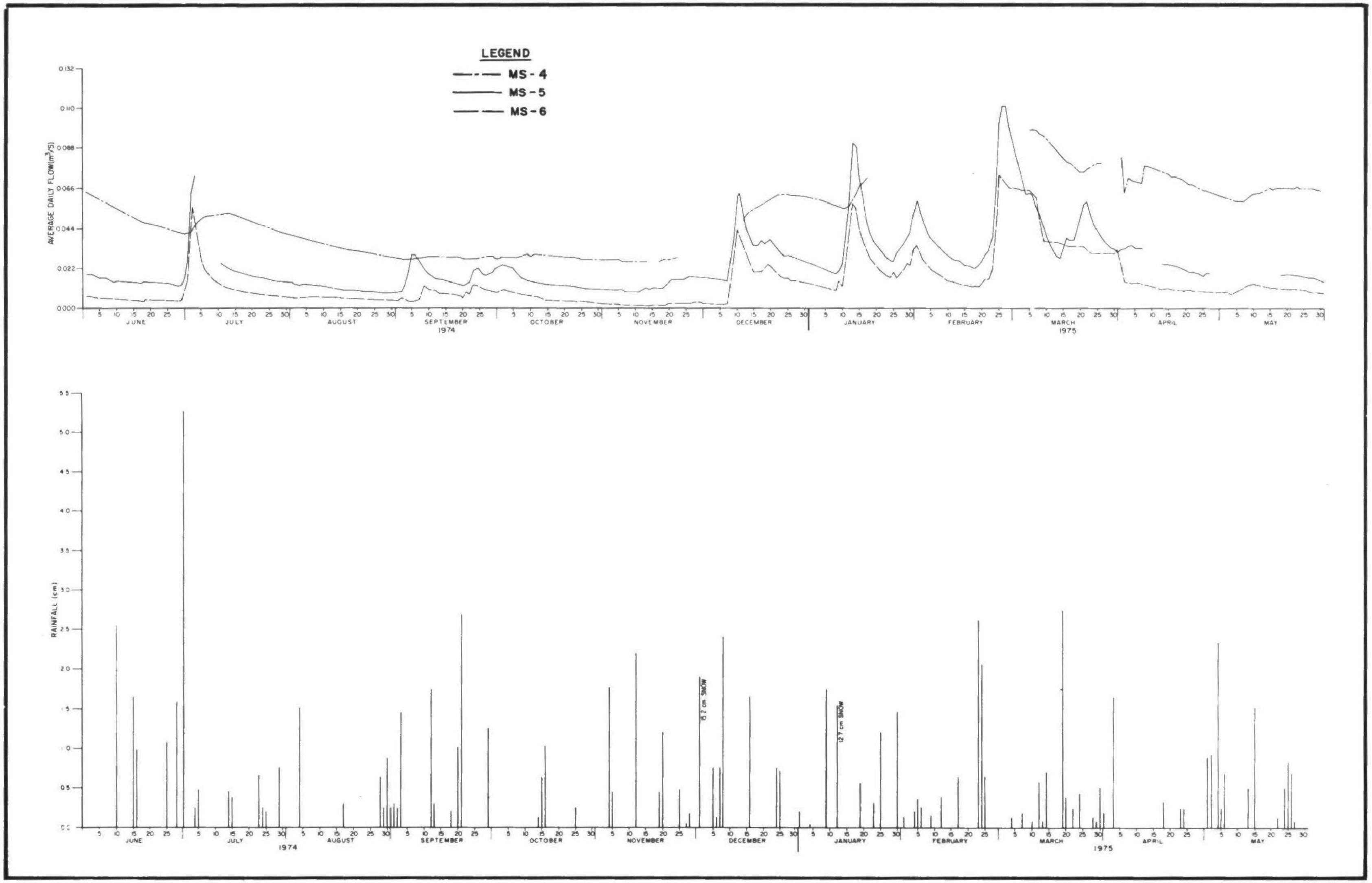


Figure 25. Comparison of daily flow at MS-4, MS-5, and MS-6 vs. rainfall before construction.

TABLE 5. AVERAGE MONTHLY FLOWS AND ACID CONCENTRATIONS AT MS-4, MS-5, AND MS-6 PRIOR TO SITE II CONSTRUCTION

		MS-4			MS-5			MS-6		
Month	Year	Days of Record	Avg. Flow (m^3/s)	Acidity as $CaCO_3$ (mg/l)	Days of Record	Avg. Flow (m^3/s)	Acidity as $CaCO_3$ (mg/l)	Days of Record	Avg. Flow (m^3/s)	Acidity as $CaCO_3$ (mg/l)
June	1974	30	0.051	280	30	0.015	1,185	30	0.007	885
July		31	0.046	405	24	0.022	1,425	31	0.014	900
August		31	0.032	405	31	0.010	1,450	31	0.005	970
September		30	0.027	487	30	0.017	1,583	30	0.007	997
October		31	0.028	580	31	0.014	1,508	31	0.005	1,058
November		19	0.026	525	30	0.012	1,513	30	0.002	1,005
December		20	0.059	565	31	0.031	1,500	31	0.017	920
January	1975	18	0.060	630	31	0.037	1,470	31	0.023	960
February		3	0.064	565	28	0.044	1,410	27	0.022	1,010
March		22	0.071	527	31	0.046	1,183	31	0.041	845
April		30	0.070	385	21	0.025	1,235	30	0.011	875
May		31	0.064	360	14	0.017	1,140	31	0.011	900
Average			0.050	476		0.024	1,384		0.014	944

Seasonal Conditions	Average Flows (m^3/s) MS-4	MS-5	MS-6
High Groundwater (Feb., Mar., Apr., and May)	0.067	0.033	0.021
Low Groundwater (Aug., Sept., Oct., and Nov.)	0.028	0.013	0.005
Average (June through May)	0.050	0.024	0.014

Using acid concentration as a sensitive water quality parameter, a summary of the sampling and analytical data during this preconstruction period is also shown in Table 5.

It was concluded that if design and construction were accomplished properly, reductions in flow at MS-4 and MS-5 could be expected. However, it was further concluded that these reductions might not be measurable because only a very small part (about one percent) of the mined area drained by these discharges was to be restored. It was also felt that MS-6 should be maintained even though Site II strip mine restoration would probably not reduce MS-6 flows.

The contractor began strip pit restoration work at Site II on February 25, 1975. By the end of May 1975, he had substantially changed the surface drainage pattern so that virtually all runoff was directed to Fall Brook. Remaining work on the site until its completion on October 6, 1975 consisted of grading to final contour, seeding, and mulching. The monitoring after May 1975 can, therefore, be considered as postconstruction. The extent of data collected allowed compilation and evaluation of flow and quality data at MS-4 and MS-5 for two full one-year periods following construction. A summary of average flows and acid concentrations of the discharges from each of the three monitoring stations for the two postconstruction periods is shown in Table 6. Average acidity concentrations for these two postconstruction periods are also summarized in Table 6.

Applying the same rationale for flow adjustment as was applied to MS-3 in determining abatement effectiveness for Site I, flows at MS-4, MS-5, and MS-6 were adjusted to reflect annual precipitation approximately 28 percent above normal for June 1975 through May 1976, and 14 percent above normal for June 1976 through May 1977, based upon precipitation recorded on the project area rain gage.

A summary of flow and acid loadings from MS-4, MS-5, and MS-6 before and after construction is presented in Table 7. Based upon these monitoring data, little or no flow reduction was detected. This may be due in part to construction at the Site II strip mine having reaffected only a very small portion of the mined area, as well as in part to gaps in the flow monitoring data. Further, it was evident that no flow reduction occurred at MS-6 in the

TABLE 6. AVERAGE MONTHLY FLOWS AND ACID CONCENTRATIONS AT MS-4, MS-5, AND MS-6 AFTER SITE II CONSTRUCTION

		MS-4			MS-5			MS-6		
Month	Year	Days of Record	Avg. Flow (m^3/s)	Acidity as $CaCO_3$ (mg/l)	Days of Record	Avg. Flow (m^3/s)	Acidity as $CaCO_3$ (mg/l)	Days of Record	Avg. Flow (m^3/s)	Acidity as $CaCO_3$ (mg/l)
June	1975	23	0.062	388	22	0.033	1,237	30	0.016	908
July		31	0.048	405	2	0.020	1,480	31	0.009	1,095
August		31	0.035	430	30	0.015	1,713	31	0.007	1,333
September		21	0.036	695	28	0.024	1,621	28	0.021	1,100
October		12	0.086	640	31	0.034	1,327	31	0.034	980
November		--	--	464	30	0.024	1,244	30	0.023	904
December		--	--	380	31	0.028	1,310	11	0.030	915
January	1976	--	--	405	8	0.027	1,325	28	0.026	935
February		14	0.077	437	20	0.056	983	29	0.027	727
March		31	0.090	365	28	0.041	855	31	0.025	735
April		29	0.068	370	23	0.027	1,090	30	0.014	835
May		31	0.058	345	29	0.030	1,110	23	0.018	850
Average			0.062	444		0.030	1,275		0.021	943
Average scaled to normal rainfall			0.049	480		0.023	1,350		0.016	1,000
June	1976	30	0.066	325	30	0.032	1,200	2	0.013	975
July		26	0.070	388	31	0.028	1,070	6	0.014	773
August		26	0.062	475	31	0.039	1,180	20	0.023	871
September		26	0.050	405	30	0.020	1,300	7	0.010	1,060
October		15	0.038	390	31	0.033	1,320	--	--	1,025
November		3	0.052	304	20	0.028	964	--	--	--
December		--	--	335	27	0.022	--	--	--	--
January	1977	21	0.045	330	24	0.012	1,265	--	--	--
February		26	0.036	349	20	0.025	1,578	--	--	--
March		31	0.061	273	31	0.040	695	--	--	--
April		29	0.107	460	30	0.049	800	--	--	--
May		23	0.073	331	31	0.041	765	--	--	--
Average			0.061	364		0.031	1,103		--	--
Average scaled to normal rainfall			0.054	400		0.027	1,200		--	--

TABLE 7. SUMMARY OF FLOW AND ACID LOADINGS AT MS-4, MS-5, AND MS-6

Period	MS-4			MS-5			MS-6		
	Average Annual Flow* (m^3/s)	Acidity mg/l	Acidity Kg/day	Average Annual Flow* (m^3/s)	Acidity mg/l	Acidity Kg/day	Average Annual Flow* (m^3/s)	Acidity mg/l	Acidity Kg/day
Preconstruction (June 1974 through May 1975)	0.050	476	2,040	0.024	1,384	2,860	0.014	944	1,090
Postconstruction (June 1975 through May 1976)	0.049**	480*	2,000	0.023	1,350*	2,720	0.016	1,000*	1,410
Postconstruction (June 1976 through May 1977)	0.054***	400*	1,860	0.027	1,200*	2,770	+	+	+

* Adjusted to normal rainfall.
** Based on 9 months data only. Data for November 1975 through January 1976 missing.
*** Based on 11 months data only. Data for December 1976 missing.
\+ Monitoring program concluded October 1976.

first year after construction. This confirmed the previous judgment that MS-6 flow would be unaffected by Site II construction.

When flows were adjusted to normal rainfall for the first year after construction, very slight decreases in flow were noted at MS-4 and MS-5, with acidity remaining about the same at MS-4 but slightly decreasing at MS-5. However, by the end of the second postconstruction year, there were 16 percent and 13 percent reductions in acidity, respectively, accompanied by and adjusted for slight flow increases at MS-4 and MS-5. The causes of this water quality improvement at MS-4 and MS-5 are not clear. Site II improvements could not be the sole cause since the area reaffected at this site is only a very small portion of the mined area contributing to these two discharges. This improvement may be the result of extensive continued strip mining and restoration along the outcrop of the Lower Kittanning seam and in several overlying coal seams on the ridge during the last several years updip from these monitoring stations.

Effectiveness of Design and Construction

Similar to the rationale developed for evaluating the effectiveness of design and construction at Site I, the key consideration is the permanent abatement or reduction of acid mine drainage by construction of preventive measures with little or no subsequent maintenance required. In evaluating Site II, there were three critical tests applied to determine the effectiveness of design and construction:

1. Initial performance to determine if a reduction in acid loadings at MS-4 and MS-5 occurred as a result of strip mine restoration at Site II.

2. The effect of unusual rainfall events on stability of the restored strip mine slopes and their ability to withstand erosion.

3. Evaluation of vegetative growth on a test plot using digested sludge as a soil conditioner in lieu of limestone and commercial fertilizers.

