EVALUATION OF MINE SEALING IN BUTLER COUNTY, PENNSYLVANIA

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INTRODUCTION

Mine drainage from abandoned deep mines is considered to be the major source of pollution in most areas of the bituminous coal fields. New techniques for source abatement, including deep mine sealing methods for both active and abandoned mines, are being developed by industry and governmental agencies. The Pennsylvania Clean Streams Law of 1966 requires all active deep mines to control mine drainage during the active operations and submit plans of how a pollutional discharge will be prevented after completion of mining. Presently, Operation Scarlift, a program conducted by the Pennsylvania Department of Environmental Resources, includes 44 mine sealing projects in abandoned mines. Of this total, 4 projects are completed, 37 are in progress and 3 are contemplated.

Included in this paper is a brief description of the various types of mine seals and a discussion of two of the Operation Scarlift Projects, SL 105-3 and SL 110-1BD. Both projects are located in Butler County in Western Pennsylvania. Project SL 105-3 is in the Moraine State Park, including the North Corridor, and Project SL 110-1BD is located in the Argentine and Whiskerville areas.

GENERAL CONSIDERATIONS

In addition to the various types of mine drainage treatment for both active and abandoned deep mines; techniques for control of mine drainage, particularly from abandoned mines, include source abatement by mine entry sealing, surface sealing, internal sealing, grouting, and various methods for dispersion or dilution of pollutants. Source abatement, including all types of mine sealing should be the initial consideration for abandoned deep mine drainage control; however, some deep mine conditions are so complex that source abatement by itself, may not be feasible. A combination of several techniques may be required to effectively abate the polluted water under these conditions.

Deep mine sealing is defined as the closure of mine entries, drifts, slopes, shafts, subsidence holes, fractures and other openings into underground mines with clay, earth, rock, timber, concrete blocks, brick, steel, concrete, fly ash, grout and other suitable materials. Mine seals have been classified into three general types as follows:

Air Seals

Conventional air-sealing consists of sealing of all mine openings into the mined area except for one or more openings at the lower elevations of the mine. A wet mine seal with an air-trap is installed in the one or more openings at these lower elevations. The function of the air seal is to exclude air from entering the mine but permitting normal flow of water at the discharge. The success of an air-mine sealing project will depend on the ability to effectively seal off the source of air supply to the mine. Previous experience has indicated this to be difficult; and, as a result, there has been only limited improvement in water quality in many cases.

