Handbook of

POLLUTION CONTROL COSTS IN MINE DRAINAGE MANAGEMENT

U. S. DEPARTMENT OF THE INTERIOR • FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

DECEMBER 1966

This Handbook was prepared by the Monongahela River Mine Drainage Remedial Project

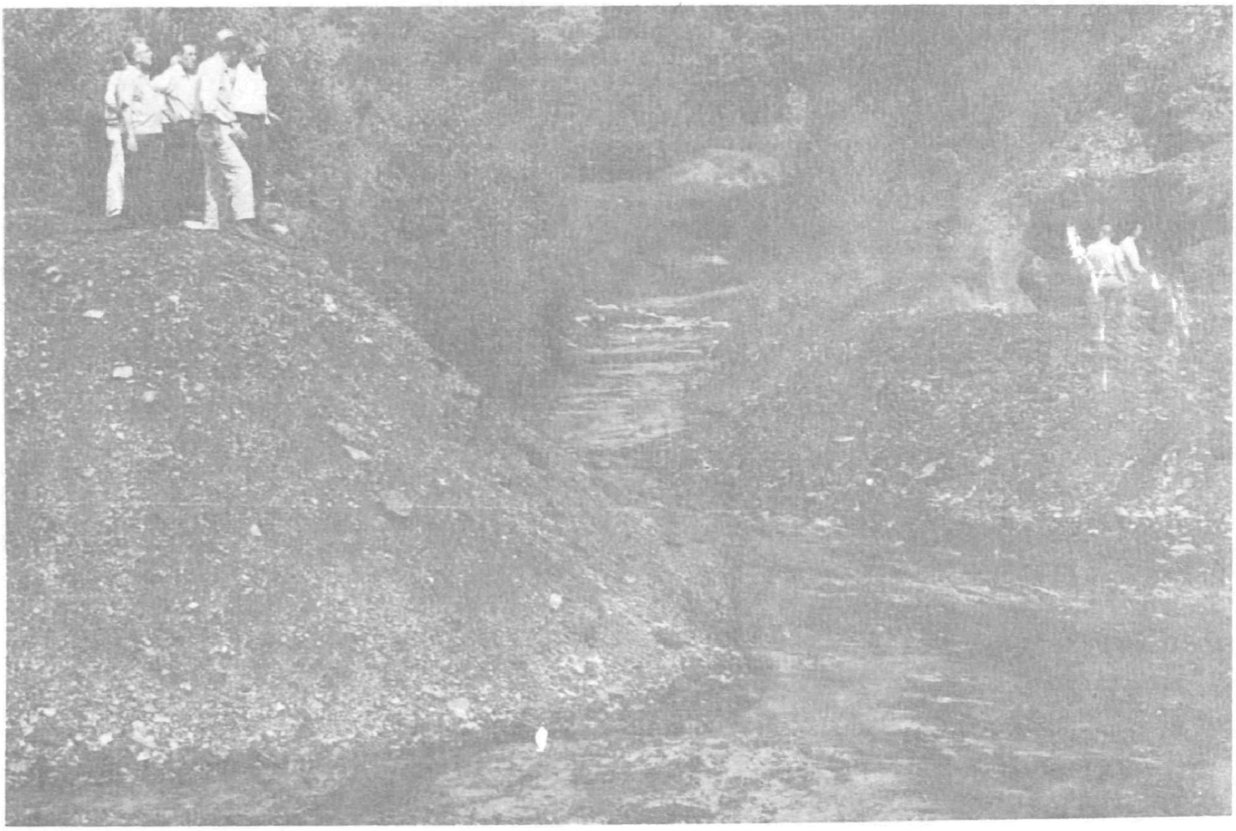
John Hyland, Project Director

and the Advisory Work Group

established by the Federal Enforcement Conference in the Matter of Pollution of the Interstate Waters of the Monongahela River and its Tributaries

Conferees represent the States of Maryland, West Virginia, and Pennsylvania, the Ohio River Valley Water Sanitation Commission, and the U. S. Department of the Interior

Members of Advisory Work Group—field meeting at Elkins, West Virginia, June 1966.



Flow of approximately one cfs coming through abandoned surface mine from worked-out underground mine intercepted by stripping.

Mine drainage from abandoned underground workings near Harding, West Virginia.

PREFACE

The information presented in this publication answers a need of the Monongahela River Mine Drainage Remedial Project for preliminary cost data in determining relative costs of mine drainage abatement. The high degree of interest and numerous requests for this type of information by others concerned with problems of mine drainage made publication of this data necessary for a wider distribution than originally contemplated.

The data presented and evaluated resulted in no small part from the interest, assistance and information provided by the Advisory Work Group composed of, at the time, Mr. Ralph Porges, Chairman, Deputy Chief, Technical Advisory and Investigations Section, Federal Water Pollution Control Administration; Dr. Alvin R. Grove, Associate Dean for Commonwealth Campuses, The Pennsylvania State University, University Park, Pennsylvania; Dr. Edward C. Kinney, U. S. Department of the Interior, Bureau of Sport Fisheries and Wildlife; Mr. Cecil J. Urbaniak, President, District #31, United Mine Workers of America, Fairmont, West Virginia; Dr. Paul H. Price, State Geologist for West Virginia, Morgantown, West Virginia; Mr. Ernst P. Hall, Research Consultant, Consolidation Coal Company, Pittsburgh, Pennsylvania; Dr. D. M. Whitt, Director, Plant Sciences Division, Soil Conservation Service; Mr. O. V. Vande Linde, Jr., Executive Director, West Virginia Surface Mine Association, Charleston, West Virginia; and Mr. John R. Hyland, Secretary, Project Director, Monongahela River Mine Drainage Remedial Project.

Figures 3, 4, 8 and 10 illustrating typical remedial measures were adapted from the "Case Histories in the Control of Acid Mine-Drainage" of the Ohio River Valley Water Sanitation Commission. Typing of the manuscript was done by Miss Joan Hile, Project Secretary.

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SUMMARY

As a result of pollution studies by the Federal Water Pollution Control Administration, a conference to review pollution problems in the Monongahela River Basin and determine necessary action to be taken was called in December 1963 at Pittsburgh, Pennsylvania. One of the recommendations made was for a Technical Committee to explore means of abating pollution caused by coal mine drainage and, among other things, develop a remedial program to include cost estimates. The Advisory Work Group established for the Monongahela River Mine Drainage Remedial Project assisted in collecting and determining useful cost data for application to the remedial measures developed and recommended.

Numerous unpublished data were consulted and used as well as available published literature in the field. Cost data available were evaluated beginning with the joint State-Federal mine sealing program of the thirties.

Methods examined are grouped into those dealing with underground mine drainage, surface mine drainage, drainage from refuse and waste disposal areas, and control and treatment of water in active mining situations.

Costs of remedial measures are listed and evaluated on a unit price basis. They cover a period of 33 years from 1933 to the present time. These include unit costs on such items as mine seals or bulkheads; surface reclamation of strip-mines along with associated planting; reclamation of refuse areas; drainage diversion and impoundment; and treatment of mine drainage.

Included are the tabulated cost data and references.

Introduction

Acid mine drainage has long been associated with the removal of coal from the earth, although there was only scant recognition of the problem. The damages resulting from the acid waters constantly increased until it became virtually a national problem.

Early remedial measures encompassed neutralization and in a few instances, reclamation of by-products. These methods were, and still are, extremely costly. In the early 1920's attention was directed towards sealing abandoned mines, proper mine drainage management, flow regulation, and even the prohibition of mining in some areas.

The first comprehensive approach to acid mine drainage control was initiated in the 1930's by the Federal and State governments through relief administrations such as Works Progress Administration, Federal Emergency Relief Administration, and Civil Works Administration. Some of the mine seals placed during those days are still effective, although only limited recordings of these activities remain. In the succeeding years, the evaluation and control of acid mine drainage continued. The Ohio River pollution study conducted by the Public Health Service evaluated the damages from this source of pollution. The Ohio River Valley Water Sanitation Commission has devoted considerable energy to the development of control practices directed towards acid mine drainage.

In 1962 the Committee on Public Works of the House of Representatives requested the Secretary of the Department of Health, Education, and Welfare to submit a report on acid mine drainage control. This document, House Committee Print No. 18 of the 82nd Congress, 2nd Session, recognized the large problem involved and recommended a three-point program involving (a) mine sealing, (b) stepped-up research, and (c) flow regulation. It recommended that a demonstration project be established to prove that abatement measures can be effective and that firm cost of control measures be developed. Congressional authorization to carry out this recommendation was given in Public Law 87-88, 88th Congress, and the first site for demonstration selected was the watersheds of Roaring Creek and Grassy Run near Elkins, West Virginia. This project is currently underway, but several years will elapse before much useful cost data will be forthcoming.

At about this time the Secretary of the Department of Health, Education, and Welfare, pursuant to his responsibilities under the Federal Water Pollution Control Act, having reason to believe that inadequately treated wastes including mine drainage originating in West Virginia was endangering the health and welfare of persons in Pennsylvania, called an Interstate Water Pollution Control Conference on the Monongahela River for December 1963.[1/] The conferees of this

1/ FWPCA, Summary of Conference, Pollution of Interstate Waters of the Monongahela River and Its Tributaries, December 17-18, 1963.

meeting unanimously agreed that interstate pollution existed on the Monongahela River Basin and that one of the principal pollutants was acid mine drainage. The conferees established a Technical Committee, consisting of representatives from the States of West Virginia, Pennsylvania, and Maryland; The Ohio River Valley Water Sanitation Commission; and the Federal Government, to explore means of abating pollution caused by coal mine drainage. This Committee was charged with determining the amount of pollution from such mines and for developing a remedial program including cost estimates.

The Committee established a project called the Monongahela River Mine Drainage Remedial Project and set up headquarters in Wheeling, West Virginia in 1964. To assist John R. Hyland, Project Director, in the fulfillment of his responsibilities, the Technical Committee, in its third meeting, decided to establish an Advisory Work Group for the purpose of advising and consulting with the Project Director on ways and means of remedial measures, on cost and safety measures, and to facilitate public relations between the Project and other groups. The first meeting of the Advisory Work Group was held October 20, 1965.

The Project Director of the Monongahela River Mine Drainage Remedial Project, during this time, recruited and trained field crews and developed supporting laboratory services, proceeding rapidly to conduct a survey to ascertain the sources of mine drainage and remedial measures to correct the acid pollution.

It was the recommendation of the Advisory Work Group that the Monongahela River Basin under consideration be handled in a sub-basin or drainage area concept and that the sub-basin reports encompassing these areas be complete in themselves. This would permit inventory and development of the reports on remedial measures in discrete units but yet identifiable and related to the basin hydrology. These sub-basin areas would contain identified sources of mine drainage with chemical analyses and flow data on each source. Cost data on remedial measures recommended would be evaluated and applied to these smaller sub-basin areas, thus reflecting physical and regional differences and costs involved without necessitating detailed engineering analyses.