<u>Effect of Rainfall Events on Regraded Areas</u>

As the strip mine restoration at Site II neared completion, erosion occurred in the downhill end of a swale located in the southern portion of the restored strip pit. The swale was regraded, reseeded, and jute matting was placed on the lower 366 meters of the swale to prevent further erosion problems. This repair work had just been completed, but vegetation had not yet sprouted, when a 13 centimeter rainstorm occurred between September 24 and September 26, 1975. Figure 26 shows the erosional effect this rainfall had on the downhill end of this swale. Ultimately, the downhill end of this swale was repaired by filling, lining 165 meters with a mulch blanket, placing riprap in the last 91 meters of the swale, and reseeding the filled area. No further erosion resulted after this repair work was accomplished. In retrospect, the significant erosion that occurred in this swale during and

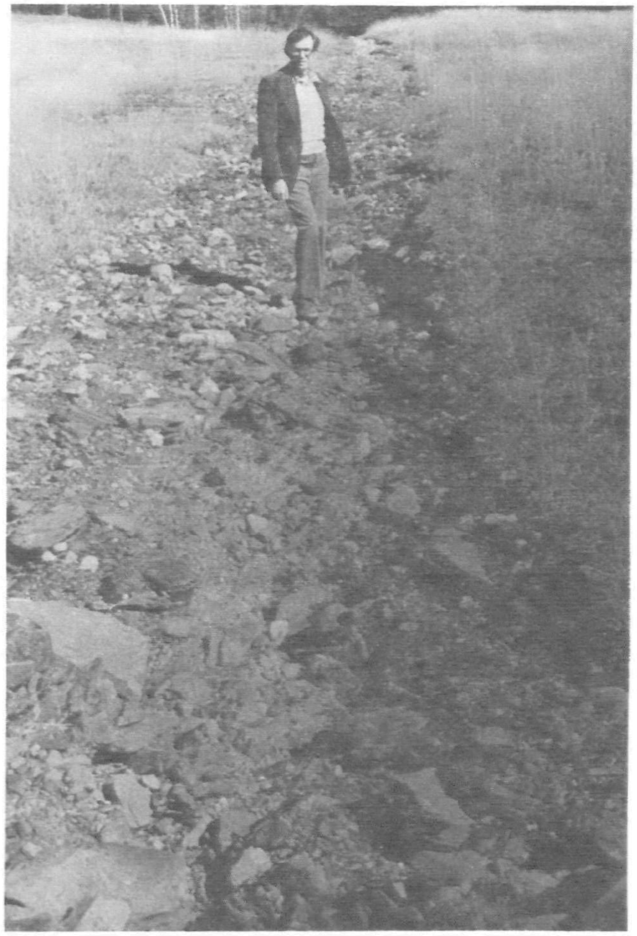


Figure 26. Erosion in swale at Site II (1976).

following construction certainly indicated that considerable volumes of surface water were no longer entering the underground mine workings through this site.

Effectiveness of Wastewater Sludge as a Soil Conditioner

To assess the effectiveness of the wastewater sludge in establishing vegetation on the test plot, on August 4, 1976, the vegetation from 12 one-square-meter areas was cut, air-dried, and weighed. Six sites were for areas where the vegetation was growing the best surrounding the sludge test plot, and the last six were representative areas within the sludge test plot. The results of this program are shown in Appendix A. The average weight of grasses cut from areas within the sludge test plot was nearly three times that from adjacent areas. However, it is recognized that considerably greater quantities of nutrients were applied to the sludge test plot when compared to the remainder of the site. Figures 27 and 28 are photographs showing the sludge treated area.

Samples of water from the infiltration ditch were collected on February 24 and August 4, 1976 for bacteriologic analysis. Total coliform organisms of 230 and 75 per 100 milliliters, respectively, were reported. Consequently, since no significant public health hazard existed and because the wildlife was extensively using the water in the ditch, it was decided to leave the infiltration ditch in place.

MONITORING PROGRAM EVALUATION

There were three separate but interrelated phases associated with the monitoring program: measuring precipitation, measuring flow, and collecting and analyzing grab samples.

There were no apparent difficulties in gathering project area precipitation information. Rainfall data collected at the project area rain gage appeared to correlate reasonably well with the published data from the two closest established weather stations.

Some difficulties were encountered during continuous flow monitoring at the six constructed monitoring stations. The most serious problems were associated with extremely cold weather and high humidity. The clock mechanisms in the installed flow recorders had a tendency to freeze until a low temperature lubricant was found that could withstand extremely cold temperatures and additional venting was provided for moisture control. In addition, the water in the stilling wells of MS-1 and MS-2 froze and remained frozen for three months during the winter of 1975-1976 despite the addition of copious amounts of lubricating oil.

The seams of floats in the stilling wells at MS-3, 4, 5, and 6 were etched by the acid water causing these floats to develop holes, fill with water, and sink. Some erroneous flow measurements resulted. The affected floats were repaired as necessary throughout the flow monitoring program. Coating the floats with an acid-resistant epoxy or providing floats resistant

Figure 27. Site II after restoration with sludge plot in background (1975).

Figure 28. Vegetative growth on sludge plot (1975).

to attack by acid would solve this problem.

Silting behind the weirs was also a problem, resulting in a tendency for the feed lines to the stilling wells to become clogged. This problem was corrected by preventive maintenance. During periods of high flows, there was a tendency for the beaded cable running from the float to the recorder to stick causing the recording mechanism to be thrown out of calibration.

For future programs of this nature, it is desirable that back-up units be available at all times to enable prompt replacement of any malfunctioning recorder. Furthermore, experience has shown that a substantial amount of maintenance is associated with an "automatic" monitoring system. The magnitude of the planned monitoring program should be critically reviewed, and adequate funding for the program should be provided.

In reviewing and evaluating the sampling and analytical phase of the monitoring program, it became evident that direct control of the analytical program should be vested with the entity responsible for evaluating the analytical results. During the formal monitoring phase of this project, analytical quality control was firmly established. Analytical results were reviewed immediately, and, as inconsistencies were noted, these inconsistencies were resolved. After the formal program had ended, analytical data were provided by the Department for an additional year. These additional data were comprised of pH, acidity, total iron, and sulfate on grab samples collected biweekly at MS-3, 4, and 5. The 307 determinations run on the 77 samples delivered to the laboratory were critically reviewed, and 28 determinations were not used because they were not compatible with other constituents.

COST EVALUATION

Costs (See Appendix A) were derived for three separate portions of the construction work accomplished for this project based upon a breakdown of actual construction costs incurred, namely:

Channel restoration at Site I	$ 60,437.03
Strip mine restoration at Site I	96,128.00
Strip mine restoration at Site II	303,577.20

Unit costs, also summarized in Appendix A, indicate that the unit cost for channel reconstruction was $166/meter. Strip mine restoration at Site I was $14,789/hectare while similar restoration at Site II was $9,370/hectare. The significant differences in these strip mine restoration unit costs were attributed to grading. Unit grading costs for Site I were $10,769/hectare compared to $6,759/hectare for Site II.

The Department's recent experience with similar projects indicated that construction costs have ranged from $7,400 to $14,800/hectare in the

Bituminous Field, and from $7,400 to $24,700/hectare in the Anthracite Field. These 1975 construction costs can be considered as top-of-the-range and mid-range, respectively. One contribution to the higher unit cost at Site I was the greater volume of earth moved per hectare when compared to Site II ($10,769/hectare versus $6,759/hectare).

REFERENCES

1. Gannett Fleming Corddry and Carpenter, Inc. Acid Mine Drainage Abatement Measures for Selected Areas Within the Susquehanna River Basin. U. S. Department of Interior, Federal Water Pollution Control Administration, Washington, D. C., 1968. 99 pp.

2. Gannett Fleming Corddry and Carpenter, Inc., Tioga River Mine Drainage Abatement Project. EPA-600/2-76-106, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1976. 63 pp.

3. Climatological Data, Pennsylvania Annual Summary 1974. Volume 79 No. 13, U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Asheville, North Carolina, 1974. p.4.

4. Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years. Technical Paper No. 40, U. S. Department of Commerce, Weather Bureau, Washington, D. C., 1961. pp. 9-105.

APPENDIX A

PROJECT INFORMATION AND DATA

TABLE A-1. WASTEWATER SLUDGE CHARACTERISTICS

Analysis	Milligrams/liter (unless otherwise noted)
Acidity	0.
Alkalinity	220.
BOD_5	73.
COD	368.
Cadmium	$<$ 0.001
Chloride	1.8
Color	240. Chloroplatinate Units
Copper	0.2
Fluoride	$<$ 0.1
Iron	4.5
Lead	0.2
Mercury	0.005
Nitrogen-Ammonia	21.0
Nitrogen-Nitrate	2.11
Nitrogen-Nitrite	None Detected
Odor (Threshold)	8. TON
pH	7.8 Units
Specific Conductivity	446. micromhos/cm
Zinc	1.3

TABLE A-2. ABSTRACT OF ENGINEER'S ESTIMATE AND LOW BID

Item No.	Description	Approx. Quantities	Unit	Engineer's Estimate Unit Price	Engineer's Estimate Total	Low Bid Unit Price	Low Bid Total
1	Clearing and Grubbing						
(a)	Site I	Job	-	Lump Sum	$ 3,500.00	Lump Sum	$ 16,000.00
(b)	Site II	Job	-	Lump Sum	12,425.00	Lump Sum	14,800.00
2	Excavation and Backfill - Site I	Job	-	Lump Sum	57,590.00	Lump Sum	77,000.00
3	Grading - Site II	Job	-	Lump Sum	218,995.00	Lump Sum	218.990.00
4	Infiltration Ditch - Site II	Job	-	Lump Sum	1,500.00	Lump Sum	1,400.00
5	Channel Lining						
(a)	Impervious Lining - Site I	2,600	S.Y.*	8.00	20,800.00	4.00	10,400.00
(b)	Filter Blanket and Quarry Stone - Site I	2,310	S.Y.*	15.00	34,650.00	12.60	29,106.00
6	Seeding and Soil Supplements						
(a)	Site I	Job	-	Lump Sum	9,600.00	Lump Sum	6,000.00
(b)	Site II	Job	-	Lump Sum	44,157.00	Lump Sum	40,300.00
7	Anti-Pollution Measures						
(a)	Site I	Job	-	Lump Sum	12,500.00	Lump Sum	11,000.00
(b)	Site II	Job	-	Lump Sum	12,500.00	Lump Sum	5,000.00
Total					428,217.00		429,996.00

* English measurement system required in bidding documents.
Metric conversion table is found on page ix.

TABLE A-3. COMPLETE ANALYSES OF SAMPLES TAKEN BEFORE AND AFTER CONSTRUCTION

	MS-1		MS-2		MS-3		MS-4		MS-5		MS-6	
Constituents	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Acidity, mg/l as $CaCO_3$	3.0	8.0	7.0	6.0	840.0	680.0	420.0	400.0	1,730.0	1,120.0	930.0	760.0
Alkalinity, mg/l as $CaCO_3$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aluminum, mg/l	0.09	<0.5	1.7	<0.5	45.2	38.5	26.1	21.8	112.5	94.9	70.1	59.9
Arsenic, mg/l	<0.3	<0.05	<0.3	<0.05	<0.3	<0.05	<0.3	<0.05	<0.3	<0.05	<0.3	<0.05
Cadmium, mg/l	<0.1	<0.01	<0.1	<0.01	<0.1	<0.01	<0.1	<0.01	<0.1	0.02	<0.1	0.02
Calcium, mg/l	5.3	4.58	3.4	4.70	118.1	94.8	107.6	99.5	152.5	134.0	162.7	172.0
Chromium, mg/l	0.1	<0.05	<0.1	<0.05	0.1	0.05	0.1	0.05	0.1	0.06	0.1	0.05
Copper, mg/l	<0.1	<0.01	<0.1	<0.01	0.3	0.14	0.2	0.08	1.5	0.70	1.1	0.64
Iron (Total), mg/l	0.1	<0.05	0.7	<0.05	68.3	67.5	14.0	17.9	50.6	37.1	17.8	28.5
Iron (Ferrous) mg/l	<0.01	<0.02	0.15	<0.02	5.8	5.6	5.7	4.5	6.4	3.6	3.9	4.4
Lead, mg/l	<0.5	<0.05	<0.5	<0.05	<0.5	<0.05	<0.5	<0.05	<0.5	<0.05	<0.5	<0.05
Magnesium, mg/l	1.4	1.04	1.8	1.02	78.2	60.3	106.2	96.1	217.5	176.0	188.1	198.0
Manganese, mg/l	<0.1	0.05	0.4	0.04	16.2	9.83	57.0	47.0	71.9	55.6	64.2	71.5
Potassium, mg/l	0.1	0.45	1.8	0.28	0.1	0.70	2.1	2.35	1.4	1.3	2.1	2.80
Sodium, mg/l	1.1	0.47	3.9	0.30	3.3	1.25	5.3	1.70	6.3	2.80	4.8	2.20
Zinc, mg/l	<0.1	0.03	0.1	<0.01	1.8	1.29	2.0	1.34	12.9	7.89	10.5	8.99
Mercury, mg/l	0.4	0.0002	<0.3	0.018	0.4	0.0003	0.4	0.0007	0.3	0.0003	0.3	0.023
COD, mg/l	8.0	0.0	11.0	0.0	8.0	0.0	4.0	4.0	8.0	0.0	4.0	0.0
Chlorides, mg/l Cl	1.01	1.0	2.5	2.0	1.51	1.0	4.03	2.0	1.51	1.0	1.01	1.0
Cyanide, mg/l CN	0.0026	0.023	<0.0003	0.065	0.0053	0.048	0.0006	0.0	0.0042	0.059	0.0003	0.018
Fluoride, mg/l	0.08	0.23	0.14	0.12	0.82	0.77	0.74	0.74	1.02	1.12	1.07	1.10
Hardness, mg/l as $CaCO_3$	18.0	12.0	22.0	30.0	740.0	580.0	900.0	810.0	1,680.0	1,300.0	1,500.0	1,510.0
Nitrate, mg/l N	0.886	0.084	0.02	0.082	0.266	0.0	0.177	0.004	1.285	0.0	0.709	0.0
pH	5.6	5.6	5.7	5.3	2.8	2.9	3.0	3.2	2.7	2.9	2.9	3.0
Specific Conductivity, umhos/cm	35.4	45.0	63.5	59.0	2,000.0	1,400.0	2,000.0	1,170.0	3,660.0	2,370.0	2,840.0	2,030.0
Sulfate, mg/l	12.0	9.6	17.0	9.9	1,240.0	950.0	1,140.0	950.0	2,880.0	2,320.0	2,180.0	2,260.0
Temperature, °C (field)	17.0	10.5	7.0	12.0	9.0	9.0	9.0	9.0	10.0	11.0	10.0	10.0
Turbidity, J.T.U.	0.66	1.2	12.0	0.96	1.2	0.44	12.0	4.9	0.29	0.37	0.31	0.88
Residue, mg/l (Total)	26.0	52.0	78.0	56.0	1,970.0	1,652.0	1,720.0	1,564.0	4,137.0	3,326.0	3,055.0	3,232.0
Residue, mg/l (Filterable)	0.0	0.0	9.0	0.0	0.4	0.0	28.4	0.0	1.6	0.0	0.8	0.0
Date sample collected	8/8/73	5/24/76	11/1/73	5/24/76	8/8/73	5/24/76	8/8/73	5/24/76	8/8/73	5/24/76	8/8/73	5/24/76
Flow on that date, m^3/s	0.005	0.053	0.143	0.054	0.168	0.201	0.084	0.067	0.050	0.043	0.017	0.023

