COMMONWEALTH TECHNOLOGY, INC.
LEXINGTON, KENTUCKY

THE APPLICATION OF SURFACE SEALANT TECHNOLOGY FOR THE PREVENTION OF ACID MINE DRAINAGE

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• TESTING • MONITORING • ENGINEERING • HYDROLOGY • BIOLOGY • GEOLOGY • SOIL SCIENCE

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INTRODUCTION

This paper presents a technology for dealing with acid mine drainage problems associated with the surface mining of coal from the Kittanning coal seams in the Buckhannon River watershed in Upshur County, West Virginia. This paper primarily addresses measures taken to reduce existing water quality problems associated with acid seeps which have been created as a result of mining activity in the area and concentrates on current work being performed with the objective of developing and demonstrating technology which can be effectively utilized as an integral part of the mining plan to prevent the creation of acid seeps. It is based on information gained over the past three years through direct work on the problem, published materials, and conversations with personnel from mining companies and regulatory agencies.

SOURCE OF THE PROBLEM

The major water quality concerns are centered around water seeps which have appeared in ' the area, generally beginning at varying periods of time after cessation of mining and completion of backfilling and reclamation of the area. These seeps are characteristically low in pH (why they are commonly referred to as "acid seeps") and relatively high in acidity, iron, manganese, other metals, and total dissolved solids as shown in Figure 1. Potential for significant water quality degradation exists if these seeps are discharged untreated into natural streams in the area. The existing water quality in these streams is somewhat fragile being already moderately acid and low in buffering capacity. Undisturbed areas contribute "background" acidity to the streams through naturally occurring acid seeps and surface runoff. The native soil in the area is acid as evidenced by the results of chemical determinations and the vegetation it supports such as broomsedge and rhododendron.

At present, at least in a general way, the mechanisms responsible for the acid water formation and seep creation is reasonably well understood. The acid is produced from certain strata which are exposed to the necessary elements (air and moisture) as a result of the mining activities. Although there are significant local variations, the majority of the potentially acid-producing materials are contained in the shale parting between the Kittanning coal seams and in certain relatively thin shale strata overlying the coal. In the past, these materials have been backfilled in the restacked overburden in various ways ranging from random placement to planned arrangements designated by regulatory agencies. They are constituted of raw overburden and interburden, and, in some cases, refuse from coal preparation plants. Within the regraded backfill, oxidation of pyritic materials results in the production of sulfuric' acid which represents acid creation per se and also solubilizes other minerals through the action of the acid on other neutral and alkaline rocks as shown in Figure 2. The surface infiltration capacity of the regraded overburden is significantly greater than the original undisturbed material, and surface infiltration resulting from rain and snowmelt is thereby enhanced.

As water resulting from this infiltration percolates downward through the potentially acid-producing materials, its acid and mineral content typically increases (Figures 3 and 4). The downward movement of this water is intercepted by an essentially impervious stratum at the bottom of the regraded backfill (the pavement formerly immediately below coal seam) and then moves horizontally until it intercepts the surface on the side of the hill at the elevation of the former coal outcrop, thus creating the seeps of concern.

CURRENT EFFORTS TO ADDRESS THE PROBLEM

Considerable amounts of time and money are spent to treat acid water f lowing from the seeps . A wide variety of chemicals have been tried with mixed success. Many of the seeps have high concentrations of manganese which requires either treatment to high pH values or with oxidizing chemicals to meet effluent limitations, Chemical treatment results in the production of large quantities of sludge which must be removed from sedimentation basins and hauled to disposal areas.

During the past several years, coal mining companies operating in the area have intensified their efforts to achieve satisfactory solutions of existing problems and to develop mining methodologies which will ensure mitigation of adverse environmental impacts from future operations. It has become obvious that continued utilization of previously used surface mining practices will result, in some cases, in a requirement for perpetual treatment of acid seeps. Since this represents an economically unacceptable alternative, the companies have determined that new approaches must be developed to abate the problem. Assistance in development of new mining techniques has been provided by the West Virginia Acid Mine Drainage Task Force, expert consultants, universities, governmental agencies, and others.

