LEAKY MINES:
MAYBE A BENEFIT IN DISGUISE

by

Frank T. Caruccio

and

Gwendelyn Geidel

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

INTRODUCTION

By definition, acid mine drainage is a water related problem. Water serves not only as an integral part of the oxidation reaction but as a conveyor of soluble acid generating sulfide oxidation products. Accordingly, the policy and problem abatement strategy has always been to reduce the flow of water into a mine and/or backfill. It has been reasoned that the more water entering the problem area, the more acid drainage formed and the greater the problem. This reasoning and policy has generally been followed - even though, more often than not, it has been consistently demonstrated not to be an effective deterrent of acid problems. Unless a vast majority of water is diverted from the site, which is seldom achieved using natural materials, there will always be a potential for an acid mine drainage problem.

The selective handling and placement of acid/alkaline overburden material in reconstructed backfills seemed to offer one possible control or technology to remedy the problem. Unfortunately, the selective placement of material does not necessarily carry with it the concomitant exposure of the various rock chemistries to avenues of water movement. For example, the design and selective placement of a calcareous shale (alkaline producing) and a sandstone (acid producing) within a backfill may not produce the desired results if the hydrology of the system is ignored. Under the set of conditions presented, water will preferentially flow through the more permeable acid producing sandstones and around the calcareous shales, essentially developing a dominantly acid producing environment, even through the overburden chemistry may indicate non-acid potentials. The drainage quality then will be an artifact of the hydrology of the backfill and not the overburden quality.

Further, mine drainage quality cannot be assessed solely on the basis of acid concentrations (mg/1). Rather, the net chemistry of acid/alkaline loads (concentration (mg/1) x volume (k) = load (mg)) is the parameter to consider. And, which presents us with an insight into the possible solution to the acid drainage problem. Mine operators treating acid discharges are sensitive to the "loads" - which determines the amount of caustic to be used to neutralize the acidity and the cost of treatment. They know that following a rain, with high flows, the amount of caustic dispensed is not proportional to increased flow. Similarly, the amount of caustic dispensed to neutralize the acidity may, in fact, have to be increased during the summer months when low flow conditions prevail.

Most backfills or reclaimed mines have a unique hydrology indigenous to the particular site conditions. In addition to the variations imposed by the mining procedures, the stratigraphy of the overburden plays an important role in determining the character of the flow regime. Whether the strata remain hard, blocky and form permeable zones, or physically decompose creating relatively impermeable zones, and the manner in which the zones with widely divergent hydraulic conductivities are distributed in spaces. Water movement through the backfill will be controlled by these configurations, and the chemistry of the drainage (seep) will be related to the rock types encountered by the flow paths that form from the recharge areas to the discharge points. As conditions exist today, with few exceptions where backfills are constructed according to a specific plan , we routinely accept this randomly oriented hydrology and the fortuitous development of seep chemistry.

Another notion regarding the hydrology of a backfill that must be reexamined pertains to the development and existence of a water table. It is commonly believed that during precipition events, a wetting front develops that saturates the backfill, forming a water table and establishing flow paths connecting areas of recharge and seep outlets. A substantial amount of field data leads us to believe that the traditional concept of a water table does not apply in a reclaimed or backfilled mine. In the mines that we examined, flow through the backfill is controlled by the most permeable zones, while the discharge points (seeps) are controlled by zones of lower hydraulic conductivity; in essence, causing the water to "back up" into the mine and generating a reservoir which slowly "leaks" out through the seep. The water, therefore, is in residence in the backfill for a period of time that may vary from weeks to several months; and the seep chemistry sampled today may, in fact, reflect conditions that existed sometime in the past.

Because of the hydraulic continuity that exists between the recharge and discharge areas, pressure gradients are transmitted almost instantly and, accordingly, seep flow increases during precipitation events. However, the mass transfer of water, the physical displacement and movement of water through the backfill progress slowly, the velocity determined by the hydraulic gradient and the hydraulic conductivity of the least permeable unit along the flow path.

Essentially, several points and concepts regarding the hydrology of a backfill, and the apparently dominant control that it has on seep chemistry, must be re-examined to provide a more rational basis upon which to structure and design reclamation strategies directed toward the prevention of acid mine drainage.

CONCEPTS FOR RE-EXAMINATION

A. Flushing (Leaching) Frequency

The kinetics (rates of reaction) of pyrite oxidation and carbonate dissolution are not parallel nor equal. Whereas the oxidation of pyrite continues through time and for all intents and purposes has no limit, the formation of alkalinity through carbonate dissolution is limited by solubility contraints on the mineral-water equilibria. As Geidel (1980) showed, the frequency of leaching acid producing material affected the concentrations of acid, but not the acid load (cumulative acidity). Whereas, because of the solubility limit, the concentration of alkalinity remained constant inspite of the leaching interval (Figure 1). However, the net alkaline load increased with more frequent leaching intervals (Figure 1).