Definitions

Listed in the appendix are those geological, mining and economic terms not found in a standard reference dictionary such as Websters New Collegiate Dictionary or for which the customary use or connotation varies from that used in this report. Additional detailed information on mining, the terms, methods of, and descriptions of equipment used may be found in the August, 1966 issue of Coal Age as a separate section titled, Coal Age Mining Guidebook.

Objectives

It was recognized early that useful cost data were scarce and that one of the prime activities of the Advisory Work Group would be the assembly and evaluation of such information for immediate use by the Project. It is the intent of the Advisory Work Group to develop useful cost data primarily for application to the Monongahela River Mine Drainage Remedial Project. These data were to facilitate completion of the project's reports in its survey encompassing the sources of pollution, and so that remedial measures and estimated costs thereof might be recommended.

It was also recognized however, that these data would have broad application for other activities concerned with acid mine drainage control that had an expressed interest in cost data. While this compilation of data may have useful application elsewhere, it is cautioned that these be applied, with knowledge of the local condition and engineering judgement.

Method of data collection and analysis

Research of existing material on the subject of pollution from coal mine sources indicated little published data from which costs of accomplishing various remedial measures could be determined. This was primarily true in the case of underground mines. State and federal agencies having responsibility in surface reclamation of coal properties however, had available documented material on costs. Some data were also available from industry and from research and pilot plant studies of treatment of mine wastes, such as those of the U. S. Bureau of Mines and Commonwealth of Pennsylvania.

Beginning with the joint State-Federal mine sealing program of the thirties, and utilizing as many of these records as could be located and verified, the project began collecting this cost data along with information on how the sealing or restoration was accomplished. To encompass all resources available, members of the Advisory Work Group were asked to provide additional data to the project from their experience and to refer any other known sources to the project. An outline and table of remedial measures and unit operations considered were submitted to the members.[1/] This resulted in additional data from industry, the states and federal agencies. The additional data also helped verify that already acquired.

Typical remedial measures

Remedial measures considered for the abatement or control of pollution from coal mine drainage include those indicated by the report[2/] of the Coal Industry Advisory Committee of the Ohio River Valley Water Sanitation Commission relating to its Resolution No. 5-60 adopted January 14, 1960. Since these are directed to active mining operations, additional search for useful solutions and practises employed in the control of mine drainage pollution was made. These have included methods tried by both state and federal agencies as well as those reported by industry. Additional solutions to these

1/ Appended. Table I - Work outline

2/ Principles and Guide to Practises in the Control of Acid Mine Drainage, compiled by the Coal Industry Advisory Committee, Ohio River Valley Water Sanitation Commission, March 1964.

are being tried in demonstration projects and feasibility studies.

The methods considered here are those related to the cost data presented and evaluated. Typical examples of remedial measures are shown in Figures 1-13.

Underground mine seals - Procedure is to close the mine by constructing bulkheads or seals at all of the exterior openings. These are placed, with knowledge of the mine workings, to produce a water-tight seal. These have been built or constructed of stone, masonry, block, compacted soil and clay. Design and placement should assure sufficient strength in the bedrock and the bulkhead to withstand the water and ground pressures present. One or more of these closures may have incorporated in it restricted outlets with water traps to permit release of controlled amounts of water. The traps are constructed so as to maintain a water seal. Grouting or rock-bolting of these seals may be involved to assure stability and to prevent leaking. Sealing of mines often involves the identification and location at the surface of associated subsidence areas. Where these are present, compacted clay or earth is most often used to prevent additional surface water from entering the mine.

Surface mine reclamation - Surface mine restoration and backfilling involves remedial measures with both significant experience and back-ground as well as legislative history. Basically involved are reshaping of the spoil banks to some conformable topography, burial of toxic and acid-forming materials, and covering of the portion of the high wall containing acid-forming materials. Following this re-establishment of vegetative growth and cover is accomplished. Dependent on topography and drainage, lined diversion ditches may need to be installed above the disturbed area, to keep additional water from the area, or through the area, to control drainage. These are particularly useful during operation of a mine.

An alternative, for control of pollution from these areas where topographic and drainage features are suitable, is the construction of impoundments to inundate acid-forming materials, as well as provide some degree of control of flow from the area.

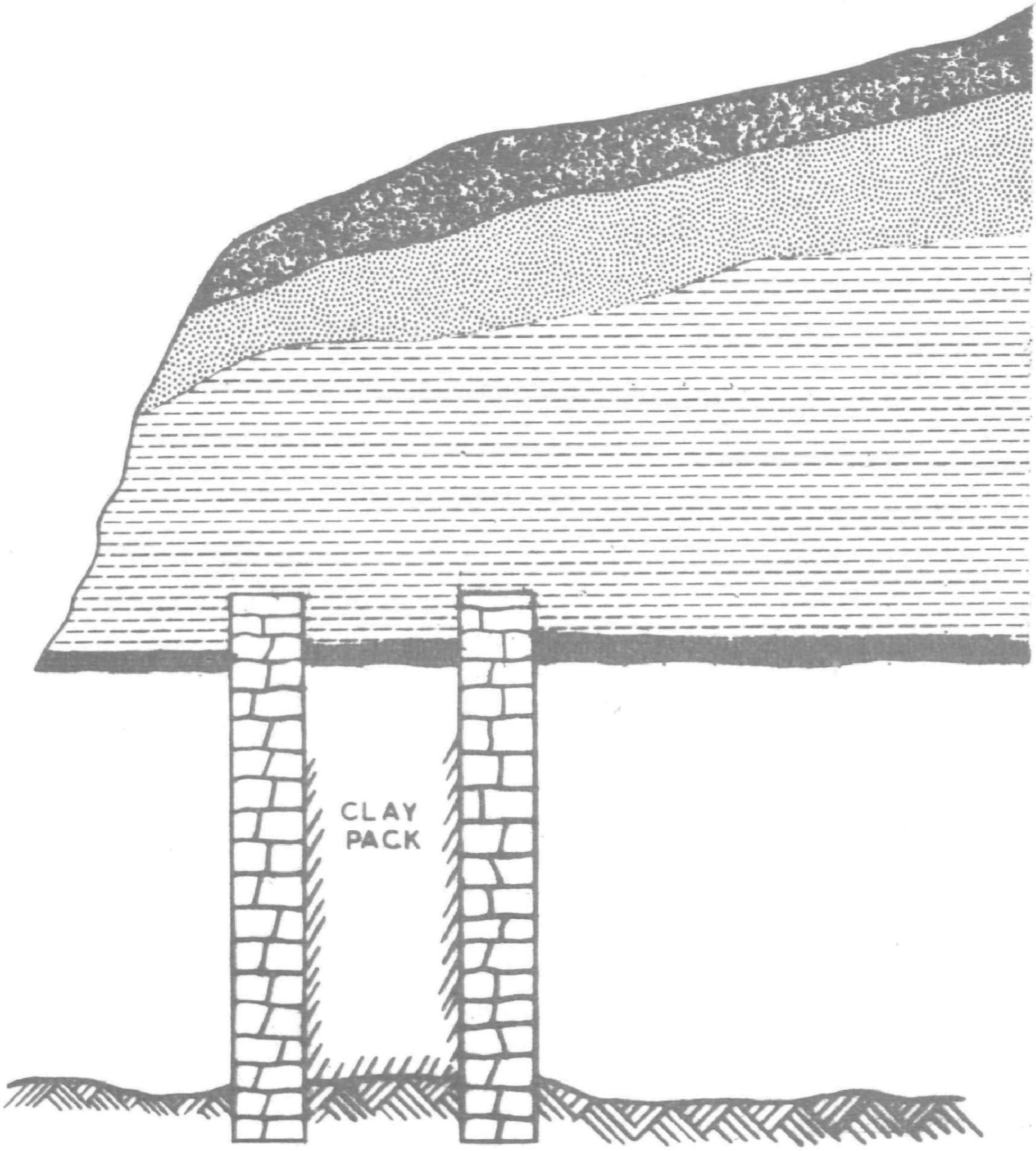
Current surface mining operations are conducted under some form of license or permit and a bond is generally required to assure that specified restoration and reclamation practises are carried out.

Experience of the operations in the West Virginia Surface Mine Association and of the Soil Conservation Service has shown that planned reclamation carried out during and immediately following mining activities is both more effective and less expensive than at some later date.

Refuse and gob disposal - This highly concentrated waste material can be handled by placement in a prepared area. The disposal area can be prepared by diking off suitable topographic depressions or low areas or by utilizing abandoned strip pits. Figures 11-13 show typical situations of this method.

Control and treatment - Although listed as a remedial measure, these methods, regulated pumping, neutralization, treatment and impounding for controlled release are typical of preventative measures available where pollution is a problem at an active mine. Regulated pumping and controlled release from impoundments equalizes the pollution load on the stream where water quality limits are not exceeded and prevents "slugging effects". Some improvement in quality is usually experienced by impounding and by impounding opportunity for minor treatment of the water such as pH adjustment and neutralization is provided. A number of lime neutralization plants were constructed since 1945 in Pennsylvania since their amended Clean Streams Law went into effect.

Research development of plant treatment for mine drainage is a fairly recent development. Two methods that have shown promise of successful treatment of mine waters without prohibitive costs are the neutralization-aeration-flocculation-sedimentation, or more simply "Operation Yellowboy", of the Pennsylvania Department of Mines and Mineral Industries and the reverse-osmosis unit of the Office of Saline Water. Both of these methods have been tried on a pilot plant basis using mine water drainage, but cost data as yet is available only in the "Yellowboy" pilot plant. The process involved in this treatment is to bring the mine water into the plant through a flow meter into a mixer where a regulated amount of hydrated lime is added for neutralization. From here it flows into an aerator and then to a thickener for settling of the mineralized solids. Flocculating agents may be added to increase settlement of the suspended solids. The clarified effluent is released as treated, leaving a sludge for dewatering and disposal.