In December, 1980, DLM Coal Corporation engaged Commonwealth Technology, Inc. to initiate a comprehensive and in-depth study. The primary objectives of this study, which is continuing to date, are to determine:

1. how to better manage current water quality problems at currently and previously mined sites, i.e., how to improve water treatment performance and reduce costs;
2. how to reduce current water quality problems, i.e., how to reduce or eliminate seeps at currently and previously mined sites; and
3. how to prevent water quality problems on sites to be mined in the future, i.e., how to prevent the formation of acid seeps.

Since December, 1980, CTI studied and made following areas.

1. Numerous water samples were analyzed treatment techniques and to determine This resulted in a detailed procedure for recommendations in the to evaluate current areas for improvement. monitoring pH, iron, and manganese in treatment pond effluents and regulating sodium hydroxide dosage to achieve optimum water treatment and compliance with effluent limits at minimum cost.
2. Developed methods to eliminate short circuiting, increase detention times, and more fully utilize available storage in sedimentation basins.
3. Performed aerial photography to produce topographic maps with two-foot contour intervals to delineate areas with poor surface drainage for the purpose of designing improved surface drainage systems to minimize infiltration into the backfill.
4. Installed cased wells into the backfill for monitoring purposes.
5. Performed extensive overburden testing on numerous borings and highwall samples to evaluate vertical and lateral variations in overburden quality. Several experiments to evaluate state-of-the-art overburden testing and handling techniques were performed.
6. Based on overburden testing results, a plan for overburden testing on future sites addition to the traditional overburden account), samples will be analyzed for for drilling holes was developed. In analyses (acid-base total iron and total manganese, for iron and manganese in a neutral water extract, and by a special procedure developed during this study.
7. Explored alternative methods of handling sludges resulting from chemical treatment of acid water.
8. Field tests were performed for the purpose of evaluating the feasibility of employing near-surface sealants to prevent surface infiltration into the backfill.

Numerous alternative approaches to solving acid drainage problems have been investigated. Several different overburden handling techniques have been tried. In general, each successive modification of the overburden handling techniques has been more successful than the previous method, but none has yet been completely successful in eliminating acid seeps. For example, overburden handling techniques used. in some of the most recent surface mining operations have apparently resulted in substantial reductions in seep formation and significant improvement in water quality as compared with earlier operations but have not eliminated acid drainage.

SURFACE SEALANT TECHNOLOGY UTILIZING IMPERMEABLE PVC LINER FOR PREVENTION OF INFILTRATION OF SURFACE WATER INTO POTENTIALLY ACID-PRODUCING BACKFILLED OVERBURDEN

Based on observations in wells drilled in backfilled overburden and on geologic and hydrologic considerations, it has been concluded that in most, if not all cases , the water appearing as acid seeps originates as infiltration through the surface of the backfilled overburden. This lead to the obvious conclusion that if this water could be intercepted at or near the surface before it could contact the potentially acid-producing material and diverted off the site, then the acid seeps could be essentially eliminated on previously mined sites and prevented on sites to be mined in the future. As a means of achieving this end, numerous alternative technologies were investigated. These included surface sealing with soil cement, bentonite clay, asphaltic materials, and various impermeable plastic materials. Table I lists some of the advantages and disadvantages of various surface sealants. Based on extensive studies of these alternatives, product literature, consultation with suppliers, visits to hazardous waste disposal sites, and actual field tests, utilization of 20 mil PVC as a sealant was concluded to be the most cost-effective alternative. DLM took immediate action to implement this recommendation to employ this technology on a large scale trial in order to evaluate its effectiveness.

The site selected for the trial is a mountaintop site east of Alton, West Virginia. The area to be covered with the sealant is a contiguous area 2,300,000 square feet in area (approximately 52 acres) as shown in Figure 5. All of this area has been previously mined. Most of it had previously been reclaimed and revegetate while a portion had been used as a disposal site for preparation plant refuse. Two significant acid seeps discharge from the area at the elevation of the former coal seam.