These relationships suggest that in backfills containing alkaline and acid zones, where water contact in both horizons is normalized, recharge through the alkaline zones should be encouraged through infiltration pits on the surface of the mine. Thus, based on the non-parallel geochemical kinetics of acid/alkaline production, water should be induced to flow into a backfill on frequent intervals.

B. Acid/Alkaline Loadings

Under natural conditions and based on the discussion presented above, after a critical equilibrium time period, acid concentrations are generally much higher than alkalinity levels produced by equivalent amounts of toxic and calcareous materials. Accordingly, equal amounts of water contacting these two horizons, will always produce acidity values (typically 200-600 mg/1) higher than alkalinity (maximum of 65 mg/1), ergo acid mine drainage. However, should 3 or 8 times more water come in contact with the calcareous material, the alkaline load will exceed the acid load and (aside from the dilution effects) the net effect will be an alkaline drainage (Figure 2). Based on the loading consideration, water should be induced to flow along alkaline producing horizons.

C. Surface Infiltration

Other than manufactured sealants, such as a plastic liner, all natural materials are permeable; albeit some materials, such as clays, having very small values. Assume a layer of clay to be uniformly applied over the entire surface of the reclaimed mine, and that this "seal" has an infiltration capacity of 1/16" per hour, it will effectively reject most precipitation events. However, should the ground not be frozen and covered by a thick blanket of snow, during the spring thaw of a two week period and at an infiltration rate of 1/16" per hour, approximately two feet of water will recharge the mine and provide for 1790 gallons per day seep discharge for every acre of mine surface. Thus, at least once a year a wetting front can be anticipated to migrate down through the backfill (Figure 3), leaching away the accumulated acid producing materials and generating a reservoir of highly acidic water that will eventually "leak" out through the backfill. In the meantime, the surface seal continues to reject rainfall as runoff while severely limiting the amount of alkalinity that could be potentially available to the backfill reservoir.

All indications point to the need to rearrange this balance. Accepting the fact that an acid reservoir will be created during those recharge events that occur once or twice a year, the volume of acid produced during this time could be diluted and neutralized by 3 to 8 times to create non-acid conditions. This could be accomplished through induced flow along alkaline producing horizons.

D. Unidentified Areas of Recharge

Regardless of the diligent efforts directed toward the surface grading and sealing of a reclaimed mine, the reduction in infiltration capacity will not be uniformly affected throughout the area. Some areas of the mine, relative to others, will provide avenues of recharge which may coincide with any of the rock chemistries. Thus, unless the recharge areas are deliberately created (Caruccio and Geidel, 1984), infiltrating water has no direction and may develop a chemistry conducive toward the creation of a problem. Given that water will, one way or another, penetrate the backfill, should we not accept this as a reality of the situation and, accordingly, structure the reclamation to accommodate leakage, thereby controlling not only the rate but the chemistry of the backfill water in particular.

CONSIDERATIONS FOR FUTURE RECLAMATION GUIDELINES

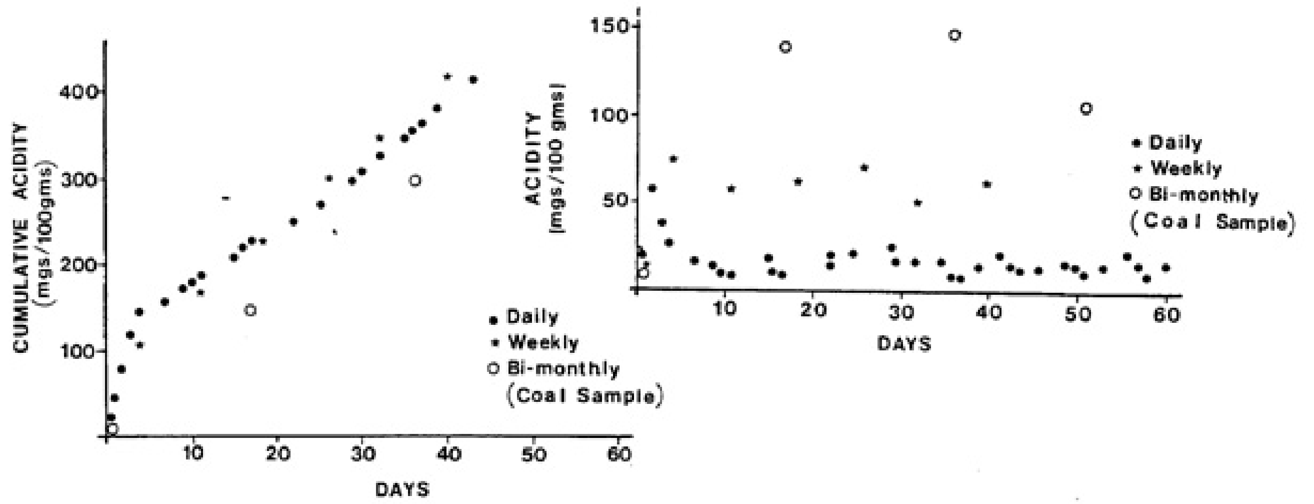
The proponderance of laboratory and field data all point to the need to reevaluate the role of water in the reclamation of mines and design strategies of backfills. We conclude and advocate that the backfilling and reclamation of a mine should be structured to accommodate the development of a reservoir of water. This reservoir must be recharged with alkaline water at a rate 3 to 8 times the maximum infiltration capacity of the surface, through surface funnels or vertical channels constructed of highly permeable alkaline producing material. The recharge channels are placed to either intersect existing flow channels or create large volumes of alkaline water to be stored within the backfill.

