VII. ABATEMENT PROGRAM

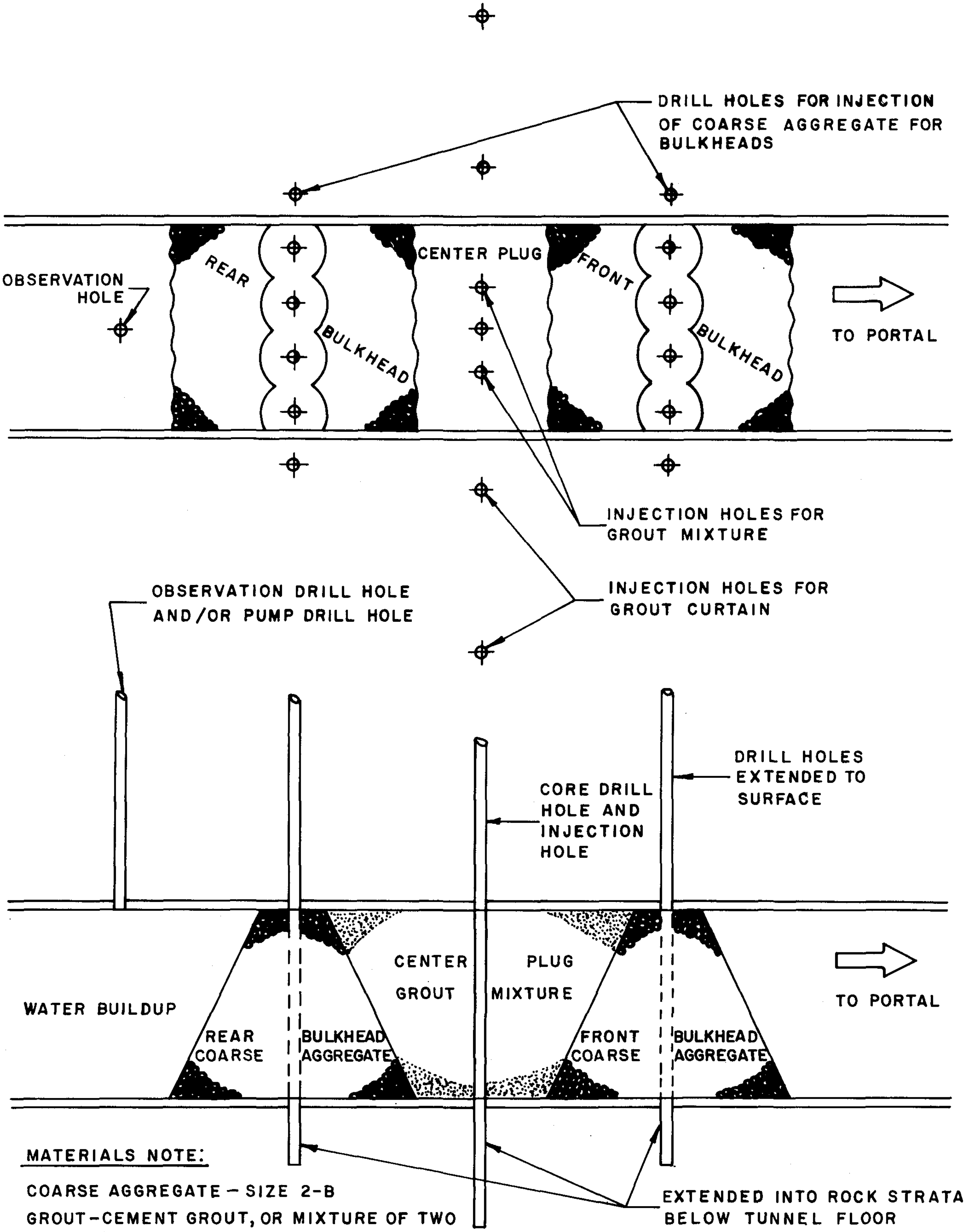
A. ALTERNATE ABATEMENT MEASURES

A review of the stream sample analysis section of this report reveals certain acid mine drainage sources produce a more profound pollution load than others. It is obvious that the two drainage tunnels of the Connell Deep Mine Complex are the most critical in terms of abatement measures. Consequently, the abatement program will deal primarily with these sources. Following is a general discussion of the alternative abatement measures that may be used for the various pollution sources. Because the tunnel discharge system involves not only an evaluation of groundwater movement, surface runoff, and groundwater recharge, several abatement techniques are applicable to the entire complex, with the end result producing a reduction of pollution from a single discharge point.

1. Deep Mine Sealing

Deep mine sealing entails the construction of a water tight bulkhead at or near the entrance to the tunnel discharge point. Typical seals involve a double bulkhead composed of coarse aggregate as well as a center plug composed of a grout mixture between the bulkheads. In order to construct this seal, drill holes drilled from the surface are bored into the rock strata at the base of the tunnel at the location of each bulkhead. Then aggregate is spread and compacted and extended to the tunnel roof via the drill holes. Grout is then pressure injected into the aggregate interstices to produce an impervious barrier. This process is performed for both front and rear bulkheads. The area between the bulkheads, or center plug, is then pressure grouted through appropriate drill holes to produce a concrete plug. Finally, a grout curtain is implemented by pressure grouting of the rock strata to either side of the seal itself. This insures the filling of any voids, fractures, or other areas that may lead to hydraulic failure of the seal and adjacent rock. Figure 9 shows the plan and profile of a typical deep mine seal used in Butler County, Pennsylvania (Foreman, 1970).

In general, the purpose of a deep mine seal is to inundate the deep mine workings above the sulfuric strata, minimizing the surface area of that strata exposed to air. In so doing, the oxidation of sulfides is reduced and the production of acids is curtailed. One facit of such deep mine seals is that at some point, a hydraulic equilibrium is reached and a new discharge point is established. Because of the inundation of the mine, the water quality of this new discharge point is improved.



MATERIALS NOTE:

COARSE AGGREGATE – SIZE 2-B

GROUT–CEMENT GROUT, OR MIXTURE OF TWO OR MORE OF THE FOLLOWING:- CEMENT, SAND, FLYASH, WATER, ADMIXTURE

TYPICAL DEEP MINE SEAL

PLAN & PROFILE

NOT TO SCALE

FIGURE 9

2. Strip Mine Reclamation

Prior to the enactment of the present strip mine laws, little effort was made to restore areas affected by mining. The scars of this period are quite evident and play an important part in the hydrology of the deep mine complex. In some instances, abandoned strip pits may allow for direct discharge to natural drainage contours, but more importantly, water introduced into these pits eventually ends in the deep mines. Reclamation of these pits precludes such infiltration and minimize groundwater recharge. Abandoned strip mine reclamation involves the backfilling of these pits with available material from spoil banks, grading to original contour or terracing, soil treatment, and revegetation. Figure 10 shows a cross-section of a typical strip mine reclamation.

3. Surface Water Diversion

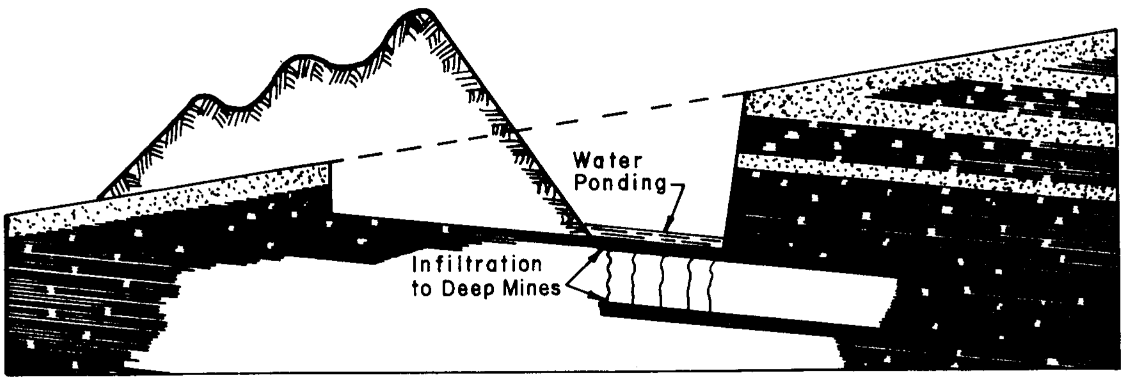
In some instances it is important to rechannel stream flow to preclude its movement into strip mine areas. This at times may be accomplished in conjunction with strip mine backfilling and regrading. Other cases may dictate the construction of a diversion ditch to rechannel water away from strip pits or refuse pile areas.

4. Refuse Pile Removal

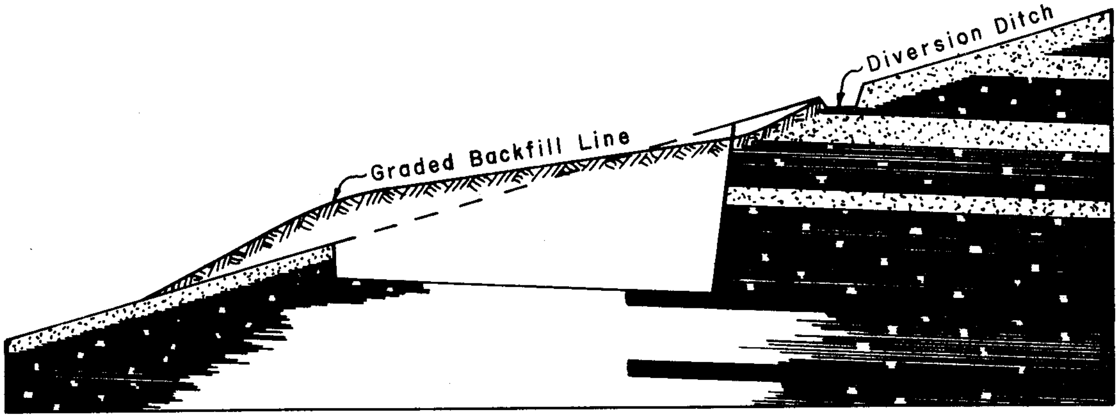
As a byproduct of past mining activity, piles of waste material, including bone, rider, and unmarketable coal waste, has accumulated in some areas. Surface runoff over these piles adds to the pollution of streams and swamps in the watershed. This material is used for the backfilling of abandoned strip pits prior to final grading and revegetating.

5. Acid Mine Drainage Treatment

Treatment of acid mine drainage can be accomplished either at the source of discharge or at the receiving stream itself. The types of neutralizing agents are numerous and several can be used in combination with another. These agents included hydrated lime, limestone, calcinated lime, quick lime, dolomite, sodium carbonate, sodium hydroxide, etc. The manner in which the neutralizing agent is incorporated into the treatment system can be varied in several ways. Various schemes of rotating drums or reactors containing a neutralizing agent, as well as more sophisticated treatment methods utilizing mixing, aeration, clarification, and sludge removal have been used with success for treating acid mine drainage. With any treatment system, the operational and maintenance factors as well as first costs and operating costs will play an integral part in the determination of the optimum system.

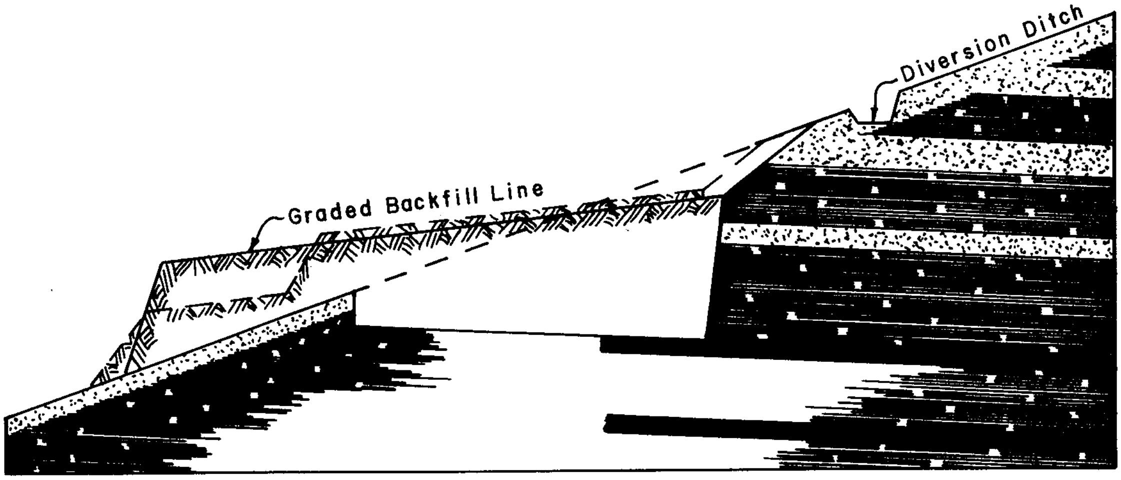


BEFORE BACKFILLING



AFTER BACKFILLING

GRADED TO ORIGINAL CONTOUR



AFTER BACKFILLING

TERRACE TYPE BACKFILL

TYPICAL STRIP MINE CROSS SECTIONS

BEFORE AND AFTER RESTORATION

Not To Scale

FIGURE 10

B. ABATEMENT PLAN DISCUSSION

Undoubtedly, the two discharge tunnels that drain the Connell Deep Mine Complex are the most critical sources when consideration is given to an abatement program. These two sources have the most impact on the water quality of Loyalsock Creek, and are responsible for the largest percentage of acid mine water. Certain abatement proposals can deal directly with the actual tunnel discharge, while other abatement measures pertain to impeding the infiltration of surface water to the deep mines. Not all abatement proposals are related to the Connell Deep Mine Complex and discharge tunnels. These other areas are of lesser importance, but will also be discussed in terms of possible abatement measures.