TABLE A-4. SAMPLING AND ANALYTICAL SCHEDULE

		SITE I					
		MS-1		MS-2		MS-3	
Phase	Sampling Frequency	Sampling Period	Analyses*	Sampling Period	Analyses*	Sampling Period	Analyses*
Precon-struction	Weekly	6/13/73-9/19/73	A	6/13/73-9/19/73	A	6/13/73-9/19/73	A
	Biweekly	10/4/73-12/26/73	A	10/4/73-12/26/73	A	10/4/73-12/26/73	A
		-	-	-	-	1/10/74-5/11/75	B
	Every 8 wks	2/20/74-5/9/75	B	2/20/74-5/9/75	B	-	-
	Other	8/8/73	E	11/1/73	E	8/8/73	E
		-	-	-	-	2/20/74	A & C
Construc-tion	Biweekly	-	-	-	-	6/3/75-9/28/75	B
	Every 8 wks	7/1/75-8/28/75	B	7/1/75-8/28/75	B	-	-
Postcon-struction	Weekly	10/19/75-12/7/75	B	10/19/75-12/7/75	B	10/12/75-12/7/75	B
	Biweekly	-	-	-	-	12/21/75-10/21/76	B
		-	-	-	-	11/9/76-10/6/77	B**
	Every 8 wks	2/1/76-10/21/76	B	2/1/76-10/21/76	B	-	-
	Other	11/30/75	A & C	11/30/75	A & C	11/30/75	A & C
		5/24/76	E	5/24/76	E	5/24/76	E

		SITE II					
		MS-4		MS-5		MS-6	
Phase	Sampling Frequency	Sampling Period	Analyses*	Sampling Period	Analyses*	Sampling Period	Analyses*
Precon-struction	Weekly	6/14/73-9/19/73	A	6/14/73-9/19/73	A	6/14/73-9/19/73	A
	Biweekly	10/4/73-12/26/73	A	10/4/73-12/26/73	A	10/4/73-12/26/73	A
		1/10/74-2/15/75	B	1/10/74-2/15/75	B	1/10/74-2/15/75	B
	Other	8/8/73	E	8/8/73	E	8/8/73	E
		2/20/74	A & C	2/20/74	A & C	2/20/74	A & C
Construc-tion	Biweekly	3/7/75-9/28/75	B	3/7/75-9/28/75	B	3/7/75-9/28/75	B
	Other	8/28/75	B & D	8/28/75	B & D	8/28/75	B & D
Postcon-struction	Weekly	10/12/75-12/7/75	B	10/12/75-12/7/75	B	10/12/75-12/7/75	B
	Biweekly	12/21/75-10/21/76	B	12/21/75-10/21/76	B	12/21/75-10/21/76	B
		11/9/76-10/6/77	B**	11/9/76-10/6/77	B**	-	-
	Other	11/30/75	A & C	11/30/75	A & C	11/30/75	A & C
		2/26/76	B & D	2/26/76	B & D	2/26/76	B & D
		5/24/76	E	5/24/76	E	5/24/76	E
		8/25/76	B & D	8/25/76	B & D	8/25/76	B & D

* A - pH, acidity, alkalinity, total iron, manganese, aluminum, sulfate, total solids.
B - pH, acidity, alkalinity, total iron, sulfate.
C - zinc.
D - zinc, copper, lead.
E - complete. See Table 4.
** Collected and analyzed by Pennsylvania Department of Environmental Resources.

TABLE A-5. NORMAL MONTHLY PRECIPITATION AT ENGLISH CENTER AND TOWANDA, PENNSYLVANIA(3)

Month	Precipitation (centimeters)	
	English Center	Towanda
January	5.51	4.67
February	5.49	4.65
March	8.41	6.81
April	8.28	7.87
May	10.41	10.08
June	8.53	7.52
July	9.45	8.86
August	8.28	7.70
September	7.24	7.90
October	7.75	6.96
November	8.92	7.59
December	6.55	5.69
TOTAL	94.82	86.30

TABLE A-6. RAINFALL FREQUENCY - DURATION TABULATION FOR SOUTHEASTERN TIOGA COUNTY, PENNSYLVANIA IN CENTIMETERS OF WATER [4]

Hours	1	2	5	10	25	50	100
0.5	1.91	2.29	3.05	3.51	4.01	4.52	4.83
1	2.41	2.84	3.81	4.37	5.08	5.72	6.22
2	3.00	3.56	4.70	5.59	6.22	7.11	7.62
3	3.30	4.32	5.08	6.10	7.11	7.62	8.64
6	4.32	4.83	6.35	7.37	8.64	9.65	10.16
12	4.83	6.10	7.62	8.64	10.16	11.18	12.45
24	5.89	6.96	8.89	10.39	12.04	12.95	14.55

TABLE A-7. MONTHLY RAINFALL DATA

Month	Year	Precipitation (centimeters) Study Area	English Center[3]	Towanda[3]
April	1974	6.71	4.11	5.28
May		7.09	8.51	7.77
June		13.23	9.12	10.52
July		3.45	8.18	7.82
August		3.86	5.74	7.06
September		9.32	15.70	12.07
October		2.06	1.98	2.34
November		6.83	6.50	7.75
December		9.09	10.85	8.00
January	1975	7.11	6.63	6.27
February		7.42	8.86	8.31
March		6.48	6.55	4.37
April		2.49	2.31	2.03
May		9.37	10.11	9.53
June		9.70	13.67	11.15
July		7.14	9.17	6.96
August		6.20	8.86	9.91
September		22.86	18.24	27.76
October		6.73	6.68	7.26
November		6.10	5.89	5.33
December		8.76	8.46	5.49
January	1976	5.84	7.34	8.18
February		4.83	5.61	4.24
March		9.78	7.24	6.15
April		4.83	3.68	5.31
May		10.64	17.75	5.54
June		16.59	15.27	9.78
July		11.63	8.13	11.81
August		7.95	6.27	9.42
September		6.15	7.75	6.27
October		13.79	15.49	15.54
November		0.84	1.02	2.13
December		4.39	4.57	3.40
January	1977	3.94	2.84	2.92
February		3.30	5.77	4.78
March		11.33	15.14	10.74
April		7.37	9.78	9.65
May		4.95	3.05	4.01
June		11.81	11.73	7.85
July		5.21	10.80	10.67
August		5.33	7.77	8.56
September		11.05	13.54	15.70

TABLE A-8. MONITORING STATION DESIGN CONSIDERATIONS

Monitoring Station	Type: Weir	Type: Weir Plate	Estimated Wet Weather Flow (m^3/s)	Maximum Measurable Flow (m^3/s): Weir Plate	Maximum Measurable Flow (m^3/s): Flow Recorder
1	Concrete	Stainless steel, 90^o V-notch	0.096	0.193	0.153
2	Concrete	Stainless steel, 90^o V-notch	0.096	0.193	0.153
3	Concrete	Stainless steel, 90^o rectangular	0.499	0.639	0.613
4	Timber	Stainless steel, 90^o V-notch	0.149	0.193	0.153
5	Timber	Stainless steel, 90^o V-notch	0.083	0.193	0.153
6	Half-round tank, baffle plated	Stainless steel, 90^o V-notch	0.039	0.070	0.077

TABLE A-9. AVERAGE MONTHLY FLOWS

Month	Year	SITE I						SITE II					
		MS-1		MS-2		MS-3		MS-4		MS-5		MS-6	
		Avg. Flow (m^3/s)	Days of Record	Avg. Flow (m^3/s)	Days of Record	Avg. Flow (m^3/s)	Days of Record	Avg. Flow (m^3/s)	Days of Record	Avg. Flow (m^3/s)	Days of Record	Avg. Flow (m^3/s)	Days of Record
March	1974*	0.049	14	0.044	14	0.193	14	0.083	14	0.031	13	--	--
April		0.092	30	0.089	28	0.267	27	0.092	30	0.046	30	--	--
May**		0.045	31	0.036	31	0.131	31	0.073	29	0.029	31	0.016	18
June		0.010	30	0.001	30	0.096	30	0.051	30	0.015	30	0.007	30
July		0.015	31	0.008	31	0.105	31	0.046	31	0.022	24	0.014	31
August		0.003	31	0.000	31	0.070	31	0.032	31	0.010	31	0.005	31
September		0.007	30	0.000	30	0.057	30	0.027	30	0.017	30	0.007	30
October		0.005	31	0.000	31	0.057	31	0.028	31	0.014	31	0.005	31
November		0.036	30	0.000	21	0.074	30	0.026	19	0.012	30	0.002	30
December		0.066	31	0.050	20	0.158	31	0.059	20	0.031	31	0.017	31
January	1975	0.069	29	0.047	31	0.184	31	0.060	18	0.037	31	0.023	31
February		0.061	28	0.046	25	0.184	28	0.064	6+	0.044	28	0.022	26
March		0.064	31	0.057	31	0.206	31	0.071	22	0.046	31	0.041	31
April		0.043	30	0.027	30	0.145	30	0.070	30	0.025	21	0.011	30
May		0.060	31	0.046	31	0.145	31	0.064	31	0.017	14	0.011	31
June		0.035	30	--	--	0.118	30	0.062	23	0.033	22	0.016	30
July		0.013	31	--	--	0.079	31	0.048	31	0.020	2	0.009	31
August		0.004	31	--	--	0.061	31	0.035	31	0.015	30	0.007	31
September		0.029	30	0.025	23	0.114	30	0.036	21	0.024	28	0.021	28
October		0.046	31	0.040	31	0.171	31	0.086	12	0.034	31	0.034	31
November		0.046	30	0.048	30	0.127	30	--	--	0.024	30	0.023	30
December		0.062	31	0.033	31	0.127	31	--	--	0.028	30	0.030	11
January	1976	0.037	18	0.008	12	0.118	31	--	--	0.027	8	0.026	28
February		0.116	6	--	--	0.210	29	0.077	14	0.056	20	0.027	29
March		0.078	31	0.057	21	0.201	31	0.090	31	0.041	28	0.025	31
April		0.048	30	0.045	30	0.136	30	0.068	29	0.027	23	0.014	30
May		0.048	28	0.451	28	0.140	31	0.058	31	0.030	29	0.018	23
June		0.060	30	0.061	30	0.145	30	0.066	30	0.032	30	0.013	2
July		0.025	31	0.026	31	0.101	31	0.070	26	0.028	31	0.014	6
August		0.028	26	0.032	28	0.118	31	0.062	26	0.039	31	0.023	20
September		0.008	30	0.007	30	0.074	30	0.050	26	0.020	30	0.010	7
October++		0.037	19	0.051	29	0.088	20	0.038	15	0.033	31	--	--
November		--	--	--	--	0.096	9	0.052	3	0.028	20	--	--
December		--	--	--	--	0.307	13	--	--	0.022	27	--	--
January	1977	--	--	--	--	0.074	27	0.045	21	0.012	24	--	--
February		--	--	--	--	0.074	23	0.036	26	0.025	20	--	--
March		--	--	--	--	0.228	31	0.061	31	0.040	31	--	--
April		--	--	--	--	0.241	29	0.107	29	0.049	30	--	--
May		--	--	--	--	0.162	30	0.073	23	0.041	31	--	--
June		--	--	--	--	0.096	29	0.064	4	0.018	27	--	--
July		--	--	--	--	0.101	30	--	--	0.033	31	--	--
August		--	--	--	--	0.083	19	0.032	21	0.018	31	--	--
September		--	--	--	--	0.118	15	0.029	30	0.036	30	--	--
October+++		--	--	--	--	0.118	9	0.043	15	0.052	15	--	--

* Recorder installed at MS-1, 2, 3, 4, and 5 on March 18, 1974.