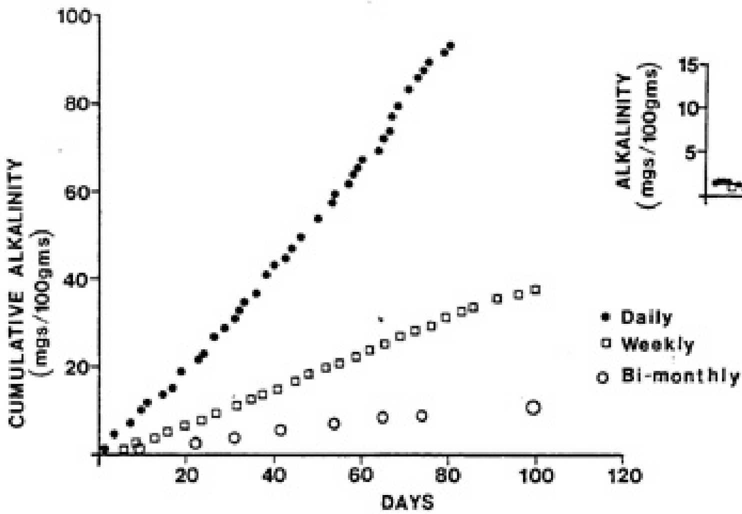
To further enhance the alkaline/acid ratio, acid producing material is to be capped with clay layers similar to what is currently advocated. In mines with a pseudo Karst hydrologic regime, the selective placement and handling of acid material should be coupled with the addition of permeable alkaline channels.

References Cited

Geidel, G., 1980, "Alkaline and Acid Production Potentials of Overburden Material: The Rate of Release," RECLAMATION REVIEW, Vol. 2, 3.

Caruccio, F. and G. Geidel, 1984, "Induced Alkaline Recharge Zones to Mitigate Acidic Seaps," Proceedings, 1984 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, Univ. of KY, Lexington, KY, pp. 43-47.





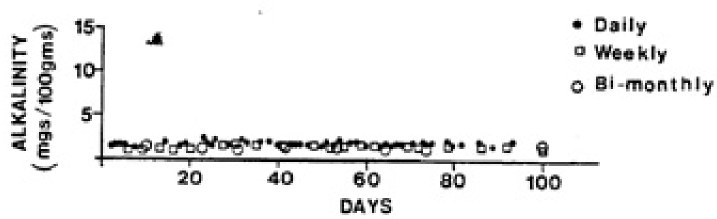


FIGURE 1 - Relationship between daily and cumulative acidities and alkalinities as a function leaching interval. Note how the net acid load remains constant irrespective of interval, the alkaline load increases with increasing interval (i.e. more water).

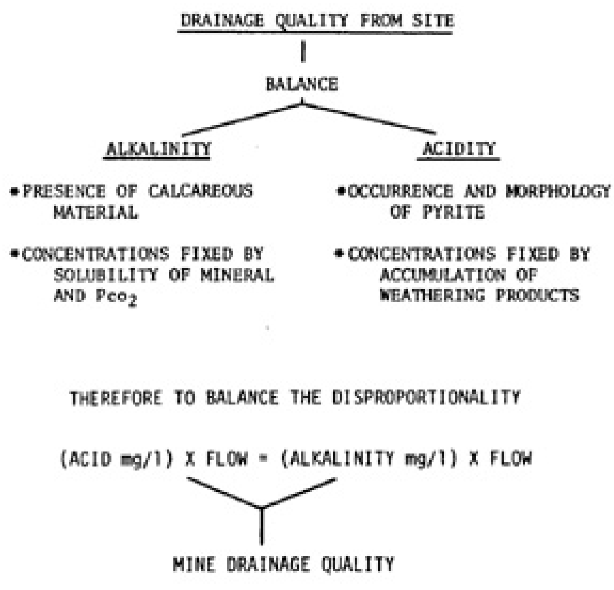


FIGURE 2- Acid and alkaline concentrations under normal conditions favor acid production. Adjusting loads, however, shifts this relationship.

