Reclamation Strategies as Applied at the DLM Properties

by

Frank T. Caruccio

and

Gwendelyn Geidel

Department of Geology
University of South Carolina
Columbia, South Carolina 29208

I - BACKGROUND

Acid mine drainage forms under natural conditions when certain coal seams are mined and the associated strata are exposed to an atmospheric oxidizing environment. In this process a variety of iron sulfides (FeS-FeS_2) oxidize in the presence of oxygen and water to form soluble hydrous iron sulfates. These compounds commonly appear as white and yellow salt crusts on the surface of weathered rock faces and in contact with water hydrolyze to form acidic drainages enriched with sulfate and iron. Ferrous and ferric oxyhydroxides impart the red and yellow color characteristic of acid mine drainage. Iron hydroxide usually precipitates and forms the "yellow boy" that is commonly observed in the streams and drainages of some coal mine areas (Caruccio and Geidel, 1978).

The general chemical reactions explaining the oxidation of FeS_2 and the production of acidity (H^+) are given by the following equations:

$$2FeS_{2(s)} + 7O_2 + 2H_2O = 2Fe^{2+} + 4SO_4^{2-} + 4H^+ \qquad [1]$$

$$Fe^{2+} + 1/4\ O_2 + H^+ = Fe^{3+} + 1/2\ H_2O \qquad [2]$$

$$Fe^{3+} + 3H_2O = Fe(OH)_{3(s)} + 3H^+ \qquad [3]$$

$$FeS_{2(s)} + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad [4]$$

(Barnes & Romberger, 1968, and Baker, 1975)

(Barnes & Romberger, 1968, and Baker, 1975)

The stoichiometry of Eq. [1] shows that I mole of FeS_2 will produce 2 moles of H^+ (acidity). In turn, the Fe^{2+} generated by the reaction of Eq [2] can readily oxidize into Fe^{3+} and produce an additional 3 moles of H^+ (Eq. [3]). In the references cited by Baker (1975), it has been shown that the FeS_2 can also be oxidized in the presence of excess Fe^{3+} in solution with water and further hydrolyze to form 16 moles of H^+ (Eq. [4]).

Critical to the chemistry of acid formation is the fact that the oxidation of Fe^{2+} to Fe^{3+} usually proceeds slowly under normal conditions, as in Eq. [2] and [3] (Singer and Stumm, 1970). However, certain iron bacteria which act as catalysts, serve to greatly accelerate the acid forming reactions. Several workers investigating the oxidation rates of sterilized versus inoculated samples showed that the iron bacteria, in aquatic systems with a pH range of 2.8 to 3.2, play an important role in the oxidation reactions and effectively increase the rate of acid production (Kleinmann et al., 1981, Walsh and Mitchell, 1972).

Acidic drainages can impact recipient streams with severe consequences on the aquatic flora and fauna. Accordingly, discharge quality standards are established and the acidic waters must be treated to a certain level prior to release from the mine site.

II - TREATMENT MECHANISMS AND OPTIONS

The operator has available several well established treatment procedures to treat the acidic drainage. These are discussed below.

A. Large-scale Neutralization - When large flows and high acid loads are encountered, large-scale, manufactured treatment facilities are commercially available to neutralize the acidity, oxidize the iron and generate a high density settleable sludge. Many of these systems are available through companies that specialize in this service on a contractual basis.

B. Small-scale Chemical Neutralization - Because of the relatively simple and controlled aspects of dispensing a caustic medium, most mining operations commonly neutralize acidic mine drainages through caustic additives. The acidic seeps are channeled into one collective flow which may be wiered. The flow rate is measured by a modified Parschall flume and a float, coupled to a valve, determines the amount of sodium hydroxide (caustic). This is dispensed directly into the acidic flow; the dosage rate being empirically determined. The pressure head is provided by locating the storage tanks at a higher elevation (and adjacent to roads to allow supply trucks easy access to refill). A narrow diameter (I to 2 cm) PVC pipe is used to convey the caustic from the storage tank to the dispensing valve. This scheme has the advantage that it does not require any electrical power and is well suited for treating acidic waters in remote parts of the mine. However, the viscosity of the caustic is readily affected by temperature changes and the dosage rates must be continually monitored during the cold winter months. Further, during periods of heavy rainfall, runoff adds to the flow through the flow monitoring device which activates additional caustic dispensing. These dilute flows generally have lower acid loads, and result in overtreatment.

Combinations of sodium carbonate briquettes, calcium oxide, potassium hydroxide, and various oxidizers (peroxide, sodium-calcium hypochlorite) may also be used as acid treatment. As in all of these treatments, a sludge is developed which is retained in settling ponds. The ponds, eventually, are cleaned and the sludge disposed of at the mine site.

C. Wetlands - Several studies have demonstrated the effectiveness of wetlands to remove acidity, sulfate, and iron from mildly to moderately acidic mine drainages (Lana and Wieder, 1982). In these reducing natural environments, sulfate is reduced to either a bisulfide (with an attendant reduction in acidity) or pyrite (with the removal of iron). Implementation of this technique is through the impoundment and conversion of a low lying, gently sloping area into a wetlands. Large amounts of organic matter (straw, hay, etc.) are then added and following a brief period of decay, a Sphagnum moss culture is introduced to the system.

The advantages of this type of treatment are the low maintenance (cost and otherwise) and the development of an aesthetically pleasing treatment facility. However, the ecosystem providing the base of the treatment is known to occupy only certain natural niches thereby restricting this treatment process to certain areas. Some researchers, however, have developed and selectively bred several moss species which may be used across a variety of conditions.

III - CONTROL MECHANISMS

In the beginning of this paper it was shown that the natural acid producing elements are pyrite, oxygen, water (moisture), and the catalytic affects of bacteria and water geochemistry. All but the pyrite, occurring as an intrinsic part of the rock matrix, may be directly affected through in-situ abatement techniques to reduce the flow rate and/or acid loads.