Dry Seals

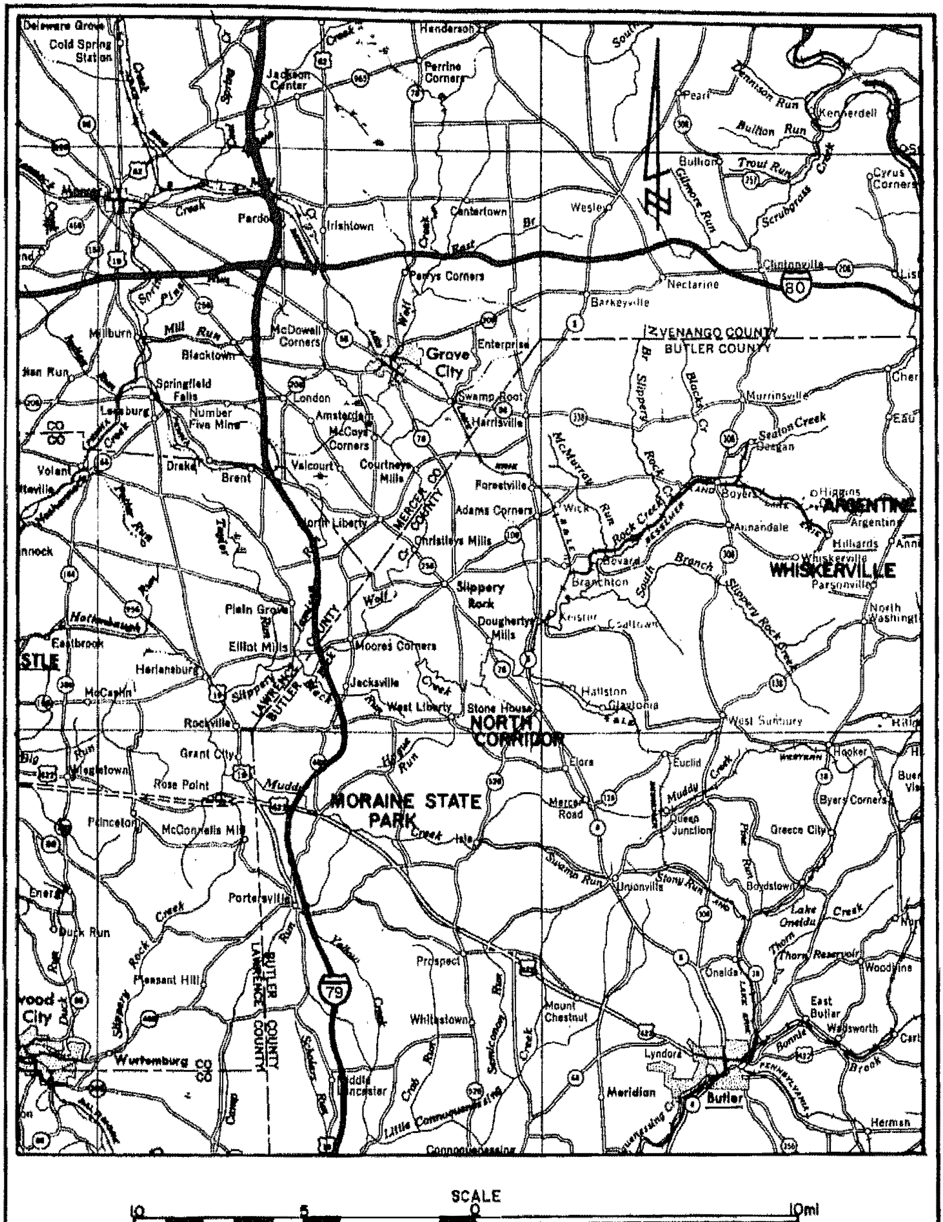
The installation of dry seals or surface sealing consists of the closure of mine drifts, slopes, shafts and subsidence areas where there will be very little or no hydrostatic pressure in the area of the seal. These seals are usually installed at the higher elevations in a mine with the mine workings to the dip, or at locations in a mine that will not be inundated. Construction of dry seals can vary from concrete block barriers in a mine entry to the filling of openings with clay, concrete or other suitable material.

Hydraulic Seals

The installation of hydraulic or wet deep mine seals consists of the sealing of mine entries, drifts, slopes, shafts and adjacent strata where there will be hydrostatic pressure in the area of the seal. Effective pressure grouting of the strata adjacent to the mine seal to prevent flow of water through the strata and, the installation of a water-tight bulkhead capable of withstanding the maximum hydrostatic head are the major factors to be considered in the construction of the hydraulic seal. Hydraulic seals include both the placement of barriers at the entries into the underground mine and the internal seal or underground dam placed well within the deep mine to isolated or impound water.

In areas where deep mine sealing work is contemplated, a thorough examination must be made before any seals are constructed. Natural conditions which will influence the techniques and methods to be used include the topography, surface drainage, ground water levels, geologic structure, strike and dip, folding, faults, washes, anticlines, synclines, fracturing and the composition and stratigraphy of the coal seams and associated strata. Mining parameters to be considered include the condition, type and extent of mine workings in the mine to be sealed and its relationship to other mines, active and abandoned, in the same and other coal seams in the area.

The condition of the mine portals to be sealed will determine the method of construction. Remote installation of mine seals are recommended when the entries are caved at the portal and it is not feasible to re-open the entries due to major expenditure involved. Installation in accessible entries is generally preferred as it affords the opportunity for direct insitu construction and visual inspection of conditions.



LOCATION MAP

FIGURE 1

BACKGROUND INFORMATION

Moraine State Park & North Corridor

The main objective of the deep mine sealing and other pollution abatement projects in the Muddy Creek Watershed of the Moraine State Park was to insure good water quality in Lake Arthur. Water quality data between the years 1963 to 1969 indicate Muddy Creek varied from a pH 5 to pH 7. The water quality of the stream during this period remained slightly on the alkaline side. The stream had been classified as variable to predominately alkaline with intermittent acid slugs. The Report of Mine Drainage Project MD-8A of May 10, 1968 indicated over 80% of the acidity came from the abandoned deep mines. On the basis of this study, recommendations were made and approved in 1968 to install hydraulic seals in all deep mine openings with the mine workings to the rise and with acid mine water discharges.