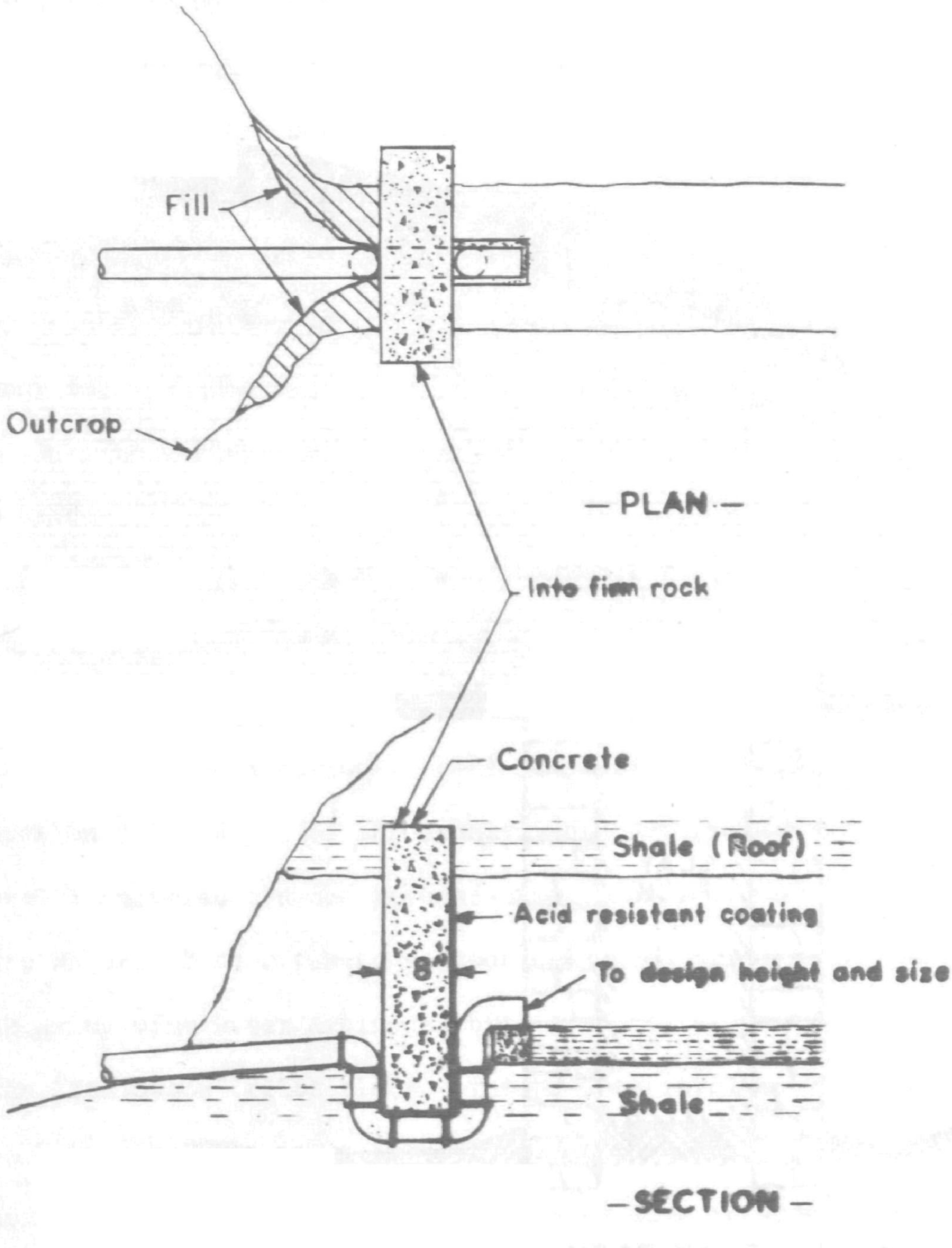
DOUBLE WALL—CLAY PACK—DRY SEAL

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U.S. DEPARTMENT OF HEALTH EDUCATION [illegible]
FEDERAL WATER POLLUTION CONTROL [illegible]
REGION III [illegible]

FIG. 1



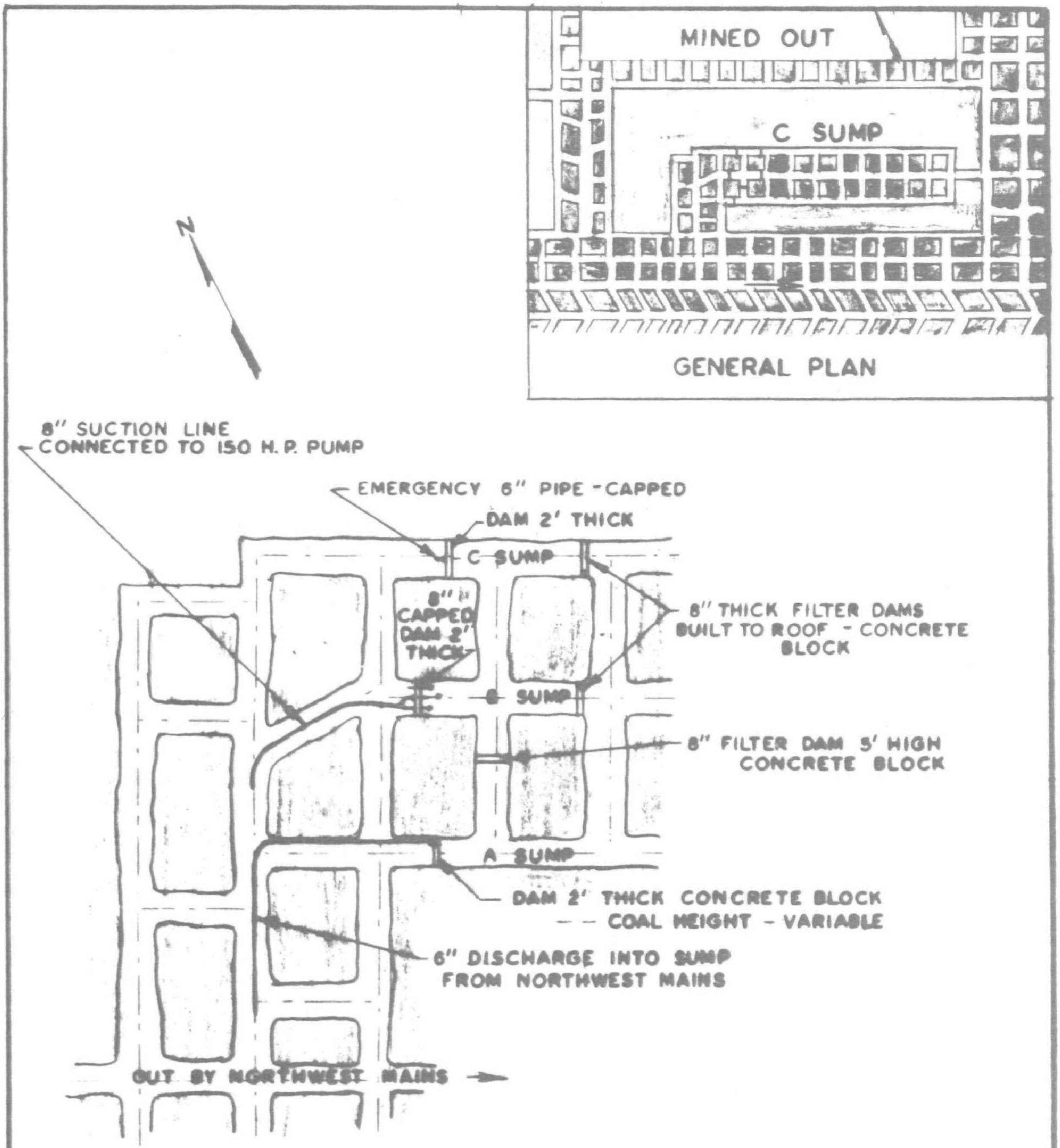
WET MINE SEAL
WITH CONTROLLED FLOW

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

FIG. 2



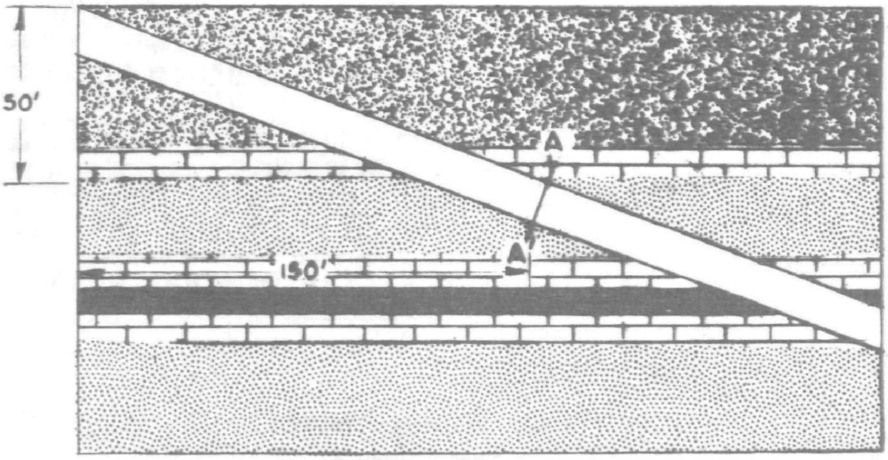
UNDERGROUND WATER DRAINAGE

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

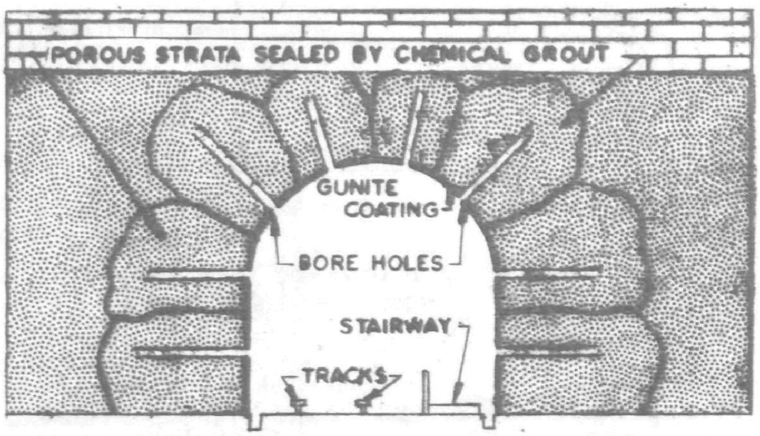
TYPICAL REMEDIAL MEASURES

U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION III CHARLOTTESVILLE, VA.