** Recorder installed at MS-6 on May 4, 1974

\+ Average calculated on the basis of six instantaneous readings.

++ Responsibility for operating and maintaining monitoring stations assumed by DER on October 21, 1976.

+++ Last flow data collected on October 15, 1977.

TABLE A-10. COMPARISON OF ANNUAL RAINFALL BEFORE AND AFTER CONSTRUCTION

	Recording Station								
	English Center[3]			Towanda[3]			Project Area		
	Annual Rainfall	Departure*		Annual Rainfall	Departure*		Annual Rainfall	Departure*	
Period	(centimeters)	(centimeters)	(percent)	(centimeters)	(centimeters)	(percent)	(centimeters)	(centimeters)	(percent)
Preconstruction (June 1974 through May 1975)	92.53	- 2.29	- 2.4	86.06	- 0.25	- 0.3	80.72	--	--
Postconstruction (June 1975 through May 1976)	112.60	+17.78	+18.8	103.28	+16.97	+19.7	103.40	+22.68	+28.0
Postconstruction (June 1976 through May 1977)	--	--	--	--	--	--	92.15	+11.43	+14.2

* Assumes preconstruction rainfall was normal.

TABLE A-11. WEIGHT OF VEGETATION:
ADJACENT AREA VS. TEST PLOT

Sample Number	Location	Air-dried weight (grams/square meter)
1	Adjacent Area	765.
2	Adjacent Area	1,531.
3	Adjacent Area	1,162.
4	Adjacent Area	1,191.
5	Adjacent Area	794.
6	Adjacent Area	425.
Average	Adjacent Area	978.
7	Test Plot	2,608.
8	Test Plot	3,742.
9	Test Plot	2,608.
10	Test Plot	2,495.
11	Test Plot	3,062.
12	Test Plot	2,835.
Average	Test Plot	2,892.

TABLE A-12. SUMMARY BREAKDOWN OF PROJECT CONSTRUCTION COSTS*

Item	Cost
Channel restoration at Site I:	
Clear and grub (assumed 20% of total cost for Site I)	$ 3,200.00
Excavation and grading (assumed 10% of total cost for Site I)	7,000.00
Channel lining	39,506.00
Anti-pollution measures (assumed 50% of total cost for Site I)	5,500.00
Change Order No. 4	3,678.00
Change Order No. 5	1,553.03
Total	$ 60,437.03
Strip mine restoration at Site I:	
Clear and grub (assumed 80% of total cost for Site I)	$ 12,800.00
Grading (assumed 90% of total cost for Site I)	70,000.00
Seeding and soil supplements	6,000.00
Anti-pollution measures (assumed 50% of total cost for Site I)	5,500.00
Change Order No. 5	1,828.00
Total	$ 96,128.00
Strip mine restoration at Site II:	
Clear and grub	$ 14,800.00
Grading	218,990.00
Infiltration ditch	1,400.00
Seeding and soil supplements	40,300.00
Anti-pollution measures	5,000.00
Change Order No. 2	5,101.20
Change Order No. 3	4,700.00
Change Order No. 5	1,828.00
Change Order No. 6	11,058.00
Change Order No. 7	400.00
Total	$303,577.20

* Work accomplished in 1975.

TABLE A-13. UNIT CONSTRUCTION COSTS*

Activity	Total Cost ($)	Quantity	Unit Cost ($)
Channel restoration, Site I	60,437.03	363 meters	166.49/meter
Strip mine restoration, Site I	96,128.00	6.5 hectares	14,788.92/hectare
Grading, Site I	70,000.00	6.5 hectares	10,769.23/hectare
Strip mine restoration, Site II	303,577.20	32.4 hectares**	9,369.67/hectare
Grading, Site II	218,990.00	32.4 hectares**	6,758.95/hectare

* Work accomplished in 1975.

** Includes 3.6 hectares on which excess fill was placed and graded to blend with the surrounding terrain, after which this area was also limed, fertilized, and seeded.

APPENDIX B

WATER QUALITY AND FLOW DATA AT MONITORING STATIONS

TABLE B-1. WATER QUALITY AND FLOW DATA AT MONITORING STATIONS

	Date Collected				Date Collected			
	6/15/73	6/21/73	6/28/73	7/5/73	7/12/73	7/19/73	7/26/73	8/2/73
MS-1								
pH	6.0	6.0	4.7	5.9	5.8	6.4	5.0	6.5
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	5.	6.	6.	3.	5.	5.	9.	2.
Sulfate (mg/l)	16.1	10.9	9.8	10.	12.	11.	13.	10.
Total Iron (mg/l)	0.6	0.2	0.2	<0.1	0.2	0.8	0.1	1.0
Aluminum (mg/l)	0.06	0.06	0.09	0.09	0.05	0.08	0.33	0.04
Manganese (mg/l)	<0.10	<0.10	<0.1	<0.1	0.1	0.2	0.2	<0.1
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	31.	34.	10.	48.	25.	28.	53.	16.
Flow (m^3/s)	0.166	0.071	0.039	0.104	0.023	0.019	0.020	0.025
MS-2								
pH	5.5	5.9		5.1				
Alkalinity (mg/l as $CaCO_3$)	0.	0.		0.				
Acidity (mg/l as $CaCO_3$)	5.	5.		5.				
Sulfate (mg/l)	14.1	19.5	dry	14.	dry	dry	dry	dry
Total Iron (mg/l)	0.8	0.4		0.7				
Aluminum (mg/l)	0.10	0.05		0.13				
Manganese (mg/l)	<0.10	0.2		<0.1				
Zinc (mg/l)	--	--		--				
Total Solids (mg/l)	35.	60.		54.				
Flow (m^3/s)	0.115	0.		0.057				
MS-3								
pH	2.8	2.8	2.8	2.8	2.8	2.7	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	550.	736.	700.	690.	730.	710.	780.	790.
Sulfate (mg/l)	1,059	1,300.	1,310.	1,240.	1,496.	1,200.	1,180.	1,230.
Total Iron (mg/l)	39.8	49.5	44.3	37.9	53.0	42.0	42.5	45.6
Aluminum (mg/l)	39.0	22.5	26.9	26.0	29.8	46.9	42.7	40.1
Manganese (mg/l)	12.5	13.9	12.0	9.7	16.2	12.1	12.0	12.2
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	1,465.	1,612.	1,634.	1,605.	1,670.	1,784.	1,784.	1,871.
Flow (m^3/s)	0.423	0.290	0.272	0.329	0.252	0.197	0.212	0.201
MS-4								
pH	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.1
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	363.	428.	400.	420.	410.	390.	410.	410.
Sulfate (mg/l)	1,085.	1,100.	1,210.	1,230.	1,288.	1,100.	1,060.	1,140.
Total Iron (mg/l)	16.4	18.1	15.4	13.2	20.1	12.9	13.0	13.6
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	27.2	15.0	18.7	19.9	19.9	27.9	23.6	22.1
Manganese (mg/l)	45.1	50.0	45.9	45.1	54.9	40.0	39.7	43.7
Total Solids (mg/l)	1,663.	1,576.	1,581.	1,839.	1,648.	1,632.	1,632.	1,689.
Flow (m^3/s)	0.166	0.145	0.136	0.131	0.115	0.110	0.100	0.114
MS-5								
pH	2.8	2.8	2.7	2.8	2.7	2.7	2.7	2.7
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,280.	1,508.	1,685.	1.560.	1,520.	1,640.	1,650.	1,660.
Sulfate (mg/l)	2,860.	3,310.	3,470.	3,420.	3,190.	2,860.	2,980.	2,820.
Total Iron (mg/l)	46.1	50.8	47.1	38.2	53.0	39.6	40.1	43.7
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	150.2	75.9	93.2	75.2	70.0	144.0	131.0	96.7
Manganese (mg/l)	53.4	65.8	54.7	48.4	63.3	48.3	48.2	49.9
Total Solids (mg/l)	3,851.	3,975.	4,079.	4,011.	3,820.	4,531.	4,094.	4,174.
Flow (m^3/s)	0.087	0.064	0.085	0.103	0.070	0.067	0.060	0.084
MS-6								
pH	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	626.	1,036.	905.	760.	785.	950.	990.	850.
Sulfate (mg/l)	1,840.	2,650.	2,690.	2,280.	2,210.	2,080.	2,180.	2,000.
Total Iron (mg/l)	13.2	20.0	13.9	10.1	18.5	13.0	13.3	13.0
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	67.9	56.0	52.1	39.8	44.1	74.8	74.7	49.8
Manganese (mg/l)	50.1	70.3	52.3	44.8	59.1	46.9	47.0	46.9
Total Solids (mg/l)	2,748.	3,449.	3,110.	2,737.	2,802.	3,106.	3,119.	3,018.
Flow (m^3/s)	0.043	0.031	0.031	0.050	0.025	0.025	0.018	0.030

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	8/8/73	8/16/73	8/23/73	8/30/73	9/6/73	9/13/73	9/19/73	10/4/73
MS-1								
pH	5.6	6.4	6.6	5.9	5.8	5.2	5.9	5.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	3.	3.	3.	5.	6.	3.	3.	4.
Sulfate (mg/l)	12.	11.	11.	11.	12.	12.	10.	11.
Total Iron (mg/l)	0.1	0.1	0.2	0.2	0.1	0.3	0.2	0.1
Aluminum (mg/l)	0.09	0.08	0.07	0.05	0.08	0.07	0.06	0.05
Manganese (mg/l)	<0.1	<0.1	<0.1	<0.1	0.1	0.07	<0.1	<0.1
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	26.	16.	44.	43.	81.	38.	15.	85.
Flow (m^3/s)	0.005	0.049	0.035	0.012	0.041	0.005	0.031	0.024
MS-2								
pH								
Alkalinity (mg/l as $CaCO_3$)								
Acidity (mg/l as $CaCO_3$)								
Sulfate (mg/l)	dry	dry	dry	dry	dry	dry	dry	dry
Total Iron (mg/l)								
Aluminum (mg/l)								
Manganese (mg/l)								
Zinc (mg/l)								
Total Solids (mg/l)								
Flow (m^3/s)								
MS-3								
pH	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	840.	870.	850.	820.	860.	870.	800.	790.
Sulfate (mg/l)	1,240.	1,670.	1,460.	1,310.	1,480.	1,510.	1,520.	1,370.
Total Iron (mg/l)	68.3	71.2	69.8	56.1	52.1	63.0	69.5	75.2
Aluminum (mg/l)	45.2	50.5	52.0	51.5	56.9	54.1	46.8	38.3
Manganese (mg/l)	16.2	17.5	15.8	12.8	14.9	18.3	16.8	17.5
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	1,970.	2,092.	1,803.	1,858.	1,945.	2,041.	1,927.	1,901.
Flow (m^3/s)	0.168	0.243	0.278	0.195	0.163	0.150	0.189	0.223
MS-4								
pH	3.0	3.0	3.1	3.0	3.1	3.1	3.1	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	420.	410.	630.	550.	530.	510.	430.	440.
Sulfate (mg/l)	1,140.	1,300.	1,480.	1,460.	1,510.	1,430.	1,410.	1,420.
Total Iron (mg/l)	14.0	16.8	46.6	21.0	20.9	22.6	23.9	24.4
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	26.1	26.5	55.5	38.9	37.8	32.6	27.3	26.3
Manganese (mg/l)	57.0	57.1	62.5	50.4	48.4	62.7	57.7	69.5
Total Solids (mg/l)	1,720.	1,712.	2,153.	2,081.	1,959.	1,968.	1,921.	2,048.
Flow (m^3/s)	0.084	0.102	0.123	0.085	0.090	0.105	0.072	0.095
MS-5								
pH	2.7	2.8	2.8	2.7	2.8	2.8	2.7	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,730.	1,440.	1,630.	1,425.	1,380.	1,690.	1,220.	1,420.
Sulfate (mg/l)	2,880.	2,830.	2,860.	2,720.	2,720.	3,030.	2,920.	2,750.
Total Iron (mg/l)	50.6	44.6	22.9	43.1	31.5	39.1	54.2	56.9
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	112.5	123.1	131.2	59.8	123.7	135.5	107.1	84.8
Manganese (mg/l)	71.9	62.9	59.7	45.9	42.2	67.2	68.4	74.2
Total Solids (mg/l)	4,137.	3,578.	3,687.	3,565.	3,271.	3,889.	3,628.	3,718.
Flow (m^3/s)	0.050	0.163	0.110	0.058	0.058	0.054	0.063	0.054
MS-6								
pH	2.9	3.0	3.0	2.9	2.9	3.0	2.8	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	930.	800.	730.	760.	840.	880.	640.	770.
Sulfate (mg/l)	2,180.	2,010.	1,730.	1,850.	2,370.	2,190.	2,070.	1,690.
Total Iron (mg/l)	17.8	18.0	11.9	13.7	14.1	14.0	18.4	19.7
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	70.1	68.8	64.0	64.6	77.9	74.9	65.3	48.4
Manganese (mg/l)	64.2	55.3	46.7	40.4	43.9	60.5	59.7	62.2
Total Solids (mg/l)	3,055.	2,697.	2,356.	2,530.	2,779.	2,930.	2,795.	2,718.
Flow (m^3/s)	0.017	0.143	0.057	0.022	0.023	0.024	0.029	0.021