The Muddy Creek Watershed area includes 22 abandoned deep mines. The Big Run Watershed area in the North Corridor has a single deep mine. All of these mines range from small to medium size operations in the Middle Kittanning or C coal seam. Most of the operations appear to be isolated from each other; however, there are a few indicated interconnected deep mine workings. The map on the following page (Figure 2) indicates the approximate limits of the deep mined areas and the location of both the hydraulic and surface seals. The existing strip mine areas have been deleted from this map in order to produce better clarity in the deep mine areas. As a result, there are several areas where the strip mines and deep mines are intercepted that are not indicated on the map.

During the period for construction of the dam for Lake Arthur and other facilities for the Moraine State Park, several mine drainage abatement projects were performed. The remedial work included strip mine reclamation, deep mine sealing, grouting, surface sealing, refuse pile removal and oil and gas well plugging. Of all the pollution abatement projects performed, the deep mine sealing was the most effective in the reduction of acidity, and at the same time, the most expensive. A total of 93 mine openings were involved in the mine sealing work; 23 dry or surface seals and 69 hydraulic seals. The 69 hydraulic mine seals were installed under Project SL 105-3. This consisted of 65 mine seals installed in the Muddy Creek Watershed and 4 mine seals in the North Corridor in the Big Run Watershed area. The construction work for the hydraulic seals and grouting was performed by B.H. Mott & Sons, Inc. from February 1969 to August 1971.

In the Muddy Creek Watershed area there were a total of 85 weirs that were initially installed at all known mine drainage discharge points. Periodic sampling and field measurements were started in May 1967 and were continued at least once a month through June 1971. This work was performed for the Commonwealth of Pennsylvania under Mine Drainage Project MD-8 and CR-85, and for the Environmental Protection Agency under Project 14010DSC. In Big Run Watershed area, water samples and flow measurements were made monthly during the year of 1969 as part of the Slippery Rock Creek Mine Drainage Pollution Study. In addition to the sampling at the weir locations, water depths and samples were obtained in the mine observation holes after completion of the individual seals on a periodic basis until July 1971. From July 1971 through December 1971, spot checks and samples were made with complete field measurements and sampling during the month of December.