> Insofar as is known, this will represent the first application of this sealant technology for prevention of infiltration on surface mined sites. However it has been used for years for similar purposes in sealing bottoms of lagoons, chemical storage ponds, hazardous waste disposal sites, etc., to prevent infiltration into the underlying materials. This technology is currently used almost exclusively at hazardous waste disposal sites. Within the past month, a contract for engineering design was awarded at the Maxey Flats Nuclear Wastes Disposal Site in Eastern Kentucky in an application almost identical to that being used at DLM. At Maxey Flats, a surface application will be made to prevent surface infiltration and the resultant groundwater contamination from nuclear wastes which has been a problem for years. Plans and specifications for the work were prepared, bids were solicited, and a contract was awarded for the site preparation, liner installation, and liner covering. Construction began on September 21, 1981. The work consists of the following:
>
> 1. Stripping and stockpiling topsoil and other surface materials suitable for covering of the liner subsequent to its placement.
> 2. Grading of all areas to be covered to drain from the center of the ridges to the periphery, but to maintain all slopes milder than 15 percent to ensure no displacement of the cover material by sliding failure. Construction of diversion ditches on the periphery of certain portions of the area to prevent infiltration of surface runoff into certain areas above the level of the seeps but too steep to cover with the liner.
> 3. Preparing a smooth surface to serve as the subgrade for the liner by finish grading and compaction with a vibratory roller.
> 4. Placement of the 20 mil PVC liner on the subgrade in large prefabricated panels, sealing the panels together at overlapped joints with the appropriate solvent/adhesive to cover the entire area including all diversion ditches.
> 5. Cover the PVC liner with a minimum of 18 inches of cover material consisting of topsoil and topsoil substitution materials suitable to support vegetation.
> 6. Apply lime, fertilizer, and revegetate the area.

For the purpose of evaluating the effectiveness of this trial application of the PVC sealant technology, a monitoring program has been designed and is currently being implemented. The program consists of monitoring four wells drilled in backfilled overburden and four seeps. Each of the four wells will be associated with a seep. Two wells and two seeps are located on the PVC-covered area and two wells and two seeps are located on an adjacent similar site which will not be PVC-covered. Daily observations of water levels in the wells and discharge rates from the seeps are made. Water quality determinations are made monthly on all wells and seeps. The information generated by this monitoring program is a direct measure of the effectiveness of the technology for elimination of seeps from this and similar previously mined sites. Results from the monitoring program are shown in Figures 6 and 7.

CONCLUSIONS

The trial area at DLM was chosen as potentially one of the most difficult available. It was felt that if the technology proves to be successful there, it will hold a great promise for future application. As shown in Figure 8, it is envisioned that utilization of this technology would be incorporated into the mining and reclamation plan for future sites as an integral part of the operation. A typical operation would consist of:

1. a thorough overburden testing program to identify all potentially acid-producing materials;
2. design of a designated disposal area for backfilling these materials. This area would contain an appropriate subsurface drainage system to prevent any contact of subsurface water with the potentially acid-producing material; and
3. the potentially acid-producing material would be covered with PVC to prevent any downward infiltration into it. The cover would be located several feet below the final surface grade. The total area to be covered would typically represent only about 15 percent of the total area disturbed during mining as contrasted with the nearly 100 percent coverage required for seep elimination from previously mined areas where no planned segregation of materials was accomplished during the backfilling.

Although apparently unique for this application, the sealant technology described above, if successful, undoubtedly will not represent the only possible means for elimination and/or prevention of the acid seeps in the area. other companies are concurrently evaluating alternative technologies which may prove successful.

Figure 1. Typical values for acid seeps in the Buckhannon River watershed.

PARAMETER	VALUE
Discharge	18 gpm
pH	2.8 standard units
Specific conductance	3630 micromhos/cm
Acidity	1500 mg/L as $CaCO_3$
Alkalinity	0 mg/L as $CaCO_3$
Total iron	94 mg/L
Total manganese	132 mg/L
Total aluminum	226 mg/L
Total magnesium	211 mg/L
Sulfate	2460 mg/L
Total suspended solids	18 mg/L
Total dissolved solids	3600 mg/L

Figure 2. Reactions leading to the formation of acid mine drainage.

$$\overbrace{\text{PYRITE}}^{\text{IN THE ROCKS}} + \overbrace{\text{AIR + MOISTURE}}^{\text{IN THE PORES BETWEEN THE ROCKS}} \rightarrow \overbrace{\text{IRON SALTS + SULFURIC ACID}}^{\text{GO INTO SOLUTION AS WATER PASSES THROUGH THE ROCKS}}$$