For purposes of discussion, Project Areas are designed for abatement proposals. Each specific area may contain one or more sampling points as described in detail in Section VI. Location maps have been included with this section, with particular attention given to the location and limits of the deep mines, restored strip mines, and unrestored abandoned strip mines. An index is presented, keying the symbols for map interpretation. (Figure 11)

There are four (4) Abatement Project Location Maps in this report - Figure Numbers 12, 13, 14 and 15. Each individual map is keyed to the larger Composite Map - Plate 2. The location of these maps is indicated from west to east on the map as follows:

A - Figure 12
B - Figure 13
C - Figure 14
D - Figure 15

Furthermore, Plate 2 also shows property lines indicating the limits of surface and mined ownership, corresponding to the abatement area descriptions.

Because mine drainage permits have been issued for a significant portion of the basin, certain abatement projects may have some impact on the responsibilities of the individual permitees. Therefore, it is pertinent to delineate the limits of the recently issued permits, both active and inactive. Appendix D, Figure 23 at the end of this report, shows the drainage basin and the mine drainage permits issued since 1967.

C. ABATEMENT COSTS

Cost estimates for the Abatement Projects were established by using the various criteria as listed below.

1. Computing quantities for materials and methods necessary for the implementation of abatement projects. This includes, for example, a takeoff for the various aspects of mine sealing (i.e. linear feet of drilling, tons of bulkhead aggregate, etc.) and measurements of the amount of backfill required for grading stripped areas.

2. An analysis of recent bid experience of the Pennsylvania Department of Environmental Resources for similar abatement projects.

3. An analysis of studies on completed abatement projects as reported in the Symposiums on Coal Mine Drainage Research, Bituminous Coal Research Inc.

4. Discussions with and analysis by equipment manufacturers and distributors, for the types of systems and appurtenant equipment necessary for abatement projects (i.e. treatment system).

5. An examination of the above factors along with the application of engineering experience and judgement.

Abatement costs have been included with the description of each abatement area. Particular attention has been given to Project Areas No. 1 and No. 2.

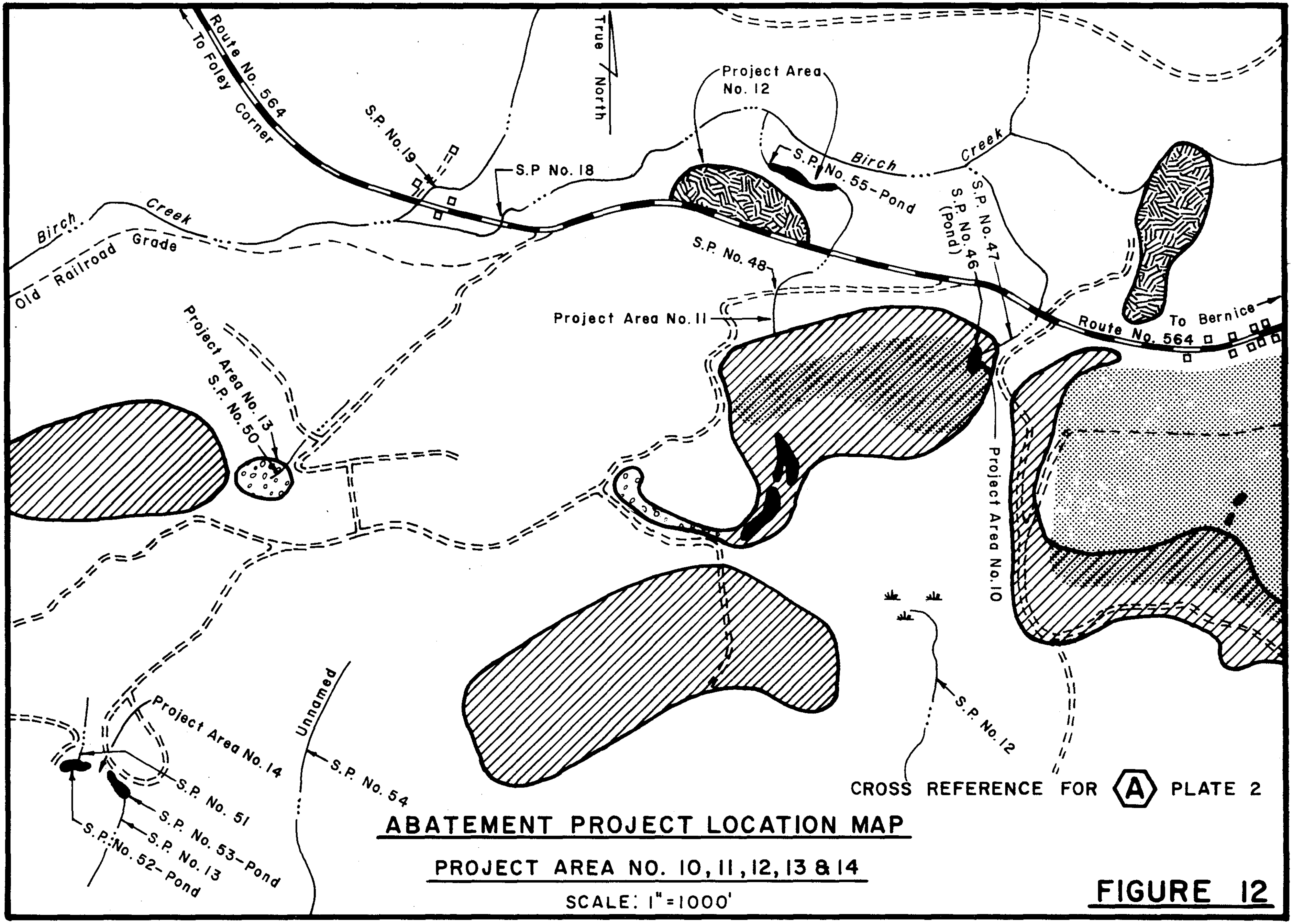
LOYALSOCK CREEK WATERSHED

POLLUTION ABATEMENT PROJECT AREA

LEGEND FOR PROJECT MAPS

▒	DEEP MINE AREAS - NON-ACTIVE
▨	STRIP MINE AREAS - PREVIOUSLY RESTORED
░	STRIP MINE AREAS - NOT RESTORED (RECLAMATION RECOMMENDED)
▩	REFUSE PILES
╲	DRAINAGE TUNNEL - DEEP MINE COMPLEX
●	ABANDONED STRIP MINE AREA - WATER PONDING
Project Area No. 1 Thru 14	ABATEMENT PROJECT AREA
S.P. No. 45	SAMPLING POINT NUMBER

FIGURE II



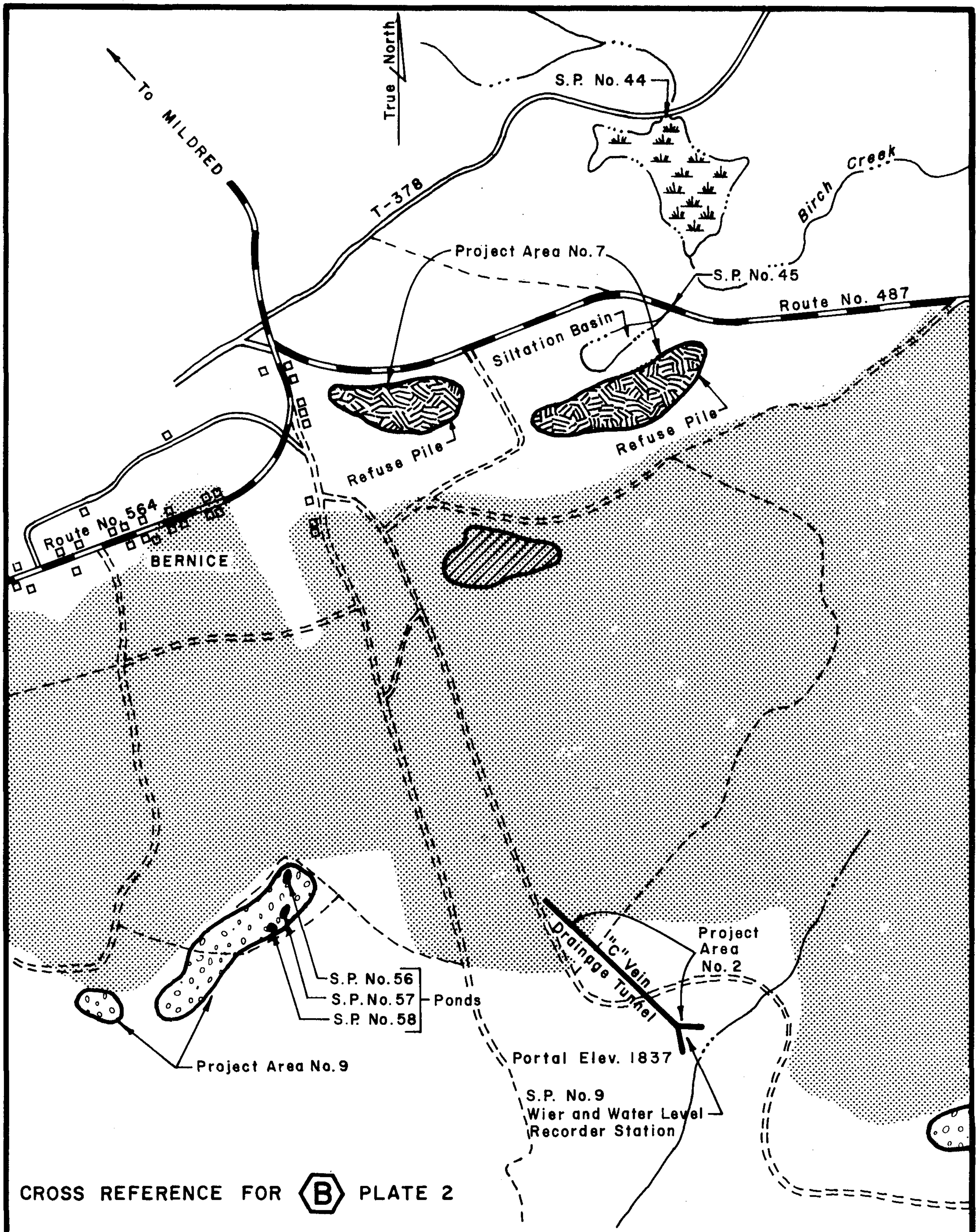
CROSS REFERENCE FOR (A) PLATE 2

ABATEMENT PROJECT LOCATION MAP

PROJECT AREA NO. 10, 11, 12, 13 & 14

SCALE: 1" = 1000'

