MINE DRAINAGE ABATEMENT

A. CONSIDERATION OF ABATEMENT METHODS

In view of the requirement for essentially total mine drainage control to achieve the stream quality goals presented earlier, intermediate abatement measures such as surface flow diversion above strip mines and stream channel improvement were abandoned in favor of more extensive, positive, long range measures. Particular attention was directed to those measures that would favorably alter or control the hydrology of the study area, measures that would reclaim both the surface and the subsurface drainage in such a way as to reduce the volume of water entering the mine voids and, concurrently, increase the unpolluted runoff to the streams.

Specifically, three abatement methods have been applied to the study area: (1) the restoration of strip mined land, (2) mine refuse regarding and burial, and (3) deep mine sealing and grouting.

In most coal mine regions adversely affected by mine drainage it is generally possible to establish abatement priorities to achieve a pollution load objective by directing corrective action to a limited number of sources) those that show the most favorable cost-benefit ratio. The situation in the Little Schuylkill Basin, however, is so severe that it was necessary to apply the three abatement procedures to their fullest extent to every possible situation, although there was one important exception.

This one exception to abatement consideration was the activities of the Greenwood Stripping Corporation, present or planned. The firm is the one active mining operation of any significant size in the Basin and, we submit, subject to drainage control by existing laws and regulations. Therefore, a large area of Panther Valley surrounded by the Greenwood Breaker and the Greenwood #10 Shaft, an area of active mining, refuse relocation and backfilling was excluded from surface reclamation evaluation. The constant changes in the landscape as the result of those activities prevent any meaningful evaluation of surface reclamation. Furthermore, no direct subsurface abatement measures were investigated for the extensive mining network associated with the mine pools pumped by the Corporation from Greenwood #10 and Tamaqua #14 pumping stations. The mine "make" includes not only that from the active operations of Greenwood Stripping Corporation, but also extensive deep mine workings throughout much of Panther Valley. To reduce this subsurface flow, however, surface reclamation in areas of Panther Valley beyond Greenwood's active interests, although many times still on their property, were evaluated.

The abatement design criteria and associated estimated costs for the analysis of the study area are presented in Appendix C.

B. ABATEMENT FROM SURFACE RECLAMATION

Surface reclamation was systematically evaluated by dividing the disturbed surface area within the watersheds of Panther Creek, Wabash Creek and the Silverbrook Basin into two categories, (1) surface area that drains to a specific stream under natural conditions and (2) surface area that drains to a related stream through an intervening mine discharge. In general, the areas in the second category are those in which the surface drainage had been destroyed by strip mining and/or mine refuse storage activities. It also includes not only the acreage directly involved in these activities, but also the surface up slope from these disturbed areas, whose drainage is intercepted.

One notable exception was made to this analysis distinction, the acreage down slope of mine-effected surface which is underlain or closely underlain by deep mine voids. In this case, although the surface drainage to the stream may be unimpeded, the subsurface drainage intercepted by the underlying mine workings flows through and becomes a source of mine discharge. Acreage in this category is discussed in relation to subsurface drainage control, the following report section.

After the separation of the surface area into the two aforementioned categories, the surface area related to mine drainage was sub-divided into over 200 internal drainage basins, to facilitate and to refine the estimates of materials to reclaim those areas.

The distinct areas were then analyzed to determine the level of backfilling or the extent of regrading to secure surface runoff. This analysis disclosed many cases where drainage from one area could be reclaimed only if the drainage from an adjacent area was first recovered. This resulted in the grouping of many dependent sub-areas and the final definition of fifty seven distinct "Reclamation Areas" .

The Reclamation Areas are delineated on Exhibits 33 through 36, while the details acquired by the application of the Abatement Design Criteria and Estimated Costs are tabulated on Table C-2 in Appendix C. These details (such as requirements for select fill, backfilling material, and sewage sludge, as well as the related costs) will aid in coordinating the availability of materials as well as for annual budgeting.