SULFURIC ACID DISSOLVES
CARBONATE ROCKS
RELEASING
Mn, Ca, Mg, PLUS MORE IRON

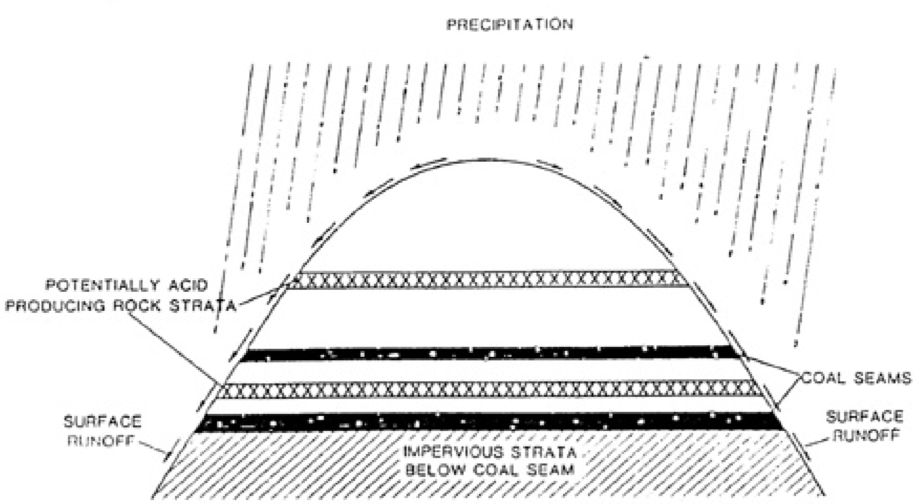


Figure 3. Pre-mining conditions. The majority of the rainfall leaves the mine site as surface runoff and does not come in contact with acid-producing material.

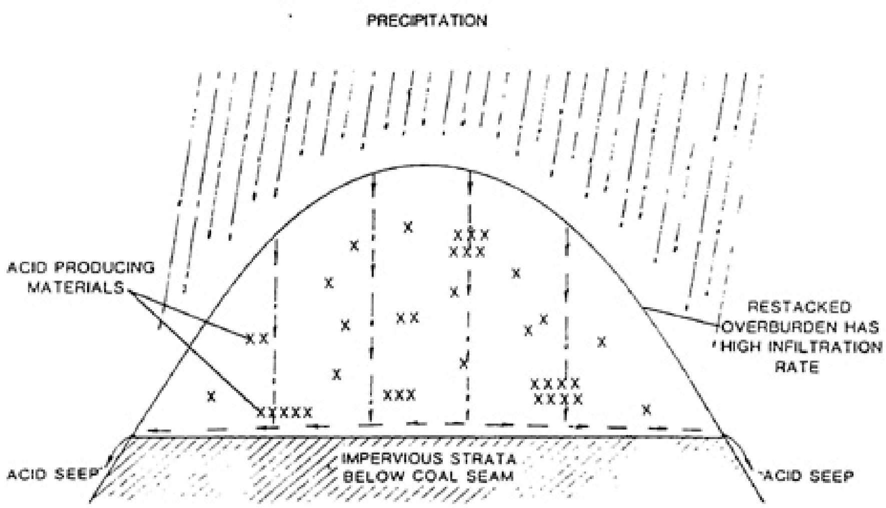


Figure 4. Post-mining conditions with random overburden placement. A large portion of the rainfall infiltrates the restacked overburden, contacts acid-producing material and emerges as acid mine drainage.