FIG. 3



SIDE VIEW - ENTRY SLOPE



FRONT VIEW, SECTION A-A', 150 FEET DOWN ENTRY SLOPE

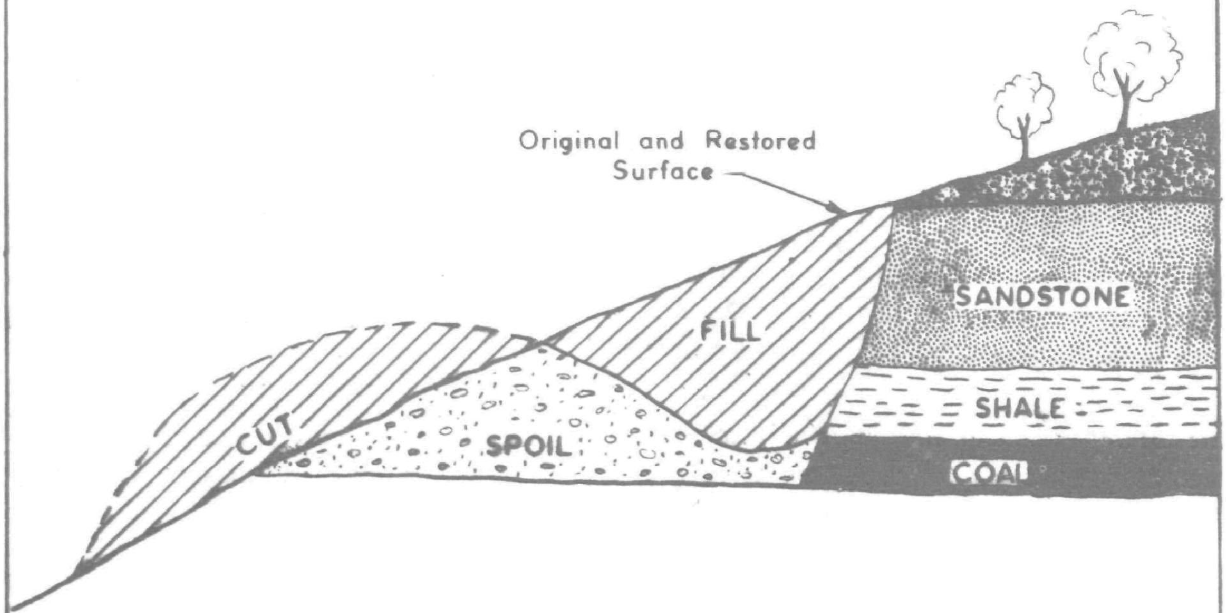
CHEMICAL GROUTING TO PREVENT INFLOW OF WATER

MONONGAHELA RIVER MINE DRAINAGE REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION III CHARLOTTESVILLE VA.

FIG. 4



STRIP MINE REHABILITATION -
COMPLETE RESTORATION

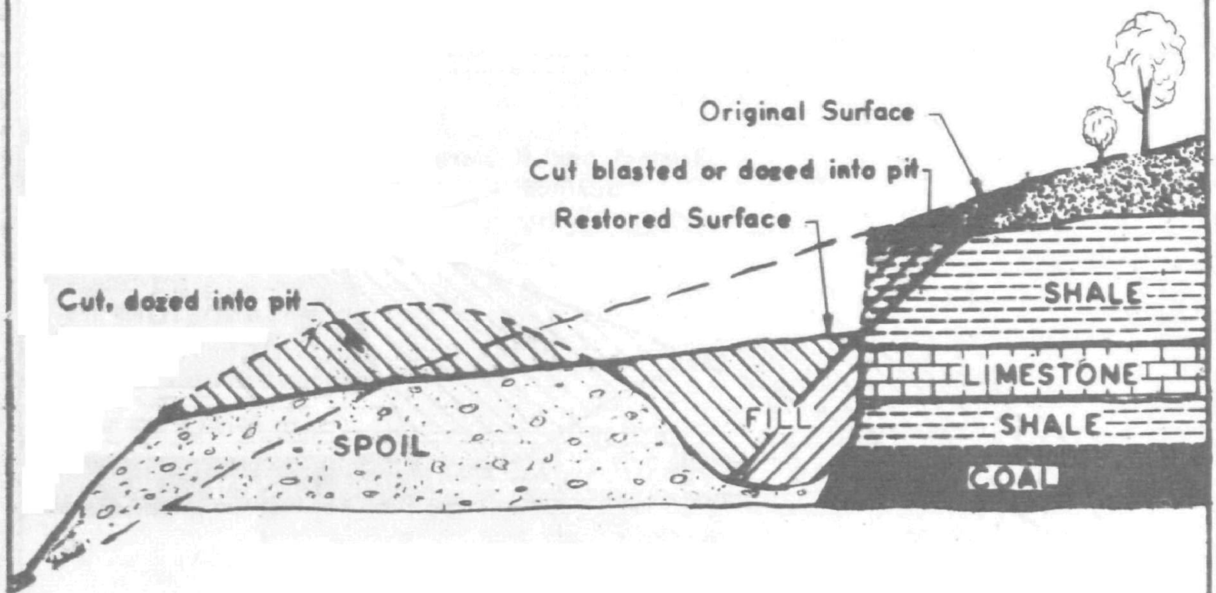
Plan A

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION III CHARLOTTESVILLE, VA.

FIG. 5



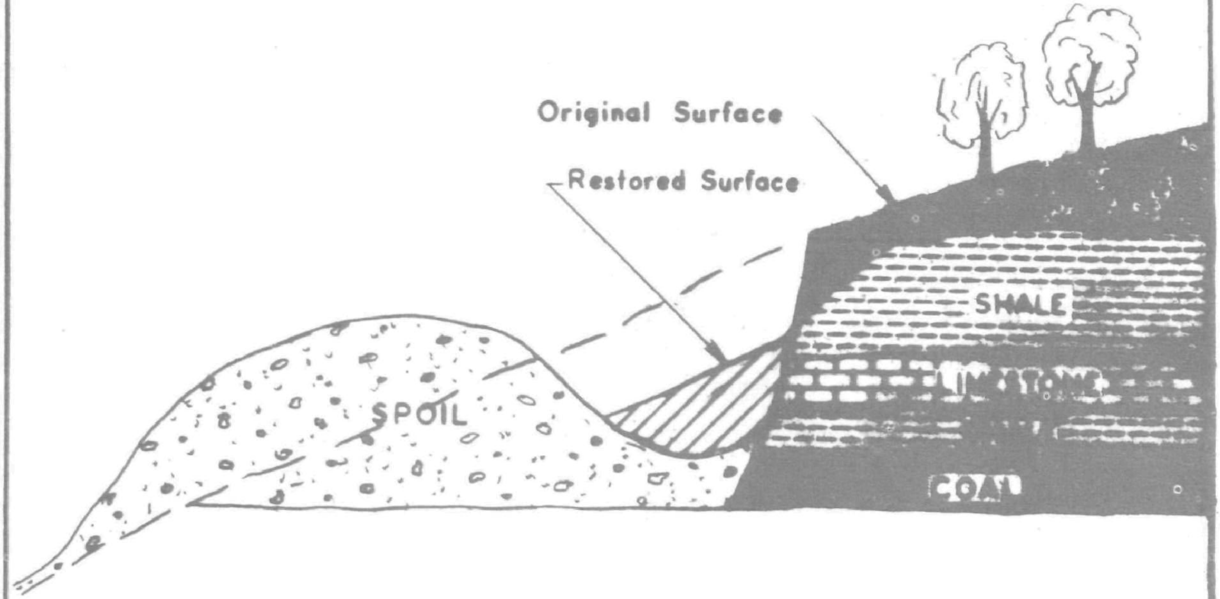
STRIP MINE REHABILITATION -
PARTIAL RESTORATION

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION III CHARLOTTESVILLE, VA.

FIG. 6



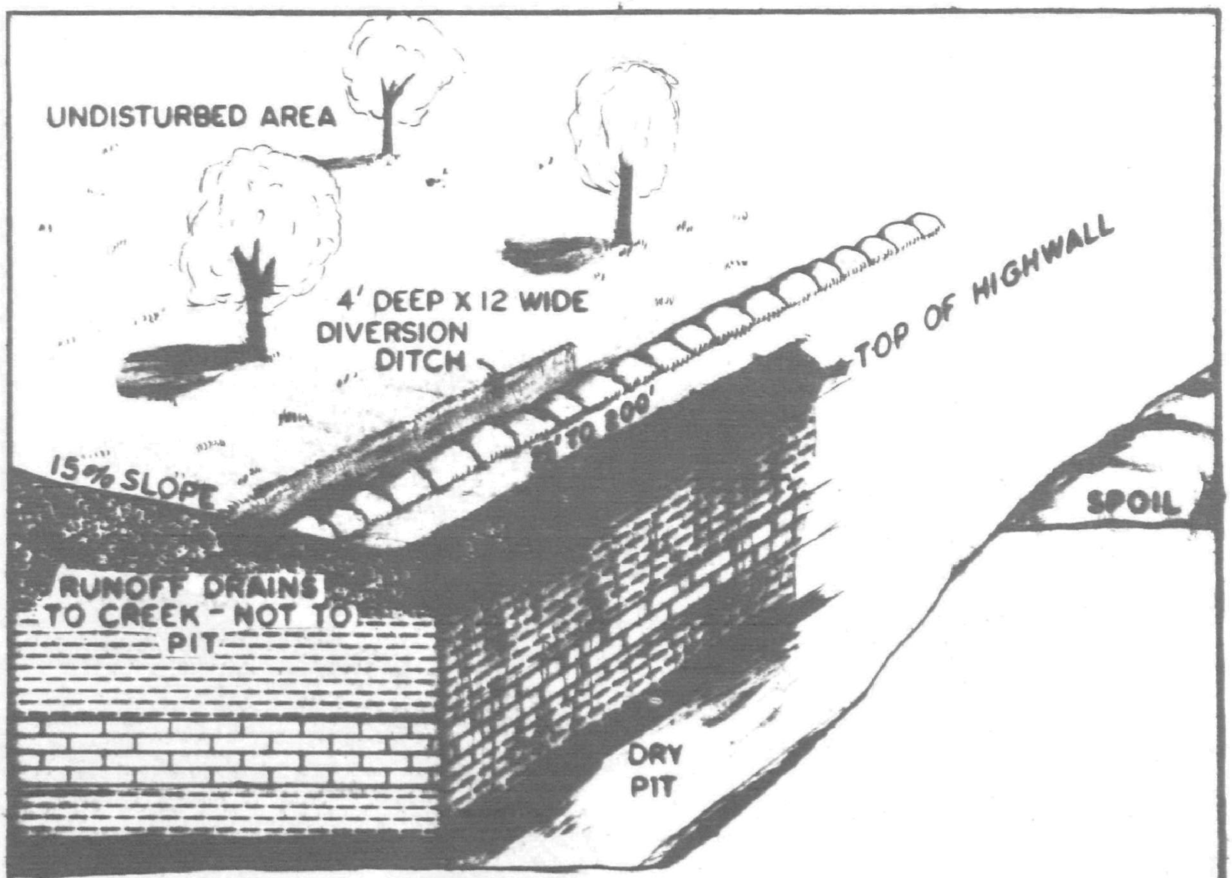
STRIP MINE REHABILITATION —
COVERING OF COAL BED

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION III CHARLOTTESVILLE, VA.

