Proceedings of

REGULATION, RISK, AND RECLAMATION WITH COAL COMBUSTION BY-PRODUCTS AT MINES:

A TECHNICAL INTERACTIVE FORUM

Held in Conjunction with the World of Coal Ash
Lexington Center, Heritage Hall
Lexington, Kentucky
April 13-14, 2005

Edited by:
Kimery C. Vories
Anna Harrington

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FOREWORD

Beginning in May of 1994, the Office of Surface Mining (OSM) has taken an active role in encouraging and promoting technological advances, research, and technology transfer related to the use and disposal of coal combustion by-products (CCBs) at mine sites. The primary activities and accomplishments of OSM in this area have been the establishment of a multi-interest group steering committee that has:

(1) conducted national technical interactive forums on:
- "A Coal Combustion By-Products Associated with Coal Mining" in October of 1996 at Southern Illinois University
- "The Use and Disposal of Coal Combustion By-Products at Coal Mines" in April of 2000 at the National Energy Technology Laboratory (NETL) in Morgantown, West Virginia
- "Coal Combustion By-Products and Western Coal Mines" in April of 2002 in Golden, Colorado
- "State Regulation of CCB Placement at Mines Sites" in May of 2004 in Harrisburg, Pennsylvania;
- and now, "Regulation, Risk, and Reclamation with CCBs at Mines" in April 2005 in Lexington, Kentucky.

(2) edited, published, and distributed thousands of copies of the forum proceedings;
(3) provided technical assistance to the American Society for Testing Methods (ASTM) on draft guidance for CCBs on mine sites; and
(4) developed and managed an Internet Website dedicated to providing a user friendly guide to CCB literature, organizations, EPA rule-making, and educational events.

Concerning cooperation with other Federal agencies, OSM has signed a Memorandum of Understanding with the NETL to collaborate on CCB research and issues. OSM serves on the NETL national steering committee of the Combustion By-Products Recycling Consortium in order to assist in directing CCB research efforts by the U.S. Department of Energy. OSM is currently working with the U.S. Environmental Protection Agency to investigate whether or not additional Federal regulations are necessary to protect the public and environment when CCBs are placed at the mine site. OSM is contributing to the effort by the Interstate Mining Compact Commission and member States on developing a State consensus on how best to regulate CCB placement at both Surface Mining Control and Reclamation Act of 1977 (SMCRA) and non-SMCRA mine sites.

OSM contributes to other professional organizations that focus on the development of useful products and applications of coal combustion by-products such as the:

(1) technical program committee for the biennial International Ash Symposium conducted by the University of Kentucky Center for Applied Energy Research; and
(2) national steering committee of the 2005 World of Coal Ash.

OSM staff has presented technical papers related to CCB placement on Surface Mining Control and Reclamation Act (SMCRA) mine sites at numerous technical conferences.

The purpose of the April, 2005 forum was to provide: an organized format for discussion of technical issues concerning the placement of CCBs at mines and the placement related to protecting the hydrologic balance; a comparison of leachate protocols and how they can be more appropriately used in the assessment of risk; an update of State and Federal regulatory efforts to determine that appropriate regulatory controls are in place to protect the public and the environment; an easily understood, state-of-the-art summary talk by knowledgeable speakers; a published post-forum proceedings that summarizes the presentations, participant discussions, and recommendations; and access to the discussions for all interested participants.

In response to a request from Congress, the National Academies of Science is conducting a study that will examine the health, safety, and environmental risks associated with using coal combustion wastes for reclamation in active and abandoned coal mines. The study will look at the placement in abandoned and active, surface and underground coal mines in all major coal basins. It will consider coal mines receiving large quantities coal combustion wastes. The committee will focus its efforts on coal combustion by-products from utility power plants and independent power producers, rather than small business, industries, and institutions. A profile of the utility industry will be taken into consideration in designing the study to focus on the sources producing the greatest quantities of coal combustion

by-products. The goal of the study is to determine whether CCBs were placed and disposed of in coal mines with inadequate safeguards and whether this activity is degrading water supplies in coal mines in contravention of SMCRA. OSM has provided extensive information to the National Academies on coal combustion by-products placement at SMCRA mines.

Based on the results of the above efforts, OSM will assess the outcomes of the forum and CCB activities and make recommendations for potential revisions to OSM policy and plans for enhancement of additional technology transfer events. I would like to sincerely thank the steering committee, invited speakers, and participants for their time and efforts in making this program a success.

Kimery C. Vories
CCB Steering Committee Chairperson

STEERING COMMITTEE MEMBERS

Kimery C. Vories (Forum Chairperson)
Mid-Continent Region
USDOI Office of Surface Mining

Dave Goss
American Coal Ash Association

Robert Bessette
Council of Industrial Boiler Owners

Dan Wheeler
Illinois Department of Commerce and Community Affairs
Office of Coal Development & Marketing

Albert Dalberto
Pennsylvania Bureau of Mines and Reclamation

John Mead
Coal Research Center
Southern Illinois University Carbondale

Dr. Tarunjit S. Butalia
The Ohio State University

Sid Stroud
TXU

Debra Pflughoeft-Hassett
University of North Dakota

William Aljoe
US Department of Energy
National Energy Technology Laboratory

Joe Galetovic
Western Region
USDOI Office of Surface Mining

Peter Michael
Appalachian Region
USDOI Office of Surface Mining

Randall Mills
Mid Continent Region
USDOI Office of Surface Mining

Hendric G. van Oss
USGS Minerals Information Team

James Roewer
Utilities Solid Waste Activities Group

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Session 1

CASE STUDIES OF CCB MINE PLACEMENT DESIGN, IMPLEMENTATION, AND MONITORING

Session Chairperson:
Peter Michael
U.S. DOI Office of Surface Mining
Pittsburgh, Pennsylvania

The Relationship Between Water Quality and Coal Combustion By-Product Placement in an Arid Western Coal Mine
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George M. Hawkey, Mississippi Lignite Mining Co., Ackerman, Mississippi and Marcelo P. Merino, The North American Coal Corporation, Dallas, Texas.

Use of a CCP Grout to Reduce the Formation of Acid Mine Drainage: An Update on the Winding Ridge Project

Robin L. Guynn, Leonard G. Rafalko, ERM, and Paul Petzrick Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, Maryland

THE RELATIONSHIP BETWEEN WATER QUALTIY AND COAL COMBUSTION BY-PRODUCT PLACEMENT IN AN ARID WESTERN COAL MINE

J. Luther, B. Musslewhite, and C. Brown
San Juan Coal Co.
Waterflow, New Mexico

Abstract

San Juan Coal Company's San Juan Mine (SJM) is located in an arid region of northwestern New Mexico with 25 cm of mean annual precipitation. SJM has been mining coal and placing Coal Combustion By-Products (CCB) in the mined areas for 30 years. The placement of CCB materials is tracked and reported annually to New Mexico Mining and Minerals Division (MMD) along with quarterly total metal and leachate analyses. Perennial streams are not located within the operating area of SJM, however, water from the ephemeral drainages that cross the mine site are sampled and analyzed in response to precipitation events. Trace element concentrations in natural geologic materials and CCB at SJM are well correlated but do not provide a good measure of leachability and mobility. A leachability and attenuation study was completed using local groundwater sources, CCB, and natural geologic materials to model future potential impacts of CCB placement. This model predicts no significant degradation of groundwater. This prediction is supported by groundwater monitoring data from 17 locations that show no impact.

Introduction

There is continued national interest regarding potential environmental impacts resulting from use of CCB as backfill at surface coal mining operations. SJM is regulated by Federal and State agencies including the Environmental Protection Agency (EPA), Office of Surface Mining (OSM), Mining and Minerals Division (MMD), and the New Mexico Environment Department. CCB placement has been extensively studied by these agencies both in the course of permit approval and in response to citizen initiated inspections. As part of the regulatory regiment, SJM has conducted analysis of CCB, surface water, groundwater, and mine backfill and has determined that water degradation has not occurred as a result of mining, backfilling, and reclamation operations.

General Setting

SJM is located approximately 15 miles west of Farmington, New Mexico on the western flank of the San Juan Structural Basin. The basin is structurally bound on the northwest, north, and east by an arcuate, southward opening structure known as the Hogback Monocline. The geologic strata in the vicinity of SJM dip gently to the east from one to two degrees towards the basin interior.

Geologic formations at SJM and adjacent areas in ascending order are Pictured Cliffs Sandstone (PCS) Formation, Fruitland Formation, Kirtland Formation, and unconsolidated alluvial deposits associated with the San Juan River and Shumway-Westwater Arroyos. The general groundwater quality is very saline with total dissolved solids typically greater than 10,000 mg/L. Mean annual precipitation within the immediate area is 25 cm. Approximately 50% of precipitation occurs during the months of July to October during the period of greatest evapotranspiration. The annual pan evaporation rate at SJM ranges from 140 to 175 cm.

SJM has recently converted from a surface coal mine to an underground mining operation. The underground mine is extracting the same Fruitland Formation coal seam that was previously mined by surface operations. Coal from the Fruitland Formation is characterized as sub-bituminous with 9,500 Btu/lb, 18 to 25% ash, and <1% sulfur. Previously mined areas are filled with CCB and backfill (spoil) material to bring the dry pits to approximate original contour (AOC) for final reclamation. CCB placement is limited in its extent as demonstrated in Figure 1. Approximately 7 million tons of coal are produced yearly with 2.7 million tons of (CCB) being placed back into the previously mined areas. The volume of CCB placed in the pits to date accounts for approximately 3% of total material handled at the mine.

Monitoring and Placement of CCB's

Fly ash, bottom ash, and flue gas desulfurization (FGD) products have been placed in excavated portions of the mine pit, haulage ramps, and depressions at SJM to achieve the approximate original contour (AOC) of premining topography. CCB materials are composed of approximately 70% fly ash, 15% bottom ash, and 15% FGD. CCB's are placed in discontinuous pockets and layers that are surrounded by and commonly interbedded with low permeability backfill (spoil) materials. CCB's are buried with an average of 10 ft of backfill material after final placement. CCB management areas are tracked to determine placement locations and elevations (Figure1).

Figure 1. CCB placement areas and selected monitoring well locations at San Juan Mine.

The principal components of CCB's at SJM are silica, alumina, oxides of calcium, magnesium, and iron. Secondary components include carbon and various trace elements. These materials are very alkaline (pH 7.4 to 12) and have low salinity (EC 0.15 to 3.18 dS m^{-1}). CCB's are commonly amorphous structured minerals composed of predominately silt sized (2 to 100 um) particles. Laboratory tests show that these materials have low permeability with saturated hydraulic conductivity of 2.3 x 10^{-7} cm sec^{-1} or about 7.3 cm yr^{-1}.

Overburden and backfill materials are saline (EC 4 to 8 dS m^{-1}), sodic (SAR 15 to 60), and alkaline (pH 7.2 to 9.5). Predominate mineralogy of these materials is sodium saturated smectitic clays with secondary accumulations of sulfate and carbonate salts. These natural geologic materials have trace element concentrations similar to CCB's. The backfill materials are essentially impermeable with saturated hydraulic conductivity < 10^{-8} cm sec^{-1}.

The San Juan Generating Station (customer of SJM coal) samples and characterizes fly ash, bottom ash, and FGD waste streams. The following samples are collected and submitted quarterly to a laboratory for analysis:

A) 4-composite samples of fly ash one from each Units 1, 2, 3, 4;

B) 3-composite samples of bottom ash one each from Units 3, 4, and one sample from the common system of Units 1 and 2;

C) 1-composite sample of FGD.

Samples are collected once per week throughout the quarter. At the end of the quarter, weekly samples are composited to provide representative samples of fly ash (4), bottom ash (3), and FGD (1). An 18-hour leachability test (Method D-3987-85) and a total digest (EPA 6010b) are used for sample characterization. A complete chemical evaluation is determined from leachability tests (Table 1). Major cations and trace element concentrations are also determined from the total digest. Quarterly monitoring results are submitted to the Director of MMD for review.

Table 1. List of parameters analyzed from 18-hour leachability tests.

Arsenic	Aluminum	Bicarbonate	Barium	Cadmium	Chromium	Lead
Mercury	Magnesium	Silver	Sulfate	TDS	Nickel	Silicon
Calcium	Carbonate	Boron	Potassium	Iron	Fluoride	Sulfide
Chloride	Copper	pH	Sodium	Zinc	Manganese	Molybdenum
Total Organic Carbon	Acid/base Accounting			Potentially Acidity		
Neutralization potential	Net neutralization potential					
Electrical conductivity	Selenium (Hot Water Soluble and Total)					

Evaluation of total element concentrations in CCBs is required for the Toxic Release Inventory (TRI) reporting process. Unfortunately, TRI data is reported to the public without risk analysis or interpretation, which leads to misinterpretation of the potential environmental impacts of CCBs. The scientific community widely accepts that total elemental concentrations of a media provide little information on fate/transport, migration, and potential toxicity. However, as a matter of comparison the concentrations of trace elements in bottom ash, fly ash, overburden (OVB), and backfill at SJM are similar (Table 2).

Leachability tests provide additional information beyond a simple total constituent analysis. At a minimum, these tests help to identify constituents of concern and allow the use of geochemical speciation models. Radian Corporation conducted a detailed leachability study at SJM to provide supplemental information for predictions about potential hydrological impacts as a consequence of mining and use of CCB materials as backfill. Tests were completed by leaching mine backfill samples and backfill-plus-CCB samples with a composite of groundwater from four wells completed in 8-seam coal. The potential impact of backfill and CCB on groundwater quality was determined by analyzing water before and after equilibration with the solids.

After reclamation, groundwater moving through the mine area will travel through abutting areas of the collapsed underground mine and eventually (several thousand years) to 8-seam coal, where water will interact with the coal. Laboratory leachates generated from interactions between groundwater, backfill, and CCB's were equilibrated with samples of coal from the water-bearing seam (8-seam). The resultant attenuates were analyzed for groundwater quality parameters, and the results were compared to leachate quality data to assess attenuation potential. In

addition to the chemical interaction studies described above, several other laboratory tests were performed in support of the impact assessment including permeability measurements on backfill and CCB and Extraction Procedure (EP) toxicity tests on the CCB. The EP toxicity test was a precursor to the toxicity characterization leaching procedure used for hazardous waste evaluations. The permeability data were previously discussed in this section and the results from EP extractions show levels well below EP toxicity limits for all parameters.

Table 2. Mean trace element concentrations in bottom ash, fly ash, overburden, and backfill materials at San Juan Mine.

Element Mean SJM	Bottom Ash mg/kg	Mean SJM Fly Ash mg/kg	Mean Mean SJM OVB DH 9801 mg/kg	SJM OVB SJM DH 9802 mg/kg	Mean OVB DH9704 mg/kg	Mean Backfill (Severson, 1981) mg/kg
Aluminum	7079	6062	7424	7740	6799	6100
Arsenic	2.76	10.8	2.85	2.28	2.32	NA
Barium	505	758	141	104	123	NA
Boron	51.1	200	NA	NA	NA	15.0
Cadmium	0.42	0.45	3.01	0.57	1.21	NA
Chromium	2.68	5.83	5.66	4.73	6.23	NA
Copper	18.6	12.7	33.4	33.0	32.6	20.0
Iron	4648	3471	NA	NA	NA	18000
Lead	8.46	5.52	10.2	9.89	10.9	13.0
Manganese	59.4	80.5	NA	NA	NA	360
Molybdenum	3.44	5.82	NA	NA	NA	2.70
Nickel	2.15	1.79	9.1	9.02	10.2	13.0
Selenium	0.55	0.58	0.39	0.36	0.62	NA
Silver	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Zinc	37.7	25.8	73.9	71.6	75.8	56.0

Table 3 shows dissolved metal concentrations for the composite 8-seam groundwater sample; backfill leachate; backfill leachate attenuated with 8-seam coal; leachate from the backfill and CCB mixture, and leachate from the backfill and CCB mixture attenuated with 8-seam coal. Dissolved metal concentrations of natural groundwater and the backfill/CCB mixture attenuated with 8-seam coal are highly similar. Concentrations of aluminum (Al), arsenic (As), boron (B), fluoride (F), and nickel (Ni) in attenuated backfill/CCB leachate are increased above levels in the 8-seam groundwater. Analysis results from 18-hour leachate quarterly monitoring data from 2001 through 2004 were used for further evaluation of these parameters (Table 4). Several elements were not detected at the Practical Quantitative Limit (PQL) and therefore could not be accurately determined. When the means are calculated, levels below the PQL were predicted by multiplying the PQL by 0.5, which provides an overestimate of actual concentrations.

Mean Al levels in CCB leachate from the 18-hour leachate procedure (Table 4) were below levels measured from natural geologic material (backfill) (Table 3). Mean As levels were 0.006 mg/L for fly ash and 0.007 mg/L for bottom ash with 92% and 85% of the sample concentrations not detected at the PQL, respectively. These concentrations are considerably lower than the New Mexico Domestic Water Quality Criteria of 0.050 mg/L. Arsenic levels in all FGD samples were not detected at the PQL and therefore a mean was not calculated. Boron levels in CCB are higher than 8-seam coal. Drinking water standards have not been established for boron. Fluoride in fly ash and bottom ash leachate are below 8-seam background concentrations and EPA Drinking Water Standards while levels in FGD are above groundwater concentrations. The weighted average concentration of fluoride is 3.4

mg/L, which is below the Primary Drinking Water Standard of 4.0 mg/L. Nickel concentrations in fly ash and bottom ash were not detected at the PQL for all monitoring samples and therefore a mean was not calculated.

Table 3. Dissolved trace element concentrations in groundwater, leachate, and leachates attenuated with 8-seam coal.

Element Gro	undwater Composite mg/L	Backfill Leachate mg/L	Attenuated Back Backfill/Leachate mg/L	fill/CCB Leachate B mg/L	Attenuated ackfill/CCB Leachate mg/L
Aluminum	<0.05	2.2	<0.05	14.0	0.11
Arsenic	<0.003	<0.003	<0.003	0.026	0.37
Barium	0.21	0.28	0.17	0.39	0.078
Boron	<0.009	0.44	0.89	7.0	6.2
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium	<0.001	<0.001	<0.001	0.006	<0.001
Cobalt	<0.006	<0.006	<0.006	<0.006	<0.006
Copper	<0.001	<0.001	<0.001	<0.001	<0.001
Cyanide	0.53	<0.02	<0.02	<0.02	<0.02
Fluoride	2.1	2.4	2.2	7.8	7.1
Iron	0.37	2	0.021	0.27	<0.008
Lead	0.02	0.01	<0.002	<0.002	<0.002
Manganese	0.18	0.16	<0.001	<0.001	<0.001
Mercury	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel	0.004	0.006	0.006	0.008	0.01
Selenium	<0.003	<0.003	<0.003	<0.003	<0.003
Silver	<0.002	0.006	<0.002	<0.002	<0.002
Zinc	0.087	0.01	0.003	0.021	0.025

Table 4. Mean concentrations of selected elements from 18hr leach tests conducted on fly ash, bottom ash, and FGD quarterly monitoring samples from 2001 through 2004.

Element Mean	Fly Ash (mg/L)	Mean Bottom Ash (mg/L)	Mean FGD (mg/L)
Aluminum 1.	9	1.19	0.134
Arsenic 0.	006	0.007	< PQL*
Boron 4.	06	0.773	4.3
Fluoride 0.	59	0.19	19.6
Nickel <PQL	*	<PQL*	0.01

*Note: All levels were below PQL, consequently, a mean could not be calculated.

Hydrology

Water bearing zones at SJM were identified during exploration and monitoring well installation. The PCS, Fruitland Formation coal units (8-seam coal and 9-seam coal), and Westwater-Shumway Arroyo alluvial fill were found to be water-bearing units in the permit area vicinity. The 9-seam coal, a thinner coal unit approximately 100 feet above the 8-seam coal, was found to have isolated areas of perched water. The 9-seam coal was considered a negligible water-bearing unit due to the lenticular nature and abrupt thinning of the coal stratum.

The PCS is nearly 120 feet thick in the vicinity of SJM. The formation strikes approximately north-south and dips to the east southeast from one to two degrees. The PCS is well-cemented marine derived sandstone that exhibits very low primary permeability. Secondary permeability predominates due to small scale fracturing occurring along fault areas

north of SJM. Groundwater use is virtually non-existent due to low permeability, poor water quality, and low production rates. Consequently, classification of the PCS as an aquifer is questionable.

Studies have demonstrated that water quality of the PCS in the San Juan Basin is poor. Water quality is increased near recharge areas (approximately 2,000 mg/L total dissolved solids (TDS) and decreases drastically down dip to over 45,000 mg/L TDS. PCS groundwater is classified as sodium-bicarbonate-chloride type with high concentrations of sulfide, fluoride, and sulfate. It is postulated, based on low permeability that the poorer water quality away from the outcrop is reflective of connate conditions. Tests conducted in 1979 show transmissivity and permeability values of 1.116 $ft^2\ dy^{-1}$ and 0.03 $ft\ dy^{-1}$, respectively.

Flow direction in 8-seam coal is predominately east. Flow gradients range from 0.001 to 0.011 $ft\ ft^{-1}$. Potential recharge areas of 8-seam coal occur at outcrops that intersect intermittent stream channels west of the mined area. Aquifer testing indicates extremely low transmissivity (0.183 $ft^2\ dy^{-1}$) and permeability (0.005 $ft\ dy^{-1}$). This situation is typical of other high pressure, low yield systems in northern New Mexico and southwestern Colorado.

Water quality in 8-seam coal varies significantly throughout the permit area. Total dissolved solids ranges from 3,645 mg/L to 18,560 mg/L and pH ranges from 8.5 to 12.6. The water quality is largely classified as a sodium-sulfate-bicarbonate type with elevated concentrations of chloride and calcium. Reduction processes are evidenced by the occurrence of hydrogen sulfide (H_2S). All samples collected from 8-seam coal exceed groundwater standards, stock watering criteria, and irrigation criteria for several constituents including SAR, pH, and TDS. Given the rather poor water quality and extremely low permeability, the significance of this water-bearing unit as a water resource is negligible.

Water chemistry of Quaternary Alluvial (QAL) waters within the Shumway and Westwater Arroyo stream valleys is characterized as a sodium-bicarbonate type with high concentrations of sulfate and chloride. The QAL water exceeds drinking water standards, stock watering and irrigation criteria, and the TDS concentration upper limit of 10,000 mg/L for protectable water supplies.

A total of 14 surface water monitoring stations are included in the SJM surface water monitoring program. Monitoring of the major drainages, Shumway Arroyo and Westwater Arroyo, occurs as they pass through the permit area. Monitoring stations on the major drainages consist of a crest stage and two or more stage sediment samplers. These arroyos are ephemeral and flows are sampled episodically following precipitation.

A total of 17 groundwater monitoring wells are included in the SJM groundwater monitoring program. Well GB is completed in the PCS and well G26 is completed in the Fruitland Formation 8-seam coal. Wells GE and GL are completed in QAL. Well GB was recently removed from the monitoring program due to the eastward progress of underground mining operations. Groundwater sampling occurs biannually and static water levels are taken quarterly. Two wells, SM-1 and SM-2, are completed in the backfill to monitor any recharge; their approximate locations are shown on a typical cross section (Figure 2). Two wells are lysimeters (L-1 and L-2) that were put in place to monitor recharge and water chemistry of a representative CCB placement area. L-1 was installed at the base of the CCB placement area and L-2 was installed at the CCB surface. To date, no samples have been collected from either the SM-1 and 2 wells or L-1and 2 lysimeters due to lack of water. Locations of the above referenced wells are provided in Figure 1.

Figure 2 shows a typical cross-section of east dipping floor of mined areas and current groundwater monitoring locations. Hydrologic modeling shows that the mine pit would require complete saturation before interaction with Shumway alluvial water could occur. The overall hydrologic gradient is from west to east, further reducing the possibility of groundwater interaction. Data from SM-1 and 2 verify groundwater is not present in backfill materials leading to the conclusion of no interaction between mined areas and Shumway arroyo.

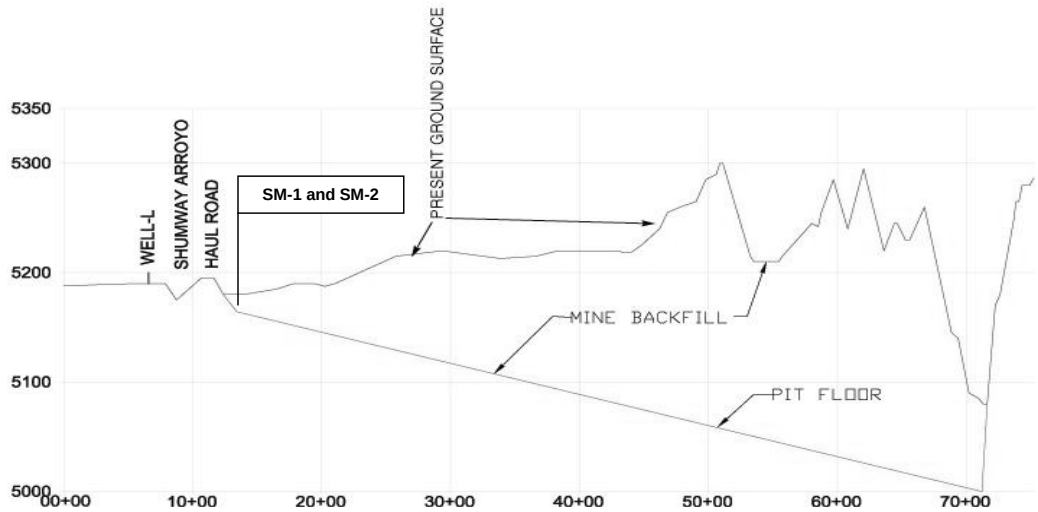
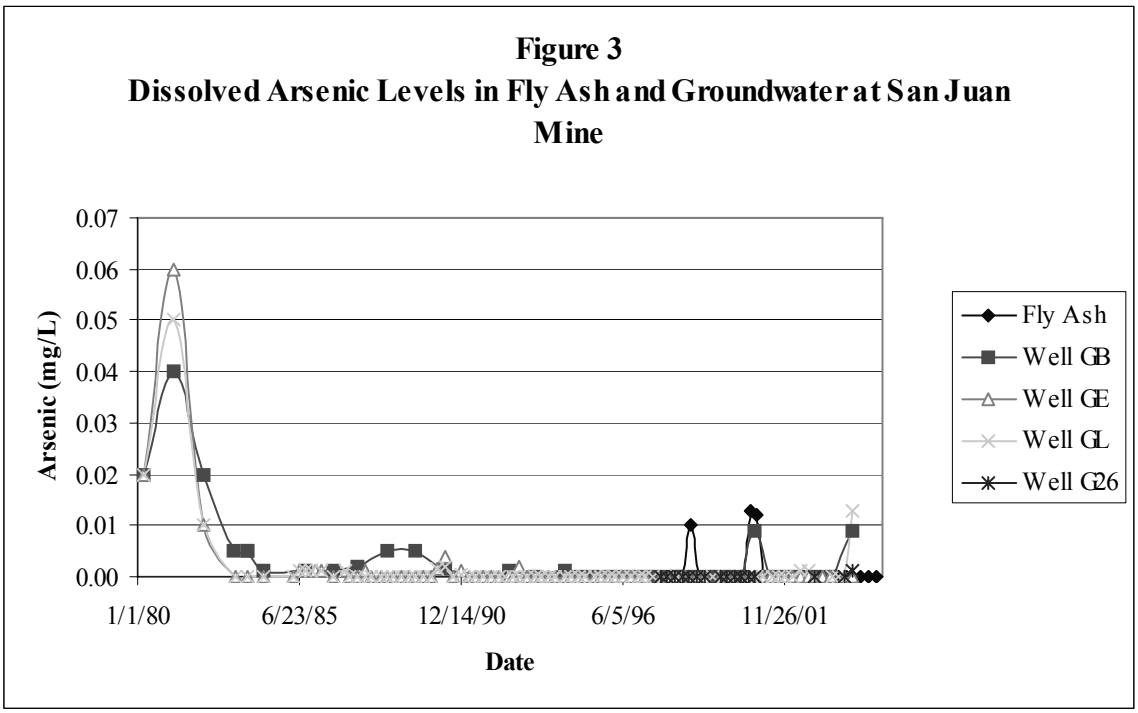


Figure 2. Typical cross-section of mined areas at SJM.

There has been much speculation regarding the effects of CCB placement on water quality. Several parameters have been selected for comparison between levels in surface and groundwater samples and levels in 18-hour leachates from CCB monitoring. Various groups have identified As, Ba, and sulfate (SO_4) as parameters of concern. This concern is the basis for presentation of the following time-series charts for these parameters (Figures 3, 4, and 5, respectively). Monitoring for wells GB, GE, GL was initiated in 1980 while G26 and fly ash monitoring started in 1997 and 1998, respectively. Concentrations below the detection limit are presented as 0.0 mg/L.



Arsenic levels in fly ash, PCS (well GB), QAL (wells GE and GL), and 8-seam coal (well G26) are consistent across the monitoring period 1980 through 2004 (Figure 3). The levels are all below the New Mexico Domestic Water Quality Criteria of 0.05 mg/L. Moreover, there is no association between As levels in CCB and groundwater with the exception of the very low concentrations in both types of media. Similarly, Ba levels in groundwater samples

are very low (Figure 4). Levels in 8-seam coal are variable and naturally higher than levels in PCS and QAL. Barium levels in CCB leachate are also variable but are commonly less than the 2.0 mg/L Primary Drinking Water Standard. Again, there is no clear correlation between CCB and groundwater concentrations. Sulfate levels in groundwater are relatively static with the exception of well GL in QAL. It is clear from the data that the increase is not due to CCB placement, which has been suggested by special interest groups. The levels of SO_4 in CCB leachate are very low with a mean concentration less than 100 mg/L, which is less than levels naturally occurring in groundwater.

Arsenic and Barium levels in downstream surface water sample sites are below the New Mexico Domestic Water Quality Criteria of 0.05 mg/L for As and 2 mg/L for Barium. Sulfate levels at these sites are slightly elevated as compared to the upstream sites and are comparable to background levels found in the San Juan River Regional Coal Environmental Impact Statement.

Figure 4
Dissolved Barium Levels in Fly Ash and Groundwater at San Juan Mine

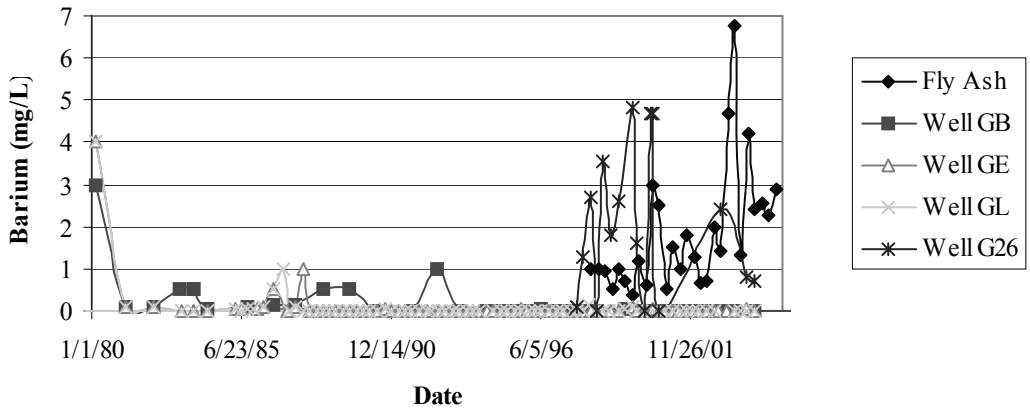
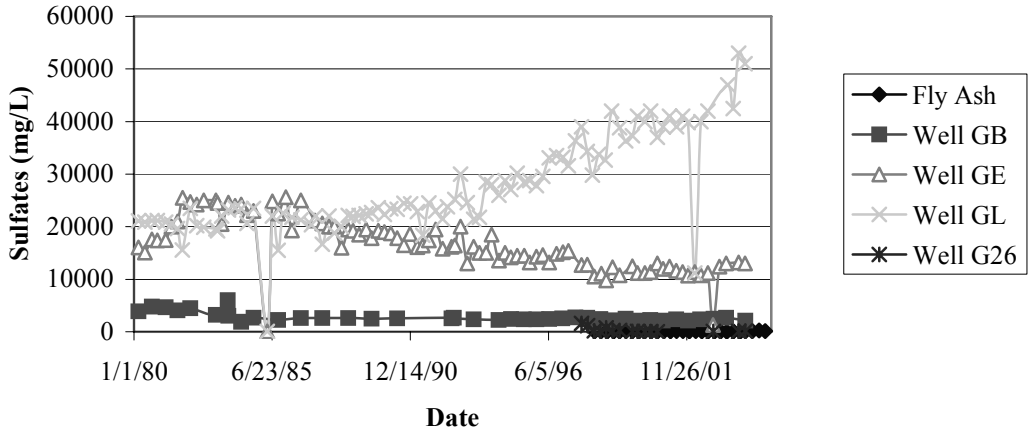


Figure 5
Dissolved Sulfate Levels in Fly Ash and Groundwater at San Juan Mine



Summary

A model of potential impacts from CCB placement must include physical and chemical characterizations as presented above along with hydrogeologic information to predict rates of recharge and potential migration. Recharge of mined areas is speculative given low precipitation (approximately 15 to 25 cm), high rates of evapotranspiration, local geology, and low permeability of CCB and backfill materials. There are no suitable uses of groundwater found in the coal bearing strata of the Fruitland Formation and underlying Pictured Cliffs Formation in close proximity to SJM because of low permeability and elevated water quality parameters such as TDS. Therefore, no plausible negative impact to groundwater can be associated with CCB placement at SJM. Similarly, surface water resources in proximity to the mine also will not be impacted by CCB placement. CCB's are buried by an average of 10 ft of backfill material and active placement areas have designed containment to prevent any surface water discharges. CCB materials are not placed below designed drainage channels to eliminate the possibility of transport from erosional processes. Placement areas are hydrologically isolated from surface and alluvial groundwater. This conclusion is supported by surface and groundwater monitoring data that show no relationship with CCB placement at SJM.

James G. Luther is the Health, Safety, Environmental and Community (HSEC) Superintendent at San Juan Coal Company (SJCC). BHP Billiton is an international mining company that owns SJCC. SJCC consists of San Juan Mine (SJM) surface and underground operations and La Plata Mine. SJM is a mine mouth operation and mines between six and seven million tons of coal per year. Approximately 1.2 million tons of Coal Combustion By-Products from the power plant that is adjacent to SJM are placed back in the mine pit. He has over 25 years environmental experience in the mining industry. He has worked as a consultant, mine regulator, and for mining companies. His current environmental responsibilities include overseeing a small staff conducting permitting, surface water and groundwater monitoring, air monitoring, waste management, ash management, wildlife, archeology and reclamation. He received his Bachelor of Science in Range Management from the University of Wyoming.

SHORT- AND LONG-TERM BEHAVOIR OF FIXATED FGD MATERIAL GROUT AT THE ROBERTS-DAWSON MINE

Harold Walker[1], Panuwat Taerakul[1], Mikko Lamminen[1], Yongtian He[2], Samuel Traina[3], and Earl Whitlatch[1]
[1]The Ohio State University,
Department of Civil and Environmental Engineering and Geodetic Science
Columbus, Ohio;
[2]Virginia Tech, Department of Geological Sciences
Blacksburg, Virginia;
[3]University of California, Merced, Sierra Nevada Research Institute
Merced, California

Abstract

Here we examine both the short- (~ 1 year) and long-term (~ 4 years) behavior of fixated flue gas desulfurization (FGD) material grout following placement within an underground coalmine. Immediately after grout injection, significant increases in acidity, Fe, Al, S, and Ca were observed for most of the surface and groundwater monitoring locations near where grouting was carried out. However, after four years, the long-term fluxes of acidity, iron, sulfur, and calcium were only slightly elevated compared to pre-grout conditions. We suspect that the initial increase in discharge of inorganic elements was due to dissolution of accumulated iron and aluminum sulfate salts and ferrihydrite within the mine voids following the increase in water level and/or rerouting of drainage flow. The long-term discharge of these constituents was likely controlled by the continued dissolution of these soluble salts as well as grout material (for Ca and S). Although the long term fluxes of some elements from the main seeps were slightly elevated, no measurable deleterious short- or long-term impact was observed for the underlying groundwater or adjacent surface water reservoir. Mineralogical analyses indicate that the fixated FGD material grout injected into the Roberts-Dawson mine was geochemically stable and groundwater sampling showed that the grout could locally neutralize mine drainage. However, a grouting strategy that minimizes the dissolution or transport of accumulated soluble salts within the mine voids upon changes in water flow paths is likely needed in order to bring about significant improvements in seep water quality.

Introduction

In a 1999 Report to Congress (USEPA 1999), the United States Environmental Protection Agency (USEPA) ruled that coal combustion by-products (CCBs) not be regulated as a hazardous waste under Subtitle C of the Resource Conservation and Recovery Act, but excluded from this determination the placement of CCBs in deep mine environments. The report noted that the presence of acid mine drainage in deep mine environments may consume the acid neutralizing capacity of the CCBs and result in prolonged release of contaminants. Further, placement of CCBs in deep mines located beneath a regional water table could result in contamination of drinking water supplies. Prior to a final determination, the USEPA recommended more information be gathered related to the risks associated with the placement of CCBs in deep mine environments. This paper represents a summary of the Roberts-Dawson project; a project focusing on the injection of a fixated FGD material grout in an abandoned underground coal mine in central-eastern Ohio. This paper presents a discussion of the characterization of the mine site, site geology and hydrogeology, FGD material placement design considerations, methods of FGD material placement, and monitoring. Finally, a summary of the engineering lessons learned is presented. This paper is based on a number of previous documents which describe various aspects of the Roberts-Dawson project (Bair and Hammer 1999; Damian and Mafi 1999; Laperche and Traina 1999; Walker et al. 1999; Lamminen et al 1999; Whitlatch et al. 1999; Metheny and Bair; 2000; Lamminen et al. 2001; Whitlatch et al. 2002; Walker et al. 2002; Taerakul et al. 2003; Taerakul et al. 2004). The reader is referred to these documents for a more thorough description of the data and conclusions presented here.

Characterization of Mine Site

The mine drainage abatement project was carried out at the Roberts-Dawson coal mine which borders Coshocton and Muskingum counties in central-eastern Ohio. The mine was abandoned in the 1950s. Approximately 2 million cubic feet of coal were removed from the mine during the period of operation. The mine covers an area of approximately 14 acres. The mine is designated Mm-127 in the Ohio Department of Natural Resources (ODNR) registry. There are four adits at the site which drain into a small un-named stream. The un-named stream enters a collection pond and eventually drains into Wills Creek Reservoir. Wills Creek drains to the Muskingum River.

Site Geology and Hydrogeology

This section contains a general description of the geology and hydrogeology of the Roberts-Dawson site. A more complete description is provided in Bair and Hammer (1999). The general topology of the site consists of steep hillsides ranging in elevation from 730 to 1100 feet above mean sea level. The geology consists primarily of interbedded, fine-grained sandstones, shales, claystones, limestones, and coal. The geology can be conceptualized as consisting of three primary layers; an upper Clarion sandstone layer, a middle Kittanning #6 coal layer, and a lower Freeport sandstone layer. The coal seam is approximately 2-5 feet depending on location at the site.

The regional water table is present in the lower Clarion sandstone layer, while the coal and Freeport sandstone layers contain perched aquifers. The general direction of groundwater flow at the site is downward, except for preferential flow paths within the mine voids.

FGD Material Placement and Design Considerations

The goal of the design at the Roberts-Dawson site was to seal the major mine entrances and coat exposed iron sulfide surfaces utilizing two different mixtures of FGD material. The hypothesis underlying this design was that the sealing of the major seeps would reduce the drainage flow and raise the water table within the mine voids, thereby reducing the levels of dissolved oxygen. Coating iron sulfide surfaces within the mine voids would further reduce the exposure of these surfaces to oxygen. Reducing the exposure to oxygen would then limit the oxidation of iron sulfides, and therefore, reduce the dissolution of these materials and the formation of acid mine drainage.

To accomplish this goal, two types of FGD material grout were used; a high strength grout and a lower strength grout. The FGD material grout used at the site consisted of a 1.25:1 mixture of fly ash and dewatered scrubber sludge (filter cake) with an additional 5% CaO. Different amounts of water were mixed with the grout to alter the strength and flow characteristics of the material. The high strength grout was used to create a "plug" at the known mine entrances. The high strength grout was designed to have a strength of 145 lb/in.^{2} and the actual strength as tested in the laboratory was 284 lb/in.^{2}. The goal in using the high strength grout was to completely fill the mine voids near the entrances of the mine. Bore-hole cameras were used during the time of grout placement, and showed that the high-strength grout effectively filled the mine voids near the injection wells. The lower strength grout, on the other hand, was used to coat exposed pyritic surfaces within the upper reaches of the mine voids, rather than completely filling the mine voids. The design strength of the lower strength grout was 75 lb/in.^{2} and the strength of the grout used was determined to be 171 lb/in.^{2}.

The design of the high strength FGD material plug was based on a "blow-out" force analysis as well as consideration of the required friction necessary to keep the plug in place. The force analysis was used to determine the design strength of the high strength FGD material with a safety factor of 4-6. Forces considered included the water pressure due to the maximum expected increase in groundwater elevation and the weight of the soil.

Methods of Placement

The placement of the high and lower strength grouts took place between August 27, 1997 and January 26, 1998. The grout mixing and injection was carried out by an outside contractor (Gunite Construction Company). Fixated FGD material from the Conesville Power Plant was mixed with water on site. Injection holes were grouted by pumping the grout from the mixer site and allowing the grout to move via gravity flow into the drilled holes.

A total of 318 vertical grout holes were drilled and grouted at the site. In addition, 5 horizontal drain pipes at the old mine entries were also grouted. A total of 41,859 linear feet were drilled and 23,778 cubic yards of grout placed. The majority of drilled holes were filled to refusal with the high strength grout. Lower strength grout was injected in the upper portions of the mine void until refusal or a predetermined volume. A significant fraction of the drilled holes (~200 out of 218) took 10 cubic yards or less of grout.

The grouting process was complicated by the presence of an area of unmapped mine voids (~7 acres). After the initial grouting described above was completed, water continued to flow from some of the adits of the unmapped area (site 3 on Figure 1). To reduce or eliminate this flow, pressure grouting of 20 holes was conducted directly above the mine openings. Water flow continued after this initial pressure grouting, so pressure grouting in the drain pipes was then carried out. This final pressure grouting stopped flow and resulted in an increase in water elevation within the voids of the coal layer. However, due to effective sealing of the adit and the buildup of water, a leak in the plug developed as water escaped through a sandstone layer approximately 8 feet above the mine roof. This created a 4 ft. x 3 ft. deep channel due to the erosion of the top edge of the clay bulkhead at the mine entry. Engineering calculations and observations at the site suggested that the mine seal was functional and not the cause of the leak.

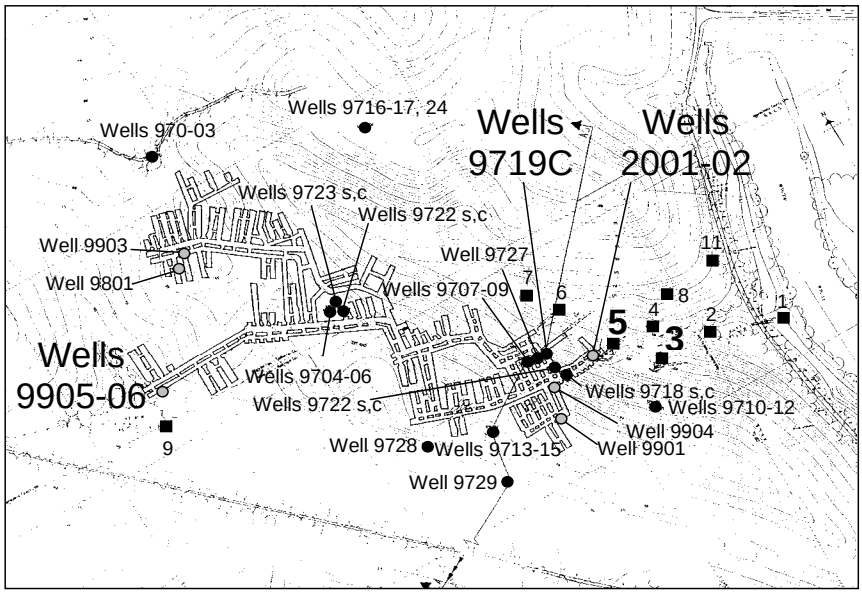


Figure 1 Groundwater and surface water sampling locations at the Roberts-Dawson mine.

Monitoring

Sampling and Analysis Methods

Water quality samples were collected from seeps and groundwater wells for over 4 years, from January 1997 through September 2001. Figure 1 shows the monitoring locations at the site. Groundwater samples were collected from the upper Freeport sandstone layer, the middle Kittanning coal layer as well as the lower Clarion sandstone layer. Monitoring results from the main seeps (sites 3 and 5) and select groundwater wells within the coal layer will be presented here.

Both filtered and un-filtered (0.45 micron cellulose acetate filters) samples were collected on-site and then analyzed for a host of inorganic compounds including Al, Ba, Be, B, Cd, Cr, Ca, Co, Cu, Fe (total and dissolved), Pb, Li, Mg, Mn (total and dissolved), Mo, Ni, P, K, Si, Na, Sr, S, and Zn. Trace metal analysis was conducted by using an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) system. Arsenic was analyzed by using a

Zeeman Graphite Furnace Atomic Absorption (GFAA) Spectrometer. Sulfate and chloride were determined by using a Dionex Ion Chromatography (IC) model DX-500 with AS-11 anion column. Alkalinity analysis was conducted by a titration method using hydrochloric acid and bromocresol green as an indicator. pH measurements were carried out using an ATI Orion pH meter. Conductivity and total dissolved solid measurements were performed using a Fisherbrand conductivity meter. The measurements of pH and conductivity were conducted either at the site or in the laboratory immediately upon returning from field sampling.

Water levels in groundwater wells were measured with a Heron Water Level Probe (Hamilton, OH). Prior to sample collection, wells were purged using either dedicated submersible Redi-Flow™ pumps (Ben Medows Company, Canton, GA) or by using a Reel E-Z portable well pump (Redmond, WA). Some wells were purged manually using disposable one-liter, high-density polyethylene bailers (Timco Manufacturing, Prairie Du Sac, WI). Stream flow rates were measured using the "bucket and stopwatch" technique for low flow rates and weirs installed at the site for high flow rates.

Core samples were also collected at the site 2-3 years following injection of fixated FGD material grout. Core samples were analyzed using a Philips Analytical x-ray diffractomer (Natick, Mass.). Prior to analysis, grout core samples were air dried and ground to less than 250 microns. After collection of core samples, monitoring wells were installed.

Short- and Long-Term Water Quality Trends

The flow rates of water exiting the two major seeps at the Roberts-Dawson site, before and after grouting, are shown in Figure 2. As can be seen, significant flow occurred after grouting. The cause of the flow for site 3 was described above and was due to erosion of the sandstone layer above the mine roof. Subsequently, a drainage pipe was installed at this location to prevent further erosion around the FGD material plug. The flow at site 5 also increased after grouting. The increase in flow at this site was due to the emergence of a new drainage seep, approximately half way between the original mine entrance and the receiving stream.

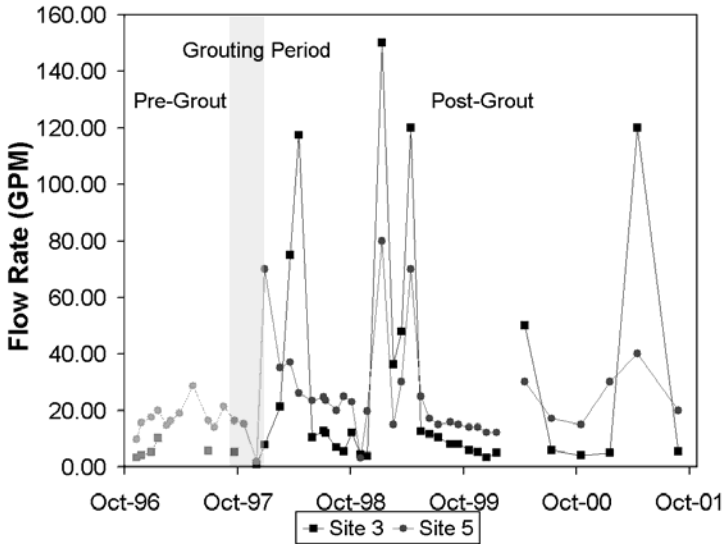


Figure 2. Surface water flow rates at the main seeps of the Roberts-Dawson mine.

Figure 3 shows the levels of acidity in the two major seeps before and after grouting operations. As can be seen, significant increases in acidity occurred at both seeps immediately after grouting operations. These high acidity concentrations then decayed to levels similar to before grouting operations began. Similar trends in both the concentrations and fluxes of Al, B, Ca, Co, K, Li, Fe, Mg, Mn, Ni, Pb, S, Si, Sr, and Zn were also observed in

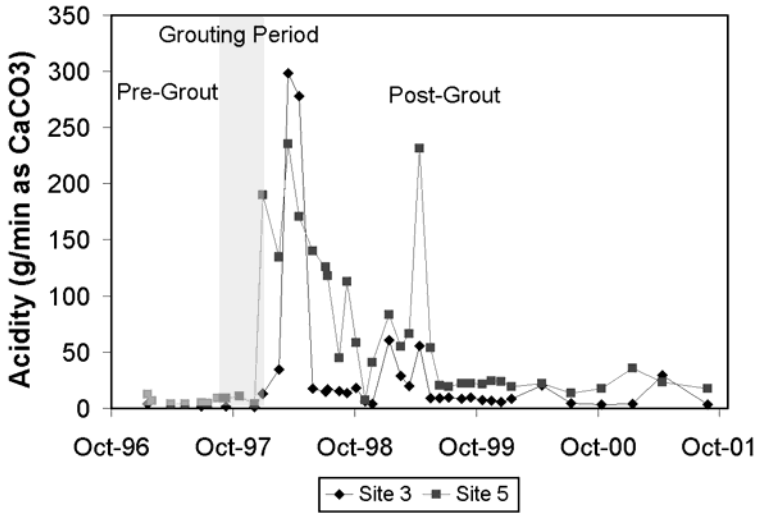


Figure 3. Acidity as a function of time at the two major seeps

surface water samples collected from the main seeps exiting the mine voids as well as in groundwater wells installed within the coal layer.