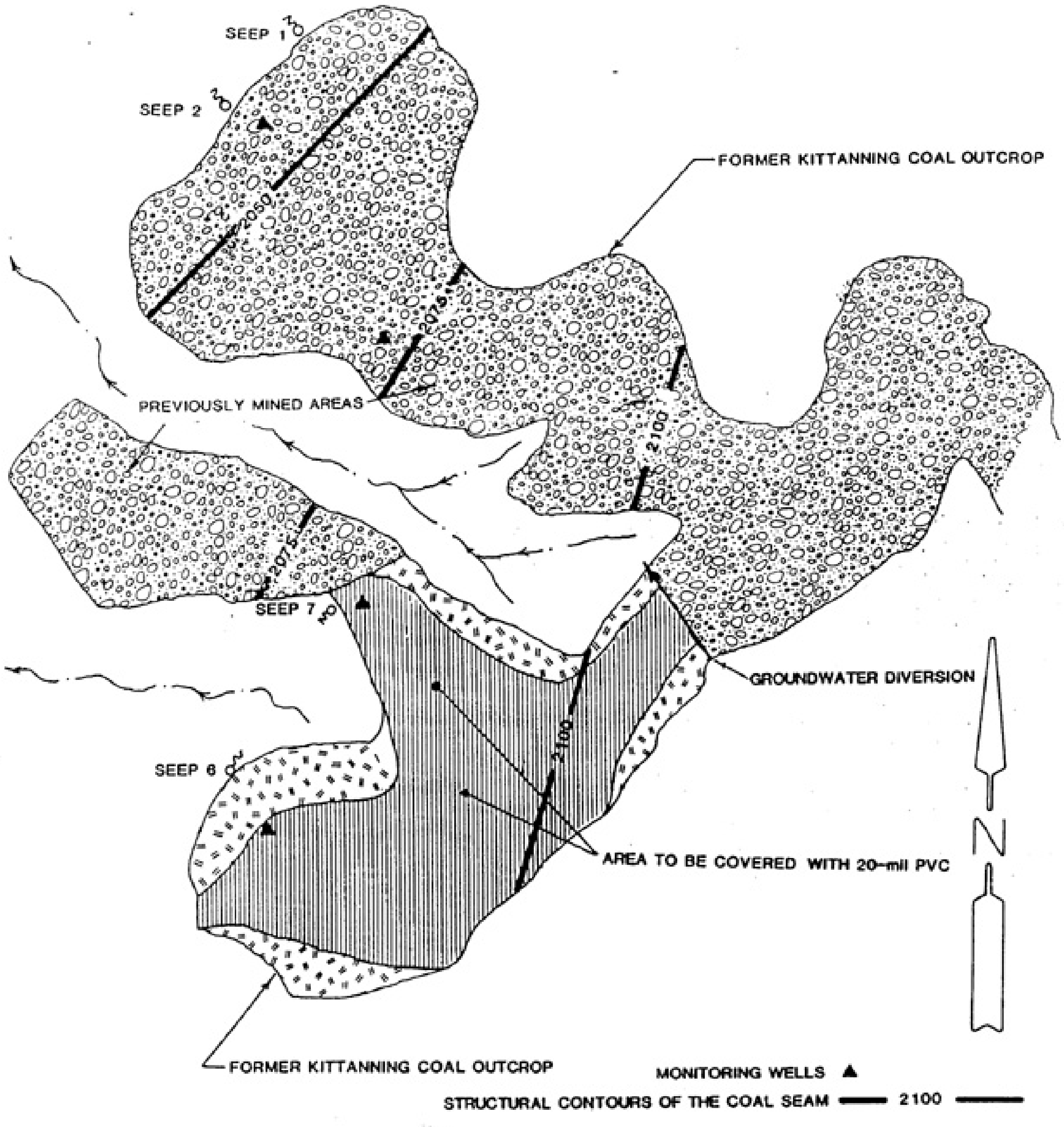


Figure 5. Map showing location of seeps, monitoring wells, and sealant technology test area.

