Excerpts from

"COAL REMINING
BEST MANAGEMENT PRACTICES
GUIDANCE MANUAL", DECEMBER 2001

Office of Water
Office of Science and Technology
Engineering and Analysis Division
U.S. Environmental Protection Agency
Washington DC, 20460

Note to reader: These excerpts are not to be construed as the complete discussion on any of the BMPs listed and should be read in their full context within the framework of the guidance manual. However, the excerpts provide a quick reference of BMPs that could be further explained or utilized in specific remining applications.

http://www.epa.gov/waterscience/guide/coal/bmp/

Introduction to Best Management Practices

Remining is the mining of abandoned surface mines, underground mines, and/or coal refuse piles that were mined prior to the environmental standards imposed by the Surface Mining Control and Reclamation Act of 1977. There are four types of abandoned mine lands available for remining operations: (1) sites that were previously surface mined, (2) sites that were previously underground mined, (3) sites that were previously surface mined and underground mined, and (4) sites that had coal refuse deposited on the surface. These sites were typically left unreclaimed and unvegetated, sometimes pose safety hazards, and are often associated with pollutional discharges or sedimentation problems. Because of associated environmental problems, these areas cannot be re-affected or remined without the implementation of minimal best management practices (BMPs) in an attempt to correct past problems. BMPs implemented during the remining and reclamation of these sites are designed to reduce, if not completely eliminate, pre-existing environmental problems, particularly water pollution. The types and scope of BMPs are tailored to specific operations based largely on pre-existing site conditions, hydrology, and geology. BMPs are designed to function in a physical and/or geochemical manner to reduce the pollution loadings. In this guidance document, BMPs have been placed into four categories: hydrologic and sediment control, geochemical, operational, and passive treatment, although there is some question whether passive treatment is a true BMP. These categories have been designed for ease of discussion, and each BMP has been placed in the category that is most appropriate. In several cases, a BMP serves more than a single function. For example, induced alkaline recharge

trenches are discussed as a geochemical BMP, but they also influence hydrology and are closely related to some passive systems. Adding to this complexity is the fact that remining operations nearly always employ multiple BMPs in an effort to abate pollution.

Hydrologic and Sediment Control BMPs include:

Physically performing BMPs and an indication of whether they influence ground-water hydrology (gw), erosion and sedimentation (e&s) or both (gw, e&s).

- **Regrading of spoil (gw, e&s) -** A significant amount of surface-water infiltration can be reduced by regrading abandoned mine spoil. Removal of closed-contour depressions, elimination of spoil ridges and valleys, and the resulting creation of runoff-inducing slopes greatly reduces surface-water infiltration into spoil. Regrading of abandoned mine spoil is one of the most frequently employed BMPs in the operation of remining permits. The application of topsoil or an available soil substitute to newly regraded spoil improves the ability of spoil to impede surface- water infiltration.

- **Revegetation (gw, e&s) -** Revegetation of mine spoil can dramatically reduce the amount of surface water that would otherwise eventually make it to the underlying ground-water system. Vegetative cover also can decrease the amount of atmospheric oxygen that can enter the subsurface, because biological activity in the soil, such as decay of organic matter, can create an oxygen sink. A well-developed soil with a dense cover of vegetation can retain a significant amount of water.

- **Diversion ditch installation (gw, e&s) -** Diversion ditches can be constructed in two different locations, both of which reduce surfacewater infiltration into the backfill. First, diversion ditches can be constructed above the final highwall or open pit to prevent surface water from adjacent unmined areas from entering the reclaimed site and infiltrating into thesubsurface. Second, diversion ditches can be constructed within the backfill area to promote the efficient and rapid removal of direct precipitation prior to infiltration into the spoil. The installation of diversion ditches above the highwall is an effective BMP to preclude recharge to the spoil from adjacent surface water runoff.