An important factor related to surface reclamation is the fact that there is an existing source for a significant amount of the select fill material for final capping, the material accumulated in the Department of Environmental Resources' desilting basin at South Tamaqua, The material is primarily medium grained fragments, with moderate portions of both coarse and fine grained substances. It is comprised not only of coal silt, for which the facility was designed to capture, but also of topsoil eroded from the watershed. In view of the volunteer vegetation observed surrounding the basin, it is our opinion that the material could serve as a soil-type cover in a surface reclamation project and its handling should be considered in this respect.

During the preparation of this report, the Schuylkill River Authority was planning to remove as much as 1.25 million yards of sediment from the basin, an amount equal to 28% of the estimated initial requirement for select fill for the proposed surface reclamation plan.

For a disposal site, the Greenwood Stripping Corporation has offered to the Authority one of its abandoned desilting facilities and, with the application of this material for surface reclamation not in the immediate future, this disposal method appears satisfactory; however, the following reservations are recommended:

(1) That the Commonwealth retain the ownership of the material and the right to remove it as the need arises;

(2) That the Greenwood Stripping Corporation guarantee that the storage area will not be utilized for the deposition of its mine refuse or waste material, or for any activity which would bury or otherwise impair the Commonwealth's ability to recover the material at the site.

Continuing with the Surface Reclamation analysis, the mine drainage contribution from each Reclamation Area was calculated and, thereafter, the abatement achievable by surface reclamation was computed. In this process, each Reclamation Area was associated with one or more mine drainage discharges, by superimposing the surface drainage map with the drainage outlets on the subsurface drainage map. The acid contribution from each Reclamation Area was estimated by applying a water budget to each of three surface categories within the boundary of the area in accordance with the following table:

Surface Condition	Runoff, %	Evap. -Trans., %	Infiltration, %
Strip Pit	0	2	98
Refuse Storage	0	5	95
Original Surface	17	50	33

The summation of infiltration yielded by the water budget represents the flow component of the acid contribution, and its corresponding present acid load was determined by applying the measured concentration of the related discharge point.

The acid abatement through the surface reclamation of each Reclamation Area was determined by recalculating the water budget according to the conditions that would prevail following reclamation. This procedure yielded the abatable flow, which was again employed with the average sampled concentration to provide the abated acid load.

The abated load was factored in order to weigh its pollution relative to the number of stream miles polluted. The acid load discharged from each Reclamation Area was multiplied by the number of stream miles polluted by the respective discharge, and this value was termed the "acid impact". In this manner, the discharge from the Silverbrook Basin, which is 29.2 stream miles from the mouth of the Little Schuylkill River, was weighted more heavily than a discharge from Wabash Creek, which is only 21.3 stream miles from the mouth.

The details of computations with respect to each Reclamation Area are also included in Appendix C, Table C-3, together with its relative cost/benefit.

It is important to note that the costs tabulated in Appendix C represent only initial construction costs, and do not include costs for replacing materials, operation or maintenance, nor engineering and administrative expenses. They do, however, present the simplest units for comparison of Reclamation Areas. A comparison of the values listed in the "Cost vs. Abatement" column reveals that the costs per pound (of acid abated) ratio varies from a low of $79.00/lb./day to a high of $ 3,359./lb./day with an average for the entire study area of $825./lb./day. The cost per unit of acid impact ratio ranges from a low of $3.70/lb.-mile/day to a high of $158./lb.-mile/day.

C. ABATEMENT FROM SUBSURFACE DRAINAGE CONTROL

Three methods of subsurface drainage control have been evaluated for the study area, (1) sealing of mine portals, (2) internal sealing or damming of deep mine gangways and (3) plugging of the churn drill holes. These measures have been applied to every deep mine discharge which flows naturally from an opening that can receive a sealing structure.

The Department of Environmental Resources permitted pump discharges associated with active operations, the Tamaqua #14 Mine, the Greenwood #10 Mine and the Zakrewsky Mine, are not applicable for control by sealing. Furthermore, it has been concluded that the gravity flow from the Silver brook Mine Pool, due to the undeterminable nature of the drainage outlet beneath the mine refuse, is not suitable for the application of subsurface control.