A. Detergents and Bactericidal Additives - Limiting the oxidation of ferrous to ferric irons effectively reduces the amount of acidity produced by almost half. By restricting the acid reactions to equations I through 3, acid levels may be reduced to levels that may be accommodated by bicarbonate alkalinity. However, should the reaction expressed by equation 4 begin, the rate of acid production is greatly enhanced and may easily overwhelm the naturally limited levels of calcareous generated alkalinity. Thus, the addition of a suitable bactericide serves to limit the rate of acid production and may be used to control the acid loads Kleinmann and Erickson, 1983).

This control measure may be applied to active as well as abandoned mines. When used to complement other treatments, it is an effective control measure and because the bactericide is water soluble and entrained by the recharge events, it can penetrate deep within the backfill or mine portals and affect physically remote sections. Depending on the flow through rate/time, the application of the bactericide must be periodically repeated in those severely acid situations.

B. Phosphate Complexes - The introduction of a phosphate compound (such as in the form of pulverized apatite) into an acid system serves to complex the free iron radical and inhibit the hydrolysis reaction; thereby reducing the amount of acidity produced (Flyn, 1969). The phosphate is solubilized only by slightly acidic conditions and consequently must be physically juxtaposed to the acid producing pyrite reaction site. Some field tests using phosphate mine slurry have provided varying degrees of success and some failures have been linked to a mass transfer problem.

Accordingly, the application of phosphate, to be effective, must coincide with the placement of the backfill and be admixed with the acid spoil material (Meek, 1984).

The advantage of this treatment, if all reaction sites are affected, is the reduction, and in some cases, the elimination, of acidity. Because it is a complexing technique, acid sources associated with iron hydrolysis are eliminated. However, some levels of acidity associated with reaction [1] will continue to be produced.

C. Selective Placement of Toxic Material - Obviously, this strategy must be developed as part of the mine plan and implemented during the reclamation phase. One part of the West Virginia Acid Mine Drainage Task Force recommendations advocates the placement of toxic spoil on top of a highly permeable inert material pad, about 3 to 5 meters (10 to 15 feet) thick. In turn, the acid material is capped with a clay seal, covered with one meter (3 feet) of soil, and the surface reclaimed. Soil in this case may be considered as the intensely weathered saprolitic profile above the bedrock. In a field test, where a small 6 ha (15 acre) hydrologically isolated hill was reclaimed according to these recommendations, it was shown that the clay seal was effective in preventing infiltrating waters from contacting the toxic spoil, and that the porous pad was instrumental in preventing the water table from contacting the acidic material (Geidel and Caruccio, 1984).

D. Plastic Liner - Reducing the flow of water through acid material, effectively reduces the acid load of the system. In this technique the surface of the acid source is graded and covered with a 20 or 34 mil continuously sealed plastic liner (similar to that routinely used in hazardous waste sites). To protect the plastic from ultraviolet ray exposure, which decomposes the plastic, a one meter (3 feet) layer of soil is placed over the plastic sheet and vegetated to afford mass stability.

In a field test, involving a 16 ha (40 acre) mine site where a 20 mil plastic liner was used, it was shown, that the net acid load emanating from two highly acidic seeps was reduced to a level such that the savings realized in reduced caustic usage was sufficient to amortize the cost of the plastic liner within a six year period (Caruccio and Geidel, 1983).

For this technique to be totally effective, however, the plastic liner must extend to the base of the spoil. Usually, the outslopes of most spoil banks are too steep to accommodate machinery or maintain slope stability necessary for soil retention and, as a result, a significant portion of the mine outslope is left exposed (unlined). This unlined area provides recharge avenues and a reversal of hydraulic head may develop which drives a wetting front under the plastic . Subsequently, drainage of acid leachates from beneath the plastic occurs when the normal gradient is re-established.

This technique is labor intensive and lends itself best to active operations. Although, if the acid material could be identified, concentrated in one area, and encapsulated in plastic, this procedure has merit in reclaiming abandoned mines.

E. Blanket (Surface) Application of Limestone - Several field studies have shown that alkaline infiltrating (recharge) waters effectively reduce acid loads. Under alkaline conditions, the elevated pH displaces the bacteria and pyrite oxidation is inhibited. One possible and economically feasible method of changing the water chemistry is through the surface application of limestone; as a blanket veneer on the surface of the mine. Rainwater or snowmelt, in contact with the limestone, becomes alkaline and creates an alkaline wetting front. In most mining situations, however, the limited solubility of calcareous material causes the amount of bicarbonate produced to be generally lower than the acid levels created by pyrite oxidation. As a result, the initial alkaline wetting front has a negligible affect on the total acid system and the mitigation of acidic seeps is recognized only after several recharge events, spanning as much as two or three years, have occurred. (Geidel and Caruccio, 1982).

This technique is best suited for those areas with highly permeable surfaces and mildly acidic drainages. For those areas where the slopes are too steep for normal reclamation methods, helicopters may be used to dispense the limestone on the steep slopes while four-wheel drive lime spreaders may be used throughout the remainder of the mine.

F. Induced Alkaline Recharge Zones - The blanket application of limestone has two disadvantages which detract from the effectiveness of this treatment. First, the limestone may not be strategically concentrated in the major recharge areas. As a result, unless the surface is highly permeable, most of the water entering the backfill is not in contact with a large portion of the limestone. Second, limestone with limited solubility generates minor amounts of alkalinity which cannot neutralize the large acid loads produced by the more soluble acidic systems.

Mechanisms designed to overcome these two deficiencies (the hydrologic uncertainty and the low alkalinity produced by the limestone) are incorporated in the induced alkaline recharge concept. In this technique, major surface water flows are intercepted by shallow (1 m or 3 ft) trenches whose bottoms are lined with a layer of sodium carbonate briquettes (applied at a rate of I kg per 0.5 m^2 or 0.5 pd per ft^2) and covered with 0.3 m (I ft) of agriculture limestone reject. Through these trenches surface runoff is converted into highly alkaline (the effect from the briquettes), high flow (hence large alkaline loads) recharges which can overwhelm the acid loads. Once accomplished, the catalyzing bacteria are displaced, the acid system is neutralized and the pyrite oxidation stabilized. The strongly alkaline system, due to the briquettes, is short-lived, lasting only until the briquettes are completely dissolved. Normally, this should take about 6 months. However, it serves to neutralize the acidic system which, once achieved, is sustained for longer periods of time by the limestone alkalinity (Caruccio and Geidel, 1984).