FIGURE 12



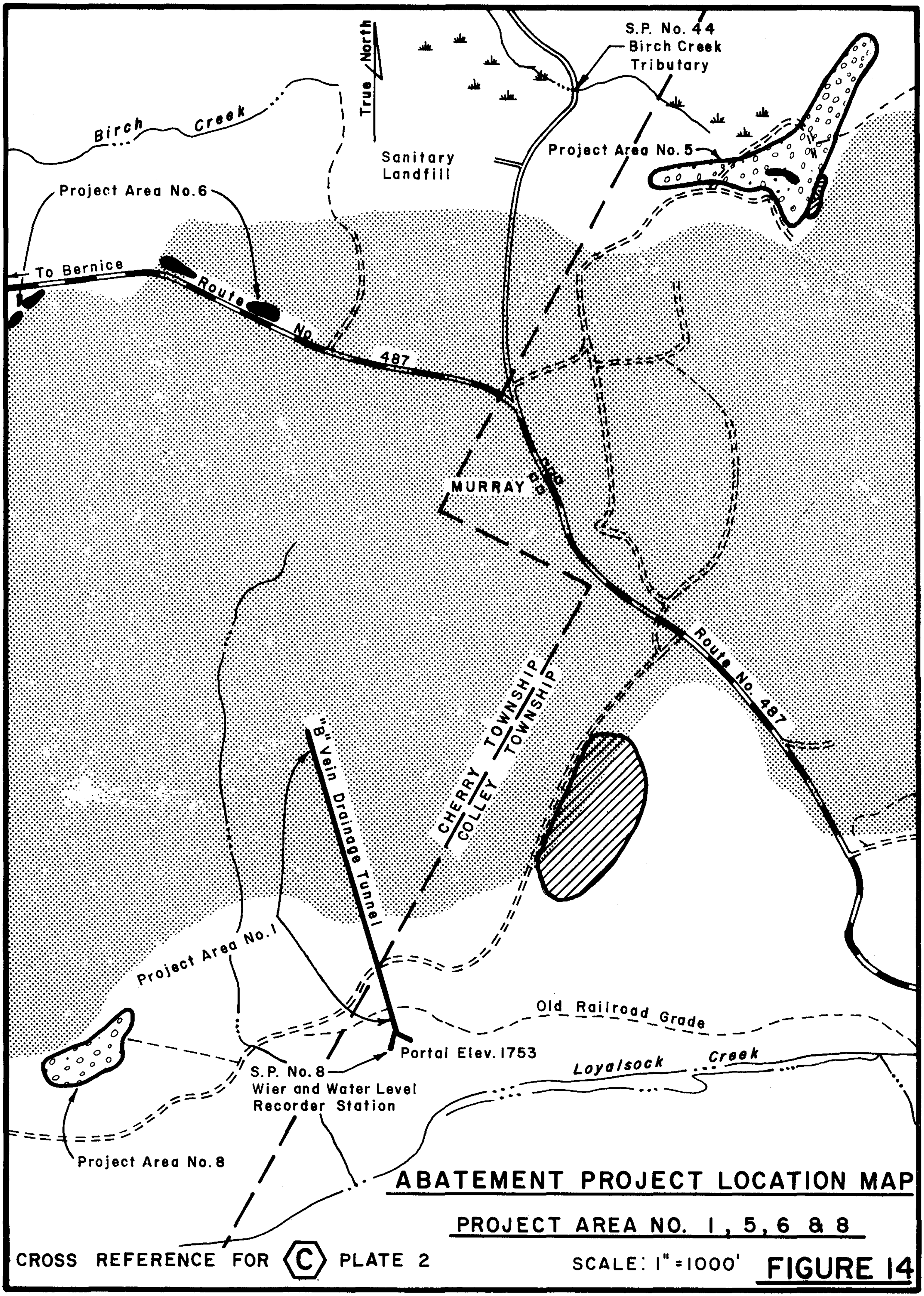
CROSS REFERENCE FOR (B) PLATE 2

ABATEMENT PROJECT LOCATION MAP

PROJECT AREA NO. 2, 7, & 9

SCALE: 1" = 1000'

FIGURE 13



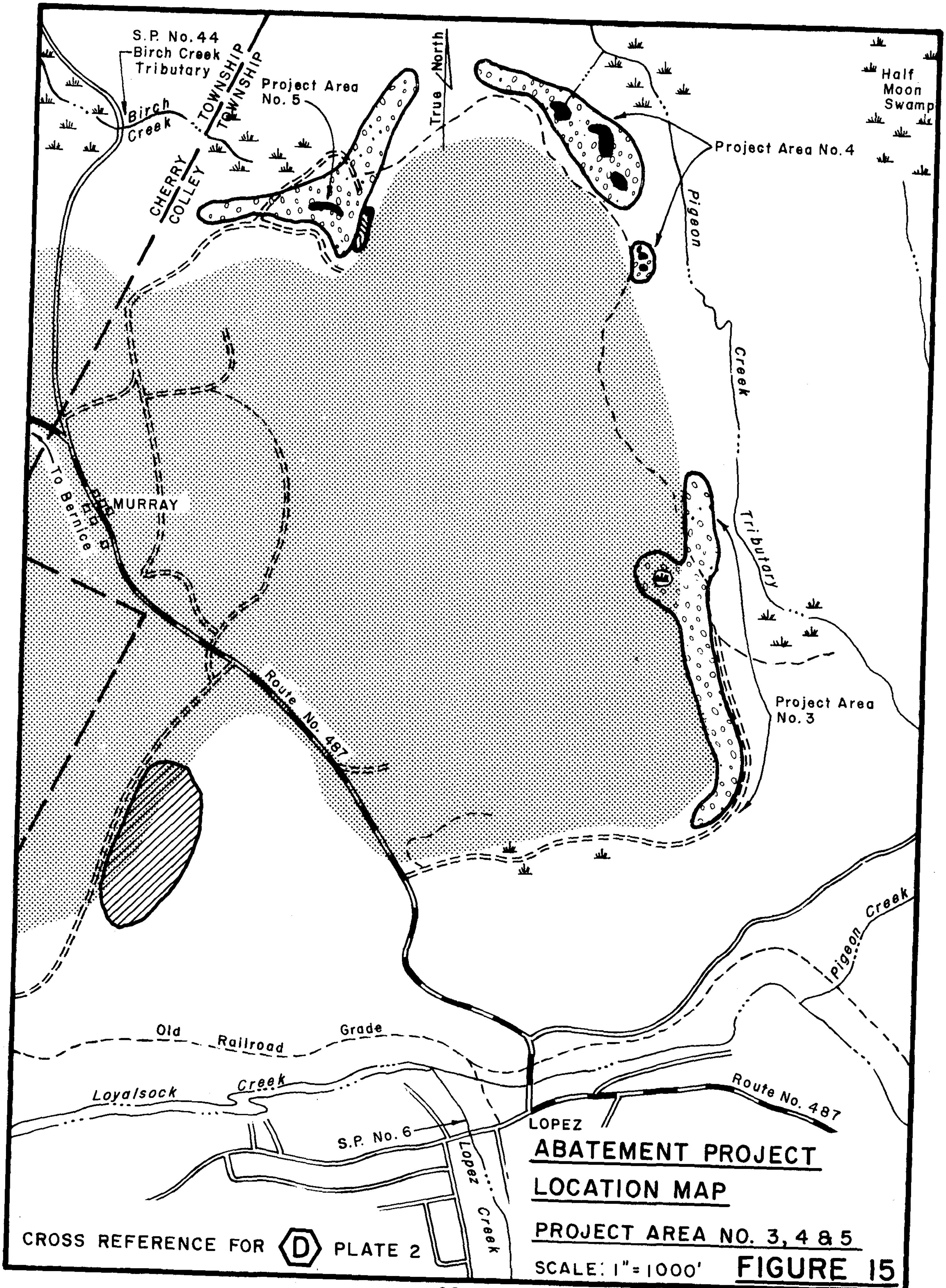
ABATEMENT PROJECT LOCATION MAP

PROJECT AREA NO. 1, 5, 6 & 8

SCALE: 1" = 1000'

FIGURE 14

CROSS REFERENCE FOR (C) PLATE 2



ABATEMENT PROJECT LOCATION MAP

PROJECT AREA NO. 3, 4 & 5

SCALE: 1" = 1000'

FIGURE 15

CROSS REFERENCE FOR Ⓓ PLATE 2

Project Area No. 1 - B Vein Discharge Tunnel
Project Area No. 2 - C Vein Discharge Tunnel

Figure 14 shows the location of Project Area No. 1, while Figure 13 shows the location of Project Area No. 2. Although each tunnel discharge would involve an abatement project of its own, the two will be reviewed concurrently here because of the hydraulic relationship of the deep mine workings of each. There are two principal means for dealing with the tunnel discharges. One approach is the mine seal, while the other alternative is discharge treatment. The use and implications of a deep mine seal for each tunnel will be discussed in. detail at this point.

1. Deep Mine Sealing

Because of the hydraulic and topographic considerations being included in this discussion, it is important: to refer to the Composite Maps Plate No. 1 and Plate No. 2.

In the normal equilibrium state of the ground water annual cycle, discharge is equal to recharge and there is no long term rise or fall of the water table. Under present conditions almost all of the recharge to the Bernice Basin is discharged through the tunnels. If both tunnels are sealed the water table will rise until new discharge points are found and a new equilibrium is established. Because of the very high permeability, the mined-out coal seams will tend to act as perched aquifers with relatively free movement of water. No perching is ever perfect, however, and. the underlying impermeable units are never totally impermeable, so that at some point sufficient head will be built up above the underlying units whereby downward percolation equals recharge. Whether or not this new equilibrium will be reached before the water in the mines finds new discharge points is the critical question.

The most probable discharge points will he along the coal outcrop lines where old workings come so close to the surface that there has been subsidence and slumping of the overburden. The low points along the outcrop of the B coal are all on the Loyalsock Creek side of the basin where erosion has cut deeply into the syncline. The lowest points are in the gully above the B tunnel at elevations of from 1840 to 1845 feet, and in the next gully to the east where the coal crops about 1840 feet above sea level. In both areas there are no visible signs of near surface workings and, in addition, there is a possibility that the glacial cover is thick enough to provide a seal. In the gully near the C tunnel, however, the outcrop is at 1865 feet and there are indications that there are near surface workings, thus affording a likely location for discharge.

It should be added that depending upon the degree of permeability and the effectiveness of natural or artificial seals on these discharge low points, leakage can and most possibly will occur at higher elevations along the outcrop line of both the B and C coals, especially in stripped areas. It is a question of how much leakage from what points is an acceptable situation. At some elevation point equilibrium will be reached wherein downward percolation will equal recharge, but it is impossible to determine the rate of percolation since no information on the horizontal or vertical permeability of the underlying rocks is available. Therefore, if deep mine sealing is to be seriously considered in the future, a comprehensive boring program should be implemented. Such a program would provide essential information regarding the permeable nature of the rock strata and the sealing capability of the glacial till. An in-depth analysis of the effects of mine sealing cannot be presented here without this information.

Assuming both tunnels are sealed it is possible the water will rise to at least 1865 feet elevation, which is the low point on the outcrop of the B coal which is not sealed by glacial till. If the water were allowed to rise higher, leakage would begin to occur along the outcrop. Therefore, if the tunnel is sealed the pool level in the old workings should be controlled at 1865 feet. If the water level is stabilized at 1865 feet elevation, 70% of the B coal workings east of the Bernice Fault will be inundated, and 66% of the C coal will be affected.

As pointed out, it might be possible to stabilize the mine pool elevation at 1865 feet, assuming the glacial material would provide a sufficient seal. However, since this is a conjecture based on the available information, to insure this level of inundation would be a substantial undertaking. For example, if a clay seam or barrier were to be provided, the trenching requirements to facilitate this seal would be very extensive. Trenching would range from twenty to twenty-five feet deep and would have to extend for several thousand feet along the southerly crop line of the basin.

The possibility exists that only one tunnel could be sealed, allowing free discharge of the acid mine water through the other. If only the B tunnel is sealed, the C tunnel will control the pool elevation at 1840 feet, or slightly less. In this case, 48% of the B coal and 30% of the C coal workings will be inundated.

If only the C tunnel were sealed, it is quite certain the mine water would quickly find its way to the B vein workings, since there is a considerable area where there are old B workings under the C coal. These workings are probably connected either by shafts or by collapse of rooms in the B vein. In addition, the C tunnel must pass through the B workings and it is not known how effectively this area was sealed. With the C tunnel alone being sealed, it would be possible for treatment to be provided at the B tunnel. Figure 16 is a cross-section through each tunnel, showing the relationship between tunnels and coal veins.

Following are cost estimates based on a projected takeoff of the various items required for a deep mine sealing.