FIG. 7



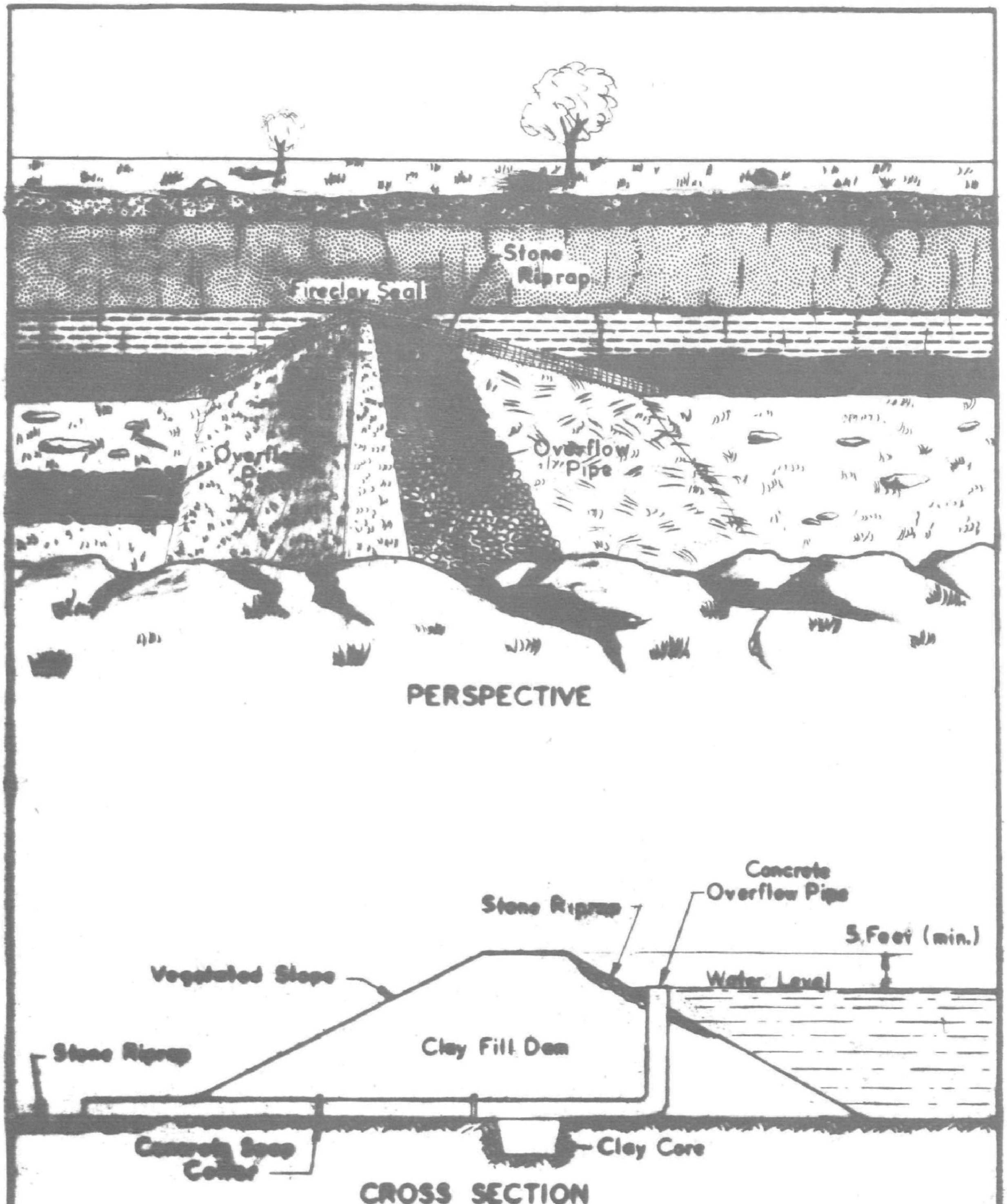
DIVERSION DITCH - SURFACE MINING

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
PUBLIC HEALTH SERVICE
REGION III [illegible]

FIG. 8



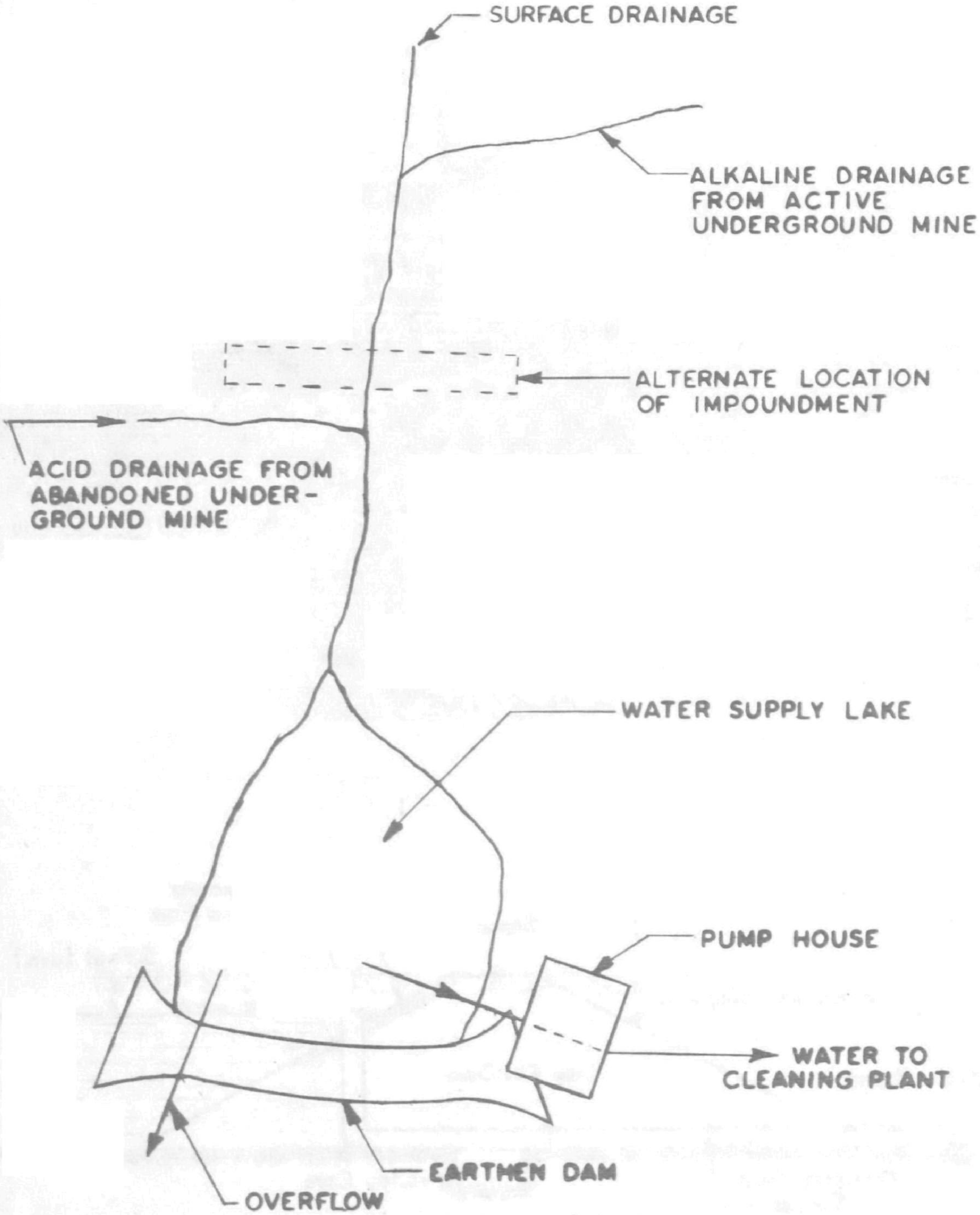
STRIP MINE
HIGH WALL DAM

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
CHARLOTTESVILLE VA.

FIG. 9



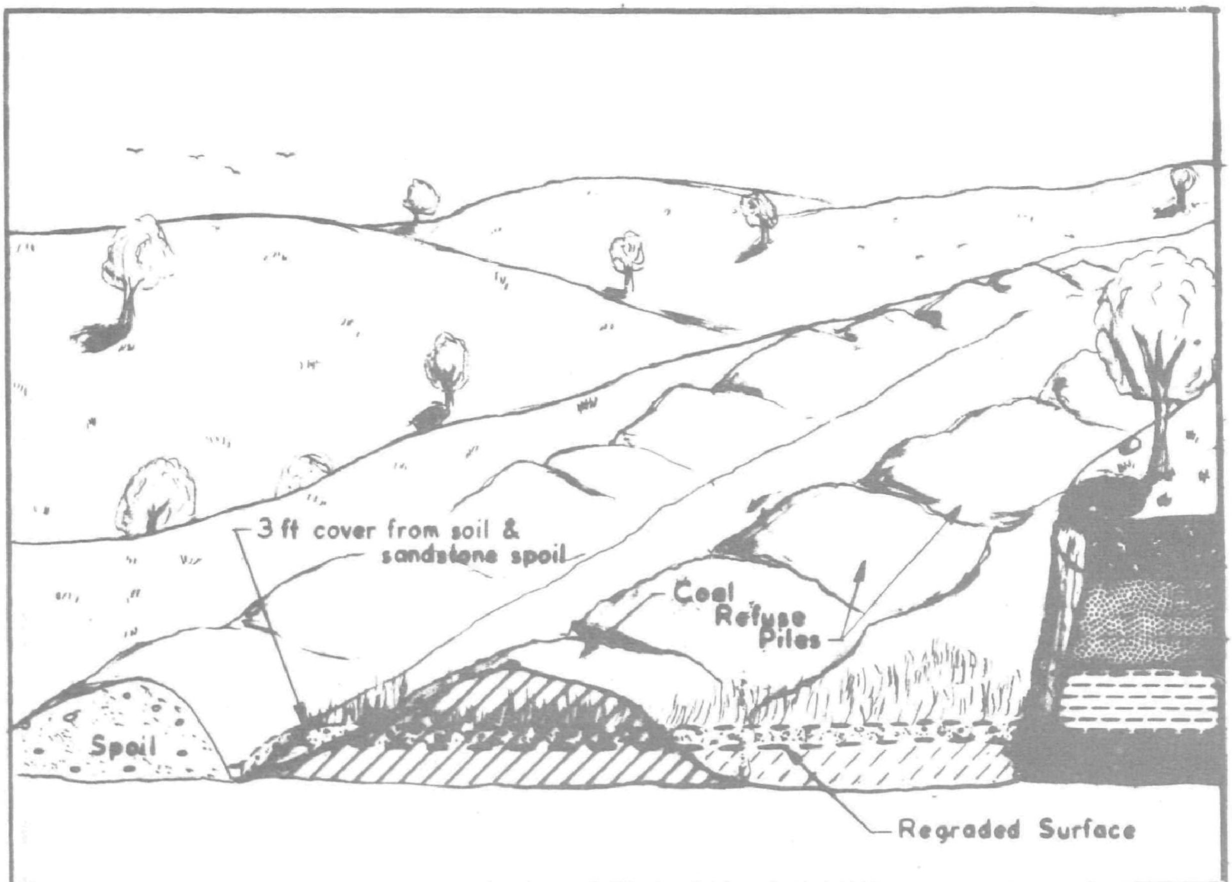
PREVENTION OF WATER POLLUTION BY SURFACE DRAINAGE CONTROL AND IMPOUNDMENT

MONONGAHELA RIVER MINE DRAINAGE REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION III CHARLOTTESVILLE, VA.