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	10/16/73	11/1/73	11/15/73	11/29/73	12/12/73	12/26/73	1/10/74	1/23/74
MS-1								
pH		5.7	5.8	5.7	6.0	5.7		
Alkalinity (mg/l as $CaCO_3$)	No	0.	0.	0.	0.	0.	No	No
Acidity (mg/l as $CaCO_3$)	Sample	7.	8.	10.	5.	6.	Sample	Sample
Sulfate (mg/l)		12.	11.	13.	12.	10.		
Total Iron (mg/l)		0.2	0.1	0.4	0.2	0.2		
Aluminum (mg/l)		0.24	0.25	0.16	0.15	0.24		
Manganese (mg/l)		0.1	<0.1	0.2	0.1	0.1		
Zinc (mg/l)		--	--	--	--	--		
Total Solids (mg/l)		62.	24.	42.	35.	31.		
Flow (m^3/s)		0.155	0.051	0.181	0.188	0.346		
MS-2								
pH		5.7	5.2	5.6	5.9	5.4		
Alkalinity (mg/l as $CaCO_3$)		0.	0.	0.	0.	0.	No	No
Acidity (mg/l as $CaCO_3$)		7.	9.	10.	5.	5.	Sample	Sample
Sulfate (mg/l)		17.	16.	12.	11.	11.		
Total Iron (mg/l)	dry	0.7	0.2	0.2	0.1	0.1		
Aluminum (mg/l)		1.7	1.4	0.19	0.14	0.37		
Manganese (mg/l)		0.43	0.36	0.2	0.1	0.1		
Zinc (mg/l)		--	--	--	--	--		
Total Solids (mg/l)		78.	27.	47.	37.	29.		
Flow (m^3/s)		0.143	0.018	0.157	0.167	0.276		
MS-3								
pH	2.8	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	860.	830.	830.	700.	680.	564.	660.	670.
Sulfate (mg/l)	1,420.	1,370.	1,350.	1,100.	1,090.	950.	1,150.	1,090.
Total Iron (mg/l)	84.5	78.6	72.8	75.1	66.0	75.2	82.6	64.9
Aluminum (mg/l)	57.5	52.4	48.5	42.6	42.1	41.5	--	--
Manganese (mg/l)	18.7	17.4	16.1	14.9	14.1	13.2	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	1,948.	1,815.	1,774.	1,636.	1,540.	1,406.	--	--
Flow (m^3/s)	0.141	0.283	0.216	0.327	0.461	0.448	0.270	0.270
MS-4								
pH	3.1	3.2	3.2	3.1	3.2	3.2	3.2	3.2
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	480.	450.	450.	390.	480.	500.	500.	420.
Sulfate (mg/l)	1,410.	1,280.	1,160.	1,020.	1,160.	1,540.	1,320.	1,090.
Total Iron (mg/l)	34.8	36.3	28.4	28.9	33.4	45.6	38.4	26.7
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	33.8	30.4	26.8	26.1	34.2	37.9	--	--
Manganese (mg/l)	76.2	66.5	61.2	62.2	67.0	86.8	--	--
Total Solids (mg/l)	1,912.	1,768.	1,667.	1,610.	1,908.	2,115.	--	--
Flow (m^3/s)	0.085	0.075	0.092	0.095	0.159	0.198	0.153	0.157
MS-5								
pH	2.8	2.8	2.9	2.9	2.9	2.9	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,490.	1,380.	1,430.	1,350.	1,335.	1,160.	1,400.	1,210.
Sulfate (mg/l)	2,910.	2,970.	2,820.	2,330.	2,400.	2,210.	2,700.	2,360.
Total Iron (mg/l)	65.2	67.6	53.0	58.4	56.6	67.4	72.6	46.4
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	135.2	132.7	117.9	105.5	104.4	105.2	--	--
Manganese (mg/l)	81.6	78.3	72.7	75.1	73.6	75.1	--	--
Total Solids (mg/l)	3,687.	3,672.	3,468.	3,225.	3,373.	3,157.	--	--
Flow (m^3/s)	0.043	0.106	0.059	0.074	0.141	0.145	0.087	0.127
MS-6								
pH	3.0	3.0	3.0	3.0	3.1	3.1	3.1	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	830.	780.	790.	780.	570.	580.	900.	890.
Sulfate (mg/l)	2,000.	2,170.	1,970.	1,950.	1,420.	1,600.	2,470.	2,270.
Total Iron (mg/l)	22.6	25.4	18.3	26.6	15.8	19.3	29.2	22.6
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	78.9	74.4	66.1	68.9	46.4	53.7	--	--
Manganese (mg/l)	71.8	67.0	61.9	71.6	51.8	59.7	--	--
Total Solids (mg/l)	2,860.	2,777.	2,596.	2,825.	2,093.	2,193.	--	--
Flow (m^3/s)	0.016	0.065	0.019	0.046	0.096	0.070	0.045	0.068

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	2/5/74	2/20/74	3/6/74	3/19/74	4/1/74	4/15/74	4/29/74	5/13/74
MS-1								
pH		6.3				5.5		
Alkalinity (mg/l as $CaCO_3$)		0.				0.		
Acidity (mg/l as $CaCO_3$)	No	6.	No	No	No	5.	No	No
Sulfate (mg/l)	Sample	12.	Sample	Sample	Sample	14.	Sample	Sample
Total Iron (mg/l)		0.1				1.25		
Aluminum (mg/l)		--				--		
Manganese (mg/l)		--				--		
Zinc (mg/l)		--				--		
Total Solids (mg/l)		--				--		
Flow (m^3/s)		0.051				0.153		
MS-2								
pH		6.3				5.6		
Alkalinity (mg/l as $CaCO_3$)		0.				0.		
Acidity (mg/l as $CaCO_3$)	No	6.	No	No	No	11.	No	No
Sulfate (mg/l)	Sample	14.	Sample	Sample	Sample	14.	Sample	Sample
Total Iron (mg/l)		0.1				0.07		
Aluminum (mg/l)		--				--		
Manganese (mg/l)		--				--		
Zinc (mg/l)		--				--		
Total Solids (mg/l)		--				--		
Flow (m^3/s)		0.029				0.153		
MS-3								
pH	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	600.	690.	630.	590.	590.	570.	590.	630.
Sulfate (mg/l)	850.	1,150.	1,060.	920.	850.	820.	1,050.	1,040.
Total Iron (mg/l)	69.7	88.6	50.3	40.1	50.3	47.6	56.2	49.6
Aluminum (mg/l)	--	38.1	--	--	--	--	--	--
Manganese (mg/l)	--	15.0	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	1,562.	--	--	--	--	--	--
Flow (m^3/s)	0.388	0.196	0.204	0.201	0.184	0.311	--	--
MS-4								
pH	3.0	3.2	3.2	3.0	3.0	3.0	3.0	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	470.	400.	460.	410.	330.	540.	350.	340.
Sulfate (mg/l)	1,150.	950.	1,060.	1,000.	920.	1,070.	1,000.	960.
Total Iron (mg/l)	36.4	32.5	22.3	17.1	16.7	25.6	17.8	16.6
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.069	0.034	0.073	0.087	0.075	0.093	0.091	--
MS-5								
pH	2.8	2.9	2.9	2.8	2.8	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	990.	1,180.	1,040.	1,020.	1,050.	1,190.	1,260.	1,170.
Sulfate (mg/l)	1,880.	2,340.	2,000.	1,780.	1,880.	2,120.	2,520.	2,350.
Total Iron (mg/l)	50.0	60.0	31.8	29.7	40.1	38.3	49.4	38.7
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.032	0.012	0.035	0.032	0.028	0.053	0.031	0.031
MS-6								
pH	3.0	3.0	3.0	2.9	3.1	3.1	2.9	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	630.	920.	1,020.	850.	840.	790.	1,110.	900.
Sulfate (mg/l)	1,370.	2,520.	2,130.	2,170.	2,580.	2,050.	2,850.	2,470.
Total Iron (mg/l)	18.7	31.5	19.1	26.8	18.9	19.7	30.9	22.1
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.051	0.024	0.049	0.039	--	--	--	--

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	5/27/74	6/10/74	6/24/74	7/11/74	7/29/74	8/5/74	8/19/74	9/2/74
MS-1								
pH		6.0				4.5		
Alkalinity (mg/l as $CaCO_3$)		3.				0.		
Acidity (mg/l as $CaCO_3$)	No	0.	No	No	No	7.	No	No
Sulfate (mg/l)	Sample	11.	Sample	Sample	Sample	12.	Sample	Sample
Total Iron (mg/l)		<0.05				0.05		
Aluminum (mg/l)						--		
Manganese (mg/l)						--		
Zinc (mg/l)						--		
Total Solids (mg/l)						--		
Flow (m^3/s)		0.023				0.004		
MS-2								
pH		5.8				4.7		
Alkalinity (mg/l as $CaCO_3$)		4.				0.		
Acidity (mg/l as $CaCO_3$)	No	0.	No	No	No	6.	No	No
Sulfate (mg/l)	Sample	15.	Sample	Sample	Sample	24.	Sample	Sample
Total Iron (mg/l)		0.26				0.51		
Aluminum (mg/l)		--				--		
Manganese (mg/l)		--				--		
Zinc (mg/l)		--				--		
Total Solids (mg/l)		--				--		
Flow (m^3/s)		0.				<0.001		
MS-3								
pH	2.8	2.8	2.8	2.8	2.8	2.8	2.9	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	620.	650.	770.	790.	780.	860.	840.	960.
Sulfate (mg/l)	1,050.	1,200.	1,290.	1,260.	1,310.	1,500.	1,350.	1,700.
Total Iron (mg/l)	49.4	60.0	64.4	69.8	73.3	77.2	75.0	100.
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.145	0.101	0.088	0.110	0.074	0.071	0.074	0.053
MS-4								
pH	3.1	3.0	3.0	3.0	3.0	3.0	3.1	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	340.	260.	300.	440.	370.	400.	410.	410.
Sulfate (mg/l)	1,060.	950.	1,090.	1,150.	1,100.	1,170.	1,170.	1,150.
Total Iron (mg/l)	19.3	11.0	13.1	20.6	18.6	17.0	19.4	22.5
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.067	0.055	0.044	0.051	0.041	0.037	0.031	0.026
MS-5								
pH	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,220.	1,060.	1,310.	1,470.	1,380.	1,400.	1,500.	1,420.
Sulfate (mg/l)	2,470.	2,650.	3,070.	2,740.	2,790.	2,870.	2,720.	3,000.
Total Iron (mg/l)	42.4	44.7	33.1	58.9	51.7	41.2	54.4	58.4
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.026	0.015	0.014	0.024	0.014	0.012	0.009	0.009
MS-6								
pH	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	740.	920.	850.	940.	900.	930.	1,010.	950.
Sulfate (mg/l)	1,800.	2,470.	2,670.	2,300.	2,470.	2,720.	2,740.	2,820.
Total Iron (mg/l)	18.5	18.8	17.0	25.5	25.3	27.1	28.2	30.8
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.011	0.007	0.006	0.012	0.006	0.006	0.005	0.005