SECTIONS THROUGH "B" and "C" TUNNELS

SCALE: HORIZONTAL 1" = 800' — VERTICAL 1" = 20'

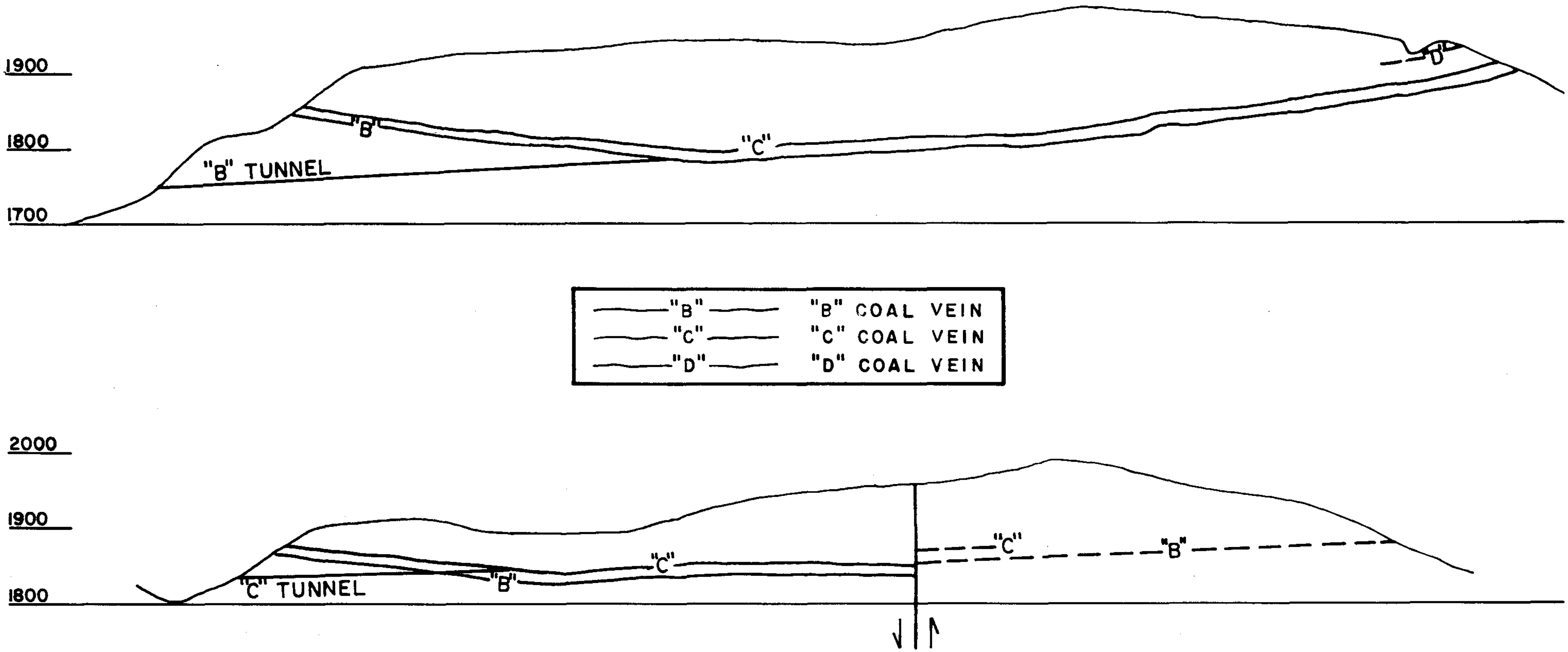


FIGURE 16

B VEIN DISCHARGE - DEEP MINE SEAL

1. Bulkhead Construction

6" Drilling	1500 L.F.	@	$10.00/L.F.	=	$15,000
Coarse Aggregate	120 Ton	@	$30.00/Ton		3,600
Concrete	70 C.Y.	@	$70.00/C.Y.		4,900

2. Observation Drill Hole

6" Drilling	100 L.F.	@	$10.00/L.F.	=	$ 1,000
6" Casing	100 L.F.	@	$25.00/L.F.	=	$ 2,500

3. Pressure Grouting and Drilling

Drilling	1000 L.F.	@	$10.00/L.F.	=	$ 6,000
Cement for Grouting	2000 sks.	@	$ 6.00/sk	=	12,000
Fly Ash for Grout	200 Ton	@	$35.00/Ton	=	7,000
Sand for Grouting	1 Ton	@	$30.00/Ton	=	30
Admixture Grout #1	100 Lb	@	$35.00/Lb	=	3,500
Grout #2	100 Gal.	@	$10.00/Gal.	=	1,000
Grout #3	100 Gal.	@	$20.00/Gal.	=	2,000
Pressure Testing	25 Hr.	@	$40.00/Hr.	=	1,000
Grout Connection	100 Ea.	@	$20.00/Ea.	=	2,000
Core Drilling	100 L.F.	@	$12.00/L.F.	=	1,200

4. Mine Voids

Coarse Aggregate	20 Ton	@	$30.00/Ton	=	$ 600
Concrete	20 C.Y.	@	$70.00/C.Y.	=	1,400

5. Mobilization and Demobilization

Lump Sum = $20,000

6. Borehole Camera Survey

Lump Sum = $2,000

7. Site Restoration

Lump Sum = $2,000

TOTAL = $88,730
$89,000

C VEIN DISCHARGE – DEEP MINE SEAL

1. Bulkhead Construction

6" Drilling	900 L.F. @	$10.00/L.F.	=	$ 9,000
Coarse Aggregate	120 Ton @	$30.00/Ton	=	3,600
Concrete	70 C.Y. @	$70.00/C.Y.		4,900

2. Observation Drill Hole

6" Drilling	60 L.F. @	$10.00/L.F.	=	$ 600
6" Casing	60 L.F. @	$25.00/L.F.	=	2,500

3. Pressure Grouting & Drilling

Drilling	600 L.F. @	$10.00/L.F.	=	$ 6,000
Cement for Grouting	200 sks @	$ 6.00/sk		12,000
Fly Ash for Grout	200 Ton @	$35.00/Ton	=	$ 7,000
Sand	1 Ton @	$30.00/Ton	=	30
Admixture				
Grout #1	100 Lb @	$35.00/Lb.	=	$ 3,500
Grout #2	100 Gal. @	$10.00/Gal.	=	1,000
Grout #3	100 Gal. @	$20.00/Gal.	=	2,000
Pressure Testing	25 Hr. @	$40.00/Hr.	=	1,000
Grout Connection	100 Ea. @	$20.00/Ea.	=	2,000
Core Drilling	66 L.F. @	$12.00/L.F.	=	800

4. Mine Voids

Coarse Aggregate	20 Tons @	$30.00/Ton		$ 600
Concrete	20 C.Y. @	$70.00/C.Y.	=	1,400

5. Mobilization and Demobilization

Lump Sum	=	$20,000

6. Borehole Camera Survey

Lump Sum	=	$ 2,000

TOTAL	=	$79,930

2. Acid Mine Drainage Treatment

The second method for abating the acid mine discharge from the deep mines is treatment. As was previously mentioned, it would be possible to seal the C drainage tunnel with the resultant flow reaching the B tunnel discharge. One single treatment plant at this point could treat the entire flow from the deep mine complex. Alternatively, each tunnel could have its own separate treatment facility, with the treated effluent reaching the Loyalsock Creek. Other than the difference in flow from the tunnels, the chemical parameters of each discharge are similar, therefore, the components and type of treatment system for each would be similar.

Several factors should be kept in mind when reviewing the systems for treating the tunnel discharge. These include:

(1) The concentration of total and ferrous iron are extremely low, thus diminishing the sludge removal aspects of the system.

(2) The concentration of acid are not severe.

(3) The volume of flow fluctuates significantly as a function of precipitation, and thus becomes a major design constraint; the design of the system for peak flows of short duration is a questionable factor.

(4) The accessibility of the treatment sites is limited.

The neutralizing agent to be used for treating the raw influent is dependent on several factors, including availability, quality, cost, and the type of system to be used. Investigations conducted with this study concluded that either limestone or hydrated lime would best be suited for this application as dictated by the treatment system. The hydrated lime or limestone would be provided from the State College area in Centre County. There the limestone has a high calcium content - approximately 96% calcium carbonate-which is desirable for maximum neutralization efficiency. The Centre County source is the closest to the study area, and is a substantial supplier of lime, etc. in the State.

As shown in the hydrogeology section of this report, with particular reference to Figure 7, the B Weir--C Weir Hydrograph, there is a wide range of flows discharging from the deep mine tunnels. Establishing an optimum design flow can be difficult, particularly in view of the economics of the treatment system to be used. Obviously, the treatment system should be such that higher than design flows will not be of long term duration and thus produce a detrimental affect on the biology of Loyalsock Creek. An examination of the stream flow data accumulated during the course of the project does not suggest any extreme variation in the water quality of Loyalsock Creek with increased tunnel flows. Furthermore, there appears to be no direct correlation between the volume of flow from the tunnels and the concentration of acid. For example, higher than average tunnel discharges do not necessarily produce lower than average acid concentrations and vice versa.

Several approaches can be considered in determining the design flow. The records from the continuous flow monitor reveal that February 1976 had the highest monthly average flows. Therefore, the design flow based on such an average would be:

B Vein Discharge - 5.4 MGD (8.3 CFS)
C Vein Discharge - 2.2 MGD (3.4 CFS)

However, it can also be seen from the hydrograph that a period of peak flows extended for a five day period. Chemical analysis performed for this period did indicate a slightly higher PH than normally recorded. The concentrations of acid, however, did not reflect a dilution factor that might be expected. Therefore, the acid load to Loyalsock Creek can be high when peak flows occur. Based on this data, maximum design flows would be in the range of

B Vein Discharge - 12.9 MGD (20 CFS)
C Vein Discharge - 5.2 MGD (8 CFS)

Obviously, this increase in flow drastically changes the scope of any treatment system and presents some severe design constraints. Of the various systems to be outlined in the following discussion, certain ones lend themselves more readily to accommodating this increased flow, such as the limestone drum method.

In order to outline a treatment system the amount of neutralizing reagent required must be determined. The average acid concentrations to be used in the design will be B Vein Discharge--34.3 MG/L. and C Vein Discharge--47.4 MG/L. With the design flow and acidity established, the parameters for calculating the alkalinity requirements are complete. Several factors concerning the alkali reagent must be considered. First, the alkali reagent has a percent purity based on the chemical formula. Secondly, the efficiency of the alkali reagent is variable depending on several factors including the solubility. Following is a list of the purity factors and efficiency plus the amount of alkali reagent needed for each discharge.

B Vein Discharge

Alkali Reagent	Purity Factor	Efficiency	5.4 MGD Lb/Alkali/Day	12.9 MGD Lb/Alkali/Day
Limestone	0.95	0.80	2,032	4,856
Hydrated Lime	0.96	0.95	1,255	2,998

		C Vein Discharge		
Alkali Reagent	Purity Factor	Efficiency	2.2 MGD Lb/Alkali/Day	5.2 MGD Lb/Alkali/Day
Limestone	0.95	0.80	1,144	2,705
Hydrated Lime	0.96	0.95	707	1,670

The following discussion will deal with specific types of treatment processes that may be used for the acid mine water in this project. The intent of this presentation is to outline a general design scheme, including treatment components, operation procedures, and locational considerations. Variations of the individual systems are certainly feasible, and should be given more extensive analysis in the design phase.