The advantages of this technique are that it may easily be applied to abandoned mined lands with a minimum amount of earth moving effort, taking full advantage of the alkaline ameliorant. However, if the major recharge areas are not clearly identified and the acid producing horizons in the backfill are not impacted by the alkaline flow lines large amounts of

acidity may be produced and the problem compounded. Further, the trenches must be located in permeable zones to preclude trench flooding which will contaminate adjacent areas with sodium, leading to vegetation kills.

G. Summary - There are many treatment and control measures available for the mitigation and abatement of acid mine drainage from surface mines. The technique deemed most appropriate for a particular mine site depends on the age of the mine site, the permeability and character of the mine surface (in other words, whether the mine surface generates substantial amounts of runoff or is highly permeable and most of the water infiltrates over the entire mine surface), the growth stage of vegetation, the amount of calcareous material present in the overburden, the availability of a particular ameliorant, accessibility of the site by equipment, and the source (physical and hydrologic) of the acidic seeps in the backfill or mine regime. These are but a few considerations to be examined in choosing a most effective treatment of technique. The problem site must be explored by drilling, the hydrogeochemical system understood and the acid source identified before the treatment technology is implemented.

IV - STRATEGIES EMPLOYED AT THE DLM SITES

A. Overview - Depending upon the combination of rainfall intensity and duration, and the permeability of the mine surface, recharge of water to the backfill may not occur as a uniform wetting front, but rather, as has been now documented, along highly permeable randomly oriented channels. This hydrologic regime is best described as pseudo-Karst and controls the effectiveness of treatments and reclamation strategies. The blanket application of ameliorants on a mine surface will only be intercepted by randomly distributed recharge zones which renders a large portion of the treatment ineffective during times of precipitation events that generate substantial runoff. Only during those few recharge events through which significant vertical infiltration of water takes place (such as the spring thaw and snow melt) can the blanket treatment of an ameliorant affect mine drainage quality.

On the other hand, highly permeable (coupled with low intensity precipitation) mine surfaces do not lend themselves to the alkaline trench concept. Under these hydraulic conditions, little runoff occurs and a substantial amount of water bypasses the trench installation and is not affected by the ameliorants.

Thus, within the DLM properties, an assessment as to whether the mine surface is permeable (under a given set of precipitation events) or conducive to runoff, determines the type of treatment that may be applied. Further, the nature of the seep and the porosity and hydraulic interconnection of the backfill pores and the mine surface, must also be considered. For example, wetlands treatment may not be applicable in steep areas where the volume of seep flow varies greatly.

B. Strategies - For the various DLM mine properties each site was evaluated in terms of anticipated runoff - infiltration ratios, ability to emplace ameliorants into the backfill openings, containment and character of the seep, accessibility of equipment, maintenance of treatments or controls, and probability and potential costs involved in the treatment or control strategies.

Each site unique to itself was explored by several monitoring wells to discern the geochemistry and hydrology existing at each site. With this information the variety of treatments and options discussed in Section III above, were evaluated in terms of probability of success, suitability for a particular site, and facility of implementation to recommend a particular treatment for a specific area. The results of these evaluations are summarized below according to sites as located in Fig. 1.

MERCER SITE

Background

Because of the substantial amount of runoff evident at this site, alkaline trenches were recommended to control acid water production. The trenches were installed at the DLM Mercer Site on August 26, 1983 with dramatic improvements in water quality. During the spring of 1984, the iodine tracer was detected at the three seeps emanating from the toe of the backfill and coincided with a substantial reduction in acidity and, significantly, sulfate. The normally red, acidic seeps became crystal clear (although still acidic) presumably because of the absence of catalyzing bacteria and the slow conversion of ferrous to ferric iron. Acidity values declined from 600-800 mg/l to around 150 mg/l with attendant decreases in sulfate. As further evidence of declining iron concentrations of the seeps, the sediment pond located at this outfall has not been cleaned of the iron sludge for about a year and a half; in contrast, the sediment ponds in the remaining portions of the mine are cleaned about once every six months.

The seeps, however, remain mildly acidic, with acidity concentrations leveling out at around 150 mg/l (Figures 2-4). These levels of acidity are created by water infiltrating the backfill through areas between the trenches and removed from the influence of the alkaline material. Inasmuch as the trenches are designed to intercept runoff, low intensity -long duration rains or snowmelt lead to recharge events that readily permeate the mine surface, create little if any runoff and produce infiltration which is not alkaline impacted. Accordingly, depending upon the runoff-infiltration ratio of a particular storm event, the recharge to the backfill may either be alkaline enriched or deficient.

Treatment

To accommodate the isolated uniform infiltration recharge events, post holes, emplaced on 25 to 50 feet centers and charged with combinations of soda briquettes, hydrated lime, and limestone, coupled with the areal broadcast of limestone at a rate of 100 tons per acre, were recommended to intercept the infiltration recharge component and induce alkalinity along these inter-trench flow paths.

Postholes were charged with 25 pounds of sodium carbonate briquettes and capped with a veneer of limestone. Those holes which were filled with water were to be charged with hydrated lime. The post holes were constructed so that a slight depression was created with a low "dam" on the downhill side (to encourage accumulation of water in the holes). Finally, the entire area, including the highwall area and slope, trench area and outslope area above seeps were covered with 100 tons/acre of limestone.