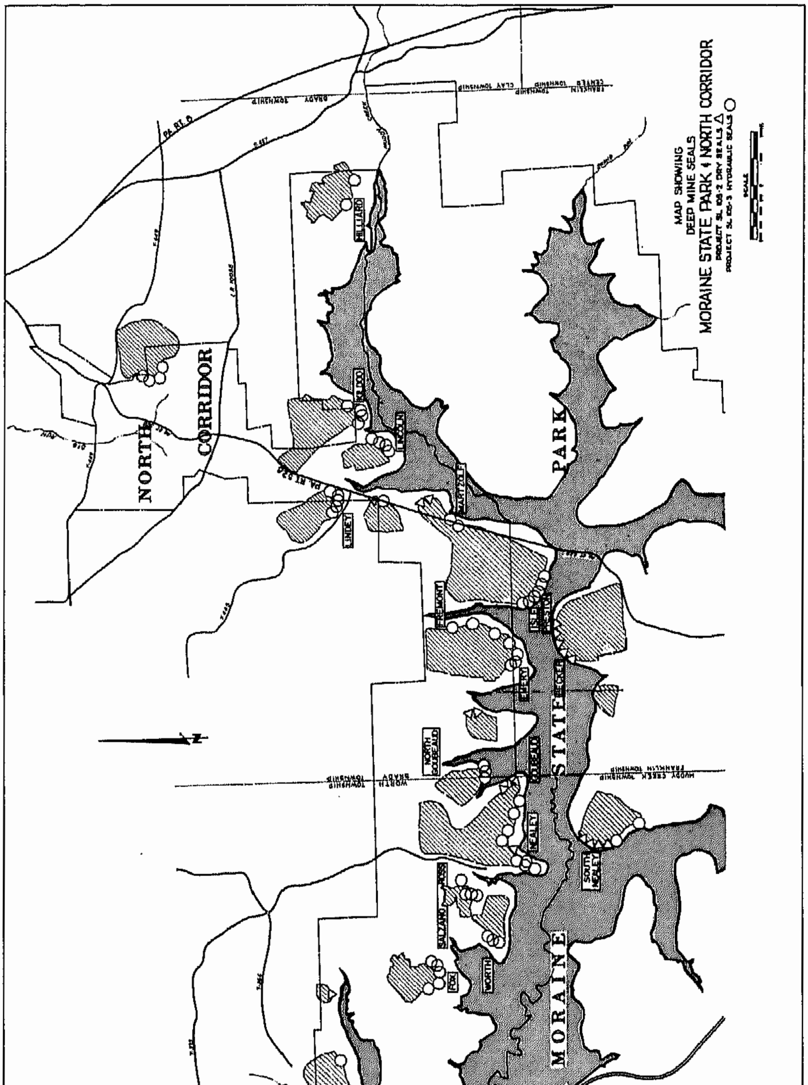

MAP SHOWING
DEEP MINE SEALS
MORAINE STATE PARK & NORTH CORRIDOR
NORTH CORRIDOR
MORAINE STATE PARK

FIGURE 2

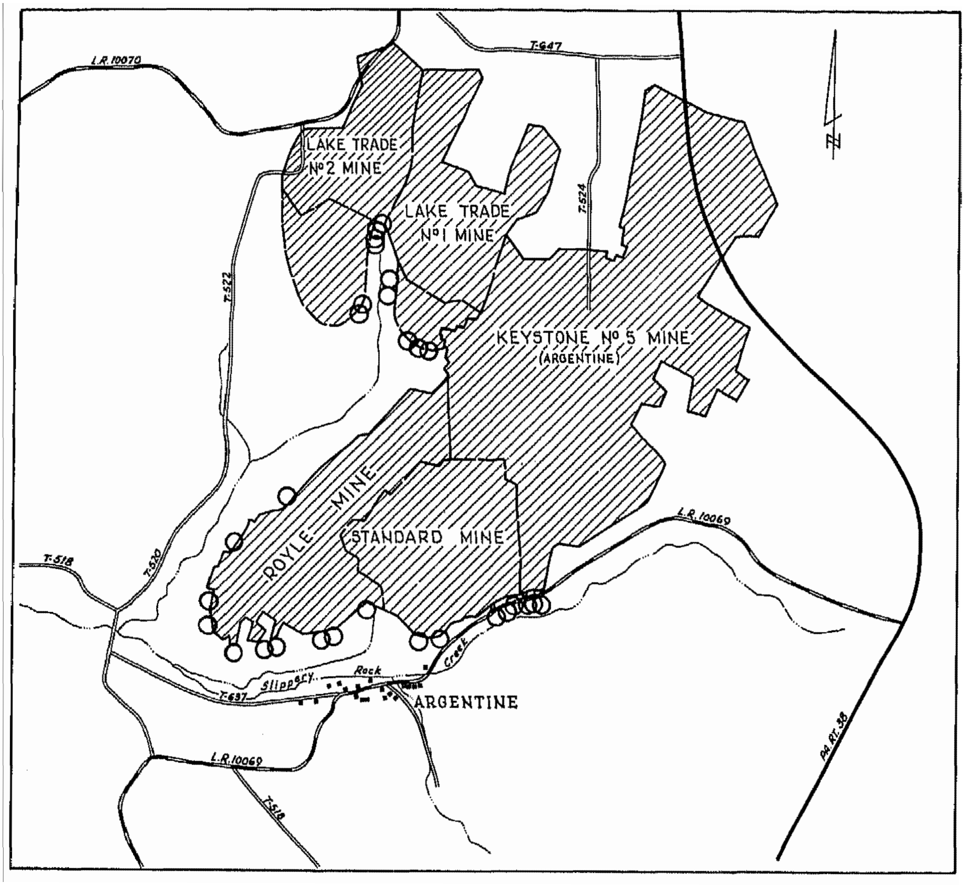
Argentine & Whiskerville

A comprehensive mine drainage study was conducted in the Slippery Rock Creek Watershed in 1969. As a result of that study, recommendations were made for source abatement of mine water pollution from abandoned deep and strip mines. High priority ratings were assigned to projects which would accomplish a substantial reduction in acid loadings. Abandoned deep mines in the eastern headwaters of the watershed were largely designated as first priority projects. On this basis, approval was given for mine seal construction in the Argentine-Whiskerville Areas.