The objective of subsurface drainage control is threefold: (1) to raise the level of water in the mine voids so as to eliminate a portion of the ground water flow into the mines. This is accomplished when ground water flow from areas between the mines and the natural stream is reverse so that flow is then away from the mine voids and into the stream. This, then, controls the component of flow from the discharge which results from infiltration in areas where surface run-off to the natural stream is unimpeded; (2) to raise the level of water in the mines so as to inundate a portion of the exposed surfaces of reaction which are producing AMD pollutants and reduce the acid and iron production and, hence, concentration of the residual discharge; and (3) to eliminate the rapid response to rainfall which many of the mine discharges exhibit and thereby suppress the pollution impact on the receiving stream.

The detailed results of the mine sealing analyses in terms of costs and abatement derived therefrom are compiled in ,Appendix C, Tables C-4 and C-5. The cost versus abatement ratios on Table C-5 can be compared on an equal basis with the same ratios included in Table C-3 for surface reclamation. For subsurface drainage control, the calculations show that the cost ranges from \$68 ./lb./day to \$800./lb./ day. Exhibits 31 and 32 show the proposed locations of the mine seals.

D. SUMMARY OF ABATEMENT ANALYSIS

The results from the analysis of the individual "Reclamation Areas" obtained by the Abatement from Surface Reclamation have been consolidated into respective discharge points and combined with the results of Abatement from Sub-Surface Drainage Control, and the data are tabulated on Tables 9 and 10, which follow. In addition, the Basic Construction Costs have been totaled and adjusted in cost to the Total Project Cost, and these are presented below.

SUMMARY OF RECLAMATION COSTS

	Basic Construction Cost	Total Project Cost [3]
Surface Reclamation	$11,320,000[1]	$16,975,000
Sub-Surface Drainage Control	$ 105,700 [2]	$ 132,000
	TOTAL	$17,107,000

Total Project Cost	$/Acre reclaimed	$ 6,207
Total Project Cost	$/lb. acid/ day abated	$ 1,178

(1) from Appendix C Table C-2

(2) from Appendix C Table C-5

(3) Total Project Cost includes Basic Construction Cost, plus 25% for engineering, legal and administrative costs and contingency, plus $1,025.00 per surface area reclaimed for maintenance for five years. Purchase price of land is not included in cost estimates.

E. SIGNIFICANCE OF RESULTS

Table 9 summarizes the abatement of mine drainage flow. That which is termed "Abatable Flow" does not disappear but would join the watercourse either as uncontaminated surface runoff or sub-surface flow. Overall, the tabulation shows that only 34% of the mine drainage volume is abatable; 79% of the non-abatable flow is the sum of Tamaqua #14 pumpage, Greenwood #10 pumpage, and the Greenwood Breaker Effluent.

Table 10 summarizes the acid abatement achievable by the surface and sub-surface programs. In this case, 46% of the measured acid load can be controlled. The Tamaqua #14 pump age accounts for 62% of the remaining 15,794 lbs./day of acid.

The results from the abatement study have been applied to the mean flow of the Little Schuylkill River and, using calculated non-abatable loads and modifying the flows for change in runoff, the resultant stream quality was calculated. The findings are shown on Table 11.

Previously, within the report section Water Quality, Exhibits 10 and 11 showed that the indigenous basin water could receive only between 5 and 8 mg/l of acid from mine drainage before reaching a depressed pH of 5.5. From Table 11, then, it is apparent that the residual acid loads following reclamation would still be too great for the river for the most part, and that perhaps in only the four-mile river reach between Pine Creek and Tamaqua would suitable pH conditions exist. The entire river below Tamaqua, twenty miles, would exhibit a pH less than 5.5.

With respect to sulfates, the river would attain desirable water quality characteristics between Lofty Creek and Tamaqua, approximately eight stream miles, but the concentration would be excessive for all uses below Panther Creek.