40 ACRE AND FAW (FORTY ACRE WELL) SITES

Background

The 40 acre site is a northwest-southeast oriented reclaimed knob that is divided by a central unminded core extending the length of the site. This core divides the 40 acre site into a northern portion, designated "40 acre site," which is bounded on the northwest by a 70 foot highwall and a southern portion designated "40 acre well (because of the existing gas well) FAW site." The pavement dips gently to the north-northwest causing Seep 5 to emerge from the 40 acre site. In the FAW site, the pavement causes the groundwater in the backfill to migrate north, pooling against the unmined core and eventually emerge as Seeps 7 and 7A at the southern portion of the site.

Data collected, with regard to water level elevations, were uploaded through a SAS program to generate a series of contour maps of the configuration of the mine-floor, water above the mine-floor and water table maps for a particular time of measurement. The output plots depict the area boundaries with contours which clearly show that the Forty Acre well site is underlain by a pavement gently dipping to the north that is consistent with the regional trend and causes the ground water to flow northerly and pond against the highwall.

Therefore, the effects of treatments in this area must first migrate northerly, intercepting the highwall, before flowing westerly to emerge as the seep. This explains why the existing preliminary treatments are not impacting the seep, and the long travel times which we are discerning at this site.

Treatment

In this area a series of alkaline trenches was constructed and charged with sodium carbonate briquettes (0.5 lb/sq.ft.) and 12 inches of limestone. This construction caused Seep 7A to increase in flow, though as of this date the water quality has not been impacted for the reasons discussed above.

To complement the existing monitoring network, three additional holes were drilled along the suspected highwall areas to better define the recharge areas and determine groundwater flow movement. The data obtained from these wells substantiated the flow patterns observed thus far and further identified a potential recharge area along the previous haul road paralleling the barrier.

To intercept the runoff from the haul road section a trench was installed across the road. The trench was charged at a rate of 0.5 lb. of sodium carbonate briquettes/sq.ft. and capped with 12-18 inches of limestone.

In addition, a series of post holes were installed along the haul road above the trench and continuing to the crest of the hill. These locations are designed to intercept infiltration. The post holes (total 11 holes) were charged with 1 bag (50 pounds) of sodium carbonate briquettes. The post holes to the top of the hill (total of 15 holes) were charged with half a bag. Post holes along the highwall in the vicinity of Seep 7A, on a flat part of the mine, (total of 15) were charged with I bag of sodium carbonate briquettes. And the post holes above Seep 7A (total of 12 holes), were charged with 2 bags of sodium carbonate briquettes.

Following the addition of the briquettes the holes were partially filled with excavated material and capped with 12-18 inches of limestone and the area dressed to encourage pooling of water in the holes. Finally, the entire area, including the area from the haul road to the highwall, the outslopes from the gas well flat to the lower road, and the outslopes above the seeps, were to be covered with limestone applied at a rate of 100 tons (plus) acre. This facet of the treatment remains to be completed. When undertaken, it is important that the outslopes be thoroughly and completely covered with limestone (which is stockpiled at the site).

Because of the extremely steep slopes of the northern flank of the 40 acre site and the established vegetative cover, it appears highly improbable that lime can be applied in sufficient amounts over the entire area to have a positive impact on Seep 5. In contrast, FAW site is relatively flat and hydrologically contained (i.e., the ground water divides and boundaries have been accurately established).

MAINTENANCE AREA

Background

In this area, a series of 10 wells was drilled to determine the hydrology of the bowl-shaped depression. This area was mined and a 50 foot barrier was left in place to prevent drainage to the Panther Fork watershed. On the Panther Fork side of the barrier a large seep emanates from what appears to be an abandoned deep mine opening. Another seep occurs in the northwest part of the hollow between the Maintenance and the Picnic Area.

The water level and seep elevations show the ground water flow to be primarily along the highwall-barrier parallel to Panther Fork with two major discharge points occurring at the seeps described above. Recharge seems to occur primarily through vertical infiltration (little runoff) with a major component flowing from the Picnic Area northwest along the barrier and into the Maintenance Area.

Treatment

A series of post holes were emplaced in the vicinity of the culvert crossing the road and leading to the hollow. This is a ground water discharge area and treatments at this location were designed to intercept the seep flow path. In addition, to control the northern seeps, a series of post holes surrounding the seep emanating from the deep mine opening were installed. All holes were charged with I bag each of sodium carbonate briquettes. The holes were partially filled with excavated material and brought to ground level with a cap of limestone at least 12 to 18 inches thick.

The post hole construction was completed so that small depressions were formed to enhance water pooling and infiltration. Finally, the entire mine surface was covered with 100 tons (plus) of limestone per acre; being certain to cover the outslopes down to the tree line of both areas.

PICNIC AREAS

The Picnic Area contains a core of unmined land which essentially separates the knob into a Picnic Area North and a Picnic Area South section. Because of the regional northwesterly dip of the pavement the recharge areas, as well as seep locations, are different for the two sites. In addition, mine personnel present during the mining phase relay that one or two cuts at the most were taken along the south wall and possibly two or three cuts were taken along the north wall (this is consistent with the logs of the wells installed in this section). This results in a seep occurring on the up-dip side of the area on the Picnic Area South section and a down-dip - gravity drain large seep on the Picnic Area North section.

PICNIC AREA SOUTH

Background

In this area a small seep occurs at pavement level in the road paralleling the highwall. Water recharging this area flows toward the highwall (down-dip along pavement), thence southwesterly along the highwall until a barrier is encountered. At this junction, the groundwater pools, rises to pavement levels and emerges as a seep. At the southwesterly portion of the site as little as 8 feet of disturbed rock underlies the area - suggesting that a barrier of unmined coal was left behind.

During an intense rainstorm we observed water draining from the limestone road, through a culvert, onto a flat area of the Picnic Area South, toward the highwall and thence into a gulley away from the tract. This alkaline water, generated by the crushed limestone road, was escaping from the area. Part of the treatment strategy was to capture and utilize this alkaline water.