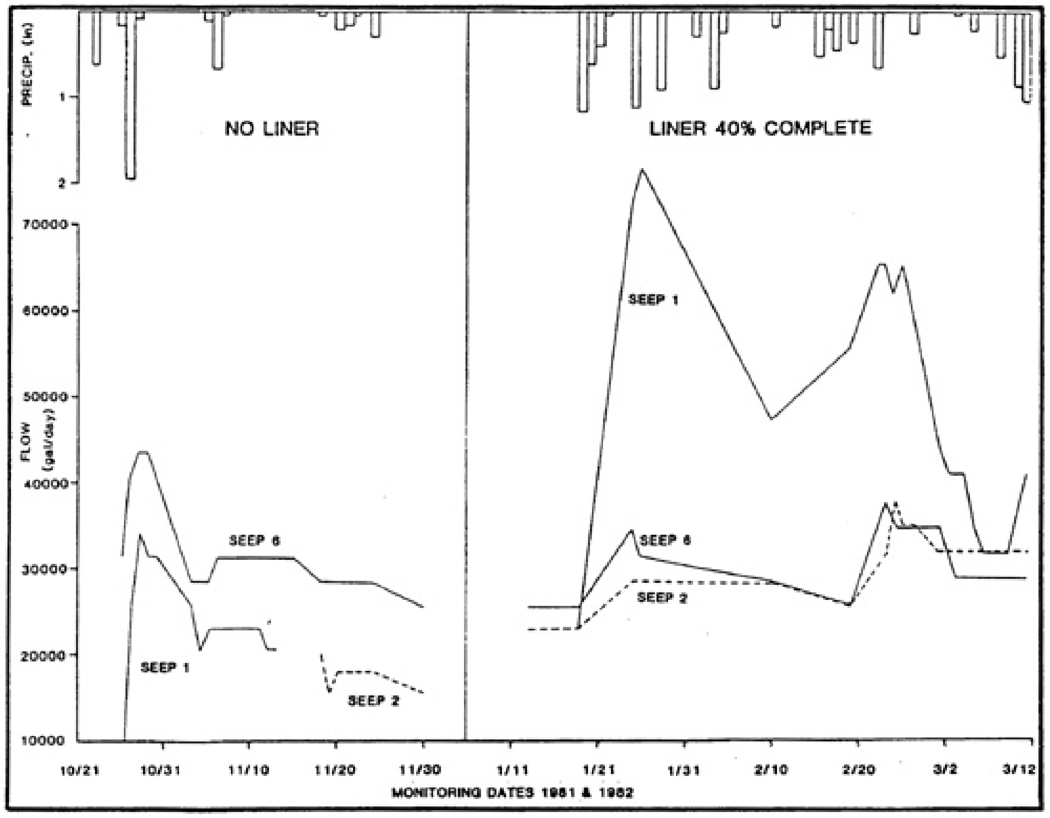


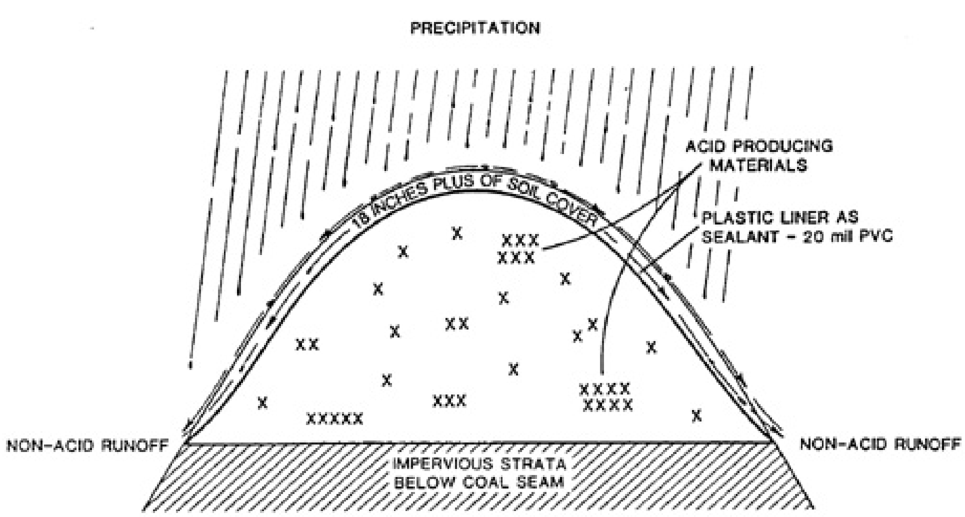
Figure 6. Results of monitoring flowrates from seeps 1, 2, and 6. Seep 6 is located down-dip from the refuse area, which is being covered by 20-mil PVC. Seeps 1 and 2 are located on a control area where no liner is to be placed. Installation of the liner began in October with approximately 40 percent of the liner installed by the end of November when adverse weather halted construction. During October when no liner was in place, seep 6 had the largest flowrate and showed the most response to rainfall of any seep. Following the first of the year, both seep 1 and 2 had larger flowrates and showed more reponse to rainfall.

Figure 7. Seasonal variations in water quality from acid seeps.