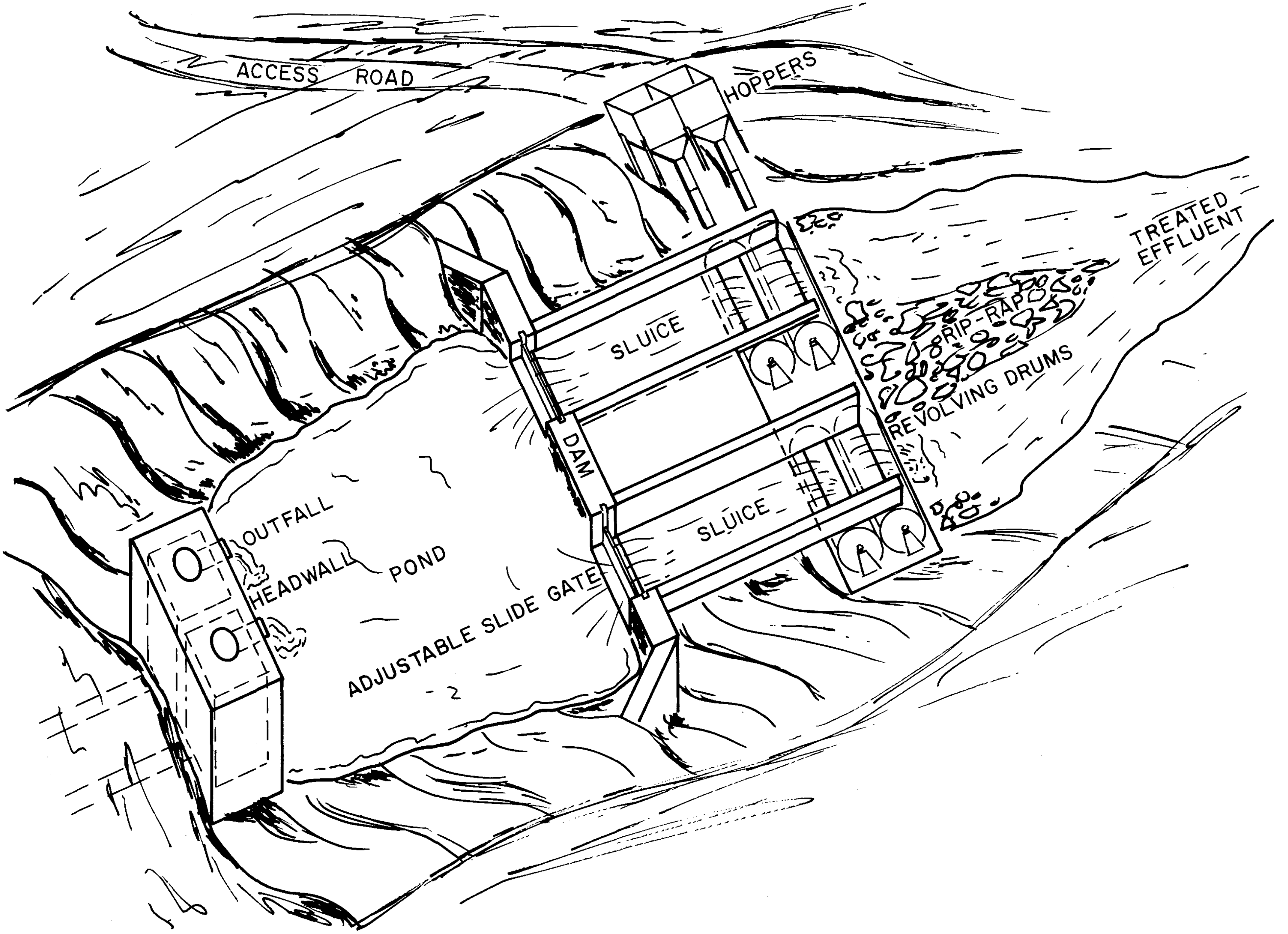
A. LIMESTONE DRUM METHOD

Zurbuch (1973) described a limestone drum method for treating an acid stream in conjunction with a project for the West Virginia Department of Natural Resources. Figures 17 and 18 show a typical installation scheme utilizing such a rotating drum, which would be applicable to the tunnel discharges in question. Various schemes using numerous drums in series and/or in parallel are possible. For purposes of discussion, two pairs of drums in parallel are shown here. Essentially a dam would be built, ponding the water just below the existing headwall. The topography at both discharge tunnels lends itself well for this application. Extending from the dam are two sluices which channel the water above the rotating drums. A sluice gate is included with the dam at the sluice opening in order to act as an adjustable weir to control the flow. Each sluice-drum assembly can be used individual or both can be used simultaneously. This feature allows for one drum assembly to be shut down during periods of low discharge, or during limestone loading and maintenance periods. A slot with a baffle is incorporated into the sluice, limiting flow to the first drum during low flow. As the discharge increases rotation on the first drum increases and excess water flows over the baffle to the next drum. It was found in the West Virginia study at Condon Run that a minimum flow of 0.5 CFS or 0.32 MGD was necessary to rotate one drum--each drum holding 1,800 pounds of limestone.

The major emphasis for maintenance of the installation concerns the loading of the drums. Although, hand shoveling of the drums was used at Condon Run, a more automated system is desirable based on the large volume of stone to be handled. A hopper with a chute would best fit this purpose. The hopper would be loaded by truck when the limestone is delivered to the site, or a backhoe could be used to load the hopper from the stockpiles when it is required.

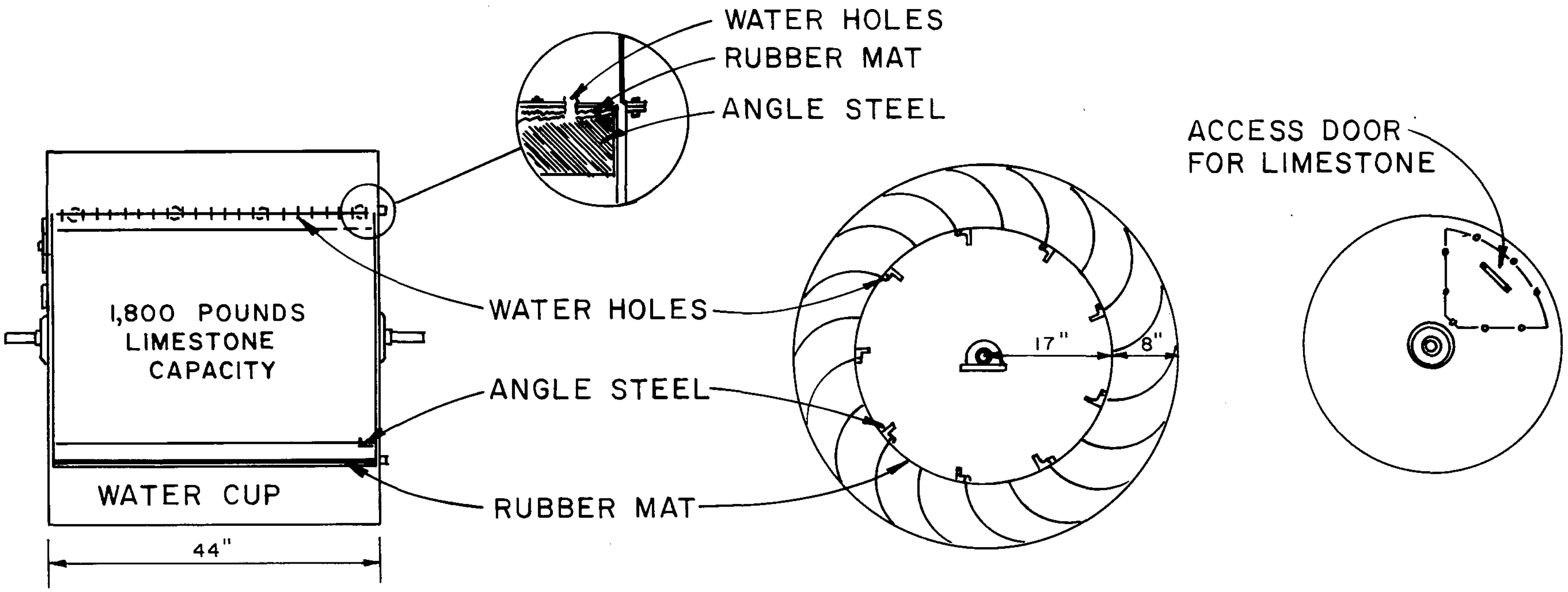
As pointed out previously, the treatment system may be equipped with any number of drums to accommodate the fluctuations in discharge. The sizing of the drums can also be varied, thus increasing the neutralizing capacity of any one drum. However, since actual operational data is only available from the West Virginia project, the drum sizing used on that project will be the basis for the alternatives presented here.

Assuming that it is desirable for maintenance personnel to service the stations once a week, it is recommended that the following minimum number

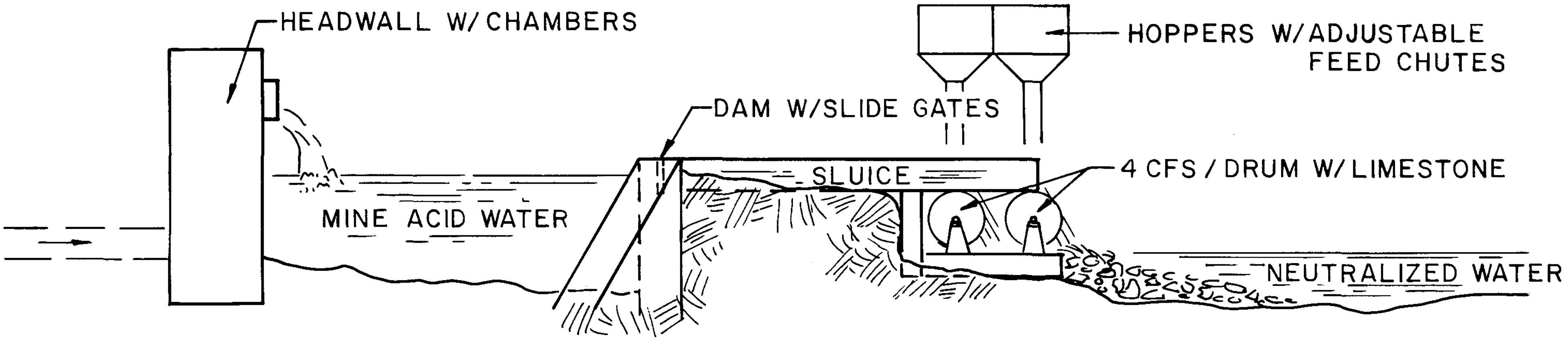


ISOMETRIC — LIMESTONE DRUM TREATMENT SYSTEM

FIGURE 17



SCHEMATIC OF LIMESTONE DRUM



SECTIONAL DIAGRAM OF LIMESTONE DRUM TREATMENT SYSTEM

FIGURE 18

of drums be provided at each tunnel based on the two (2) designated design flow.

	5.4 MGD	12.9 MGD
B Vein Discharge	8 Drums	19 Drums

	2.2 MGD	5.2 MGD
C Vein Discharge	5 Drums	11 Drums

Obviously, the total number of drums would be in operation only during periods of high flow and there would be extended periods of time when many of the drums would be idle.

In order to maintain simplicity in the treatment system it may be possible to eliminate the solids and sludge removal stages. In so doing, there would undoubtedly be increased turbidity in the resultant effluent. It was found in the West Virginia study that the stream tunnel milky downstream, but this turbidity was dissipated significantly after a short distance. Whether the solids and sludge removal stages can be eliminated from the treatment scheme is dependent upon the effluent criteria. According to the Pennsylvania Water Quality Criteria for Loyalsock Creek the minimum requirements are:

Total Iron -	not more than 1.5 MG/L.
Dissolved Solids -	not more than 500 MG/L. as a monthly average; not more than 750 MG/L. at any one time.

PH - not less than 6.0 and not more than 8.5

Estimating the amount of sludge generated from the neutralization process becomes a primary factor if the above criteria cannot be met. The amount and characteristics of sludge produced is dependent upon the raw water parameters as well as the type of neutralizing reagent. The use of a limestone reagent will produce an effluent with a high turbidity, with near colloided size limestone particles which are slow to dissolve. It is estimated that this process will produce a sludge volume of about 0.5% of the treated water volume and consisting of from 1% - 3% solids by weight. The volume of sludge generated from the tunnel discharges would be as follows:

Source	Flow	Sludge Volume
B Vein Discharge	5.4	133 Cu. Yd./Day
C Vein Discharge	2.2	54 Cu. Yd./Day

B. LIMESTONE REACTOR METHOD

Lovell (1973) described a power operated limestone reactor which was constructed as part of a research program in conjunction with Penn State

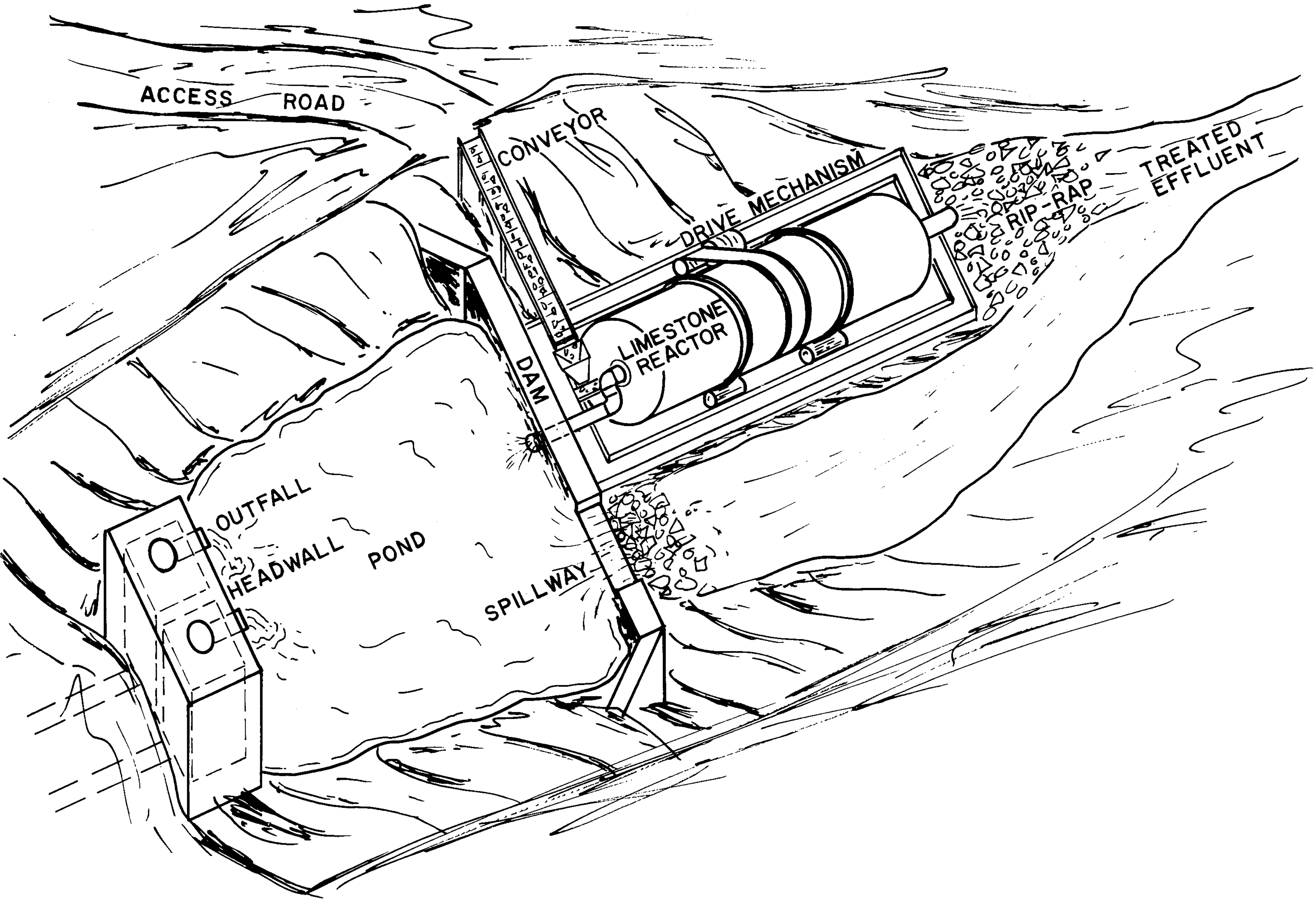
University and the U.S. Environmental Protection Agency. The entire facility was constructed at Hollywood, Pennsylvania and was a multi-scale plant examining several neutralizing agents, and utilizing several alternate treatment processes including biological oxidation, neutralization, solid-fluid separation, and sludge removal. The limestone reactor segment of the treatment plant is applicable to the design situation desired at the two drainage tunnels.