Treatment

In the flat area unto which the road culvert runoff flowed, 4 post holes were emplaced. The ones filled with water were charged with 2 bags of hydrated lime, and the dry holes with 2 bags of sodium carbonate briquettes. The holes were dressed as previously described with 12-18 inches of limestone.

Post holes were installed along the recharge zone along the highwall and road (to include wooded area; a total of 20 holes) and charged with 2 bags of sodium carbonate briquettes and capped with limestone.

A trench was installed from the road diagonally to the highwall to intercept the alkaline road drainage. This trench was charged with 0.5 lb. of sodium carbonate briquettes per I square foot and capped with 12-18 inches of limestone.

During a field visit, when a rapid change in barometric pressure occurred, we discovered several "breathing holes" in the small wooded area near the highwall. 5 bags of sodium carbonate briquettes where added to these holes.

Finally, the entire area was covered with 100 tons (plus) per acre of limestone, including the wooded upslope area above the highwall - as far as the blower could reach.

PICNIC AREA NORTH

Background

In this section two major seep locations occur on the down-dip side of pavement elevation. In addition to the diffuse seeps observed from the road, a distinct, well defined, high volume seep occurs along the pavement elevation on a line parallel to the highwall southwest of the area. Although similar to an abandoned deep mine opening seep, we believe this major seep to be supplied by water entering the Picnic Area North Tract on the northeast, thence flowing southwesterly along the highwall until it emerges as a seep.

In discussions with mine personnel, it was learned that a major box cut (almost 70 to 80 feet deep) exists under the road immediately northeast of the Picnic Areas Tract. This may provide a potential hydrologic connection between the Zickefoose Tract and the Picnic Area north section. The Zickefoose Tract should be treated to accommodate this possibility.

Treatment

For this area we recommend, that in the flat area immediately above the large seep a series of post holes be installed and charged with 2 bags each of sodium carbonate briquettes and 12-18 inches of limestone as described previously. The holes were to be completed to encourage ponding of water in the holes.

In the area above the diffuse seeps post holes were to be installed as described above (total number of holes between two areas is 54).

A trench was to be emplaced parallel to the highwall and charged with 0.5 lb. of sodium carbonate briquettes per square foot and an 18 inch veneer of limestone. Finally, cover the area with 100 tons (plus) of limestone per acre. Include outslopes down to pavement elevation as well as up-slopes above highwall.

At the time of this writing, the lime spreading remains to be completed.

8 ACRE SITE

Background

The 8 ACRE SITE is located immediately to the north of the plastic lined area. Based on the water level data collected from the wells up gradient from Seep 6, we have identified the unlined outslope to be the major recharge area for the seep. This relatively small area can be readily and easily impacted with alkaline post holes. The surface of the area appears to be permeable and during rains was observed to readily absorb water through surface infiltration.

The area has an extremely steep slope and some portions of the site are inaccessible except by tractor or dozer.

In an attempt to impact the seep quality, a series of post holes and back holes were dug on 25 foot centers above the pavement elevation and charged with sodium hydroxide - dosages varying from 6 to 10 gallons. Following the treatment and shortly after a rain, a minor seep in the vicinity of Seep 6 became alkaline - although Seep 6 was not affected to a noticeable extent.

Treatment

To complement the caustic that was added, the following additional treatments were recommended for the 8 ACRE SITE:

Add 1/2 bag (50 lb.) of sodium carbonate briquettes to each of the existing post holes and fill in holes excavated material creating small depressions to encourage pooling of water in the depressions.

In addition, cover the entire area with limestone at a rate of 100 tons (plus) per acre. Should the application of the limestone be restricted by the steep slope or be inaccessible to the lime spreader, an access road may be cut mid-way between the pavement elevation and the diversion ditch. This access road will then be converted to an alkaline trench (charged with 0.5 lb. of sodium carbonate briquettes/square foot and covered with a 12-18 inch veneer of limestone).

Because of the extremely steep slope and limited access to machinery, the area has not, at the time of this writing, been limed.

200 ACRE (THA) SITE

<u>Background</u>

This is a large (approximately 60 acres) area underlain, in part, with refuse. Several major seeps, notably Seeps I and 2, originate from this area. During major rain storms we traced the runoff, along clearly defined surface paths, into major recharge areas. As observed, a considerable portion, and during the recessional phase of the storm, all, of the water drained into the backfill along clearly defined holes on the mine surface and highly permeable zones. The pavement dips to the northwest and is bounded on the north by a barrier of unmined coal left in place to prevent water from draining into the Panther Fork watershed. This barrier, coupled with the attitude of the pavement, causes the groundwater to flow in a northwesterly direction and emerge as seeps in the northwestern part of the site.

At this mine tract, several monitoring wells were installed and the water table elevations showed the THA SITE to be hydrologically divided into two sections; a northwest section of THA which showed little change with precipitation events and a southeast section (bordering the Maintenance Area) which responded quickly to rainfall events. This pattern clearly persists through time and shows that the hydraulic conductivities of the backfill are substantially different and treatments should be designed accordingly.

In both sections of the THA SITE infiltrations are difficult to discern and other than the recharge zones established during runoff events, as discussed above, it appears as though most of the rain falling on these sections runs off the surface. Surely, during the Spring thaw, groundwater recharge occurs, but these events take place possibly once or twice a year. Based on these considerations our recommendations for treating the THA SITE were restricted to trenches and a surface veneer of limestone.

<u>Treatment</u>

The surface water drainage network, observed to be major recharge areas, was formed into a series of 12 trenches which were charged with approximately 0.5 pounds of sodium carbonate briquettes per square foot. In the first trench, an addition of 550 pounds of hydrated lime were also added. Further, all trenches were to be filled with 12 to 18 inches of limestone. Finally, the entire area was covered with 100 tons per acre of limestone, paying particular attention to the outslopes above seeps.

At the time of this writing, the limestone (stockpiled at the site) remains to be spread.

V - SUMMARY

A series of treatments was recommended and scheduled for the DLM sites. These included alkaline trenches, emplacement of caustic material in shallow post holes and the blanket application of limestone. The individual mine site are discussed below as to their character, the treatment implemented and their status. Refer to Figure 1 for the locations.