- **Installation of low-permeability caps (gw) -** The intention of sealing or capping is to preclude area-wide surface-water infiltration by placing a low-permeability cap over the backfill material, before the soil is replaced (Figure 1.1.1b). Because of the large surface area to be covered and the generally low profit margin at remining sites, the capping material should be readily available and inexpensive to make this BMP a viable option. Capping materials generally should be composed of a locally available waste product, such as pozzolonic (self-cementing) coal combustion waste or a naturally occurring clay within a short hauling distance.

- **Stream sealing (gw) -** The sealing of streams reconstructed across backfill areas is intended to preclude direct infiltration into the spoil. Stream sealing as a BMP is

appropriate only where a section of a stream is mined through and subsequently reconstructed.

- **Underground mine daylighting (gw) -** The act of daylighting is the removal of the strata above the coal (overburden), the removal of the collapsed rock (gob) around the existing pillars, and the loading out of the coal. Once the coal is removed, the site is reclaimed. Daylighting works to reduce lateral ground-water infiltration in several ways. Abandoned underground mines are recharged, to a large degree, from fractures in the overlying rock. The original ground-water flow path is interrupted by the subsequent installation of seals and/or drainage systems. In general, daylighting as much area of an abandoned underground mine as possible yields positive results in terms of reducing pollution loads. Daylighting can work both physically and geochemically to effect a pollution load reduction. If the entire mine is not daylighted, the remaining underground mine entries need to be adequately sealed to restrict or prevent ground-water movement between the underground mine and the backfill, and to preclude oxygen infiltration into the mine entries.

- **Mine entry and auger hole sealing (gw) -** As an integral part of daylighting, abandoned mine entries and auger holes exposed at the final highwall are sealed with a low-permeability material. Sealing these abandoned workings inhibits the infiltration of atmospheric oxygen. Sealing also prevents ground-water movement into these workings from the mine spoil and from these mine workings into the mine spoil.

- **Highwall and pit floor drains (gw) -** There are two basic forms of highwall drains (horizontal and vertical) that work together or separately to collect ground water entering the spoil from the highwall. Horizontal drains can be installed to work on a stand-alone basis. Vertical (chimney) drains usually are not installed as stand alone, but are commonly tied into a horizontal drain. Highwall drain systems work to minimize or prevent the contact between ground water and potentially acid-forming spoil by interception, collection, and transport away from the spoil. Pit-floor drains are similar in construction to and perform a similar function as Horizontal highwall drains. Depending on the dip of the pit floor, they can be tied into each other to create a common drainage system. Pit-floor drains are designed to capture ground water that has entered the backfill either through lateral or vertical infiltration. The water is then rapidly drained from the site without intercepting additional spoil material.

- **Grout curtains (gw) -** Grout curtains are vertical or nearly vertical, tabular-shaped, low-permeability layers that are emplaced to prevent or divert ground-water movement. In remining operations, grout curtains can be installed at and against the highwall, or they can be installed in the undisturbed strata above the highwall.

- **Ground water diversion wells (gw) -** Diversion wells are installed specifically to intercept and collect ground water prior to infiltration into the reclaimed backfill. These wells are drilled up-gradient of the backfill area and can be oriented vertically or horizontally. Diversion wells should prevent water movement into the strip, not create a pump-and-treat operation.

Geochemically performing BMPs include:

- **Alkaline addition** - Alkaline addition is conducted where there is an inadequate quantity of naturally occurring alkaline rocks. It is widely recognized that mine sites with an abundance of naturally occurring limestone or alkaline strata produce alkaline water, even in the presence of high sulfur. However, many sites contain little or no alkaline material and, as a consequence, often produce acidic drainage even when sulfur contents are relatively low. One approach to improving alkaline deficient sites is to import alkaline material to amend the spoil in order to obtain alkaline drainage. Alkaline material is best applied by distributing and thoroughly mixing it throughout the backfill.

- **Alkaline redistribution** - Alkaline redistribution takes place where only a portion of the site has a significant amount of alkaline material which is then distributed more evenly across the site. A practice similar to alkaline addition is the redistribution of alkaline materials to alkaline deficient areas from areas of the same or adjacent mine sites which have more than ample alkaline strata. This procedure is practical where sufficient quantities of alkaline material are present, but distribution is so uneven that some portions of the backfill do not contain enough neutralizers to prevent or neutralize AMD. Alkaline redistribution then becomes largely an exercise in materials handling.