The Argentine and Whiskerville project areas are located in the headwaters of the main stem of Slippery Rock Creek in the eastern end of the watershed. The Argentine area includes the largest deep mined area in the Slippery Rock Creek Watershed. This mining complex, in the Clarion seam of coal, consists of five contiguous mines: Royle, Standard, Keystone #5, Lake Trade #1 and Lake Trade #2. The existing mine maps of the various operations used in the preparation of the project plans indicate numerous cut-throughs and thin barriers between the mines. The deep mine sealing project area at Whiskerville consists of a small deep mine in the Middle Kittanning seam of coal. The location of the hydraulic seals and applicable deep mine areas are indicated on Figure 3 for Argentine and on Figure 4 for Whiskerville. Other deep mines west and south of the project area in Argentine and a strip mine situated southeast of the Whiskerville deep mine have been deleted from the maps for clarity.

A total of 32 hydraulic mine seals are included in Project SL 110-1BD; 30 seals are located in the Argentine mine complex and 2 seals in Whiskerville. Also included in the Argentine area are several hundred feet of grout curtain at two locations along the coal outcrop. The construction work for the hydraulic sealing and grouting is being performed by the Allied Asphalt Company, Inc. This work was started in August 1970 and by January 1972 a total of 29 seals had been completed with all three of the remaining seals and curtain grouting in the final stages of construction. In addition to mine sealing, there are other mine drainage abatement projects recommended in both the Argentine and Whiskerville Areas. This work, as indicated in the Slippery Rock Creek Mine Drainage Pollution Study, includes refuse pile and stream channel reclamation in Argentine and strip mine reclamation in Whiskerville.

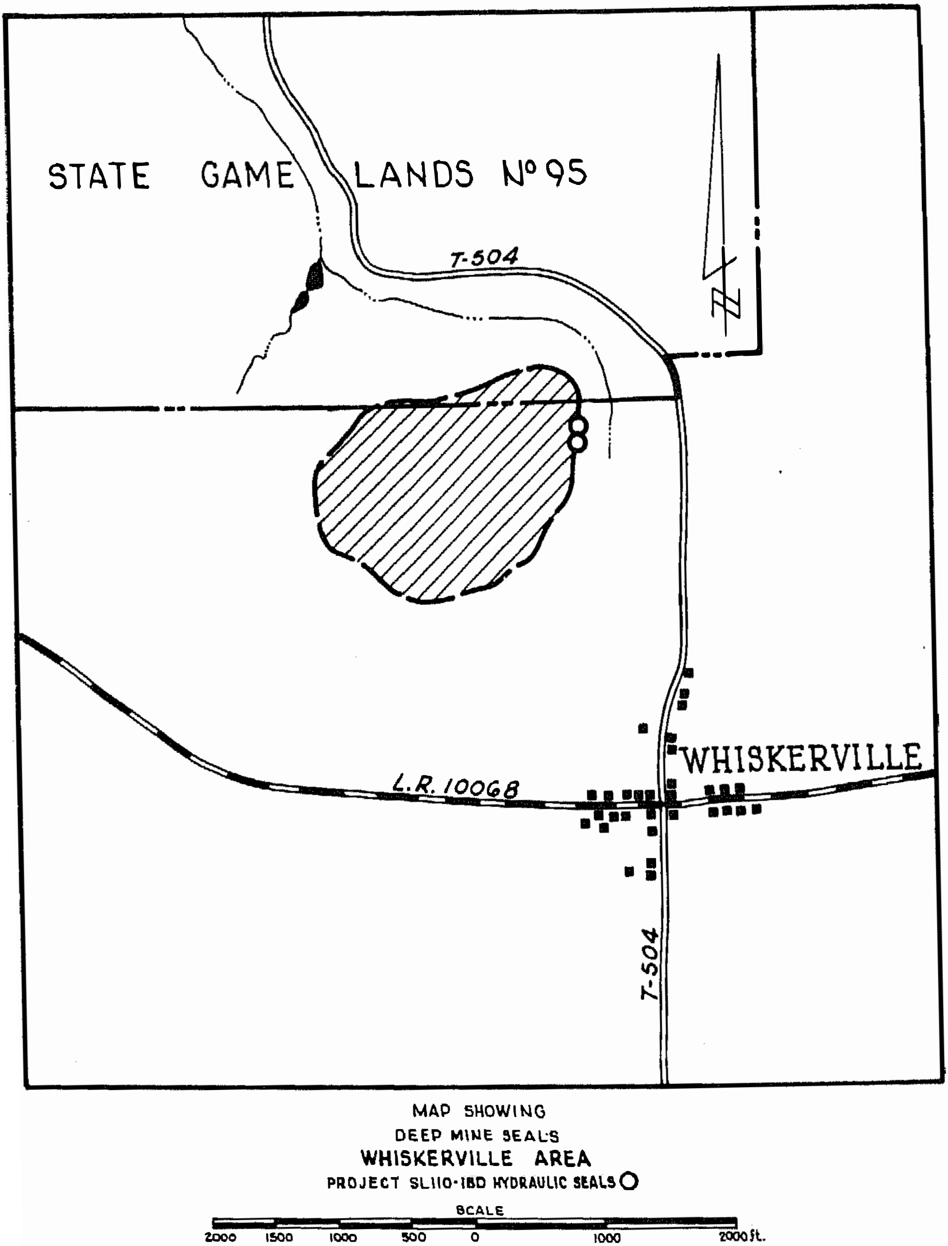
Discharges from the abandoned deep mines were monitored at seven locations in the project areas. Six of these locations were in Argentine and one in Whiskerville. Samples and flow measurements were obtained monthly during 1969 at the seven locations as part of the Slippery Rock Creek Mine Drainage Pollution Study. A total of six deep mine observation holes, five in Argentine and one in Whiskerville, were installed. Mine water levels and discharges from the applicable mines were checked as part of the routine inspection by the resident engineer and inspectors during the construction phase. In addition, water samples from the mine drainage discharge points, mine observation holes and stream locations were collected and analyzed in January 1972.