Field data and geochemical speciation calculations suggested that the increase in concentration of a number of these elements immediately after grouting was at least partially due to re-routing of mine drainage waters and the dissolution of accumulated metal salts previously present within the mine voids (Lamminen et al. 2001). For example, iron containing solids including Jarosite-K and a number of iron hydroxides had saturation indices orders of magnitude above saturation, suggesting these were important solids controlling the solubility of iron in the mine drainage waters. This is consistent with previous studies by Nordstrom (Nordstrom 1982; Nordstrom and Ball 1986) who found that the levels of iron and aluminum in mine drainage waters below pH 4.5 are controlled by the dissolution of evaporated metal salts such as aluminite, jurbanite, siderotil, coquimbite, and basaluminite. Also, groundwater flow into previously inaccessible areas could provide new exposed surfaces for pyrite oxidation.

As indicated above, high concentrations and fluxes of calcium and sulfur were also observed immediately after grouting, followed by a decrease to near pre-grouting levels. Figure 4 shows the flux of calcium at sites 3 and 5 before and after grouting. Previous laboratory studies have shown that AMD may accelerate the dissolution of FGD material grout. Thus, the high levels of calcium and sulfur immediately after grout may be partially attributable to dissolution of the FGD material grout. However, the re-routing of mine drainage waters within the voids also may have resulted in the exchange of calcium or the dissolution of calcium from the bulk soil. Also, it is evident from Figure 4 that the flux was dependent on seasonal factors. In particular, strong precipitation events typically in January and April resulted in the highest flux values.

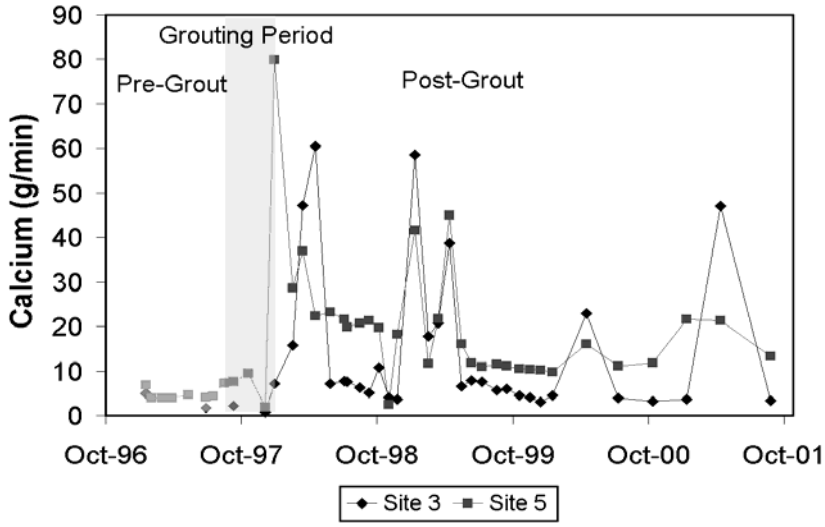


Figure 4. Flux of calcium at sites 3 and 5 at the Roberts Dawson site.

Two monitoring sites were selected to assess the impact of the Roberts-Dawson project on the regional groundwater table (Site 9727) and Wills Creek Reservoir (Site 12). Except for Mn, all parameters throughout the duration of the project generally met all relevant primary and secondary drinking water standards, including pH, TDS, sulfate, As, Al, Ba, Be, Cd, Cr, Cl, Cu, Fe, Ni, Pb, and Zn. Although Mn concentrations were generally above the established MCL, the concentrations were not significantly greater after grouting than compared to before grouting. It should also be noted that the MCL values were not established as regulatory limits for the project. This analysis simply demonstrates that the project had no detectable deleterious impact on the water quality of the surrounding surface and groundwater.

Table 1. Water quality in wells in the downdip area of the mine, installed either before (9719) or after (2002) grouting operations. Water quality data for one well (9906) installed in the upper mine works after grouting are also shown. Concentrations are in mg/L, unless noted. All concentrations correspond to average values over the period April 2000 to September 2001. The number of sampling dates (n) recorded for each well during this period is shown in parentheses.

Parameter	9719 (n=5)	9906 (n=6)	2002 (n=4)
Acidity (mg/L as $CaCO_3$)	284 ± 349.	1 ± 4.6 21	.1 ± 36.7
Alkalinity (mg/L as $CaCO_3$)	nd	262 ± 98 8.	7 ± 3.1
pH (pH units)	4.1	10.2	5.9
Conductivity (µS/cm)	1431 ± 135 17	86 ± 186 33	0 ± 109
TDS	956 ± 91 11	94 ± 124 21	7 ± 77
As (ppb)	5.1 ± 2.1 61	.2 ± 17.5	nd
Al	3.75 ± 1.11 1.	501 ± 0.864 0.	216 ± 0.419
B	0.297 ± 0.030 0.	398 ± 0.057 0.	073 ± 0.049
Ba	0.004 ± 0.001 0.	020 ± 0.010 0.	021 ± 0.012
Be	0.001 ± 0.001	nd nd	
Cd	0.021 ± 0.028	nd nd	
Ca	184 ± 14 78	± 48 3	6 ± 12
Cl	27.6 ± 9.1 40	9.4 ± 64.6 10	.2 ± 5.3
Cr	0.001 ± 0.002 0.	002 ± 0.003	nd
Cu	0.093 ± 0.089	nd	0.007 ± 0.010

Table 1 continued.

Parameter 97	19 (n=5)	9906 (n=6)	2002 (n=4)
Fe (dissolved)	94.2 ± 10.7 0.	246 ± 0.525 6.	9 ± 12.4
Mg	40 ± 5 7.	6 ± 16.5 10	.2 ± 4.6
Mn (dissolved)	2.74 ± 0.44 0.	077 ± 0.148 0.	59 ± 0.61
Na	25 ± 3 93	± 40 4	.1 ± 1.7
Ni	0.045 ± 0.015 0.	003 ± 0.006 0.	008 ± 0.011
Pb	0.010 ± 0.022 0.	010 ± 0.013	nd
S	284 ± 24 71	± 17 4	4 ± 24
Si	17.15 ± 1.82 2.	86 ± 0.83 6.	84 ± 2.07
Zn	0.101 ± 0.009	nd	0.020 ± 0.017

Long-Term Geochemical Stability of FGD Material Grout

Previous laboratory studies and the field data suggested the potential for FGD material grout dissolution. To examine the stability of the grout, core samples were collected in both the upper portions and down-dip portions of the mine void areas. The core sample collected at the site of well 9906 had a fluid, paste-like consistency. The x-ray diffraction pattern for this sample indicated the presence of hannebachite, ettringite, quartz, ferrihydrite and gismondine. The presence of ferrihydrite clearly indicates the reaction of the FGD material grout with mine drainage waters either during or after grout placement. The core sample collected in the downdip area of the mine voids at site 2002 was much harder than the core collected from site 9906. The core was dominated by hannebachite and ettringite with lesser quantities of quartz. The lack of any iron hydroxide phases indicates little or no penetration of mine drainage waters into the FGD material grout at this location. The long-term persistence of hannebachite in these core samples is noteworthy as it suggests minimal altering of the fixated material grout.

Water in Vicinity of FGD Material Grout

Monitoring wells were installed following collection of core samples to better understand the chemical interactions occurring within the grout material. Data for two of these monitoring wells (9906 and 2002), along with data from a well installed prior to grouting (well 9719) are shown in Table 1. In general, monitoring wells installed following core sample collection (i.e., well 2002) had higher pH, higher alkalinity, and lower trace element concentrations than water collected from wells installed within coal pillars prior to grouting operations (i.e. well 9719). Exceptions to this were the concentrations of Ca and B which were higher in wells installed following grout core collection, which likely reflects the greater contribution of the FGD material to the solution properties. These data indicate that the mine drainage waters were partially neutralized within the immediate vicinity of the grout.

Lessons Learned

From the results observed from this project, a number of lessons were learned which may prove useful in future projects involving the injection of fixated FGD material grout into underground coal mines.

- Core samples of fixated FGD material grout injected into the downdip portions of the Roberts-Dawson mine had strengths exceeding the design strength, and therefore, the hardening of these samples was not significantly affected by the presence of AMD.
- Injection of grout, such as fixated FGD material, into underground mines can result in significant re-routing of mine drainage flow which may release previously accumulated metal salts deposited on the mine floor and walls.
- Since the water flow rate at both major seeps was not reduced, complete filling of mine voids with fixated FGD material may be a better solution to eliminate the formation of AMD water. Bypassing of AMD water under a grout seal could potentially be prevented by adding a high strength fixated FGD material grout trench, starting at the mine openings and extending vertically downward.

- Bore hole cameras indicated that the grout had good flowability, however, it was likely that portions of mine voids were inaccessible to the grout. A multi-stage grouting approach could help to provide more extensive coverage of the grout and eliminate the water flow paths in the coal layer. Borehole tomography surveys could also be useful to determine the extent of inaccessible regions.
- After the seeps were sealed, accumulated salts in previously inaccessible regions were flushed out. This flushing process could be reduced by starting grouting at the upper mine works instead of near the mine entry points.

Acknowledgement

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Dr. Harold G. Walker is currently an Associate Professor in the Department of Civil and Environmental Engineering and Geodetic Science at Ohio State University. He has over 8 years experience examining the environmental impacts associated with coal combustion by-product re-use, in applications such as acid mine drainage abatement, construction of low permeability liners, and accelerated testing of coal by-products in full scale pavement systems, to name a few. His recent work has focused on understanding the fate of mercury and other trace elements upon utilization of coal combustion by-products in concrete and other civil engineering applications. He has M.S. and Ph.D. degrees in Environmental Engineering from the University of California, Irvine and a B.S. degree in Environmental Engineering from Cal Poly San Luis Obispo. He is a member of ASCE, ACS, AAAS, and AWWA. He is also a registered Professional Engineer in the State of Ohio.

DIAGENESIS OF FBC ASH IN AN ACIDIC PIT LAKE

Barry E. Scheetz,[1] William B. White[1] Caroline M. Loop[2], Roger J. Hornberger[3],
and Michael Menghini[3]
[1]The Pennsylvania State University,
University Park, Pennsylvania,
[2]Groundwater Management Associates,
Greenville, North Carolina
[3]Pennsylvania Department of Environmental Protection,
Pottsville Office

Abstract

Mineralogical evolution of placed fluidized bed combustor ash for mineland reclamation can result in the development of cementitious monolithic solids. Hydration reactions based on the early formation of ettringite and gypsum can result in unconfined compressive strengths that vary, depending on the ash source, from a few hundreds of pounds per square inch to a few thousands of pounds per square inch. Extended hydration of these cementitious elements at elevated pH values further involves the reaction with dehydroxylated clays in the ash to form an amorphous hydrous calcium silicate phase similar to that found in ordinary Portland cement. This phase commonly identified in the cement literature as C-S-H, is the 'glue' that is responsible for the mechanical and chemical properties of Portland cement concrete. Hydration products formed from the reaction of FBC ash grouts with water have been identified in the laboratory, in field specimens, and most recently confirmed by thermodynamic modeling of the pore waters associated with placed ash. The confirmation at this level allows for further modeling of placed monolithic cementitious solids using Portland cement durability as an analog.

Keywords: Portland cement, longevity model, mineralogy, thermodynamic model

Introduction

The use of fly ash from utility power stations or from waste coal burners for unammended mineland remediation applications is practical and offers a cost effective means of achieving the otherwise extremely costly reclamation. If practiced correctly, the use of coal combustion products [CCPs] can offer benefits that constitute a win-win situation for both the citizens and regulators for the utilities. Annually, millions of tons of CCPs are used in the reclamation of abandoned minelands (DEP 2004). For the majority of these projects, the CCP is approached from an engineering standpoint, as a material that is routinely monitored for chemistry to ensure environmental compliance with the overseeing governance body. The most important characteristic for long-term stability of the fly ash in reclamation applications is the mineralogy and the evolution of mineralogy changes that occur with time.

The pozzolanic activity of Class F fly ashes has been discussed by Scheetz et al. (1993,1994,1995), and the reactions with fluidized bed ashes by Fontana (1993) and Zhao (1995). These authors addressed the progress of changes in the mineralogical compositions of the fly ash resulting from the chemical reactions of the glass and meta-clays from the ash with alkalis, either added directly to the ash or resulting from excess free lime from the ash. FBC ashes, resulting from the burning of high sulfur-containing bituminous coals, routinely produce ettringite which has been identified by many authors (Schlorholtz et al. 1987).

Cementitious behavior resulting from the hydration of the ash is similar to the hydration reactions observed in the chemical reactions in ordinary Portland cement. Loop (2003) reported the formation of these cementitious phases through thermodynamic modeling of both the pore fluids and water in contact with large-scale FBC ash placement. Analyses of the solid hydrated ashes support the theoretical modeling with visual evidence for the presence of the hydration products. Using the hydration products of Portland cement as an analog, modeling the long-term behavior of emplaced fly ash is possible.

Paragenesis of the Mineralogical Assemblage in Ash

The bulk chemistry and mineralogy of ash from a co-generation facility, NEPCO, in Mcadoo, PA was quantified and reported in tables 1 and 2, respectively. This site is located in the East Central Anthracite Coal Fields of Central Pennsylvanian. The "Big Gorilla" was a pre-act water-filled surface strip mine adjacent to the NEPCO cogeneration facility. The work represents a demonstration of dry-to-wet ash placement in cooperation with the Pennsylvania Department of Environmental Protection with oversight from the Pottsville Regional Office.

Table 1. Bulk chemistry for FBC ash from NEPCO contrasted to an average composition from 5 similar facilities in the anthracite coal fields.

Oxide	**NEPCO ash composition [wt %]**	**Average composition of 5 culm-derived ash analyses**
SiO2	64.47	60.69
Al2O3	18.82	23.11
Fe2O3	5.74	5.08
CaO	5.45	5.44
MgO	1.48	1.15
K2O	3.77	2.90
SO3	0.26	1.60

Table 2. Bulk mineralogical analyses of the NEPCO fly ash obtained by multiple analytical methods.

Mineral	***Formula***	***Analytical method***	***Wt. %***
Quartz	SiO2	QXRD, wet chem	20.0
Mullite	Al6Si2O13	QXRD	7.0
Hematite	Fe2O3	QXRD	2.0
Portlandite	Ca(OH)2	DTA, QXRD, wet chem	6.5
Calcite	CaCO3	QXRD, wet chem	0.4
Gypsum	CaSO4.2H2O	QXRD	0.5
Meta-clays		QXRD	63.6
Total			100

Some of the mineralogical constituents of the ash remain inert with respect to the chemical reactions that take place within the ash fill and can be ignored in subsequent discussions. Quartz, mullite, and hematite, which constitute about 30% of the ash minerals from the NEPCO, fall into this category and act essentially as fillers. The meta-clays, which constitute the bulk of the sample, interact with the portlandite to produce the cementitious behavior.

The pore fluids were sampled and determined to have a pH of 12. Loop et al. (2003) demonstrated, with the use of PHREEQC, a thermodynamic equilibrium code, that this pH was in part a result of the fluids approach to a pH of 12.45, the equilibrium value for water saturated with portlandite. Reaction of $Ca(OH)_2$ with atmospheric carbon dioxide in an open system precipitated the observed calcite. The high pH and the presence of both gypsum and sulfates in the mine water are responsible for the reaction of the thermally altered clays to form ettringite and possibly gismondine.

$$\text{Alumino-silicate} + CaSO_4 \cdot 2H_2O \rightarrow Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 24H_2O$$
$$\text{Clay} \quad + \quad \text{gypsum} \quad \rightarrow \quad \text{ettringite}$$

It has been thermodynamically demonstrated that ettringite is controlling the solubility of aluminum in the mine-pit lake waters at high pH (Loop 2003). Ettringite is also an important component in cementitious reactions and a control for arsenic sequestration. Scanning electron microscopic (SEM) characterization of placed ash has visually predicted the development of ettringite (Fig. 3).

The high alkalinity pore water also causes a large amount of meta-clay to undergo pozzolanic reactions with the formation of hydrous calcium silicate phases. Thermodynamic modeling has indicated the existence of 14Å tobermorite. This phase is the crystalline equivalent of C-S-H, the glue in Portland cement. Although thermodynamic calculations have been established for a phase that contains no aluminum, C-S-H forming under real world cement hydration conditions always contains a finite amount of aluminum substitution at the maximum solubility limits (Barnes and Scheetz 1989).

Thermodynamic calculations also suggest the formation of gismondine, a calcium zeolite in the assemblage of reaction products in the ash. Although this particular zeolite has not been identified in the ash via SEM characterization, the presence of zeolites in hydrating cementitious systems is well documented (Grutzeck et al. 1997, 1999, 2003). Finally, the thermodynamic calculations also suggest that in the presence of atmospheric carbon dioxide, common minerals of the alkaline earth elements will form, including calcite and to a lesser extent, witherite.

Although these FBC ashes are not strongly pozzolanic, the presence of large amounts of thermally altered clays in the presence of an alkalinity source that will raise the pH above 9.5 results in hydration products forming that are similar to those formed in the Portland cement system. The similarities offer an unprecedented opportunity to model the behavior of these structural ash fills.

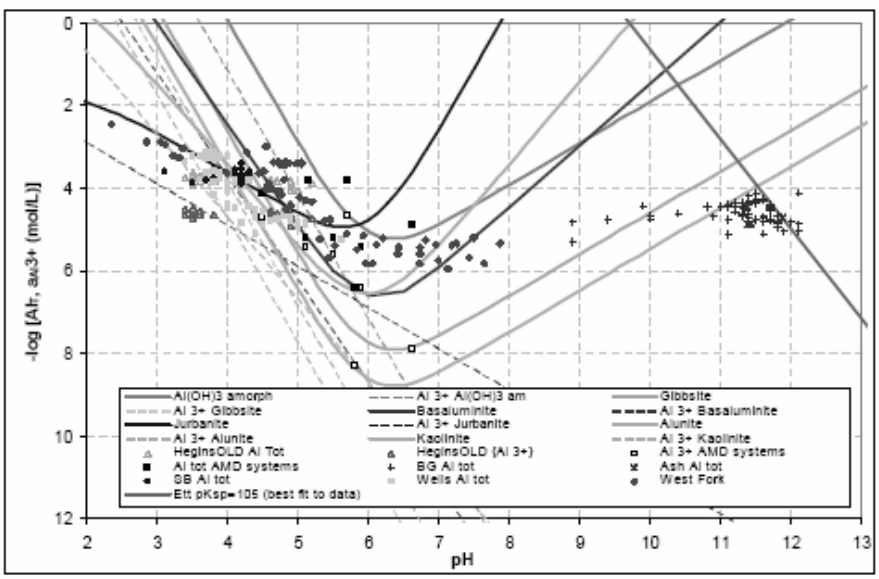

Figure 1. Thermodynamic control over the solubility of aluminum in AMD and the Gorilla mine-pit lake waters. Plot constructed by Dr. Charles Cravotta of the U.S. Geological Survey, with an ettringite solubility line altered by the authors to best fit the Big Gorilla data.

The hydrated phases in the ash structure have the potential to form large quantities of C-S-H from the 63 wt% thermally altered clays. Based on a Portland cement model, suggested by thermodynamic calculations of the pore fluids, a portrait of the long-term behavior of the ash structure can be constructed. Figure 2 is a schematic representation of the resulting phase assemblage and pH.

Stage I, (To – T1) represents a period when the pH of the ash structure is controlled by the buffer established by portlandite and C-S-H. The leachate pH will remain at a value of 12.45 until such time as all of the portlandite has been removed.

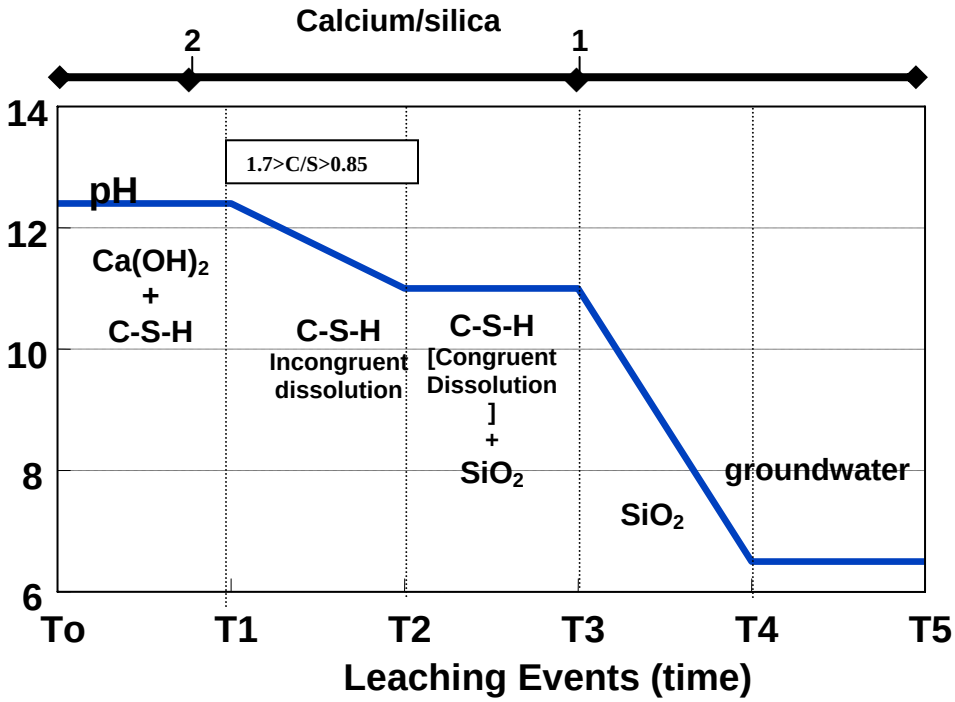

Figure 2. Effects of leaching on pH of C-S-H-portlandite-silica system as a function of continued leaching (after Atkinson 1985).

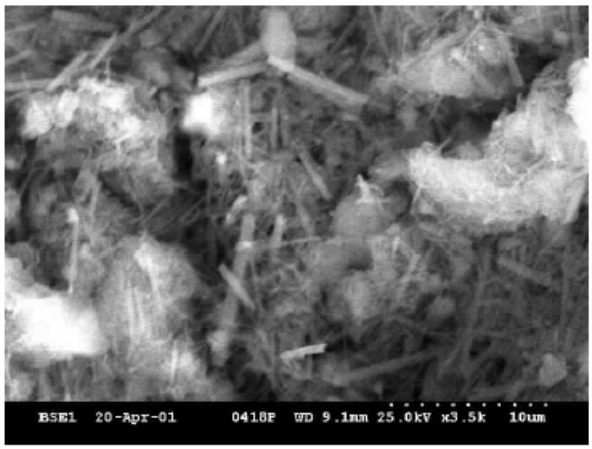

Figure 3. Scanning electron micrograph of ettringite growth in FBC ash.

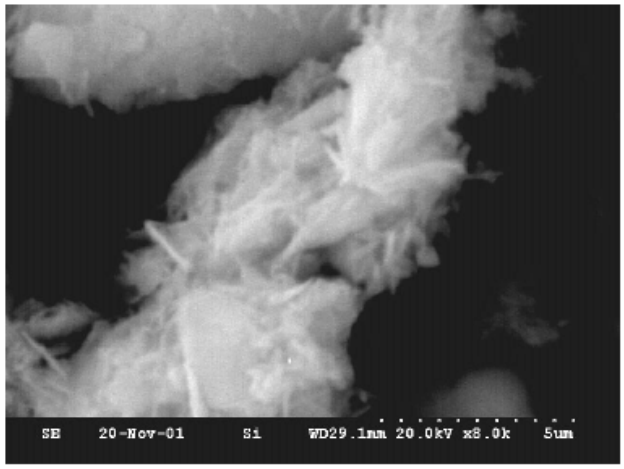

Figure 4. Development of C-S-H in ash.

Longevity of the Ash Fill

The most commonly asked question of a structural fill concerns the timescale of stability. This is a fair question that can be addressed in several ways. Subsequent calculations will attempt to provide bounding calculations that will bracket the anticipated longevity based upon several different approaches describing the ash fill.

Case I – Darcy's Law Approximation.

During the course of the ash placement, both compaction measurements on the ash fill and hydraulic conductivity measurements were made. It was determined that the hydraulic conductivity of the ash was $1x10^{-6}$ cm/sec, a value not atypical of others reported for ash monofills (Ghosh and Subbarao 1998). The structural fill can be represented as a homogeneous body in which water movement will remain in a laminar flow condition. With these assumptions, Darcy's law can be used to describe the time it would take for a given volume of water to flow through the mass. Figure 5 provides details for the dimensions of this model calculation.

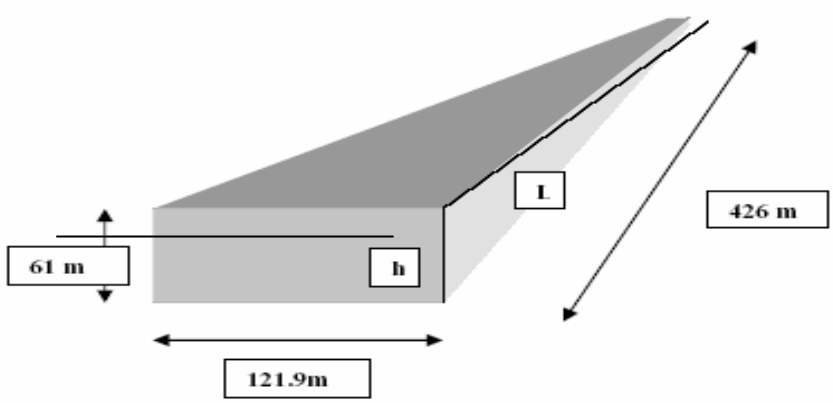

Figure 5. Model for calculation of hydraulic conductivity.

Q = KIA

Where:

Q = flow rate (vol/time)
K = hydraulic conductivity (1×10^{-6} cm/sec)
I = hydraulic head (h/L)
A = cross sectional area of the pile (cm^2)

The compacted ash in the Gorilla represents approximately 1.7 million m^3 of ash. If the porosity is approximately twenty percent, the volume of ash contains about 12 million cubic feet or about 90 million gallons (0.34 million m^3) of pore water. Using Darcy's Law, one can determine the time required for a single gallon of this 90 million gallons of pore water to flow through this modeled system based on the conservative assumptions that the hydraulic head is the complete thickness of the fill. Using the stated assumptions and the dimensions of the Big Gorilla pit and assuming a rectangular parallelepiped as shown in Figure 4, an estimated 3,000,000 years is calculated for that one gallon of pore water to move through the entire ash body. It must also be recognized that as this water moves through the fill, it will become alkaline with the fill acting as a large alkaline reservoir.

The initial calculations were conservative, based on a hydraulic head of ~15% compared to the more commonly encountered 1% head. The corresponding time interval for the smaller gradient is well in excess of 10,000,000 years.

<u>Case II –Shrinking Core Model for Portlandite Dissolution.</u>
Bounding calculations can be conducted for the leach interval To-T1 based upon a) ash structure control of the leaching and b) the contacting geologic control of the leaching.

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$$

The flux is calculated from:

$$\text{Flux} = -D_i\,[(C_\ell - C_{gw})/X]$$
$$dX/dt = [D_i/X][C_\ell - C_{gw}/C_s]$$

Walton et al. (1990) have developed an approach for the depth of leaching of portlandite from a cementitious body that takes the form:

$$\mathbf{x=[2Di(Cp-Cgw)/Cs\ t]}^{½}$$

Where:

X	distance	cm
Di	intrinsic diffusivity	cm^2/sec
Cp	concrete pore	moles/cm^3
Cgw	groundwater	moles/cm^3
Cs	solids	moles/cm^3
t	time	sec

The shrinking core model assumes that the removal of calcium from the exterior surface of the concrete is rapid relative to the movement through the concrete. This relationship takes the inventory of Ca-ions in the pore fluids of the ash structure minus the leaching water concentration and ratios it to the total available in the solids. By multiplying against the intrinsic diffusivity for calcium in the ash as a function of the square

root of time (diffusion controls the leaching), a depth of penetration into the structure can be calculated. Because concrete is less permeable than the surrounding bed rock, the dominant flow direction will rarely be normal to the concrete (structural fill) surface.

Based on 61 m, the smallest dimension of the filled Gorilla pit and assuming diffusion through both sides toward the middle of the structure, a time (t) can be calculated when both diffusion surfaces meet. The results of this calculation, based on a conservative intrinsic diffusivity of 3×10^{-6} cm^2/sec, yielded a time frame for T_o-T_1 on the order of 10,000,000 years. Figure 6 summarizes this calculation release as percentage portlandite leached from the smallest dimension of the Gorilla ash fill as a function of time based on an ash structure-controlled leaching model.

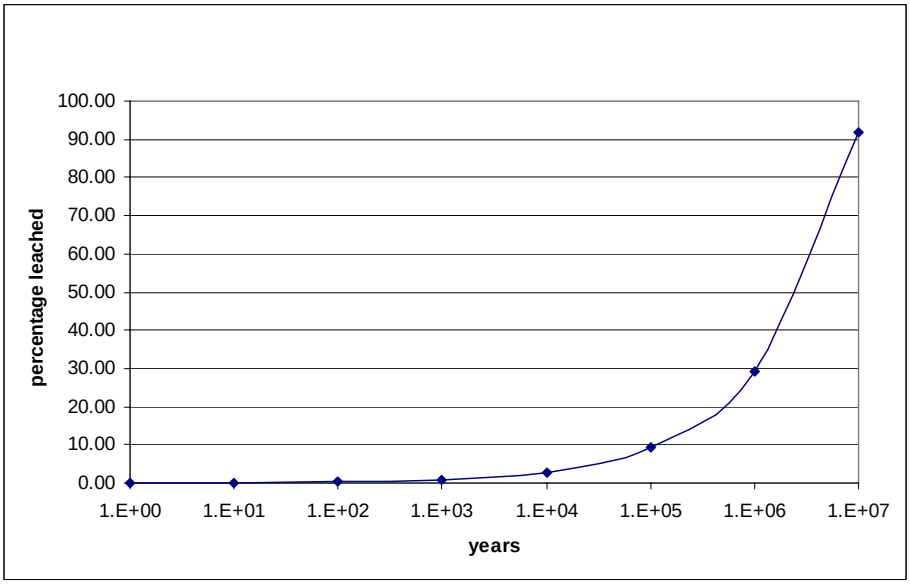

Figure 6. Percentage leached of the smallest dimension of the Gorilla ash fill as a function of time based on an ash structure-controlled leaching model.

Case III – Diffusion Model for the Dissolution of Portlandite.

The alternative approach suggested by Walton et al. (1990) after Atkinson and Hearne (1984), was to allow the surrounding geology to control the diffusion of calcium from portlandite in the ash fill to diffuse into the surrounding geology. In this approach, the concentrations are described by an error function:

$$[C-C_{gw}/C_{\ell}-C_{gw}] = \mathrm{ercf}[X/(4D_e t/R_d)^{1/2}]$$

The total material leached in a given time period is obtained by integrating with respect to time:

$$M_t = \Phi C_l - C_{gw}(4R_d D_e t/\pi)^{1/2}$$

The total amount of calcium hydroxide removed can be related to the inventory in the fill as:

$$M_t = XC_{bulk}$$

Following a similar approach, Walton presented the following equation in which he calculated the depth of leaching in the ash fill:

$$x=2\Phi[Cp-Cgw/Cs](RdDeT/\pi)^{0.5}$$

where:

X	distance	cm
Cp	concrete pore	moles/cm^3
Cgw	ground water	moles/cm^3
Cs	solids	moles/cm^3
Rd	retardation	
De	effective diffusivity	cm^2/sec
Φ	porosity	
t	time	sec

In this analysis, he also utilizes the percentage of the total inventory of calcium in the ash released but controlled by the effective diffusivity of the geologic media as well as the retardation of the geologic media. Assuming conservative values for R_d and D_e, the estimated time that the leaching process took to diffuse through parallel sides of the ash structure 61 m thick was on the order of 255,000 years (Fig. 7).

Although the length of time to accomplish the total removal of portlandite from the ash structure in the Gorilla ranges over two-orders of magnitude, the bounding calculations suggest that for the leaching interval T_o-T_1, times in excess of a quarter of a million years will transpire. It is noteworthy to point out that during this time interval a slow release of alkalinity in the form of calcium hydroxide will be taking place. Only after the total removal will the pH begin to drop.

Stage II [T_1-T_2] is represented by the stability of a single phase and described by the incongruent dissolution of C-S-H from a calcium to silica ratio of 1.7 to a value of 0.85 and will proceed until pH 10.7 is reached. All of the excess calcium in the structure is removed and C-S-H begins to undergo congruent dissolution. Estimates of the length of time involved in this stage of leaching of the fill are difficult to make since they depend on the amount of C-S-H formed during the hydration of the ash components. In Portland cement concrete as a point of reference, this stage typically is calculated to require approximately 1,000,000 years to reach the onset of congruent dissolution of the C-S-H (Atkinson 1985).

The transition marks the onset of Stage III [T_2-T_3] in which the phase rule dictates the coexistence of two phases, C-S-H and SiO_2. Dissolution follows at a constant pH until all of the C-S-H is removed. Following similar argument, direct estimates of the durability are not possible. However, by analogy with concrete Atkinson (1985) calculates about 500,000 years to achieve complete dissolution of the C-S-H. Stage IV represents the stability of only a single phase, SiO_2, thus allowing, by the Gibbs Phase Rule, the pH to drop to the controlling groundwater pH, Stage V.

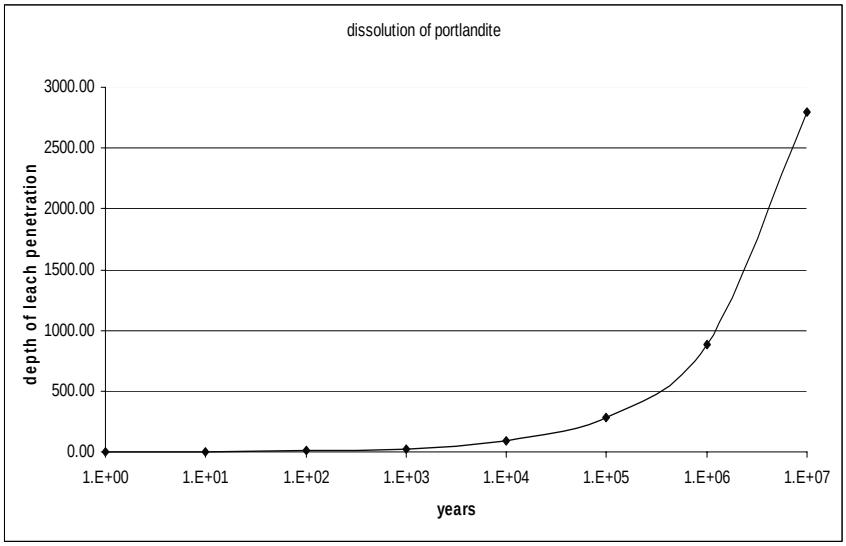

Figure 7. Percentage leached of the smallest dimension of the Gorilla ash fill as a function of time based on a geology-controlled leaching model.

Conclusions

The above exercises were conducted in order to provide some sense of the long-term stability that may be anticipated from the structural fill in the Big Gorilla Pit. The calculations were conducted based upon our recognition that the changing mineralogy of the fill materials could be modeled using phase relationships for calcium silicate in Portland cement as an analog. The approach presented a stepped four stage dissolution of the portlandite and hydrous calcium silicate. Furthermore, the calculations were conducted with conservative input data to the model. Reasonable but aggressive parameters were chosen that would 'hasten' the leaching of the fill and in this manner provide a more conservative interpretation of the data. The calculations for Case II and Case III followed the dissolution of portlandite and made the assumption that when the portlandite was removed, the cementitious element was compromised.

These results suggest that the structural fill will be stable for a period of time most probably in excess of 100,000 years and likely well in excess of 1,000,000 years. During the period of time in which it is altering, the pH of the leachates released from the fill will be above a value of 10.7 for the vast majority of that time. In an environment where the ground waters are impacted by acid mine drainage, it is anticipated that projects such as these can have profound long-term environmental benefits.

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Dr. Barry E. Scheetz, professor of materials, civil and nuclear engineering, has been a faculty member at The Pennsylvania State University for 29 years and is affiliated with the Department of Civil and Environmental Engineering. During this time, he has focused his research on a variety of environmental issues concerning nuclear waste disposal and the utilization/reutilization of industrial waste materials, so-call "cast-off materials." The emphasis of his research in these applications areas has been on cementitious systems. He holds some of the pioneering patents on high performance concretes and worked extensively with grout and concrete formulation development. A thrust area in this research was the utilization of industrial by-products like silica fume, fly ash and slag, used to tailor the properties of the grouts and concretes. Recent programs have been utilizing fly ash and alkaline waste activators to fabricate non-traditional alkali-activated cements for large volume use in environmental restoration of minelands. This program is field oriented and has placed in excess of 8,000,000 tons of grout in the past ten years. He holds approximately 80 combined U.S. and foreign patents and is the author of 160 scientific publications. He actively serves as a consultant to industry and government.

BENEFICIAL USE OF FBC COAL ASH FOR MINE RECLAMATION IN THE ANTHRACITE REGION AT THE WHEELABRATOR FRACKVILLE AND MOUNT CARMEL CO-GEN SITES.

Michael J. Menghini[1], Roger J. Hornberger[1], Thomas D. Owen[1], Sharon Hill[1] and Barry E. Scheetz[2]
[1]Pennsylvania Department of Environmental Protection,
Pottsville District Office
[2]The Pennsylvania State University,
University Park, Pennsylvania

Abstract

The Wheelabrator Frackville and Mount Carmel Co-Gen sites are located in the Anthracite Region of Pennsylvania, utilize anthracite culm, silt, and refuse as fuel and reclaim abandoned and active mine lands with the coal ash they produce. Since the plants have been operating, they have reclaimed over 300 acres of abandoned mine lands, and have also eliminated a large number of safety hazards via that reclamation work. Site monitoring has also revealed no degradation associated with the coal ash placement, and some groundwater and surface water improvements will be evident once the projects and all site related reclamation is completed.

Introduction

The remining and reclamation of abandoned mine lands in Pennsylvania increased significantly with the construction of waste coal fired power plants in recent years. The coal ash produced by these power plants has resulted in a significant growth in the use of coal ash for mine reclamation in the anthracite and bituminous regions of Pennsylvania. The nine anthracite region waste coal power plants account for over 39 million tons of coal ash beneficially used for abandoned mine reclamation via the remining of waste coal piles and the filling and reclamation of abandoned mine land pits. The majority of the reclamation associated with these plants is through the utilization of coal ash as fill material and the resultant reclamation of the abandoned mine land features. The reclamation associated with these sites has, in most cases, also improved the groundwater and/or surface water in the vicinity of the projects. All of this reclamation has been conducted at no cost to the Commonwealth and represents a significant monetary savings for Pennsylvania's Abandoned Mine Land Reclamation Program.

The Wheelabrator Frackville and Mount Carmel Co-Gen sites represent two sites where significant remining and reclamation of abandoned mine lands has and is occurring via the operation of the power plants, and the beneficial use of the coal ash produced by the plants. This paper will give a short description of each site, and the resultant effects of the remining and reclamation of the sites through the beneficial use of coal ash.

Wheelabrator Culm Services, Inc. – (Wheelabrator Frackville Co-Gen)
This 580 acre surface mining permit site (SMP No. 54880202) was issued for coal refuse reprocessing with coal ash utilization in October, 1991 and is located in Mahanoy Township, Schuylkill County, as shown on Figure 1. Known as the Morea/New Boston Operation after the historic colliery names, the operation is situated entirely on previously mined areas. The land surface consisted of abandoned anthracite culm banks, multiple open strip-mined pits, and overall disturbed surface-water drainage. It is located in the southeastern portion of the Western Middle Anthracite Field.

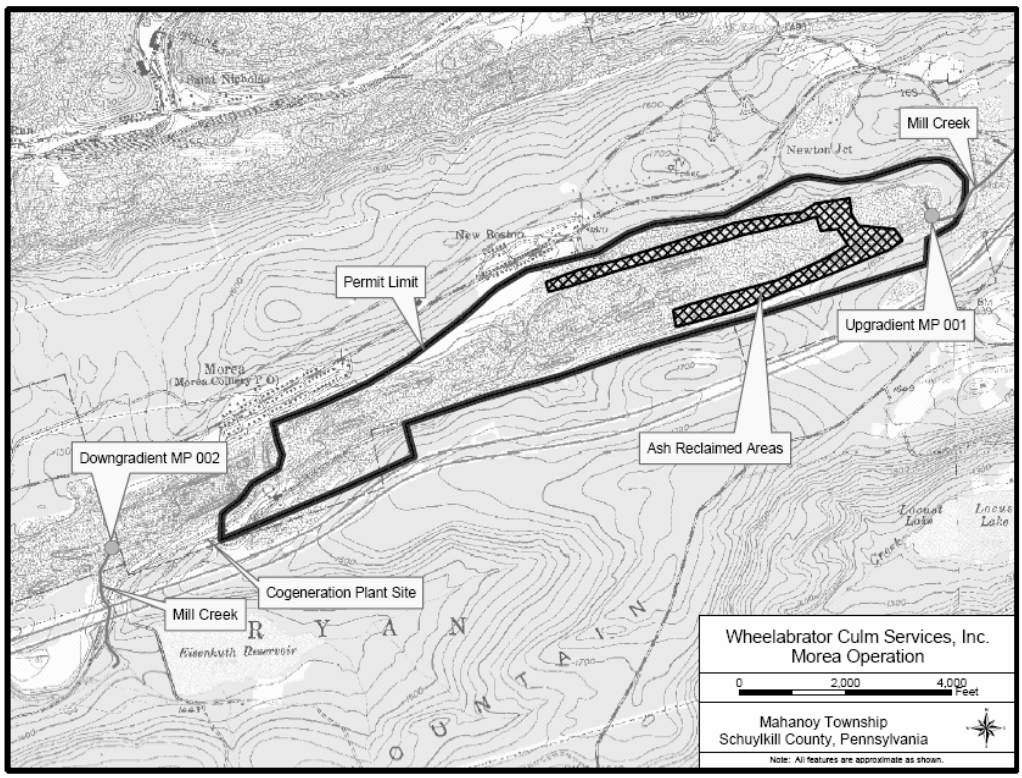

Figure 1. Site map of Wheelabrator – Morea mine site.

The minepool and groundwater flow system of the Morea and New Boston Collieries is somewhat isolated from the remainder of the Western Middle Field. These two collieries are located in a narrow basin on top of Broad Mountain. This case study site was selected because it is a good example of extensive abandoned mine reclamation with coal ash from a FBC plant, the ash reclamation project has significant potential for surface water and groundwater improvement (when completed), and the groundwater monitoring scenario is relatively simple.

Most of the permit area was taken over from the previous operator, Lehigh Valley Anthracite. The Wheelabrator Frackville Energy Co., Inc. constructed the circulating fluidized bed boiler plant (FBC) in 1988 on-site, near their primary fuel source – (anthracite culm) and potential ash placement areas. Coal refuse and coal silt from other local permitted areas is conveyed to the plant. Fly and bottom ash are then hauled from the plant by truck to the active ash placement area. The operation is conducted in phases of refuse recovery and ash utilization. Over 11 years, the operator has had nine phases approved for ash placement, various support activities and refuse reprocessing. At the end of 2004, the operator reported over six and a half million tons of anthracite coal refuse burned in the plant, and over four million cubic yards of ash utilized for reclamation on-site, with 123 acres of abandoned mine lands reclaimed.

The primary use of the coal ash produced by the plant was to fill the abandoned open pits on site. Several 10 to 20 acre pits were filled with ash. On-site spoil and abandoned coal refuse material is used to line the pits prior to ash placement, with the best material saved for final cover. Photographs of the abandoned surface mine pits reclaimed with coal ash are shown in Figure 2a. Extensive wildlife habitat plantings have been established on the reclaimed areas shown in Figure 2b. In addition, the coarse bottom ash from this plant is approved for use as anti-skid material for on-site access and haul roads. This material is stored separately and used during inclement weather.

Figure 2a. Ash placement in pits

Figure 2b. Wildlife plantings

Initially, 8 feet of fill (spoil and refuse material) was needed to line the pits. All ash conveyed to the active placement area was dumped into the working area and then spread and compacted in lifts of 2-4 feet within 24-48 hours of placement. The ash is conditioned at the plant with adequate moisture for compaction, which is achieved simply by the process of repeated passes of the haul trucks and dozers during spreading. Each daily cell is 150 by 200 feet. A final cover of 4 feet is placed on top, utilizing the adjacent spoil material, with the top one foot being the best available from the site. Daily and intermediate cover is used, as needed, to control dust before the final cover. Since the plant utilizes treated minepool water for cooling purposes, the sludge from the water treatment process is blended with the ash in a 1 to 467 ratio, and placed in the ash use areas.

The site was extensively affected by pre-Act mining. There is no point-source discharge or direct drainage to a stream – water percolates directly through the surface material or drains to the pits and ultimately is conveyed to the minepool underneath. Upgradient diversions are used to prevent runoff onto the site. There is essentially no natural soil present.

Of the nine mining and coal ash placement phases shown on the permit maps, three phases (1, 2 and 3) are substantially completed, and some reclamation work has been completed on two other phases (4 and 5), which are shown in the cross-hatched symbol on Figure 1. When this entire remining project is completed, significant surface-water and groundwater benefits should occur, in addition to the extensive reclamation of abandoned mine lands. With every acre of abandoned surface mine pits that are reclaimed to approximate original contour on this site, there is a reduction in water infiltrating directly into the underlying minepool, and an accompanying increase in surface water runoff. The tributary to Mill Creek in the eastern end of the SMP presently flows to the subsurface through abandoned mine workings within the permit area, but this stream should be restored to the surface and emanate from the permit as a perennial stream before completion of the project. The elimination of stream loss (or dramatic reduction in stream bed leakage) and the reduction in direct infiltration to the abandoned underground mines through coal ash backfilling of abandoned surface pits is expected to significantly reduce the flow of the Morea Colliery discharge (downgradient monitoring point MP 002), shown on Figure 1. The reduction in flow of abandoned mine discharges by remining operations is one of the most common and significant benefits according to Hawkins (1995), Brady et al. (2001), and Smith et al. (2004). It is anticipated that the extensive placement of alkaline coal ash at the Wheelabrator site will improve the water quality of the Morea Colliery discharge. However, if the concentration of some water quality parameters does not change significantly, the overall pollution load of the discharge should decrease significantly due to the reduction in flow.

As part of the permit conditions, the permittee is required to conduct groundwater and ash monitoring. For this site, the minepool conditions are such that sampling points are easily identified. Mill Creek runs on the surface before it reaches the Wheelabrator site and then goes underground into the minepool complex. A point was picked on Mill Creek as an upgradient monitoring site, shown on Figure 1. The minepool overflows downgradient from the site which represents the emergence of Mill Creek to the surface. It is worse in quality due to acid mine drainage pollution of the minepool. This is the designated downgradient monitoring point that theoretically would reflect any changes in water quality due to the mining and ash placement activities. The DEP has monitoring data on these

points from 1986 to the present. The major problem in comparing upgradient monitoring point 001 with downgradient monitoring point 002 is that they represent two different hydrologic regimes that are only interconnected because the stream (001) flows subsurface into the minepool, emanating at the minepool discharge (002). The concentrations of acidity, sulfates, manganese, and other analytes have been consistently higher in the downgradient point since the start of monitoring (except for a few rare occasions), not due to degradation caused by Wheelabrator mining and reclamation activities, but due to the fundamental difference in analyte concentrations between the minepool and the stream. Thus, interpretations may be made from the presence of any trends within the data from either point. For example, it appears that the pre-mining acidity at the downgradient monitoring point was usually about 90 to 100 mg/L, whereas during ash placement it has typically been about 50 to 80 mg/L as shown in Figure 3a. However, alkalinity has not increased and is still negligible, because the acidity in the minepool is still overwhelming any alkalinity attributable to the coal ash placement.

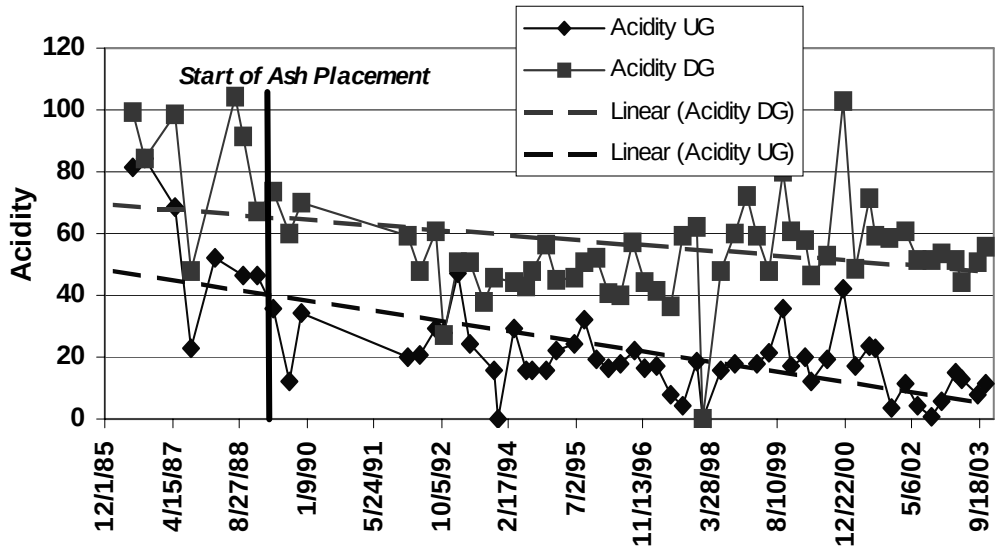

Figure 3a. Acidity in minepool and stream at Wheelabrator site.

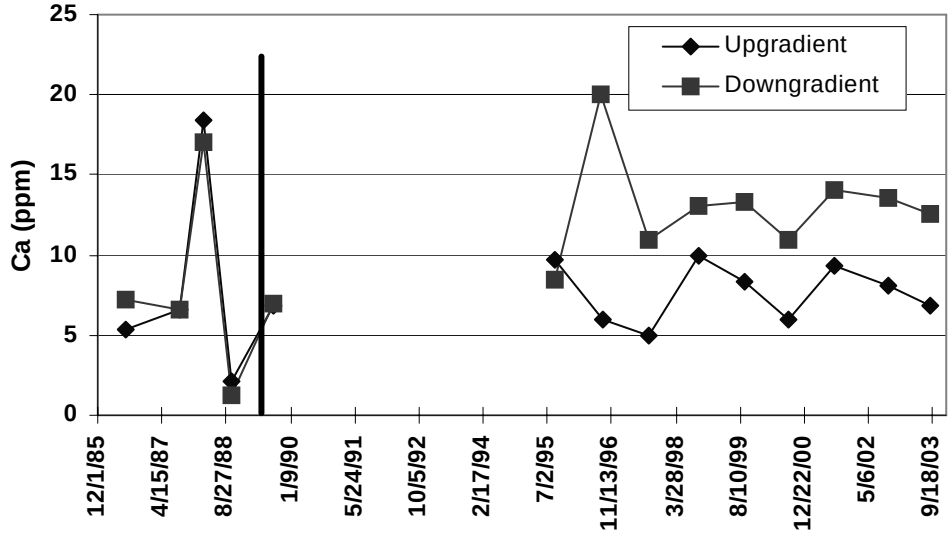

Figure 3b. Calcium concentration in minepool and stream at Wheelabrator site.