FIG. 10



Refuse graded and covered with three feet of overburden and native sandstone spoil, limed, fertilized and drill-seeded with rye, Kentucky red fescue, Korean lespedeza, crown vetch or Reed canary grass.

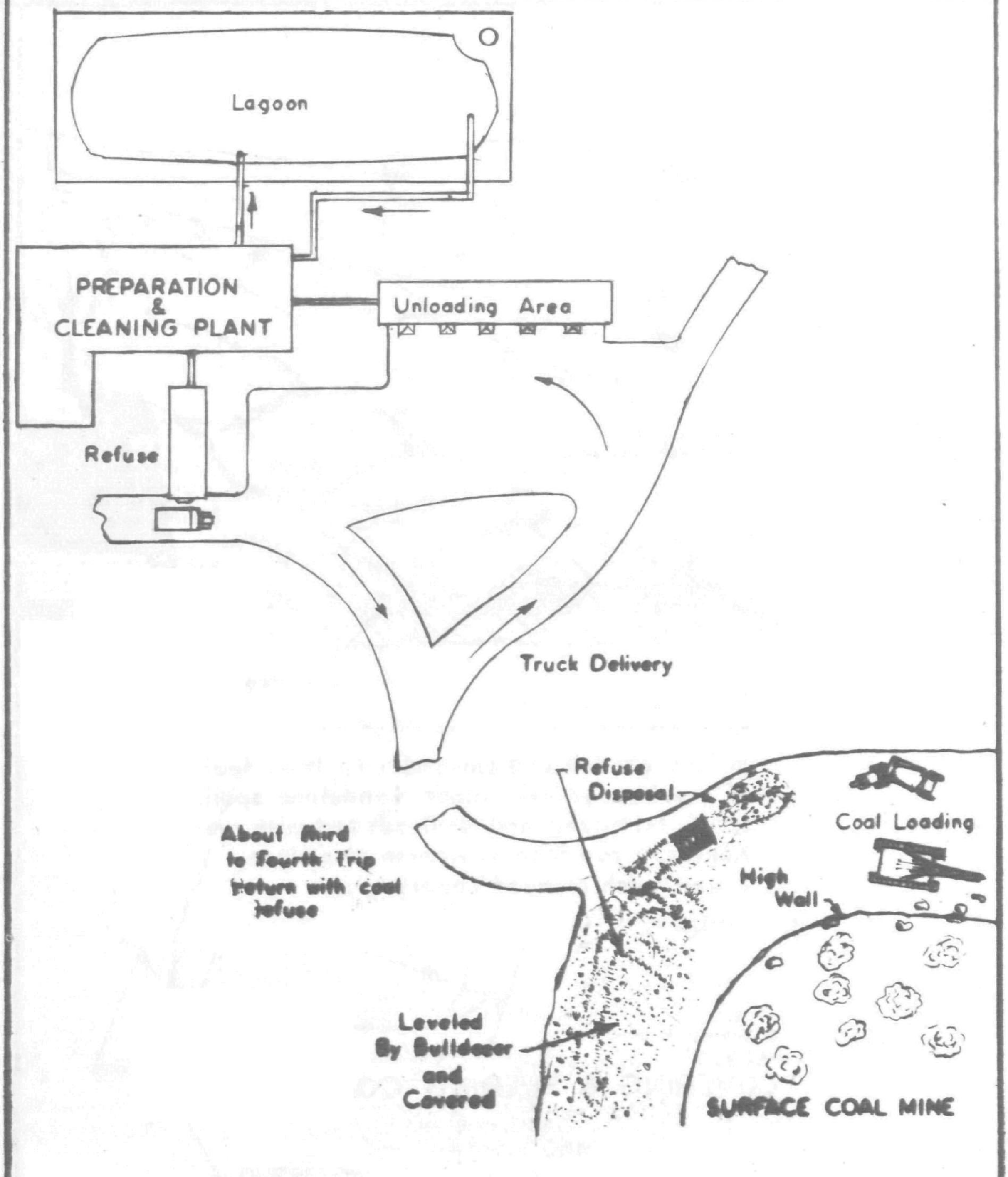
COVERING & SEEDING COAL REFUSE

MONONGAHELA RIVER MINE DRAINAGE REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION III CHARLOTTESVILLE, VA.

FIG. 11



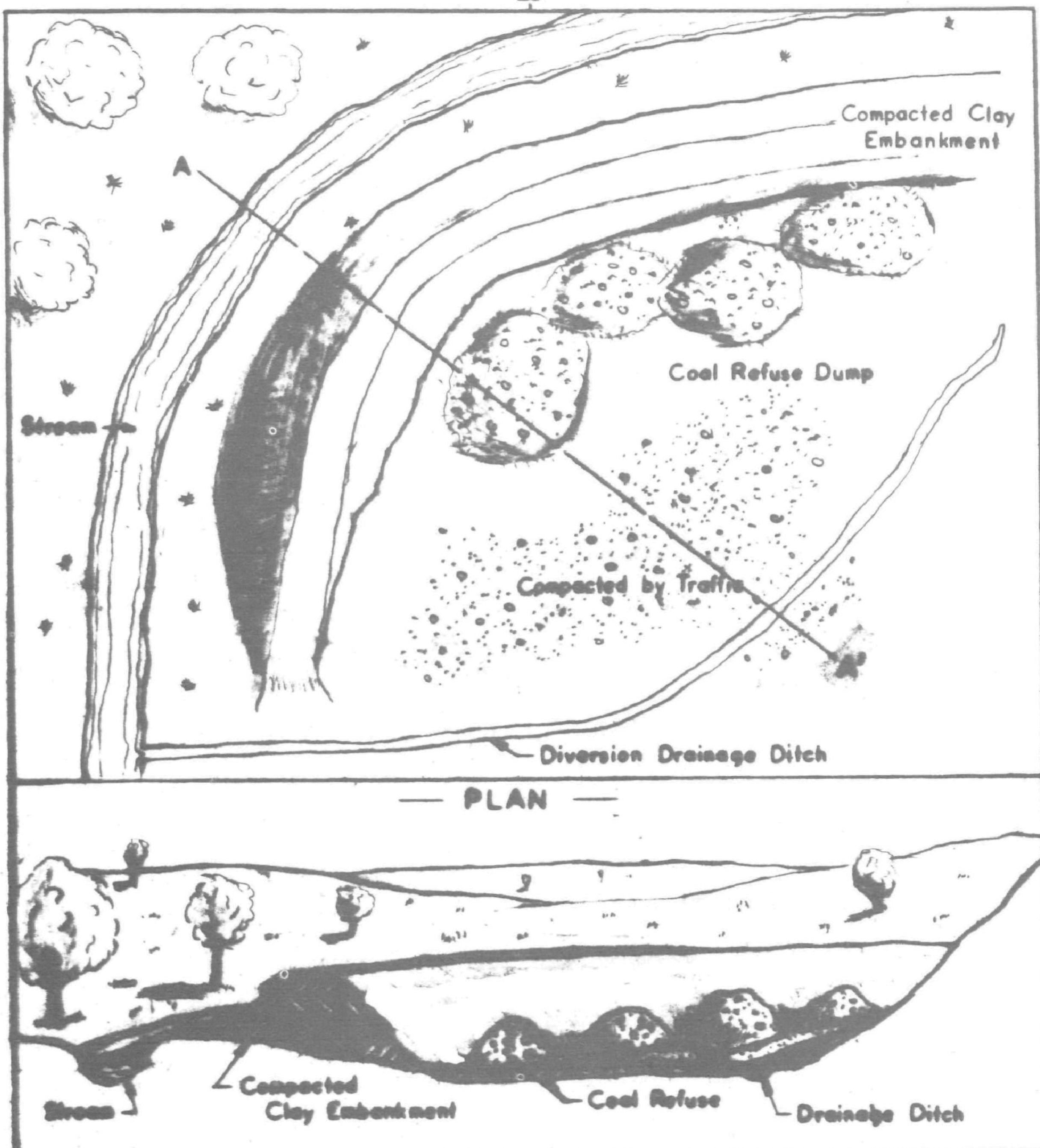
DISPOSAL OF COAL PREPARATION PLANT
REFUSE IN SURFACE MINING

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE

FIG. 12



— SECTION A-A' —

COMPACTION & DISPOSAL OF COAL REFUSE
WITH DIVERSION OF DRAINAGE

MONONGAHELA RIVER MINE DRAINAGE
REMEDIAL PROJECT

TYPICAL REMEDIAL MEASURES

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE

FIG. 13

Presentation and evaluation of costs

These methods were grouped first according to general physical conditions common to sources within the subdivision such as underground, surface, waste disposal and treatment. These were further sub-divided according to the particular technique or remedial measure that predominated. Although further examination would reveal other factors that might affect costs, it seemed that this particular one permitted a reasonable grouping of the basic factors to any one cost determination. Variations still existed, however these were due to the wide variety of physical conditions possible. As for example the differences in type and condition of rock layers from one mine to another. Interpretation should take into account that while data may be useful for estimating costs and determining cost ranges, individual exceptions may vary widely.

It was found further that some adjustment also was necessary from the viewpoint of economic conditions and price changes during the years involved. In order to maintain some basis for comparison both the Engineering News-Record (ENR) Construction Cost Index, reflecting labor and materials cost variations of actual construction contracts in twenty cities across the U. S., and the U. S. Department of Commerce Index of composite prices reflecting the changing economic conditions, were used to a current cost basis. The ENR index was originally based on an average in 1913 of 100. The index of the U. S. Department of Commerce was originally on the base year of 1915, but is currently based on the period 1957-59 equals 100. The median index of the 1964-65 period was used in each case in adjusting costs and these indexes respectively were 948 and 113.

Following is an example of cost adjustments made:

ENR Construction Cost Adjusted to 1964-65 (Cost Index, U.S. Average - 948)

Cost	Year	Index	Current Cost
$1874	1933-39	196	$7496
158	1935-39	216	692
1171	1947-49	450	2342
373	1956-58	725	485
		Avg.	$2753

U. S. Department of Commerce, composite adjusted to 1964-65

(Cost index 1915 = 100, adjusted to 1957-59 = 100; 1964-65 index = 113 (1957-59 base index)

Cost	Year	Index	Adjusted to 1957 = (482)		Adjusted to Current Cost
$1874	1933-39	160	$5640		$6373
158	1935-39	170	447		505
1171	1947-49	352	1593		1800
373	1956-58	477	373		421
		Avg.	$2013	Adj. Avg.	$2274

Underground mine seals - It was found that while the cost of mine seals ranged from $158 reported under the WPA program in West Virginia to $2640 under a program in Pennsylvania during the period of 1947-49, the average cost, adjusted to current prices and weighted by a factor of use and experience, amounted to $1070 using the ENR construction cost index and $1006 by the U. S. Department of Commerce index. These compare favorably with the few current costs quoted, one, by the West Virginia Department of Mines of $1650, and another from a mine in western Pennsylvania involving a bulkhead costing $1100. Prior estimates ranged around $1000 for a constructed closing of an opening. Recommended range for current use in estimating is from $1000 to $2000 per opening depending on degree of difficulty.