	OCT	NOV	DEC	JAN	FEB	MAR	APR
			Acid Concentration (mg/L as $CaCO_3$)				
Seep #1	500	-	256	350	350	390	420
Seep #2	-	750	700	550	700	780	795
Seep #6	1800	1900	1800	1350	1200	1190	1310
			Acid Loading (lbs./day as $CaCO_3$)*				
Seep #1	131	-	49	68	138	93	72
Seep #2	-	98	135	106	167	134	190
Seep #6	611	453	429	261	287	284	253
			Fe Concentration (mg/L)				
Seep #1	59	-	112	75	93	77	91
Seep #2	-	177	179	163	176	165	195
Seep #6	239	270	268	225	217	192	194
			Fe Loading (lbs./day)*				
Seep #1	15	-	22	14	37	18	16
Seep #2	-	23	35	31	42	28	47
Seep #6	81	64	64	43	52	45	37

* Loading in lbs./day equals the concentration in mg/L times the discharge in million gallons/day times 8.34.

As described in Figure 6, seeps 1 and 2 are on a control area is being placed, and seep 6 is on the sealant technology test area. When construction ceased in November, approximately 40 percent of the liner had been installed. Both concentrations and loadings of iron and acidity decreased from seep 6 following liner installation while iron and acidity concentrations where no liner from seeps 1 and 2 varied randomly.



SEALANT TECHNOLOGY APPLIED TO PREVIOUSLY MINED SITE WITH RANDOMLY RESTACKED OVERBURDEN

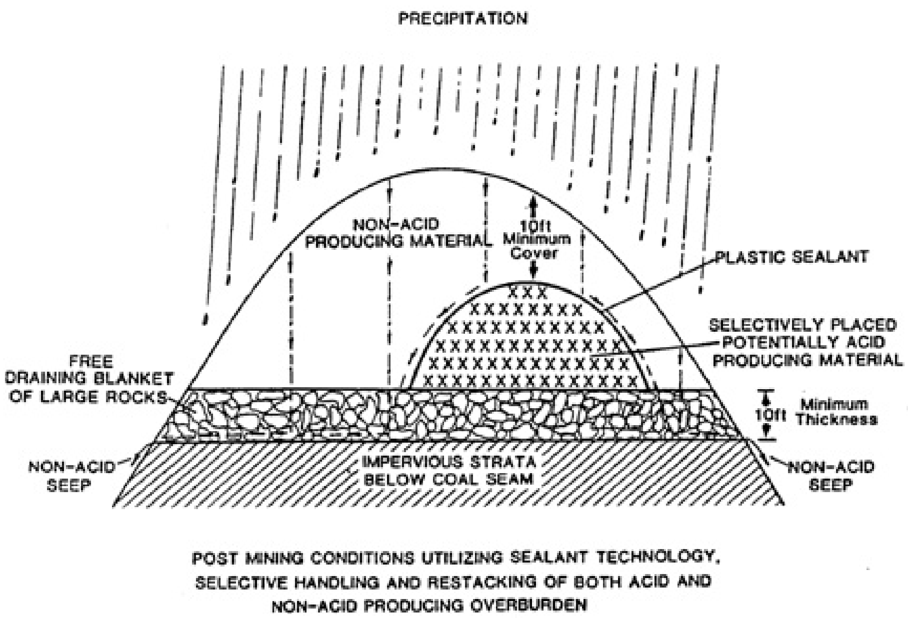


Figure 8. Future applications of sealant technology for the prevention of acid mine drainage

TABLE I

EVALUATION OF POTENTIAL SEALANT MATERIALS

ADVANTAGES OF POTENTIAL COVER MATERIALS

Asphalt:	Essentially watertight: if surface is carefully prepared and asphalt is properly applied.
Membrane liners:	Essentially impermeable if seams are properly bonded and unpunctuated. Large areas can be quickly covered with minimal equipment hence low application costs.
Bentonite:	Can be placed with agricultural equipment. A naturally occurring material with resultant long life.
Soil cement:	Can be placed with agricultural equipment. Low material cost compared to other sealant choices. Develops some structural strength.

DISADVANTAGES OF POTENTIAL COVER MATERIALS

Asphalt:	Cost, requires specialized equipment for placement (outside labor), develops holes if surface is not carefully prepared.
Membrane liners:	Subject to puncture (exact degree unknown). Material cost slightly higher than cement. High winds could create installation problems.
Bentonite:	Material and transportation costs too high. Uncertain of compaction required to produce **desired permeability.** Becomes grease-like if rain occurs before bentonite is properly mixed. Application cost higher than membrane liners.
Soil cement:	Uncertain of compaction necessary to produce desired permeability. Subject to sulfate attack and possibly weathering. Rainfall before mixing can cause problems. Application costs higher than membrane liners.