There has been no significant change in the overall water quality in an upgradient to downgradient comparison, but some trends of particular constituents are noticeable. The upgradient pH is consistently between 4 and 5 whereas the downgradient is consistently between 3 and 4. For both points, specific conductance trends slightly upward and acidity trends slightly downward. Figure 3b shows that calcium concentrations in the upgradient stream monitoring point and the downgradient minepool discharge were nearly identical prior to 1990, while the data since 1995 show the calcium concentrations in the minepool discharge are consistently higher than the upgradient sample site. This difference, however subtle, may be due to dissolution of the calcium hydroxide in the coal ash.

Overall, the Wheelabrator mine site and cogeneration plant operations have resulted in the use of refuse material to produce energy while not only reclaiming the banks of waste material, but also providing stable fill, as ash, to decrease the safety and environmental hazard of open, abandoned pits. Formerly unusable land is being restored to a graded, vegetated condition for future use as shown in the photos in Figure 2a and 2b. It is not anticipated that the ash placement will result in an overall degradation of water quality. Over the long-term, further pollution resulting from flow to the minepool will be reduced as more natural overland drainage patterns are restored and Mill Creek is eventually returned to a surface stream across the site.

Susquehanna Coal Company – (Mt. Carmel Co-Gen Site)

During a night in December 1989, a woman was walking in a wooded area near Route 54 between the city of Mt. Carmel and the village of Marion Heights in PA when she fell into a 100 foot deep abandoned surface mine pit and was killed. That fatality elevated the backfilling priority of that abandoned mine land feature to the Priority 1 class on the OSM list of backfilling projects, in order to abate the mine hazard and prevent future fatalities. In April 1987, Susquehanna Coal Co. applied for a surface mining permit (SMP #49870202) to mine and process abandoned culm banks from the Natalie and Richards collieries to be used as fuel in the fluidized bed combustion boiler of the Foster Wheeler Mt. Carmel, Inc., cogeneration plant being constructed on-site (Fig. 4). That SMP was issued on August 24, 1987 and included approval to place fly ash and bottom ash from the cogeneration plant in the abandoned pit and adjacent areas. By 1995, all of the abandoned pits (except for an access area near the ash conveyor) were reclaimed to approximate original contour at no cost to the State or Federal government (Fig. 5b).

The Susquehanna Coal Co. site is located in Mount Carmel and Coal Townships in Northumberland County. The SMP boundary of the 788 acre site is shown on Figure 4. The SMP overlies four abandoned underground mines. These mines are, from east to west, the Richards Water Level, Natalie, Hickory Ridge and Hickory Swamp Collieries. The area of the Richards Colliery within the SMP is very minor, and near to the cogeneration plant site adjacent to Route 54; thus Borehole No. (BH) 48 shown on Figure 4 serves as an upgradient monitoring well. Most of the permit area, including the ash placement areas, is overlying the Natalie and Hickory Ridge Collieries. These four abandoned underground mines and several additional adjacent collieries are all hydrologically interconnected through breeched, leaking barrier pillars, with the Scott overflow shown on Figure 4 being the major mine discharge point. The Scott discharge emanates from the Scott Colliery located south of the permit area. These collieries are within the western portion of the Western Middle Anthracite Field.

Geologically, the site is located within the Western Middle Synclinorium, which is depicted by Arndt (1971). Of the many anticlines and synclines within this synclinorium, the axis of the Hickory Swamp Syncline passes directly through the permit area and is parallel to the long dimension of the SMP boundary shown on Figure 4. Hence, the abandoned surface mine pits and the extensive abandoned coal refuse piles within the permit area shown on Figure 5a, sat within this relatively narrow trough-like geologic structure, and were underdrained through abandoned underground mine voids to the Scott Overflow. Millions of tons of these coal refuse deposits were mined, transported to the cogeneration plant by a conveyor system and combusted with limestone in the circulating fluidized bed boiler. The resultant alkaline coal ash has been returned to an abandoned surface mine pit by a conveyor system (with trucks currently used to transport ash to western portions of the SMP that are out of reach of the conveyor). The coal ash deposits on the site range from greater than 50 feet thickness in the area of prior deep abandoned pits, to relatively thin veneers of coal ash used to regrade and reclaim other abandoned mine land features (Fig. 5a, b & c). Any water infiltrating through these reclaimed coal ash areas or active coal ash placement areas will flow within the synclinal trough, and thence through cross-connecting mine voids to the Scott Overflow shown on Figure 4. Apparently, this groundwater flow system functions effectively as an underdrain for the site.

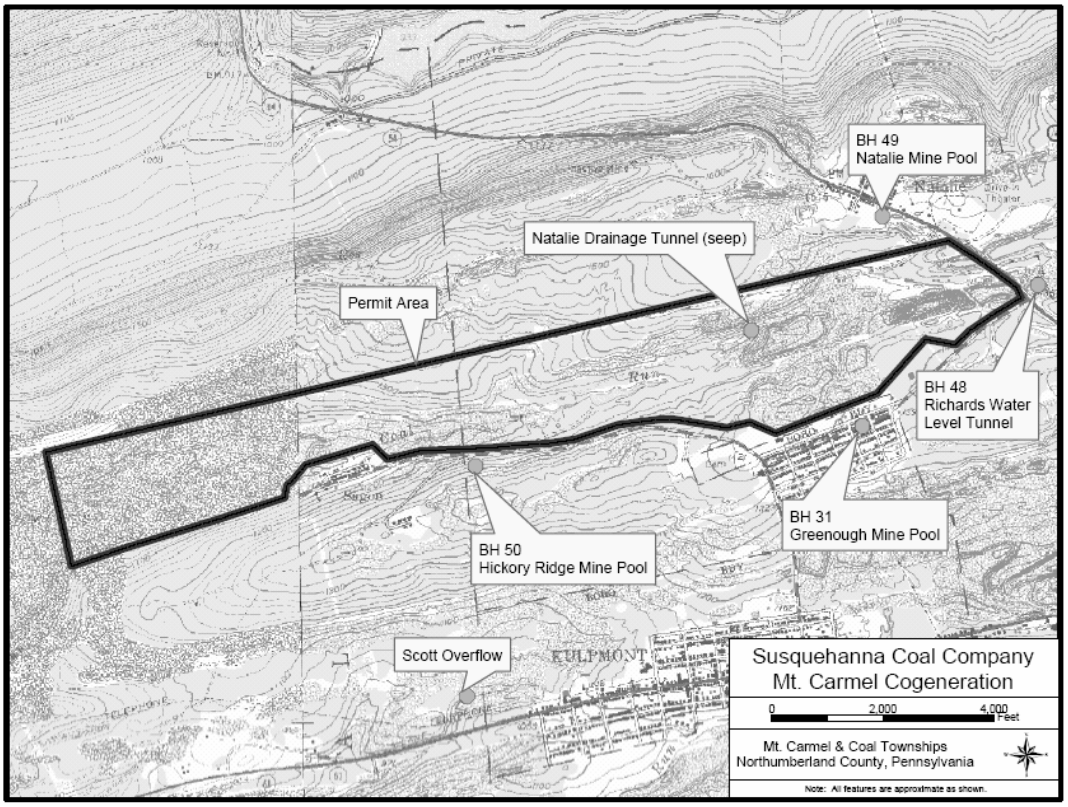

Figure 4. Site map of Susquehanna Coal – Mt Carmel Cogeneration site.

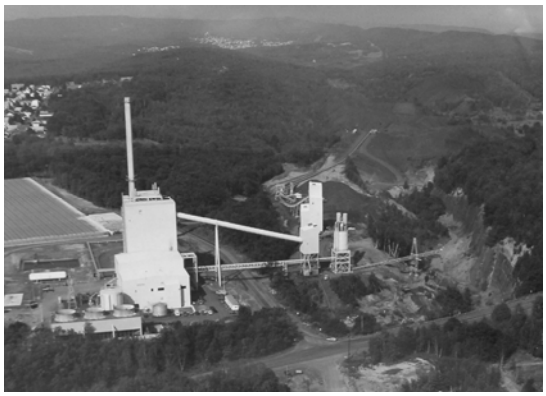

Figure 5a. Abandoned pits and refuse piles at start of ash placement.

5b. 10 years of ash placement and reclamation of pit.

5c. Coal ash deposit greater than 50 feet thick near conveyor.

5d. Scott Overflow monitoring point.

The Mount Carmel cogeneration plant consumed a total of 9,106,000 tons of coal refuse from 1990 through 2004, and produced 6,099,975 tons of alkaline coal ash for mine reclamation on-site during that 15 year period. The average yearly culm consumption was 607,067 tons, and the average annual coal ash production was 406,665 tons. A total of 209 acres of abandoned mine lands were reclaimed with coal ash within the SMP for an average of 16.1 acres reclaimed per year. Additional reclamation has also occurred through the remining of coal refuse banks in and around the plant area. These operations are permitted to supply fuel for the cogeneration plant and include an additional 50 acres of abandoned mine land reclamation directly associated with this cogeneration plant operation.

Groundwater monitoring data for five of the monitoring points shown on Figure 4 are compiled in Table 1. These data are representative samples of quarterly and annual groundwater monitoring by the permittee from 1989 through 2003. BH 48 in the Richards Colliery has characteristics of acid mine drainage with acidity from 18.0 to 131.0 mg/L (median 67.6 mg/L); sulfate from 34.0 to 283.0 mg/L (median 141.0 mg/L); and iron 0.41 to 380.0 mg/L (median 12.30 mg/L). These ranges and medians were computed from the 55 samples in the permit file. This upgradient monitoring well was intended to be a companion to the other upgradient well, BH 49 within the Natalie Colliery, but the water quality of these two wells is very different. The highest acidity in BH 49 is 40.0 mg/L but most of the samples were alkaline with alkalinity from 15.0 to 93.6 mg/L (median 47.0 mg/L). The iron in BH 49 ranges from 14.20 to 296.0 mg/L (median 58.0 mg/L), but the sulfate ranges from 1.51 to 362.0 mg/L with a median of 6.0 mg/L. Most of the sulfate values for BH 49 were less than 10.0 mg/L, thus this monitoring well does not exhibit acidic or neutralized mine drainage characteristics, and may not be intercepting the actual Natalie minepool. These two boreholes were used as downgradient monitoring wells for the Mount Carmel Township landfill located immediately east of the permit area. There is the possibility that the alkalinity in BH 49 is attributable to landfill leachate or sewage. However, significant influence from landfill leachate can probably be ruled out, based upon 18 groundwater analyses that were conducted for Chemical Oxygen Demand (COD). In these analyses, the COD for BH 48 ranged from 7.70 to 43.20 mg/L, while the COD for BH 49 ranged from 0 to 69.0 mg/L. According to a 1986 EPA study, which sampled leachate from municipal waste landfills throughout the United States, the median COD was 2,800 mg/L and the maximum was 50,450 mg/L.

BH 31 in the Greenough minepool and BH 50 in the Hickory Ridge Colliery are both of questionable value as long-term groundwater monitoring points for the Susquehanna Coal Co. site. This monitoring well has a chemical signature that resembles neutralized acid mine drainage, but there are no distinct trends of water quality improvement nor degradation. Further, from its location, BH 31 cannot be considered an upgradient well, but it is unlikely to be a reliable downgradient monitoring well.

The location of BH 50 within the Hickory Ridge Colliery should make it a suitable downgradient monitoring well, at the southern edge of the permit area (Fig. 4) and north of the Scott Overflow discharge. However, its chemical signature does not resemble mine drainage, and the well has little value in groundwater quality interpretation related to the surface mine and ash placement site. The sulfates in BH 50 are less than 10.0 mg/L in 47 of 55 samples in the data set. The median alkalinity is 45 mg/L and most of the samples fluctuate about that concentration from 1988 to 2003; thus, there is no apparent trend of increasing or decreasing alkalinity concentrations. Also, there were only 2 samples with detectable acidity concentrations. This water is not representative of acidic or neutralized minepool

water quality, and clearly does not represent groundwater influenced by the area of coal ash placement. Thus the water quality data from BH 50 and BH 31 were deemed to be unworthy of further consideration.

Table 1. Groundwater monitoring data of the Susquehanna site in (mg/L). (0.00 values = below detection limit).

SAMPLED	pH	SPECIF. COND.	ALK	ACID	Fe	Mn	SO4	TDS	TSS	Al	As	Cd	Ca	Cr	Pb
B.H. #31 Greenough															
7/9/90	4.85	450	11.2	26.9	64.0	2.3	71	341	53						
3/10/92	6.60	380	79.0	0.0	22.9	1.5	26	215	24						
9/19/95	6.10	327	105.0	0.0	27.0	1.7	81	158	26	0.00	0.000	0.000	30.2	0.000	0.000
8/27/99	6.10	590	46.8	0.0	18.9	2.0	81	316	14	*0.70*	*0.005*	*0.010*	32.1	*0.040*	*0.100*
9/29/00	6.04	548	60.0	*1.0*	24.4	2.0	90	303	3	1.00	*0.005*	*0.010*	31.6	*0.040*	*0.100*
8/6/01	4.12	445	3.6	24.0	10.3	2.3	80	290	20	1.30	*0.005*	*0.010*	3.4	*0.040*	*0.100*
11/6/01	5.48	430	39.9	*1.0*	16.5	1.8	72	254	10						
B.H. #48 Richards Water Level															
6/29/90	3.55	700	0.0	61.6	60.0	4.5	133	452	229	5.20	0.000	0.000		0.000	0.000
6/13/94	3.70	557	0.0	67.6	8.6	4.7	278	524	25						
3/6/95	3.80	656	0.0	79.2	25.0	4.2	283	532	36						
9/26/95	3.60	684	0.0	81.0	28.0	5.1	179	559	45	7.20	0.000	0.000	20.7	0.000	0.000
12/8/98	3.67	1350	0.0	70.0	2.4	4.3	141	589	5						
9/23/99	3.61	1120	0.0	66.5	12.3	5.2	225	586	4	8.40	*0.005*	*0.010*	20.8	*0.040*	*0.100*
6/13/00	3.48	488	*1.0*	131.0	380.0	3.9	120	764	900						
B.H. #49 Natalie															
6/9/92	5.90	105	38.0	40.0	51.0	0.8	2	73	78						
9/30/93	6.20	98	45.0	0.0	44.0	0.9	362	58	86	0.00	0.000	0.000		0.000	0.000
12/22/96	6.11	246	47.0	2.5	53.4	1.0	152	114	40						
9/25/97	6.37	93	63.0	0.0	296.0	1.1	6	82	332	3.50	0.000	0.000	7.4	0.000	0.000
8/27/99	6.19	275	93.6	0.0	159.0	1.2	2	166	274	1.20	*0.005*	*0.010*	9.7	*0.040*	*0.100*
3/2/01	5.75	200	36.0	*1.0*	58.0	1.0	3	84	120						
B.H. #50 Hickory Ridge															
7/9/90	6.60	75	43.0	0.0	26.3	0.4	2	37	88	0.00	0.000	0.000		0.000	0.000
8/3/90	2.49	1200	0.0	464.0	21.0	0.3	5	105	15						
3/22/94	6.50	569	83.0	0.0	20.0	0.4	0	372	36						
12/14/94	5.87	472	43.0	22.0	31.0	4.0	341	435	1	0.00	0.000	0.000	47.2	0.000	0.000
12/17/99	6.00	127	45.0	0.0	34.2	0.3	0	50	54						
8/7/02	6.50	96	14.4	*1.0*	10.0	0.5	3	94	6	*0.70*	*0.005*	*0.010*	10.4	*0.040*	*0.100*
3/12/03	6.58	1060	56.0	*1.0*	7.4	0.6	25	756	18						
8/7/03	6.78	133	20.1	*0.4*	21.3	1.4	2	67	51						
Scott overflow															
10/16/89	6.52	660	38.0	54.8	31.2	4.6	371	200	4						
2/2/90	6.50	650	38.0	35.1	26.5	4.3	248	20	12						
10/3/90	6.05	658	32.3	30.4	23.5	3.8	170	546	0						
4/9/91	5.67	700	38.0	82.0	28.0	3.8	260	450	2						

The Scott Overflow is considered the most reliable downgradient groundwater monitoring point for the Susquehanna Coal Co. permit site. It exhibits a discernable trend of groundwater quality improvement, which is most likely attributed to the beneficial use of coal ash in mine reclamation, plus the removal of large volumes of coal refuse for combustion in the FBC power plant. USGS sample data of the Scott discharge from 1975 (Growitz et al. 1985) and 1991 (Wood 1996) show that the flow of the discharge was measured at 15 cfs (6733 gpm) on April 17, 1975 and a flow of 4.8 cfs (2154 gpm) on November 1, 1991. The acidity in the 1975 sample was 165 mg/L and 161 mg/L in 1991. The alkalinity concentration of the 1975 sample was 16 mg/L, and the 1991 sample was 38 mg/L. Representative samples from the permittee's self-monitoring data are in Table 1. Of the 60 permittee's monitoring samples of the Scott Overflow in the DEP permit file, the median acidity is 26.15 mg/L and the median alkalinity is 43.0 mg/L. Acidity exceeds alkalinity in 12 out of 60 samples in this data set, but 7 of these are in 1989

and 1990, when ash placement on the site was in its infancy (Fig. 5a), and the last time that acidity exceeded alkalinity was the sample of December 15, 1994. The median alkalinity for the samples prior to 1991 is 32.3 mg/L as compared to the median alkalinity of 44 mg/L for all samples from 1991 to 2003. The corresponding median acidity values are 35.1 mg/L for pre 1991 samples, and 21.3 mg/L for the past 12 years. This trend of acidity reduction is shown on Figure 6a for the Scott Overflow discharge as compared to the relatively consistent acidity in upgradient monitoring well BH 48. The corresponding trend of increasing alkalinity concentration in the Scott Overflow discharge is shown in Figure 6b. The least- squares trend line fitted to the alkalinity data for the Scott Overflow indicates an increase through time, however, the plotted monitoring data are not equally spaced through time – so the slope of the line may not be an accurate representation of the actual time trend. There also has been a subtle trend of decreasing sulfate concentration in the Scott discharge since 1995 as shown on Figure 6c. This indicates that the acidity production at the Mt. Carmel cogeneration plant site may be decreasing due to the removal of the coal refuse and the concomitant addition of alkaline coal ash to reclaim abandoned pits on the site.

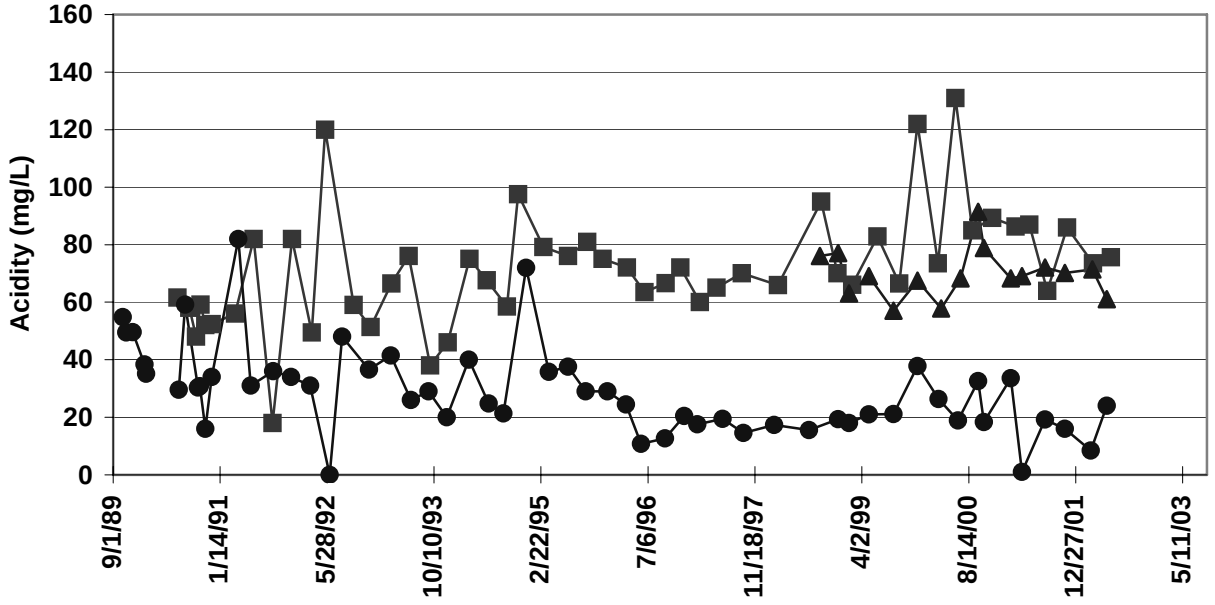

Figure 6a. Acidity in upgradient monitoring points and downgradient Scott Overflow at the Susquehanna site.

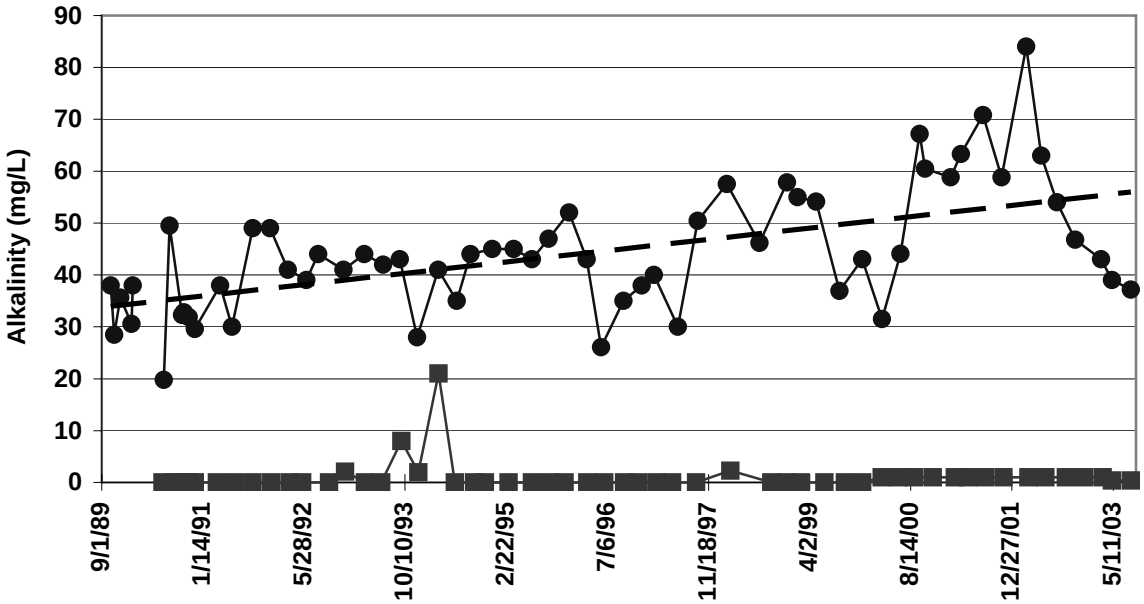

Figure 6b. Alkalinity increase in downgradient Scott Overflow.

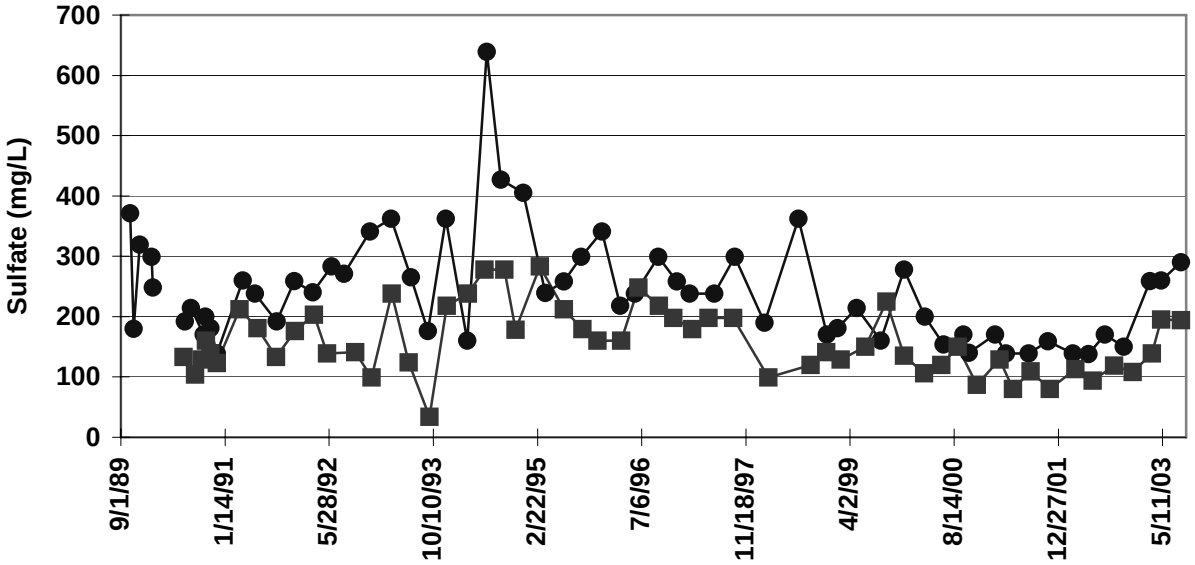

Figure 6c. Sulfate in monitoring points at the Susquehanna Coal site.

Conclusion

1. A very significant amount of abandoned mine reclamation in the four anthracite coal fields has been completed through the beneficial use of coal ash on remining sites. This extensive reclamation is significant, not only on individual sites associated with FBC power plants (e.g. the before and after photos in Fig. 5a and b, but also in the total acreage reclaimed at no cost to the government or taxpayers.

2. The evaluation of more than 15 years worth of groundwater monitoring data for the case study sites presented in this paper, and other permitted sites throughout the anthracite region, has not resulted in any significant findings of environmental damage or groundwater pollution cases, as measured at key downgradient minepool monitoring points. Several sites discussed in this paper showed no significant change in groundwater/minepool water quality, despite extensive ash placement and land reclamation – although these sites significantly reduced infiltration to the minepool, and thus should represent a reduction in the flow and thereby the pollution load of acidity, iron and other metals in these high volume minepool discharges. At least one site discussed in this paper produced a significant increase in alkalinity concentrations, or reduction in acidity, iron, or other analytes that is attributable to the beneficial use of coal ash on these sites.

3. The range of mine site characteristics, coal ash placement configurations, and groundwater/minepool monitoring scenarios presented in this paper demonstrates that a "one size fits all" approach to the permitting and compliance monitoring of the sites is not practical or effective. Site specific application of engineering principles and evaluation of geologic factors is essential, particularly: (a) the soil-mechanics engineering of ash placement, (b) the mining engineering of the active surface mine and abandoned underground mines, (c) the geologic structure of the site and surrounding area (e.g. synclinorium), and (d) the hydrogeology of the site and underlying minepool system. Permit applicants, their consultants and regulatory agency scientists and engineers must collaborate to promote effective ash placement technology and to develop practical and realistic groundwater monitoring plans.

4. The groundwater monitoring data for various coal ash placement sites and a hydrologic budget review demonstrates that the "high and dry" concept of placing relatively dry (optimum moisture content) coal ash into a relatively dry mine environment is working well. It is feasible to develop a matrix approach that would match the range of physical and chemical properties of FBC and PC coal ash classes to various ash placement alternatives, in order to optimize cementitous behavior of specific ash types, or maximize alkalinity production in groundwater – and solve a variety of abandoned mine land and mine drainage problems.

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Michael J. Menghini is a Mine Inspector Supervisor and currently the Acting Monitoring and Compliance Manager for the Department of Environmental Protection's (DEP) Pottsville District Mining Office. He has worked for DEP since 1983 and has been involved with coal ash regulatory issues since the late 1980's. He is Pennsylvania's representative for the Environmental Protection Agency's CCW regulatory initiative. He has helped develop the current State coal ash beneficial use regulations and related permit conditions, mine permit coal ash modules, and technical guidance documents. He is involved in all issues related to the beneficial use of coal ash in mine placement and reclamation activities. He holds a BS in Environmental Resource Management from Pennsylvania State University.

BENEFICIAL APPLICATIONS OF CFB ASH AT MISSISSIPPI LIGNITE MINING COMPANY'S RED HILLS MINE

George M. Hawkey, Environmental Manager
Mississippi Lignite Mining Company
and
Marcelo P. Merino, Senior Staff Engineer
The North American Coal Corporation

Abstract

Mississippi Lignite Mining Company (MLMC) operates the Red Hills Mine, an open pit, multiple seam, lignite mining operation, in northeast Mississippi. The mine produces and supplies approximately 3.6 million tons of lignite annually to the neighboring Red Hills Power Plant which is operated by an affiliate of Tractebel Power Inc. The Red Hills Power Plant is a 440 megawatt power station utilizing modern circulating fluidized bed (CFB) boiler technology. Fuel conversion produces 670,000 tons of dry CFB ash annually that is disposed of in excavated, lined, and permitted solid waste disposal cells adjacent to the power plant.

Mine production is impacted greatly by haul road conditions. Roads must support haulage trucks that weigh 550,000 pounds and carry 150 ton payloads at speeds up to 34 mph. During inclement weather, roads become soft, spongy, and rutted. Haul truck speeds and production are seriously impacted. Construction of all-weather roads is difficult because of a lack of suitable, locally available, sub-base soils and surfacing materials. Trucking costs for aggregate from distant Mississippi and Alabama quarries make this material too costly for use on most primary haulage roads.

Following extensive reviews, the Mississippi Department of Environmental Quality (MDEQ) gave MLMC approval to use CFB ash for the construction of primary heavy earth moving and coal haulage equipment roads, dragline walkways, pit ramps, parking areas, and other minor construction purposes. MDEQ considers these uses to be beneficial and an economical replacement of crushed limestone the mine has traditionally imported from considerable distances. The use of ash as a mine road building material not only has improved haulage production, reduced diesel fuel consumption, and reduced road maintenance, but also will conserve natural aggregates from quarries and lengthened the life span of the primary ash disposal facility.

This paper describes the environmental considerations given for ash applications, permitting and monitoring requirements of MDEQ, ash handling methods that the mine has used in various applications, and results the mine has observed.

Introduction

Red Hills Mine is a surface lignite mine that has been in operation for seven years and is located 7 miles northwest of Ackerman, in Choctaw County, Mississippi (Figures 1 and 2). It is owned and operated by the Mississippi Lignite Mining Company (MLMC), an affiliate of The North American Coal Corporation. Development of the Red Hills Mine began in 1998, with commercial lignite deliveries in 2002. Coal production of the Red Hills Mine is approximately 3.6 million tons-per-year. Lignite from the Red Hills Mine fuels the neighboring Red Hills Generation Facility (RHGF), which is owned and operated by Choctaw Generation Limited Partnership, an affiliate of Tractabel Power Inc. (Tractabel). The RHGF generates 440 MW of electricity using two circulating fluidized bed (CFB) boilers. Fuel conversion produces 670,000 tons of dry CFB ash annually that is primarily disposed of in excavated, lined, and permitted solid waste disposal cells (referred to as Ash Management Units (AMU's) in this paper) adjacent to the power plant (Figure 3).

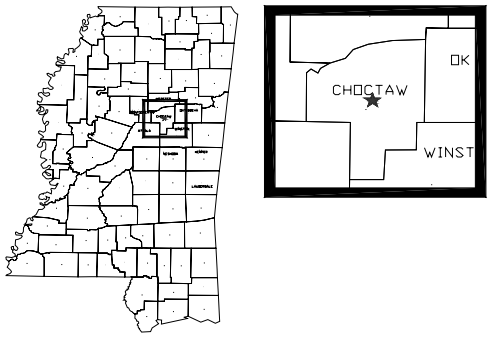

Figure 1. Project Location Map.

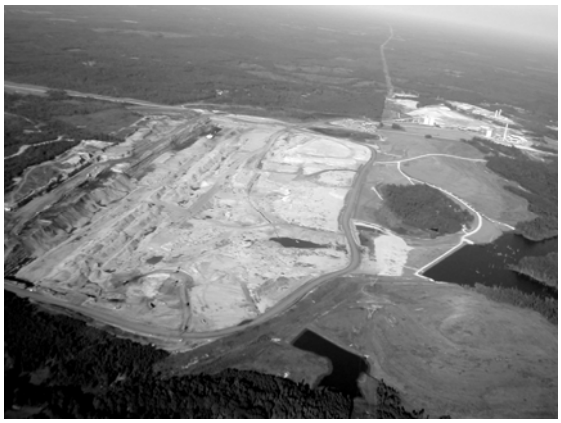

Figure 2. Aerial photo of the Red Hills Mine.

Figure 3. Aerial photo of the RHGF and AMU (right of plant).

The 5,800 acre life-of-mine area is characterized as wooded, rural countryside with occasional pasturelands, ponds, sparse residential development, and few industrial features. The terrain is gently rolling with wide valleys, small streams and dissected uplands. More than 80% of the area is woodland, with deciduous, evergreen, and mixed timber stands. The predominant pre and post mine land use is and will be commercial forest.

The Red Hills Mine lies within the Wilcox Group of Mississippi. This is the most abundant lignite bearing stratum in the State. Within the mining area, ten major lignite seams (A through J Seam) have been mapped with A seam being the deepest. Of the ten seams, only six relatively continuous lignite seams (C through H Seam) are being mined. Average depth to the C seam is 200 feet, with the average depth to the A seam being 340 feet. Only the upper portion of the Wilcox Group, principally the Tuscahoma Formation and Grampian Hills Member of the Nanafalia Formation, will be disturbed by mining. Compared to the Gravel Creek Member and Tuscahoma Formation, the Grampian Hills Member is relatively sand-poor and has no ground water resource value. Little or no ground-water development has occurred within this stratum. The Lower Wilcox Aquifer, a fresh water aquifer of

local importance, is located below the A seam and is overlain by 70 to 80 feet of interbedded clay, silt, sand, and the relatively discontinuous A and B lignite seams. Since the depth of the Lower Wilcox Aquifer is over 100 feet below the C Seam and is separated from the mine floor by several strata of fine-textured materials, it has not been impacted by ongoing mining operations and is not expected to be impacted in the future.

Mining involves the removal of six lignite seams (C, D, E, F, G, and H) uncovered by continuous removal of overlying burden soils. Suitable plant growth materials (SPGM) and overburden materials are removed by a combination of truck and shovel operations, dozer push operations, and with a dragline. In general, the truck and shovel operations remove the upper SPGM and overburden to the first lignite seam. Caterpillar D-11 class dozers sequentially uncover the next three seams by pushing overburden into the preceding pit. The last two seams are uncovered by an 82 cubic yard walking dragline. As lignite seams are exposed they are recovered using 22 cubic yard excavators, a 40 cubic yard electric loading shovel, and an Easi-Miner to load 165-ton end dump trucks for delivery.

Reclamation involves grading spoil to a gently rolling terrain, which approximates original contours, covering or re-spreading the graded spoil with four feet of SPGM, seeding with a grass cover crop for erosion control, and planting with loblolly pine seedlings to achieve the primary post-mine forest land use requested by area landowners.

Surface coal mining operations in Mississippi are regulated by MDEQ's Office of Geology under delegated authority granted by the United State Department of the Interior, Office of Surface Mining, pursuant to the Surface Mining Control and Reclamation Act of 1977, 30 U.S.C. § 1201 et seq. Solid waste disposal is regulated by MDEQ's Office of Pollution Control. This office is in charge of regulating the disposal and beneficial uses of RHGF ash. Currently there are no specific regulations that address the beneficial use of coal combustion products. MLMC and RHGF working with both aforementioned MDEQ offices, developed beneficial ash use criteria that could be used to prepare a proposal for regulatory framework and incorporation into MLMC's Surface Coal Mining and Reclamation Permit. These criteria included:

- a description of the proposed beneficial use of the ash
- a description of how the use of as h would replace or c onserve other natural resources or other materials, thereby qualifying RHGF ash as a "product" and it's use as "beneficial"
- a chemical and physical characterization of the ash
- the potential environmental consequences of the beneficial use of the ash.

Most of what is known today about coal combustion products in the United States is based on ash produced in pulverized coal boilers (PCBs) that combust coal at approximately 3,000^{o} F. Comparatively little is known about CFB combustion products because fluidized bed boilers are relatively new and few in number. Fluidized bed boilers combust a mixture of coal and limestone at about 1,400^{o} F. These boilers have two significant benefits over PCB units, they capture and bind sulfur and lime into calcium sulfate and reduce nitrogen oxides (NOX).

The source of lime used by RHGF in its boilers is the Selma chalk, a lime rich clay, which is mined about 60 miles from the plant. The ash that RHGF produces has properties specifically associated with the lignite and lime burned in its CFB. As such, Tractebel is very interested in characterizing the ash as having a beneficial use and developing marketable applications for it rather than disposing of it as a solid waste. Currently, RHGF's Ash Management Units occupy 72 acres and have cost millions of dollars to design and construct. Additional disposal storage areas will be needed in the future unless other beneficial applications can be developed. In addition to RHGF ash that MLMC is using as described in this paper, this ash is being used locally by Choctaw County and neighboring counties as an inexpensive county road stabilization material, by various contractors as a building site stabilization material, and by several landfills as a solidification or absorbent material. RHGF also is working with the Mississippi Department of Transportation to have RHGF ash approved as a stabilization product for State Highway construction projects.

Beneficial Use of CFB Ash at the Red Hills Mine

Mining conditions at the Red Hills Mine can be best characterized as challenging. Removal of SPGM, multiple lignite seams and overlying burden material from a 7,000 foot long pit requires continuous construction of new haul

roads, ramps, trails, and dragline walkways capable of supporting the large and heavy earth moving equipment used. While ground water is less of an operational concern, surface water runoff has significant impact on the trafficability of the roadways which has a tremendous impact on productivity. Red Hills Mine has received from 55 to over 80 inches of annual rainfall since it began operations. The only road building materials available on-site are sandy or silty Wilcox clays, which exhibit high shear strength under dry conditions but rapidly lose shear strength as their moisture content increases. Furthermore, suitable road base aggregates are not available in the area and need to be purchased and imported from distant suppliers. During the winter months shorter daylight hours, lower temperatures, and common back-to-back storms result in saturated roads that remain rutted, soft, and spongy for long periods. Under these conditions, truck traffic on primary roads becomes slow, and trafficability on spoil trails and softening dragline walkways is almost impossible. Until RHGF ash was used, the only option for constructing durable haul roads was to place a crushed limestone base over woven textile over the clay sub-grade of the roads. The nearest source of base rock is located 170 miles from the mine making its use too expensive for all but the most important and long life segments of primary haul roads.

Road deterioration is not the only problem that rain causes. The clay backfill placed in culvert installations becomes soft and erodes. Rutting and excessive settlement of soft soils, result in the collapse of culverts under heavy vehicle loads.

Since crushed limestone, a common road base material, is used as acid neutralizing medium in the RHGF CFB boiler, MLMC surmised that the CFB ash might possess attractive binding characteristics and might be used as a clay stabilizer and help improve the trafficability of the mine roads, dragline walkways, parking, and shop entrance areas. If so, then the use of ash as a clay stabilizer and/or road base material would be a "beneficial use." Its use would also have the benefit of reducing natural limestone demand from quarries and associated transportation costs.

Also, the beneficial use of ash as a mine road stabilization product would reduce the land area needed for disposal/storage of ash at the RHGF AMU's and extend the life of the AMU. For the mine operation, stabilization of roads, trails, ramps, walkways, and parking areas would certainly be beneficial. Rain delays would be shortened, vehicle wear would be reduced, safety would improve, and productivity would be enhanced.

Ash Characterization and Application Considerations

As previously described, the ash generated at the RHGF consists of fly ash and bottom ash from a fluidized bed combustion boiler. The dry ash from the boilers is hydrated (pugged) using blow-down water from the power plant water cooling tower system prior to being loaded on trucks for final disposition. Hydrating ash controls dust during transportation and uses excess cooling tower water. Blow-down water has concentrated amounts of salts found in the raw water and extracted during treatment of the cooling water stream.

Mineralogical Analysis

Mineralogical analyses of the RHGF ash (dry), Selma chalk and a common brand of commercially available limestone, Vulcan, were performed as an initial step in comparing ash to natural limestone (Table 1). The Selma chalk is used in the CFB boiler. Vulcan brand limestone is used widely as a road base material in northern Mississippi. Dry samples of RHGF ash taken approximately a year after the initial sample analysis confirmed the stable composition of the ash (Table 2). Alumina, silica, lime, and sulfur trioxide constitute over 90 percent of the mineral content of ash. These oxides provide the pozzolanic properties commonly observed in many lignitic fly ashes. Notably, as seen on Table 2, the RHGF ash does not quite meet all the classification standards of either a Class F or Class C ash. This is not surprising since the RHGF ash comes from a CFB boiler rather than a PC boiler.

Mineralogical analyses shown on Tables 1 and 2 indicate that the RHGF ash is basically a soil (aluminum silicate) with moderate cementing properties.

Table 1. Initial Mineralogical Analysis of the RHGF Ash and commercial limestone used at the RHGF and mine site (as percentage of weight on a dry basis).

	RHGF ASH	SELMA CHALK	VULCAN LIMESTONE
Silica, SiO_2 49	.63	Not Reported	10.28
Alumina, Al_2O_3 18	.65	3.80	0.28
Titania, TiO2	0.89	Not Reported	0.00
Ferric Oxide, Fe_2O_3 3.	35	1.70	0.23
Lime, CaO	15.90	44.80	86.04
Magnesia, MgO	2.21	3.40	1.70
Potassium Oxide, K_2O 1.	06	0.06	1.13
Sodium Oxide, Na_2O 0.	34	0.04	0.00
Sulfur Trioxide, SO_3 6.	17	0.06	0.31
Phosphorous Pentoxide, P_2O_5 0.	18	0.02	0.00
Strontium Oxide, SrO	0.18	Not Reported	0.05
Barium Oxide, BaO	0.17	Not Reported	0.00
Manganese Oxide, Mn_3O_4 0.	11	0.03	0.00
Undetermined 1.	16		0.00
Alkalis, as Na_2O, Dry Coal Basis	1.01	Not Reported	Not Reported
Base: Acid Ratio	0.33	Not Reported	Not Reported

Table 2. Additional Mineralogical and Physical Analyses of the RHGF ash (as a percentage of weight on a dry basis). Note: Ash classification standards are provided as reference only.

	February 2004	**October 2003**	**CLASS C Classification**	**CLASS F Classification Criteria**
Mineralogical Analysis				
Silicon Dioxide ($Si0_2$) 41	.73	46.69		
Aluminum ($A1_20_3$)Oxide	16.71	14.47		
Iron Oxide (Fe_20_3) 6.	04	4.52		
Sum of $Si0_2$, $A1_20_3$, and Fe_20_3	64.48	65.48	50 Min.	70 Min.
Magnesium Oxide (MgO)	1.65	1.65		
Sulfur Trioxide ($S0_3$)	6.25	5.43	5.0 Max.	5.0 Max.
Moisture	0.17	0.14	3.0 Max.	3.0 Max.
Loss on ignition	0.32	0.29	6.0 Max.	6.0 Max.
Available Alkalies as Na_20 0.	44	0.38		
Calcium Oxide (CaO)	22.53	21.60		
Free (CaO)	2.20	1.90		
Physical Analysis				
Fineness: percent retained by the 325 sieve	35.29	34.95	34% Max.	34% Max.
Water Requirement, % Control	111%	110%	105% Max.	105% Max.
Specific Gravity	2.53	2.60		
Autoclave Expansion, %	0.00	+ 0.01	0.8% Max.	0.8% Max.

Table 2 continued.

Strength activity index with Portland Cement:				
7 Day	82%	80%	75% Min.	75% Min.
28 Day	86%	95%		

As part of characterizing the chemistry of the ash, trace metal analyses were performed. The results indicate a concentration of trace metals of less than five (5) grams per kilogram of ash (Table 3).

Leachate Analysis

After evaluating the chemical content of the ash, the investigation focused on the chemistry of the RHGF ash leachate. This was done by first carrying out standard leachate extraction procedures and, in a second phase, analyzing the leachate obtained from column tests. The latter tests also served to determine the hydraulic conductivity of the ash after being saturated in water and during the ensuing cementing process. Results of Toxicity Characteristic Leaching Procedure (TCLP) analysis performed on two samples are presented in Table 4. For comparison, the maximum contaminant level (MCL) concentrations for drinking water, established by the US. Environmental Agency (USEPA) in 40 CFR § 146.62, are also indicated in Table 4. TCLP results reported in Table 4 indicate that RHGF ash leachate is non-toxic.

Table 3. Concentration of Trace Metal Analyses in the ash.

Metal Co	**ncentration (mg/g)**		**Metal**	**Concentration (mg/g)**	
	Oct 2002	Jun 2003		Oct 2002	Jun 2003
Antimony 14			Manganese	1320	
Arsenic 15		10.8	Mercury	0.7	<0.1
Barium 93	0	318	Molybdenum	29	
Beryllium <2			Nickel	96	14.8
Cadmium <2		<0.5	Selenium	6	<1.25
Chromium 12	0	47.3	Silver	5.7	<0.125
Cobalt 82			Strontium	1830	
Copper 11	5	47.3	Tin	13	
Lead 62		9.87	Vanadium	67	
Lithium 81			Zinc	52	10.7
			Zirconium	21	

Table 4. TCLP Analysis (test concentrations in mg/l)

	Sample 1	Sample 2	MCL
Arsenic, As	<0.05 <0.	05 0.	05
Barium, Ba	0.34	0.36	2.0
Cadmium, Cd	<0.005 <0	005 0.	005
Chromium, Cr	0.04	0.03	0.1
Lead, Pb	<0.01	<0.014	0.015
Mercury, Hg	<0.0002	<0.0002	0.002

Selenium, Se	<0.05 <0.	05 0.	05
Silver, Ag	<0.005 <0	.005 n	o MCL

Note: Current arsenic MCL is 0.05 mg/l. However the level of 0.01 mg/l will be effective on 1/23/2006.

Results of the column tests performed on ash from the bag house (dry ash) and the AMU (pugged ash) are presented in Table 5. The column tests were performed using groundwater obtained from a well constructed in the Wilcox Formation. The rationale for using groundwater was to better simulate groundwater found in the mine excavations.

Results presented in Table 5 indicate, as do the results shown in Table 4, that ash from the RHGF is non-toxic. The ratio of sulfate to calcium indicates a chemically stable calcium sulfate matrix with other inorganic elements like sodium and potassium in smaller concentrations. Use of the ash as a road stabilization material was not expected to have an adverse environmental impact.

The pH range of the deeper overburden soils at the mine varies from 6.0 to 8.5. Topsoil and subsoil have a lower pH range of 4.0 to 6.0. Limestone is basically inert within the pH ranges of the deeper overburdens and only minor dissolution should be expected at the lower pH levels found in soils with a pH of less than 5. On the road base, water re-binds limestone fines generated during application and compaction of limestone gravel. Conversely, ash when applied to soils is expected to promote physical stabilization of the clay soils by chemically binding the clay minerals with the aluminum silicates and the lime contained in the ash. The pH, measured in the column leachate tests, is presented in Table 5. It ranges between 10 and 10.5. This indicates that RHGF ash is less basic than hydrated lime, which is commonly used in road sub-grade stabilization.

Table 5. Column Test Leachate Analyses

General Parameters	**Ash from the Bag House**	**Ash from the AMU**
Sample Date	11/19/2002	11/19/2002
Field pH	10.00	10.27
Lab pH	10.11	10.44
Electrical Conductivity (mS)	2620	3390
Magnesium (mg/l)	0.62	0.86
Calcium (mg/l)	545	725
Potassium (mg/l)	43.5	33.4
Sodium (mg/l)	60.3	96.8
Chloride (mg/l)	21.4	31.2
Sulfate (mg/l)	1040	1570
Nitrate/Nitrite (mg/l)	ND	ND
Trace Metals Total Concentration in mg/l		
Antimony ND		ND
Arsenic ND		ND
Barium 0.	16	0.16
Beryllium ND		ND
Chromium ND		ND
Copper ND		ND
Iron ND		ND
Manganese ND		ND
Mercury 0	.0027	0.0012
Molybdenum ND		ND
Nickel 0.	14	0.14
Selenium ND		ND
Silver ND		ND
Zinc 0.	027	0.046

Hydraulic Properties of the ash

Lime and magnesium oxides found in RHGF ash are present in the form of calcium and magnesium sulfates. The addition of water causes quick hydration of the ash and converts into a cementing mixture of low permeability.

Permeability or hydraulic conductivity was measured during the leaching experiments. The measured hydraulic conductivity of the ash during the initial leaching of the columns was in the order of $1x10^{-5}$ centimeters per second (0.028 feet per day) and showed a decreasing trend over time. The clay nature of the soils combined with the low permeability of the ash exhibited during column tests further suggest that no adverse consequences will result from the proposed use of this ash.

Geotechnical Investigation

Pritchard Engineering Laboratory in Starkville, Mississippi conducted a geotechnical investigation to provide an initial assessment of the stabilization benefits to be derived by incorporating RHGF ash into prevalent mine site soils. Varying dosage rates and different hydrating sources of water were studied. The scope of geotechnical work consisted of:

1) Identifying and classifying prevalent soil types utilized in earthwork activities and establishing baseline compressive strength data for these soils.
2) Incorporating ash into the prevalent soils at 10%, 20%, and 60% rates and evaluating changes in strength through unconfined compression testing. Ash dosage rates of 10%, 20%, and 60% by weight were evaluated.
3) Evaluating the use of both cooling tower water (CT) and plant process brine water (BW) (the possible ash hydrating sources from the power plant) in the sample preparation process.

Representative samples of selected mine site soils were collected, classified, and tested for compressive strength. Soil samples were then mixed with 10%, 20%, and 60% ratios of ash (hydrated with CT or BR water). Selected mine site soil samples were taken from the overburden above the D, F, and H coal seams and an upper sandy clay soil above the H burden, with D being the lowest and H being the upper coal seam in the list. These are the burden soils most often used for road construction purposes. Initial classification testing revealed that the upper sand clay material is very similar in physical characteristics to the overburden above the F seam. Consequently, compression strength tests on the F-Burden were not performed. Results of the classification tests are included in Table 6.