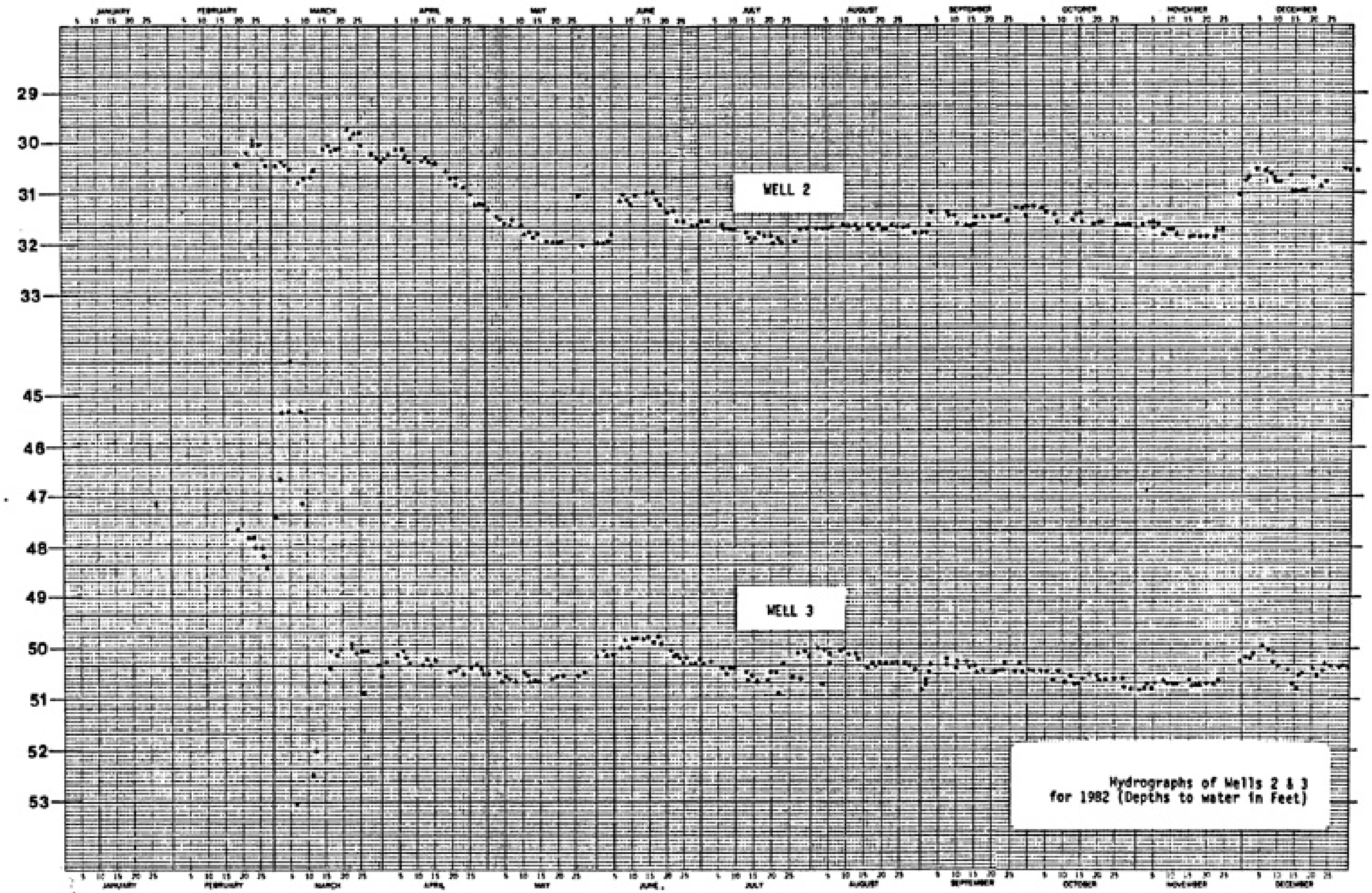


FIGURE 3 - Hydrographs for two wells set in backfill. Note how selected recharge intervals accompanying spring thaw and summer rains provide substantial replenishment of water to the backfill.