TABLE 9

SUMMARY OF FLOW ABATEMENT BY DISCHARGE

DISCHARGE POINT	MEASURED FLOW gals./day	ABATABLE FLOW By Surface Rec. gals./day	ABATABLE FLOW By Surface Rec. % of meas. flow	ABATABLE FLOW By Mine Sealing gals./day	ABATABLE FLOW By Mine Sealing % of meas. flow	NON-ABATABLE FLOW gals./day	NON-ABATABLE FLOW % of meas. flow
Silverbrook Basin	3,046,626	1,586,169	52.1	--	--	1,460,457	48.0
West Lehigh Shaft	201,600	132,425	65.7	20,160	10.0	49,015	24.3
E. Elm St. Seep	39,000	39,000	100.0	--	--	--	--
Zakrewsky Pumps	360,000	319,042	88.6	--	--	40,958	11.4
A & D Mine	25,920	14,148	54.6	2,590	10.0	9,182	35.4
Zakrewsky Gravity	129,600	96,498	74.5	12,960	10.0	20,142	15.5
Smith Bros. Mine	36,000	7,196	--	3,600	--	25,204	--
1st. No. Drift	14,400	--	--	14,400	100.0	--	--
SUB-TOTAL	3,853,146	2,194,478	Av. 57.0	53,710	Av. 1.4	1,604,958	Av. 41.6
Tamaqua #14 Pumps	6,566,400	1,652,019	25.2	--	--	4,914,381	74.8
Greenwood #10 Pumps	6,710,400	2,435,886	36.3	--	--	4,274,514	63.7
Coaldale Seep	165,600	107,971	65.2	--	--	57,629	34.8
Greenwood West Seep	288,000	124,190	43.1	--	--	163,810	56.9
Manbeck Seep	299,520	194,846	65.1	--	--	104,674	34.9
Greenwood Breaker	4,752,000	--	--	--	--	4,752,000	100.0
Greenwood East Seep	64,800	--	--	--	--	64,800	100.0
Coaldale #7 Mine	187,200	122,054	65.2	18,720	10.0	46,426	24.8
Slum Creek	36,000	--	--	--	--	36,000	100.0
SUB-TOTAL	19,069,920	4,636,966	Av. 24.3	18,720	Av. 0.1	14,997,434	Av. 75.6
Newkirk Mine	936,000	551,071	58.9	110,020	11.8	274,909	29.4
Newkirk Seeps	175,176	114,326	65.3	--	--	60,850	34.7
Newkirk Drain.Tunnel)							
Reevesdale #2 Drift)	2,016,000	1,253,952	62.2	201,600	10.0	560,448	33.8
Reevesdale #1 Drift	144,000	--	--	144,000	100.0	--	--
Reevesdale Seeps	174,489	113,872	65.3	--	--	60,617	34.7
SUB-TOTAL	3,445,665	2,033,221	Av. 59.0	455,620	Av. 13.2	956,824	Av. 27.8
TOTAL	26,368,731	8,864,665	Av. 33.6	528,050	Av. 2.0	17,559,216	Av. 64%

Calculated numerical values as the result of abatement measures do not always total the measured values due to hydrologic changes introduced.

TABLE 10

SUMMARY OF ACID ABATEMENT BY DISCHARGE

DISCHARGE POINT	MEASURED ACID		ABATABLE ACID				NON-ABATABLE ACID[1]	
			By Surface Rec.		By Mine Sealing			
	lbs./day	mg/l	lbs./day	% of Meas. Load	lbs./day	% of Meas. Load	lbs./day	% of Meas. Load
Silverbrook Basin	3,140	158	1,950	66.6	--	--	1,200	40.4
West Lehigh Shaft	1,175	700	773	65.8	118	10.0	286	24.3
E. Elm Street Seep	660	2,000	660	100.0	--	--	--	--
Zakrewsky Pumps	660	220	528	80.0	--	--	132	20.0
A & D Mine	700	3,300	390	55.7	71	10.1	239	34.1
Zakrewsky Gravity	105	100	80	76.2	11	10.5	14	13.3
Smith Bros. Mine	50	320	19	38.0	10	20.0	21	42.0
1st North Drift	100	470	--	--	100	100.0	--	--
SUB-TOTAL	6,590		4,400	Av. 66.8	310	Av. 4.7	1,892	Av. 28.2
Tamaqua #14 Pumps	13,700	250	3,926	28.7	--	--	9,774	71.3
Greenwood #10 Pumps	--	--	--	--	--	--	--	--
Coaldale Seep	1,500	1,100	990	66.0	--	--	510	34.0
Greenwood West Seep	1,350	750	777	57.5	--	--	573	42.4
Manbeck Seep	1,500	600	975	65.0	--	--	525	35.0
Greenwood Breaker	555	14	--	--	--	--	555	100.0
Greenwood East Seep	500	1,000	--	--	--	--	500	100.0
Coaldale #7 Mine	140	90	92	65.7	14	10.0	34	24.3
Slum Creek	80	266	--	--	--	--	80	100.0
SUB-TOTAL	19,325		6,760	Av. 35.0	14	Av. 0.07	12,551	Av. 65.0
Newkirk Mine	2,030	260	1,194	58.9	238	11.8	598	29.5
Newkirk Seeps	1,400	1,000	953	68.1	--	--	447	32.9
Newkirk Drain.Tunnel & Reevesdale #2 Drift	1,250	80	837	66.9	135	10.8	278	22.2
Reevesdale #1 Drift	100	75	--	--	100	10.0	--	--
Reevesdale Seeps	80	100	52	65.2	--	--	28	34.8
SUB-TOTAL	4,860		3,036	Av. 62.5	473	Av. 9.7	1,351	Av. 27.8
TOTAL	30,775		14,196	46.1	797	Av. 2.6	15,794	Av. 51.3