Typically, soils exhibiting a high PI are susceptible to significant changes in volume (i.e. shrinkage and swelling) with fluctuations in moisture content and experience severe loss of shear strength as a result of saturation and increased water content. Low PI soils experience minor volume changes in response to moisture changes and normally are suitable for use as road sub-grade material. High PI soils, on the other hand, can have dramatic volume changes induced by moisture changes and are not a good sub-grade material.

Table 6. Soil Classification of Burden Soils.

Material	Ash Content (%)	LL PI		Percent Fines	Unified Classification
D - Burden	0	39	19	81.9	CL
10		50	18		ML
60		62	23		MH
F - Burden	0	51	27	97.5	CL-CH
10		59	28		MH
60		66	28		MH
H - Burden	0	36	7	85.0	CL
10		50	19		ML-MH

Table 6 continued

H-Burden 60		58	18		M H
Upper Sandy Clay	0 50		27	92.4	CL-CH

The increase in liquid limit with increased ash content suggests that clay/ash mixture takes on a silty character. As ash content increases, soils tend to acquire an MH (highly plastic silt) Unified Classification.

Some geotechnical properties of the ash used in the mixtures were measured to assess the intrinsic properties of the RHGF ash. These are shown in Table 7.

Table 7. Geotechnical Properties of RHGF Ash.

Property Valu	e
Maximum Wet Density	97.5 pcf
Maximum Dry Density	64.2 pcf
Optimum Moisture	51.8%
Dry Unit Weight:	
Loose in Stockpile Moisture	37.61 pcf
Compacted Unit Weight	57.27 pcf
Unconfined Compressive Strength (100% Compaction):	
7 day	851 psi
28 days	951 psi
Yield (Tons per cubic yard at 100% Compaction)	1.32
Coverage: (Pounds per s quare y ard p er 1" de pth at 100% compaction)	13.13
Loss On Ignition:	0.66
Fineness:	34.95
Specific Gravity:	2.60
pH	10.53
Absorption:	0.96 fly ash : 1.0 H_20

The compressive strength results of the soil/ash mixtures using CT and BW hydration are presented in Table 8.

Table 8. Compressive Strength of Burden Soils.

Material	Ash Content (%)	Compressive Strength (psi)	
		CT Water	BW Water
D - Burden	0	23.1	
10		22.3	38.9
20		18.6	33.0
60		27.8	42.9
F - Burden	0	23.6	
10		23.9	40.2
20		32.2	33.0
60		61.9	71.7
H - Burden	0	39.3	
10		40.5	44.6

Table 8 continued

H-Burden	20	38.4	43.2
60		56.3	87.2

Results presented in Table 8 indicate that only significant doses of ash result in a beneficial use as a soil stabilizer. Indeed ash without soil exhibits significant compressive strength (851 psi at 7 days and 951 psi at 28 days) as seen in Table 7. Observations of trucks operating on the AMU's also suggested that a 100% ash road base could support heavy mining equipment traffic better than an ash/soil mixture and would compared fairly well vis-a-vis a crushed limestone base.

MDEQ Review, Approval and Monitoring Considerations

In 2003 MLMC prepared and submitted to MDEQ an initial plan entitled Plan for Beneficial Use of Coal Combustion Byproducts to Stabilize Mine Roads, Dragline Benches and Truck Fills at the Red Hills Mine. This plan included the proposed uses, application methods, approximate tonnage, the characterization previously described and an assessment of potential environmental impacts. The plan was submitted to MDEQ as a revision to be incorporated into MLMC's State of Mississippi Surface Coal Mining and Reclamation Permit (MS002) which required review under both relevant surface mining regulations and other State regulated programs. The proposal was reviewed by various MDEQ Offices including the Office of Geology (mining regulations), Office of Pollution Control (solid waste), and Office of Land and Water (ground and surface water quality).

In this plan, MLMC described potential environmental impacts and proposed mitigation measures, where applicable.

"*Dust Control*

Ash will be delivered from the RHGF to the Red Hills Mine by the R-dump haul route, which connects the plant to the mine. No ash will be hauled over county roads. The ash may be transported in a hydrated (pugged) or dry state. Hydrated ash will produce little or no dust during haulage and incorporation. If ash is transported in a dry state, it will be hauled by fully enclosed tanker truck or the top of the dry ash will be wetted to prevent ash dust generation during transportation. Ash will be hauled and incorporated immediately into the area requiring stabilization. No ash will be stockpiled prior to incorporation but rather will be incorporated concurrent with its delivery.

Probable Hydrologic Consequences

The use of ash as a stabilization product is not expected to have an adverse impact on the ground or surface water systems. The characterization of the ash indicates the RHGF ash does not contain hazardous substances and has chemical characteristics of natural clays. When incorporated into roads, truck fills, and dragline walkways, the ash and clay soil mixture will become a cemented matrix of low permeability, resistant to erosion. The compacted ash and soil admixture will remain in the place in which it is applied. Places where ash will be applied consist of clayey soils with confining characteristics. The usable ground water resources of the area will not come in contact with the ash-clay admixture. Due to the disposition of the ash and clay admixture, its low hydraulic conductivity, and the characteristics of the leacheate, described in the charaterization, no adverse impact is foreseeable as a result of the use of ash as proposed. The cemented nature of the admixture will result in only minor erosion of the ash clay admixture. Any erosion and dissolution of the ash will not result in toxic concentrations as documented by the characterization.

Potential Effect on Rooting Depth of Pine Trees

Ash used to stabilize haul routes and truck fills will be placed at varying depths. The shallowest placement of the ash clay admixture (routes and truck fills) will not be less than ten feet from the surface of the reclaimed surface topography. Ash used to stabilize dragline walkways will not be near the ground surface. Pine tree roots may reach the admixture at the shallower placement depths. Loblolly pine trees normally have root depths of two to three feet but can go as deep as ten-feet. The minimum depth of ten feet, at which the ash clay admixture will be placed, will provide an adequate rooting zone above the cemented admixture.

<u>Effect on RHGF Ash Disposal Area</u> While only a very small quantity of the total ash produced at the RHGF is proposed for beneficial use at the Red Hills Mine, the quantity represents a volume of disposal area that will no longer be needed for ash disposal purposes. Basically, this means less land area will be needed for ash disposal purposes, a positive environmental effect resulting from the beneficial use of ash."

MDEQ approved the plan in July 2003 with the following conditions:

1) *"The roadbed construction and equipment platform construction activity will be restricted to the use of the coal combustion ash produced by the Red Hills Electric Generating Facility and only applied to the project areas in the mine in the manner described in the approved proposal.*

2) *During the construction phase of the mine construction projects, Mississippi Lignite Mining Company shall ensure that the coal combustion ash material is properly managed such that storm water discharge or washout of the material to state surface waters is prevented and such that the project does not cause or contribute to a violation of applicable state and federal water quality standards."*

Surface Mining Regulations require mine operators to construct and operate sediment control ponds that catch and retain surface water runoff from all areas disturbed by mining activities. Before being discharged from the mine, surface water runoff contained in these ponds must meet specific water quality standards approved by the State in a National Pollutant Discharge Elimination System (NPDES) permit issued and regulated by the State. All discharges are sampled and analyzed for pH, total suspended solids, iron and manganese with reports submitted monthly to MDEQ. During review of MLMC's proposal, MDEQ considered the sediment control ponds as primary containment for ash that might be transported by surface runoff and, based on the characteristics of the ash, required no additional monitoring parameters. Sampling of discharges from AMU ponds operated by the RHGF indicate that storm water runoff from ash covered areas is innocuous. Table 9 contains results of storm water analysis from the AMU ponds and from runoff from ash treated roads.

Table 9. Analysis of storm water runoff from AMU ponds and ash treated haul roads (results in mg/l unless specified).

Parameter	AMU	Ash Treated Road	Detection Limit
pH (s.u.)	7.74	8.06	
Total Suspended Solids	37	43	1.0
Specific Conductance (mS)	613 20	20	
Total Dissolved Solids	314	1540	1.0
Chloride 10	2	194	1.0
Fluoride 0.	1	0.2	0.1
Sulfate 61	.9	717	20
Chromium ND		0.05	0.05
Selenium ND		0.05	0.05
Arsenic ND		0.05	0.05
Barium 0.	08	0.01	0.01
Boron 0.	09	0.01	0.01
Cadmium ND		0.02	0.02
Silver ND		0.005	0.005
Copper 0.	013	0.010	0.01
Iron 0.	85	0.02	0.02
Lead ND		0.050	0.05
Manganese 0.	05	0.01	0.01
Mercury N	D	0.0002	0.0002

Table 9 continued

Molybdenum ND		0.05	0.05
Nickel ND		0.02	0.02
Zinc 0.	056	0.025	0.025

3) *"The Mississi ppi Lignite Min ing Comp any sha ll ma intain records listin g t he l ocations and quantity of ash applied to those locations."*

MLMC keeps records of the volumes of ash used for each project by documenting the number of loads of ash hauled to the mine for each project. Locations of ash are documented by surveying each location and preparing an annual map of these locations.

4) *"A b eneficial u se su mmary repo rt in cluding th e lo cations, quantity, a nd description of th e observed performance of the material shall be provided to the Department by July 1 of each year of th e p roject life. Th e Depa rtment ma y co nsider a req uest to red uce th e freq uency o f su ch reporting upon the collection of appropriate historical data."*

In accordance with MDEQ's reporting requirement, MLMC submits an annual Beneficial Ash Use Report for Mississippi Lignite Mining Company's Red Hills Mine that describes where ash was used and the results observed, provides the yearly analytical characterization (required by condition 5), and proposes further beneficial application projects for the upcoming year. MDEQ reviews these reports (one to date) and responds accordingly.

5) *"A yea rly analytica l ch aracterization of the co al comb ustion ash w hich shou ld in clude t otal metals, % moisture, sieve size analysis, and pH should be conducte d and submitted to t he Department by Jul y 1 of e ach ye ar and may be c oordinated w ith ot her a nalytical t esting by Tractabel Power, Inc. and other users of the ash. Please be advised that should the results of the total metals analysis approach or exceed twenty (20) times the TCLP characteristics limit for any particular p arameter, a TC LP an alysis w ill need t o be co nducted for t hat pa rticular parameter. Should col lection of a dequate hi storical dat a i ndicate t hat t he chara cteristics of t he coal combustion as h are c onsistent a nd t hat c ontinued use w ould be of l ow haz ard, t he D epartment may consider a request to decrease the frequency of sampling."*

MDEQ further stated that approved used of ash was *"not considered to be an endorsement of those uses or that material nor an absolution of liability should problems arise and should not be construed as such"*. MDEQ retained the authority to modify, terminate or rescind any approval of beneficial use activity.

In addition to these conditions and specific ash monitoring requirements, surface coal mining regulations require various other monitoring requirements as a normal part of mine operation including life-of-mine surface and ground water monitoring, SPGM soil monitoring, and vegetation monitoring on reclaimed lands. These monitoring activities have been conducted before and during mine development and establish pre ash-use baseline parameters from which post ash-use parameters can be compared. Surface coal mining regulations also require an operator to post a performance bond with the regulatory agency to ensure compliance with regulations and adherence to all plans in the operator's approved surface mining permit. Red Hills Mine currently is bonded for approximately $19,500,000, which can be adjusted to reflect additional or reduced operational liability over the life of the mine.

The basic proposal and approval criteria used by MLMC and MDEQ are that the use must be beneficial and serve to replace or conserve some other natural resource. Initially, the focus was conserving natural limestone, but many other conservation and non-conservation factors are being considered as experience with beneficial ash use advances. These factors include increased mine safety, higher productivity and efficiency, reduced diesel fuel use and emissions, and lower steel usage for repairs of damaged equipment components.

Methods of Application and Results Observed

Ash is delivered to the mine via an ash haul road constructed between the mine and power plant. This road allows the ash to be delivered directly to the mine, eliminating the need to operate trucks on public roads and highways as

required by MLMC's initial proposal. Forty-ton haul trucks deliver hydrated ash to the desired mine location. Initially, MLMC attempted to incorporate or disc ash into existing roadway surfaces with little if any improvement being observed. However, MLMC discovered that placing a 4-foot base layer of 100% ash resulted in a competent and durable road with sufficient bearing capacity for all mining equipment, including machinery having the highest applied ground pressures (i.e. up to 115 psi). Ash is dumped and spread with a dozer, graded with a motor grader and compacted with a smooth steel drum vibratory roller compactor. Heavy equipment traffic is kept off of newly constructed road base for several days allowing the hydrated ash to set and cure. Interestingly, MLMC tried to lay ash in small 1 foot lifts and compact each lift individually to form a more compacted 4 foot platform but found that this only complicated the construction process and provided no performance benefit.

Ash has also been found to be superior to soils available on the mine site for culvert bedding and backfill material. Traditional culvert installations typically require laborers to work in a backhoe trench between the culvert and trench wall within the operating radius of a backhoe. Employees slowly level and mechanically pack layers of dirt deposited by the backhoe up the sides and over the top of the culvert. For large and long culvert installation this process can take several days. At Red Hills Mine, even the best installed culverts have been crushed or badly compressed over time. MLMC has found that a backhoe can be used to backfill and lightly tamp hydrated ash (using the heel of the bucket) into a culvert trench, let the ash set for several days and complete the installation with ash or clay. These ash installations are fast and require no employee exposure to potential safety hazards associated with traditional installation methods. Culverts installed in ash backfill have shown no signs of failure to date.

Ash has not yet been used to construct dragline walkways, as improving the haul road network has been a higher priority.

Since beneficial ash use was approved, MLMC has used 88,678 tons of ash to construct 2.9 miles of primary haul roads and 0.7 miles of pit ramps, install several culverts, and place an ash base over a large equipment parking area. Thousands of loads of lignite, overburden, and ash have been hauled over these roads, ramps, and culvert installations (Figures 4, 5 and 6). Wet or dry, the ash roads and culvert installations do not exhibit compression failures and remain firm and compacted. With MDEQ's approval, an additional 806,000 dry ash tons will be used to complete haul roads and pit ramps and to construct dragline walkways and equipment spoil trails.

To date, using RHGF ash to construct base layers for operation of heavy equipment has allowed MLMC to reduce by 52,000 tons the amount of mechanically mined and crushed limestone used – limestone that would have been hauled 170 miles (one-way) over Mississippi State Highways by 8000 diesel powered trucks to cover 64,000 square feet of engineering fabric at a cost of $1,090,000. Data collected on the ash, the leachate tests, column tests, and storm water runoff indicate that use of the RHGF ash as applied at Red Hills Mine is beneficial and does not pose adverse environmental impacts.

Modern large scale mining equipment is designed to operate at peak efficiency on running surfaces capable of consistently supporting the weight, speed, and payloads of the equipment. Poor running surfaces causes vehicle engines and drive trains to work harder resulting in higher fuel consumption and greater wear of all mechanical and structural components. MLMC uses approximately 4.8 million gallons of diesel fuel per year to uncover and deliver lignite to the power plant. Trucks hauling over soft and rutted roads and other diesel powered equipment needed to maintain these roads will consume an estimated 10% more fuel (400,000 gallons/year) than those running on hard roads that require little or no maintenance. At the current diesel fuel price of $1.38/gal, this translates into a savings of $662,400 per/year. Also, as roads improve, productivity improves, which allows trucks to run fewer hours to meet production requirements.

In addition to the natural resource conservation and cost benefits, the use of ash constructed roads has improved safety in several ways, especially during the rainy winter months. First, when wet, ash roads are not quite as slippery and are easier to maintain and dry faster than clay roads. Second, ash running surfaces reduce the amount of mud that must be graded or dozed to the sides so road width can remain constant eliminating equipment crowding. Third, ash base on roads requires less maintenance and reduces the time that road graders and haul trucks are both present on the same haul road. One negative is that during the dry and warmer summer months, ash roads have required more frequent water spraying to control dust than clay surface roads. Dust suppressants applied to roads may provide enhanced dust control during dry periods and further reduce slippery conditions during wetter periods.

Environmentally, erosion and sediment transfer from ash constructed roads is much less than that from clay constructed roads. The continual rutting and removal of clay mud during and following rain events and the re-spreading and drying of the same material during dry periods causes much more material to be transferred to road ditches and ultimately sediment control structures during heavy precipitation events. Ash roads and back slopes are competent and resistant to erosion. Rills and small gullies often observed in clay road back slopes are non-existent in ash road back slopes.

Figure 4. Loaded haul truck coming up pit ramp constructed of ash.

Figure 5. Haul truck fleet parking area constructed with ash.

Figure 6. Sixty-six inch culvert bedded in and backfilled with ash.

Summary

The use of RHGF ash as a replacement alternative to using natural limestone to construct various equipment platforms at Red Hill Mine has proven to be an economical and beneficial use of this coal combustion product. The use of ash as a mine road construction material also allows secondary roads and trails that could not economically be surfaced with limestone to be improved significantly. Secondary benefits in the form of increased productivity, lower operational costs, reduced diesel fuel consumption and emissions, and enhanced operator and equipment safety have resulted from the use of ash. The beneficial use of ash at the mine also aids the RHGF by reducing the amount of ash to be disposed of, reducing the land area needed for future disposal and the associated construction costs of future ash disposal facilities.

The properties of RHGF ash combined with appropriate handling and application methods allow this material to be used with little if any environmental risk. Monitoring programs and bonding requirements provide for the long-term assurance that the beneficial use of this product will be carefully evaluated as its use continues.

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George M. Hawkey is the Environmental Manager of the Mississippi Lignite Mining Company, an affiliate of the North American Coal Corporation. His 24 years of service with North American Coal have included environmental and operational positions with: the Falkirk Mining Company; and Coteau Properties Company in North Dakota; The Sabine Mining Company in Texas; the Red River Mining Company in Louisiana; and more recently, the Mississippi Lignite Mining Company. His work in surface mine and environmental permitting and post-mine land use planning and reclamation oversight, has received various Excellence in Surface Mining Awards from the Office of Surface Mining. He holds a B.S. degree in Wildlife Conservation and Management from the University of Wyoming.

Marcelo P. Merino is a Senior Staff Engineer with the North American Coal Corporation. Marcelo has over 30 years of experience, 24 with North American coal, in the areas of hydrology, environmental engineering and project management. He holds a Bachelor of Science in Civil Engineering from the University of Iowa, a Master of Science in hydraulic engineering and hydrology from the University of Iowa and a Master of Science in water resources engineering from Princeton University. Prior to his engagement with North American Coal, he was a professor of Engineering at the Catholic University in Quito, Ecuador. Marcelo also has worked for the South Florida Management District in West Palm Beach, Florida, and Phillips Coal Company in Dallas, Texas. Marcelo has worked on the design of ash disposal facilities and strategies for lignite mines in Texas, North Dakota, and Mississippi. Marcelo has worked in ash characterization protocols and beneficial use of ash, particularly in geotechnical applications. His experience in the ash use and disposal include assessment of impacts and development of protective measures for the surface and underground water system. He was personally involved in the development of data and documents used in support of the request to MDEQ for authorization of the beneficial use of ash described in this paper.

USE OF A CCP GROUT TO REDUCE THE FORMATION OF ACID MINE DRAINAGE: AN UPDATE ON THE WINDING RIDGE PROJECT

Robin L. Guynn[1], Leonard G. Rafalko[1], Paul Petzrick[2]
[1]Environmental Resources Management, Inc.
Annapolis, Maryland
[2]Maryland Department of Natural Resources
Power Plant Research Program
Annapolis, Maryland

Abstract

In 1995, the Maryland Department of Natural Resources Power Plant Research Program (PPRP) and the Maryland Department of the Environment (MDE) initiated the Western Maryland CCP/AMD Initiative. The Initiative is a joint effort with private industry to demonstrate the beneficial application of CCPs to create flowable grouts to abate AMD. The Initiative started with the Winding Ridge Project in 1996 with the injection of 5,600 cubic yards (4,280 m^3) of CCP grout into a small, abandoned, deep coal mine in Garrett County, MD. Post-injection monitoring has continued since that time and included analysis of mine discharge water quality and grout core strength and permeability. This paper presents an update of more than eight years of post-injection monitoring, including water quality and grout core retrieval from the mine.

The results of post-injection monitoring indicate that placement of CCP grout into the mine has improved the quality of mine discharge. Concentrations of iron, sulfate, aluminum, manganese, zinc, cobalt, copper, nickel, and acidity in mine discharge have decreased below pre-injection concentrations. The pH of mine discharge has increased by one pH unit, and the estimated rate of acid production in the mine has decreased by approximately 80%.

Grout cores were collected in 1997 and 2004: one and seven years after injection. Testing of the cores has shown that, in general, the grout has maintained high strength and low permeability in the mine tunnels.
Key words: beneficial use, grout, acid mine drainage, Winding Ridge Project

Introduction

The Maryland Department of Natural Resources Power Plant Research Program (PPRP) and the Maryland Department of the Environment Bureau of Mines (BOM) have undertaken the Western Maryland Coal Combustion Products (CCPs)/Acid Mine Drainage (AMD) Initiative. The Initiative is a joint effort with private industry to demonstrate the beneficial application of CCPs to create flowable grouts for placement in underground coal mines to reduce acid formation. The Initiative is a key component of Maryland's overall ash utilization program to promote and expand the beneficial use of all CCPs on a massive scale. Ultimately, the Initiative is targeting significant acid reduction at large AMD sources in Maryland, such as the Kempton Mine Complex, which is Maryland's largest source of AMD, and mitigation of subsidence problems associated with both disturbed lands and natural karst topography.

The Initiative is a multi-year project that started in April 1995 with the Winding Ridge Project. This project involved the injection of a 100% CCP-based grout into the Frazee Mine, which is a small 10 acre (40,500 m^2), underground coal mine in Garrett County, Maryland (Figure 1). In 1999, the authors reported on the means and methods of the grout injection phase of the project, and presented post-injection water quality data for the first year following injection[1]. In 2001, the authors presented an update on post-injection water quality monitoring including three years of post-injection water quality data[2]. Since that time, additional water quality data has been collected and monitoring is ongoing. As a result, an extensive database has been generated, including a total of eight years of post-injection water quality data. The purpose of this paper is to present the key findings to date regarding post-injection monitoring of grout stability and mine discharge water quality.

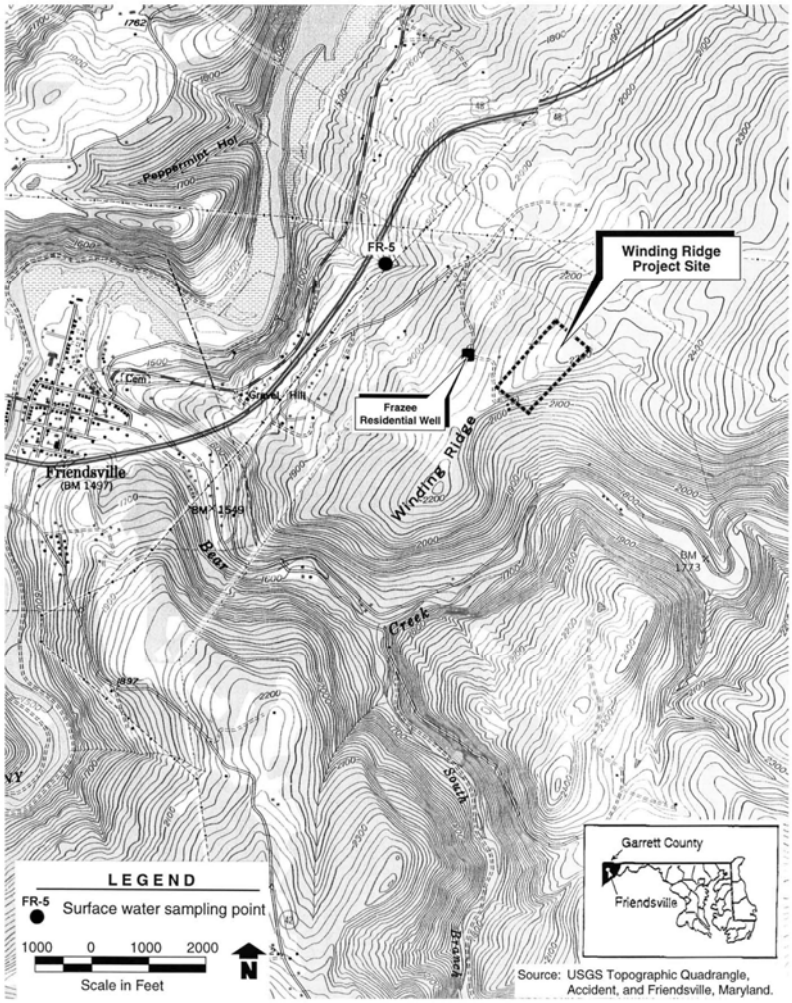
Setting

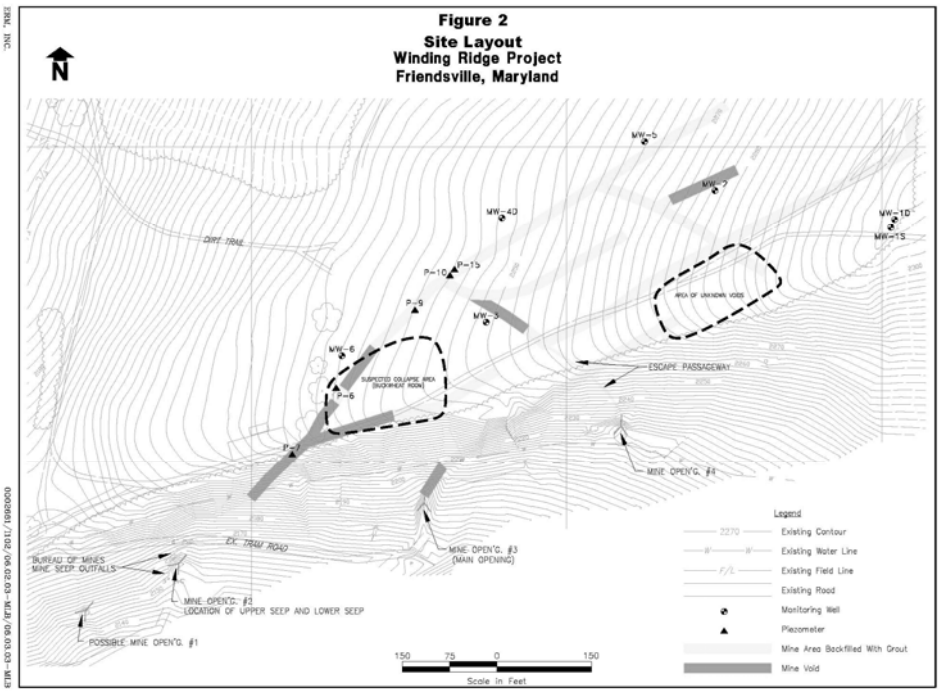
The Frazee Mine is located atop of Winding Ridge in Garrett County, Maryland (Figure 1). The mine is a small, hand-dug, abandoned, underground coal mine that was used to mine coal from the Upper Freeport seam from the 1930s to circa 1960. The sulfur content measured in Upper Freeport coal samples from the project site ranged from 1.0% to 3.5%. Acid-base accounting performed on overburden samples indicates that a small, 6 -18 inch (15 to 46 cm)-thick, rider coal seam above the Frazee Mine is the only other potential source of acid producing rock besides the Upper Freeport. Total sulfur content of the rider coal seam is about 1.5% to 4.5%.

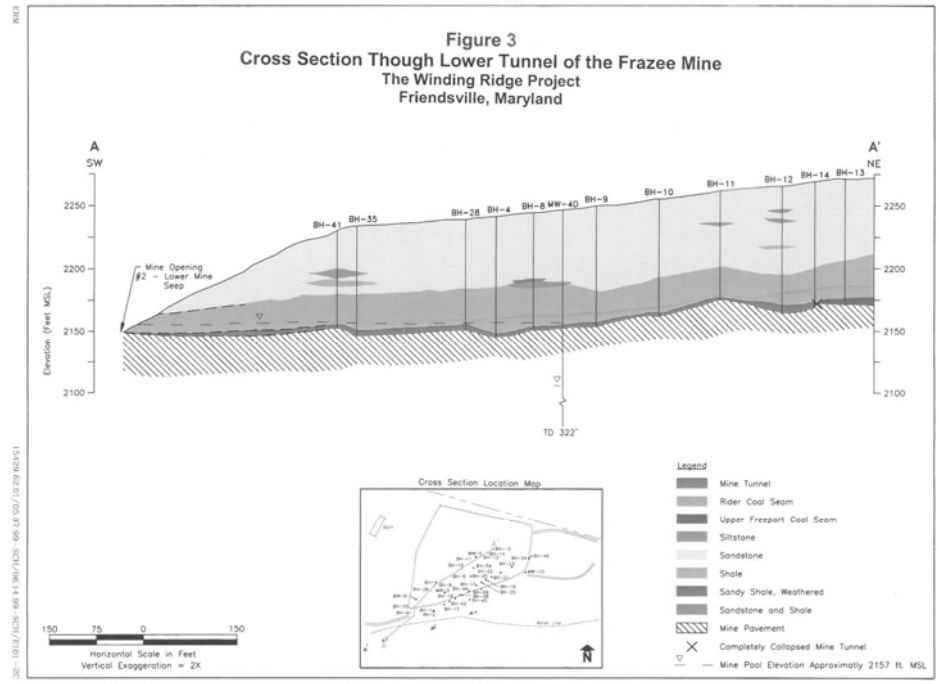
Investigative drilling at the site indicated that the mine consists of two main tunnels, a lower and an upper tunnel, connected by an unknown number of crosscuts (Figure 2). Downhole camera investigations of the mine indicated that the mine was in poor condition, the tunnels were poorly timbered and a number of roof falls and collapses were evident.

Ground water monitoring wells installed at upgradient and downgradient locations showed that the Frazee Mine occurs in unsaturated bedrock, and that the regional ground water table is approximately 50 feet (15 m) below the mine pavement. The cross section shown in Figure 3 shows the lithology of the Winding Ridge area and the relative elevations of the mine tunnel and mine pool.

Figure 1
Winding Ridge Site Location Map







Infiltrating precipitation impounded within the Frazee Mine created a pre-injection mine pool of at least 550,000 gallons (2,000,000 liters). This mine pool resided in the lower tunnel, while the upper tunnel was predominantly dry. Although there are four known mine entries, the only mine discharge is from Mine Opening No. 2 (MO2). At MO2, discharge occurs from a lower and upper seep. The elevation of the lower seep is about 9 feet (3 meters) below the mine pool elevation, and flow is continuous at about 2 gallons per minute (gpm) (0.12 l/s). Flow from the upper seep is intermittent and dependant upon the mine pool elevation. When the mine pool elevation is above the

upper mine seep, flow occurs generally at about 3 to 5 gpm (0.19 to 0.32 l/s), although flash events of 20 to 30 gpm (1.3 to 1.9 l/s) have been recorded after rainfalls. Otherwise, the upper seep is dry.

The pre-injection water quality from MO2 was typical of AMD-quality water with an average pH of 2.8 and average total acidity of 1,300 mg/L. The average sulfate, iron, aluminum, and total dissolved solids concentrations were 1,300 mg/l, 190 mg/l, 69 mg/l, and 2,100 mg/l, respectively.

Grout Formulation and Injection

The CCPs used for the Project were: fluidized bed combustion (FBC) by-product (commingled bed ash and fly ash), from the Morgantown Energy Associates power plant; Class F fly ash, from the Virginia Power Company's Mt. Storm power plant; and flue gas desulfurization (FGD) by-product, also from the Mt. Storm power plant. The FBC provided the free lime, the fly ash provided pozzolan, and the FGD by-product (mostly calcium sulfite and calcium sulfate with no free lime) was used as a bulking agent.

The mix design consisted of 60% fresh (defined as less than 24 hours old) FBC ash, 20% FGD product, 20% fly ash, and virtually 100% mine water. The FBC was conditioned at the plant to contain about 15% moisture, which resulted in about 3% to 5% free lime content. The final grout moisture content was about 57% on a dry weight basis, and contained about 2% to 3% free lime. Grout samples collected during injection showed a spread of about 8 inches (20 cm), and a 28-day unconfined compressive strength of about 550 pounds per square inch (psi) (3.8 MPa).

Full-scale injection began on 7 October 1996 and ended on 8 November 1996. Approximately 5,600 yd^3 (4,280 m^3) of grout were injected into the Frazee Mine. The grout consisted of 3,800 tons (3,400 metric tons) of FBC ash, and 1,200 tons (1,100 metric tons) each of fly ash and FGD by-product. The project used 520,000 gallons (1,970,000 L) of water, consisting of 449,000 gallons (1,700,000 L) of untreated mine water (pH of about 3) and 71,000 gallons (270,000 L) of river water. The river water was used at the end of injection when grouting precluded any further withdrawal of mine water.

Post-Injection Monitoring Results

In-Situ Grout Sampling Results

Two sets of in-situ grout cores have been collected from Winding Ridge. The first set was collected in September 1997, approximately 1 year after grout injection. These coreholes targeted both wet and dry areas of the mine. Nine coreholes were drilled, grout was encountered in five coreholes, and samples from four coreholes were submitted for laboratory testing. Mine tunnel piezometers were constructed within four of the coreholes in order to monitor the presence and water quality of water within the mine tunnels.

The second set of grout samples was collected in July 2004, approximately 8 years after grout injection. These coreholes were located near the mine tunnel piezometers that were constructed in the 1997 coreholes. Three coreholes were drilled, grout was encountered in two coreholes. One sample was submitted for laboratory testing. The results of laboratory testing for all grout samples are shown in Table 1.

Table 1 Results of Grout Core Analyses
Winding Ridge Site, Friendsville, Maryland

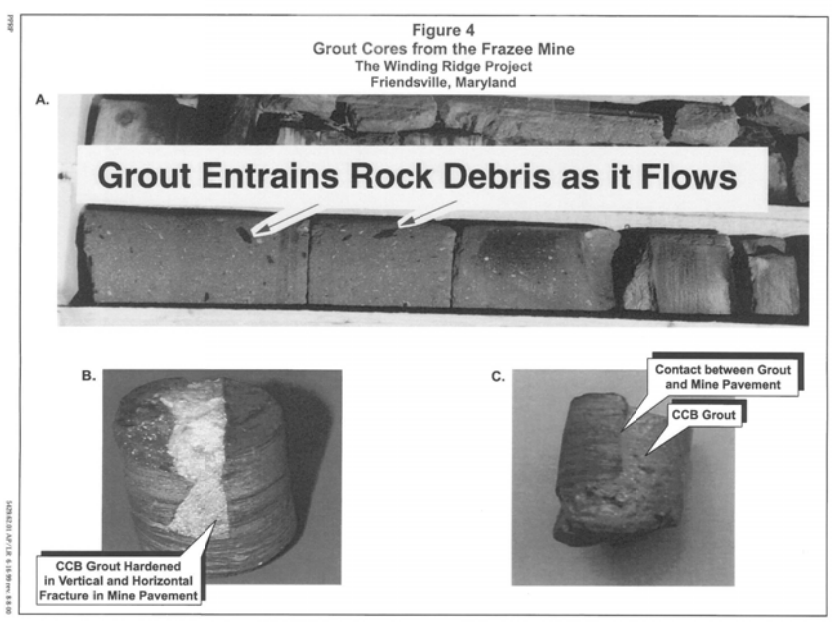
Parameter	Location/ Sample ID	Injection Samples	CH-3	P-1D		P-6		P-7	P-9
	Sample Label	28 - day samples	CH-3	CH-1	CH-3-04	CH-6	CH-1-04	CH-7	CH-9
	Year	1996	1997	1997	2004	1997	2004	1997	1997
	Sample Depth (ft)	na	71.7 - 72.8	84.3 - 85.7	85.5 - 87.3	83.2 - 84.4	85.0 - 86.5	70.0 - 70.5	85.0 - 87.1
Strength (psi)		245 - 850	1208 / 1128	560	773 / 844	1339	not suitable for testing	not suitable for testing	1417
Strength (Mpa)		1.69 - 5.86	8.33 / 7.78	3.86	5.33 / 5.82	9.23			9.77
Permeability (cm/sec)		---	2.58E-07	1.89E-06	9.18E-07 / 4.14E-07	1.29E-07	not suitable for testing	not suitable for testing	6.02E-08
Dry Density (pcf)		---	76.8	70.6	80.1 / 82.7	80.4	not suitable for testing	not suitable for testing	75.4
Dry Density (g/cm^3)		---	1.23	1.13	1.28/1.32	1.29			1.21

Notes:
Grout cores from P-7 in 1997 and P-6 in 2004 were too soft to be tested.
--- - sample not analyzed for this parameter
na - not applicable

In general, the grout cores were in very good shape and had little evidence of in situ weathering caused by the mine environment. The grout cores showed good contact with the mine roof and pavement and showed that the grout was able to entrain mine debris and to fill vertical and horizontal cracks in the mine pavement (Figure 4).

In the 1997 samples, the measured permeabilities ranged from 10^{-8} to 10^{-6} centimeters per second (cm/sec). The unconfined compressive strengths ranged from about 560 to 1400 psi (3.9 to 9.8 MPa). The 2004 sample had a measured permeability of about 10^{-7} cm/sec and a compressive strength of 800 psi (5.5 MPa).

Two grout cores have shown possible evidence of in-situ weathering or poor grout curing. The samples from P-7 (collected in 1997) and from P-6 (collected in 2004) were cohesive, but too soft for testing. Both of these sample locations are situated relatively close to MO2 and grout in these areas was injected in contact with water. Water has been present in the piezometers at these locations since they were constructed in 1997. These coreholes were also distant from the injection points and therefore the grout may have been excessively diluted by the mine pool prior to curing.



Post-Injection Mine Hydrology

AMD continues to flow from the mine from ungrouted areas. Post-injection water level measurements from the mine tunnel piezometers show that the mine pool elevation is essentially the same as its elevation prior to injection, indicating that grout injection has not created new sub-pools or raised the water level to the point that it is contacting the rider coal seam. The seep characteristics have changed little since injection. The horizontal location of the lower seep has shifted a few feet, requiring the placement of a new pipe to facilitate sample collection, however, the rate of flow has stayed constant at about 2 gpm (0.12 l/s). The discharge from the upper seep remains intermittent, and dependent upon the mine pool elevation. The upper seep has been dry during approximately 25% of the post-injection monitoring events.

Post-Injection Water Quality Results

Mine discharge from the seeps at MO2 and ground water within the mine tunnels (mine tunnel piezometers) and within the bedrock outside of the mine (monitoring wells) have been monitored regularly since injection for AMD-related parameters (i.e. pH, total acidity, iron, sulfate, and aluminum), other major ions (i.e. calcium, potassium, sodium, and chloride), and for trace elements such as arsenic, copper, and chromium.

The lower seep is considered to be most representative of the long-term water quality conditions of the mine water in contact with the grout since its flow is continuous and independent of the mine pool elevation. In comparison, the upper seep is intermittent, and much more susceptible to water quality variation caused by repeated wetting and drying cycles of pyritic strata in the mine roof and ribs as the pool elevation fluctuates.

The mine tunnel piezometers were installed in 1997, approximately 1 year after injection, and water quality at these locations has been very similar to that observed at the lower seep. The monitoring wells were installed prior to injection, and water quality at these locations is essentially unchanged from pre-injection conditions.

AMD-Related Parameters and Other Major Ions

Table 2 summarizes the pre and post-injection water quality results for AMD-related parameters and other major ions for the lower and upper seeps at MO2, as well as the mine tunnel piezometers and ground water monitoring wells. The results show that there have been no significant increases (or decreases in the case of pH) in AMD-related parameters in the mine water discharging from the seeps. The results also show that there have been no adverse impacts to ground water quality.

At the lower seep, pH fluctuated within the historically observed range of values during and immediately after grout injection (Figure 5). Since injection, however, pH has exhibited a beneficially upward trend at the lower seep. Overall, the pH of water discharging from the lower seep has increased by about 1 pH unit above pre-injection conditions. Conversely, the upper seep has not shown any appreciable change in pH since injection. This observation is attributed to the recharge of hydrogen ions to the mine water as the mine pool rises and falls, exposing pyritic strata to wetting and drying cycles.

Figure 6 summarizes the loadings of AMD-related parameters (acidity, iron, aluminum, and sulfate) and calcium discharging from the lower seep over time. The results show a transient condition of mine water quality during the first year (November 1996 to September 1997) after grout injection. During this time period, the concentrations and loadings for AMD-related parameters increased significantly compared to pre-injection conditions. After that period, the concentrations and loadings gradually decreased to below pre-injection levels.

Table 2 - Summary of Water Quality Results
Winding Ridge Site, Friendsville, Maryland

L-2 Lower Seep Water Quality Data Summary

	Pre Injection	Injection	Post Injection							
Parameter	1/95 - 9/96	10/96 - 11/96	11/96 - 12/97	1/98 - 12/98	1/99 - 12/99	1/00 - 12/00	1/01 - 12/01	1/02 - 12/02	1/03 - 12/03	1/04 - 12/04
Flow Rate (l/s)	0.06 - 0.32	0.05 - 0.06	< 0.06 - 0.06	< 0.06 - 0.13	< 0.06 - 0.13	< 0.06 - 0.13	< 0.06 - 0.13	dry - 0.13	dry - 0.06	< 0.06 - 0.19
pH	2.50 - 3.04	2.50 - 3.01	2.68 - 3.37	3.07 - 3.32	2.92 - 3.45	3.18 - 3.44	3.16 - 3.46	3.10 - 3.36	3.16 - 3.55	3.06 - 3.38
Total Acidity (mg/l)	800 - 2361	1218 - 1910	204 - 2902	304 - 1002	379 - 1105	440 - 543	166 - 941	240 - 420	200 - 368	104 - 190
Major Ions (mg/l)										
Iron	35 - 329	152 - 320	42 - 323	6 - 130	34 - 76	24 - 78	7 - 65	23 - 64[5]	18 - 51	3 - 25
Calcium	< 1 - 68	3 - 242	3 - 490	70 - 352	159 - 251	117 - 199	48 - 182	115 - 186	19 - 127	49 - 76
Magnesium	13 - 97	45 - 64	21 - 69	23 - 49	25 - 34	20 - 55	11 - 38	19 - 31	14 - 28	10 - 18
Potassium	< 1 - 3	< 1 - 3	9 - 27	11 - 26	9 - 14		---	---	5 - 10	5 - 9
Sodium	< 1 - 3	1 - 5	4 - 22	5 - 15	5 - 11		---	---	4 - 8	2 - 3
Sulfate	140 - 1769	821 - 4201	496 - 5840	945 - 1478	870 - 1230	906 - 1111	136 - 1031	479 - 1200	628 - 1067	70 - 545
Chloride	ND - 37	< 1 - 2	ND - 27	ND - 13	2 - 5	3 - 4	---	< 1 - 4	3 - 5	2 - 4
Trace Elements (mg/l) [1]										
Aluminum	20 - 110	55 - 175	28 - 250	10 - 46	16 - 30	29 - 49	7 - 41	25 - 36	13 - 28	9 - 15
Cobalt	0.62 - 0.93[2]	0.76 - 0.89	0.46 - 2	0.35 - 0.45	0.31 - 0.41	---	0.29	---	---	0.18
Copper	0.02 - 0.32	0.29 - 1.76	0.08 - 2.01	0.03 - 0.11	0.03 - 0.09	---	---	---	ND	ND
Manganese	3 - 16	1 - 12	2 - 13	2 - 17	3 - 6	1 - 5	2 - 4	2 - 3	2 - 5	< 1 - 2
Nickel	< 1 - 2	2 - 3	1 - 5	0.2 - 1.18	0.07 - 0.88	---		---	0.61 - 0.80	0.16 - 0.39
Zinc	3 - 4	4 - 5	2 - 11	2 - 12	0.28 - 3	---	4	ND - 1	< 1 - 2	0.40 - 0.74

C-2 Upper Seep Water Quality Data Summary

	Pre Injection	Injection	Post Injection							
Parameter	1/95 - 9/96	10/96 - 11/96	11/96 - 12/97	1/98 - 12/98	1/99 - 12/99	1/00 - 12/00	1/01 - 12/01	1/02 - 12/02	1/03 - 12/03	1/04 - 12/04
Flow Rate (l/s)	dry - 1.7	< 0.06 - 0.19	dry - 1.32	dry - 1.14	dry	< 0.06 - 0.13	< 0.06 - 0.50	dry - 0.82	dry - 0.19	0.13 - 0.38
pH	2.80 - 3.45	2.50 - 3.20	2.84 - 3.30	3.22 - 3.34	---	3.10 - 3.22	3.16 - 3.5	3.15 - 3.30	3.13 - 3.41	3.18 - 3.42
Total Acidity (mg/l)	50 - 957	128 - 515	258 - 2519	167 - 169	---	387 - 495	160 - 307	114 - 217	104 - 141	80 - 112
Major Ions (mg/l)					---					
Iron	3 - 151	8 - 50	11 - 320	13 - 33	---	9 - 11	4 - 10	2 - 11	3 - 8	2 - 3
Calcium	1 - 36	31 - 520	7 - 354	112 - 227	---	95 - 126	48 - 123	47 - 110	51 - 80	44 - 67
Magnesium	3 - 47	12 - 22	19 - 76	14 - 26	---	16 - 21	10 - 44	10 - 21	7 - 17	8 - 12
Potassium	< 1 - 3	1.5 - 2	2 - 17	8 - 13	---	---	---	---	5 - 6	3 - 5
Sodium	< 1 - 3	< 1 - 1	< 1 - 12	4 - 6	---	---	---	---	2 - 3	2 - 3
Sulfate	87 - 761	209 - 2948	472 - 2609	500 - 997	---	556 - 699	119 - 555	280 - 559	192 - 437	141 - 327
Chloride	< 1 - 14[4]	1.50	1 - 18	3 - 6	---	2.7 - 3.0	---	5.9	2 - 4	< 1 - 3
Trace Elements (mg/l) [1]										
Aluminum	4 - 48	12 - 35	21 - 175	18 - 38	---	21 - 32	8 - 25	11 - 23	7 - 13	7 - 12
Cobalt	ND - 0.39[5]	0.08 - 1.1	0.29 - 1.1	0.18 - 0.36	---	---	---	---	0.10	0.08
Copper	ND - 0.24	0.03 - 0.04	0.08 - 1.1	0.08 - 0.12	---	---	---	---	ND	ND
Manganese	0.48 - 5.7	1.6 - 2.8	1 - 6	1.2 - 2.3	---	1.2 - 2.0	0.81 - 2.4	1 - 2	0.66 - 1.4	0.68 - 0.97
Nickel	0.08 - 1.78	0.23 - 0.24	0.02 - 3	0.38 - 0.75	---	---	---	---	0.21 - 0.33	0.17 - 0.24
Zinc	0.26 - 1.75	0.56 - 0.64	1 - 6	0.89 - 1.5	---	---	---	0.4 - 0.7	0.35 - 0.59	0.30 - 0.46

Mine Tunnel Piezometers Data Summary

	Pre Injection	Injection	Post Injection							
Parameter	1/95 - 9/96	10/96 - 11/96	11/96 - 12/97	1/98 - 12/98	1/99 - 12/99	1/00 - 12/00	1/01 - 12/01	1/02 - 12/02	1/03 - 12/03	1/04 - 12/04
pH	---	---	4.43 - 6.1	3.39 - 5.12	3.37 - 5.85	---	3.94 - 4.49	3.65 - 4.77	3.53 - 4.90	3.37 - 4.83
Total Acidity (mg/l)	---	---	128 - 376	90 - 439	15 - 898	---	186 - 498	---	40 - 191	65 - 222
Major Ions (mg/l)										
Iron	---	---	23 - 92	3 - 92	< 1 - 64	---	13 - 15	---	6 - 35	9 - 41
Calcium	---	---	183 - 489	5 - 350	2 - 258	---	117 - 166	---	41 - 183	45 - 144
Magnesium	---	---	17 - 48	15 - 122	2 - 45	---	11 - 21	---	5 - 16	9 - 23
Potassium	---	---	17 - 74	1 - 33	4 - 27	---	---	---	5 - 12	5 - 11
Sodium	---	---	9 - 20	< 1 - 18	1 - 23	---	---	---	2 - 13	2 - 4
Sulfate	---	---	620 - 1600	210 - 1329	66 - 1009	---	279 - 615	---	108 - 683	95 - 537
Chloride	---	---	8 - 19	ND - 15.2	3 - 99	---	---	---	2 - 3	2 - 4
Trace Elements (mg/l) [1]										
Aluminum	---	---	6 - 16	0.22 - 28	0.5 - 20	---	10 - 32	---	3 - 14	4 - 20
Cobalt	---	---	0.15 - 0.32	0.08 - 0.34	0.02 - 0.31	---	---	0.049 - 0.28	0.049 - 0.28	0.07 - 0.25
Copper	---	---	0.02	0.08	ND - 0.10	---	---	---	0.05	---
Manganese	---	---	2 - 4	0.95 - 8	0.3 - 5.0	---	1.1 - 2.6	---	0.59 - 2.0	0.59 - 2.0
Nickel	---	---	0.57 - 1.03	0.20 - 0.92	0.05 - 0.69	---	---	---	0.03 - 0.44	0.11 - 0.51
Zinc	---	---	0.73 - 3.0	0.30 - 1.5	0.14 - 1.2	---	---	---	0.19 - 0.78	0.28 - 1.15

Ground Water Monitoring Well Data Summary

	Pre Injection	Injection	Post Injection							
Parameter	1/95 - 9/96	10/96 - 11/96	11/96 - 12/97	1/98 - 12/98	1/99 - 12/99	1/00 - 12/00	1/01 - 12/01	1/02 - 12/02	1/03 - 12/03	1/04 - 12/04
pH	5.84 - 6.14	---	5.62 - 5.96	5.25 - 6.24	5.92 - 6.3	---	5.67 - 5.99	5.97 - 6.24	5.55 - 6.06	5.41 - 6.05
Total Acidity (mg/l)	6 - 43	---	6 - 34	2 - 15	ND - 78[6]	---	24 - 60	---	ND - 10	20 - 33
Major Ions (mg/l)		---								
Iron	3 - 18	---	5 - 8	2 - 8	4 - 45	---	2 - 3	---	2 - 9	7 - 9
Calcium	1 - 5	---	2 - 8	1 - 8	2 - 56	---	36812.00	---	1 - 2	1 - 3
Magnesium	4 - 10	---	10 - 18	3 - 23	4 - 52	---	2 - 6	---	1 - 2	3 - 5
Potassium	< 1 - 2	---	< 1 - 2	1 - 6	1 - 15	---	---	---	< 1 - 1	< 1 - 1
Sodium	< 1 - 2	---	7 - 11	< 1 - 3	1 - 14	---	---	---	< 1 - 1	< 1 - 2
Sulfate	1 - 33	---	12 - 27	7 - 25	6 - 266	---	5 - 12	---	12 - 17	6 - 15
Chloride	1 - 2	---	< 1 - 2	< 1 - 10	2 - 8	---	---	---	0.6 - 0.9	0.6 - 0.9
Trace Elements (mg/l) [1]										
Aluminum	0.10 - 0.55	---	ND - 1.21	ND - 0.37	ND	---	ND	---	ND - 0.36	ND
Cobalt	---	---	0.004 - 0.006	0.0034 - 0.01	0.0045 - 0.0093	---	---	0.005 - 0.0058	0.007 - 0.0075	ND
Copper	ND - 0.03	---	ND - 0.03	ND	0.03 - 0.04	---	---	---	ND	ND
Manganese	0.61 - 0.73	---	0.68 - 0.83	0.5 - 0.7	0.87 - 4	---	0.52 - 0.65	---	0.46 - 0.49	0.37 - 0.46
Nickel	ND - 0.09	---	ND - 0.12	ND	0.03 - 0.5	---	---	---	ND	ND
Zinc	ND - 0.96	---	ND - 0.08	ND - 0.08	0.03 - 0.8	---	---	---	ND	ND

Notes

--- - No samples analyzed for this parameter during this year.