The reactor is a motor driven rotary mechanism. Figures 19 and 20 show schematic views of the reactor as presented by Lovell (1973). As with the rotating drums, a dam is constructed with an outlet pipe to funnel the raw mine water to the reactor. A spillway, with sluice gate is also provided as an integral part of the dam to allow for by-passing of untreated acid mine water during maintenance period or times of extremely high flow. The limestone is fed into the reactor by a conveyor-hopper operation. Stone size can be varied in the reactor from 3 inch stone and smaller as controlled by the internal sieve or screening design. The reactor is sloped towards the discharge point to allow for gravity feeding and treatment of the raw water as well as size distribution of the limestone. With lifters provided as part of the internal structure, the rotation allows for continuous exposure of stone surface area, and consequently enhances comminution and mixing. The Hollywood unit demonstrated its effiveness for handling over 0.25 MGD and had a projected usability to treat in excess of 0.50 MGD. It is obvious, based on the mine water volumes generated with the two tunnels that either extremely large reactors or a substantial number of reactors would be necessary for total treatment. Additional capacities for any one reactor could be realized by increased drum length and greater drum diameter. The Hollywood reactor was twenty feet in length and five feet in diameter, and thus the sizing of the reactors to accommodate the design flow becomes an engineering problem with severe design constraints. This sizing coupled with the mechanical and electrical requirements dictates the use of daily operations and servicing personnel.

C. HYDRATED LIME TREATMENT SYSTEM

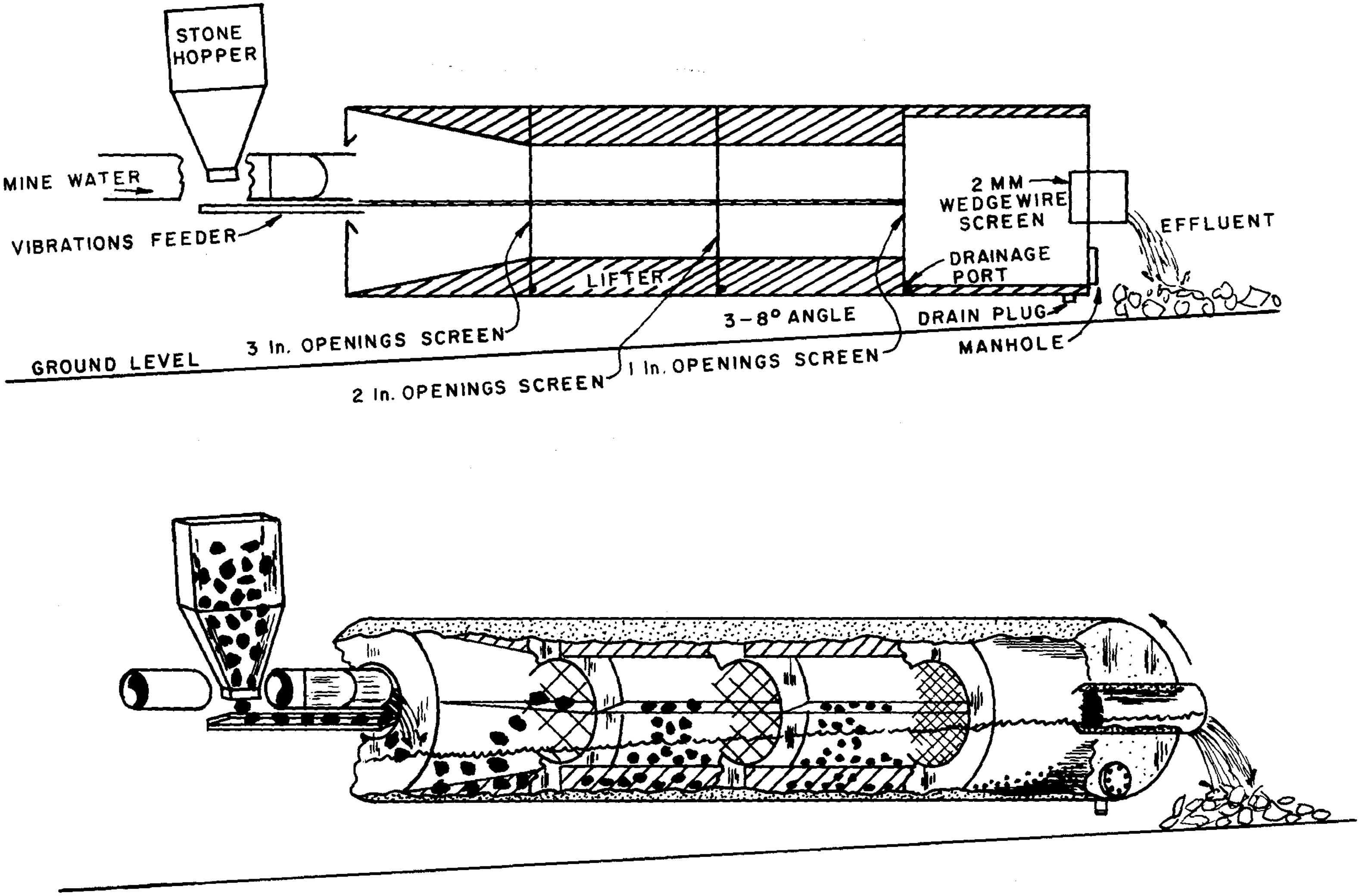
The use of hydrated lime for a neutralization system necessitates a more sophisticated process than either of the previously outlined limestone systems. Because it is possible to overtreat with hydrated lime, the monitoring of one or more of the influent chemical parameters is required. From actual operating experience at a mine drainage treatment plant on Little Scrubgrass Creek, Venango County, Pennsylvania (Dorr-Oliver Inc. 1967), it was found that with a relatively constant PH, the hydrated lime requirements can be determined by the amount of flow through the plant. With a fluctuating range of PH, more elaborate instrumentation is necessary to regulate the feeder mechanism. Essentially, this treatment plant would include the following components and system operations.

The hydrated lime would be loaded into a charging or vibrating hopper with sufficient capacity for several days operations. The hopper would converge to a volumetric feeder and solution chamber. A PH recorder controller, with PH electrode at the influent or effluent line, senses the need for treatment and starts or stops the feeder as required. The small solution chamber, attached to the feeder, provides a constant strength slurry which is discharged to a mixing tank or flocculation chamber. Here the slurry is mixed with the raw influent, this increasing PH and neutralizing the acidity load. The flocculation tanks would be equipped with two or more power driven rotors or mixers. Because



ISOMETRIC — LIMESTONE REACTOR TREATMENT SYSTEM

FIGURE 19



SECTIONAL OF LIMESTONE REACTOR TREATMENT SYSTEM

FIGURE 20

hydrated lime in this process tends not to settle the addition of flocculates is advisable. Polymeric flocculates either non ionic or weak anionic would be used. The effluent from the flocculation chamber flows to a clarifier which facilitates the removal of settleable solids. In designing a clarifier it is assumed that the overflow rate for sizing is 700 gallons per square foot per day. However, a higher overflow rate perhaps 1500 gallons per square foot per day will lessen the efficiency of the operation but will significantly reduce the size of the clarifier. The settleable solids that are collected in the clarifier are funneled to a central sump and removed. A sludge holding pond or lagoon would be needed to store and dewater the sludge until the solids are removed. With the hydrated lime treatment it is estimated that the volume of sludge will be between 5% and 2% of the volume of treated water. It is also estimated that the sludge will be 0.5% solids by weight. Therefore, the sludge generated from the hydrated lime treatment process will be:

Source	Flow	Sludge Volume
B Vein Discharge	5.4 MGD	531 Cu. Yd./Day
C Vein Discharge	2.2 MGD	218 Cu. Yd./Day

Because there is no permitted sanitary landfill near the treatment site that has provisions to handle the processed sludge, and because of the isolated location of the site, sludge disposal becomes a difficult design constraint. Trucking of sludge to disposal sites has been found to be inefficient. Pumping of the sludge once implemented provides an easier operational procedure. An abandoned strip mine located near the southerly crop line of the basin and situated equidistant from each tunnel discharge lends itself well for sludge disposal. Being approximately 2200 feet from the treatment areas it is the closest potential disposal site. Other sites to be considered for such use would be located much further to the east and would most likely be affected by future stripping operations.

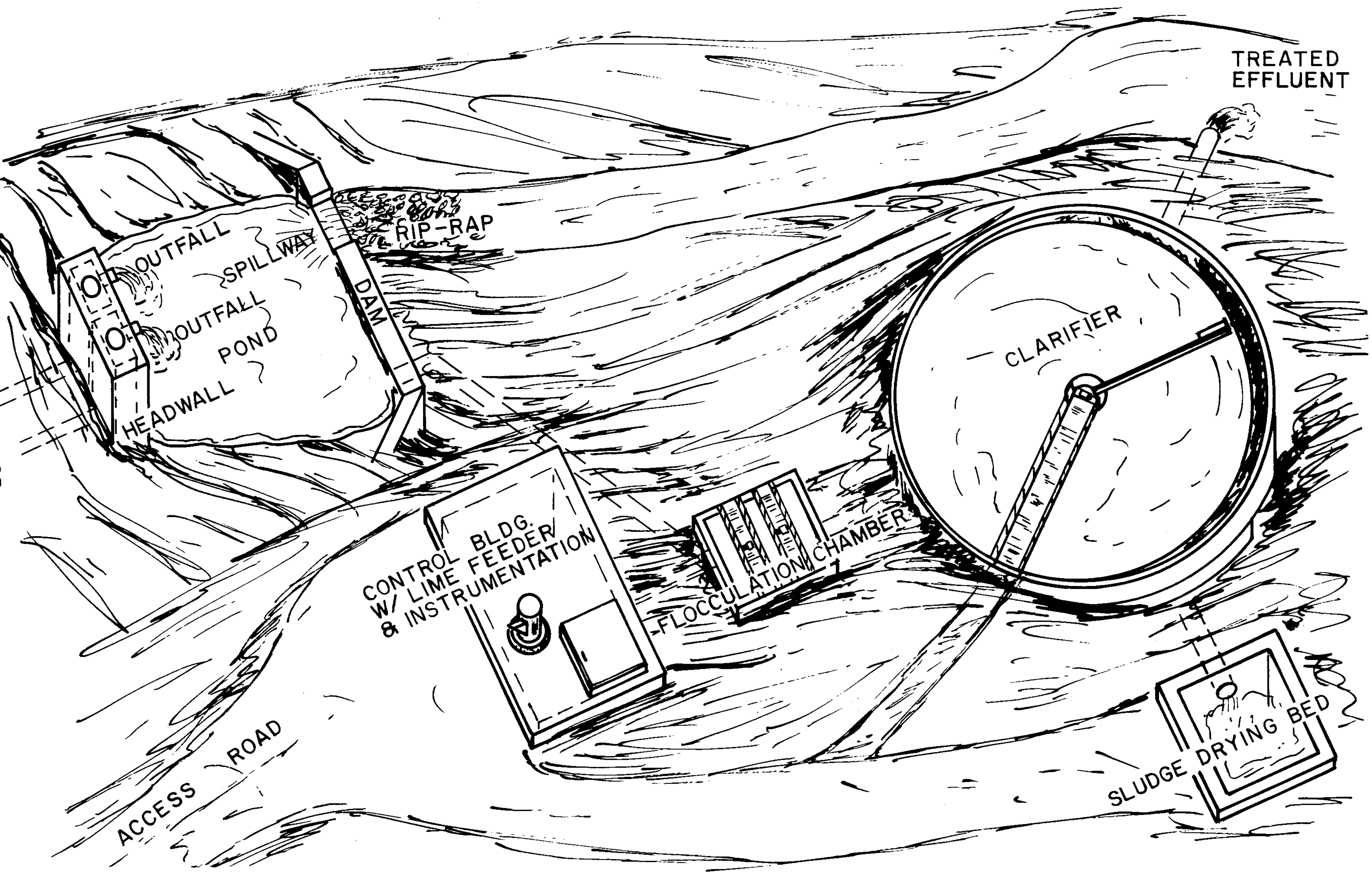
As a guideline for sizing the components of the treatment system following is an outline of the capacities required.