MAP SHOWING
DEEP MINE SEALS
ARGENTINE AREA
PROJECT SL110-1BD HYDRAULIC SEALS ○

SCALE
2000 1500 1000 500 0 1000 2000 ft.

FIGURE 3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MAP SHOWING
DEEP MINE SEALS
WHISKERVILLE AREA
PROJECT SL110-18D HYDRAULIC SEALS
SCALE
2000 1500 1000 500 0 1000 2000 ft.

FIGURE 4

DISCUSSION OF RESULTS

Moraine State Park & North Corridor

Table 1 indicates average values before and after mine sealing in the Muddy Creek Watershed Area of the Moraine State Park. A comparison of these values indicate an overall reduction in the discharge flow rates from 146 to 57 gallons per minute (60%), an overall reduction in net acidity from 501 to 160 pounds per day (68%) and an overall increase iron from 34 to 42 pounds per day (24%).

All of the 19 mines in the project had mine discharges prior to sealing with the exception of the Worth Mine. This mine was included in the sealing due to possibilities of the interconnection with the Salzano Ross Mine and probable inundation of both mines.

The discharge rates after sealing indicate eight mines have no flows, one mine has an average of less than 1 gallon per minute, eight mines have reduced flow rates, one mine has the same flow rate and one mine increased from 1 to 2 gallons per minute.

The acid loading after sealing indicate eight mines with no acid production, two mines with less than 1 pound per day and a reduction in acidity in all of the other mines with the exception of one mine where the production average remained the same. All of the larger acid producers had substantial reductions with the exception of the Lincoln Mine.

Most of the mines indicated a reduction in iron after sealing with the exception of the Lindey and Lincoln Mines. Both of these mines had increased production after sealing.