ND - Not detected

[1] Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver, Thallium, and Vanadium were sporadically detected, in generally less than 25% of the mine discharge samples.

[2] Does not include anomalous result of 42 mg/l on 10/6/95

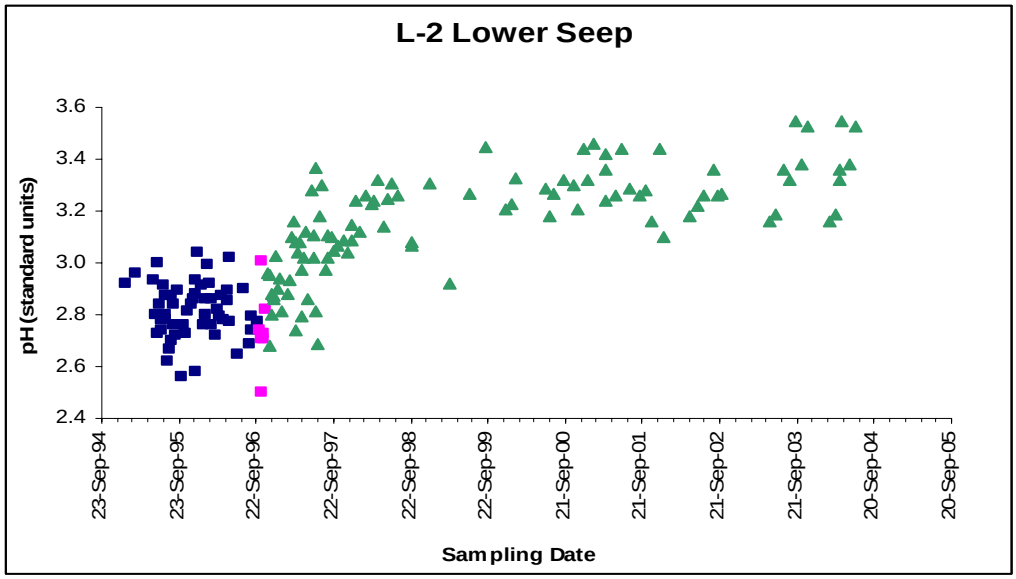
[4] Does not include anomalous result of 238 mg/l on 1/2/02

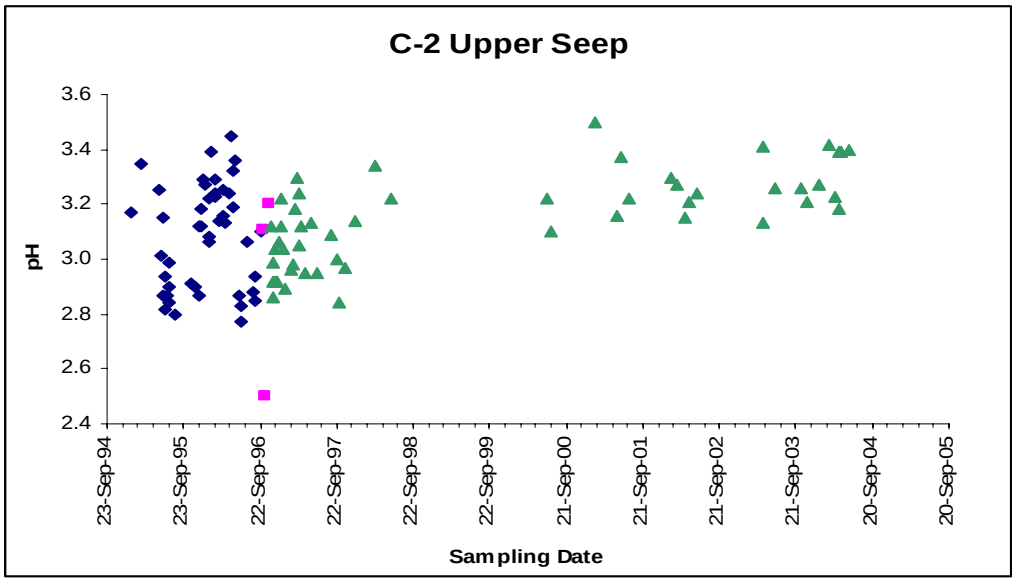
[4] Does not include anomalous result of 42 mg/l on 1/4/96

[5] Does not include anomalous result of 6.3 mg/l on 11/20/95

[6] Does not include anomalous result of 203 mg/l on 1/2/02

Figure 5
pH Results for Upper and Lower Seep at Mine Opening Number 2





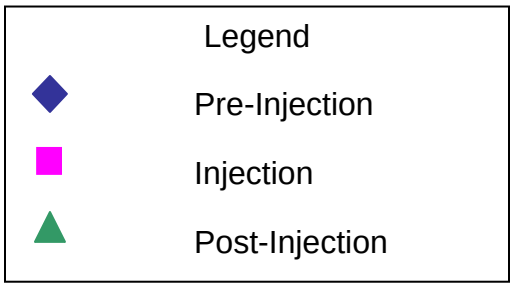
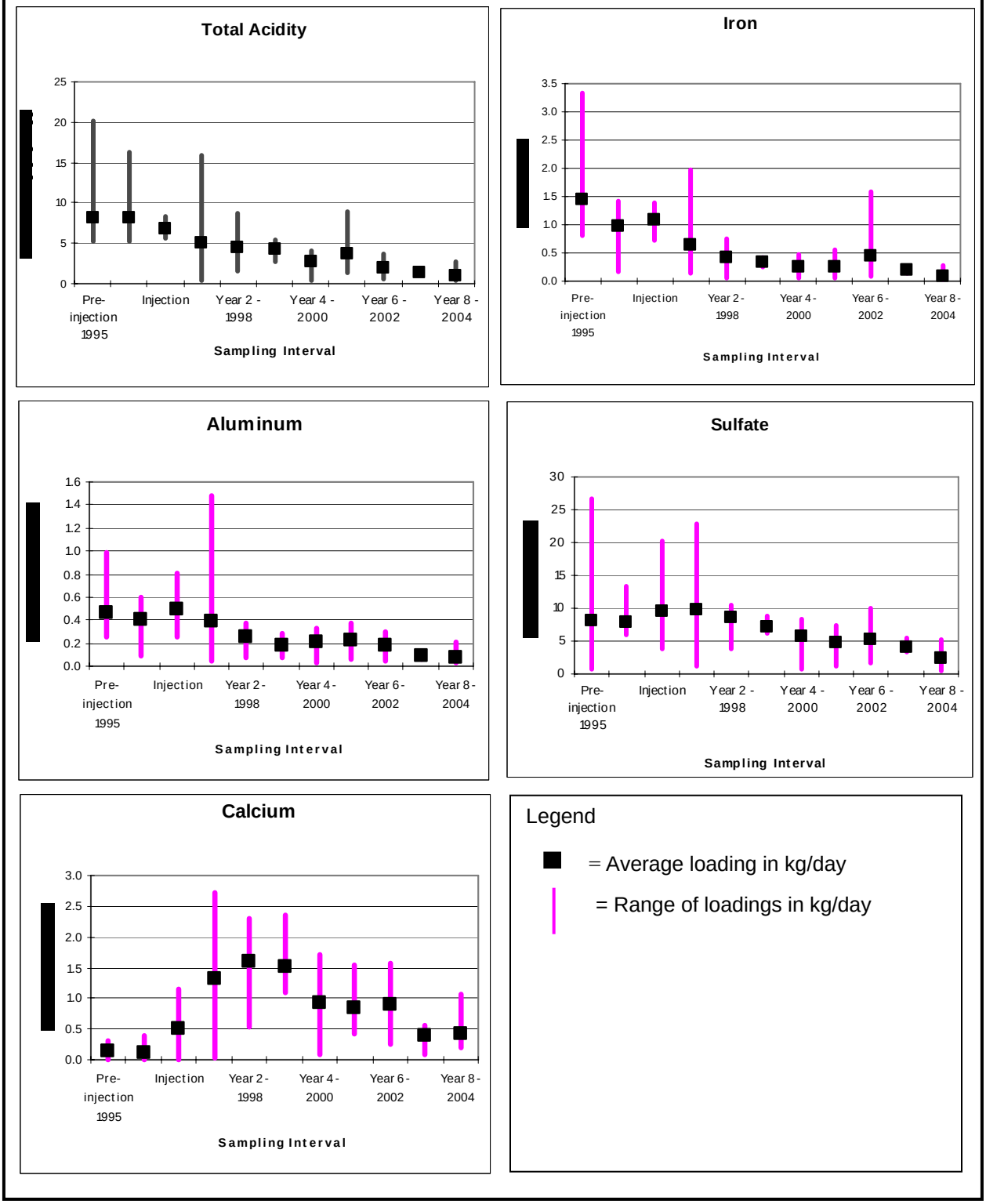


Figure 6
Loading Ranges and Averages for AMD Parameters and
Calcium for the Lower Seep at Mine Opening Number 2



The transient condition is probably due to a combination of factors. One contributing factor is that the grout injection phase could have indirectly caused an increase in acidity when the mine pool was lowered as a result of pumping mine water for grout mixing. The lowering of the mine pool would have exposed previously submerged mine areas to oxidizing conditions, which would have created acid weathering products available for mobilization once the mine pool rose to pre-injection levels. Another contributing factor could have been the re-routing of mine water through previously isolated mine workings. Nonetheless, the water quality data show that the transient condition was a relatively short occurrence.

Co-plotting pre and post-injection concentrations against mine discharge flow rates provided for further evaluation of the difference between the pre and post-injection water quality for AMD-related parameters. This method was selected to allow a direct comparison of pre and post-injection concentration data under normalized flow conditions. Accordingly, Figure 7 shows that the post-injection concentrations for total acidity, iron, and aluminum at the lower seep fall within or below the pre-injection concentrations. The results for the upper seep show some post-injection concentrations above pre-injection concentrations for similar flows. This is not considered significant as the upper seep has been dry for many monitoring events after grout injection, and is affected by repeated drying/wetting cycles of pyritic strata.

The post-injection loadings of calcium, potassium, sodium, and chloride remain elevated compared to pre-injection levels (Figure 6 and Figure 8). These are non-toxic elements, and the post-injection concentrations for each of these elements in the mine discharge (Table 2) fall well below their average concentrations in sea water. The post-injection concentration of calcium is less than half of that in sea water (which contains about 400 mg/l calcium). The post injection concentrations of potassium, sodium, and chloride are one or more orders of magnitude below those in sea water (which contains about 400 mg/l potassium, 10,000 mg/l sodium, and 19,000 mg/l chloride).

Calcium, potassium, sodium, and chloride are most likely dissolving from the grout into the mine water. Part of the increase in sulfate loading observed during the transition period may also have been due to dissolution of grout components. However, since the grout cores from the mine show that the grout is strong, intact, and competent, it is reasoned that dissolution is most likely localized to grout surfaces that are exposed to or in contact with acidic mine waters. In addition, though the levels of these major ions remain elevated relative to pre-grouting levels, their concentrations in the mine discharge have gradually decreased in the eight years since injection. This suggests that dissolution rates are slowing. A reduction in the dissolution rate could be due to the formation of a low-solubility surface layer on the grout surface. Such a layer could be formed by the rapid dissolution more soluble grout components from the grout surface, leaving a layer of less soluble grout components which acts as a sort of crust, preventing water from reaching the rest of the grout. Another contributing factor could be precipitation and coating by secondary minerals (i.e. iron and aluminum hydroxides) on the grout surface as the chemical conditions within the mine tunnel change.

Figure 7
Comparison of Pre-Injection and Post-Injection Results for Total Acidity, Iron, and Aluminum for the Lower Seep at Mine Opening 2

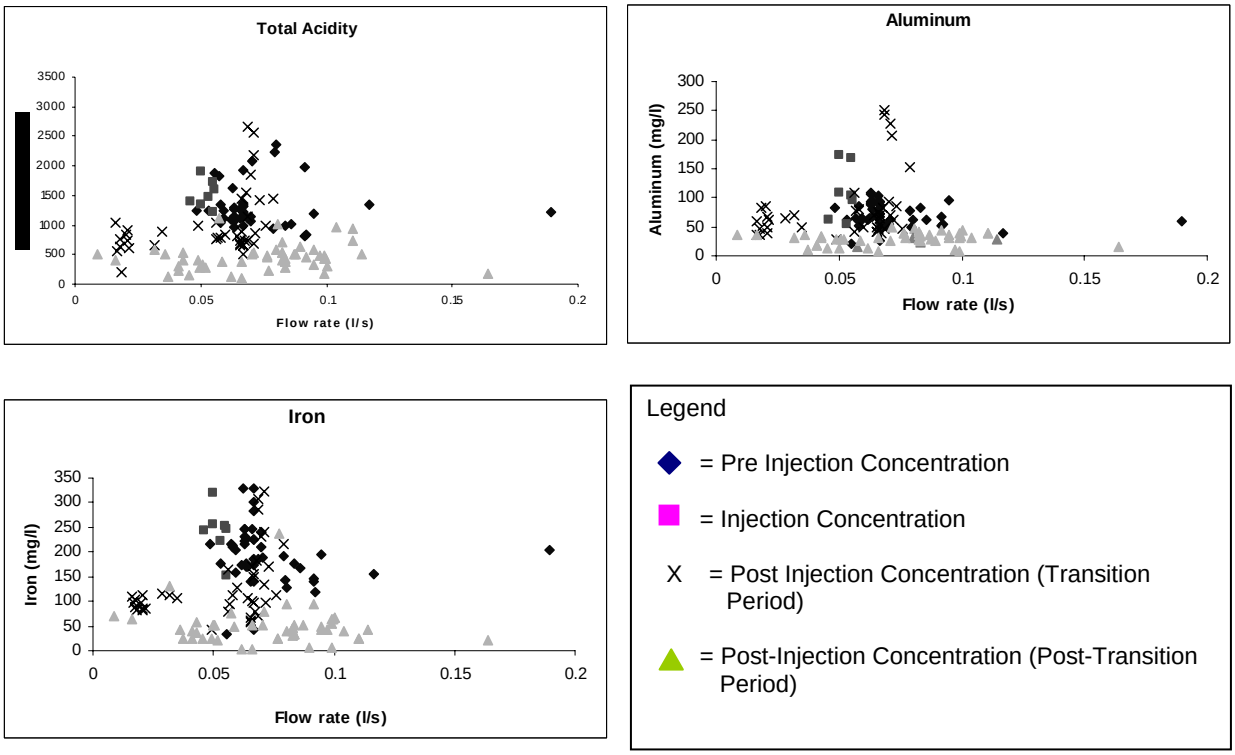
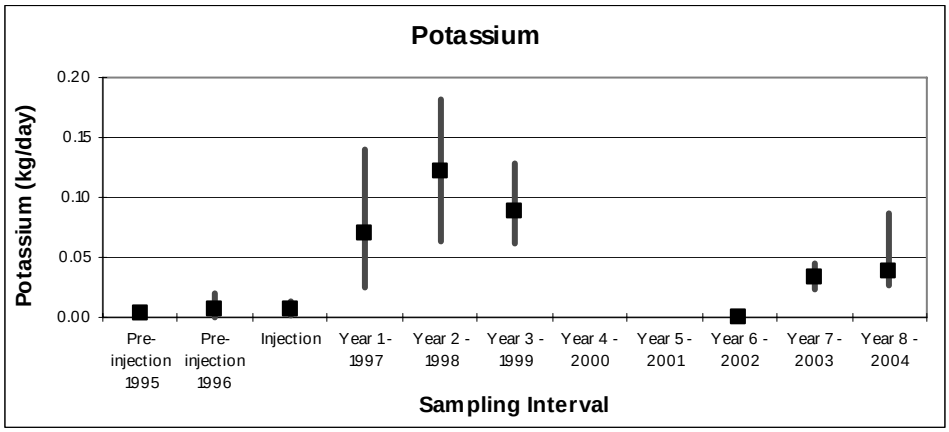
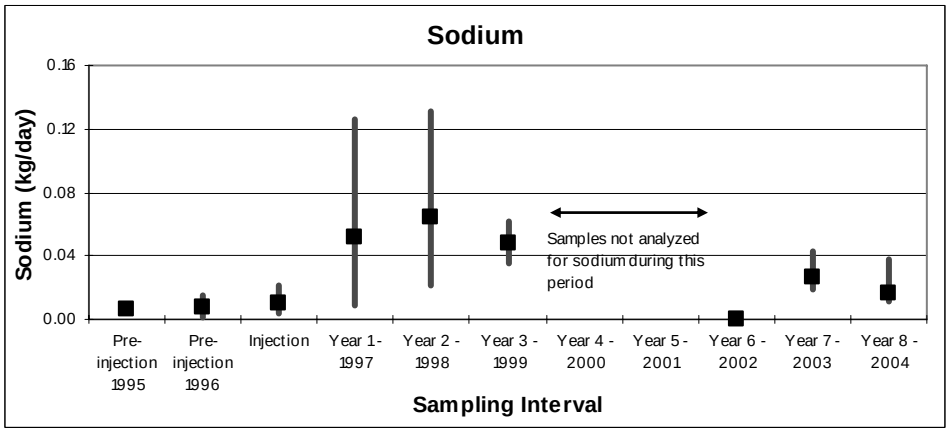
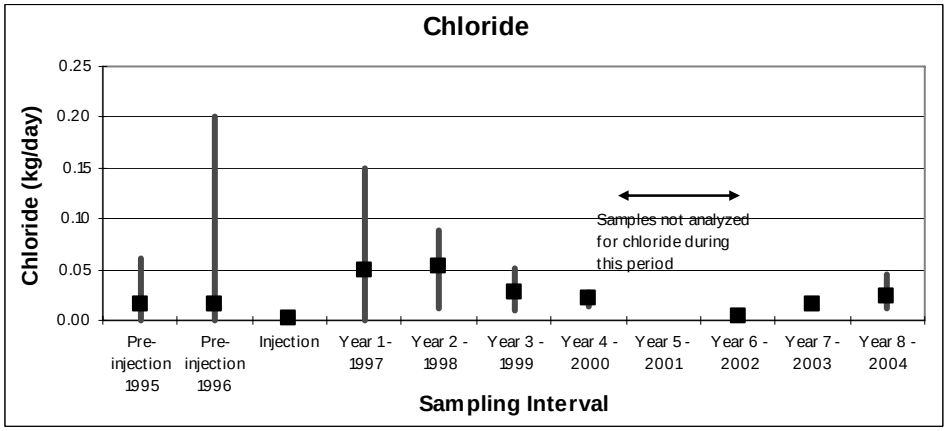


Figure 8
Loading Ranges of Potassium, Sodium, and Chloride for the
Lower Seep at Mine Opening 2







Legend

■ = Average loading in kg/day

| = Range in loading in kg/day

Trace Elements

Table 2 also summarizes the results of the trace element analyses for mine water samples collected from the lower and upper seeps at MO2, the mine tunnel piezometers, and the ground water monitoring wells. The only trace elements that were routinely detected during pre and post-injection monitoring were cobalt, copper, manganese, nickel, and zinc. The water quality data show that there have not been any significant increases in trace element concentrations in the discharge from the Frazee Mine and no trace elements have been detected in the mine discharge that were not present in the pre-injection samples. Similarly, the results from the ground water monitoring wells show that there have been no increases in trace element concentrations in the ground water since the grout injection.

Figure 9 summarizes the loading data for copper, cobalt, nickel, manganese, and zinc. As with the AMD-related parameters, the plots show a period of transition during the first year following grout injection. Since the second year after grout injection, however, the trace elements have consistently been detected at concentrations within or below those prior to injection.

The difference between the pre and post-injection water quality for the trace elements was evaluated in the same manner described above for the AMD-related parameters. Figure 10 was prepared by co-plotting pre and post-injection concentrations for copper, manganese and nickel (the results were similar for cobalt and zinc), against the mine discharge rate from MO2. For the lower seep, the analyses show that the post-injection concentrations for these trace metals all fall within or below their pre-injection concentrations. The results for the upper seep show some post-injection values above per-injection concentrations for similar flows. As mentioned earlier, this is not considered significant as the upper seep has been dry for many monitoring events after grout injection.

Ground Water

Ground water quality outside of the mine pool has been monitored at several ground water monitoring wells at the site. Essentially, there is no evidence of AMD at these monitoring locations, and grout injection has not altered this condition or introduced any new dissolved constituents at these monitoring locations.

Figure 9
Loading Ranges and Averages for Trace Metals
For the Lower Seep at Mine Opening 2

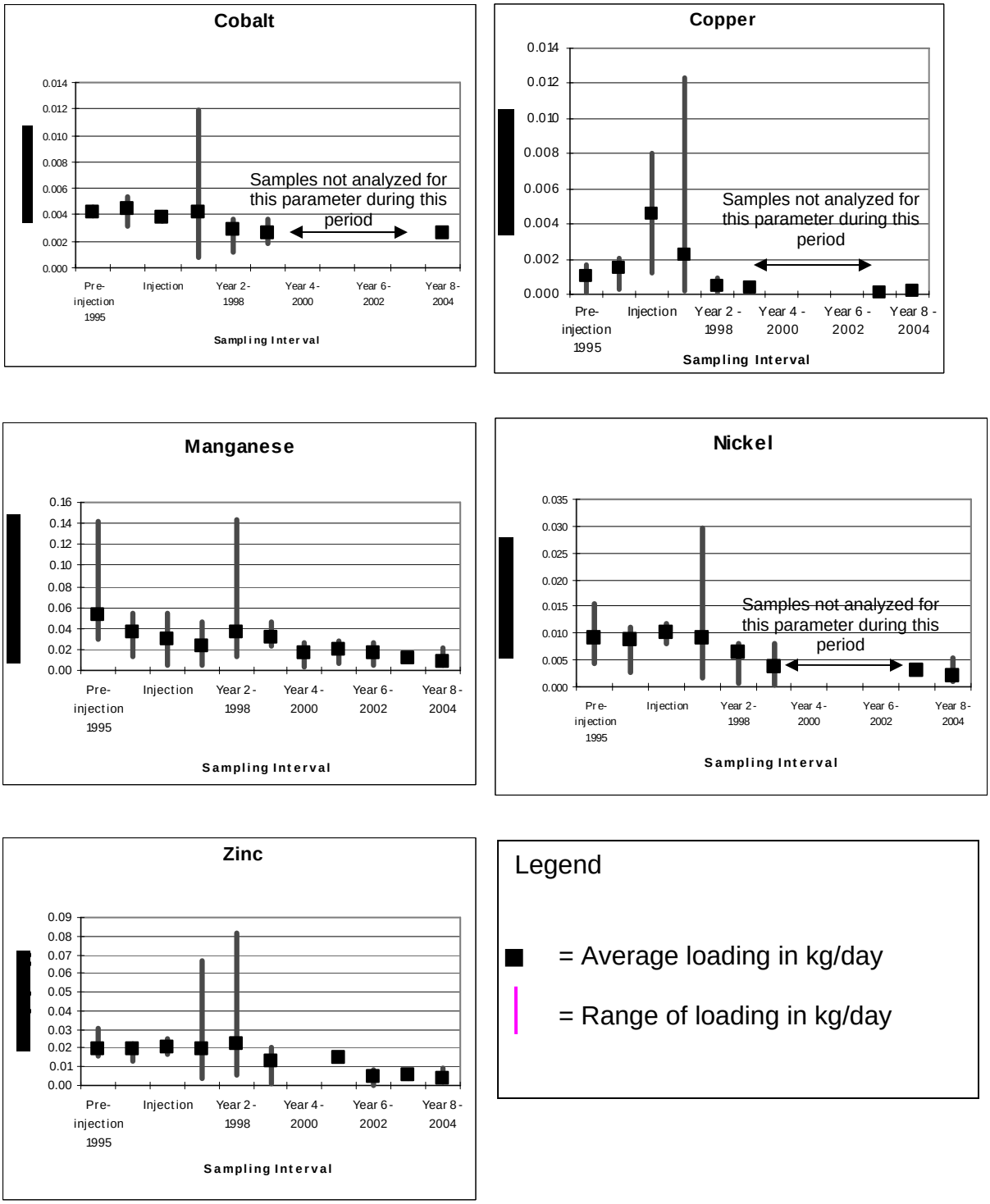
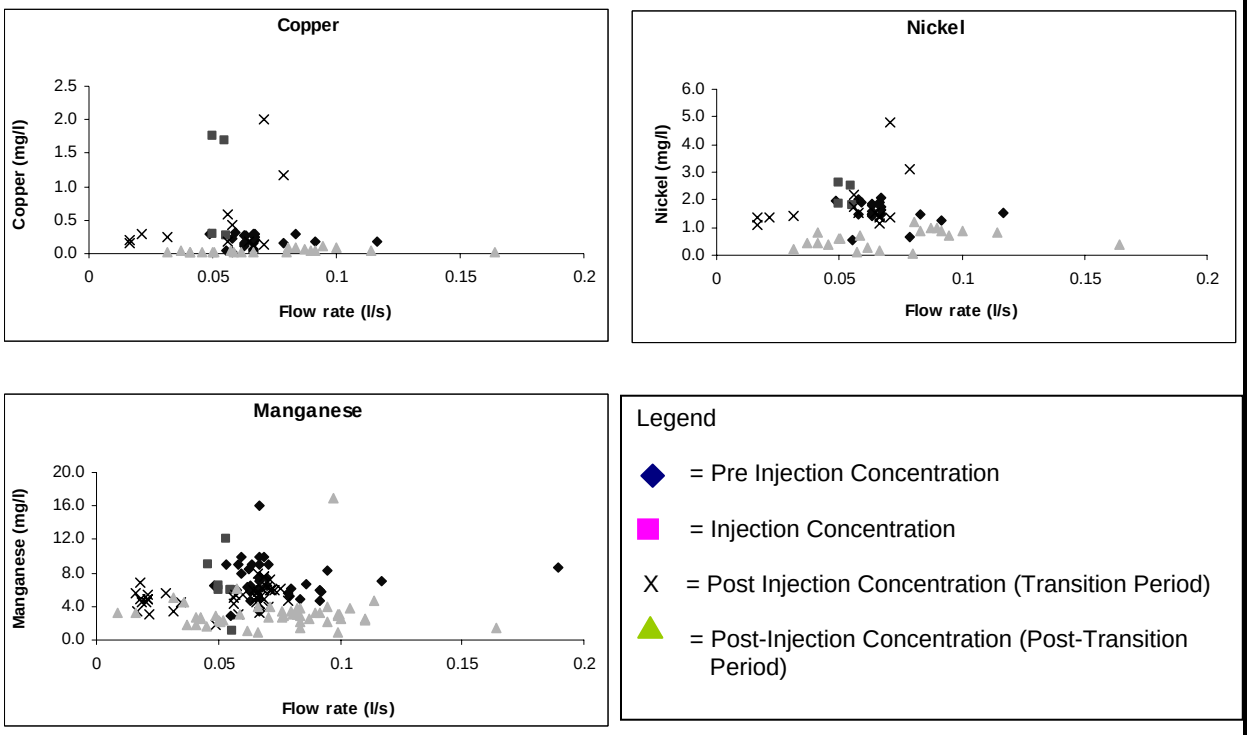


Figure 10
Comparison of Pre-Injection and Post-Injection Results for
Copper, Nickel, and Manganese at the Lower Seep at Mine Opening 2



Discussion

Mechanisms for Water Quality Change

The goal of the grout injection at the Winding Ridge site was to reduce the formation of AMD within the mine by covering and trapping pyritic mine debris and exposed mine walls with grout, thereby preventing the interactions between water, oxygen, and pyrite, which produce AMD. The changes in water quality observed during post injection monitoring (increased pH, decreased acidity, and decreased concentrations of AMD parameters and trace metals) are consistent with reduced AMD formation within the mine; however, other possible processes which could account for the changes are considered as follows.

Alkalinity Provided by Grout

One possible contributing process is dissolution of alkalinity-producing components (i.e. lime) from the grout. This process would raise the pH and decrease the acidity of the mine water, which in turn, would cause precipitation of iron and aluminum hydroxides. Trace metals may co-precipitate with metal hydroxides or adsorb to their surfaces, reducing their concentrations in solution as well.

In order to investigate this possibility, speciation and saturation index calculations were performed using the geochemical modeling program PHREEQC[4]. Saturation indices for amorphous iron and aluminum hydroxides at the upper seep are plotted in Figure 11 (while trace metals were included in the calculations, they are not present in high enough concentrations to form secondary minerals). The graphs show that the mine discharge was undersaturated with respect to these phases prior to injection and that status has not changed significantly during the

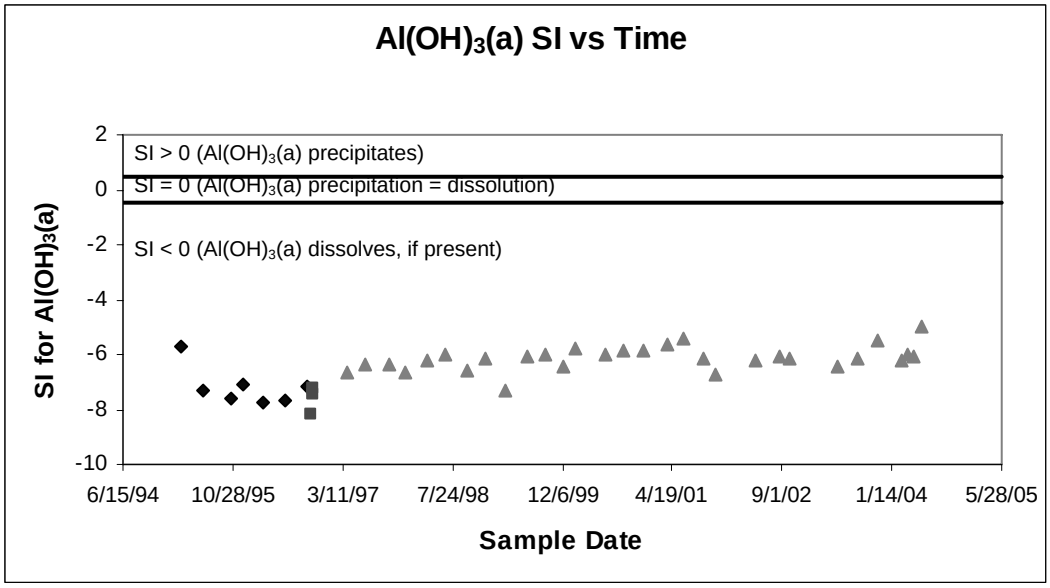
post-injection period. Although not shown in Figure 11, the same calculations were performed for samples collected from the upper seep and mine tunnel piezometers and the results show the same pattern. The calculations indicate that iron and aluminum hydroxides have not been precipitating from the mine water during any part of the study (pre- or post injection). Therefore, the decreasing concentrations of these parameters (and trace metals) observed since injection must be due either to adsorption of these elements to the grout surface or to a decreasing source of the elements (i.e. a reduction in the rate of acid production in the mine.)

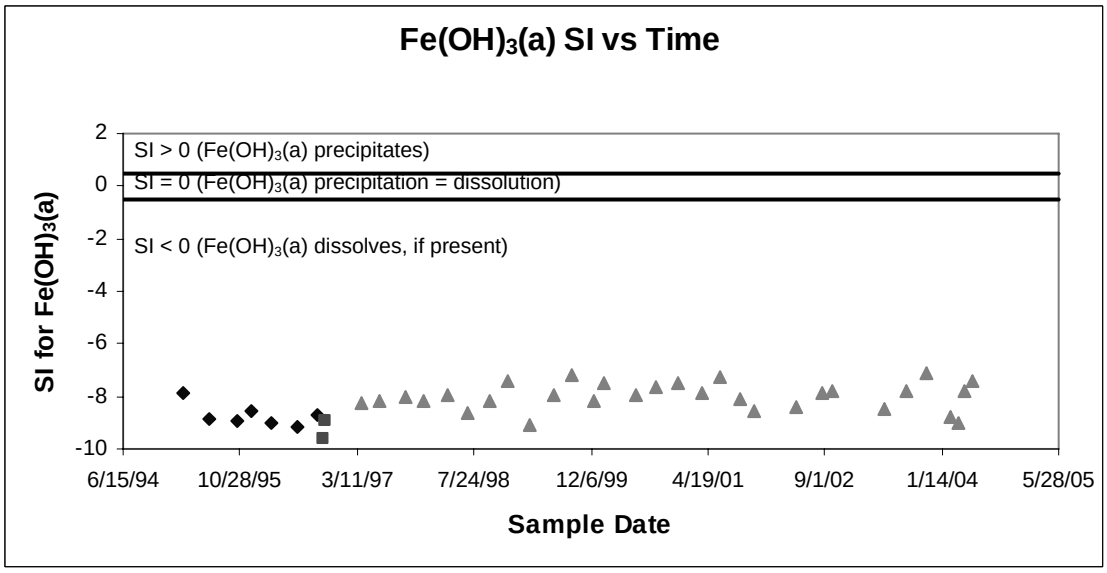
Sorption onto Grout

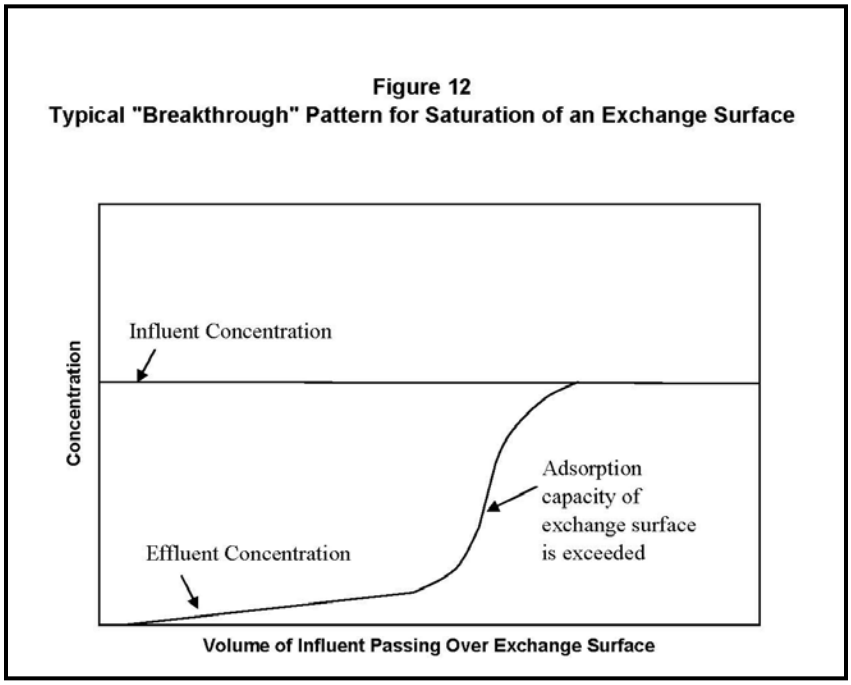
A second process that could explain the observed reductions in iron, aluminum, and trace metals in the mine discharge is adsorption of these constituents to the grout surface. In this scenario, metal cations adsorb to the predominantly negatively charged grout surface. Because iron and aluminum contribute to total acidity, removing them from solution could lower the acidity of the mine discharge somewhat and lead to some increase in pH. This process alone does not account for significant decreases in sulfate concentration in the mine discharge.

Figure 12 shows a typical curve for the concentrations of a sorbing dissolved parameter after the solution reacts with an exchange surface. An influent solution of constant composition (i.e. water flowing from the mine pool out to the MO2 discharge) interacts with an exchange surface having a finite number of exchange sites (i.e. the grout surface). The initial effluent solution would be expected to have very low concentrations of the sorbing constituents (i.e. iron, aluminum, and trace metals). Over time, as the influent solution continues to flow past and interact with the exchange surface, the exchange sites are filled and the concentration of sorbing constituents (iron, aluminum, and trace metals) in the effluent gradually increases. At some point, the exchange sites may be completely filled and the concentration of sorbing constituents in the effluent quickly rebounds to match the influent concentration (i.e. "breakthrough") because the exchange surface can no longer adsorb any more ions. The concentrations of iron, aluminum, and trace metals observed at Winding Ridge during the last eight years of post-injection monitoring do not match this pattern. Rather than a sharp initial decrease in iron, aluminum, and trace metal concentrations, the Winding Ridge seep samples show a steady gradual decrease in iron, aluminum, and trace metal concentrations, which has remained consistent since the second year of post-injection monitoring.

Figure 11
Saturation Indices for Amorphous Aluminum and Iron Hydroxides
For Lower Seep at Mine Opening 2







Even if the grout at Winding Ridge may not have been in place long enough for the exchange sites on the grout to reach saturation ("breakthrough"), the pattern of gradually decreasing concentrations of iron, aluminum, and trace metals, do not match the early part of the sorption curve either. Therefore, sorption processes alone do not readily explain the water quality patterns observed at Winding Ridge.

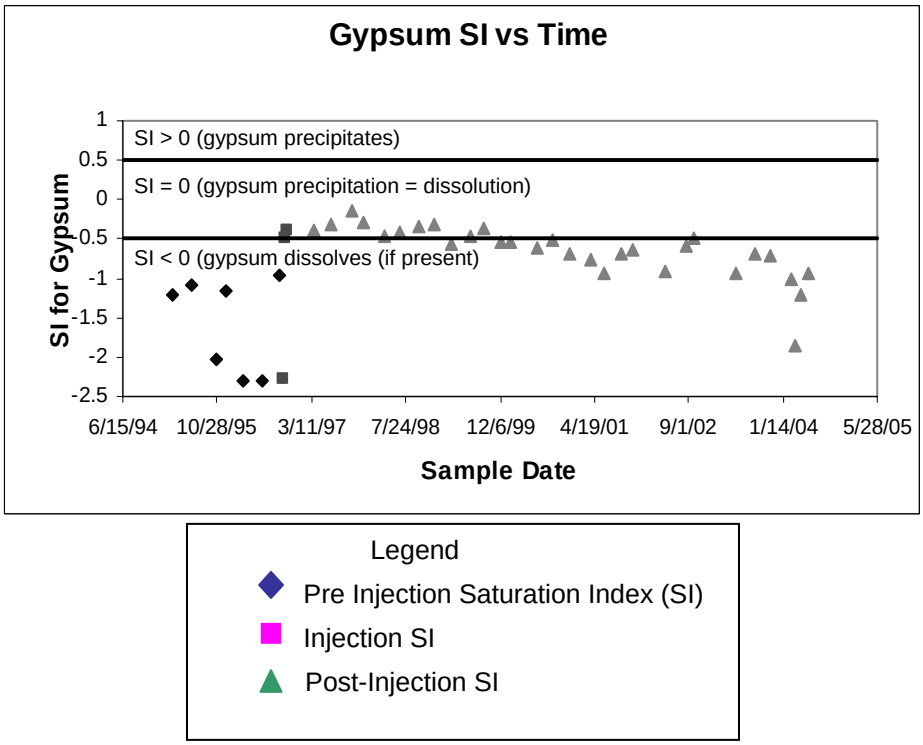
Thus, analyses of the water quality data and trends from Winding Ridge suggest that the changes in water quality observed since injection are due, in large part, to reduced AMD formation within the mine as a result of reduced contact between water and pyrite-containing mine debris.

Grout Dissolution

As mentioned previously, the concentrations of some major ions (sodium, potassium, and chloride) increased significantly after injection and remain at or above their pre-injection levels. It is assumed that these constituents, along with calcium and sulfate, have been dissolving from the grout. Speciation calculations were also used to evaluate the dissolution of the grout.

Due to the composition of the CCPs used in the grout, calcium sulfate (i.e. gypsum or anhydrite, which are relatively soluble minerals), is expected to make up a significant portion of the grout. Saturation indices for gypsum in mine discharge samples from the lower seep are plotted in Figure 13. The graph shows that the mine discharge was unsaturated with respect to gypsum phase prior to injection. During the injection period, the discharge was saturated with respect to gypsum, presumably due to dissolution of calcium sulfate minerals present in the fly ash. During the post-injection period, the discharge remained near saturation with respect to gypsum, but over the last few years, the gypsum saturation index of the mine discharge has gradually decreased. This suggests that dissolution of calcium sulfate from the grout has slowed, possibly due to the formation of a residual crust of less soluble grout components, or precipitate coating at the grout surface. Although not shown in Figure 13, the same calculations were performed for samples collected from the upper seep and mine tunnel piezometers; the results show the same pattern.

Figure 13
Saturation Index for Gypsum at the Lower Seep at Mine Opening 2



In general, the concentrations of the major ions that appear to indicate dissolution of the grout (calcium, sulfate, potassium, sodium, and chloride) have progressively decreased over the long term monitoring and appear to be asymptotically approaching their pre-injection levels. This also suggests that dissolution of the grout is slowing and may be limited due to the formation of a residual low solubility layer or precipitate coatings at the grout surface.

Grout Injection vs Traditional Treatment Methods

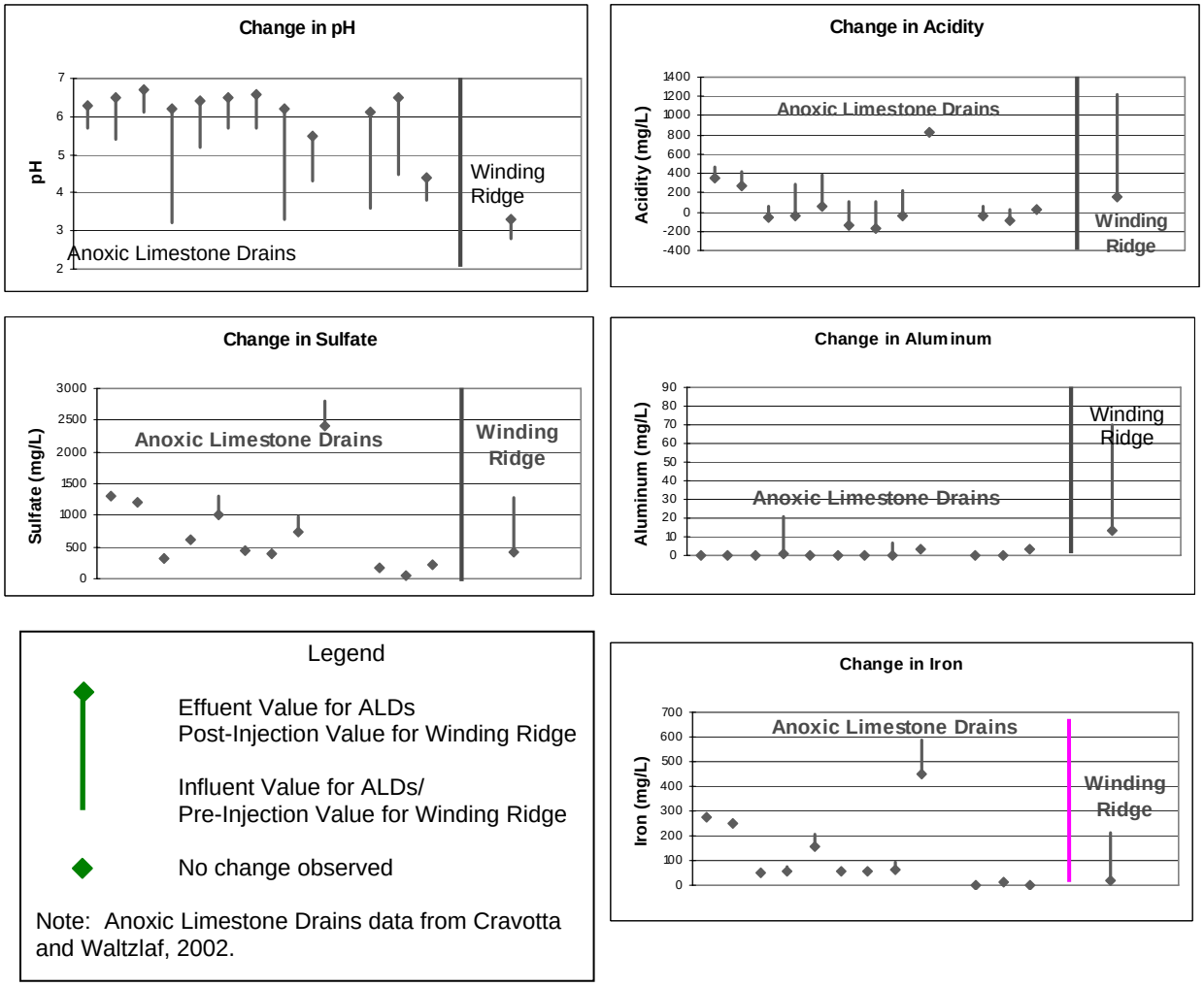
Figure 14 shows a comparison of the changes in water quality observed at Winding Ridge compared with the changes in water quality observed at several sites using anoxic limestone drains (ALDs), which are a commonly used passive treatment method for AMD[3]. While the Winding Ridge project did not achieve the increases in pH or alkalinity observed with most of the ALD systems, the Winding Ridge project achieved much more significant reductions in acidity, sulfate, iron and aluminum. It should be noted that high concentrations of aluminum, such as those observed at the Winding Ridge site are problematic for ALD systems, because as the system increases the pH of the AMD, aluminum hydroxides precipitate on the limestone surfaces, preventing contact between the mine water and the limestone, eventually causing failure of the system. The grouting approach used at Winding Ridge avoids this problem.

Grout injections, like the one at Winding Ridge, could also be viewed as pre-treatment approaches to reduce the load of acidity or other dissolved constituents that must be addressed by additional treatment systems. For example, the computer program AMDTreat[5] was used to calculate the chemical costs to actively treat pre and post-injection discharge at Winding Ridge.

The average flow rate from both seeps was used to calculate the annual volume of water discharging from the mine. The annual cost of chemicals needed to treat this volume of water with hydrated lime was calculated (only the annual cost of chemicals required for treatment was calculated as it was assumed that the costs to construct the treatment system would not change for pre-injection vs. post-injection conditions). The cost of hydrated lime was

assumed to be $0.022 per kilogram, transportation costs are not included in the analysis. Based on these assumptions, the annual cost to treat the pre-injection discharge using hydrated lime was estimated at $3,500 per year, while the annual cost to treat the post-injection discharge using the same treatment method was estimated at $430 per year. This represents a significant reduction in long-term maintenance costs if an active treatment system were to be installed at this site. While active treatment may not be a likely option at a small site, like Winding Ridge, lowering the levels of metals and acidity in mine discharge could significantly reduce the costs of treatment systems at larger sites.

Figure 14
Comparison of Winding Ridge Data to Anoxic Limestone Drains



Conclusions

The CCP grout placed in the Frazee Mine remains stable eight years after injection. Acid discharge from the mine has not been eliminated. However, significant improvements in the water quality of the mine discharge have been achieved. The average pH of the discharge has increased by approximately 1 pH unit and the average acidity of the mine discharge has decreased by more than 80%. The concentrations of other AMD-related parameters (Fe, Al, and sulfate) have also decreased relative to their pre-injection levels. The concentration of trace metals (Co, Cu, Mn, Ni, and Zn) has also decreased since injection.

Some dissolution of the grout has occurred, as indicated by concentrations of nontoxic major ions (Ca, K, Na, and Cl) that increased during injection and remain at or above pre-injection levels. The concentrations of these parameters in the mine discharge have decreased steadily over the past eight years since injection, indicating that dissolution of the grout is slowing. Trace metals do not appear to be leaching from the grout into the mine water. No trace metals have been detected in the mine discharge that were not detected prior to injection (in other words, no new trace metals have been detected since injection) and the concentrations of trace metals that were detected prior to injection are currently below their pre-injection levels, and in some cases are regularly below detection. Analysis of samples from ground water monitoring wells at the site show that ground water outside of the mine has not been impacted by the grout.

The results of the Winding Ridge Project show that CCPs can be used to create a grout for mine backfilling, which both reduces the volume of CCPs that must be placed in landfills and mitigates the environmental impacts associated with acid mine drainage.

Building upon the success of the Winding Ridge Project, the Initiative is planning to implement CCP-grout injection projects at the Kempton Mine Complex (Kempton Complex). The Kempton Mine Complex is Maryland's largest source of AMD as it discharges thousands of pounds of acidity per day into Laurel Run. Through the Initiative, PPRP is working jointly with the Kempton Work Group, which includes MDE and private industry, to fund, design, and implement AMD abatement projects at Kempton. The Kempton Complex consists of nine interconnected mines and covers twelve square miles. As such, the Kempton Complex provides an enormous opportunity to beneficially use millions of tons of CCPs for the betterment of Maryland's terrestrial and aquatic resources and to demonstrate CCP use under various conditions.

In 2003, a CCP grout was used to construct a seepage barrier at the Kempton Manshaft, a former mine shaft, which acts as a conduit directing good quality ground water into the Kempton mine pool. Future projects which are planned at the Kempton Complex include the use of a CCP grout to coat acid-producing mine pavement at a small section of the Kempton Complex known as Siege of Acre. In addition, the Initiative has initiated a cost optimization study to evaluate the use of CCPs for deep mine restoration. Specifically, the Cost Optimization Study will consider the means, methods, and associated costs to use CCPs from the AES Warrior Run power plant for deep mine restoration in the nearby Georges Creek Basin.

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Robin Guynn is a geologist with Environmental Resources Management (ERM). ERM acts as the Environmental Engineering Integrator (EEI) for the Maryland Power Plant Research Program (PPRP). As part of its role as EEI for PPRP, ERM conducts and coordinates research projects that investigate the beneficial use of coal combustion products (CCPs) within the State of Maryland. Robin's responsibilities include field construction oversight, data interpretation and management, and technical report preparation. In particular, her direct relevant experience has included monitoring the geochemical impacts of CCP placement to ground water and the management and analysis of new and historical data on CCP-related sites, including the Winding ridge site and a CCP landfill site. Robin holds a Bachelor of Science in Geological Sciences from Virginia Tech and a Master of Science in Geosciences from the Pennsylvania State University.