Source	Volumetric Dry Feeder (Ft.^{3}/Hour)	Mixing Tank L x W x H	Clarifier 700 gal/ft^2/Day	Clarifier 1500 gal/ft^2/day
B Vein Discharge	1.75	48'x24'x10'	100' Dia.	65' Dia.
C Vein Discharge	1.00	34'x17'x8'	70' Dia.	45' Dia.

Figure 22 shows a schematic section of the hydrated lime treatment system. Figure 21 presents the locational aspects of the system in relation to the discharge point.

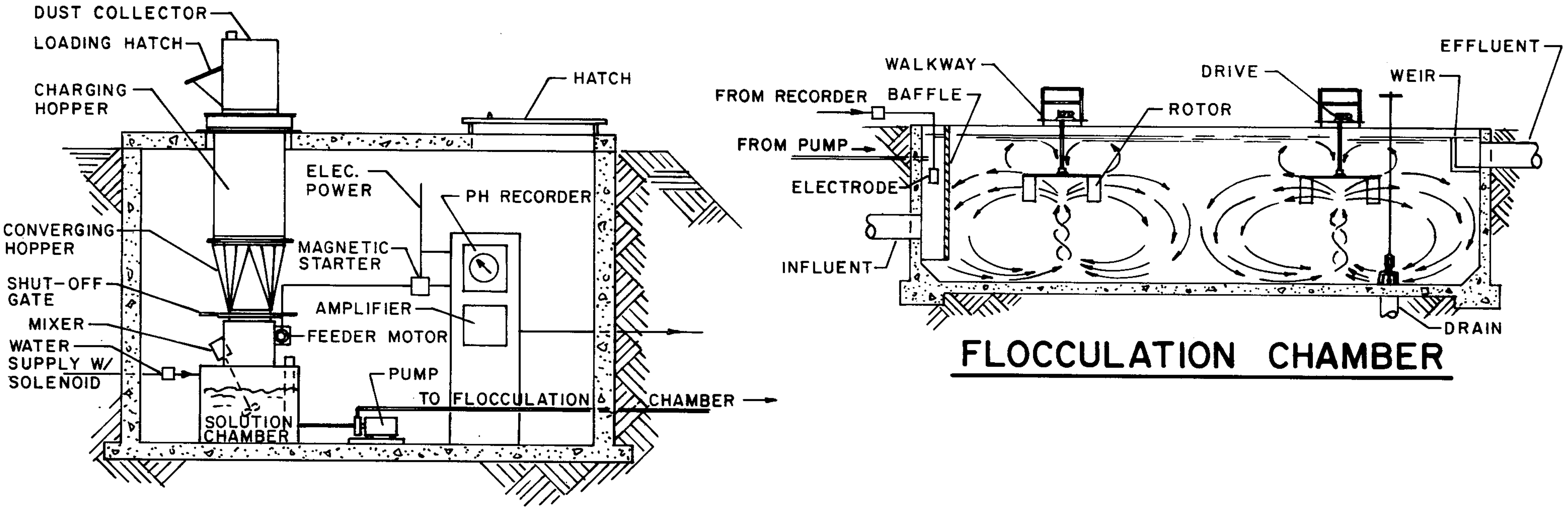
D. TREATMENT SUMMARY

As was pointed out previously, the possible variations of the individual treatment systems are numerous. Not only is it possible to use limestone or hydrated lime, but the use of soda ash, caustic soda, quick lime, and hot or bag lime is also feasible. Various demonstration projects have used combinations of



ISOMETRIC — HYDRATED LIME NEUTRALIZATION TREATMENT SYSTEM

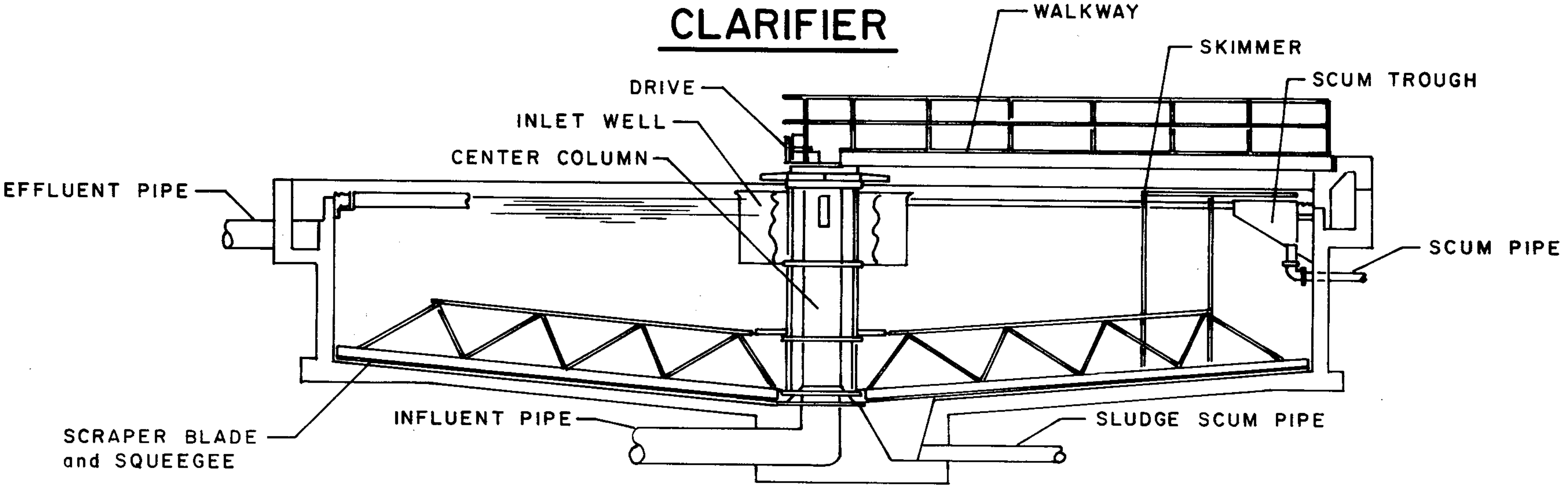
FIGURE 21



FLOCCULATION CHAMBER

CONTROL BUILDING

CLARIFIER



SECTIONAL DIAGRAMS OF HYDRATED LIME NEUTRALIZATION TREATMENT SYSTEM

FIGURE 22

neutralizing reagents such as limestone treatment followed by adding hydrated lime. Obviously, the systems outlined in this report are not all inclusive and can be equipped with additional treatment features. For example, the limestone reactor could be provided with a hydrated lime feeder to facilitate further treatment.

There are certain advantages that are inherent in the use of specific neutralizing reagents and in the resultant treatment system as described by Lovell (1973). The advantages of limestone over hydrated lime are:

(1) Lower cost per unit weight of reagent.

(2) Lower sludge volume generated.

(3) Limestone sludges have higher solids content.

(4) Overtreatment of water not possible.

(5) Limestone does not require protective enclosures, and is easy to handle.

(6) System design is simple particularly in terms of electrical and mechanical requirements (rotating drum method).

(7) Reduced plant operations and maintenance.

(8) Hydrated lime treatment requires a building for housing feeder mechanisms, PH analyses, and miscellaneous electrical and mechanical components.

(9) Size requirements of clarifier, etc., puts restraints on site selection for hydrated lime treatment.

The disadvantages of limestone treatment in comparison to hydrated lime is as follows:

(1) Reactively is less, particularly when stone surface becomes coated.

(2) Near colloidal size particles creates turbidity in the plant effluent.

(3) Carbon dioxide is formed with limestone reaction and may produce an unstable PH.

(4) If sludge removal is incorporated as part of a limestone method, the sludge weight produced may be greater than with a lime reagent.

E. TREATMENT SYSTEM COST SUMMARY

Because of the relative isolation of the discharge points, the accessibility of the site is restricted. Therefore, in addition to land acquisition for the treatment site itself, right-of-way for access to the site is also required. Following is a cost breakdown for the three treatment systems delineated in the report.

ROTATING DRUM METHOD

First Costs

	B Vein Discharge		C Vein Discharge	
Item	12.9 MGD	5.4 MGD	5.2 MGD	2.2 MGD
Land Acquisition	$ 2,000	$ 2,000	$ 2,000	$ 2,000
Access Right-of-Way	15,000	15,000	15,000	15,000
Road Construction and Site Preparation	30,000	30,000	30,000	30,000
Dam Construction	8,000	8,000	5,000	5,000
Sluice Construction	6,000	6,000	4,000	4,000
Drum Installation	19,000	8,000	11,000	5,000
Engineering	8,000	7,000	7,000	6,000
Other	2,000	2,000	2,000	2,000
TOTAL:	$90,000	$78,000	$76,000	$69,000

Annual Operating Costs

Item		B Vein Discharge - 12.9 MGD
Limestone	886 tons/year x $10/ton	$ 8,860
Labor	52 weeks/year x 22 hours/week x $10/hour	11,440
Misc. Maintenance		1,500
	Total Per Year:	$21,800

Item		B Vein Discharge - 5.4 MGD
Limestone	370 tons/year x $10/ton	$ 3,700
Labor	52 weeks/year x 16 hour/week x $10/hour	8,320
Misc. Maintenance		1,000
	Total Per Year:	$13,020

Item		C Vein Discharge - 5.2 MGD
Limestone	494 tons/year x $10/ton	$ 4,940
Labor	52 weeks/year x 14 hour/week x $10/hour	7,280
Misc. Maintenance		1,000
	Total Per Year:	$13,220

Item		C Vein Discharge - 2.2 MGD
Limestone	208 tons/year x $10/ton	$ 2,080
Labor	52 weeks/year x 12 hour/week x $10/hour	6,240
Misc. Maintenance		800
	Total Per Year:	$ 9,120

LIMESTONE REACTOR METHOD

First Costs

Item	5.4 MGD B Vein Discharge	2.2 MGD C Vein Discharge
Land Acquisition	$ 2,000	$ 2,000
Access Right-of-Way	15,000	15,000
Road Construction and Site Preparation	30,000	20,000
Dam Construction	8,000	5,000
Electrical Installation	20,000	20,000
Reactor	100,000	60,000
Engineering	18,000	12,000
Other	3,000	2,000
Total:	$196,000	$136,000

Annual Operating Costs

Item		B Vein Discharge
Limestone	370 tons/year x $10/ton	$ 3,700
Labor	52 weeks/year x 16 hours/week x $10/hour	8,320
Power	2,700,000 GPD* x $0.01/1000 gallons	9,855
Misc. Maintenance		4,000
	Total:	$25,875

Item		C Vein Discharge
Limestone	208 tons/year x $10/ton	$ 2,080
Labor	52 weeks/year x 12 hours/week x $10/hour	6,240
Power	1,000,000 GPD* x $0.01/1000 gallons	3,650
Misc. Maintenance		3,000
	Total:	$14,970

* It is assumed that the maximum design discharge will not be constant throughout the year for power usage.

HYDRATED LIME TREATMENT

First Costs

Item	5.4 MGD B Vein Discharge	2.2 MGD C Vein Discharge
Land Acquisition	$ 4,000	$ 4,000
Access Right-of-Way	15,000	15,000
Road Construction and Site Preparation	40,000	25,000
Control Building	10,000	10,000
Lime feeder-hopper	8,000	8,000
PH Controller-Instrumentation	7,000	7,000
Flocculation Chamber	50,000	30,000
Clarifier	200,000	130,000
Settling Pond	30,000	22,004
Sludge Pumps & Piping	35,000	35,000
Electrical Installation	20,000	20,000
Misc. Electrical & Mechanical	10,000	8,000
Engineering	36,000	26,000
Other	5,000	5,000
Total:	$405,000	$288,000

Annual Operating Cost

Item		B Vein Discharge
Hydrated Lime:	229 tons/year x $50/ton	$ 11,450
Labor:	52 weeks/year x 28 hrs./week x $10/hr.	14,560
Power:	2,700,000 GPD* x $0.01/1000 gallons	9,855
Misc. Maintenance		5,000
	Total:	$ 40,865

Item		C Vein Discharge
Hydrated Lime:	129 tons/year x $50/ton	$ 6,450
Labor:	52 weeks/year x 28 hrs./week x $10/hr.	14,560
Power:	1,000,000 GPD* x $0.01/1000 gallons	3,650
Misc. Maintenance		4,000
	Total:	$ 28,660

Project Area Nos. 3, 4, 5 - Abandoned Strip Mines

During the middle stages of this study, certain abandoned strip pits were examined for potential abatement measures and the above referenced project areas were defined. However, towards the end of this study, active strip mine operations were initiated in the immediate vicinity of these areas. At the time of the writing of this report, a very large segment of the northeast end of the basin had been affected making it increasingly difficult to evaluate these areas. It would be advisable that these areas be reclaimed as part of the overall restoration plan of the active stripping operations. Because of the extensiveness of the recent earth moving activities associated with these areas, to delineate specific restoration measures in terms of acreage, etc. is pointless. However, a brief description, defining each area will be presented here. A cost estimate will not be required. All three areas are shown on Figure 15.