Summary of DLM Site, Character and Status
of Treatment Schedules Relative to this Study

Summary of DLM Site, Character and Status
of Treatment Schedules Relative to this Study

DLM Site	Mine Character	Status (as of December, 1985
1. Mercer Site	Abandoned mine, used in original study. Substantial runoff.	Mine site has been trenched and entire area covered with 100 tons per acre. No well control
2. 40 Acre Sites		
2a. Forty Acre Site	Extremely permeable and steep slope. Heavily vegetated.	Seep 5 monitored in addition to water levels in wells. No treatment scheduled.
2b. FAW Site (Forty Acre Well site)	Combined runoff and and infiltration.	Mine site has been trenched and post holes added to absorb sodium carbonate briquettes. Excellent well control. Remains to be limed at a rate of 100 tons per acre.
3. Maintenance Area	Highly permeable, internally drained area that recharges a seep from an abandoned deep mine opening on the north (to Panther Fork) and a major seep in the gully to the south.	Area has been completely treated with post holes. Excellent well control. Wells and seeps monitored regularly. Excellent study area regarding chemical and hydrologic control.
4. Picnic Area	Small permeable area that contains an unmined core. North-western part has intermittent seep, southern part has large perennial seep.	Southern area partially treated with trenches and post holes. Northern area completely treated with trenches and post holes. Excellent study area regarding chemical impact and control.
5. 8 Acre Site	Highly permeable area below liner that recharges Seep 6.	Area has been treated with a high density post hole array. Remains to be treated with 100 tons per acre limestone.

			Well control and flow data measured on a daily basis for mass balance study.
6.	200 Acre (THA) Site	Highly permeable area with disappearing streams. Source of Seeps 1 and 2 series.	Area has been treated trenches. Liming to be completed, especially outslopes. Excellent well and seep control which are routinely monitored for mass balance studies.

The Maintenance Area has been completed, both in scheduled treatments and well control. We are currently monitoring the water level elevations of the wells and seep quality. This area offers us the excellent opportunity not only to observe the impact of the treatments on seep quality but what effect the treatments have on deep mine drainage outfalls. Disturbance of this area should be minimized.

The Picnic Area, too, is completed and offers us the opportunity to evaluate interflow recharge events and chemical impacts of treatment.

The 8 Acre Site not only evaluates further the liner effectiveness but also provides the opportunity to complete a water mass balance in detail. This area has also been treated with a tightly spaced post hole array and the seep is being monitored to evaluate the chemical impact.

Finally, the 200 Acre Site, because of the excellent well control and seep flow data, provides us with the opportunity to gain a better understanding of the hydrology of a backfill.

REFERENCES

Baker, M. 1975. Inactive and pollution prevention Washington, D.C. abandoned underground mines - water and control. EPA - 440/9-75-007. USEPA,

Barnes, H.L. and S.B. Romberger. 1968. Chemical aspects of, acid mine drainage. J. Water Pollut. Control. Fed. 40: 371-384.

Caruccio, F.T. and G. Geidel. 1978. Geochemical factors affecting coal mine drainage quality. Reclamation of Drastically Disturbed Lands, Chapt. 8 (129-147). Am. Soc. Agron., Madison, WI.

Caruccio, F.T. 1983. The effect of plastic liner on acid loads: DLM site. Proc. 4th Annual W.V. Surf. Mine Drainage Task Force Symp., W.V. DNR, Charleston, W.V.

Caruccio, F.T. and G. Geidel. 1984. Induced alkaline recharge zones to mitigate acidic seeps. Proc. Symp. on Surf. Mining, Hydrology, Sedimentology and Reclamation, Univ. of KY, Lexington, KY, 43-47.

Flyn, J.P. 1969. Treatment of earth surface and subsurface for prevention of acidic drainage from soil. U.S. Patent # 3,443, 882, U.S. Patent Office.

Geidel, G. and F.T. Caruccio. 1982. Acid drainage response to surface limestone layers. Proc. Symp. on Surf. Mining, Hydrology, Sedimentology and Reclamation, Univ. of KY, Lexington, KY, 403-406.

Geidel G. and F.T. Caruccio. 1984. A field evaluation of the selective placement of acidic material within the backfill of a reclaimed coal mine. Proc. Symp. on Surface Mining, Hydrology, Sedimentology and Reclamation, Univ. of KY, Lexington, KY, 127-131.

Kleinmann, R.L., Crerar, D.A. and R.R. Pacelli. 1981. Biogeochemistry of acid mine drainage and a method to control acid formation. Mining Erg., March, 1981, 300-305.

Kleinmann, R.L. and P. Erickson. 1983. Control of acid drainage from coal refuse using anionic surfactants.

Bur. of Mines. Report of Inv. 8847, Dept. of Int., 16 pp.

Lang, G.E. and R.K. Wieder. 1982. The use of wetlands to modify acid mine drainage. Personal Communication, Dept. of Biology, W.V. Univ., Morgantown, W.V. 26506.

Meek, F.A. 1984. Research into the use of apatite rock for acidic drainage prevention. Proc. 5th Annual W.V. Surf. Mine Drainage Task Force Symp. W.V. DNR, Charleston, W.V.

Singer, P.C. and W. Stumm. 1970. The rate-determining step in the formation of acidic mine drainage. Science, 167 : 1121-23.

Walsh, F. and R. Mitchell. 1972. A pH dependent succession of iron bacteria. Env. Sci. and Tech. 6 (9) : 809-12.