Session 2

LEACHING PROTOCOLS AND STUDIES SUPPORTING CCB RISK ASSESSMENT AT MINES

Session Chairperson:
Debra Pflughoeft-Hassett
University of North Dakota
Energy & Environmental Research Center
Grand Forks, North Dakota

Using Laboratory Leaching Methods to Evaluate CCBs
David J. Hassett, University of North Dakota, Energy & Environmental Research Center, Grand Forks, North Dakota

Leaching Methods Applied to the Characterization of Coal Combustion By-Products
Dr. Ann Kim, US DOE National Energy Technology Laboratory, Pittsburgh, Pennsylvania

US EPA Leach Testing of Coal Combustion Residues
Gregory Helms, U.S. EPA, Office of Solid Waste, Washington, D.C.

Mine Water Leaching Procedure
Dr. Paul Ziemkiewicz, West Virginia Water Research Institute, West Virginia University, Morgantown, West Virginia

Prediction of Coal Ash Leaching Behavior in Acid Mine Water: Comparisons of Laboratory and Field Studies
Dr. Paul Ziemkiewicz, West Virginia Water Research Institute, West Virginia

The Use of Leachate Data and Other Factors in Evaluating CCBs for Placement at Coal Mine Sites in Pennsylvania

Michael J. Menghini, Roger J. Hornberger, and Alfred D. Dalberto,Pennsylvania Department of Environmental Protection, Pottsville District Mining Office, Pottsville and Harrisburg, Pennsylvania

The Use of Neutral Leachate Test Data in Indiana's Coal Combustion By-Product Disposal Program

Deborah Dale, Indiana Department of Natural Resources,Division of Reclamation, Jasonville, Indiana

USING LABORATORY LEACHING METHODS TO EVALUATE CCBs

David J. Hassett
University of North Dakota
Energy & Environmental Research Center
Grand Forks, North Dakota

Abstract

The Energy & Environmental Research Center (EERC) has performed numerous research projects that have included the use of laboratory leaching tests to evaluate the environmental performance of Coal Combustion By-Products (CCBs), and that experience has lead the EERC to develop an understanding of the key considerations that must be made when evaluating CCBs. These key considerations include the need for use of an appropriate leaching solution, the need to include multiple long-term leaching tests for reactive CCBs (and other reactive materials), and the need to use a test that provides information that has relevance to the potential disposition of the CCB.

Keywords: Leaching, SGLP, CCBs

Introduction

Even following the U.S. EPA determination to place CCBs under RCRA Subtitle D for solid wastes (1), CCB generators are frequently asked to provide information on the environmental performance of CCBs that are being either disposed or utilized. Frequently, the leaching protocol to be used is mandated or recommended by the requesting party, but considering that the leaching results may have multiple uses and that the U.S. EPA has indicated that any leaching test that can be shown to be appropriate may be used, it is meritorious to consider options for leaching tests. In considering which test or tests to use, the number and types of available tests may be somewhat overwhelming, if not confusing. It is important to understand what information the leaching test is being performed to provide and that the results of the leaching tests must be scientifically valid and defensible. If the goal is simply to categorize a material under an existing regulatory policy, rule, or law, and there is a mandated test for that categorization, it may be reasonable to apply that test as dictated. Categorization of a CCB usually provides an indication of a regulatory status for that material within a State and subsequently an indication of how the CCB can be managed, especially how it may be utilized. Applying an authorized test, however, should not preclude the generation of valid data potentially through the use of an alternate test. This may require a dialogue with regulatory agencies or users of the data. The process of selecting a leaching test and subsequent dialogue with stakeholders should take into account several criteria that will facilitate the generation of valid information that can be used to make good CCB management decisions potentially beyond those included in a preconceived categorization process.

These criteria are:

1. Reactivity or other properties of the material being leached that may influence the leaching profile;
2. The setting where the material is to be placed and the water that will most likely contact that material in that setting; and
3. The leaching time required to allow adequate time for hydration reactions to occur in reactive materials, such as high calcium coal fly ash.

The Value of Laboratory Leaching Tests

Understanding the information that can be ascertained from laboratory leaching is important. A laboratory leaching method can only be used to determine a few important elements of leaching, but these are extremely important, and if properly utilized, can provide information on which responsible CCB management decisions can be made.

These are:

1. The mass of easily mobilized trace elements can be determined using a leaching test with a short equilibration time.
2. A comparison of bulk concentrations of elements with their leachate concentrations provides a means of estimating how various elements will be mobilized with respect to time.
3. The evolution of leachate concentrations can be determined with multi-equilibration time long-term leaching,

Laboratory leaching cannot provide an estimation of the concentration of elements in leachates under natural conditions with any high degree of accuracy. This, however, is not as limiting as it might seem for several reasons. First, the concentration of chemical constituents under natural leaching conditions will be a product of several factors that are not easily duplicated in laboratory leaching. These are rate of flow through the leached material and rate of flow around the mass of leached material, assuming that there is a flow of water through and around the individual site. In properly engineered disposal or utilization sites, this should not be the case. Assuming, however, that there is flow in and around the material, simple modeling using known flow rates can be used to determine likely field concentrations under natural groundwater flow conditions. Since flow in many natural settings is extremely slow (10^{-5}-10^{-7} cm/sec), it is impractical to use laboratory column leaching tests to determine potential for environmental impact of reactive alkaline CCBs. Column leaching could be used and supported both legally and scientifically if the flow rate through the column were slow enough to allow for the formation of secondary hydrated phases, but since this takes months or longer, a flow rate that low through a 50–100 cm column is too slow to be practical. The problem with faster flow rates is that individual components required for secondary hydrated phase formation are washed away before reactions can occur. Ettringite formation requires the presence of alkalinity, soluble calcium, aluminum, and a source of suitable oxyanion such as sulfate. Since these must be leached from the ash, and since the leaching and dissolution rates are different for each of the elements, a relatively high water flow would be expected to wash away critical parameters necessary for ettringite formation.

Advantages and Disadvantages of Common Laboratory Leaching Tests When Used With CCBs

There are advantages and disadvantages to most leaching tests currently being used for CCB environmental performance testing. The advantages alone do not make any one test the best test. It is important to also understand the way in which the CCB is to be introduced into the environment and, of course, what information is being sought by performing the leaching test. Similarly, the disadvantages of individual tests may not disqualify that test from being appropriate for a particular use. It is important to understand the advantages and disadvantages. The EERC has assembled a list of leaching tests commonly used for CCBs and the advantages and disadvantages of each as the EERC sees it (Table 1).

The EERC preferentially uses and recommends the SGLP with the long-term leaching (LTL) option where appropriate because it has the advantage of meeting the criteria for a scientifically valid and legally defensible method. When distilled deionized water is used for the SGLP, it is equivalent to ASTM D3987. Results from SGLP are easily compared to those from TCLP, SGLP, SPLP because all tests use very similar protocols. When incorporating the LTL option with reactive materials, the interpretation of the test results include a comparison of the short-term data set and results of two LTL tests of 30 and 60 (or 90) days. This comparison provides an indication of changes to the leaching profile of a reactive material over time. Since it is unrealistic to assume that a laboratory leaching test can provide an indication of field leachate quality, the EERC believes it is important to assess laboratory leachate data carefully. The EERC agrees that a specific set of limits for laboratory leachate concentrations may be useful in assessing the appropriateness of a material for placement in the environment as long as those limits have been developed with an understanding of the environmental setting. The use of laboratory leaching data in computer models used to predict impacts to groundwater may provide better predictions of actual field concentrations of constituents mobilized from CCBs, but computer models frequently do not incorporate adequate information on the environmental criteria that impact field leachate quality.

Summary

The debate of which method or methods are appropriate for characterizing environmental performance of CCBs continues with a productive dialogue underway. It is important that this dialogue includes stakeholders from the CCB industry and experts in the fields of both CCBs and environmental performance testing. It is unrealistic to think that one leaching test will emerge as the single test appropriate for use with CCBs, but it is expected that the dialogue will facilitate a better understanding of what leaching data can tell producers, users, regulatory agencies, and other interested parties.

David J. Hassett is a Senior Research Advisor at the Energy & Environmental Research Center (EERC) of the University of North Dakota. He also serves as the Fuels Analyst for the State of North Dakota. He has authored or coauthored over 200 publications and holds a patent entitled "Enhanced Ettringite Formation for the Treatment of Hazardous Liquid Wastes, U.S. Patent 5,547,588. He is presently involved in several research projects. His principal areas of interest and expertise include the application of analytical chemistry to address environmental issues associated with trace element occurrence, transport, and fate; coal combustion byproduct management; groundwater quality; and air quality. The most recent research focus has been on trace element transformations during coal conversion processes and interaction between groundwater and coal conversion solids as related to the leachability of trace elements. Additional areas of expertise include hydration reactions of coal conversion solid residues as well as organic synthesis, radiochemistry, x-ray spectrometry, analytical chemistry, and vegetable oil diesel fuels. In 1985, he presented his research on vegetable oil diesel fuels as a member of a People to People Biomass Utilization Delegation to the People's Republic of China and, in 1998, was an invited keynote speaker at the 15th Conference on Clay Mineralogy and Petrology held in Brno in the Czech Republic. He has laboratory experience with infrared spectroscopy, gas chromatography, neutron activation analysis, atomic spectroscopy (atomic absorption and inductively coupled argon plasma), thin-layer chromatography, ultraviolet and fluorescence analysis, x-ray fluorescence spectroscopy, nuclear magnetic resonance spectroscopy, ion chromatography, laser spectroscopy, and capillary electrophoresis. He holds a B.S. in Chemistry and Mathematics from Winona State University in Minnesota.

Table 1. Leaching tests commonly used for CCBs, advantages and disadvantages.

Leaching Test	Advantages	Disadvantages
TCLP EPA 1311 Toxicity Characteristic Leaching Procedure	1) Easy to perform and replicates well between laboratories.	1) Leaching solution limits use to materials only when disposed in sanitary landfills. 2) Lacks long term component for reactive ash.
SPLP EPA 1312 Synthetic Precipitation Leaching Procedure	1) Easy to perform and replicates well between laboratories. 2) Uses a leachate appropriate to specific environmental situations.	3) Lacks long term component option for reactive ash. 4) Developed to evaluate impact of contaminated soils on groundwater.
ASTM D3987	1) Easy to perform and replicates well between laboratories.	1) Lacks long term component option for reactive ash.
MWLP Mine Water Leaching Procedure	1) Well designed for evaluating CCBs to be placed in acidic mine settings.	1) Designed for specific site conditions, so results are not broadly applicable.
SBLP Serial Batch Leaching Protocol	1) Contains an option to evaluate alkaline CCBs.	1) Not yet standardized. 2) Lacks long term component option for reactive ash. 3) Multiple liquid-to-solid ratios and leaching solutions make the test time consuming and results difficult to interpret.
SGLP/LTL Synthetic Groundwater Leaching Procedure/ Long-Term Leaching	1) Provides optional long term component for reactive ashes. 2) Allows for leaching solution to be selected site specific conditions. 3) Easy to perform.	1) Not yet standardized. 2) Long term component may require up to 90 days.

LEACHING METHODS APPLIED TO THE CHARACTERIZATION OF COAL UTILIZATION BY-PRODUCTS

Ann G. Kim
ORISE Research Fellow
National Energy Technology Laboratory, US Department of Energy
Pittsburgh, Pennsylvania

Abstract

There are more than one hundred leaching methods, but there is no agreement on which method is most appropriate to estimate the environmental consequences of the use or disposal of coal utilization by-products (CUB). Leaching methods are often categorized by whether the leaching fluid is a single addition (static extraction tests) or is renewed (dynamic tests). Methods can also be classified as batch leaching in which the sample is placed in a given volume of leachant solution, as column or flow through systems, and as bulk or flow around systems for monolithic samples. Commonly used methods developed by EPA or promulgated by ASTM, as well as methods developed specifically for CUB, are discussed.

Introduction

Leaching is a method to remove soluble components from a solid matrix. A survey of the literature identified over 100 leaching methods (Hesbach and Lamey 2001). Given the plethora of methods, the question often arises as to what is the "best" method. The simplest answer is "It depends."

Describing leaching by a very simple equation:

$$\text{material (leachee)} + \text{leachant} \rightarrow \text{leachate.}$$

It can be assumed that the material to be leached is known, although its physical and chemical/mineralogical properties will affect the final result. The purpose or what you expect to find in the leachate will determine the selection of a leachant and also the conditions of the test.

Several common leaching methods are regulatory methods, mandated to characterize materials; others are approved by organizations for establishing compliance to particular specifications. Some methods are intended to mimic natural conditions or to obtain information about the nature of the extractable material within a particular solid. The methods vary in the mass and particle size of the sample, the type and volume of leachant solution(s), the leachant delivery method, and time. Most procedures are performed at ambient temperature, although a few decrease the time required to solubilize components by increasing the temperature. Although many were developed for application to municipal solid waste or industrial wastes, most leaching methods have been applied to a variety of materials, including coal utilization by-products (CUB).

For a simple, one compound material, leaching is relatively simple. It depends on the pH and composition of the leachant, the solubility of the chemical compound, and surface area of the solid. This can be fairly well described by a shrinking core model (Batarseh et al. 1989) or and adsorption/desorption model (Chaiken 1992). Most natural materials, including CUB, are not that simple, and leaching behavior is controlled by these and other variables.

With respect to leaching, it is important to recognize that CUB, particularly fly ash, is not a homogeneous material. Its elemental and mineralogical composition and its physical properties are a function of the original coal, the combustion temperature and post-combustion cooling rate (Kim 2002). Volatilization, melting, decomposition, and the formation of new minerals, as well as oxidation, are the mechanisms that transform the minerals in coal.

Concentration is one of several factors in determining leaching potential; volatility and solubility also influence leaching potential. Most elements, particularly trace elements, in CUB are only slightly soluble (Kim et al 2003).

Heavy metals are most soluble in acidic solutions, while those elements that form oxyanions are more soluble at high pH. There is no particular element or group of elements that is characteristic of CUB leaching potential. Elemental solubility appears to be an independent variable.

Solubility is also a function of speciation within the ash. The primary minerals in CUB are silicates (quartz), alumino-silicates (clays and feldspar), oxides (hematite), and sulfates (gypsum, anhydrite). Silicates and alumino-silicates are comparatively insoluble. Oxides tend to be only slightly soluble, while sulfates are more soluble. The silicate/non-silicate distribution of various cations has been shown to influence elemental solubility (Kim & Kazonich 2004); the condensation of mixed particles (Osgood-Kutchko and Kim 2002) also affects elemental solubility. Volatile inorganic elements may condense as compounds forming surface coatings on other particles.

The physical characteristics of combustion residues include particle size, particle shape or morphology, hardness, and density. These properties are a function of the particle size of the feed coal, the type of combustion, and the particulate control device. Due to the high temperature of P.C. combustion, fly ash particles tend to melt and condense as spheres with a diameter of less than 0.010 mm. The spherical shape of fly ash particles results in a minimum surface area, which reduces the potential number of leaching sites.

Choosing the most effective leaching method for CUB must consider the chemical and physical properties of fly ash particles which are a function of the mineral matter in the coal, the combustion conditions and post-combustion cooling. Since these factors may be unknown, a variety of leaching methods have been proposed based on the type of information desired or on particular conditions the method simulates.

Leaching Methods

Summaries of many of the more commonly used leaching methods have been given by Sorini (1997), Wilson (1995), and Kim (2003). The International Ash Working Group (IAWG) based in Europe has done extensive work on the integration of a variety of tests into a comprehensive leaching system (Eighmy and van der Sloot 1994; van der Sloot 1998).

Leaching methods are often categorized by whether the leaching fluid is a single addition (static extraction tests) or is renewed (dynamic tests). Methods can also be classified as batch leaching in which the sample is placed in a given volume of leachant solution, as column or flow through systems, and as bulk or flow around systems for monolithic samples. Results are generally reported as a concentration, sometimes as the concentration in the leachant solution (mg/L) or as the leached concentration from the solid (mg/kg). In many methods, the liquid to solid ratio (L/S) is used to quantify the volume of leachant with respect to the amount of solid sample, usually as mL/g or L/kg. Representative methods are listed in Table 1.

Batch Methods

Batch leaching methods are those in which a sample is placed in a given volume of leachant solution for a set period of time. Most of these methods require some type of agitation to insure constant contact between the sample and the leachant. At the end of the leaching period, the liquid is removed and analyzed.

The most commonly used batch leaching methods are the Toxicity Characteristic Leaching Procedure (TCLP), the Extraction Procedure Toxicity Test (EPTOX), the Synthetic Precipitation Leaching Procedure (SPLP), the Standard Test Method for Shake Extraction of Solid Waste with Water (ASTM D-3987), and the California Waste Extraction Test (CA WET 1984). The Leachate Extraction Procedure approved by the Canadian General Standards Board (CGSB 1987) and the Leachate Extraction Procedure (LEP 1993) of Ontario are very similar to EPTOX. The parameters for these methods are compared in Table 2.

In serial batch methods, a sample of waste is leached successively with fresh aliquots of the same leaching fluid. This method is intended to eliminate the effect of concentration on solubility and to simulate long-term exposure to the leachant solution. These methods include EPA's Multiple Extraction Procedure (MEP), the Standard Test Method for Sequential Batch Extraction of Waste with Acidic Extraction Fluid (ASTM D-5284), and the Standard Test Method for Sequential Batch Extraction of Waste with Water (ASTM D-4793).

Sequential leaching tests use a single sample that is leached by a series of different leaching fluids. The Availability Test for Granular Materials (NEN 7341), a Dutch Standard leaching test, leaches a material at pH 4 and at pH 8; the two pH's are intended to bracket the range found naturally in the environment. In more complex sequential extractions, the constituents extracted with a particular leachant are associated with a mineral phase or chemical species. Palmer at the USGS developed a Sequential Leaching Method as a rapid indirect method of determining the modes of occurrence of trace elements in coal (Palmer et al. 1999). Like the later USGS sequential extraction procedure, Tessier (1979) uses a series of four extractant fluids to dissolve metals associated with particular ligand phases in a complex sample. A modified Tessier procedure uses aqua regia in place of hydrofluoric/nitric acid (Raksasataya et al. 1996). A three-step sequential extraction procedure (Quevauviller et al. 1997) developed by the commission of the European Communities Bureau of Reference has also been modified to include aqua regia digestion of the residual material (Raksasataya et al. 1996). A Short Sequential Procedure uses two steps to assess the lability of heavy metals in soil particles (Maiz et al. 2000).

Column Methods

Column leaching tests are designed to simulate the flow of percolating groundwater through a porous bed of granular material. The flow of the leaching solution may be in either down-flow or up-flow direction, and continuous or intermittent. The flow rate is generally accelerated when compared to natural flow conditions. However, it should be slow enough to allow leaching reactions to occur. A basic assumption in column leaching is that the distribution of the leaching solution is uniform and that all particles are exposed equally to the leachant solution. Precipitation or sorption within the column may affect the results.

The Standard Test Method for Leaching Solid Material in a Column Apparatus (ASTM D-4874) is intended to maximize the leaching of metallic species from a solid. The aqueous fluid passes through particles of known mass in a saturated up-flow mode. The Dutch Standard Column Test (NEN 7343) is also an up-flow application, and the Nordtest Column Method (NORDTEST 1995) is similar to the Dutch Column test, except that column dimensions are optional**.** The up-flow column procedures are designed to insure that the leachant solution is equally distributed throughout the column. However, gravity flow columns can also be used to study leaching of porous media. Column experiments more closely approximate the particle size distribution and pore structure, leachant flow, and solute transport found in the field (Zachara and Streile 1990).

The NETL column leaching system is a continuous gravity flow system in which five leachant solutions are used to simultaneously leach 1 kg samples of a CUB (Kim and Sharp 1995; Kazonich and Kim 1997). The leachant solutions are sulfuric acid, synthetic precipitation, sodium carbonate, acetic acid, and deionized (DI) water.

Column experiments can be conducted in both saturated and unsaturated conditions. Unsaturated conditions are usually intended to mimic vadose zone placement. Intermittent addition of a given volume of leachant solution at the top of the column can provide uniform distribution of the fluid and approximate a constant fluid front moving through the unsaturated column. Saturated columns are obtained by a constant fluid flux, and allowing the fluid to pond at the top of the column. Variables, such as leachate collection, sampling frequency, leachant flow rate, and duration of the experiment, are determined by the experimental objectives**.**

Monolithic and Bulk Methods

Monolithic leaching methods are used to evaluate the release of elements from a material that normally exists as a massive solid, cement for example, and are frequently used to characterize the release of pollutants from stabilized waste materials. The release of an element is a function of the exposed surface area as opposed to the mass. Flow-around systems relate solubility to the surface area of a particular volume. Flow-through systems also consider the internal pore surface. And some systems take into account the rate of diffusion of the leachant solution into the pores.

In static monolithic leaching, a particle of regular geometry and known surface area is immersed in a volume of leachant solution. The same leachant solution is sampled at defined intervals and replaced with fresh solution (Hoberg et al. 2000).

The flow through leaching test (Poon et al. 2001) is used to characterize leaching from a waste that is more permeable than the surrounding material. The solid sample is placed in a flexible wall permeameter, and in this method, the leaching solution is DI water at a mean flow rate of .0166 mL/min at a pressure of 400 kPa.

Bulk leaching generally refers to leaching large samples, either in a large column or in heaps. They are either hydro-metallurgical systems (Fleming 1996) or are used in a research setting to leach a non-homogeneous sample with a large particle size (Dalverny et al. 1996). Neither system is particularly applicable to CUB.

The ASTM Static Leaching of Monolithic Waste Forms (ASTM C-1220) is intended to evaluate the durability of radioactive waste in glasses and ceramics. The testing period varies from 7 days to 1 year or more. Water, de-aerated water, brine, and silicate water ($NaHCO_3$ and silicic acid) or site-specific repository waters may be used as the leachant solution. The sample is a single piece of regular geometry so that the surface area can be determined. The volume of the reaction vessel, between 20 mL and 1 L, sets the size of the sample. The International Standards Organization also has a leaching protocol developed for application to solidified radioactive waste (ISO 6961 1982).

Combined Methods

The International Ash Working Group (IAWG) has designed a combined leaching protocol to quickly determine the total leachable elements in a material and to estimate metal release in a normal environmental setting (van der Sloot et al. 1994; van der Sloot 1998). It combines the sequential batch availability test (NEN 7341) with a serial batch extraction using water. A two-step availability test of fine-grained material, at a L/S of 50 and controlled pHs of 4 and 8, is used to determine leachability at the upper and lower pH limits found in natural environments. From the total acid consumption, the acid neutralization capacity of the material is estimated. Total elemental release as a function of time is estimated by leaching at several L/S values between 1 and 100 in a serial batch test with water. The release of contaminants is usually expressed in mg/kg leached against the L/S ratio.

The US Environmental Protection Agency Office of Solid Waste (EPA/OSW) has proposed a three-tier approach to the environmental assessment of CUB, particularly for the release of mercury (Kosson et al. 2002). It includes batch leaching at 11 pH's between 3 and 12 at a L/S of 10, batch leaching with DI water at 5 L/S ratios, and a monolithic procedure using 10 mL of DI water per cm^2 of surface area of a solidified cylinder or cube. A similar combination of pH dependent release and long term estimated release has been developed at NETL (Hesbach and Kim 2005).

Conclusion

The selection of a leaching method is not a simple or trivial task. The ASTM E 50.03 committee is currently developing a standard guide or procedure to identify the best available leaching tests for specific materials or material types (Pflughoefft-Hassett 2004). In the absence of an accepted protocol, the project objective and the type of data desired determine what method is most appropriate. Critical variables include the sample size and particle size distribution, the leachant volume and pH, and the duration of the leaching test. The use of regulatory or standard methods by different laboratories does not always produce duplicate results. Even when tests are performed with the same methods, extraneous variables, such as analytical sensitivity and sample inhomogeneity, may influence the reproducibility of the results. Also, compliance tests and standard methods are not necessarily appropriate as leaching tests to simulate natural processes, to obtain data on reaction mechanisms, or to unravel complex solubility relationships. Limited comparative studies of leaching methods (Heaton et al. 1981; Mason and Carlile 1986; Zachara and Streile 1990) found that various methods could generate reproducible data, but there was no consistent correlation in the data generated by various methods. To evaluate four commonly used or proposed leaching methods for CUB, five laboratories are participating in an informal inter-laboratory comparison (Hesbach et al. 2005). The results will be compared on total elemental solubility and on internal and comprehensive reproducibility.

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Ann Kim is an ORISE Research Fellow in the Environmental Science and Technology Division at the Department of Energy's National Energy Technology Laboratory. She currently serves as Team Leader for the By-Product Utilization Team in the Environmental Science and Technology Division. She is responsible for leading an in-house research team effort that includes determining environmental consequences of utilizing coal combustion by-products from conventional and innovative electricity producing systems. She is the primary author of more than 75 technical publications. She holds a BA in Chemistry/Physics from Carlow College, an MS in Earth and Planetary Science from the University of Pittsburgh, an MS in Engineering Management from the National Technological University and a PhD in geochemistry at the University of Pittsburgh.

Table 1. Representative Leaching Methods

	Regulatory Standard		**Research (Other)**
Batch			
Static	TCLP	ASTM 3987	
	SPLP		
	Ca WET		
Dynamic			
Serial	MEP	ASTM D5284	
		ASTM D4793	
Sequential	NEN7341		Palmer (USGS)
	BCR		Tessier
Column	NEN7343	ASTM D4874	Kim (NETL)
	NORDTEST		
Bulk			
Static		ASTM C1220	
		ISO 6961	
Dynamic		ANS-16.1	Heap
			Trickle Bed Reactor

Table 2. Characteristic Parameters of Static Batch Leaching Methods

Method	**Leachant**	Sample size, g	pH	L/S[1]	Time, hr
ASTM D-3987	Water	70		20	18
EPTOX	Water	100	5.0	20	24
SPLP	Water acidified with nitric and sulfuric acids	100	4.2	20	18
TCLP	Acetic Acid or Acetate Buffer	100	2.88	20	18
CA WET	0.2 M sodium citrate	50	5.0	10	48
LEP	Water acidified with 0.5 N acetic acid	50	5.0	16	24

[1]L/S: Liquid to Solid ratio, L/kg

US EPA LEACH TESTING OF COAL COMBUSTION RESIDUES

Gregory Helms
US EPA Office of Solid Waste
Washington, D.C.

RCRA Background

EPA regulates waste management under the Resource Conservation and Recovery Act (RCRA). Groundwater contamination is a key waste management concern and has been since the beginning of the program. Leach testing has been used in our regulatory programs to help EPA make regulatory decisions in order to determine: (1) what waste is hazardous and needs to be regulated: listings, delistings, Toxicity Characteristic (TC) regulation; and (2) (especially for inorganic wastes) what treatment is adequate: Land Disposal Restriction (LDR) treatment requirements.

TCLP is the most used leaching test developed by EPA and was published in a final regulation in 1990. It was the successor to the EP toxicity test. It is probably the most frequently used test because it is a regulatory test. TCLP was designed as a screening test to consider conditions that may be present in a municipal solid waste (MSW) landfill. It is acetic acid buffered to pH 5 (initial); 20:1 liquid/solid ratio; particle size reduction to 9.5 mm; equilibrium. The reason it was designed this way was because, under RCRA, EPA is required to regulate as hazardous all wastes that may pose a hazard to human health and the environment if they are mismanaged. EPA had to ask the question, if a waste is not managed in a hazardous waste landfill, how will it be managed? The answer was that co-disposal of industrial solid waste with MSW is considered to be a plausible "worst case" management of unregulated waste. If EPA believed that a waste would cause a groundwater contamination problem when placed in an MSW landfill, then EPA wanted to regulate it as a hazardous waste. Because of its regulatory program use, TCLP is also used when it is not required. It may be used in: non-hazardous waste reuse (State Beneficial Use programs); industrial non-hazardous waste landfills; and site remediation where LDRs are not triggered (usually in-place of on-site treatment and disposal).

EPA Science Advisory Board (SAB) Concerns Re: TCLP

The SAB/EEC commented on Agency leach testing in 1991 and 1999. The SAB expressed concern about over-broad use of the TCLP test. The SAB urged the EPA to undertake new leaching research on both occasions. The SAB urged development of tests that consider actual disposal conditions affecting leaching and field validation of new tests.

Technical Issues with TCLP

The SAB found that TCLP is a screening test that evaluates leaching potential under a single set of environmental conditions. EPA realizes that if you want to evaluate how a waste is actually managed, you are likely to have conditions which are different from those at an MSW landfill. Under this scenario, the MSW would have initially acidic conditions. EPA did not consider final conditions that were not considered critical and usually not known. In designing TCLP, EPA considered that conditions in the landfill would predominate and dictate the overall leaching conditions in a generally oxidizing environment. It was also considered that a relatively small proportion of industrial wastes would be co-disposed with MSW. What EPA has found in subsequent years is that for most metals, leaching is pH dependent. This means that by looking at a waste with a single pH, this doesn't give you the best information. You can also get reducing conditions in the bottoms of landfills that can also affect leaching.

EPA Response to Concerns

In response to these concerns, EPA began considering alternatives to TCLP and what attributes should be investigated. As EPA began seeking approaches to be developed into reliable tests for routine use, it found that: (1) much non-TCLP testing has been research or *ad hoc* modifications of TCLP; (2) EPA needed defined protocols

that are validated; validation includes inter-laboratory and field evaluations; and (3) most existing alternatives have not been validated (particularly field validation).

The Agency has been seeking new testing approaches with: (1) better accuracy over a range of disposal conditions; (2) a better foundation in basic science (i.e. not empirical like TCLP) EPA wants to understand from the test what parameters affect leaching and how that effects a particular waste; (3) better applicability in environmental assessments (i.e., groundwater fate and transport modeling); and (4) flexibility to apply to a broad range of waste types and over a range of conditions that affect leaching and occur in the environment.

EPA gave consideration to the factors that affect leaching like: (1) waste form (TCLP requires a particle size reduction as an initial step to obtain an equilibrium test); (2) pH (generated by the waste itself or by external conditions like co-disposal in a landfill or acid rain); (3) infiltration rate; (4) redox conditions; and (5) others.

EPA is trying to respond to the science advisory board so that we can find an approach where we can get validation in both the laboratory and field. EPA would like a test that can also be practically applied. In conducting leach tests of CCRS, EPA made regulatory determinations about TCRs in 1993 and 2000. EPA mostly relied on total concentration data, TCLP, and EP toxicity leach test results because that was what was available at the time. In going forward, EPA is likely to do regulations under subtitle D of RCRA or SMCRA that will be a performance based approach.

Future Leach Testing of CCRs for Mercury

EPA is currently evaluating leaching from CCRs resulting from mercury emissions controls. Although the focus has been mercury, EPA has also been testing for arsenic, selenium, and other metals. EPA has been using a leach testing approach developed by Kosson et al. (2002) at Vanderbuilt. The Kosson Framework addresses many EPA program needs and addresses many of the SAB concerns. EPA chose this method because it considers factors known to affect leaching of metals like: (1) a range of pH values (solubility of many metal salts change with pH); several liquid to solid (L/S) ratio values (or infiltration rate); and (3) form of waste (granular, compacted, or monolithic). Because of this, EPA expects to obtain a better accuracy. The Kosson approach is tiered and flexible so you can do an equilibrium test. It can test both worst-case and more realistic cases. For small volumes, it can do conservative and cheaper testing. The outputs can be used with site conditions data to generate probabilistic leaching estimate and most appropriately drives groundwater fate and transport modeling.

This same approach was being used for supportive consultation with SAB in 2003 for evaluating metals. The SAB reviewed the Kosson framework for assessment of leaching from CCRS and general waste re-use and considered the framework broadly applicable to waste assessment, especially inorganics. The SAB urged further development of relationship to field data, interpretation of data for decision making, and also include organics leaching and microbial effects on leaching. More detailed information (including the Kossen Framework publication) is available at the SAB website: http://www.epa.gov/sab/eecconsultationonleaching.html.

In EPA's ongoing leaching assessment of CCRs, we are evaluating class C and F fly ashes and scrubber sludges in a number of air pollution control configurations. We have generally found low leaching of mercury even with enhanced mercury controls. There has been some leaching of arsenic and selenium. EPA has conducted extensive QA/QC performed per a QA/QC plan that uses reference fly ash, spikes, blanks, and replicates, to ensure valid results. EPA performed laboratory mass balance study of mercury because we found initial low mercury leaching results. We were asked how we knew that the mercury was not just volatilizing. Our tests found good recovery of the mercury and we were not losing it in the glassware nor was it being volatilized. More detail can be found in the February 18, 2005 memo on "Cross Media Transfers" in the EPA public docket for the "Clean Air Mercury Rule."

Final Questions

Why didn't we use TCLP for evaluation of CCRs from enhanced mercury control? This is because: (1) EPA is not making a hazardous waste determination that was done by the May 22, 2000 regulatory determination (65 FR 32214); (2) actual management conditions for CCRs are known; MSW co-disposal is minor, so TCLP is not

technically appropriate; and (3) EPA is seeking an estimate of CCR leaching potential that best reflects actual management .

Why doesn't EPA use other existing leaching tests for CCR assessment? EPA found that most tests: (1) are not field validated; (2) do not try to assess environmental releases (i.e., assess leaching "under the conditions of the test"); (3) do not consider environmental conditions of waste management; and (4) do not robustly support groundwater fate and transport modeling.

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THE MINE WATER LEACHING PROCEDURE

Paul F. Ziemkiewicz
National Mine Land Reclamation Center
West Virginia University
Morgantown, WV 26506-6064

Abstract

Federal and State regulations encourage reduction of industrial waste streams to decrease the acreage consumed by landfills. In particular, applications that resolve environmental problems are recognized by State policy as "beneficial uses." These large-scale projects may involve filling surface and underground coal mines with ash to address hydraulic problems, acid mine drainage, pit backfilling, and subsidence. In some States, those mine filling projects classified as beneficial are not subject to industrial waste disposal conditions such as liners, leachate collection, and monitoring. Coal Combustion Byproducts (CCBs) are attractive for such applications because they constitute a source of low cost alkalinity and favorable economics resulting from transport back to the mine in otherwise empty coal haulage trucks. The environmental risk of land filling CCBs is generally evaluated by the Toxic Characteristics Leaching Procedure (TCLP) or the Synthetic Precipitation Leaching Procedure (SPLP). However, there is doubt regarding the applicability of these tests to long-term CCBs leaching behavior in groundwater associated with coal mines. The Mine Water Leaching Procedure (MWLP) was developed to provide a site specific risk assessment tool. The MWLP procedure is presented in this chapter as a study case and comparisons with TCLP results were made.

The Mine Water Leaching Procedure

MWLP was developed to determine the long-term leaching behavior of industrial wastes when placed in contact with the groundwater on a given site. The method sequentially leaches the CCB with a sample of the site's groundwater until the alkalinity is exhausted and the pH of the leachate returns to that of the mine water sample.

The MWLP is applied identically for all waste products, differing only in the number of leaching cycles required for alkalinity exhaustion. This point is determined as the pH of the untreated mine water. A general outline of the procedure is included below:

- One hundred grams of fly ash were weighed out and transferred into 2-L plastic reaction bottles. To each ash sample was added one of two leachants: mine water or deionized water (control). Three replicates of each ash were prepared. The bottles were then sealed with Parafilm and the lids were secured. Reaction bottles were arranged evenly on a rotating platform, identical to that used in the TCLP test, and rotated end-over-end for 18 hours at 30 rpm.
- Following each 18 hour cycle the contents of each bottle were filtered through a 0.7 um glass, borosilicate filter using a stainless steel pressure filtration unit at or below 40 psi. A two liter container was placed under the base of the filtration apparatus to collect the filtrate. The contents of the fly ash + AMD reaction bottle were poured into the top of the pressure cylinder, the lid was secured and N_2 was introduced to pressurize the filtration unit. The pressure was slowly increased to 40 psi until all the liquid was removed from the unit.
- Following filtration the unit was dissembled and the filter cake (filter + solids) removed and saved for use in the subsequent cycle.
- Five hundred ml of each leachate was collected in two 250 ml bottles. One bottle was sent to an analytical laboratory for pH, acidity and alkalinity determinations using a Brinkman Autotitrator. The other bottle was acidified using 1 ml of 1N nitric acid and sent to the lab for elemental analysis (Sb, As, B, Ba, Cd, Cr, Pb, Hg, Ag, Cu, Ni, Tl, V, Zn, Mo, Fe, Mn, Al, and B) using a high resolution ICP-Mass Spectrometer.

- Solids collected during filtration were rinsed back into their corresponding reaction bottles with 2 "fresh" liters of leachant and placed back on the rotating platform for another 18 hour cycle. The leaching-agitation-filtration cycles continued until all alkalinity was removed from the system.

Interpreting the Results

Leachate metal concentrations can be attributed to four possible sources: leachant (AMD), released metals from dissolution of the waste matrix; remobilized AMD metal precipitates; and remobilized ash metal precipitates (Figure 1). Since concentrations and volumes of leachant and leachate waters were known, it was possible to prepare a series of mass balances. So, by subtracting the elemental masses exported from the system (in the leachate) from the elemental masses imported to the system (in the AMD or leachant), it was possible to determine the net effect of ash addition on the concentration of toxic elements in the leachate. Table 1 shows the cumulative import, export, sequestration and release of Cr during a MWLP leaching series. This example indicates that between pH 4.2 and 3.8, the system stops sequestering Cr and begins releasing it.

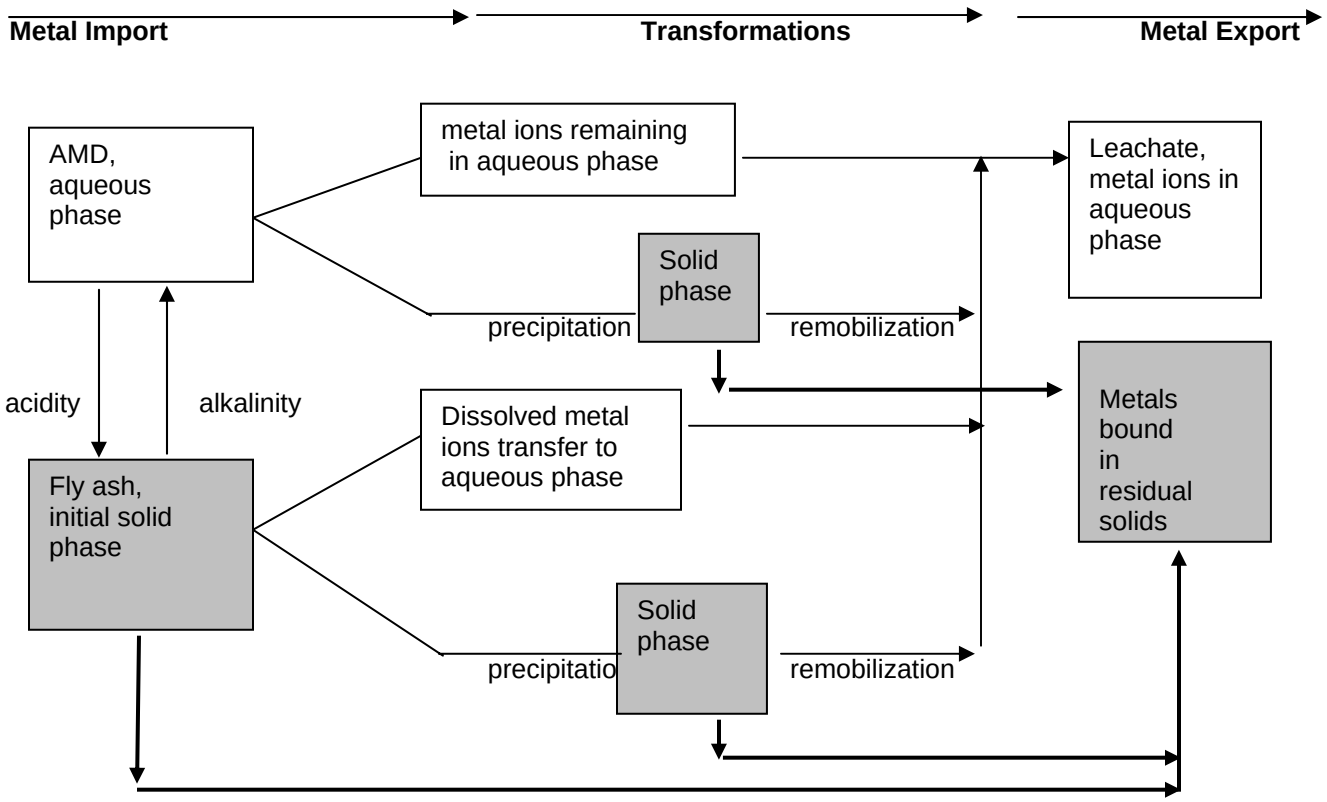

Figure 1. Diagram of the experimental system. *Metals can be imported to the system from either the AMD (aqueous form) or fly ash (solid form). Once in the system, metals can either stay in the aqueous phase, precipitate into the solid phase or resolubilize into the aqueous phase.*

Table 1. Example of Cr Import/ Export Table for Class F Fly Ash MWLP.
All in, out and release values are cummulative. For example, the value of .180 mg for Cr In at Cycle 5 is the cummulative concentration of Cr in the import water (AMD) for cycles 1-5. The Cr Out is calculated similarly. This permits the calculation of the mg of cr released into the leachate water as a result of the fly ash addition to the AMD.

Cycle	Leachate pH	Cr In (mg)	Cr Out (mg)	Fly ash Release (mg)	% Released
1	4.17	0.044	0.032	-0.012	-28.0%
2	3.82	0.088	0.161	0.073	83.0%
3	3.54	0.132	0.362	0.230	174.3%
4	2.87	0.176	0.547	0.371	210.9%
5	2.92	0.220	0.732	0.512	232.5%
average					134.5%

Discussion

The MWLP differs from TCLP in two ways. First, TCLP, uses standard synthetic extraction fluids, titrated to various pH ranges with acetic acid, MWLP uses water from the intended application site. It is expected to provide a more accurate simulation of field conditions than TCLP and accounts for chemical interactions between ions released from the CCB and those in the mine water. Second, TCLP uses a single 18 hr leach cycle while MWLP continues leaching until all alkalinity is exhausted. In the case of many CCBs, the TCLP stops while the pH is still strongly alkaline. While the intent of the CCB application may be to neutralize mine water acidity, the TCLP sheds no light on situations where re-acidification of the CCB mass is a possibility.

While MWLP is meant to simulate the likely chemical products resulting from exposure of a given CCB to a particular mine water, in its current configuration, it does not simulate reducing conditions. Additionally, MWLP simulates many years of weathering in a short period (roughly 32 pore water exchanges per leach cycle). It is important to remember that field concentrations of contaminants will be strongly influenced by the method of CCB placement, its volume, groundwater gradients, and spoil quality. Therefore, the concentrations yielded by the test are not expected to estimate concentrations under field conditions.

As pH and acidity change through the MWLP cycles, various elements appear in the leachate. In some instances, an element will appear for one or two cycles then drop below detection limits. This could indicate that an element is being sequestered or it could mean that its soluble fraction has been leached out of the fly ash. In either case, MWLP will highlight elements that may become mobile and the pH range in which it is likely to occur.

It is understood that the short 18 hour cycle time may not allow many intermediate mineral phases to come into equilibrium. Accounting for these phenomena and their significance over the long term are yet to be determined.

The MWLP is helpful in predicting the long term leaching behavior of wastes placed in acid environments. Many metals, such as Al, Cu, and Pb may not be leached from the waste until the leaching fluid becomes very acidic. In the case of highly alkaline wastes, this may not happen until dozens of pore water exchanges have occurred. The benefits of MWLP are most apparent when dealing with alkaline waste products, where a single leaching cycle will not exhaust the alkalinity in the system. In these cases, several leaching cycles are necessary in order to understand the leaching behavior of these wastes as its alkalinity is exhausted and the leachate becomes acidic. This is not meant to imply that all CCB minefills will become

acidic. Rather, it allows the user to evaluate leaching behavior through a range of pH conditions controlled by the pH of the leachant and the inherent alkalinity of the CCB.

Conclusion

The Mine Water Leaching Procedure (MWLP) was developed to determine the long-term leaching behavior of industrial wastes in groundwater found on the potential application site. The method sequentially leaches the fly ash with a sample of the site's groundwater until the alkalinity is exhausted and the pH of the leaching solution is reestablished at its pre treatment level.

Import/export calculations showed the extent to which metals entering the leaching system via AMD were sequestered as solid phase precipitates. It appeared that precipitation and remobilization was a significant pathway for most metals.

A single MWLP cycle represents about 32 pore water exchanges. If one could estimate groundwater flux through the CCB mass, it would be possible to estimate the years required under field conditions to affect a single pore water replacement. This would allow placement of a temporal axis on the leachate data and further enhance the ability to predict risks associated with CCB placement in mine fills.

Elemental concentrations obtained via MWLP are unlikely to reflect actual field concentrations. They will also be influenced by the method of CCB placement, its hydraulic conductivity, the ability of the surrounding mine spoil to sequester toxic elements, adjacent ground water quality, and gradients. Nevertheless, MWLP is expected to provide an important component of the overall risk assessment picture.

Dr. Paul Ziemkiewicz is the Director, West Virginia Water Research Institute, West Virginia University and the National Mine Land Reclamation Center. He has over eighty publications including publications on Coal Combustion By-Products related to coal mining issues. His most recent publications is on Prediction of Coal Ash Leaching Behavior in a Acid Mine Water: Comparison of Laboratory and Field Studies. His related associations include: Member, Board of Directors, National Environment and Education Training Center, Research Associate Professor of Plant and Soil Science, West Virginia University, Research Professor, Department of Biology, West Virginia University, Member, West Virginia Acid Mine Drainage Task Force, Member, Eastern Mine Drainage Federal Consortium, Technical Support Team Leader: Appalachian Clean Streams Initiative/Acid Drainage Technology Initiative, Member, National Research Council Study Team: Water Quality in the Pittsburgh Region, Member, West Virginia Special Reclamation Fund Advisory Council, and Member, Board of Directors, The Annapolis Center for Science-Based Public Policy. He holds a B.S. from Utah State University with a major in Biology and minor in Chemistry. He holds a M.S. from Utah State University in Range Ecology and a Ph.D. from the University of British Columbia in Forest Ecology.

PREDICTION OF COAL ASH LEACHING BEHAVIOR IN ACID MINE WATER: COMPARISON OF LABORATORY AND FIELD STUDIES

Paul F. Ziemkiewicz
West Virginia Water Research Institute,
West Virginia University,
Morgantown, West Virginia

Abstract

Strongly alkaline fluidized bed combustion (FBC) ash is commonly used to control acid mine drainage (AMD) in West Virginia coal mines. Objectives include acid neutralization and immobilization of the primary AMD pollutants: iron, aluminum, and manganese. The process has been successful in controlling AMD though doubts remain regarding mobilization of other toxic elements present in the ash. In addition, AMD contains many toxic elements in low concentrations and each mine produces AMD of widely varying quality. So, predicting the effect of a particular ash on a given coal mine's drainage quality is of particular interest. In this chapter, we compare the results of a site-specific ash leaching procedure with two large-scale field applications of FBC ash. The results suggested a high degree of predictability for roughly half of the 25 chemical parameters and poor predictability for the remainder. Of these, seven parameters were successfully predicted on both sites: acidity, Al, B, Ba, Fe, Ni, and Zn while electrical conductivity, Ca, Cd, SO4, Pb, and Sb were not successfully predicted on either site. Trends for the remaining elements: As, Ag, Be, Cu, Cr, Hg, Mg, Mn, pH, Se, Tl, and V were successfully predicted on one but not both mine sites.

Introduction

Several test procedures have been developed in an attempt to predict the leaching behavior of coal combustion byproducts (CCBs). CCBs include various types of coal ash, flue gas desulfurization solids, and boiler slag. The most widely used procedure is the Toxicity Characteristic Leaching Procedure (TCLP), which was designed by the United States Environmental Protection Agency to "determine the mobility of both organic and inorganic analytes present in liquid, solid and multiphasic wastes"(USEPA 1992). However, this test may only account for fast reactions that take place in short term leaching processes (Yan et al. 2000). The results obtained with the TCLP on a limited number of fly and bottom ash samples showed that the range of concentrations of specified constituents was well below regulatory limits (Muraka et al. 1993). These residues are therefore classified as non-hazardous wastes and can be disposed of on land without risk of contaminating groundwaters to the extent of exceeding drinking water standards. However, Bhumbla et al. (2000) concluded that environmental concerns about toxic element release from fly ash amended soils have been lessened by evaluation of data from short-term studies in highly alkaline environments. They point out that all soils in humid regions ultimately become acidic and that the behavior of ash under conditions pertaining over the long term needs to be addressed. They encouraged a better understanding of the mechanisms and rates of trace element release from CCBs so that behavior over the long term can be predicted**.**

Regulatory agencies, industry, and the public need a tool for quantitative prediction of leachate composition to properly assess the risks and benefits of a particular CCB application for mine reclamation. Currently applied laboratory extraction procedures yield imprecise estimates of field leachate composition and field studies alone do not provide the causal relationships for the observed behavior. Also, since TCLP and SPLP use standard leaching solutions, they do not predict interactions between the solid waste and components of a specific mine water. Therefore, our research has focused on developing improved laboratory methods for predicting the leaching behavior of CCBs under field conditions. The geochemical reactions of dissolution/precipitation, adsorption/desorption, and oxidation/reduction are recognized as controlling the mobilization of various constituents from solid residues (Ainsworth and Rai 1987, Roy and Griffin 1982).

To address these uncertainties, a leaching procedure has been developed that, through an empirical procedure, recognizes the interactions among mine water chemistry and specific CCBs. This sheds light on the fundamental geochemical reactions critical to interpretation and prediction of leachate chemistry and interactions with various

geological materials. Such laboratory studies can be conducted for a wide range of conditions, such as pH, complexations, and ionic strength of leachates and porewaters that would be encountered at different field sites. It is hoped that the result will yield a laboratory procedure that will recognize site conditions and predict in a timely and inexpensive manner the risks and benefits of CCB applications in coal mines. We are attempting to first isolate the modeled system first as an interaction between mine water and the CCB. Subsequent study will include interactions between the resulting leachate and the mine spoil.