Calculated numerical values as the result of abatement measures do not always total the measured values due to hydrologic changes introduced.

(1) Non-abatable iron and sulfate will follow similar percentages as acid, except Greenwood #10 pumpage, with no net acid, will show a percentage near that listed in Table 9 for flow, 58.3%.

TABLE 11

ESTIMATED STREAM QUALITY THAT WOULD RESULT FROM RECLAMATION TO THE EXTENT CONSIDERED UNDER MEAN FLOW CONDITIONS AND UNIFORM PUMPAGE

Location, downstream of:	Flow, CFS	Acidity (1)	Sulfate	Iron
Silverbrook	4.4	56	152	3.7
Lofty Creek	8.2	32	92	2.0
Still Creek	16.9	16	56	1.0
Neifert Creek	20.7	12	50	0.80
Pine Creek	29.9	9	41	0.55
Locust Creek	45.4	6	34	0.36
Zakrewsky Mine	54.5	5	33	0.31
Panther Creek	82.5	32	266	7.8
Wabash Creek	87.0	34	260	7.6
Tamaqua	87.0	35	260	7.7

(1) Values are acid amounts added to the River as calculated from the loads contributed and the river flow rates; the values are not identical to the titratable acid that would be measured if the River water were analyzed, because of equilibrium buffering, but are comparable to the data presented by Exhibits 10 and 11 which show pH response to acid added.

Iron, because of its instability in solution, is difficult to evaluate. However, the River below Lofty Creek again would probably be suitable for aquatic life and the river would be improved to a point below Locust Creek such that it would be acceptable as a water supply. Below Tamaqua, however, concentrations would be much too great for any purpose.

The overall unfavorable result, that is, the probable recovery of only a four mile reach of stream that would meet the quality parameters raises the question of what other steps could be taken or what other circumstances could arise that would alter the result. Two obvious circumstances that deserve attention and have been evaluated are: -- (1) the result of supplemental treatment of selected sources of mine drainage; and (2) the condition that would arise if Greenwood Stripping Corporation were to cease operations and its disturbed surface areas were reclaimed.

In the case of mine drainage treatment, it was concluded that if this means of pollution control is to be successful, it must be applied at Silverbrook and to the three principle sources of residual pollution emanating from the activities associated with the Greenwood Stripping Corporation: the Tamaqua #14 Pumps, the Greenwood #10 Pumps, and the Greenwood Breaker.

The outcome of treatment was considered on the basis of utilizing lime neutralization, as no advanced technological method has been shown to be economically feasible at the magnitudes being considered herein. Furthermore, an attainable iron level of 7 mg/l in the treated effluent was presumed, a reasonable value and a level identical with the Department of Environmental Resources' effluent standard. Inasmuch as the raw iron concentration of 9 mg/l at Silverbrook is but little above the attainable level, only acid neutralization, without iron removal, was considered applicable to that situation. The Greenwood Breaker Effluent also exhibits a low iron concentration and, here again, treatment limited to neutralization was considered adequate.