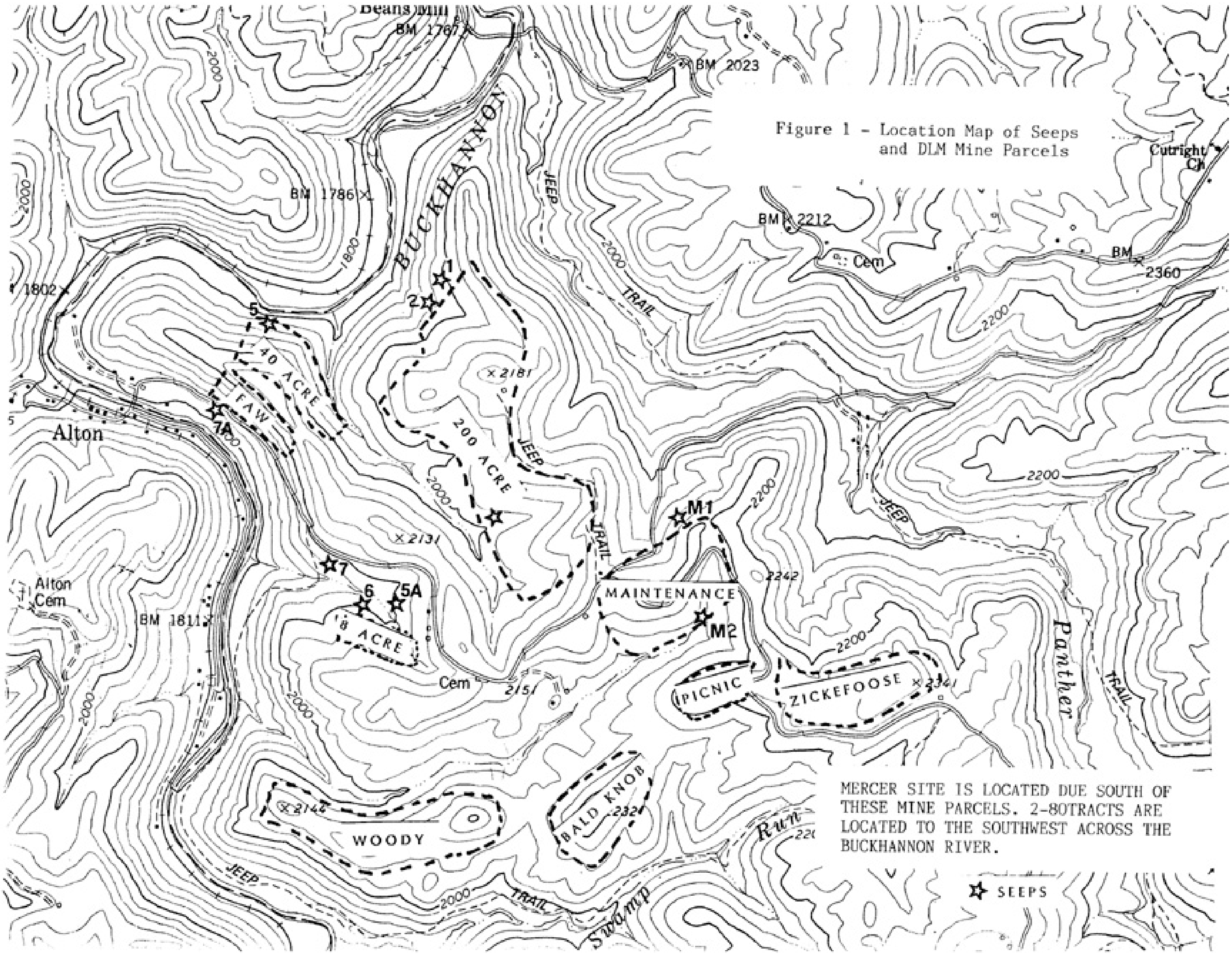

Figure 1 - Location Map of Seeps and DLM Mine Parcels

MERCER SITE IS LOCATED DUE SOUTH OF THESE MINE PARCELS. 2-80TRACTS ARE LOCATED TO THE SOUTHWEST ACROSS THE BUCKHANNON RIVER.

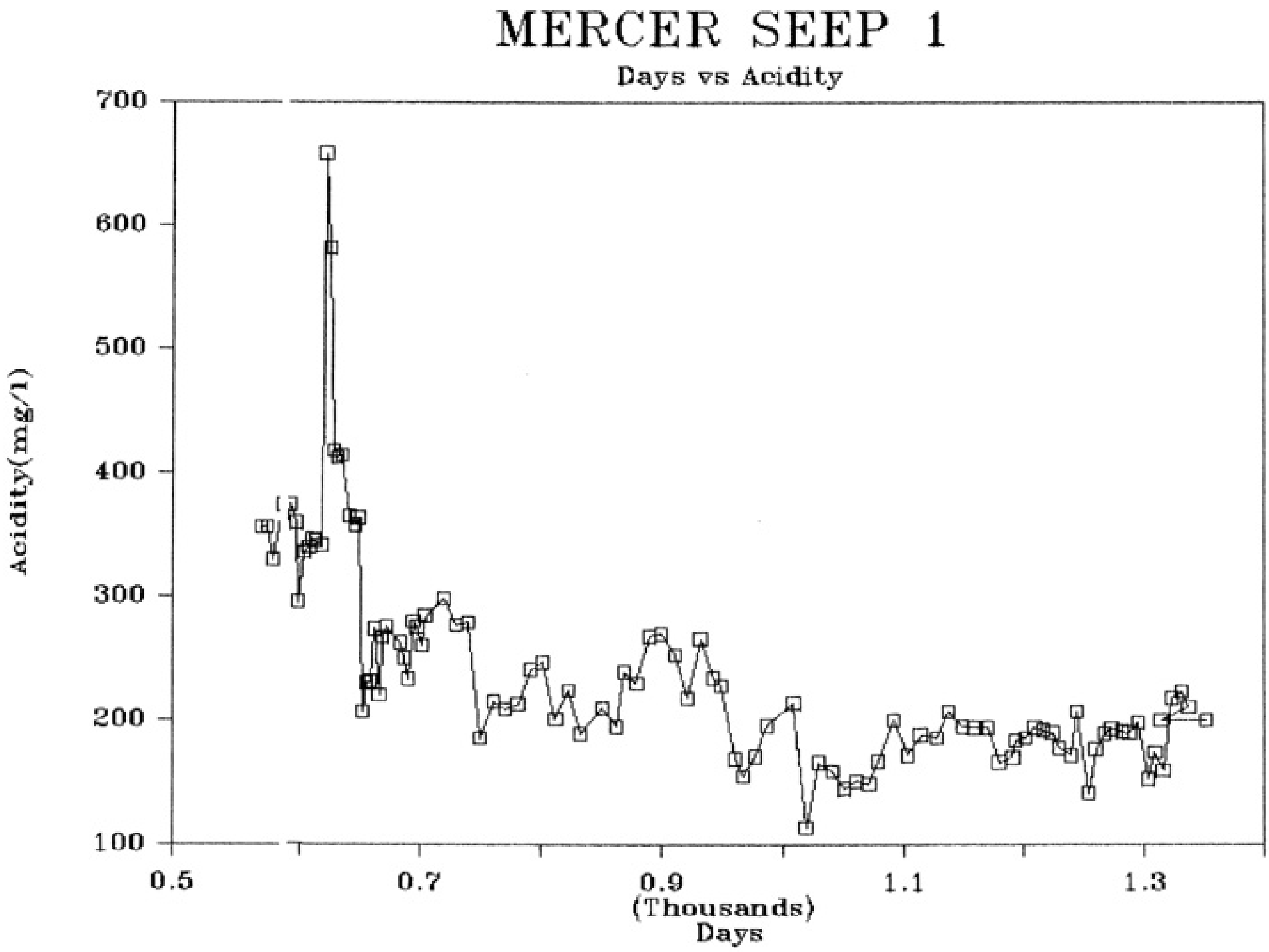
MERCER SEEP 1
Days vs Acidity
700
600
500
400
300
200
100
Acidity(mg/l)
0.5
0.7
0.9
1.1
1.3
(Thousands)
Days