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	9/16/74	9/30/74	10/13/74	10/27/74	11/10/74	11/23/74	12/9/74	12/21/74
MS-1								
pH	No Sample	5.5	No Sample	No Sample	No Sample	6.0	No Sample	No Sample
Alkalinity (mg/l as $CaCO_3$)		0.				0.		
Acidity (mg/l as $CaCO_3$)		11.				4.		
Sulfate (mg/l)		13.				12.		
Total Iron (mg/l)		0.02				0.16		
Aluminum (mg/l)		--				--		
Manganese (mg/l)		--				--		
Zinc (mg/l)		--				--		
Total Solids (mg/l)		--				--		
Flow (m^3/s)		0.007				0.041		
MS-2								
pH	No Sample	5.3	No Sample	No Sample	No Sample	5.8	No Sample	No Sample
Alkalinity (mg/l as $CaCO_3$)		0.				0.		
Acidity (mg/l as $CaCO_3$)		5.				5.		
Sulfate (mg/l)		60.				15.8		
Total Iron (mg/l)		2.43				0.37		
Aluminum (mg/l)		--				--		
Manganese (mg/l)		--				--		
Zinc (mg/l)		--				--		
Total Solids (mg/l)		--				--		
Flow (m^3/s)		0.				--		
MS-3								
pH	2.8	2.8	2.8	2.8	2.8	2.9	2.8	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	990.	1,020.	1,065.	970.	1,060.	790.	840.	770.
Sulfate (mg/l)	1,700.	1,960.	2,130.	1,650.	1,660.	1,260.	1,240.	1,320.
Total Iron (mg/l)	84.9	81.1	84.3	115.0	99.4	75.6	77.8	87.8
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.053	0.057	0.053	0.053	0.061	0.101	0.145	0.184
MS-4								
pH	3.0	3.0	3.1	3.0	3.1	3.0	3.0	3.1
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	470.	580.	600.	560.	540.	510.	490.	640.
Sulfate (mg/l)	1,350.	1,480.	1,980.	1,570.	1,570.	1,640.	1,460.	1,670.
Total Iron (mg/l)	17.3	22.6	20.0	33.2	36.0	30.3	30.2	46.3
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.028	0.028	0.028	0.026	0.025	--	--	0.061
MS-5								
pH	2.8	2.8	2.8	2.8	2.8	2.9	2.8	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,630.	1,700.	1,565.	1,450.	1,555.	1,470.	1,570.	1,430.
Sulfate (mg/l)	3,140.	2,990.	3,150.	3,200.	3,200.	3,130.	3,050.	2,720.
Total Iron (mg/l)	51.5	42.5	42.4	62.0	57.1	51.0	58.1	74.4
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.014	0.021	0.014	0.010	0.009	0.015	0.037	0.035
MS-6								
pH	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,070.	970.	1,055.	1,060.	1,000.	1,010.	910.	930.
Sulfate (mg/l)	2,750.	2,630.	3,050.	2,830.	2,950.	2,920.	2,400.	2,170.
Total Iron (mg/l)	22.2	21.6	20.4	36.5	35.4	33.5	33.1	38.4
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.007	0.008	0.004	0.003	0.001	0.002	0.027	0.020

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	1/5/75	1/18/75	2/2/75	2/15/75	3/7/75	3/14/75	3/31/75	4/13/75
MS-1								
pH		5.2				5.9		
Alkalinity (mg/l as $CaCO_3$)		0.				0.		
Acidity (mg/l as $CaCO_3$)	No Sample	9.	No Sample	No Sample	No Sample	4.	No Sample	No Sample
Sulfate (mg/l)		11.				11.		
Total Iron (mg/l)		0.37				0.08		
Aluminum (mg/l)		--				--		
Manganese (mg/l)		--				--		
Zinc (mg/l)		--				--		
Total Solids (mg/l)		--				--		
Flow (m^3/s)		0.073				0.024		
MS-2								
pH		5.8				5.9		
Alkalinity (mg/l as $CaCO_3$)		0.				0.		
Acidity (mg/l as $CaCO_3$)	No Sample	6.	No Sample	No Sample	No Sample	4.	No Sample	No Sample
Sulfate (mg/l)		11.				11.		
Total Iron (mg/l)		0.13				0.07		
Aluminum (mg/l)		--				--		
Manganese (mg/l)		--				--		
Zinc (mg/l)		--				--		
Total Solids (mg/l)		--				--		
Flow (m^3/s)		0.040				0.024		
MS-3								
pH	3.0	3.0	2.9	2.9	3.0	3.1	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	760.	710.	690.	810.	810.	700.	600.	680.
Sulfate (mg/l)	1,070.	940.	1,000.	1,040.	1,120.	950.	850.	1,050.
Total Iron (mg/l)	67.6	65.7	61.1	68.0	83.7	62.7	58.1	62.7
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.140	0.228	0.193	0.127	0.193	0.149	0.197	0.149
MS-4								
pH	3.1	3.1	3.1	3.1	3.2	3.2	3.1	3.2
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	570.	690.	630.	500.	770.	430.	380.	380.
Sulfate (mg/l)	1,450.	1,650.	1,570.	1,170.	2,040.	1,080.	1,150.	1,200.
Total Iron (mg/l)	31.2	40.2	34.2	20.3	42.9	23.8	15.8	22.2
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.058	--	0.071	--	0.097	0.084	--	0.075
MS-5								
pH	2.9	2.9	2.9	2.9	2.9	3.1	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,530.	1,410.	1,410.	1,410.	1,350.	1,170.	1,030.	1,180.
Sulfate (mg/l)	2,470.	2,700.	2,750.	2,630.	2,270.	1,880.	2,350.	2,700.
Total Iron (mg/l)	56.1	56.8	58.0	50.1	55.9	36.5	34.0	38.4
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.021	0.041	0.052	0.023	0.056	0.028	0.031	0.024
MS-6								
pH	3.0	3.0	3.1	3.2	3.1		3.0	3.2
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.		0.	0.
Acidity (mg/l as $CaCO_3$)	1,000.	920.	1,000.	1,020.	890.	No Sample	800.	820.
Sulfate (mg/l)	2,380.	2,390.	2,550.	2,580.	2,120.		2,230.	2,270.
Total Iron (mg/l)	30.4	29.4	33.6	28.4	29.7		25.2	27.2
Copper (mg/l)	--	--	--	--	--		--	--
Zinc (mg/l)	--	--	--	--	--		--	--
Lead (mg/l)	--	--	--	--	--		--	--
Aluminum (mg/l)	--	--	--	--	--		--	--
Manganese (mg/l)	--	--	--	--	--		--	--
Total Solids (mg/l)	--	--	--	--	--		--	--
Flow (m^3/s)	0.011	0.027	0.030	0.012	0.060		0.032	0.010

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	4/25/75	5/9/75	6/3/75	6/7/75	6/23/75	7/1/75	7/16/75	8/1/75
MS-1								
pH		4.5				5.0		
Alkalinity (mg/l as $CaCO_3$)		0.				0.		
Acidity (mg/l as $CaCO_3$)	No Sample	9.	No Sample	No Sample	No Sample	4.	No Sample	No Sample
Sulfate (mg/l)		11.8				10.		
Total Iron (mg/l)		0.10				0.10		
Aluminum (mg/l)		--				--		
Manganese (mg/l)		--				--		
Zinc (mg/l)		--				--		
Total Solids (mg/l)		--				--		
Flow (m^3/s)		0.083				0.009		
MS-2								
pH		5.3						
Alkalinity (mg/l as $CaCO_3$)		0.						
Acidity (mg/l as $CaCO_3$)	No Sample	6.	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)		13.3						
Total Iron (mg/l)		0.17						
Aluminum (mg/l)		--						
Manganese (mg/l)		--						
Zinc (mg/l)		--						
Total Solids (mg/l)		--						
Flow (m^3/s)		0.068						
MS-3								
pH	2.7	2.9	2.9	2.9	2.8	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	730.	630.	650.	670.	755.	790.	820.	960.
Sulfate (mg/l)	1,070.	980.	900.	1,180.	1,140.	1,350.	1,350.	1,650.
Total Iron (mg/l)	66.1	60.6	61.5	71.4	71.2	92.8	79.5	80.7
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.114	0.206	0.096	0.136	0.110	0.088	0.079	0.070
MS-4								
pH	2.9	3.1	3.1	3.1	3.1	3.0	3.0	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	590.	360.	340.	385.	440.	440.	370.	410.
Sulfate (mg/l)	1,010.	1,080.	940.	1,170.	1,080.	1,150.	1,100.	1,300.
Total Iron (mg/l)	17.8	16.6	16.1	19.5	12.0	14.9	16.8	15.8
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.064	0.062	0.061	0.060	--	0.057	0.046	0.039
MS-5								
pH	2.7	2.9	2.9	2.9	2.9	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,290.	1,140.	1,280.	1,080.	1,350.	1,510.	1,450.	1,630.
Sulfate (mg/l)	2,470.	2,330.	2,350.	2,430.	2,670.	3,040.	2,870.	2,820.
Total Iron (mg/l)	44.6	47.7	44.4	42.4	50.5	57.1	54.6	55.2
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.018	--	0.018	0.039	0.028	0.020	--	--
MS-6								
pH	2.8	3.0	3.0	3.0	3.0	3.0	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	930.	900.	800.	985.	940.	1,130.	1,060.	1,230.
Sulfate (mg/l)	2,570.	2,130.	2,350.	3,020.	2,620.	2,930.	3,090.	2,700.
Total Iron (mg/l)	31.3	29.4	31.4	41.1	36.5	33.2	37.0	38.0
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.009	0.012	0.007	0.024	0.014	0.010	0.008	0.009

TABLE B-1. (Continued)

	Date Collected							
	8/14/75	8/28/75	9/12/75	9/28/75	10/12/75	10/19/75	10/25/75	11/2/75
MS-1								
pH		5.2				5.4	5.6	5.3
Alkalinity (mg/l as $CaCO_3$)		0.				0.	0.	0.
Acidity (mg/l as $CaCO_3$)	No	5.	No	No	No	4.	4.	5.
Sulfate (mg/l)	Sample	12.	Sample	Sample	Sample	11.	11.	11.
Total Iron (mg/l)		1.26				<0.05	0.06	0.13
Aluminum (mg/l)		--				--	--	
Manganese (mg/l)		--				--	--	
Zinc (mg/l)		--				--	--	
Total Solids (mg/l)		--				--	--	
Flow (m^3/s)		0.005				0.141	0.062	0.028
MS-2								
pH						5.8	5.9	6.2
Alkalinity (mg/l as $CaCO_3$)						0.	0.	0.
Acidity (mg/l as $CaCO_3$)	No	No	No	No	No	9.	4.	5.
Sulfate (mg/l)	Sample	Sample	Sample	Sample	Sample	12.	11.	11.
Total Iron (mg/l)						0.89	<0.05	<0.05
Aluminum (mg/l)						--	--	
Manganese (mg/l)						--	--	
Zinc (mg/l)						--	--	
Total Solids (mg/l)						--	--	
Flow (m^3/s)						0.148	0.069	0.032
MS-3								
pH	2.8	2.8	2.8	2.7	2.8	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,080.	1,130.	1,140.	1,240.	930.	850.	850.	820.
Sulfate (mg/l)	1,690.	2,000.	1,850.	1,820.	1,300.	1,200.	1,320.	1,130.
Total Iron (mg/l)	86.8	124.0	98.4	181.	74.7	92.0	65.6	63.0
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.057	0.052	0.050	0.509	0.136	0.145	0.215	0.153
MS-4								
pH	3.0	3.0	3.0	2.9	3.0	3.0	3.0	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	440.	440.	490.	900.	760.	560.	600.	510.
Sulfate (mg/l)	1,300.	1,120.	1,260.	2,860.	1,920.	1,580.	1,650.	1,420.
Total Iron (mg/l)	13.1	22.7	20.0	72.0	24.3	30.4	24.2	17.1
Copper (mg/l)	--	0.07	--	--	--	--	--	--
Zinc (mg/l)	--	1.56	--	--	--	--	--	--
Lead (mg/l)	--	<0.05	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.035	0.031	0.028	0.075	0.078	--	--	--
MS-5								
pH	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,760.	1,750.	1,700.	1,541.	1,390.	1,270.	1,320.	1,290.
Sulfate (mg/l)	2,900.	3,300.	2,660.	2,580.	2,660.	2,360.	2,650.	2,570.
Total Iron (mg/l)	53.9	62.7	50.4	78.0	36.7	42.0	38.1	35.7
Copper (mg/l)	--	0.90	--	--	--	--	--	--
Zinc (mg/l)	--	11.6	--	--	--	--	--	--
Lead (mg/l)	--	<0.05	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.016	0.013	0.020	0.057	0.034	0.040	0.039	0.028
MS-6								
pH	2.9	2.9	2.9	3.0	3.0	2.9	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,430.	1,340.	1,360.	840.	1,070.	1,000.	870.	940.
Sulfate (mg/l)	3,100.	3,120.	2,760.	2,200.	2,760.	2,820.	2,470.	2,750.
Total Iron (mg/l)	45.1	50.2	56.6	31.3	25.3	37.7	29.4	27.4
Copper (mg/l)	--	0.89	--	--	--	--	--	--
Zinc (mg/l)	--	13.3	--	--	--	--	--	--
Lead (mg/l)	--	0.05	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.007	0.004	0.014	0.076	0.024	0.021	0.026	0.028