Table 2 is information compiled from the Mine Observation (MO) Hole data. This table includes the name of the mine; the estimated minimum and maximum elevations of the mine; the Mine Observation (MO) Hole number and elevation at the bottom of the coal or mine in the (MO) hole; and the minimum and maximum water elevations in the mine as measured in the (MO) hole as the inundation elevations. This information indicates two mines are completely flooded under both high and low mine water conditions; seven mines are completely flooded under high mine water conditions and partly flooded under low; eight mines are partly flooded under high to normal mine water conditions and one mine reported with less than one foot of water under all conditions. Mine observation hole measurements were reported on a periodic basis starting in 1970 or after completion of the applicable mine seal.

This information indicates fluctuating pool levels in most of the mines. Generally the pool levels will vary following changes in precipitation and infiltration. The majority of the mines had changes in pool levels between one to five feet. The inundation elevations shown in (-) indicate a limited number of measurements due to a caved or blocked hole or insufficient time after completion of the seal. Water quality information as determined from the (MO) hole samples indicate ten of the mines had alkaline mine, three had acid water and five had both acid and alkaline mine water during the test period. Both of the mines that were completely flooded and eight of the partly flooded mines had alkaline water. Five of the partly flooded mines had both acid and alkaline water and the remaining three mines had acid water in the mine.

MUDDY CREEK WATERSHED
MORAINE STATE PARK
AVERAGE VALUES BEFORE AND AFTER MINE SEALING

Deep Mine	No. of Hydraulic Seals	DISCHARGES Gallons per Minute		ACIDITY Pounds per day		IRON Pounds per Day	
		Before Sealing	After Sealing	Before Sealing	After Sealing	Before Sealing	After Sealing
WIMER	3	18	8	35	22	4	2
ALBEN	2	5	0	35	0	3	0
SHIELDS	5	Ⓐ	Ⓐ	Ⓑ	Ⓑ	Ⓒ	Ⓒ
FOX	5	14	3	28	1	3	Ⓒ
WORTH	3	0	0	0	0	0	0
SALZANO ROSS	4	10	5	147	13	4	4
SOUTH NEALEY	2	2	0	3	0	1	0
NEALEY	6	5	0	4	0	Ⓒ	0
GOUBEAUD	2	2	0	2	0	Ⓒ	0
NORTH GOUBEAUD	3	8	0	Ⓑ	0	Ⓒ	0
WEST EMERY	3	4	3	2	2	1	Ⓒ
EMERY	2	6	3	6	6	1	Ⓒ
FREMONT	2	1	2	1	Ⓑ	Ⓒ	Ⓒ
ISLE	6	6	0	2	0	1	0
MARTZOLF	2	4	0	2	0	1	0
LINDEY	5	5	5	18	12	2	6
LINCOLN	4	20	9	108	70	5	23
KILDOO	4	25	15	102	30	8	7
HILLIARD	2	11	4	6	4	Ⓒ	Ⓒ
	65	146	57	501	160	34	42

Ⓐ Variable flows - Average less than 1 G.P.M.
Ⓑ Sporadic acid discharge - Average less than 1 P.P.D.
Ⓒ Sporadic iron discharge - Average less than 1 P.P.D.

TABLE 1

SEALED DEEP MINE INFORMATION
IN
MORAINE STATE PARK
FROM
MINE OBSERVATION HOLE DATA

Deep Mine	Estimated Mine Elevations		MO Number	MO Coal Elevation	Inundation Elevations	
	Min.	Max.			Min.	Max.
WIMER	1274	1295	1	1276	(1278)	(1278)
SHIELDS	1272	1280	11 13	1275 1272	1278 1272	1281 1281
FOX	1230	1254	18 20	1240 1230	1240 1238	1241 1243
WORTH	1225	1235	22	1230	(1252)	(1252)
SALZANO ROSS	1224	1235	23	1224	1232	1239
SOUTH NEALEY	1200	1220	29	1220	1209	1213
NEALEY	1216	1240	34 36	1216 1218	1222 1222	1224 1224
GOUBEAUD	1215	1238	38	1215	1215	1218
NORTH GOUBEAUD	1218	1230	44	1218	1218	1218
WEST EMERY	1196	1222	54	1196	1199	1203
NORTH EMERY	1198	1222	58	1198	1235	1236
FREMONT	1204	1220	60	1204	1204	1207
ISLE	1180	1200	64 65 66	1195 1183 1182	1197 1197 1197	1200 1200 1200
MARTZOLF	1190	1200	69	1190	1198	1212
LINDEY	1205	1230	75 87	1207 1208	1220 1220	1230 (1230)
LINCOLN	1195	1210	76	1195	1209	1214
KILDOO	1200	1225	79	1202	1206	1210
HILLIARD	1210	1224	84	1210	1219	1225