- **Mining into highly-alkaline strata** - Alkaline material that is located stratigraphically high above the coal may require mining into higher cover to access it or may require a reorientation of the pit so that the alkaline material is encountered with every mining cut.

- **Induced alkaline recharge -** Constructed recharge infiltration pathways composed of limestone within mine backfill have been used to increase alkalinity in mine spoil and to increase oxygen availability within spoil. These pathways can be near surface features (trenches) or deeper structures that extend from the surface to the base of the spoil (funnels).

- **Special handling of materials** - Special handling at surface mines encompasses the selection, handling, and controlled placement of acid-producing and/or calcareous rock. The primary purpose of special handling is to place acidic or alkaline strata in such a way as to minimize acid production and transport, and to maximize the alkalinity generation within the mine spoil water. Special handling of acidic material occurs where there is a significant amount, but not an over-abundance, of this material that can be field-identified and segregated. “Blending” of overburden is often appropriate where the alkaline and acidic overburden occur in proximity. Ripping (disaggregating) the pit floor can be done to incorporate alkaline material into the mine backfill at sites where alkaline strata exist below the lowest coal seam to be mined. Placement of acidic materials above the water table using segregation, isolation, and encapsulation techniques minimizes contact between acid-forming material and ground water.

- **Use of bactericides -** It is possible that the application of massive amounts of bactericides on the Unreclaimed spoil may temporarily prevent the deleterious effects of a protracted cessation. Bactericides can, for a time, dramatically slow the rate of pyrite oxidation. However, the use of bactericides on surface mines in the past has been less than successful. Some success has been observed for the temporary stockpiling of coal refuse subsequent to burial (Sobek and others, 1990). Additionally, because the use of bactericides is expensive, it may not be economically feasible for many remining operations.

Operational BMPs include:

- **Coal refuse reprocessing (and or reclamation) -** These piles, even though some may be approaching 100 years old, are still producing AMD. The coal and true refuse material (e.g., carbonaceous black shales, some roof and seat rock) that comprise refuse piles usually have a significant sulfur content (>0.50 percent total sulfur)making acid generation almost inevitable. Acid production is additionally facilitated by the fact that coal refuse does not readily support vegetation. The acidic nature of the refuse inhibits plant growth, and the commonly dark color generates considerable heat in the summer causing heat toxicity. Without vegetation, the infiltration of atmospheric oxygen and surface water into the pile is virtually unimpeded, promoting continual acid generation within the pile. If the size of the piles and the amount of acid-forming material they contain can be reduced, and if the piles can be regraded, topsoiled, and vegetated, the volume of acid generation will be reduced.

- **Rapid mining and concurrent reclamation –** The speed at which mining and subsequent reclamation are conducted can have a substantial impact on the resulting post-mining water quality. Accelerated pyrite oxidation occurs when the overburden is broken up and exposed to atmospheric oxygen. The process of overburden removal during mining breaks the rocks into clay- to large boulder-sized particles, which increases the exposed surface area by several orders of magnitude. This greater exposed surface area in turn greatly increases the potential amount of pyrite that is freshly exposed to the atmosphere and is susceptible to oxidation.

- **Limited or no auger mining -** Auger holes, depending on the hydrologic system of the site and the sulfur content of the coal, have a high potential to create additional AMD. Ground water entering the auger holes contacts primarily coal and perhaps a minor amount of roof and seat rock. All three of these rock units are composed of potentially acid-forming materials. The amount of increased surface area caused by auger holes can be considerable compared to exposure of the remaining coal at a final highwall. There are circumstances where auger mining may be permissible at remining operations with little chance of increasing the pollution load. These include, but are not limited to:

  • If the hydrologic system is such that the auger holes are likely to be flooded and remain so permanently, auger mining may be acceptable. Permanent flooding will preclude the introduction of atmospheric oxygen, thus the acid mine drainage

production should cease. Augering below the regional drainage system will likely allow for complete and permanent inundation the auger holes.