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	11/9/75	11/16/75	11/23/75	11/30/75	12/7/75	12/21/75	1/4/76	1/19/76
MS-1								
pH	5.9	5.6	8.8	4.4	6.5			
Alkalinity (mg/l as $CaCO_3$)	0.	0.	17.	0.	0.	No	No	No
Acidity (mg/l as $CaCO_3$)	4.	6.	0.	11.	3.	Sample	Sample	Sample
Sulfate (mg/l)	11.	10.	11.	13.	10.			
Total Iron (mg/l)	0.20	<0.05	<0.05	0.1	0.27			
Aluminum (mg/l)	--			<0.5	--			
Manganese (mg/l)	--			0.06	--			
Zinc (mg/l)	--			0.02	--			
Total Solids (mg/l)	--			51.	--			
Flow (m^3/s)	0.021	0.070	0.037	0.038	0.038			
MS-2								
pH	6.3	5.4	5.9	6.0	6.6			
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	No	No	No
Acidity (mg/l as $CaCO_3$)	4.	7.	7.	7.	2.	Sample	Sample	Sample
Sulfate (mg/l)	11.	14.	11.	14.	11.			
Total Iron (mg/l)	0.07	0.35	<0.05	<0.05	<0.05			
Aluminum (mg/l)	--	--	--	<0.5	--			
Manganese (mg/l)	--	--	--	0.06	--			
Zinc (mg/l)	--	--	--	<0.01	--			
Total Solids (mg/l)	--	--	--	54.	--			
Flow (m^3/s)	0.023	0.070	0.035	0.039	0.039			
MS-3								
pH	2.7	2.8	2.9	2.8		2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	Broken	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	850.	840.	800.	760.	In	750.	720.	640.
Sulfate (mg/l)	1,250.	1,200.	1,340.	1,320.	Transit	980.	1,050.	920.
Total Iron (mg/l)	104.0	92.0	80.7	87.2		75.4	75.4	74.6
Aluminum (mg/l)	--	--	--	46.7		--	--	--
Manganese (mg/l)	--	--	--	14.0		--	--	--
Zinc (mg/l)	--	--	--	1.53		--	--	--
Total Solids (mg/l)	--	--	--	1,814.		--	--	--
Flow (m^3/s)	0.127	0.118	0.118	0.096		0.162	0.136	0.083
MS-4								
pH	3.0	3.0	3.2	3.0	3.1	3.0	3.1	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	500.	470.	410.	430.	310.	450.	450.	360.
Sulfate (mg/l)	1,300.	1,250.	1,350.	1,500.	990.	1,200.	1,070.	1,040.
Total Iron (mg/l)	28.4	29.7	24.0	36.2	19.3	20.1	25.8	20.4
Copper (mg/l)	--	--	--	0.09	--	--	--	--
Zinc (mg/l)	--	--	--	1.75	--	--	--	--
Lead (mg/l)	--	--	--	<0.05	--	--	--	--
Aluminum (mg/l)	--	--	--	27.2	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	1,826.	--	--	--	--
Flow (m^3/s)	--	--	--	--	--	--	--	--
MS-5								
pH	2.9	2.8	2.9	2.9	2.9		2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.		0.	0.
Acidity (mg/l as $CaCO_3$)	1,150.	1,310.	1,240.	1,230.	1,300.	No	1,390.	1,260.
Sulfate (mg/l)	2,750.	2,710.	2,950.	3,050.	2,680.	Sample	2,590.	2,680.
Total Iron (mg/l)	50.8	50.7	44.4	47.2	41.1		45.5	45.4
Copper (mg/l)	--	--	--	0.81	--		--	--
Zinc (mg/l)	--	--	--	9.23	--		--	--
Lead (mg/l)	--	--	--	<0.05	--		--	--
Aluminum (mg/l)	--	--	--	117.	--		--	--
Manganese (mg/l)	--	--	--	--	--		--	--
Total Solids (mg/l)	--	--	--	3,638.	--		--	--
Flow (m^3/s)	0.023	0.025	0.022	0.019	0.019		0.027	--
MS-6								
pH	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	860.	980.	870.	870.	890.	940.	950.	920.
Sulfate (mg/l)	2,710.	2,710.	2,800.	2,720.	2,670.	2,320.	2,740.	2,620.
Total Iron (mg/l)	45.5	46.7	38.7	40.5	34.7	36.2	36.9	39.1
Copper (mg/l)	--	--	--	0.69	--	--	--	--
Zinc (mg/l)	--	--	--	10.9	--	--	--	--
Lead (mg/l)	--	--	--	<0.05	--	--	--	--
Aluminum (mg/l)	--	--	--	75.8	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	4,705.	--	--	--	--
Flow (m^3/s)	0.027	0.026	0.020	0.017	--	0.028	0.027	--

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	2/1/76	2/13/76	2/27/76	3/11/76	3/23/76	4/8/76	4/23/76	5/7/76
MS-1								
pH	5.0				5.5			
Alkalinity (mg/l as $CaCO_3$)	0.				0.			
Acidity (mg/l as $CaCO_3$)	10.	No Sample	No Sample	No Sample	12.	No Sample	No Sample	No Sample
Sulfate (mg/l)	11.				10.			
Total Iron (mg/l)	0.09				0.13			
Aluminum (mg/l)	--				--			
Manganese (mg/l)	--				--			
Zinc (mg/l)	--				--			
Total Solids (mg/l)	--				--			
Flow (m^3/s)	--				0.066			
MS-2								
pH	5.3				4.6			
Alkalinity (mg/l as $CaCO_3$)	0.				0.	No Sample	No Sample	No Sample
Acidity (mg/l as $CaCO_3$)	6.	No Sample	No Sample	No Sample	13.			
Sulfate (mg/l)	10.				12.			
Total Iron (mg/l)	0.06				0.09			
Aluminum (mg/l)	--				--			
Manganese (mg/l)	--				--			
Zinc (mg/l)	--				--			
Total Solids (mg/l)	--				--			
Flow (m^3/s)	--				0.060			
MS-3								
pH	2.8	3.0	2.9	2.9	2.9	2.8	2.8	2.7
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	700.	650.	560.	590.	620.	690.	770.	720.
Sulfate (mg/l)	1,090.	990.	870.	870.	940.	950.	1,170.	1,310.
Total Iron (mg/l)	79.3	74.7	61.6	69.7	68.3	66.4	77.8	70.7
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.192	0.105	0.263	0.228	0.149	0.175	0.101	0.101
MS-4								
pH	3.0	3.2	3.1	3.1	3.1	3.1	3.1	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	450.	410.	450.	390.	340.	420.	320.	290.
Sulfate (mg/l)	1,310.	1,080.	1,290.	1,100.	900.	950.	1,020.	930.
Total Iron (mg/l)	22.4	26.4	21.5	19.5	12.4	14.5	12.8	11.2
Copper (mg/l)	--	--	0.14	--	--	--	--	--
Zinc (mg/l)	--	--	2.03	--	--	--	--	--
Lead (mg/l)	--	--	<0.05	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	--	0.064	0.092	0.100	0.081	0.064	0.064	0.058
MS-5								
pH	2.8	2.9	2.9	2.9	2.9	2.8	2.8	2.8
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,150.	1,020.	780.	850.	860.	1,070.	1,110.	1,100.
Sulfate (mg/l)	2,320.	2,320.	1,540.	1,800.	1,820.	2,080.	2,440.	2,600.
Total Iron (mg/l)	42.6	41.7	29.7	32.7	29.8	30.9	28.9	31.4
Copper (mg/l)	--	--	0.63	--	--	--	--	--
Zinc (mg/l)	--	--	6.24	--	--	--	--	--
Lead (mg/l)	--	--	<0.05	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	--	0.041	0.049	0.050	0.028	0.032	0.021	0.019
MS-6								
pH	2.9	3.0	3.0	3.0	3.0	3.0	3.0	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	780.	760.	640.	680.	790.	820.	850.	940.
Sulfate (mg/l)	2,130.	2,470.	1,780.	2,020.	2,510.	2,130.	2,750.	2,970.
Total Iron (mg/l)	25.3	34.3	22.4	25.7	25.5	28.8	30.1	35.7
Copper (mg/l)	--	--	0.63	--	--	--	--	--
Zinc (mg/l)	--	--	7.33	--	--	--	--	--
Lead (mg/l)	--	--	<0.05	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.023	0.019	0.032	0.031	0.014	0.018	0.011	--

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	5/24/76	6/3/76	6/18/76	7/4/76	7/19/76	7/29/76	8/11/76	8/25/76
MS-1								
pH	5.6				6.3			
Alkalinity (mg/l as $CaCO_3$)	0.				0.			
Acidity (mg/l as $CaCO_3$)	8.	No Sample	No Sample	No Sample	7.	No Sample	No Sample	No Sample
Sulfate (mg/l)	9.6				10.			
Total Iron (mg/l)	<0.05				0.06			
Aluminum (mg/l)	<0.5				--			
Manganese (mg/l)	0.05				--			
Zinc (mg/l)	0.03				--			
Total Solids (mg/l)	52.				--			
Flow (m^3/s)	0.053				0.014			
MS-2								
pH	5.3				6.4			
Alkalinity (mg/l as $CaCO_3$)	0.				0.			
Acidity (mg/l as $CaCO_3$)	6.	No Sample	No Sample	No Sample	7.	No Sample	No Sample	No Sample
Sulfate (mg/l)	10.				10.			
Total Iron (mg/l)	<0.05				0.09			
Aluminum (mg/l)	<0.5				--			
Manganese (mg/l)	0.04				--			
Zinc (mg/l)	<0.01				--			
Total Solids (mg/l)	56.				--			
Flow (m^3/s)	0.054				0.013			
MS-3								
pH	2.9	2.8	2.8	2.8	2.9	2.9	2.7	2.9
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	680.	690.	740.	645.	750.	870.	820.	790.
Sulfate (mg/l)	950.	1,120.	1,090.	1,090.	1,220.	1,130.	1,170.	1,140.
Total Iron (mg/l)	67.5	58.5	76.0	65.4	70.4	82.2	77.7	79.1
Aluminum (mg/l)	38.5	--	--		--	--	--	--
Manganese (mg/l)	9.8	--	--		--	--	--	--
Zinc (mg/l)	1.29	--	--		--	--	--	--
Total Solids (mg/l)	1,652.				--	--	--	--
Flow (m^3/s)	0.201	0.118	0.118	0.105	0.096	0.079	0.153	0.114
MS-4								
pH	3.2	3.0	3.1	3.1	3.1	3.2	3.0	3.2
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	400.	330.	320.	415.	370.	380.	480.	470.
Sulfate (mg/l)	950.	880.	860.	1,270.	1,110.	1,120.	1,400.	1,310.
Total Iron (mg/l)	17.9	9.4	15.0	17.3	15.6	14.2	18.6	18.6
Copper (mg/l)	0.08	--	--	--	--	--	--	0.10
Zinc (mg/l)	1.34	--	--	--	--	--	--	2.07
Lead (mg/l)	<0.05	--	--	--	--	--	--	0.06
Aluminum (mg/l)	21.5	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	1,564.	--	--	--	--	--	--	--
Flow (m^3/s)	0.067	0.067	0.059	0.078	0.071	0.061	0.060	0.065
MS-5								
pH	2.9	2.8	2.8	2.8	2.9	3.0	3.1	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	1,120.	1,180.	1,220.	1,160.	1,170.	880.	1,170.	1,190.
Sulfate (mg/l)	2,320.	2,230.	2,380.	2,380.	2,600.	1,710.	2,370.	2,060.
Total Iron (mg/l)	37.1	36.6	37.6	38.8	34.7	25.7	43.3	42.7
Copper (mg/l)	0.70	--	--	--	--	--	--	0.75
Zinc (mg/l)	7.89	--	--	--	--	--	--	8.27
Lead (mg/l)	<0.05	--	--	--	--	--	--	0.08
Aluminum (mg/l)	94.9	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	3,326.	--	--	--	--	--	--	--
Flow (m^3/s)	0.043	0.023	0.017	0.035	0.023	0.024	0.050	0.031
MS-6								
pH	3.0	2.9	2.9	3.0	3.0	3.3	2.9	3.1
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	760.	1,010.	940.	920.	920.	480.	870.	930.
Sulfate (mg/l)	2,260.	2,600.	2,550.	2,530.	2,940.	1,300.	2,430.	2,560.
Total Iron (mg/l)	28.5	32.5	40.2	32.2	34.0	7.09	35.8	33.9
Copper (mg/l)	0.64	--	--	--	--	--	--	0.68
Zinc (mg/l)	8.99	--	--	--	--	--	--	10.2
Lead (mg/l)	<0.05	--	--	--	--	--	--	0.10
Aluminum (mg/l)	59.9	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	3,232.	--	--	--	--	--	--	--
Flow (m^3/s)	0.023	--	--	--	--	--	0.027	0.018