Grouting - Grouting of subsidence areas to prevent surface water from entering is a method for which little information is available in connection with mine sealing. In order to establish useful techniques and associated costs, the Demonstration Projects will be involved in trials using this method for controlling mine water. Until this data is available, estimated costs based on normal construction use and practise are shown.

Surface mine reclamation - Reasonable agreement was found in costs concerning surface reclamation. There was additionally a far wider source of data and experience available here. Costs are given by cubic yard of material moved, acreage of reclaimed land, or lineal foot of high wall. Since costs related to lineal feet of high wall can vary because of terrane and does not represent the same amount of unit effort, these were listed for information value only and comparisons made on units of acres and cubic yards.

Current costs of earth-moving in surface reclamation varied from $.04 to $.20 per cubic yard, with the more extensive operations being in the range of \$.05 to \$.10. These costs are somewhat dependent on availability of equipment and tend to be lower where equipment is available and not being utilized on production work full-time. Costs for restoration of surface or grading ranged from \$71 to \$350 per acre depending on size and location of the project.

Planting costs - Planting costs were in good agreement on an average cost of \$35/acre for trees. A combination of trees, ground cover and fertilizing would cost as high as \$125/acre.

Costs of complete reclamation then, including grading and planting, would range from \$106 to \$475/acre and the two figures cited from Kentucky and Pennsylvania of \$439 and \$486 per acre respectively reflect the higher end of the range. Costs can be lower where work can be more mechanized and where terrane and project size permit savings. Recent experience of operators shows that reclamation completed soon after mining also lowers costs. Data from the West Virginia Surface Mine Association on over 5000 acres of current reclamation work there show an average cost of \$119/acre.

Drainage diversion - Little actual experience complete with cost data was found in drainage diversion practises associated with coal mining, possibly because so much of it is practised in surface mining where it becomes a minor matter in relation to the complete operation. Estimated cost per lineal foot of diversion is as much as $6.00 per foot. Drainage diversion of mine water can be a significant factor in relation to an underground situation. In at least one instance water pumped from a mine has been diverted into another drainage area and there are cases in which mined-out workings are used for this diversion. Costs quoted however are for the usual surface type of diversion around or through a surface mine or refuse disposal area.

Impoundments - Impoundment of water either where it collects in a surface mine or for purposes of quality and flow regulation is another practise sometimes followed in an effort at abatement. Costs on a unit basis such as acre-feet can vary over wide ranges because of size and natural physical features. Estimated costs given of up to $1000 per acre-foot reflect the smaller size and special conditions that might be expected in connection with coal mining. That of $500 per acre-foot represents an average cost that might be used for estimating other than for unusual conditions.

Refuse and gob - Estimates for handling and reclamation of refuse and gob material (highly concentrated sources of pollution) were made by the Soil Conservation Service and the West Virginia Department of Mines. One actual case experience in Kentucky cited by the Ohio River Valley Water Sanitation Commission was included since location generally would not change representative cost data on this particular method. Figures cited showed a cost of $.10 per ton-mile for hauling the material to the disposal location and up to $600 per acre for reclamation practises at the site. Information on underground disposal was not available, but a reasonable assumption would be that, where useful, disposal underground would not exceed costs of surface disposal.

Control and treatment - Pumping costs vary directly according to equipment and conditions and can be computed directly. A cost of $.08 - .09 per million gallons per foot of pumping is shown as typical for pumping from a deep mine sump. These are listed to show some of the ranges that may be encountered as an item in either re-regulation of flow or disposal to an injection well.

Treatment costs are related to type of treatment and quality of water. The range listed is from $.03 to $1.29 per thousand gallons. Those listed show both experience in a pilot plant operation and relative costs of standard chemical additives for neutralization. Other methods are available, but most work in mine water treatment has been aimed at neutralization, although additional removal of iron and other metals resulted in the "Operation Yellowboy" plant.

APPENDIX

Table I - Work outline submitted to the Advisory Work Group for information.

Costs and Remedial Measures in Mine Drainage Abatement or Control

A. Underground

1. mine seal ("dry" and above ground water table)

    constructed (materials as masonry, concrete)

    placed (compacted earth, clay, sand)

2. mine seal ("dry" and below ground water table)

3. mine seal ("wet" and below water table)

    constructed (as above) with controlled flow

4. surface sealing of mine openings

    air shafts, constructed openings

    closure

5. sealing of subsidence and surface cracks or voids

    grouting materials

    compacted clay, earth cover

B. Surface mines

1. complete restoration of contours

    by regrading spoil

    by borrow from high wall

    by combination

2. partial restoration (covering coal and acid producing materials only)

    by regrading

    by borrow

    combination

B. Surface mines (cont'd)

3. planting

    reforestation

    ground cover

    combination

    fertilizing and/or liming

4. diversion of drainage from area

    ditching above area

    streams through area

5. submersion of material by earthen dams

C. Refuse and gob piles

1. preparation of disposal areas

2. sealing by edge and surface compaction

3. haulage of material

    to available prepared area

4. haulage and covering

D. Control and treatment

1. regulated pumping

2. chemical neutralization

3. treatment for removal

4. impounding with controlled or semi-controlled release

Table II - Cost of remedial measures

Listed are methods for which cost data in some form were available. These are listed separately for each source or estimate and grouped according to the general method involved. Summaries of underground mine seals and surface reclamation costs are provided at the end of each of these groups.

Method	Unit	Cost	Year	Remarks
Wet and dry mine seals (109)	per opening	$1171 average	1947-49	State of Pennsylvania program
Wet and dry (19) mines	109 openings	Range 161-2640	1947-49	State of Pennsylvania program (Bureau of Mines)
(718) mine units	mine	1874	1933-39	WPA
Mine seals (5)	mine opening	373	1956-58	State of Pennsylvania
Mine seals (7260)	mine opening	158	1935-39	from report WPA in West Virginia
Mine sealing	mine	942	to 11/36	West Virginia - Tisdale and Chapman report
Wet and dry mine seal	per seal	1650	1965-66	Department of Mines, West Virginia
Wet seal	per seal	846	1965-66	Project estimate
Mine bulkhead	per opening	1100	1966	Active mine - Pennsylvania
Average of above - 8092 seals current cost of mine seal	per opening	$1070	weighted average current prices	Using ENR construction cost index
		$1006	weighted average current prices	Using U. S. Department of Commerce Index

Method	Unit	Unit Cost	Year	Location and Remarks
Subsidence - grouting	cubic feet (in place)	\$4 - \$8	1965	Monongahela quotation
Subsidence - grouting	acre	4-6000	1965-66	Pennsylvania
Surface reclamation	cubic yard	\$ .10	1965-66	Department of Agriculture - SCS - Pennsylvania and West Virginia
Fill material	cubic yard	.038	1965-66	Pennsylvania
Surface backfilling by grading	lin. ft. of high wall	5.18	1965	U. S. Bureau of Mines - Report #6772 - Demonstration and evaluation of five methods of secondary backfilling - Method A
Surface backfilling by grading	lin. ft. of high wall	15.73	1965	U. S. Bureau of Mines - Method B
Surface backfilling by grading	lin. ft. of high wall	11.70	1965	U. S. Bureau of Mines - Method C
Surface backfilling using explosives	lin. ft. of high wall	14.08	1965	U. S. Bureau of Mines - Method D
Surface backfilling using explosives	lin. ft. of high wall	8.84	1965	U. S. Bureau of Mines - Method E
56 sites reclamation	cubic yard acre	.048 605	1958	Pennsylvania
4 sites reclamation	acre	159	1955	Pennsylvania

Method	Unit	Unit Cost	Year	Location and Remarks
Surface reclamation	cubic yard acre	$.20 150-350	1965-66	West Virginia
Regrading, 94 projects	acre	130	1964	Ohio - average per acre cost during the year
Regrading, 269 acres	acre	71	1965-66	West Virginia - including planting costs
Surface restoration, area to original contour	acre	374	1965-66	Pennsylvania - bituminous areas
Surface restoration, contour mining, moderate slope, to original contour	acre	631	1965-66	Pennsylvania - bituminous areas
Surface restoration, contour mining, steep slope, minimum grading	acre	79	1965-66	Pennsylvania - bituminous areas
Surface restoration contour mining, moderate slope, minimum grading	acre	75	1965-66	Pennsylvania - bituminous areas
Surface restoration, area terracing	acre	257	1965-66	Pennsylvania - bituminous areas
Surface restoration, contour mining, moderate slope, terracing	acre	270	1965-66	Pennsylvania - bituminous areas
Regrading, 3,736 acres	acre	486	1965-66	Pennsylvania, including planting

Method	Unit	Unit Cost	Year	Location and Remarks
Summary	cubic yard	$.04-.20	Current	depending on terrain and location
	acre	$453	Current	weighted average - current projects - Pennsylvania (excluding partial reclamation)
	acre	$71-350	Current	West Virginia - range of costs

Method	Unit	Unit Cost	Year	Location and Remarks
Planting				
reforestation	acre	$ 75	1965-66	SCS
reforestation	acre	35-40	1965-66	Pennsylvania - Department of Forestry
trees	acre	35	1964	Ohio
trees	acre	25-45	1965-66	Most areas - Appalachia
ground cover	acre	50	1965-66	SCS
grass, 34 acres	acre	24	1948-66	Ohio
grass, 1,785 acres	acre	30	1965-66	Pennsylvania
grass, 84 acres	acre	68	1965-66	West Virginia
combination	acre	125	1965-66	SCS
fertilizer and/or lime	acre	100	1965-66	SCS
Drainage diversion	square yard X section	.20	1965-66	West Virginia Department of Mines
Drainage diversion (6" coated pipe)	lin. feet	6	1965	Project
Drainage diversion	lin. feet	.04	1965-66	SCS
Stream diversion	lin. feet	1.51	1965-66	SCS

Method	Unit	Unit Cost	Year	Location and Remarks
Impoundments	acre feet	$ 125	1965-66	Department of Mines - West Virginia
Impoundments (5-30 acres)	surface acre	$1000	1965-66	Pennsylvania and West Virginia
Impoundments	acre feet	500	1965-66	SCS
Surface reclamation - refuse	acre	$ 439	1964	ORSANCO practices - Kentucky
Refuse and gob reclamation	acre	600	1965-66	West Virginia Department of Mines
Refuse and gob reclamation	acre	600	1965-66	SCS
Hauling refuse and gob	ton-mile	.10	1965-66	West Virginia - Department of Mines
Hauling refuse and gob	ton-mile	.09-.10	1965-66	SCS
Pumping	m.g./ft. - lin. feet	$.08-$.09	1966	Bureau of Mines
Pumping	1000 g.	1.29	1965-66	West Virginia Bureau of Mines
Pumping to injection well	1000 g.	$.20-75	1965	Pennsylvania

Method	Unit	Unit Cost	Year	Location and Remarks
Treatment (Yellowboy) *	1000 g.	$1.09	1965	Marianne report - Pilot plant, Pennsylvania research project
Treatment (Yellowboy)	1000 g.	1.29	1965	Bethlehem's estimate
Treatment - Hydrated Lime	1000 g.	.030	1964	U. S. Bureau of Mines chemical cost only
Treatment - Limestone	1000 g.	.066	1964	U. S. Bureau of Mines chemical cost only
Treatment - Soda Ash	1000 g.	.155	1964	U. S. Bureau of Mines chemical cost only
Treatment - Caustic Soda	1000 g.	.163	1964	U. S. Bureau of Mines chemical cost only
Treatment - Ammonia	1000 g.	.500	1964	U. S. Bureau of Mines chemical cost only

Remarks: WPA - Mine sealing program of 1933-39
ENR - Engineering News Record

Units:

lin. ft. - lineal feet
m. g. - million gallons
g. - gallons

* Most recent results experienced during operation of the pilot plant during the summer of 1966 gave costs of $.72/1000 gallons.