• Augering above regional drainage may be permissible if auger hole sealing can be achieved to a degree that precludes the infiltration of atmospheric oxygen and/or inhibits ground-water drainage from the holes. If the auger holes, once sealed, flood and the flooded conditions are maintained, AMD production should be prevented.

- **Off-site disposal of acid-forming coal cleanings, pit and tipple refuse -** In the course of a remining operation, quantities of acid-forming rocks associated with the coal (e.g., pit and tipple cleanings) are removed and frequently stockpiled for later disposal within the spoil. These rocks include rocks immediately overlying the coal (commonly a black shale or pyritic sandstone), parting or binder (usually a carbonaceous black shale or bone coal), immediate seat rock (carbonaceous and/or pyritic shales or claystones) removed along with the coal, unsaleable rider or split seams, and other acid-forming materials separated from the coal during loading out of the pit or during the initial coal cleaning at the tipple/breaker. Total sulfur concentrations of several percent are common in these rocks. There are a few circumstances that would allow on-site disposal of acidic pit and tipple cleanings while limiting the potential to produce more acid. These conditions include, but may not be limited to:

  • Sites where the overburden is composed to a great extent of calcareous (alkaline)material. Any potentially acidic material can be entirely encapsulated within this material. In these situations, the production of alkalinity will most likely either preclude acid production (iron oxidizing bacteria do not thrive in an alkaline environment) or overwhelm any acidity that is produced.

  • Sites where the amount of pit and tipple cleanings are relatively small in volume and insignificant compared to the entire volume of the spoil. In these cases, the acidic material can be specially handled (e.g., strategically placed, capped, encapsulated, etc.) to prevent additional acid production. Care should be taken in these situations to ensure that the special handling technique is physically viable (See Section 2.4, Special Handling of Acid-Forming Materials). For example, if the special handling plan is to place the acid-forming materials above the water table, the backfill should be thick enough allow material placement well above the anticipated highest
  level of the postmining water table.

Passive treatment methods **include**:

- **Anoxic limestone drains -** Anoxic mine water passing through limestone drains allows for the production of alkalinity without iron armoring and precipitation. For these drains to function properly, the mine drainage dissolved oxygen content should be less than 1 mg/L Anoxic limestone drains are designed to generate alkalinity in acid mine drainage

without atmospheric exposure. In addition to preventing iron hydroxide precipitation, the closed environment of an ALD fosters increased CO_2 concentrations, which in turn facilitates higher alkalinity production.

- **Constructed wetlands -** The flow of AMD through *Sphagnum* moss bogs illustrated that iron and acidity concentrations could be reduced without degrading the wetland. Studies on naturally formed wetlands treating mine drainage were initially conducted in Ohio and West Virginia.

- **Successive alkalinity-producing systems -** Successive alkalinity-producing systems (SAPS) utilize the alkalinity production of anaerobic wetlands and ALDs to remove metals from mine water, while greatly increasing the alkalinity production over either of the two systems working singly.

- **Open limestone channels -** In contrast to treating AMD with limestone in an anoxic environment, more recent research has been conducted on this treatment in an environment open to the atmosphere (oxic).

- **Oxic limestone drains -** An oxic limestone drain (OLD), unlike an ALD, is designed to treat water containing appreciable dissolved oxygen and iron that has been oxidized (ferric). Like ALDs, OLDs are designed to promote higher limestone dissolution, hence alkalinity production, by concentrating the partial pressure of CO_2.
- **Alkalinity-producing diversion wells -** Alkalinity-producing diversion wells, a low maintenance method for treating acidic water, were developed in Norway and Sweden using a water pressure-driven, fluidized limestone bed. This technology has been modified for use in treating AMD and streams contaminated by AMD.

- **Pyrolusite® systems -** Manganese removal from AMD is extremely difficult and has been historically costly. Manganese does not precipitate as easily as iron, and certain manganese oxides are soluble in the presence of ferrous iron. For these reasons, many operators should raise the pH to above 10 in order to effectively precipitate it out of solution.