Experimental System

Figure 1 illustrates the model that we are attempting to simulate. It assumes that all metal ions are imported either via the acidic mine groundwater or the CCB. The shaded squares indicate that the metal ions reside in the solid phase and the white squares indicate aqueous compartments. Initially, acid/base neutralization reactions occur between the CCB and the AMD. This step may persist over many years and it is a function of the alkalinity content of the CCB, its permeability and the acid flux generated by the AMD. Contact between AMD and CCB groundwater can liberate ions through dissolution of the CCB and immobilize others as hydroxides, complexes or through adsorption to precipitated metal hydroxides. These hydroxides may dissolve and adsorbed ions may be released as the pH changes. Heavy lines in Figure 1 indicate immobilization pathways leading to storage in residual solids. Thin lines indicate transfer to mobile or aqueous phases as dissolved ions.

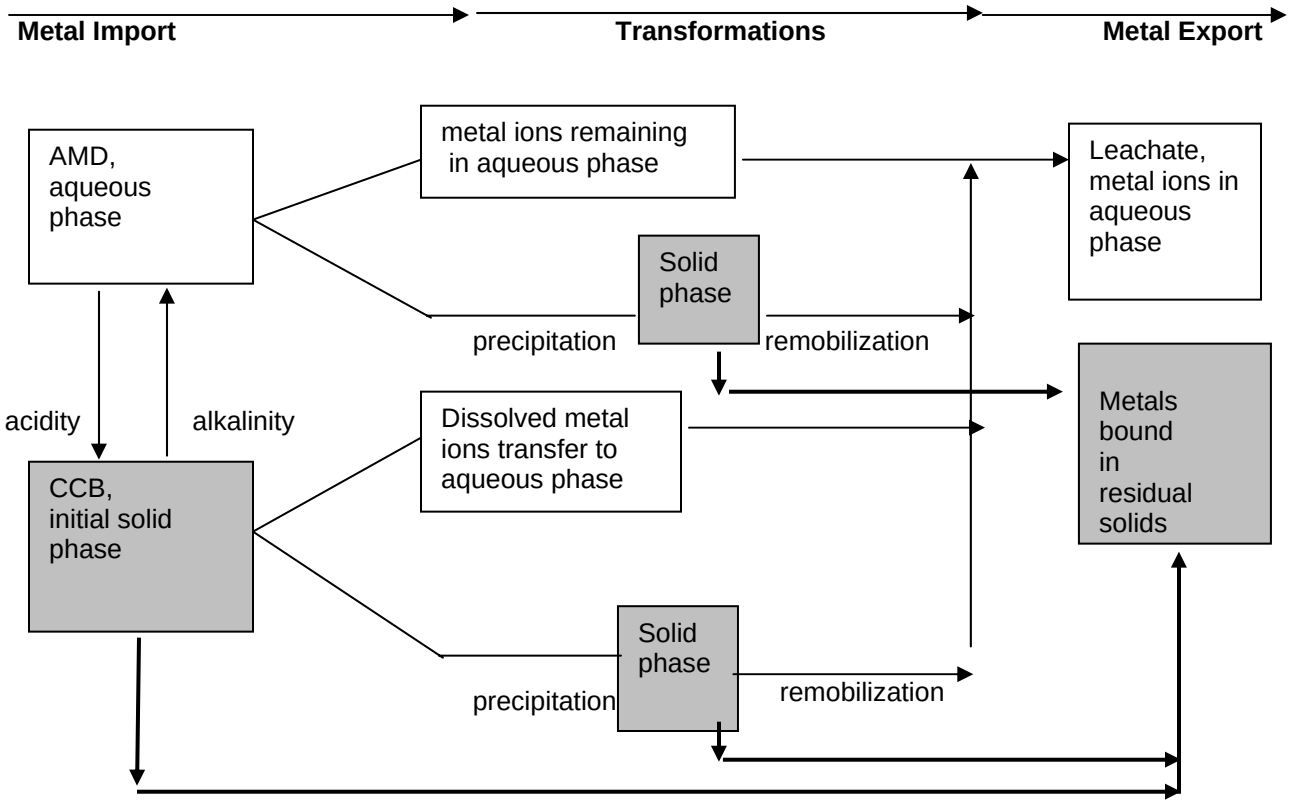

Figure 1. Diagram of the experimental system. *Metals can be imported to the system from either the AMD (aqueous form) or the waste (solid form). Once in the system, metals can either stay in the aqueous phase, precipitate into the solid phase or resolubilize into the aqueous phase.*

The above model does not account for interactions with mine spoil. Rather, this is a first step toward a systematic study of the factors that mobilize and immobilize toxic ions in CCB-minefill settings. Here we only explore the interaction of CCB and the mine's groundwater. Our objective is to test the validity of the laboratory leaching procedure by comparing the results with actual field results using the same CCB and AMD. Throughout, we are using the Mine Water Leaching Procedure (MWLP). It was developed to provide a site-specific risk assessment tool for CCB-minefills. The procedure was developed to determine the long-term leaching potential of toxic elements present in industrial wastes when placed in the groundwater found at a specific mine. Of particular concern is the leaching behavior of these materials when placed in acidic environments associated with reclamation of acidic mine spoils.

It is recognized that correlations between leaching studies and field observations are tenuous at best. We hope that by studying the laboratory leaching behavior of individual parameters and by comparing the results to multiple field sites we can begin to distinguish laboratory artifacts and parameters that have predictive value.

Use of CCBs for Coal Mine Reclamation

According to the American Coal Ash Association, 122 million tons of CCBs were produced by the power generating utilities in 2003. Of that total, 2.23 million tons were used in mining applications (American Coal Ash Association 2004). CCBs are used as structural fills in mining and are also used to control acid mine drainage, subsidence, and for soil reclamation (Butalia and Wolfe 2000). Class C Fly ash and Class F fly ash mixed with lime exhibit self-cementing properties and can be used to cap surfaces, line pavements, and isolate acidic materials in the backfill to prevent AMD formation. In addition, highly alkaline CCBs, such as FGD and FBC residues, are used to directly neutralize acidic materials.

Fly ash generally has a strong influence on spoil pH (Elseewi et al. 1980). Fly ashes are commonly alkaline but may be neutral or acidic as a function of CaO, salts, and various amorphous oxides of Fe, which adhere to the exterior of the fly ash spheres (Martens 1971). Alkalinity released as CaO is liberated from the dissolving alumino-silicate matrix (Elseewi et al. 1980, Hodgson and Brown 1982). Alkaline fly ashes normally contain sufficient neutralization capacity to raise the pH of acid soils (Hodgson and Holliday 1966). While many class F fly ashes have a high paste pH (10 to 12), their neutralization potential is low so extremely high additions (up to 625 tonnes of fly ash per hectare) may be needed to sustain a neutral pH in acidic coal mine soils (Jastrow et al. 1981, Keefer et al. 1983, Phung et al. 1978). There have been several case studies on the direct neutralization of AMD using highly alkaline CCBs (Ashby 2001, EPRI 2001).

CCBs are also used during surface reclamation to improve soil physical and chemical properties of acidic minesoils (Capp 1978, Singh et al. 1992). A study conducted by Dhaliwal and associates compared the properties of a mineland area reclaimed with fly ash to an adjacent area that received no fly ash. Even after 22 years the fly ash treated mine soil had a higher pH and thicker organic horizon than the adjacent untreated area (Dhaliwal et al. 1995). Bhumbla used a fly ash/rock phosphate mixture as a topsoil substitute and found that fly ash addition improved certain physical conditions of the mine soils and reduced Al, Fe, and Mn toxicities (Bhumbla 1991).

Placement of coal combustion byproducts (CCBs) in coal mines raises the prospect of reactions with geochemically aggressive, acidic groundwater in the mine. The CCPs are generally alkaline and are often seen as valuable amendments for groundwater improvement. However, the weathering behavior of CCPs will change with exhaustion of their alkalinity and regulatory agencies need to know the potential to leach toxic elements over extended time periods.

Materials and Methods

Field Sites

Coal ash and acid groundwater (AMD) were collected from two sites where FBC ash had been used to line the acid-generating mine floor rock and also to isolate toxic materials in the backfill of two surface mines in North Central West Virginia. One mine is in Monongalia County (Site M) and the other is in Preston County (Site P). Site M produces a mild AMD with a pH of 4.5, [acidity]: 144 mg/L, [Fe]: 5 mg/L and [Mn]: 0.3 mg/L and [Al]: 23 mg/L.

This site is a contour surface mine where a 0.3 m layer of compacted FBC ash was placed on the pit floor prior to backfilling and another 0.3 m layer placed over the pyritic spoil prior to placement of the final soil cover. This method has prevented further AMD formation on the site. We collected our AMD sample from earlier mining works on the same mine that had not received the FBC ash treatment.

The Site P surface mine recovered coal from a more highly pyritic seam. As a result the AMD is more strongly acidic. The pH is 2.9, [acidity]: 766 mg/L, [Fe]: 169 mg/L, [Mn]: 2 mg/L and [Al]: 39 mg/L. FBC ash placement was similar to Site M. The FBC ash used at both mines came from the same FBC unit. FBC ash had been applied to both sites about 10 years prior to sampling.

Field Sampling

The pH and water temperature were taken with a Hanna Waterproof pH Tester. Sample bottles for water samples were acquired from a State certified analytical laboratory. Two sample bottles were used per sample: one non-acidified bottle for analyzing lab pH, acidity, alkalinity, conductivity, and SO_4; and one acidified bottle for analyzing metals such as Fe, Al, Mn, Ca, Mg, As, Ag, B, Be, Ba, Sb, Cd, Cr, Hg, Ni, Pb, Se, Tl, V, and Zn. A non-acidified bottle was used to acquire the first sample. The bottle was rinsed with the sampled water three times before it was entirely filled with the sample. The non-acidified sample was refrigerated until taken to the analytical laboratory. The second acidified bottle was filled with a filtered water sample. A cleansed syringe with a 0.45µm filter was attached and at least 80 mls of water were filtered into the pre-acidified bottle. Samples were taken to the State certified analytical laboratory for analysis within 48 hours

All samples were collected on 20 September 2004. Estimated flows at Site M were about 20 gpm while those at Site P were about 60 gpm Samples were collected at seeps from both ash treated and untreated locations at each site. Water from the untreated sites was then used as the sites's AMD sample and was used as the leachant for the laboratory leaching tests.

Laboratory leaching procedure

We used the Mine Water Leaching Procedure (MWLP) (Ziemkiewicz et al. 2003a, Ziemkiewicz et al. 2003b) as our laboratory leaching method. It was developed to sequentially leach a particular CCP with the target mine's groundwater to evaluate which elements are likely to be mobilized as alkalinity is exhausted. This provides insight into long-term behavior as well as physical and chemical interactions among the reaction products. This study compared the results of laboratory MWLP leachings with field observations at large-scale CCP applications at acid producing coal mines. Ten grams of coal ash were weighed out and transferred into clean, dry, 2-L plastic reaction bottles. Two liters of AMD were added to each experimental bottle. The bottles were then sealed. The bottles were then agitated for 18 hrs on an end-over-end rotating platform at 30 rpm. After agitation the contents of each bottle were filtered through a 0.7 um glass, borosilicate filter using a stainless steel pressure filtration unit at or below 40 psi. Filtered leachate samples were then analyzed for acidity, pH, electrical conductivity, Al, As, Ag, B, Ba, Be, Ca, Cd, Cr, Cu, Fe, Hg, Mg, Mn, Ni, Pb, Sb, Se, SO_4, Tl, V, and Zn. Acidity was calculated from pH and major metal concentrations by the formula:

$$Acidity = 50(1000(10^{-pH}) + \sum_{i=1}^{n}(O_{me}[Me]/A_{me})_i) \qquad (1)$$

where: *acidity is given in mg/L $CaCO_3$ equivalent*
O_{me} = oxidation state of metal ion i
[Me] = concentration of metal ion i in mg/L
A_{me}= atomic weight of metal ion i

Since pH, Fe, Mn, and Al account for virtually all of the acidity in coal mine drainage, the following formula is used:

$$acidity = 50((1000x10^{-pH})+(3x[Fe]/55.8)+(2x[Mn]/54.9)+(3x[Al]/27)) \quad (2)$$

Leaching cycles were repeated until the pH approached that of the mine water. This required only five cycles for the more acidic AMD from Site P while after 15 leaching cycles the Site M samples were still above the pH of the AMD leachant. Method detection limits are given in tables 1 and 2. In order to facilitate calculation, analytical results that were below the detection limit were assigned the detection limit.

Results and Discussion

Interpretation of laboratory and field data: The following discussion includes absolute and proportional data. The latter may be easily misinterpreted. For example, net gains in elemental concentrations may be almost infinitely large, particularly with parameters that start at near detection limits. Apparently large proportional increases may reflect nearly trivial changes in concentration. For example, an increase from 0.001 to 0.010 mg/L represents a 900% increase yet the parameter may still meet primary drinking water standards. Obviously, the converse applies. On the other hand, decreases in a given parameter obviously cannot exceed 100%. For these reasons, both absolute and proportional data as well as U.S. primary drinking water standards are given to help the reader evaluate the significance of a given change in concentration. In summary, proportional changes in concentration are used to identify statistical trends, they do not imply environmental significance.

The laboratory results reflect a pure system with controlled inputs and outputs. The field data are subject to many confounding factors: unknown degree of contact between groundwater and FBC ash, interactions of the leachate with mine spoil, dilution with other groundwater streams, uncertain groundwater flow paths as well as redox zonation with the spoil. Nonetheless, comparison of the laboratory and field data will help identify those elements whose field behavior is predictable from empirical, laboratory testing and those that undergo significant interactions with the mine spoil

Leaching Studies

Leaching FBC ash with Site M mine drainage caused an immediate rise in pH from 4.5 to 9.6 which then declined very gradually (Table 1). Surprisingly, acidity values remained well above alkalinity even with pH values at or above neutral. This coincides with an increase in Mn values throughout the leaching cycles starting at 0.3 mg/L in the leachant, reaching a maximum of 70.3 mg/L at cycle 5 and falling no lower than 47 mg/L by cycle 15. $Mn(OH)_2$ is soluble at a pH below 9.6 so after the leachate pH fell below this level by cycle 5, Mn began appearing in solution. The spike in Mn concentration probably resulted from solubilization of previously precipitated $Mn(OH)_2$ in the filter cake. Formula (1) illustrates how this soluble Mn would account for this increase in acidity.

Table 1.
Changes in leachate chemistry through 5 leach cycles using 10g of FBC ash leached with AMD from the Site M surface mine. The far right column is the net difference between AMD and cycle 15 leachant.

	units	method detect. limit	US Primary DW Std.	Site M AMD	Cycle 1	Cycle 5	Cycle 10	Cycle 15	AMD vs. last cycle
pH				4.5	9.6	7.6	6.5	6.6	48%
acidity	mg/L			144.0	3.0	133.0	96.7	86.3	-40%
alkalinity	mg/L			0.0	20.6	13.3	37.8	53.8	
Mg	mg/L	0.1		374.1	247.0	420.9	333.5	333.5	-11%
Ca	mg/L	0.1		534.5	834.6	561.4	511.4	543.6	2%
Fe	mg/L	0.1		5.0	0.3	1.3	0.1	0.1	-98%
Al	mg/L	0.1		23.2	0.3	0.2	0.1	0.1	-100%
Mn	mg/L	0.1		0.3	0.2	70.5	52.7	47.0	15344%
SO4	mg/L	10		2590.7	2587.2	2847.4	2660.6	2908.1	12%
Sb	mg/L	0.00087	0.006	0.00087	0.00087	0.00087	0.00087	0.00087	0%
As	mg/L	0.00410	0.05	0.00410	0.00410	0.00410	0.00410	0.00410	0%
B	mg/L	0.01000	2	0.03120	0.11747	0.10200	0.08307	0.11367	264%

Table 1 continued.

	units	method detect. limit	US Primary DW Std.	Site M AMD	Cycle 1	Cycle 5	Cycle 10	Cycle 15	AMD vs. last cycle
Ba	mg/L	0.00116	0.004	0.00116	0.10292	0.02324	0.01528	0.01650	1323%
Be	mg/L	0.00071	0.005	0.01091	0.00710	0.00710	0.00710	0.00710	-35%
Cd	mg/L	0.00191	0.1	0.00191	0.00191	0.00191	0.00191	0.00191	0%
Cr	mg/L	0.00089	0.015	0.00089	0.00089	0.00089	0.00089	0.00089	0%
Pb	mg/L	0.00135	0.002	0.00135	0.00135	0.00135	0.00135	0.00135	0%
Hg	mg/L	0.00050	0.05	0.00050	0.00050	0.00050	0.00050	0.00154	209%
Se	mg/L	0.01350		0.01350	0.04118	0.02197	0.01350	0.01350	0%
Ag	mg/L	0.00115	1.3	0.00115	0.00115	0.00115	0.00115	0.00115	0%
Cu	mg/L	0.00046		0.02139	0.00046	0.00741	0.00046	0.00046	-98%
Ni	mg/L	0.00242	0.002	0.88031	0.02971	1.09037	0.73447	0.50629	-42%
Tl	mg/L	0.00173		0.00173	0.00173	0.00173	0.00173	0.00173	0%
V	mg/L	0.00089		0.00089	0.00089	0.00089	0.00089	0.00089	0%
Zn	mg/L	0.00352		1.52641	0.00894	0.33229	0.25811	0.20112	-87%
Cond	Umhos/cm			1458	2232	1448	1479	1390	-5%

NM = Not Measured

The far right column in Table 1 shows the net change in each parameter during the leaching procedures. Net change is expressed as a percent change in concentration between the raw AMD leachant and cycle 15 leachate. The final cycle was chosen since this was expected to most closely approximate long-term conditions in the field. The most dramatic change was a 15,000% increase in Mn concentration. Ba accounted for the second largest increase. Increases in both B and Hg were about 200%. Note that the concentrations of elements such as B, Ba and Hg were well below 1 mg/L and that in the case of Hg, levels were near the method detection limit. Other than Mn, all of the parameters that increased under leaching with the mildly acidic Site M water were either volatile or semi-volatile ions that are known to adhere to the outer surface of the ash particles. Thus leaching, rather than dissolution of the ash's alumino-silicate matrix probably accounts for much of the ionic increase. Major decreases occurred in the concentrations of acidity, Fe, Al, Cu, Be, Ni, and Zn. Their proportional reductions ranged from 35 to 100%. Nine of the parameters were unchanged reflecting non-detectable levels in both the AMD leachant and the resulting leachates.

Leaching the same FBC ash with the more acidic Site P water yielded a very different picture (Table 2). For example, even though a pH of 9.4 was reached on the original leach cycle, its strong acidity caused the original pH of 2.9 to be reached in only five leach cycles. Rather than a strong increase in Mn, it decreased by 11%. The greatest increases were in Al, Zn, Ni, Cr, Cu, Pb, Ba, V and Ag. The greatest decreases were in As, Hg, Fe, Cd, B, Tl, Se, and acidity. Fourteen of the twenty-five parameters decreased and pH was unchanged. Perhaps the most interesting result was for As. Its concentration in the untreated site's AMD was 0.025 mg/L and it declined to 0.002 mg/L (the method detection limit) after five leach cycles, never exceeding 0.005 mg/L. This may be the result of an interaction with the high iron content of the Site P AMD since the arsenate oxyanion is strongly adsorbed to precipitated ferrihydrite which has an anion exchange capacity at low pH. As was below the method detection limit in Site M water both in the AMD and through all leach cycles. Sorption to positively charged ferrihydrite surfaces may explain the decreases in the other elements that form oxyanions such as: Tl, B, Se, SO_4, and Be.

Table 2. Changes in leachate chemistry through 5 leach cycles using 10g of FBC ash leached with AMD from the Site P surface mine. The far right column is the net difference between AMD and cycle 5 leachant.

	units	method detect. limit	US Primary DW Std.	Site P AMD	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	AMD vs. last cycle
pH				2.9	9.4	4.4	4.0	3.2	2.9	0%
acidity	mg/L			766.3	12.4	51.8	482.7	504.8	567.0	-26%
alkalinity	mg/L			0.0	49.4	0.0	0.0	0.0	0.0	
Mg	mg/L	0.1		36.6	16.9	46.4	39.2	37.1	33.8	-8%
Ca	mg/L	0.1		48.8	97.4	110.5	39.2	33.7	45.3	-7%
Fe	mg/L	0.1		168.6	0.5	0.6	0.7	1.2	58.6	-65%
Al	mg/L	0.1		39.0	2.0	7.6	84.7	84.4	58.4	50%
Mn	mg/L	0.1		2.0	0.0	3.4	2.0	1.8	1.7	-11%
SO4	mg/L	10		1529.0	1663.7	1409.3	1479.3	4950.3	1442.0	-6%
Sb	mg/L	0.00087	0.006	0.04800	0.05333	0.05567	0.04667	0.05533	0.04867	1%
As	mg/L	0.00200	0.05	0.02500	0.00233	0.00467	0.00133	0.00233	0.00167	-93%
B	mg/L	0.01000	2	0.24700	0.41300	0.35767	0.28833	0.18900	0.11833	-52%
Ba	mg/L	0.01000	0.004	0.01000	0.01000	0.02000	0.01333	0.01333	0.04000	300%
Be	mg/L	0.00010	0.005	0.00850	0.00123	0.00523	0.01050	0.00983	0.00743	-13%
Cd	mg/L	0.00010	0.1	0.00400	0.00403	0.00560	0.00327	0.00203	0.00177	-56%
Cr	mg/L	0.00010	0.015	0.00570	0.00780	0.00343	0.00547	0.01433	0.01733	204%
Pb	mg/L	0.00300	0.002	0.00400	0.02567	0.04067	0.03367	0.05200	0.05567	1292%
Hg	mg/L	0.00010	0.05	0.00070	0.00030	0.00013	0.00040	0.00023	0.00010	-86%
Se	mg/L	0.00300		0.01600	0.00867	0.00867	0.02733	0.01167	0.01133	-29%
Ag	mg/L	0.00115	1.3	0.00200	0.02000	0.00467	0.00567	0.00767	0.00500	150%
Cu	mg/L	0.00010		0.18400	0.00700	0.12367	0.38600	0.36433	0.23567	28%
Ni	mg/L	0.00200	0.002	0.18800	0.02667	0.45867	0.35233	0.31200	0.26067	39%
Tl	mg/L	0.00100		0.02100	0.01400	0.01600	0.05533	0.02833	0.01200	-43%
V	mg/L	0.00089		0.00300	0.00467	0.00900	0.00800	0.00833	0.01100	267%
Zn	mg/L	0.00100		1.24000	0.00833	2.30000	1.72000	1.42667	1.37333	11%
Cond	Umhos/cm			2910	2423	2117	1834	1983	2500	-14%

Other than Al and Ba, all of the ions mobilized by the strongly acidic Site P water were transition metals. Al increased by 50% suggesting dissolution of the alumino-silicate ash matrix and exposure of the embedded metal ions to mobilization. In contrast, leaching the FBC ash with Site M water resulted in a net loss of Al.

Field Observations

At the Site M surface coal mine, ash application raised the pH from 4.5 to 7.4 changing the groundwater from net acid (144 mg/L) to net alkaline (96 mg/L) (Table 3). On the ash site, ten parameters increased and fifteen decreased. The largest proportional increases were in V, Ba, Cr, and Ag. Increases also occurred in Mn, B, Sb, and Cd. Nearly 100% decreases occurred in Al, Zn, Ni, Fe, and Se. Smaller but substantial decreases occurred in Mg, Be, As, SO4, Hg, Ca, Tl, and Pb.

Table 3. Comparison of drainage from sites with and without FBC ash application: Site M surface mine.

	units	method detect. limit	US Primary DW Std.	no ash applied	ash applied	net change
pH				4.5	7.4	65%
acidity	mg/L			144.0	3.6	-97%
alkalinity	mg/L			0.0	100.0	0%
Mg	mg/L	0.1		374.1	111.0	-70%
Ca	mg/L	0.1		534.5	238.0	-55%
Fe	mg/L	0.1		5.0	0.4	-93%
Al	mg/L	0.1		23.2	0.1	-100%
Mn	mg/L	0.1		0.3	1.3	311%
SO4	mg/L	10		2590.7	795.0	-69%
Sb	mg/L	0.00087	0.006	0.00087	0.00500	475%
As	mg/L	0.00200	0.05	0.00410	0.00100	-76%
B	mg/L	0.01000	2	0.03120	0.10000	221%
Ba	mg/L	0.01000	0.004	0.00116	0.10000	8521%
Be	mg/L	0.00010	0.005	0.01091	0.00500	-54%
Cd	mg/L	0.00010	0.1	0.00191	0.00500	162%
Cr	mg/L	0.00010	0.015	0.00089	0.05000	5518%
Pb	mg/L	0.00300	0.002	0.00135	0.00100	-26%
Hg	mg/L	0.00010	0.05	0.00050	0.00020	-60%
Se	mg/L	0.00300		0.01350	0.00200	-85%
Ag	mg/L	0.00115	1.3	0.00115	0.01000	770%
Cu	mg/L	0.00010		0.02139	0.02000	-6%
Ni	mg/L	0.00200	0.002	0.88031	0.04000	-95%
Tl	mg/L	0.00100		0.00173	0.00100	-42%
V	mg/L	0.00089		0.00089	0.10000	11136%
Zn	mg/L	0.00100		1.52641	0.05600	-96%
Cond	Umhos/cm			1458	2180	50%

At Site P the pH was 2.9 on the non ash treated location and 4.3 at the ash treated site. Groundwater acidity decreased from 766 mg/L to 308 mg/L. Despite ash treatment, this remained an acid dominated groundwater. The largest relative increases in elemental concentrations were in V, Ba, Cr, Ni, Ag, Mn, Ca, Mg, Be, Cd, and Zn. Of these Mg, Ca, and Ba are semi-volatile alkaline earths known to form soluble salts on the exterior of the fly ash particles. The transition metals, Ni, Ag, Mn, Cd, and Zn, are present in solution as free metal ions are soluble at low pH and form insoluble hydroxides at high pH. All are soluble at pH 4.3. Decreases of between 60 and 100% were observed for Fe, As, Tl, Se, Hg, acidity, B, Cu, and Sb. Sorption to precipitated ferrihydrite may partly explain the decreased mobility of the anionic species: As, Tl, Se, and B.

Table 4. Comparison of drainage from sites with and without FBC ash application: Site P surface mine.

	units	method detect. limit	US Primary DW Std.	no ash applied	ash applied	net change
pH				2.9	4.3	51%
est. acidity	mg/L			766.3	308.4	-60%
alkalinity	mg/L			0.0	0.0	0%
Mg	mg/L	0.1		36.6	206.0	463%

Table 4 continued.

	units	method detect. limit	US Primary DW Std.	no ash applied	ash applied	net change
Ca	mg/L	0.1		48.8	471.0	865%
Fe	mg/L	0.1		168.6	0.2	-100%
Al	mg/L	0.1		39.0	47.6	22%
Mn	mg/L	0.1		2.0	22.4	1049%
SO4	mg/L	10.0		1529.0	1750.0	14%
Sb	mg/L	0.00087	0.006	0.04800	0.00500	-90%
As	mg/L	0.00200	0.05	0.02500	0.00100	-96%
B	mg/L	0.01000	2	0.24700	0.10000	-60%
Ba	mg/L	0.01000	0.004	0.01000	0.10000	900%
Be	mg/L	0.00010	0.005	0.00850	0.03500	312%
Cd	mg/L	0.00010	0.1	0.00400	0.00800	100%
Cr	mg/L	0.00010	0.015	0.00570	0.05000	777%
Pb	mg/L	0.00300	0.002	0.00400	0.00400	0%
Hg	mg/L	0.00010	0.05	0.00070	0.00020	-71%
Se	mg/L	0.00300		0.01600	0.00200	-88%
Ag	mg/L	0.00115	1.3	0.00200	0.01000	400%
Cu	mg/L	0.00010		0.18400	0.07000	-62%
Ni	mg/L	0.00200	0.002	0.18800	1.13000	501%
Tl	mg/L	0.00100		0.02100	0.00100	-95%
V	mg/L	0.00089		0.00300	0.10000	3233%
Zn	mg/L	0.00100		1.24000	3.29000	165%
Cond	Umhos/cm			2910	4310	48%

Though preliminary, it seems that the 22 elemental test parameters fall into three broad, activity classes:

Activity class A: semi-volatile cations: Ba, Ca, Mg, Hg removal mechanism: Other than Hg, these form the cation in salts coating the ash particles.

Primary removal mechanism: cation exchange with spoil clays

Activity class B: oxyanions: B, Se, As, Tl, Cr, V, SO_4
While these include semi-volatiles, their behavior is likely dominated by their tendency to form oxyanions in aqueous phase. Redox conditions are important in determining their tendency to sorb to ferrihydrites and clays.

Primary removal mechanism: sorption to ferrihydrite at low pH

Activity class C: metal cations: Al, Be, Zn, Ni, Fe, Cu, Mn, Pb, Cd, Sb, Ag
The soluble phases of these metals are dominated by free cations that form insoluble hydroxides with increasing pH. Some like Fe and Mn have multiple oxidation states, the oxidized forms having lower solubilities.

Primary removal mechanism: precipitation as hydroxides at high pH

While hypothetical, systematic investigation of these removal pathways will enhance our understanding of their behavior in mine groundwater settings.

It is important to note that even after 15 leach cycles the Site M leaching procedure still had not exhausted the alkalinity in the ash sample. Site M water had a pH of 4.5 and after the final leaching the pH was 6.6, while the Site P water had returned to its original pH of 2.9 after five leach cycles indicating exhaustion of the ash's inherent alkalinity. This may account for some of the differences in results between the two laboratory leaching results.

Comparison of Laboratory and Field Results

The effects of ash on laboratory and field concentrations were compared to identify which field trends (increasing or decreasing) were correctly predicted by the laboratory leaching procedure (Table 5). Trends in twelve of the twenty-five parameters were correctly predicted at Site M. Fourteen of twenty-five parameters were correctly predicted at Site P. Seven parameters were successfully predicted on both sites while six were not successfully predicted on either site. The remaining elements were successfully predicted on at least one of the two field sites. Considering the many other factors that influence field leachate quality, these results indicate significant promise for predicting the effects of CCB minefills on a mine's water quality. Future study will undertake a detailed statistical analysis in the field and the laboratory to identify an improved risk assessment method. Also, sequential extraction of the residual solids would assist in interpreting the sequestration mechanisms. Approached systematically, we will begin to understand the effects of mine water on CCBs and the effects of spoil composition and hydrology on the resulting leachates.

Table 5. This table illustrates the ability of the MWLP leaching procedure to predict increasing (positive values) or decreasing (negative) trends. Field and laboratory data representing Sites M and P are given. Where the MWLP correctly predicted increasing or decreasing trends in the field data, the row was assigned a 'yes' while those trends that were not correctly predicted were assigned a 'no'. Activity classes represent: A-semi-volatile cations, B-oxyanions, C-metal cations.

Site M Surface Mine (mildly acidic AMD)					Site P Surface Mine (strongly acidic AMD)				
	Activity class	MWLP results	Field data	predicted trend?		Activity class	MWLP results	Field data	predicted trend?
Al	C	-100%	-100%	yes	Fe	C	-65%	-100%	yes
acidity		-40%	-97%	yes	As	B	-93%	-96%	yes
Zn	C	-87%	-96%	yes	Tl	B	-43%	-95%	yes
Ni	C	-42%	-95%	yes	Se	B	-29%	-88%	yes
Fe	C	-98%	-93%	yes	Hg	A	-86%	-71%	yes
Mg	A	-11%	-70%	yes	acidity		-26%	-60%	yes
Be	C	-35%	-54%	yes	B	B	-52%	-60%	yes
Cu	C	-98%	-6%	yes	Al	C	50%	22%	yes
pH		48%	65%	yes	Zn	C	11%	165%	yes
B	B	264%	221%	yes	Ag	C	150%	400%	yes
Mn	C	15344%	311%	yes	Ni	C	39%	501%	yes
Ba	A	1323%	8521%	yes	Cr	B	204%	777%	yes
Se	B	0%	-85%	no	Ba	A	300%	900%	yes
As	B	0%	-76%	no	V	B	267%	3233%	yes
SO4	B	12%	-69%	no	Sb	C	1%	-90%	no
Hg	A	209%	-60%	no	Cu	C	28%	-62%	no
Ca	A	2%	-55%	no	Pb	C	1292%	0%	no
Tl	B	0%	-42%	no	SO4	B	-6%	14%	no
Pb	C	0%	-26%	no	Cond		-14%	48%	no
Cond		-5%	50%	no	pH		0%	51%	no

Table 5 continued.

Site M Surface Mine (mildly acidic AMD)						Site P Surface Mine (strongly acidic AMD)				
	Activity class	MWLP results	Field data	predicted trend?			Activity class	MWLP results	Field data	predicted trend?
Cd	C	0%	162%	no		Cd	C	-56%	100%	no
Sb	C	0%	475%	no		Be	C	-13%	312%	no
Ag	C	0%	770%	no		Mg	A	-8%	463%	no
Cr	B	0%	5518%	no		Ca	A	-7%	865%	no
V	B	0%	11136%	no		Mn	C	-11%	1049%	no

Trends for elements in activity classes A and C: semi-volatile cations and metal cations respectively were evenly divided with respect to predictability. However, trends for all but one of the oxyanions comprising activity class B were not predicted by leaching procedure with Site M AMD while all but one were successfully predicted for Site P. This may be explained by the high iron content of Site P water and the availability of ferrihydrite as a scavenging agent for oxyanions at pH 2.9.

Conclusions

This study attempts field verification of the results of a laboratory leaching procedure that uses mine water to sequentially leach coal ash. In addition, we attempted to begin the process of identifying which chemical parameters could be predicted in the laboratory.

The Mine Water Leaching Procedure is a sequential leaching procedure that was developed to determine the long-term leaching behavior of industrial wastes in acidic mine environments. The complex hydrology, redox, and geochemical conditions found within the backfills of most surface mines are difficult, if not impossible to reproduce in a laboratory setting. However, preliminary comparisons of MWLP leachates with field leachates indicates that this procedure may be a valuable tool for predicting the overall trend of leaching behavior for CCBs placed in unique acidic environments.

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Dr. Paul Ziemkiewicz is the Director, West Virginia Water Research Institute, West Virginia University and the National Mine Land Reclamation Center. He has over eighty publications including publications on Coal Combustion By-Products related to coal mining issues. His most recent publications is on Prediction of Coal Ash Leaching Behavior in a Acid Mine Water: Comparison of Laboratory and Field Studies. His related associations include: Member, Board of Directors, National Environment and Education Training Center, Research Associate Professor of Plant and Soil Science, West Virginia University, Research Professor, Department of Biology, West Virginia University, Member, West Virginia Acid Mine Drainage Task Force, Member, Eastern Mine Drainage Federal Consortium, Technical Support Team Leader: Appalachian Clean Streams Initiative/Acid Drainage Technology Initiative, Member, National Research Council Study Team: Water Quality in the Pittsburgh Region, Member, West Virginia Special Reclamation Fund Advisory Council, and Member, Board of Directors, The Annapolis Center for Science-Based Public Policy. He holds a B.S. from Utah State University with a major in Biology and minor in Chemistry. He holds a M.S. from Utah State University in Range Ecology and a Ph.D. from the University of British Columbia in Forest Ecology.

THE USE OF LEACHATE DATA AND OTHER FACTORS IN EVALUATING CCB's FOR PLACEMENT AT COAL MINE SITES IN PENNSYLVANIA

Michael J. Menghini, Roger J. Hornberger and Alfred D. Dalberto
Pennsylvania Department of Environmental Protection

Abstract

Leachate data, proposed site characteristics, and various other factors are all part of the assessment process that is utilized to evaluate a proposed coal ash utilization permit for a mine site. The assessment evaluates the likelihood of the coal ash degrading the ground and surface water associated with the proposed utilization site and serves as the basis for approval or denial of the proposed site. Some factors employed in the assessment are more important than others, but all factors should be utilized to determine the feasibility of a proposed coal ash utilization site.

Introduction

The assessment process utilized to evaluate a proposed coal ash site has been developed, critiqued, and refined over the past 15 to 20 years as each site is evaluated and reevaluated in respect to what effect the coal ash placement has on the site and surrounding areas. Additional items to review have also been identified during the refinement period, as well as scientific information that has been obtained through coal ash research and several coal ash demonstration projects. State regulatory requirements and the type of beneficial use are also an integral part of any application review and assessment. All of these items serve as the basis for our review process and conclusions related to the beneficial use of coal ash for mine reclamation.

Regulatory Framework

Coal ash is defined in Pennsylvania's Solid Waste Management Act as fly ash, bottom ash, or boiler slag resulting from the combustion of coal. This includes the ash generated from coal refuse; however, ash generated from burning waste material (e.g. petroleum coke) with coal is not considered coal ash under this definition. The addition of waste from pollution devices (e.g. wet scrubber sludge) to the coal ash also excludes that ash by this definition.

The beneficial use of coal ash in Pennsylvania is regulated under the Solid Waste Management Act, the Surface Mining Conservation and Reclamation Act, the Coal Refuse Disposal Act, the Clean Stream Law, and Air Quality Control Act.

Beneficial use of coal ash was authorized under the 1986 amendment to the Solid Waste Management Act (SWMA). SWMA authorized the beneficial use of coal ash for mine site reclamation along with other beneficial uses. Prior to 1986, the Department of Environmental Protection (DEP) required a residual waste disposal permit for the use of coal ash at mine sites. In 1992, the residual waste management regulations were amended in accordance with SWMA to regulate the beneficial use of coal ash at mine sites (under 25 Pa. Code Sections 287.661 to 287.666). The regulations were further revised in 1997 in regard to water monitoring, volumes of coal ash that may be used at mine sites, and certification guidelines for coal ash. In addition, the DEP developed a Memorandum of Understanding between its waste and mining programs and three technical guidance documents to further coordinate and manage the beneficial use of coal ash on both active and abandoned mine sites.

Types of Beneficial Uses Permitted on Mine Sites

Pennsylvania currently defines the following four uses of coal ash on active mine sites as beneficial uses: (1) alkaline addition; (2) low permeability material; (3) soil substitute or additive; (4) placement.

Alkaline addition takes advantage of the potential for some coal ashes to generate alkaline leachate and is used to offset the potential for on-site materials to generate acid mine drainage. Brady and Hornberger (1990), Perry and

Brady (1995), and Skousen et al. (2002) have shown in empirical studies of completed mine sites that post mining water quality correlates more strongly with the amount of alkaline material on a mine site than with the amount of sulfur in the rocks. According to Pennsylvania's current guidelines, to qualify for use as an alkaline addition agent the coal ash should have a neutralization potential (NP) of at least 100 parts per thousand and a pH of between 7.0 and 12.5. The amount of coal ash needed to offset potential acid production can be calculated using the methods described by Smith and Brady (1998).

Using coal ash as a low permeability material usually entails sealing or encapsulating materials on site that have the potential to produce acid mine drainage. Potential uses for coal ash as a low permeability material on a mine site include paving the pit floor, capping material segregated from the rest of the mine spoil due to its potential to generate AMD, encapsulating reject material on coal refuse reprocessing operations, and in some cases, capping entire sites or significant parts of sites. For use as a low permeability material on a mine site, coal ash should have pozzolonic characteristics and should be capable of achieving permeability equal to or less than 1.0×10^{-6} cm/sec under laboratory conditions.

As a soil supplement, alkaline coal ash is used as a liming agent and also to improve the physical characteristics of the soil or soil substitute being used as site cover. In some re-mining settings soil is not readily available, especially on coal refuse reprocessing operations, and coal ash can be used to enhance the characteristics of other on-site material to produce an acceptable growth medium. The soil/coal ash mixture must result in a pH between 6.5 and 8.0 to be considered suitable, and the amount of coal ash used must otherwise be commensurate with the need to establish a growth medium.

The term "ash placement" involves the use of coal ash on a mine site to backfill pits or re-contour refuse piles on re-mining sites. The pH of the coal ash must be in the range of 7.0 to 12.5 at the generator's site for placement approval.

In practice, coal ash use on a mine site typically fulfills more than one of the above beneficial use criteria. For example, coal ash being returned to a refuse reprocessing site may serve as an alkaline addition agent, an encapsulating agent (capping), as a soil additive, and for backfilling and re-contouring.

Summary of Present Permitting Requirements

The following discussion presents only some of the most significant of the permitting requirements for coal ash use on mine sites. For more detailed information, the reader should view the program guidance documents, permit modules and regulations, (25 Pa Code Sections 287.661-287.666) that are pertinent to ash use on mine sites and that are available on DEP's website at www.dep.state.pa.us. The reader should keep in mind that each mine site is different, and the data and information requirements may vary according to site-specific considerations.

Administrative Requirements

Beneficial use of coal ash on a surface mine site can be requested as part of an original permit application or as a permit amendment. Either way, public notice and public participation are an integral part of the review process for all beneficial uses of coal ash on mine sites, with the exception of use as a soil amendment or supplement, which involves the use of very small volumes of coal ash.

For mine sites where coal ash is used as an alkaline addition agent, low permeability material or for placement, the applicant must place a public notice in a local newspaper explaining the proposal. The public has the right to comment on the proposal and may request a public meeting or public hearing, if desired. The applicant must provide written approval from the landowner for the proposal, and the DEP office reviewing the application provides notice of the proposal to the local municipality, the county planning agency, and other state agencies. The review process is an open one with opportunity for input from individuals, organizations and local governments and other State agencies.

The application for use of coal ash on a mine site must include a detailed operational plan, which includes:

- Identification of the coal ash source(s);

- A certification from the coal ash generator(s);
- Amount of coal ash to be used;
- Purposes(s) of coal ash utilization;
- Operational details of how the coal ash is to be handled and incorporated into the site;
- A demonstration that the coal ash is chemically and/or physically suitable for the proposed use;
- Documentation of the hydrogeology of the coal ash-use area;
- A monitoring program, including background data collection, designed to show any influence of coal ash use on surface and groundwater quality.

Pre-testing of Coal Ash: Leachate Testing and other Requirements

An application for use of coal ash on mine sites must include chemical analyses of the ash proposed for use. An SPLP [synthetic precipitation leach procedure] leachate analysis is required for pH, sulfate, chloride, plus sixteen metals. Coal ash must meet the maximum acceptable leachate limits for contaminants, based on the minimum requirements for an acceptable waste at a Pennsylvania Class III residual waste landfill. Pennsylvania DEP and numerous other State and Federal regulatory agencies use the SPLP to evaluate the leaching behavior of coal ash and other residual wastes. The Synthetic Precipitation Leaching Procedure (SPLP) is Method 1312 in the EPA manual entitled Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, and it is designed to determine the mobility of both organic and inorganic analytes present in samples of soils, wastes, and waste waters.

This test method provides leachate data that serves several useful purposes in evaluating coal ash for mine placement. These purposes include: (a) comparison of the relative abundance of chemical elements in the solid ash to their relative concentration in the leachate, (b) determination of the leachability of an element of concern (e.g. aluminum or arsenic) in various coal ash samples, and (c) comparison of leachate data to a set of regulatory guidelines in a pass/fail context. An example of these guidelines is the "maximum acceptable leachate concentration" used by the Pennsylvania DEP waste management program and mining program, wherein the guideline numbers were developed by multiplying 25 times the drinking water standards for cations, and 10 times the drinking water standards for anions (e.g. Al=5.0 mg/l, As=1.25 mg/l, SO_4=2500 mg/l).

The use of SPLP data in comparing the relative abundance of chemical elements in the solid ash and leachate associated with two anthracite cogeneration plants is shown in several tables and figures in Hornberger et al. (2004, 2005). The leachate concentrations of major, minor, and trace elements can easily be compared to the solid ash analyses, and it is evident that the relative abundance of certain elements in the solid ash is not matched by their relative abundance in the leachate. For example, aluminum and potassium are more concentrated in the leachate than iron, and barium concentrations in the leachate are higher than manganese or zinc, while the barium content of the solid ash is several times greater than the manganese and zinc.

Some limitations or criticisms of the usefulness of the SPLP test deal with the pass/fail or go/no go nature of the results, as compared to other types of leaching test methods where the goal is to produce data on leaching rates over some unit of time. Therefore several researchers in government agencies, academia, and industry are either developing new leaching test methods or evaluating the usefulness of other existing leaching tests for coal ash evaluations.

Sorini (1997) from the Western Research Institute conducted a survey for the American Coal Ash Association of 56 leaching methods used in many countries that were classified into 8 types of test methods. Some of these leaching methods were developed under a major national program in the U.S. (e.g. Argonne National Laboratory, Pacific Northwest Laboratory) to study nuclear waste leaching processes as described in Scheetz et al. (1981), White (1986), Ebert and Bates (1992) and numerous other references. In the nuclear waste industry, a significant amount of research was done on leaching processes leading to the development of ANS 16.1 (American Nuclear Society, 1984) and the MCC1 leach test (Pacific Northwest Laboratory, 1980). An example of the use of the MCC1 leach

test on nuclear waste is described in Ebert and Bates (1992), while Zhao (1995) provides extensive data on leach testing of flyash and fluidized bed combustor (FBC) ash cements using the MCC1 test.

Currently Dr. Barry E. Scheetz and associates at the Materials Research Institute at the Pennsylvania State University are investigating modifications to the MCC-3S Agitated Powder Leach Test Method on the leaching behavior of a variety of FBC and PC coal ashes. Also, Ziemkiewicz et al. (2002) developed the Mine Water Leaching Procedure (MWLP) to evaluate the environmental risk of backfilling mines with coal ash. This MWLP method sequentially leaches the CCB material with a sample of the mine site groundwater until the alkalinity is exhausted and the pH of the leachate returns to that of the mine water samples.

In addition to the SPLP test results, results of a neutralization potential test must be provided if the proposed use is for alkaline addition, and a hydraulic conductivity test must be provided when the proposed use is as a low conductivity material. Coal ash generators may obtain Statewide certification of their ashes for specific uses through DEP's Bureau of Mining and Reclamation by submitting a request along with the analyses discussed herein, or the analyses data may be submitted to a DEP district mining office as part of a specific mine permit proposal. Periodic (typically biannual) re-certification and/or monitoring of the coal ash quality are required as long as the coal ash is being used on the mine site. The coal ash shipped from most power plants usually includes proportions of both fly ash and bottom ash and analyses should be provided of both.

When the proposed use of coal ash on a site is as a soil supplement or additive, the applicant must also provide a background soil analysis (from the mine site) for pH, PCB's, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc so that potential plant up-take levels may be considered as part of the permitting process.

Monitoring

Groundwater monitoring is required for all coal ash applications on mine sites, except for sites where the only application is as a soil amendment. The volume of coal ash used on soil application sites is so small as to negate the need for water monitoring. Surface water monitoring is required on coal ash sites where the coal ash may potentially affect any surface water in the vicinity of the proposed mine site.

For all other applications of coal ash on mine sites, groundwater monitoring is required before, during, and after ash placement on the site. Monitoring points are chosen so as to best show the effects, if any, of ash placement on the site. On many sites, especially re-mining sites, directly downgradient groundwater seeps, springs, and discharges may provide the most representative monitoring points for the site. Typically, the hydrologic connection of such groundwater discharges to the site is relatively clear, especially in re-mining cases, where the water quality data often prove the connection. Care should be taken to choose points that are perennial under most climatic conditions and that are not subject to complicating influences. The monitoring program should include monitoring wells, where existing groundwater discharge points are inadequate in number or character to fully monitor the site. Special attention should be given to well location, depth, and construction to ensure that what is being monitored will reflect any influence from the ash placement site that may occur. Upgradient wells, while they may not need to be as numerous as the downgradient points, are important, especially in an area where potential upgradient influences on water quality, such as other mine sites are present. In some upland settings, upgradient groundwater monitoring is not possible.

For most mine sites, Pennsylvania requires a minimum of six monthly background samples for each monitoring point, and coal ash monitoring points are no exception. The coal ash monitoring points must be sampled for a suite of standard mine drainage parameters plus aluminum, arsenic, cadmium, calcium, chloride, chromium, copper, lead, magnesium, mercury, nickel, potassium, selenium, sodium, and zinc. During operations, monitoring must be done, at a minimum, quarterly for the mine drainage parameters and annually for the additional metals and chloride. More frequent monitoring is required on some sites. Once the site is completed, monitoring continues until the site is judged stable or reclaimed and there is no evidence of ground or surface water degradation from the coal ash.

Coal ash generally must be placed no closer than within eight feet of the top of the regional groundwater table. However, this requirement may be waived under the regulations if there is a demonstration that contamination will not occur or if DEP approves the placement as part of a demonstration project.

Basic Assessment and Mine Site Evaluation Criteria for Coal Ash Placement

The first step associated with any coal ash placement scenario should be the testing of the proposed coal ash to be utilized at the site. If the coal ash does not meet the regulatory guidelines or limits, the project cannot proceed. Should the coal ash meet the regulatory guidelines or limits, the next step is to review the proposed site information. The site information reviewed should include, but is not limited to the following: depth to groundwater, geologic/hydrologic site characterization, site volume calculations, proposed site reclamation plan, water uses in and around the proposed site (both surface and groundwater), location of any adjacent public or private buildings, any suitable or unsuitable site characteristics related to the proposed placement, and the potential to mitigate any safety or pollution issues once the site is reclaimed. Some of these items may limit the type of coal ash that should be proposed for utilization at the site, and one must not forget that not all types of coal ash are suitable for all proposed placement scenarios.

If the coal ash and the proposed site meet the regulatory requirements and/or guidelines, the project design phase should begin. The project design or operational plans should include a number of basic requirements or specifications related to fugitive dust control, coal ash placement criteria, final grading, erosion and sedimentation controls, and final cover and revegetation. The proposed site monitoring plan should also be included in these plans, and a thorough review of the adequacy of the plan should be conducted. Once the coal ash and site design or operational plan are reviewed and deemed adequate, the overall site and assessment of the proposed coal ash placement can be conducted. This assessment considers all the pertinent site factors and the characteristics or properties of the coal ash itself. The assessment is also based on known historical or scientific information, or data related to the coal ash and sites with similar geologic and hydrologic site characteristics, and other pertinent site information.

Some basic site evaluation factors that have been established by the approximately 20 years of coal ash placement and site monitoring, as well as scientific research and modeling are:

A. Is the tested and approved coal ash being placed in or above groundwater?
B. Is the tested and approved coal ash going to be conditioned to the optimum moisture content and compacted to 90% Modified Proctor Density if the use requires such compaction?
C. Is the groundwater degraded or impacted by acid mine drainage?
D. Is the final cover or capping designed to promote positive drainage and the development of vegetation?
E. What type of coal ash is planned to be utilized: FBC (Fluidized Bed Combustion) or PC (Pulverized Coal)?
F. What are the chemical and physical characteristics of the coal ash to be utilized?
G. Are the site's operational and monitoring plans adequate and practical?
H. What resources exist in or around the site that could possibly be impacted if something unplanned occurs?
I. What is the nature and the scale of the abandoned mine features to be reclaimed, and what is the value of that reclamation in terms of dollars and public safety.