Figure 2

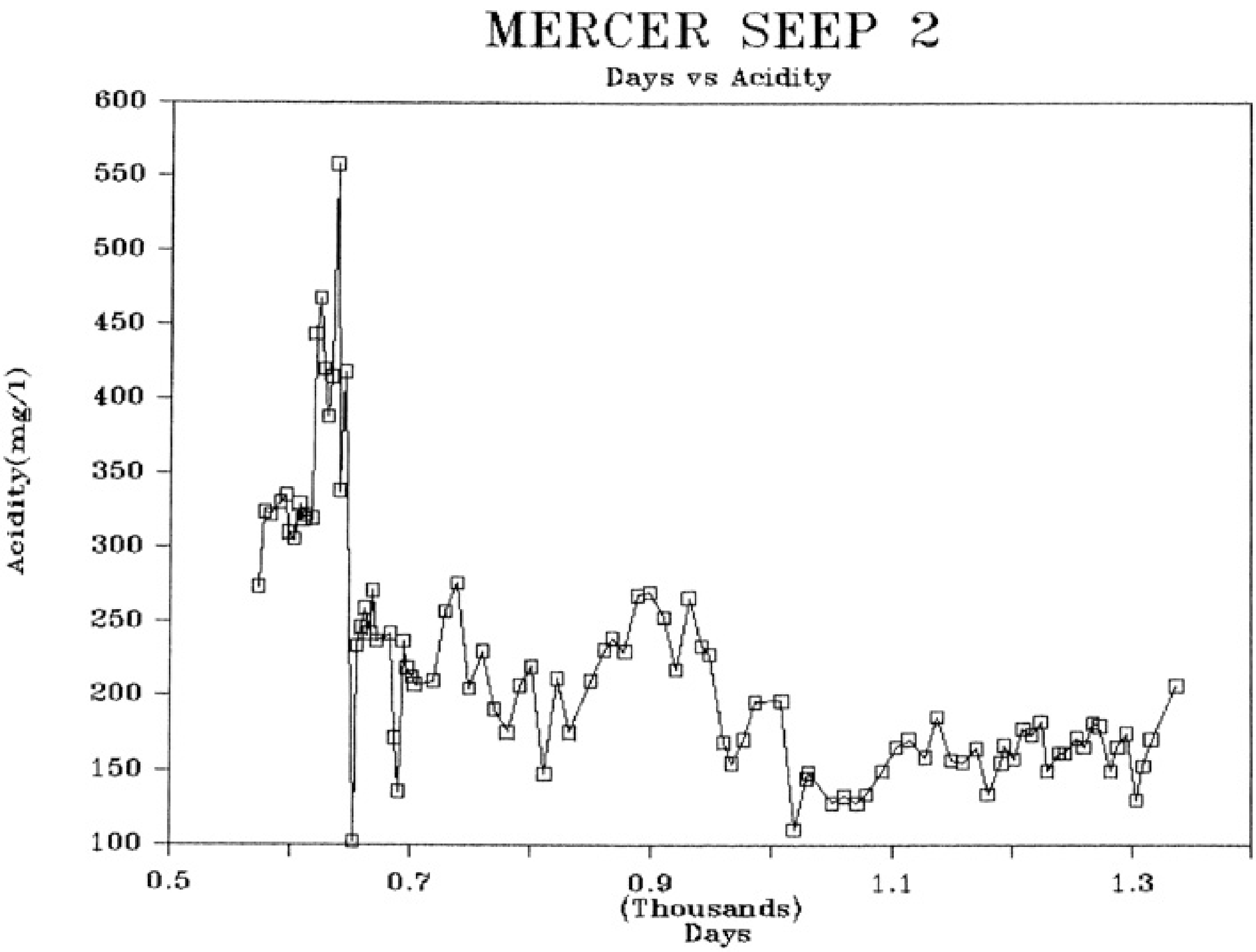
MERCER SEEP 2
Days vs Acidity
Acidity(mg/l)
600
550
500
450
400
350
300
250
200
150
100
0.5
0.7
0.9
1.1
1.3
(Thousands)
Days

Figure 3

MERCER SEEP 3