Project Area No. 3 includes an abandoned strip mine which extends along the eastern border of the deep mine complex for approximately 2,200 feet. This stretch is not one continuous strip mine, but does include several strip pits paralleling the coal crop line. Interspaced within this entire area of disturbed earth, is a small swamp representing an area of perched water. During periods of heavy rainfall the water level in this swamp rises and has been observed overflowing into crevices and openings in the rock strata. This overflow eventually reaches the deep mine workings. The elevation of this swamp is approximately 1893 feet which is very close to the elevation of the coal vein at that point. Restoration of this entire area involves the backfilling of the strip pits as well as substantial grading over a large area. The northerly limits of this affected area has been disturbed to the extent that a steep slope is now present with the aforementioned swamp located at the toe of the slope. Grading of this area will entail the use of terracing to control surface runoff. Emphasis in this area will be to eliminate the swamp and its potentiality as a source of deep mine water recharge.

Project Area No. 4 is situated at the extreme northeasterly end of the basin on the periphery of the deep mine complex. The major area of concern centers around the three strip pits which have accumulated water. There is evidence that during periods of heavy rainfall as the water level in these pits rises, rock crevices in these pits may serve as direct avenues for infiltration to the deep mines. At or near these points the deep mines were terminated due to the close proximity of the coal veins to the surface. The westerly most strip pit is particularly important due to the adjacent swamp to the northeast. The water entering the strip pit and consequently reaching the deep mine system is augmented by surface water flowing from this adjacent swamp. This flow is not continuous throughout the year, with only some minor seepage trickling into the pit during the drier summer months. However, during periods of increased runoff, particularly in the winter months, a definite stream flow, estimated at several hundred gallons per minutes has been observed feeding this strip. The swamp supplementing the runoff to this pool is part of the watershed of a tributary of Pigeon Creek, and includes a significant drainage area. This accounts for the increase in flow to this pond during heavy rains and spring thaws. Restoration will include backfilling of strippings, grading the entire site, soil treatment, and revegetation. In addition, a diversion ditch will be required to channel the previously mentioned stream flow away from the affected area.

Project Area No. 5 is also on the periphery of the deep mine complex and includes several small strip pits with adjacent areas of perched water.

Abatement Recommendations

Backfill and Grade Stripped Areas
Soil Treatment and Revegetation
Diversion Ditching

Property Ownership

Surface	Mineral
Romuld A. Deinorwicz Sewell, New Jersey	Romuld A Deinorwicz Sewell, New Jersey

Project Area No. 6 - Abandoned Strip Mines

Midway between Murray and Bernice just north and just south of Pennsylvania Route 487, are located several abandoned strip pits, one of which has accumulated water. As with the other project areas these strippings are on the outer limits of the deep mine complex, and may aid in the infiltration of water to the deep mines. Restoration will include backfilling, regrading, and revegetation. Project Area is shown on Figure 14.

Abatement Recommendations and Costs

Items	Amount	Unit Cost	Total Cost
Backfill & Grade Stripped Area	42,000 C.Y.	$0.75/C.Y.	$31,500
Soil Treatment & Revegetation	4 Acres	$765/Acre	3,060
		Total	$34,560

Property Owners

Surface	Mineral
White Ash Land Association Mildred, Pa.	Michael and Joan Comerford Scranton, Pa.
Joseph Pernisi	Joseph Pernisi

Project Area No. 7 - Refuse Piles-Siltation Basin

Approximately one-half mile east of the town of Bernice, as shown on Figure 13, there exist the remains of a former coal processing area, including a breaker, refuse or culm piles, and siltation basins. The eventual runoff from this area reaches a pond on the southerly side of Pennsylvania Route 487. As discussed in the sample analysis section of this report, Sampling Point No. 45 is located at this siltation basin and demonstrates a high pollution factor as a result of these spoil piles. The water in this basin eventually reaches the swamp area north of Route 487 and subsequently Birch Creek (Sampling Point No. 44).

With the development of the active strip mine operations, as designated in Project Areas No. 3, 4 and 5, this project area is presently being utilized for coal processing with a breaker and appurtenant structures. Any abatement measures would have to be coordinated with these processing operations.

The scope of restoration required is extensive including the removal of refuse piles, grading, soil treatment, and revegetating. The refuse pile removal would be used in some of the project areas previously outlined, for backfilling purposes. However, it is doubtful whether all of this material could be utilized. Because of the nature of the material present at this site, revegetation would be more extensive in terms of soil preparation and planting. As has been pointed out, the pollution loading from this area is not critical and the restoration will provide mostly an aesthetic benefit.

Abatement Recommendations and Costs

Item	Amount	Unit Cost	Total Cost
Refuse Removal	150,000 C.Y.	$2.00/C.Y.	$300,000
Grading	16 Acres	500.00/Acre	8,000
Revegetation	16 Acres	1,000.00/Acre	16,000

Total: $324,000

Property Owner

Surface	Mineral
Barca Land and Coal Co.	Barca Land and Coal Co.
White Ash Land Association Mildred, Pa.	Joan and Michael Comerford Scranton, Pa.

Project Area No. 8 - Abandoned Strip Mine

At the southerly side of the Bernice Basin approximately 2400 feet west of the B vein tunnel discharge, an abandoned strip mine is located on the edge of the deep mine workings. Reclamation would be aimed at preventing surface water from infiltrating to the deep workings which are relatively close to the surface. Restoration would entail backfilling, grading, and revegetation. Project Area is shown on Figure 14.

Abatement Recommendations and Costs

Item	Amount	Unit Cost	Total Cost
Backfill and Grade Stripped Areas	22,200 C.Y.	$0.75	$16,650
Soil Treatment and Revegetation	1.2 Acres	$765	918
		Total:	$17,568

Property Owner

Surface	Mineral
White Ash Land Association Mildred, Pa.	Joan and Michael Comerford Scranton, Pa.

Project Area No. 9 - Abandoned Strip Mines

Figure 13 shows an area of abandoned stripping located approximately 3400 feet west of the C vein tunnel discharge. This area includes three (3) pits filled with water (Sampling Points 56, 57, 58) plus additional stripped openings in close proximity to the coal crop line or limits of the deep mine working. This project area is just west of the Bernice Fault, and the impact of any infiltration to the deep mines at these points would be minimal. Restoration would include backfill, grading and revegetation.

Abatement Recommendations and Costs

Item	Amount	Unit Cost	Total Cost
Backfill and Grade Stripped Areas	27,800 C.Y.	$0.75/C.Y.	$20,850
Soil Treatment and Revegetation	3.2 Acres	$765.00/Ac.	2,448
		Total:	$23,298

Property Owners

Surface	Mineral
White Ash Land Association Mildred, Pa.	Francis and Carl Bliss Dushore, Pa.

Project Area No. 10 - Abandoned Strip Mine and Resultant Discharge

Figure 12 shows the location of this project area which coincides with the location of Sampling Points No. 46 and 47. Sampling Point No. 46 is an abandoned strip pit with accumulated water being replenished by surface runoff and direct rainfall. This pit contributes to the flow of groundwater--groundwater being responsible for the stream (Sampling Point No. 47) which flows to Birch Creek. It is felt that the backfilling of the strip pool would limit or impede the direct recharge of the groundwater and consequently, reduce the amount of water surfacing at Sampling Point No. 47.

Abatement Recommendations and Costs

Item	Amount	Unit Cost	Total Cost
Backfill and Grade Stripped Areas	6,944 C.Y.	$0.75/C.Y.	$5,208
Soil Treatment and Revegation	0.2 Acre	$765.00/Ac.	153
		Total:	$5,361

Property Owner

Surface	Mineral
White Ash Land Association Mildred, Pa.	Carl and Francis Bliss Dushore, Pa.

Project Area No. 11 - Gutten Drift Discharge

Figure 12 shows the location of the Gutten Drift, Sampling Point No. 48. Because of the lack of reliable data, particularly early mining maps, it is not clear what is the size of the area drained by this drift. The rock strata around the drift relates to the dip of the coal. Because of the small amount of flow from this drift, a mine sealing project, as opposed to treatment, might be applicable to abating the discharge. However, more information concerning the stratigraphy and hydrology of this deep mine would be necessary. On the south side of the Basin, particularly east of the Gutten Drift, other drifts are known to have been used. It is possible that sealing the Gutten Drift may lead to a new discharge from one of these other drifts. A sealing project would undoubtedly require a grout curtain either side of the bulkhead to seal those areas where collapse of the rock strata is evident.

Abatement Recommendations and Cost

Item	Cost
Deep Mine Seal	$50,000

Property Owners

Surface	Mineral
Dwight Lewis Hillsgrove, Pa.	Carl and Francis Bliss Dushore, Pa.

Project Area No. 12 - Refuse Piles

Figure 12 shows the location of refuse banks that lie just south of Birch Creek. Runoff from these piles reaches Birch Creek and as has been noted at Sampling Station No. 18 causes some siltation. At the base of the largest culm pile in this project area, is a small pond (Sampling Station No. 55) which receives runoff from these piles as well as a portion of the discharge from the Gutten Drift. Consequently, the acid load that reaches Birch Creek from this area is not totally a product of runoff from the culm piles. Restoration would involve the removal of the refuse piles which could be used for filling abandoned strip pits. In addition, grading, soil treatment, and planting would be extensive. Probably not all of the refuse could be used for backfilling in other project areas.

Abatement Recommendations and Costs

Item	Amount	Unit Cost	Total Cost
Refuse Removal	80,000 C.Y.	$2.00/C.Y.	$160,000
Grading	10 Acres	$500.00/Acre	5,000
Revegetation	10 Acres	$1,000.00/Acre	10,000
		Total:	$175,000

Property Owner

Surface	Mineral
Dwight Lewis Hillsgrove, Pa.	Carl and Frances Bliss Dushore, Pa.

Project Area No. 13 - Abandoned Strip Mine

On Figure 12 is shown Sampling Point No. 50 at the opening of this abandoned strip mine. The bottom elevation of the strip is readily accessible from an adjoining road. As pointed in the sample station analysis, the water from this strip comes from surface runoff and some lateral movement of groundwater. The pollution factor from this area is small, not only at its source but particularly downstream where the flow becomes dissipated and less definitive. Restoration would entail the backfilling with refuse material, grading, and revegetation.

Abatement Recommendations and Cost

Item	Amount	Unit Cost	Total Cost
Backfill and Grade Stripped Area	29,600 C.Y.	$0.75/C.Y.	$22,220
Soil Treatment and Revegetation	0.5 Acre	$765.00/Ac	383
		Total:	$22,603

Property Owner

Surface	Mineral
Dwight Lewis Hillsgrove, Pa.	Dwight Lewis Hillsgrove, Pa.

Project Area No. 14 - Abandoned Strip Mine

Sampling Points 51, 52, 53 and 13 define the limits of this project area as shown on Figure 12. Two abandoned strip pits are being continuously fed by a surface stream from adjacent swamp area. The water in the strip pits certainly contributes to the flow of water surfacing below the pools. This surfacing stream drains towards Loyalsock Creek. By backfilling these strippings and diverting the surface water away from this area, the amount of water discharging to the surface would be reduced. Because the water quality of the incoming surface stream, pits, and discharging flow are all similar, the pollution impact of these strippings is minimal.

Abatement Recommendations and Cost

Item	Amount	Unit Cost	Total Cost
Backfill and Grade Stripped Area	37,000 C.Y.	$0.75/C.Y.	$27,750
Soil Treatment and Revegetation	0.5 Acre	$765.00/Ac.	383
Diversion Ditch	200 L.F.	3/L.F.	600
		Total:	$28,783

Property Owner

Surface	Mineral
Dwight Lewis Hillsgrove, Pa.	Francis and Carl Bliss Dushore, Pa.