TABLE 2

ARGENTINE & WHISKERVILLE

AVERAGE VALUES BEFORE SEALING
BASED ON SAMPLING DURING YEAR OF 1969

WEIR NO.	FLOW GPM	pH	Parts per Million				Pounds per Day			
			ALK.	ACID	IRON	SULF.	ALK.	ACID	IRON	SULF.
SR 109	118	3.1	0	200	24	403	0	271	34	550
SR 110	2	5.4	6	4	2	42	0.2	0.1	0.1	0.9
SR 114	33	5.2	17	142	23	504	8	58	10	212
SR 115	1	4.0	5	71	12	226	0.1	0.6	0.1	2
SR 116	5	3.1	0	117	15	412	0	8	1	27
SR 119	190	5.9	29	69	26	248	65	152	59	539
SR 129	3	3.6	0	66	10	328	0	3	0.4	13
TOTALS	352						73	493	105	1344

VALUES AFTER SEALING
BASED ON SAMPLING DURING JANUARY 1972

WEIR NO.	FLOW GPM	pH	Parts per Million				Pounds per Day			
			ALK.	ACID	IRON	SULF.	ALK.	ACID	IRON	SULF.
SR 109	0	--	0	0	0	0	0	0	0	0
SR 110	0	--	0	0	0	0	0	0	0	0
SR 114	12	5.3	16	178	181	653	2	26	26	94
SR 115	0	--	0	0	0	0	0	0	0	0
SR 116	0	--	0	0	0	0	0	0	0	0
SR 119	94	5.6	6	40	22	250	7	45	24	282
SR 129	0	--	0	0	0	0	0	0	0	0
TOTALS	106						9	71	50	376

TABLE 3

No evaluation of the change in flows or acid loading with reference to North Corridor deep mine sealing work has been made. These deep mines were located in the highwall of an abandoned strip mine. The strip mine is presently being backfilled under Project SL 110-2 and as a result, discharge data from the deep mine area is not possible.

Argentine & Whiskerville

While it is too early to draw firm conclusions regarding this project, enough information has been collected to make some preliminary observations. Table 3 is a summary of data for the mine drainage sources which collectively represent the pollution load (before and after sealing) from the project area. Weir number 129 is the lone discharge from the Whiskerville Area. All other weir points designate flows associated with the Argentine Project. Preliminary indications are that the sealing program affected an overall reduction in flow of 70%. Initial reductions in net acidity, sulfates and iron were determined to be 85%, 72% and 52% respectively. The water quality in Slippery Rock Creek immediately downstream from the Project Area (Millers Crossing) has shown some improvement, although this is necessarily a tentative evaluation due to limited post-construction data. Recent sampling indicates a pH of 4.0 at this location compared with an average pH of 3.4 before mine sealing. A decrease in acidity was also noted, from an average of 91 ppm before the abatement work to 66 ppm during January 1972 sampling.

SUMMARY AND CONCLUSIONS

Deep mine sealing has been an indispensable tool in abatement of mine drainage pollution in the Slippery Rock Creek Watershed. The two projects discussed, one of immediate importance to land and water-use objectives (Moraine State Park), and the other of long range significance to watershed improvement, have demonstrated the degree of effectiveness which can be expected by current sealing methods.

The overall reduction in acid load from deep mine discharges in Moraine was 68%. This evaluation represents the collective effect of mine sealing projects in a number of mines, isolated and scattered throughout the work area. The Argentine Project concentrates sealing efforts essentially in one large mining complex. The results of this project show that the acid load has been reduced by 85%.

On the basis of this experience it is reasonable to anticipate that, while the success of individual seals may vary widely, the overall effect of a deep mine sealing project will reduce acid loadings by more than 60%.

Benefits in terms of acio reduction and costs for individual mine seals are difficult to evaluate since actual costs, as indicated by the Moraine projects can result in a wide range from $8,300 to $58,000 per seal. The average cost per mine seal for Moraine, including grouting was $19,500.