With respect to the Greenwood #10 and the Tamaqua #14 discharges, lime treatment to an excess alkalinity of 20 mg/l and with subsequent iron removal to 7 mg/l, was calculated. In addition, their effect was considered on the basis of a controlled uniform rate of discharge, as opposed to slugging loads at present pump rates.

An important aspect of the analysis is the fact that the treatment method will not reduce the sulfate ion in the drainage, as it would not be expected that concentrations of calcium sulfate will exceed its solubility limit.

Based on the aforementioned conditions, the resultant stream quality was calculated and the values are presented on Table 12.

The elimination of acidity in the upper portion of the river, on Table 12, reflects the lime addition at Silverbrook; however, sulfate and iron are unaffected. As a result the River conditions above Tamaqua

TABLE 12

ESTIMATED STREAM QUALITY THAT WOULD RESULT FROM RECLAMATION TO THE EXTENT CONSIDERED UNDER MEAN FLOW CONDITIONS AND TREATMENT (1)

Location downstream of:	Acidity [2]	Sulfate	Iron
Silverbrook	None	152	3.7
Locust Creek	None	34	0.36
Zakrewsky Mine	Negligible	33	0.31
Panther Creek	1.7	266	1.3
Wabash Creek	4.7	260	1.4
Tamaqua	5.7	260	1.4

[1] Treatment consisting of acid neutralization at Silverbrook and Greenwood Breaker and acid neutralization to excess alk of 20 mg/l and with iron removal to 7 mg/l at Tamaqua #14 and Greenwood #10 Pumps, with uniform rate of discharge.

[2] Values are acid amounts added to the River as calculated from the loads contributed and the river flow rates; the values are not identical to the titratable acid that would be measured if the River water were analyzed, because of equilibrium buffering, but are comparable to the data presented by Exhibits 10 and 11 which show pH response to acid added.

would be suitable for aquatic requirements for approximately eight miles and suitable for most other uses downstream of Locust Creek to Tamaqua.

Downstream of Panther Creek, acid would be adequately controlled; however, sulfates would render the stream unsuitable for the aquatic environment and marginal for other uses. As a water supply, the iron level below Tamaqua would still be excessive.

The Little Schuylkill River quality was again estimated under the second circumstance proposed; that is, the condition that would exist if the Greenwood Stripping Corporation ceased operations and the disturbed surface relevant to its activities were reclaimed. Calculations were based on a 60% reduction of the pollution loads normally discharged by the Greenwood #10 and Tamaqua #14 pumps, a percentage that corresponds to that generally attainable in other areas of the study; a 70% reduction in the contribution from the Greenwood East Seep, which is largely fed by the Greenwood Breaker; and the complete elimination of the substances contributed by the Greenwood Breaker.

The calculated stream quality under those conditions is presented in Table 13. Since the hypothetical situation affects only Panther Creek and the River downstream, the river quality above Panther Creek would be the same as that shown in Table 11.

Reviewing the results, the data indicate that the residual mine drainage from the #10 and #14 mine pools would contribute a pollution load that would continue the severe pollution of the Little Schuylkill River. With a total acid contribution from mine drainage equivalent to a 20 mg/l addition to the river, the river's pH would be depressed well below 5.5 and would probably remain below that value for the twenty miles to its mouth.

Sulfate levels below Tamaqua would be excessive for aquatic requirements, but acceptable for most other needs. However, the estimated concentration of iron would preclude the river's use for both general and aquatic purposes below Panther Creek.

TABLE 13

ESTIMATED STREAM QUALITY THAT WOULD RESULT FROM CECESSATION OF THE OPERATION OF GREENWOOD STRIPPING CORPORATION AND RECLAMATION OF THE SURFACE

Location downstream of:	Acidity [1]	Sulfate	Iron
Silverbrook	56	152	3.7
Locust Creek	6	34	0.36
Zakrewsky Mine	5	33	0.31
Panther Creek	17	175	4.4
Wabash Creek	19	171	4.3
Tamaqua	20	172	4.3

[1] Values are acid amounts added to the River as calculated from the loads contributed and the river flow rates; the values are not identical to the titratable acid that would be measured if the River water were analyzed, because of equilibrium buffering, but are comparable to the data presented by Exhibits 10 and 11 which show pH response to acid added.