SUMMARY OF CONFERENCE

POLLUTION OF INTERSTATE WATERS

OF THE

MONONGAHELA RIVER AND ITS TRIBUTARIES

(MARYLAND-PENNSYLVANIA-WEST VIRGINIA)

December 17-18, 1963

The Monongahela River is formed by the confluence of the West Fork and Tygart Rivers at Fairmont, West Virginia. The drainage basin includes the southwest corner of Pennsylvania, the northeast portion of West Virginia and a small section of western Maryland. The basin drains an area of 7,380 square miles. The river flows in a northerly direction and joins the Allegheny at Pittsburgh to form the Ohio River. The main stem of the Monongahela River flows through the Appalachian Plateau region and is characterized by rugged topography, with narrow stream valleys several hundred feet below the level of the uplands.

Major tributaries of the Monongahela are the Youghiogheny, Cheat, West Fork and Tygart Rivers.

The section of the Monongahela River of concern in this conference extends downstream to Charleroi, Pennsylvania. The section of the Youghiogheny involved extends down to Sutersville, Pennsylvania.

On the basis of reports, surveys, or studies the Secretary of Health, Education, and Welfare having reason to believe that pollution of the Monongahela River and its tributaries caused by discharges of untreated and inadequately treated sewage and industrial waste and mine drainages from active and inactive mines originating in West Virginia is endangering the health and welfare of persons in Pennsylvania, a State other than that in which the discharges originate, called a conference in the matter of pollution of interstate waters of the Monongahela River and its tributaries. The conference was held December 17-18, 1963, Ballroom 3, of the Pittsburgh Hilton Hotel, Gateway Center, Pittsburgh, Pennsylvania.

The following conferees representing the State water pollution control agencies of Pennsylvania, Maryland, and West Virginia, the Ohio River Valley Water Sanitation Commission, and the Department of Health, Education, and Welfare attended the conference:

Charles L. Wilbar, Jr., M.D.	Chairman, Sanitary Water Board, Pennsylvania Department of Health Harrisburg, Pennsylvania
Paul W. McKee	Director, Maryland State Water Pollution Control Commission Annapolis, Maryland
Robert M. Brown	Chief, Bureau of Environmental Hygiene, State Department of Health, Baltimore, Maryland
Bern Wright	Chief, Division of Water Resources, Department of Natural Resources Charleston, West Virginia
Thomas Yost	Assistant Attorney General State of West Virginia

Joseph R. Shaw	Chairman, Ohio River Valley Water Sanitation Commission Cincinnati, Ohio
Earl J. Anderson	U. S. Department of Health, Education, and Welfare New York, New York
Murray Stein, Chairman	U. S. Department of Health, Education, and Welfare Washington, D. C.

Senator Jennings Randolph presented a statement supporting the conference. The following also participated in the conference:

R. J. Boes	Sanitary Engineer Ohio River Valley Water Sanitation Commission Cincinnati, Ohio
John E. Costello, Esq.	Chairman, Resolutions Committee, Pennsylvania Municipal Authorities Association
Ernst P. Hall	Research Consultant, Consolidation Coal Company Representing Mining Industry
William D. Henning, Esq.	Allegheny County Sportsmen's League
Granville A. Howell	Assistant to Vice President United States Steel Corporation Representing Pennsylvania State Chamber of Commerce
G. W. Josephson	Bureau of Mines Department of the Interior
Honorable John Laudadio	Member, House of Representatives Commonwealth of Pennsylvania Representing Pennsylvania Federation of Sportsmen's Clubs
Francis X. McCulloch, Esq.	Allegheny County Boroughs Association

Fred C. Perkins	President, Pennsylvania Division Izaak Walton League of America, Inc. Uniontown, Pennsylvania
F. R. Perrin	Chief Chemist, South Pittsburgh Water Company Representing Pennsylvania Section of the American Water Works Association
A. D. Sidio	Public Health Engineer U. S. Department of Health, Education, and Welfare Cincinnati, Ohio
Gerald G. Taylor	Fishery Biologist Bureau of Sport Fisheries and Wildlife Department of the Interior Pittsburgh, Pennsylvania
Everett Thayer	Pittsburgh, Pennsylvania
Meredith Thompson, Ph.D.	Assistant Commissioner for Environmental Services New York State Department of Health
George W. Whetstone	District Chemist U. S. Geological Survey Department of the Interior

The Chairman of the conference pointed out that:

1. Under the Federal Water Pollution Control Act (33 U.S.C. 466 et seq.) pollution of interstate waters which endangers the health or welfare of persons in a State other than the one in which the discharges originate is subject to abatement under procedures described in section 8 of the Federal Act.
2. The first step of this procedure is the calling of a conference.

3. The purpose of the conference is to bring the States, the interstate agency, and the Department of Health, Education, and Welfare together to review the existing situation and progress made, to lay a basis for future action by all parties concerned, and to give the States and localities an opportunity to take any remedial action which may be indicated under State and local law.

Mr. A. D. Sidio of the Department of Health, Education, and Welfare presented a report on the Monongahela River and its tributaries which specifically covered some of the sources of pollution, the type of wastes discharged, and the interferences with water uses.

Representatives of the Pennsylvania Sanitary Water Board, the West Virginia Department of Natural Resources, the Maryland State Department of Health, and the Ohio River Valley Water Sanitation Commission presented reports concerning pollution of the Monongahela River and its tributaries,

The conferees unanimously agreed on the following conclusions and recommendations:

1. Pollution of an interstate nature exists in the Monongahela River Basin which adversely affects municipal and industrial water supplies, fish and wildlife, and recreation, such as fishing, boating, swimming, and navigation.

2. The States of West Virginia, Pennsylvania, Maryland and the Ohio River Valley Water Sanitation Commission have made

appreciable progress in water pollution abatement and have presented acceptable programs for the control of industrial and municipal wastes.

3. Cognizance is taken of Pennsylvania's program to abate pollution from such sources by the end of 1966. Commensurate programs have been developed by West Virginia and Maryland. It is recognized that court action may necessarily modify this program and that economically depressed communities in the Basin may have to depend on outside financial assistance.
4. The establishment of a technical committee consisting of representatives of West Virginia, Pennsylvania, Maryland, the Ohio River Valley Water Sanitation Commission and the Federal Government to explore the means of abating pollution caused by coal mine drainage is recommended. This committee will be charged with determining the amount of pollution from such mines. The committee also will be charged with developing a remedial program, including a cost estimate.

Definitions

Auger, augering - method of drilling a hole, usually with a shaped, hardened-steel bit, into rock and/or earth; in coal mining, a method of horizontal drilling into a seam to recover the coal.

Bedded deposit - an ore deposit of tabular form that lies horizontally or only slightly inclined to the horizontal, and is commonly parallel to the stratification of the enclosing rocks.

Bench - natural terrace marking the outcrop of any stratum; a stratum of coal forming a portion of the coal seam, generally separated by partings.

Bone - slaty coal or carbonaceous shale found in coal seams.

Core - cylindrical-shaped samples of rock produced by core-drills, usually with hollow diamond bits.

Development - the work of driving openings to and in a proved ore body to prepare it for mining and transporting the ore.

Dip - the angle at which a bed, stratum or vein is inclined from the horizontal.

Drift - a horizontal opening in or near an ore body and parallel to the course of the vein or coal seam.

Floor - the wall or rock underlying a coal bed or vein.

Fold - a pronounced bend in stratified rocks, such that results in a reversal of the direction of dip.

Gob - that part of the mined material, either coal or other minerals that is not marketable and is therefore wasted.

Highwall - the vertical working face of a strip or surface mine.

Mining - process of obtaining useful minerals from the earth's crust and includes both underground excavations and surface workings.

Outcrop - that part of a stratum which appears at the surface of the ground.

Overburden - consolidated and unconsolidated material that overlies a coal bed or other mineral deposit especially in surface mining operations.

Parting - any thin interstratified bed of earthy material.

Roof - the wall or rock on the upper side of mine opening.

Room and pillar - a system of working coal by which solid blocks of coal are left on either side of the rooms or entries to support the roof until the rooms are completely mined, after which the pillars are usually partially or completely removed.

Seam - synonymous with bed, vein, etc.

Shaft - a vertical or inclined excavation in a mine extending downward from the surface or from some interior point as a principal opening through which the mine is exploited. A shaft is provided with a hoisting engine at the top for handling men, rock and supplies, or it may be used in connection with pumping or ventilating operations.

Spoil - see Waste

Strike - the horizontal course or bearing of an inclined bed, stratum or vein; the direction of a horizontal line in the plane of an inclined bed, stratum or vein.

Subsidence - a downward movement of natural ground surface not induced by external loads.

Sump - an excavation made underground to collect water, from which water is pumped to the surface or to another sump nearer the surface. Sumps are placed at the bottom of a shaft, near the shaft on a level or at some interior point.

Trough - a trough of sedimentation or a syncline; sometimes used for the line along the bottom of a syncline.

Tunnel - a horizontal or nearly horizontal underground passage that is open to the atmosphere at both ends.

Waste - the barren rock in a mine. It is also applied to the part of the ore deposit that is too low in grade to be of economic value at the time, but this material may be stored separately in the hope that it can be profitably treated later. For surface mines this is more often termed 'spoil' and refers to wasted rock removed above the coal.

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