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	9/8/76	9/22/76	10/6/76	10/21/76	11/9/76	11/21/76	12/5/76	12/19/76
MS-1								
pH	5.8			5.4				
Alkalinity (mg/l as $CaCO_3$)	0.			0.				
Acidity (mg/l as $CaCO_3$)	4.	No Sample	No Sample	7.	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)	9.			10.				
Total Iron (mg/l)	<0.05			0.12				
Aluminum (mg/l)	--			--				
Manganese (mg/l)	--			--				
Zinc (mg/l)	--			--				
Total Solids (mg/l)	--			--				
Flow (m^3/s)	0.005			0.153				
MS-2								
pH	5.4			5.1				
Alkalinity (mg/l as $CaCO_3$)	0.	No Sample	No Sample	0.				
Acidity (mg/l as $CaCO_3$)	5.			8.	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)	13.			11.				
Total Iron (mg/l)	0.07			0.33				
Aluminum (mg/l)	--			--				
Manganese (mg/l)	--			--				
Zinc (mg/l)	--			--				
Total Solids (mg/l)	--			--				
Flow (m^3/s)	0.005			0.153				
MS-3								
pH	2.8	2.9	2.9	2.8	2.5	2.5	2.5	2.7
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	--	--	--	--
Acidity (mg/l as $CaCO_3$)	810.	940.	970.	790.	--	820.	--	710.
Sulfate (mg/l)	1,420.	1,480.	1,550.	1,300.	1,000.	950.	1,320.	900.
Total Iron (mg/l)	93.4	95.7	103.0	97.3	70.5	80.0	86.0	74.75
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.083	0.066	0.066	0.104	--	0.094	--	0.350
MS-4								
pH	3.1	3.1	3.2	3.1	2.8	2.8	2.8	3.0
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	0.	0.	0.	0.
Acidity (mg/l as $CaCO_3$)	410.	400.	380.	400.	202.	406.	340.	314.
Sulfate (mg/l)	1,110.	1,160.	1,120.	1,100.	1,400.	1,050.	1,220.	1,150.
Total Iron (mg/l)	20.3	15.2	17.3	17.6	27.75	22.5	21.2	23.25
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.056	0.044	0.035	--	--	0.052	--	--
MS-5								
pH	2.9	2.9	2.9	2.9	2.6	2.6		2.7
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.	--	--		--
Acidity (mg/l as $CaCO_3$)	1,260.	1,340.	1,340.	1,300.	--	964.	No Sample	--
Sulfate (mg/l)	2,550.	2,900.	2,800.	2,720.	1,800.	1,780.		1,900.
Total Iron (mg/l)	45.7	45.3	50.1	49.0	43.0	40.0		--
Copper (mg/l)	--	--	--	--	--	--		--
Zinc (mg/l)	--	--	--	--	--	--		--
Lead (mg/l)	--	--	--	--	--	--		--
Aluminum (mg/l)	--	--	--	--	--	--		--
Manganese (mg/l)	--	--	--	--	--	--		--
Total Solids (mg/l)	--	--	--	--	--	--		--
Flow (m^3/s)	0.022	0.018	0.018	0.024	0.032	0.027		0.022
MS-6								
pH	3.0	3.1	3.0	3.0				
Alkalinity (mg/l as $CaCO_3$)	0.	0.	0.	0.				
Acidity (mg/l as $CaCO_3$)	1,030.	1,090.	1,130.	920.	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)	2,870.	3,170.	3,350.	2,930.				
Total Iron (mg/l)	38.4	39.2	46.4	44.4				
Copper (mg/l)	--	--	--	--				
Zinc (mg/l)	--	--	--	--				
Lead (mg/l)	--	--	--	--				
Aluminum (mg/l)	--	--	--	--				
Manganese (mg/l)	--	--	--	--				
Total Solids (mg/l)	--	--	--	--				
Flow (m^3/s)	0.011	0.007	--	--				

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	12/29/76	1/9/77	1/23/77	2/6/77	2/20/77	3/6/77	3/17/77	3/30/77
MS-1								
pH								
Alkalinity (mg/l as $CaCO_3$)								
Acidity (mg/l as $CaCO_3$)	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)								
Total Iron (mg/l)								
Aluminum (mg/l)								
Manganese (mg/l)								
Zinc (mg/l)								
Total Solids (mg/l)								
Flow (m^3/s)								
MS-2								
pH								
Alkalinity (mg/l as $CaCO_3$)								
Acidity (mg/l as $CaCO_3$)	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)								
Total Iron (mg/l)								
Aluminum (mg/l)								
Manganese (mg/l)								
Zinc (mg/l)								
Total Solids (mg/l)								
Flow (m^3/s)								
MS-3								
pH	2.8	2.7	2.7	2.6	2.8	2.8	2.8	2.9
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	--	880.	780.	--	850.	760.	--	400.
Sulfate (mg/l)	900.	1,090.	1,280.	1,480.	1,350.	1,220.	1,360.	460.
Total Iron (mg/l)	89.0	81.0	88.0	99.0	--	82.0	--	57.0
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	--	0.090	0.077	0.070	--	0.233	0.294	0.270
MS-4								
pH	3.0	3.0	3.1	2.9	3.0	3.2	3.1	3.1
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	350.	400.	260.	358.	340.	304.	206.	310.
Sulfate (mg/l)	1,020.	880.	1,020.	1,200.	860.	1,300.	980.	780.
Total Iron (mg/l)	18.20	20.40	20.75	19.75	21.50	22.50	16.65	21.00
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	--	0.045	--	0.036	--	0.047	0.066	0.075
MS-5								
pH	2.8	2.7	2.7	2.6	2.8	2.9	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	--	1,500.	1,030.	1,856.	1,300.	880.	--	510.
Sulfate (mg/l)	2,205.	2,688.	2,604.	2,940.	2,562.	1,740.	1,300.	1,050.
Total Iron (mg/l)	53.0	44.5	45.75	48.0	54.00	32.00	26.25	27.25
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.021	--	0.010	0.008	--	0.057	0.037	0.058
MS-6								
pH								
Alkalinity (mg/l as $CaCO_3$)								
Acidity (mg/l as $CaCO_3$)	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)								
Total Iron (mg/l)								
Copper (mg/l)								
Zinc (mg/l)								
Lead (mg/l)								
Aluminum (mg/l)								
Manganese (mg/l)								
Total Solids (mg/l)								
Flow (m^3/s)								

TABLE B-1. (Continued)

	Date Collected				Date Collected			
	4/12/77	4/26/77	5/10/77	5/24/77	6/7/77	6/21/77	7/5/77	7/19/77
MS-1								
pH								
Alkalinity (mg/l as $CaCO_3$)								
Acidity (mg/l as $CaCO_3$)	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)								
Total Iron (mg/l)								
Aluminum (mg/l)								
Manganese (mg/l)								
Zinc (mg/l)								
Total Solids (mg/l)								
Flow (m^3/s)								
MS-2								
pH								
Alkalinity (mg/l as $CaCO_3$)								
Acidity (mg/l as $CaCO_3$)	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)								
Total Iron (mg/l)								
Aluminum (mg/l)								
Manganese (mg/l)								
Zinc (mg/l)								
Total Solids (mg/l)								
Flow (m^3/s)								
MS-3								
pH	2.9	2.9	2.9	2.6	2.8	2.5	2.9	2.7
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	--	--	--	610.	750.	850.	--	870.
Sulfate (mg/l)	520.	640.	720.	840.	800.	920.	1,020.	1,000.
Total Iron (mg/l)	55.5	54.0	56.0	65.5	76.50	83.12	83.1	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.271	0.138	0.158	0.137	0.099	0.089	0.105	0.103
MS-4								
pH	3.1	3.2	3.2	2.8	3.1	2.8	3.1	3.0
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	460.	--	322.	340.	400.	330.	--	456.
Sulfate (mg/l)	860.	840.	980.	820.	800.	850.	900.	1,020.
Total Iron (mg/l)	15.40	18.50	16.60	17.50	18.50	18.25	15.15	19.90
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.135	0.088	0/073	0.071	--	--	--	--
MS-5								
pH	2.9	2.9	3.0	2.6	2.8	2.5	2.9	2.8
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	800.	--	880.	650.	590.	1,050.	1,260.	--
Sulfate (mg/l)	1,380.	1,400.	1,480.	1,420.	1,700.	1,800.	2,310.	2,000.
Total Iron (mg/l)	40.50	29.75	29.75	35.00	42.0	42.0	37.5	46.5
Copper (mg/l)	--	--	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--	--	--
Flow (m^3/s)	0.049	0.040	0.035	0.029	0.021	0.014	0.048	0.021
MS-6								
pH								
Alkalinity (mg/l as $CaCO_3$)								
Acidity (mg/l as $CaCO_3$)	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample	No Sample
Sulfate (mg/l)								
Total Iron (mg/l)								
Copper (mg/l)								
Zinc (mg/l)								
Lead (mg/l)								
Aluminum (mg/l)								
Manganese (mg/l)								
Total Solids (mg/l)								
Flow (m^3/s)								

TABLE B-1. (Continued)

	Date Collected				Date Collected	
	8/3/77	8/14/77	8/28/77	9/8/77	9/22/77	10/6/77
MS-1						
pH						
Alkalinity (mg/l as $CaCO_3$)						
Acidity (mg/l as $CaCO_3$)	No	No	No	No	No	No
Sulfate (mg/l)	Sample	Sample	Sample	Sample	Sample	Sample
Total Iron (mg/l)						
Aluminum (mg/l)						
Manganese (mg/l)						
Zinc (mg/l)						
Total Solids (mg/l)						
Flow (m^3/s)						
MS-2						
pH						
Alkalinity (mg/l as $CaCO_3$)						
Acidity (mg/l as $CaCO_3$)	No	No	No	No	No	No
Sulfate (mg/l)	Sample	Sample	Sample	Sample	Sample	Sample
Total Iron (mg/l)						
Aluminum (mg/l)						
Manganese (mg/l)						
Zinc (mg/l)						
Total Solids (mg/l)						
Flow (m^3/s)						
MS-3						
pH	2.8	2.8	2.8	2.6	2.7	2.7
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	870.	1,360.	--	920.	--	736.
Sulfate (mg/l)	1,100.	1,920.	870.	940.	800.	--
Total Iron (mg/l)	100.0	42.0	49.5	103.0	97.0	82.5
Aluminum (mg/l)	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--
Flow (m^3/s)	0.086	0.074	--	--	0.128	--
MS-4						
pH	3.0	3.0	3.0	2.9	2.9	2.9
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	408.	460.	256.	--	426.	528.
Sulfate (mg/l)	850.	1,090.	840.	780.	1,040.	1,140.
Total Iron (mg/l)	19.5	19.0	19.4	17.9	23.9	26.5
Copper (mg/l)	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--
Flow (m^3/s)	--	0.034	0.031	0.028	0.026	0.044
MS-5						
pH	2.8	2.7	2.8	2.6	2.7	2.7
Alkalinity (mg/l as $CaCO_3$)	--	--	--	--	--	--
Acidity (mg/l as $CaCO_3$)	1,180.	930.	1,450.	1,030.	1,100.	984.
Sulfate (mg/l)	1,900.	--	1,740.	1,840.	1,740.	1,500.
Total Iron (mg/l)	46.0	44.8	44.0	48.0	57.00	42.75
Copper (mg/l)	--	--	--	--	--	--
Zinc (mg/l)	--	--	--	--	--	--
Lead (mg/l)	--	--	--	--	--	--
Aluminum (mg/l)	--	--	--	--	--	--
Manganese (mg/l)	--	--	--	--	--	--
Total Solids (mg/l)	--	--	--	--	--	--
Flow (m^3/s)	0.020	0.018	0.016	0.011	0.071	0.039
MS-6						
pH						
Alkalinity (mg/l as $CaCO_3$)						
Acidity (mg/l as $CaCO_3$)	No	No	No	No	No	No
Sulfate (mg/l)	Sample	Sample	Sample	Sample	Sample	Sample
Total Iron (mg/l)						
Copper (mg/l)						
Zinc (mg/l)						
Lead (mg/l)						
Aluminum (mg/l)						
Manganese (mg/l)						
Total Solids (mg/l)						
Flow (m^3/s)						

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The Tioga River Demonstration Project in southeastern Tioga County, Pennsylvania, is essentially defined by an isolated pocket of coal that has been extensively deep and strip mined within the Pennsylvania Bituminous Coal Field. The Tioga River watershed is subjected to acid mine drainage from abandoned mines in the vicinity of the Borough of Blossburg and the Village of Morris Run.

The project demonstrated effective techniques for mine drainage abatement, reduced a specific mine drainage problem, and restored portions of a strip mined area to their approximate original surface grades. Techniques demonstrated included: restoration of strip pits utilizing agricultural limestone and wastewater sludge as soil conditioners; burial of acid-forming materials within strip mines that were restored; and reconstruction and lining of a stream channel. Effectiveness of these preventive measures and their costs were determined.

17. KEY WORDS AND DOCUMENT ANALYSIS

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