These are only a few of the questions that are entertained in a site assessment or selection, but they represent the core of what a decision to approve or deny an application is usually based on by a reviewer for the following reasons:

A. If the proposed coal ash placement is above groundwater, and if the coal ash meets all regulatory beneficial use requirements, and the coal ash is going to be placed in accordance with generally accepted practices, the likelihood of any adverse impact from the ash placement is very low.
B. If the coal ash is FBC ash or alkaline PC ash, the likelihood of degradation from any coal ash leachate should be minimal as the metals within the coal ash are less likely to be leached by any water that may come in contact with the coal ash.

These conclusions or generalizations are based on data, testing, and scientific information that has been developed over the past 20 years from actual coal ash placement sites, coal ash demonstration projects, scientific testing, and a host of other measures. However, each proposed coal ash placement site or project must be reviewed individually, and if necessary, additional testing or permit required actions should be implemented for any potential issues that may arise from the proposed coal ash placement. In fact, we have determined that there are specific coal ash types

and mine site scenarios that should not be approved for various chemical, geological, or other scientific reasons, even though the sites may represent significant abandoned mine land hazards. The risk of the potential solution creating a bigger problem should never be dismissed. For example, in the Bituminous Region, where coal ash has been used as an alkaline addition agent on some surface mine sites to offset large deficiencies in overburden quality, the results have generally not been favorable and additional AMD was produced. The coal ash itself caused no problem or damage, but it did not prevent AMD, just as limestone addition has sometimes failed to prevent AMD on sites with clearly bad overburden. Based on these results, using alkaline ash to offset large deficiencies in site overburden as in most cases would not be an advisable practice.

Conclusions and Closing Thoughts

This paper has presented descriptions of the regulatory and assessment procedures that were utilized to review project sites in Pennsylvania where coal ash has been beneficially used in mine reclamation and mine drainage remediation. Most of the beneficial sites have been clear success stories: abandoned mine lands and their associated safety and environmental hazards have been reclaimed at no cost to the taxpayer; water quality has been improved; a waste material has been recycled to a useful end rather than being landfilled. None of the approved sites represent environmental damage groundwater pollution cases attributable to the coal ash quality. However, a few of the mine sites cannot be counted as successes, because existing mine drainage worsened as a result of the re-mining of the sites. The production of AMD on these sites occurred because the ability of the alkaline ash to remediate and prevent the AMD was overestimated. On at least one site, poor mining and reclamation techniques were also a factor.

Are the sites where AMD worsened "coal ash damage cases?" Some investigators, particularly those associated with various advocacy groups, have argued "yes," but the correct answer to this important question is clearly "no." To be meaningful and useful the term "coal ash damage case" must be reserved for sites where the application of coal ash has caused some deleterious effect. The cause-effect relationship is critical to the integrity of the term. Where other site activities, such as additional mining have caused problems, it is important those problems be identified and understood so that the conditions that led to them are not repeated. However, incorrectly labeling such sites as "coal ash damage cases," serves to obscure the causes and potential remedies for the production of AMD on those sites, and only muddies the discussion over when and how coal ash may be beneficially used at mine sites. The determination of whether a site represents a damage case should be based on science, not semantics.

Recently, attention has been given to the potential effects of coal ash placement on groundwater quality and in the many criticisms of coal ash use on mine sites. That attention is well founded, because land reclamation benefits should not be achieved at the cost of water quality degradation. That principle has been a centerpiece of Pennsylvania's coal ash beneficial use program from the beginning and will continue to be so.

Finally, the Department has obtained some significant new information on the interactions between coal ash and minewater that has not been previously published. These findings were set forth in a book detailing the Beneficial Use of Coal Ash in Pennsylvania. The book describes several waste demonstration sites where the coal ash was placed directly into the minewater, or mixed with the minewater in the ash slurry application. The presence of significant sulfate concentrations in the minewater, which is characteristically the dominant anion in acid mine drainage and neutralized AMD, fortuitously promotes the formation of ettringite and other similar mineral phases. These minerals enhance the cementitous behavior of the coal ash and also sequester arsenic and other constituents of concern found in the ash and in coal refuse. These findings suggest that, while the traditional practice of maintaining a separation distance between the coal ash and the groundwater table was a prudent practice, there may be applications beyond these waste demonstration permit sites where some types of coal ash should be permitted to be in contact with minewaters, in order to reclaim abandoned pits, abate mine hazards, or remediate mine drainage problems. This is not to suggest the wholesale application of the techniques employed at the waste demonstration sites, but rather to provide alternatives for consideration by those engaged in defining the range of acceptable practices in the beneficial use of coal ash.

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Michael J. Menghini is a Mine Inspector Supervisor and currently the Acting Monitoring and Compliance Manager for the Department of Environmental Protection's (DEP) Pottsville District Mining Office. He has worked for DEP since 1983 and has been involved with coal ash regulatory issues since the late 1980's. He is Pennsylvania's representative for the Environmental Protection Agency's CCW regulatory initiative. He has helped develop the current State coal ash beneficial use regulations and related permit conditions, mine permit coal ash modules, and technical guidance documents. He is involved in all issues related to the beneficial use of coal ash in mine placement and reclamation activities. He holds a BS in Environmental Resource Management from Pennsylvania State University.

THE USE OF NEUTRAL LEACHATE TEST DATA IN INDIANA'S COAL COMBUSTION BY-PRODUCT DISPOSAL PROGRAM

Deborah A. Dale
Indiana Department of Natural Resources
Division of Reclamation
Jasonville, Indiana

Abstract

The disposal of coal combustion by-products in active coal mines has been occurring in southwestern Indiana since 1989. During this 15-year time period, a total of over seven million tons of ash material has been deposited in nine surface mines. The approval to dispose of coal combustion by-products is an arduous process including characterization of the disposal site's hydrogeologic setting, a qualitative and quantitative analysis of the effects of ash placement within that setting and characterization of the coal combustion by-products through bulk, 18-hour and 30-day neutral leachate tests. Quarterly evaluation of the ash, as well as monitoring of the surface and ground water at the site, is maintained throughout the active disposal phase and through final bond release.

Results of surface and ground water data collected from the Universal Ash Site in Terre Haute, Indiana, suggest the neutral leachate test ASTM D 3987-85, "Shake Extraction of Solid Waste With Water" can generally provide reliable information on anticipated concentrations of the eight Resource Conservation and Recovery Act metals. However, when comparing the leachate test results for other metals (i.e. boron and molybdenum) with results from water samples collected at the Universal site, some of the field samples contain higher concentrations than indicated in the leachate analysis.
Keywords: CCB Placement, Coal mining, Water quality

Introduction

Nationwide, the State of Indiana is second only to Texas as the largest generator of Coal Combustion By-products (CCBs). This distinction is directly related to the fact that approximately 98 percent of Indiana's residents rely on coal for their electrical needs. This dependency results in a CCB production of roughly six million tons per year that must be either beneficially used or disposed of in a suitable environment.

In 1988, the Indiana General Assembly passed Public Law 103 exempting the disposal of CCBs from solid waste regulations administered by the Indiana Department of Environmental Management when disposal occurred at surface coal mines regulated by the Indiana Department of Natural Resources (IDNR) under the Surface Mining Control and Reclamation Act (SMCRA). The Assembly recognized the general characteristics of the CCBs did not warrant the material being regulated under stringent solid waste (landfill) regulations, and by placing the ash in active surface mines rather than landfills, much needed landfill space would be retained for municipal waste. It was also recognized coal mines could provide a more desirable environment for ash disposal when compared to floodplain areas utilized by some powerplants for the siting of CCB holding ponds and storage cells. The practice of constructing ash disposal areas in floodplains in Indiana resulted from powerplants being located adjacent to major rivers; however, the hydrologic characteristics of these floodplains can often result in the dissemination of ash constituents into the ground water if proper controls are not in place.

Active coal mines located within the southwestern portion of Indiana (Figure 1) were recognized as a suitable alternative to floodplains and landfills for the placement of CCBs. The process of coal extraction fractures bedrock strata within the mined area increasing the surface area of the rocks exposed to weathering. The weathering process generally results in an increase in the mineralization of water recharging within the mined area restricting its usage as a potable water source. In addition, limited amounts of ground water from the bedrock strata in this region (Fenelon et al. 1994), and the fact that water quality decreases with depth (Wangsness et al. 1983, Wangsness et al. 1981), generally result in few bedrock residential wells located within the vicinity of coal mines.

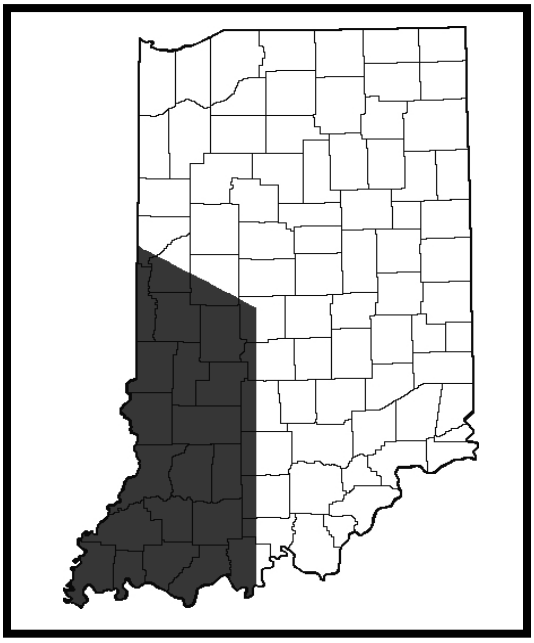


Figure 1. Red area denotes coal-mining region in SW Indiana.

Ash Disposal Permitting

The IDNR is the agency responsible for the regulation of coal mining and reclamation operations, including the disposal of CCBs in surface coal mines, in the State of Indiana. The disposal of CCBs at mine sites can only be achieved through a new coal-mining permit or a significant revision to an existing permit issued by the IDNR. Both types of permits require public notice with the opportunity for public comments and appeals.

As part of the coal-mining permitting process, thus the CCB disposal permitting process, the applicant must obtain and submit detailed geological and hydrogeological information regarding the proposed mine site and vicinity. Included in this information is a lithologic description of the subsurface; a chemical analysis of the overburden material and the coal seam(s) planned for extraction; and a characterization of aquifers located above, below (if the IDNR determines a lower aquifer could be impacted by mining), and including, the target coal seam(s). The applicant must also identify all surface and ground water users in and within 1,000 feet of the proposed permit boundary and provide documentation concerning the existing quality and quantity of the water supply.

In addition to site characterization, the applicant must provide specific CCB disposal information including, but not limited to: disposal method(s); landowner notification and approval; disposal volumes (total and annual); identification of ash type(s) (flyash, bottom ash, mixture, etc.); and CCB characterization. The ash characterization must include bulk analyses and 18-hour and 30-day leachate test results for over 30 parameters for each waste stream and ash type planned for disposal. Although several different leachate test methods were originally considered, ASTM D 3987-85, "Shake Extraction of Solid Waste With Water" was found to be a more appropriate and reliable test method with regard to CCBs (Hassett 1991). Although this test method has been found to provide dependable information on anticipated concentrations of other parameters including the eight Resource Conservation and Recovery Act (RCRA) metals, some water samples obtained from the Universal Ash Site suggest boron and molybdenum leachate levels may not correlate well with actual field samples.

Universal Ash Site

The Universal Ash Site, owned by Cinergy Corp, is located in Vigo County approximately two miles southeast of New Goshen, Indiana (Figure 2). Permit approval for surface coal mining in this area was granted in 1985 to

Peabody Coal Company who owned and operated the mine as Snow Hill Area No. 14. Disposal of CCBs, consisting of a fly ash/bottom ash mixture and a limited amount of ash from coal gasification, began in the early part of 1989 with all material deposited within one final-cut monofill (Figure 3). Disposal was completed in October of 2001 with a total of 1,644,923 tons of CCBs placed into the monofill.

Currently, there are nine wells located in the vicinity of the disposal operations that monitor the surficial ground water in the unconsolidated material, the ground water within the bedrock or the pore water within the spoil/ash material (active pit disposal area) (Figure 3). There have been as many as 12 monitoring wells at this location; however, damage required the abandonment of three of the wells. In addition to the wells, there are currently five surface water points (Figure 3). A sixth point, monitoring the water within the disposal area, was eliminated as the disposal pit was filled in.

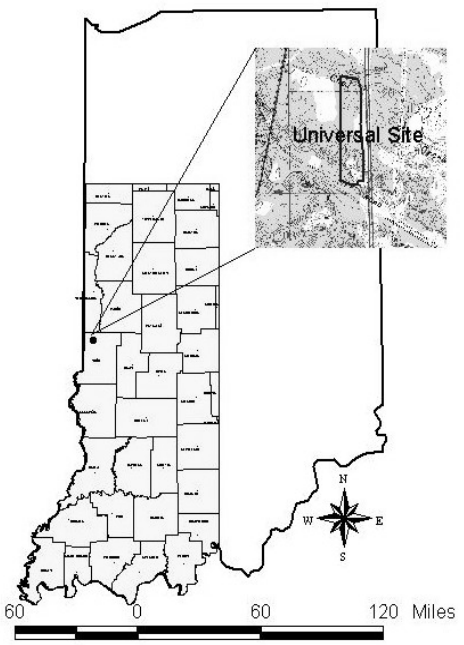


Figure 2: Universal Ash Site, Vigo County, Indiana

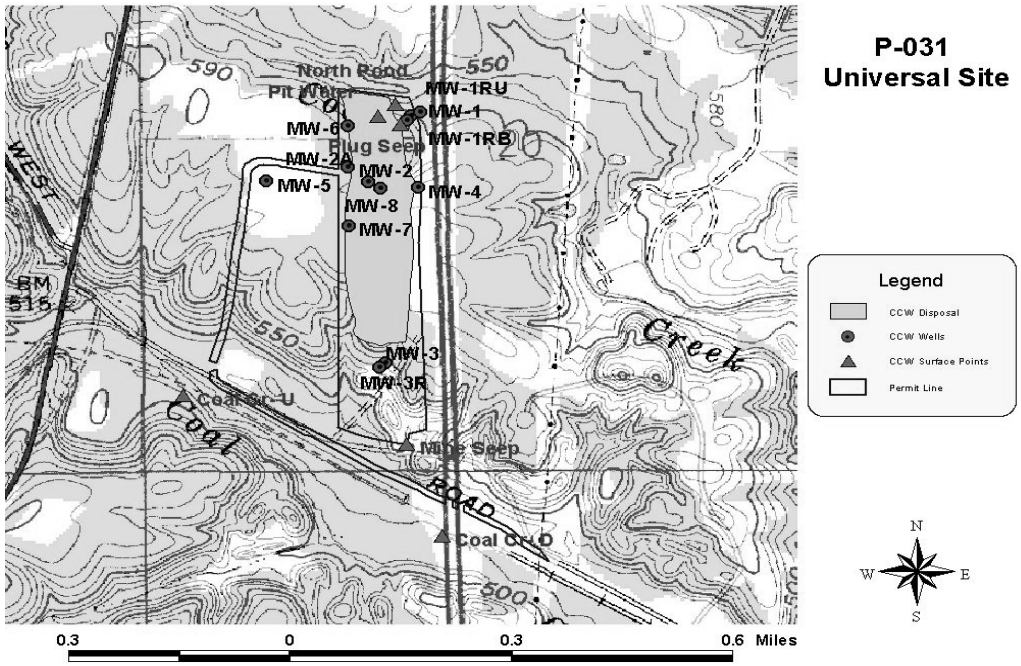


Figure 3: Monitoring Locations, Universal Ash Site

Discussion

The IDNR ash database contains over 3,000 entries of bulk and leachate (18-hour and 30-day) data for the Universal site. Focusing on the eight RCRA metals, boron, and molybdenum, Table 1 presents the highest bulk, 18-hour leachate, and 30-day leachate values reported for the ash material disposed of at the site. In addition, Table 1 includes the highest detected concentrations of these metals in monitoring wells MW-8, MW-1RU and MW-1RB. Well MW-8 was selected for comparison due to its location within the disposal pit (within the ash material itself)(Figure 3). Wells MW-1RU and MW-1RB were selected because these wells contain the highest boron concentrations as compared to the remaining wells (with the exception of MW-8). Please note, well MW-2 was formerly located within the ash disposal area; however, this well was damaged beyond repair and replaced with MW-8 in 1997. Likewise, MW-1 was replaced by MW-1RU and MW-1RB in 2001 when MW-1 was found to have a leaking seal.

Table 1
RCRA Metals, Boron and Molybdenum
Highest Bulk and Leachate Values vs. Highest Field Values in MW-8, MW-1RU and MW-1RB

Metals	Highest Bulk Value (mg/kg)	Highest 18-Hour Leachate Value (mg/l)	Highest 30-Day Leachate Value (mg/l)	Highest Detected Value in MW-8 (mg/l)	Highest Detected Value in MW-1RU (mg/l)	Highest Detected Value in MW-1RB (mg/l)
Arsenic	160 1.	3	0.86	0.26	0.0059	0.0125
Barium	220	0.24 0.	37 0.	35	0.15	0.05
Cadmium	4.2 0.	01	0.007	0.0004	ND	0.0004
Chromium	136 0.	17	0.034	0.0084	ND	0.007
Lead	81 0.	052	0.075	0.08	ND	ND

Table 1 continued.

Metals	Highest Bulk Value (mg/kg)	Highest 18-Hour Leachate Value (mg/l)	Highest 30-Day Leachate Value (mg/l)	Highest Detected Value in MW-8(mg/l)	Highest Detected Value in MW-1RU (mg/l)	Highest DetectedValue in MW-1RB (mg/l)
Mercury	0.35 <0.	002	<0.002	ND	ND	ND
Selenium	9.8 0.	17	0.25*	0.006	ND	ND
Silver	1.9 <0.	04	<0.04	0.01	ND	0.007
Boron	545 5.	5	7.9	82.6	28.2	41.9
Molybdenum	25 0.	76	0.77	2.34	0.048	0.6

ND = Non-Detect
*Value represents a single sample at this elevated concentration. This value resulted in a notification letter to Cinergy to stop disposal and verify sample results. Subsequent samples were less than 25% of the RCRA limit. Under the IDNR program, CCB leachate concentrations exceeding one-quarter RCRA levels cannot be disposed.

As noted in Table 1, levels of the RCRA metals detected in the monitoring wells are similar or less than the anticipated concentrations based on the leachate results; therefore, the neutral leachate test ASTM D 3987-85 is a viable test method for predicting field concentrations of these metals. This assumption is supported by data obtained from the remaining eight mine sites in Indiana where ash disposal has occurred. However, when viewing the leachate concentrations for boron, and to a lesser degree, molybdenum, the ash material disposed of at Universal leached these metals at a much higher concentration than expected based on the laboratory tests. This discussion will focus on boron due to its usefulness as an indicator for CCB leaching (Branam et al. 1999).

Boron in ground water

Boron concentrations in the CCBs disposed of at Universal averaged 237 mg/kg until the middle of 1999, at which time, the levels increased maintaining an average of 338 mg/kg throughout the remaining disposal period (42.6 % increase). These higher concentrations were also noted in the leachate analyses with a 78.3 % increase in boron in the 18-hour and a 63.5 % increase in the 30-day. Although these increases are considerable, the absolute boron levels reported in the leachate analyses since the middle of 1999 are substantially lower than the levels detected in the samples from MW-8, MW-1RU and MW-1RB.

The increased boron content in the ash material is presumed to be the source of the boron detected in the water samples at Universal. Although boron increases have not been as conspicuous in other locations at the site, the locations of MW-8, MW-1RU and MW-1RB relative to the ash material impart these wells with direct communication with the water within the ash material. The increased concentration in wells MW-1RU and MW-1RB may be due to, at least in part, the direction of the ash placement within the disposal area. The CCBs were deposited within the disposal area as a progressive sequence from south to north; therefore, the ash containing the highest concentrations of boron was placed in the northern portion of the pit. Well MW-8 is located in the northern region of the ash disposal area, and wells MW-1RU and MW-1RB are proximal to the northeast corner of the pit.

Since MW-8 monitors the water within the ash disposal area (Figure 3), it is expected that samples from this well would contain the highest concentrations of ash constituents. Boron continues to display an increasing trend in this well with a marked increase in concentrations following the completion of the ash disposal activities and the complete covering of the disposal pit at the end of 2001 (Figures 4 and 5). The covering of the pit reduced the influx of atmospheric water to infiltration through the capping material, thus reducing the dilution effect.

Well MW-1RU is located in proximity to the ash monofill and monitors the shallow ground water within the unconsolidated material. Boron concentrations have been steadily increasing in this well, and again, substantial increases in boron levels are evident following the filling in of the disposal pit (Figures 5 and 6).

MW-1RU is presumed to be in direct communication with water in the disposal area through a surficial sampling point referred to as the "Plug Seep." Water at this location is the result of leakage from the disposal area through the levee surrounding the monofill. Water from the disposal area moves through the levee then migrates into the unconsolidated material and is detected in MW-1RU. A similar increase in boron as seen in MW-1RU is evident in

samples obtained from the seep area with concentrations again increasing following completion of the disposal activities (Figure 7).

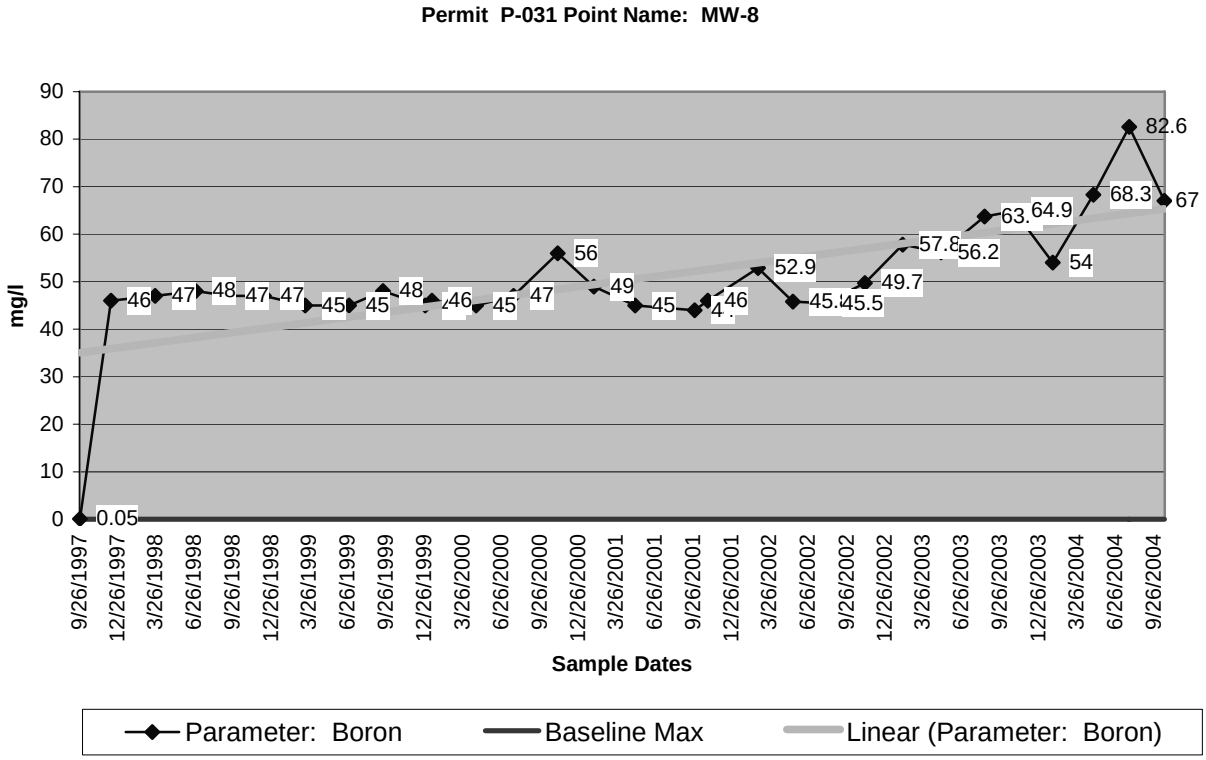
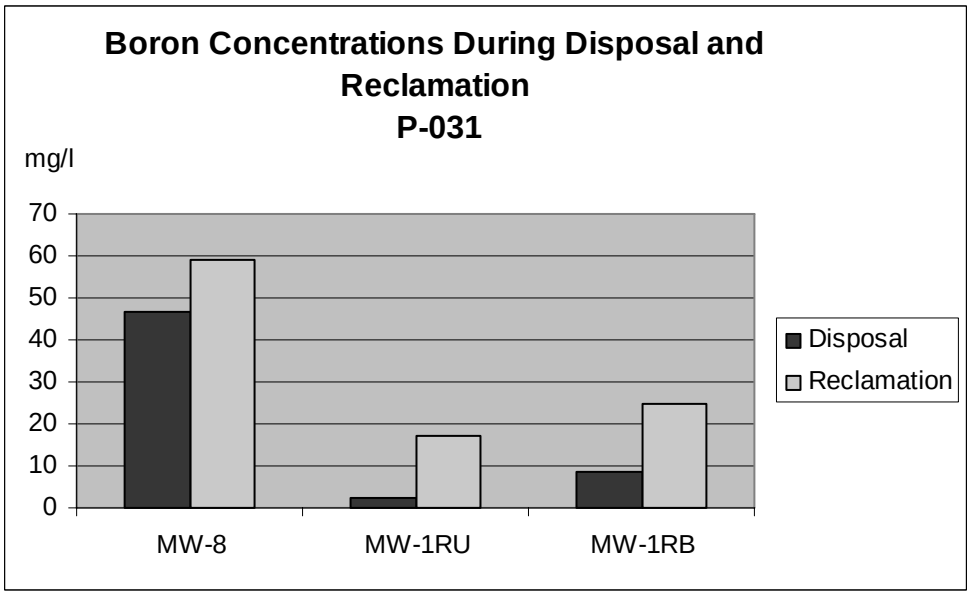


Figure 4



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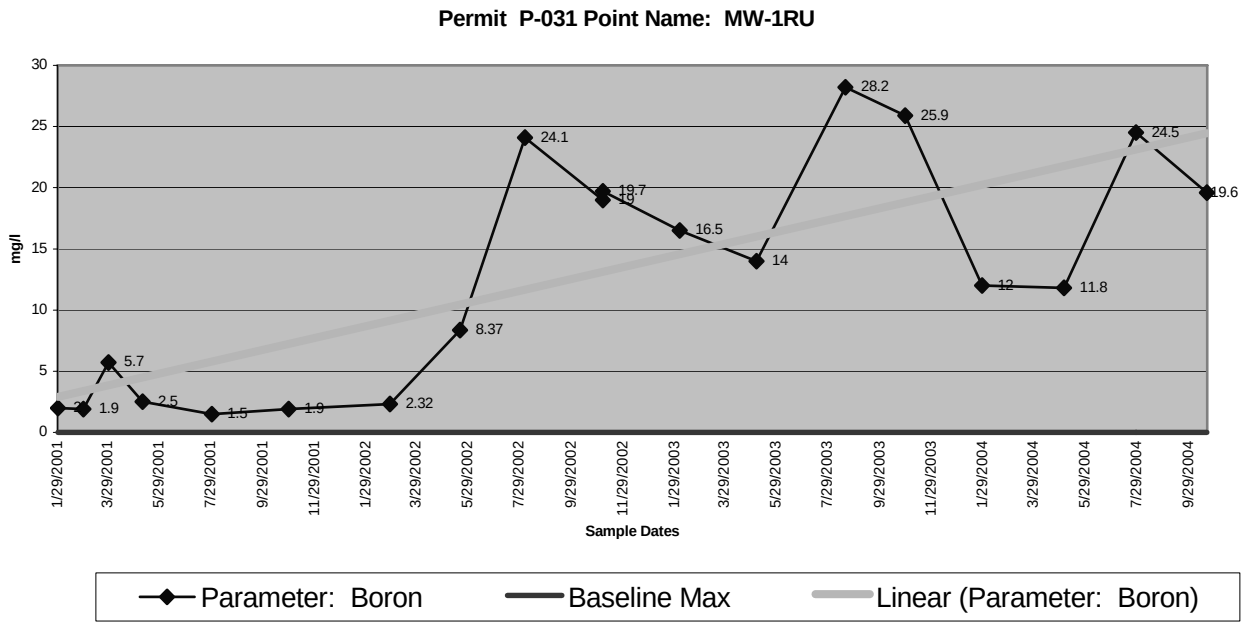

Figure 6

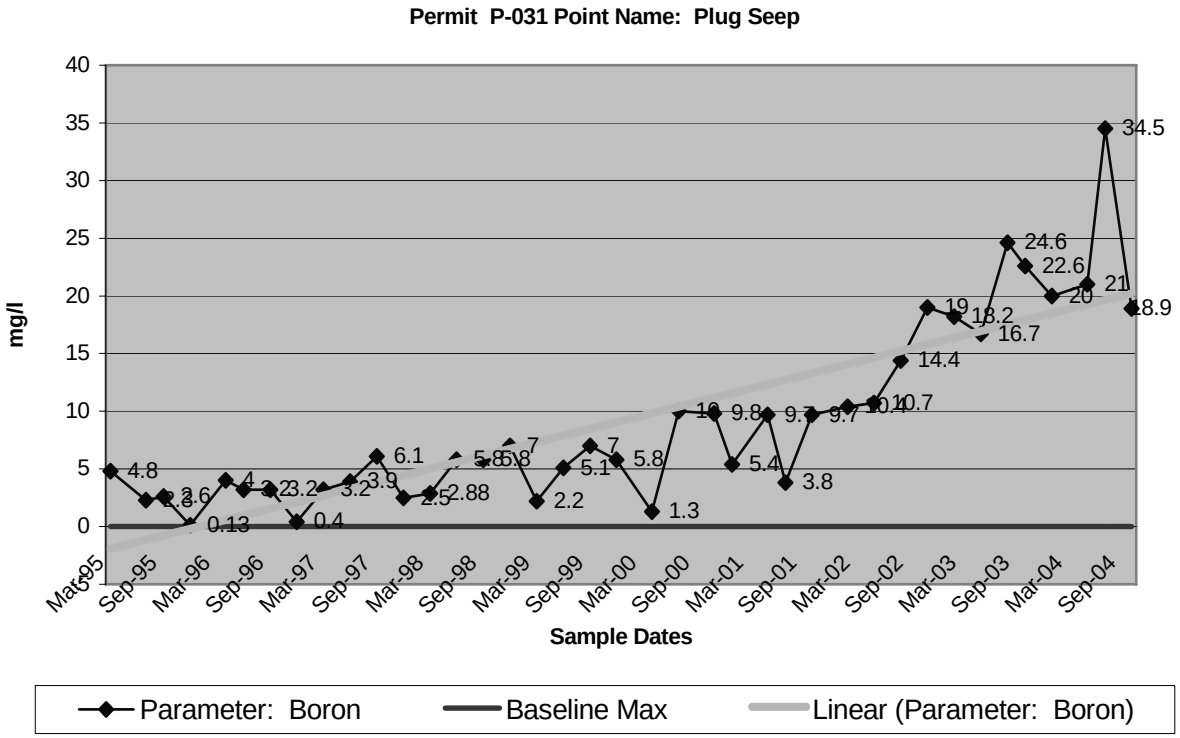

Figure 7

Well MW-1RB is located in proximity to the ash monofill and to MW-1RU and monitors the ground water within the bedrock strata above, and including, the Indiana VI Coal seam that was mined in this location in the 1980's. As seen in MW-1RU, boron concentrations have been steadily increasing in this well, and again, substantial increases in boron levels are evident following the filling in of the disposal pit (Figures 5 and 8).

MW-1RB is presumed to be in direct communication with water in the disposal area through a series of auger holes located in the consolidated strata along the eastern boundary of the ash disposal area (Figure 3). During active mining operations, the Indiana VI Coal was extracted from the highwall (eastern pit boundary) using augers that extended about 46 meters into the undisturbed bedrock. These auger holes, some emanating from the disposal area, provide a direct conduit for the ash water to migrate in the vicinity of MW-1RB. During drilling activities for the installation of MW-1RB, a void space was penetrated that was at the approximate depth of the Indiana VI Coal. Rather than installing the well in this void area (auger hole), the drill hole was sealed, and an additional boring was completed nearby. The Indiana VI Coal was encountered in this boring, and the well was installed through the base of the coal seam. Thus, it is plausible that water from within the pit migrates through an auger hole adjacent to MW-1RB and into this well through the Indiana VI seam.

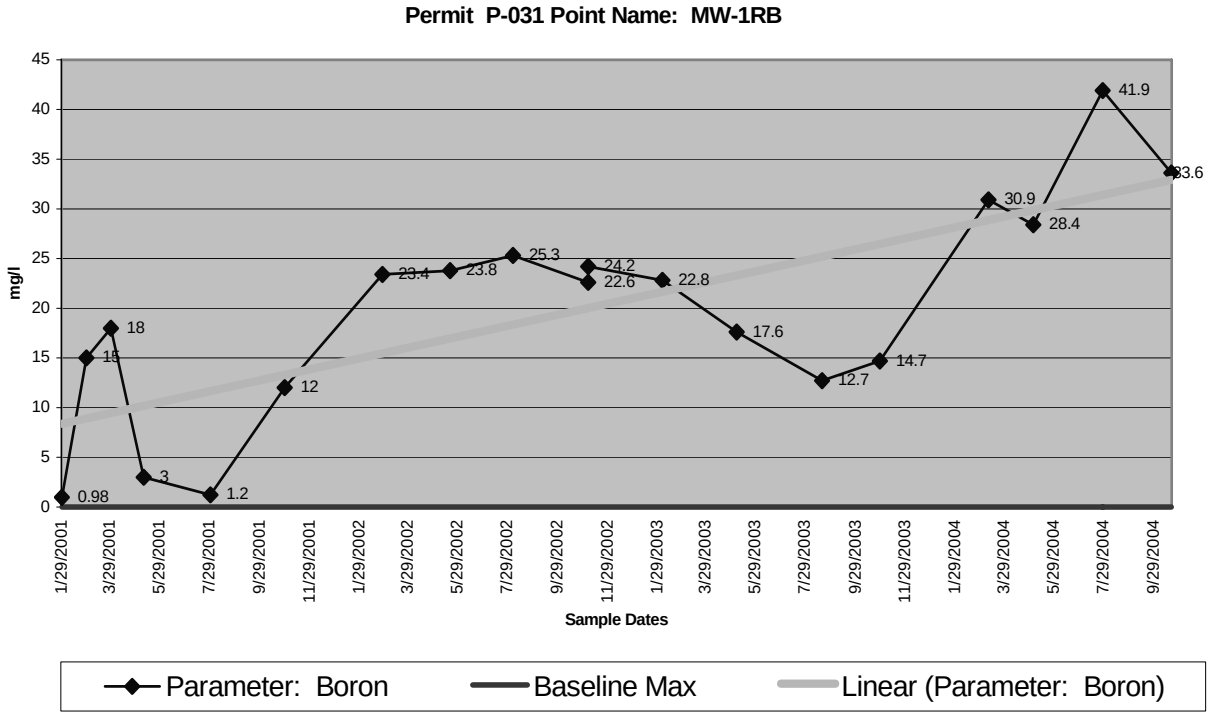

Figure 8

Conclusions

Boron concentrations in excess of what was anticipated based on leachate analyses have been documented at the Universal Ash Site in west-central Indiana. The leachate test method ASTM D 3987-85, "Shake Extraction of Solid Waste With Water" provided reliable data concerning post-placement leaching of the eight RCRA metals; however, boron levels in some surface water and ground water monitoring locations far exceed expected concentrations based on laboratory testing.

Leachate analyses of CCBs at the other eight ash disposal sites in Indiana have not experienced a discrepancy in laboratory and field leachate concentrations as significant as those seen at Universal while utilizing the same test method (ASTM D 3987-85). Water quality research is currently ongoing at Universal for boron and other constituents.

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Deborah A. Dale has been employed as a hydrogeologist with the Indiana Department of Natural Resources, Division of Reclamation since 1998. As a hydrogeologist with the Technical Services Section, she is involved with geological and hydrogeological reviews of surface and underground coal-mining permit applications, surface and groundwater data interpretation, coal combustion by-product issues, regulatory issues, outreach programs and training. She is also involved in various research projects utilizing stable isotopes in evaluating hydrologic regimes. Prior to joining the Division, she worked as an environmental consultant and as instructor for DePauw University in Greencastle, Indiana. She has a M.S. (Geoscience/Hydrogeology) from the University of Nevada, Las Vegas and a B.S. (Geology) from Nicholls State University in Thibodaux, Louisiana. She is also a Licensed Professional Geologist in the State of Indiana.

Session 3

REGULATION OF CCB PLACEMENT AT MINES

Session Chairperson:
David Goss
American Coal Ash Association
Aurora, Colorado

A State Perspective of Regulation of Mine Placement of Coal Combustion Wastes
Gregory E. Conrad, Interstate Mining Compact Commission, Herndon, Virginia

Coal Ash Beneficial Use at Mine Sites in Pennsylvania
Roger J. Hornberger, Michael J. Menghini, Alfred D. Dalberto, Timothy C. Kania, Daniel J. Koury, and Thomas D. Owen, Pennsylvania Department of Environmental Protection, Pottsville, Harrisburg, and Ebensburg, Pennsylvania, and Barry E. Scheetz, Pennsylvania State University, University Park, Pennsylvannia

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Michael J. Nasi and Rebecca L. Fink, Lloyd Gosselink Blevins Rochelle & Townsend,P.C., Austin, Texas

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The State of Indiana's Experience in Regulating the Disposal of Coal Ash at Surface Mines
Deborah Dale, Indiana Division of Reclamation, Jasonville, Indiana

A STATE PERSPECTIVE OF REGULATION OF MINE PLACEMENT OF COAL COMBUSTION WASTES

Gregory E. Conrad
Executive Director
Interstate Mining Compact Commission

Abstract

Beginning in May of 2001, the Interstate Mining Compact Commission (IMCC) has sponsored a series of meetings between the States and the Federal government, including representatives from the Environmental Protection Agency, the Office of Surface Mining, and the Department of Energy. The purpose has been to discuss potential adjustments to existing State regulatory programs relating to the placement of coal combustion waste (CCW) into surface and underground mines. Over the past several years, the States have had the opportunity to learn from one another about their existing regulatory approaches. Discussions have focused on the various operational, environmental, and economic issues associated with the practice of placing CCW in mines, including how States can adjust or improve current regulatory practices and examining the impacts of various Federal regulatory proposals on the content and implementation of existing State programs. This presentation will report on the progress of State/Federal discussions concerning placement of CCW in mines. The presentation will also address the regulatory requirements under SMCRA and RCRA that attend mine placement of CCW. The States believe that when a comprehensive comparison of the jurisdictional bases and the applicable statutory and/or regulatory requirements under these two national environmental laws is undertaken, it is abundantly clear that the States, pursuant to their regulatory programs under SMCRA and/or RCRA, currently and historically have managed the placement of CCW at mine sites in a safe, environmentally protective manner. There are no significant gaps in regulatory coverage and the States continually seek to improve and upgrade their programs where new requirements are identified through program benchmarking and/or Federal oversight. In the final analysis, the placement of CCW at mine sites amounts to a beneficial use that generally enhances the environment and, in every case, is comprehensively and effectively regulated by the States.

Introduction

Good morning. My objective today is to provide you with an overview from the States' viewpoint about where we are in the regulatory development process in the area of mine placement of coal combustion wastes and, more specifically, about our on-going State/Federal initiative to inform one another about our existing regulatory approaches. I will also touch on what the future might hold.

In May of 2000, EPA published a Notice of Regulatory Determination on Wastes from the Combustion of Fossil Fuels. Among other things, and of particular concern to the States, EPA found that, although coal combustion by-products (CCBs) (or coal combustion wastes (CCW)) did not warrant regulation under subtitle C of the Resource Conservation and Recovery Act (RCRA) as "hazardous waste", the agency had determined that national regulations under subtitle D of RCRA are warranted when these wastes are disposed in landfills or surface impoundments, and that regulations under subtitle D and/or possible modifications to existing regulations established under the Surface Mining Control and Reclamation Act (SMCRA) are warranted when these materials are used as fill in surface or underground mines. IMCC was especially concerned about the "mine placement" aspects of the determination given the significant interplay between approved state regulatory programs under SMCRA and any potential adjustments to the national SMCRA regulations (which serve as a template for State regulatory programs).

Following publication of EPA's notice, IMCC suggested to both EPA and the Office of Surface Mining (OSM) that an intergovernmental forum would serve as a valuable mechanism to initiate discussions between State and Federal governments concerning next steps pursuant to the regulatory determination. This suggestion followed on the heels of a resolution adopted by IMCC in May of 2000 affirming the appropriateness and effectiveness of state regulations and policies for the safe handling, recycling, beneficial use and placement of coal combustion by-products and supporting the management of CCBs without the application of federal RCRA subtitle C requirements.

Both EPA and OSM saw the value of proceeding in this manner and the first intergovernmental form on mine placement of CCBs was held on May 15 and 16 of 2001 in St. Louis, Missouri. The forum was open to all States, not just IMCC member States, and also involved tribal government representatives. Other Federal participants included the U.S. Geological Survey and U.S. Department of Energy. At the forum, attendees heard from OSM, EPA, and the States about current issues and problems being encountered in the mine placement of CCBs in anticipation of the potential development of a new regulatory approach by EPA. One of the key objectives of the forum was to engage State and Federal representatives affected by a potential mine placement rule in an open discussion about challenges being encountered in the field: identifying potential regulatory gaps, anticipating potential inter-agency jurisdictional conflicts, and discussing implementation concerns associated with any new rule. A key outcome of the forum was the establishment of an ongoing dialogue among the States, Tribes, and Federal representatives concerning the various operational, environmental, and economic issues associated with the practice of mine placement of CCBs. A copy of the notes from that forum and the four that followed can be found at EPA's website: www.epa.gov/epaoswer/other/fossil/index.htm.

Following the initial forum, the States met separately and developed a discussion outline that contains the basic position of the States/Tribes concerning the regulation of CCB placement at mine sites. The outline has served as the basis for continuing discussions with EPA and OSM regarding the need for national regulations given the adequacy of existing State and Tribal regulatory programs. The outline addresses categories of coal ash management, principles for beneficial use, regulatory requirements, and disposal/placement at mine sites other than beneficial use.

Throughout the discussions on mine placement of CCBs, the States and Tribes have attempted to reflect the input and positions of the various departments and/or agencies within each State that have jurisdiction over this matter. This often includes the mining regulatory agencies within the Departments of Natural Resources or Environmental Protection; the solid waste regulatory agencies within the Departments of Environmental Protection or Environmental Quality or the Departments of Health; and the water quality regulatory agencies within the Departments of Environmental Protection or Environmental Quality.

In preparation for the second State/Federal dialogue, the States requested that EPA make available for State and Tribal review two draft documents that the agency had been developing: "Regulation and Policy Concerning Mine Placement of Coal Combustion Waste in 26 States" and "Mine Placement of Coal Combustion Waste -- State Program Elements Analysis." These documents provide an overview of State regulations and policy (under both mining and solid waste programs) concerning CCB mine placement, with an emphasis on coal mines. The reports summarize the elements of existing State programs that are applicable to CCB mine placement, including permitting and public participation; planning and enforcement; waste characterization and monitoring; design and operational program elements; and closure and post-closure care.

These reports by EPA are dynamic documents and their accuracy and completeness have changed as states continue to provide information to the agency concerning current state regulatory program requirements. Since the initial release of the reports, several of the States, including some that were not represented in the early drafts of the reports, have provided updates, clarifications, and new information to EPA in an effort to improve the nature and usefulness of the reports. In addition, EPA has incorporated changes to the reports based on site visits and interviews that the agency conducted in various states.

Two additional intergovernmental forums were held, one in November of 2001 and another in April of 2002 that focused on the States' outline on coal ash management. EPA and OSM presented a detailed response to the States' outline, which was helpful in informing the ongoing debate and clarifying EPA's and OSM's positions and concerns. Finally, and perhaps most valuable to our ongoing discussions, the participants spent time reviewing EPA's minefill regulatory concerns, primarily from a RCRA perspective. This discussion was most promising in terms of bridging the gap between how the States currently operate under their respective SMCRA and RCRA programs and what EPA is anticipating based on its understanding of those RCRA elements that it believes should be applicable to mine placement of CCBs.

Over the course of the State/Federal discussions, the States have consistently articulated the following concerns to EPA and OSM, several of which remain to be addressed or resolved within the context of EPA's determination concerning next steps:

1. SMCRA appears to serve as an adequate and effective baseline for any type of regulatory analysis concerning mine placement of CCBs. In this regard, we see the SMCRA permit serving as the platform for CCB mine placement at coal mines. For non-coal mines, we believe that the existing State permitting framework, which is often RCRA-based, is adequate.
2. It is essential to examine the effectiveness and comprehensiveness of existing State programs before adding additional regulatory requirements. Experience at the State level in implementing existing State and Federal laws substantiates the adequacy of the existing regulatory structure.
3. There is a need to coordinate among all applicable statutes/regulations that impact the regulation of mine placement of CCBs, including SMCRA, RCRA, the Clean Water Act, and the Safe Drinking Water Act. There is a belief that many of the necessary regulatory requirements are already in place in the context of these statutes and their respective regulatory programs.
4. There is an absolute need for flexibility to accommodate differences among the States related to geology, climate, ash characterization, and agency operation. Comprehensive Federal regulation will be difficult to implement on a nationwide basis due to these differences.
5. There needs to be consideration given to both coal and noncoal sites and the differences between them (possibly a segmented approach). In this regard, heavy-handed Federal efforts to achieve some sort of uniformity will only undermine effective and efficient regulation at the State level.

As an overall objective in the area of regulating mine placement of CCBs, the States are hoping to strike a balance between existing State regulatory program requirements and any gaps that may be defined and justified. To date, although there are differences among the States in the way they regulate mine placement of CCBs (for instance, in terms of sharing jurisdiction among several state agencies; relying primarily on the SMCRA program for mine placement at coal mines; and differentiating between beneficial use and classic disposal), there has been little evidence of major gaps that require filling through new national regulations under either SMCRA or RCRA. And in those States that do not have well defined programs for mine placement of CCBs, it is usually because they have not had to deal with its beneficial use or disposal within their borders. Even in those States, a comparison of their programs with States who actively regulate mine placement of CCBs demonstrates that most, if not all, of the program elements are in place and would likely operate effectively when needed.

The few areas within State programs that have been shown to need some degree of shoring up can best be addressed through intergovernmental discussions, such as have occurred over the past several years. Also, through a benchmarking type of approach, States can identify areas in their programs that would benefit from fine-tuning and this can be accomplished by patterning these areas after other state programs. If and when specific regulatory gaps are found to exist in a significant majority of State programs, then it would be appropriate to consider national guidance from EPA and/or OSM. However, all of EPA's program analyses to date do not yet justify the need for such guidance, and OSM has stated on numerous occasions that it believes State programs are adequate (at least as far as SMCRA programs for CCB mine placement at coal mines are concerned).

The States have prepared additional documents supporting their view of the CCB regulatory world, including four documents that address several components of the minefill program. One is a regulatory matrix that attempts to capture the minimum SMCRA and RCRA regulatory components applicable to mine placement of CCBs at minesites. The second is a table that lists the various beneficial uses of CCBs, both in terms of use, applicable industrial standards, environmental and practical benefits, and the applicable "regulatory safety net" (which consists of state and federal requirements that are potentially applicable to each beneficial use). The third is a narrative and diagram description of applicable jurisdictional authorities with respect to CCB placement and utilization at active and abandoned coal and noncoal sites, which is intended to serve as a summary of the states' understanding of overall jurisdictional authorities and requirements. The fourth document is a summary description of the applicability and impact of minefill regulations associated with abandoned mine land projects and sites.

All of these documents are interrelated and should be read together. They not only respond to EPA's regulatory concerns document, but compliment the analysis that OSM has done in response to those same concerns.

Furthermore, and most importantly, the States assert that these working draft documents provide the case for why existing State regulatory programs under both SMCRA and RCRA are adequate and comprehensive enough to insure the appropriate regulation of minefilling practices where CCB's are used.

The most recent facilitated discussion regarding mine placement was a meeting of stakeholders held on May 19 and 20, 2003 in Washington, DC. Representatives from the Federal government, the States, the mining and utility industries, the environmental community, and citizen groups participated in the two-day session. From the States' perspective, we believe this was a productive sharing of information and furthered the debate about the need for Federal regulation in the area of minefilling. We believe that the information presented at the meeting supports our view that the States are doing an effective job of regulating in this area and that the need for additional or supplemental Federal regulation has not been adequately demonstrated. The forum also provided an opportunity to focus on the handful of issues that may require additional enhancements in some state regulatory programs such as post-closure care and financial guarantees, each of which can be addressed at the State level without expansive new Federal rules.

There will be at least one additional opportunity to address the handling of CCBs at minesites. During the last session of Congress, Congressman Rahall of West Virginia called for a study by the National Research Council (which is part of the National Academy of Sciences) concerning whether what he labels "power plant wastes" are being placed and disposed in coal mine sites with adequate safeguards and whether this activity is degrading water supplies in coal mines in contravention of SMCRA. Funding was approved for this study and the NRC has established a Committee on Mine Placement of Coal Combustion Wastes consisting of a panel of experts who will oversee the study. The first meeting of the Committee took place on October 27 in Washington, DC and IMCC, among other interested and affected parties, presented an overview of the states' perspective on the regulation of mine placement of CCBs. With the initiation of this study, we will see an additional opportunity for all affected parties to make their case to yet another reviewing body. It is our hope that this study will result in an objective analysis of the subject matter and will further inform the debate as we move toward an ultimate conclusion that CCBs are adequately and fully regulated by the States.

What does the future hold? From the States' perspective, we are hopeful that EPA and OSM will now move forward expeditiously with a jointly developed position on the need for additional Federal regulation of minefill practices for coal combustion wastes. We believe that all of the information required by the two agencies to make this decision is in hand and that they are well poised to render that decision. We fully expect, however, that both agencies will await the findings of the NRC before taking final action. That study is expected to take 18 months to complete. In the end, we anticipate that EPA and OSM may appropriately recommend that the States continue their on-going efforts to work cooperatively with both agencies to assess the effectiveness of their respective regulatory programs and make appropriate adjustments. Furthermore, we anticipate that the States will continue their benchmarking initiatives, which provide for the analyses and comparison of State program elements with the overall objective of enhancing their respective programs through the adoption of lessons learned during program implementation and the incorporation of innovative approaches. In the final analysis, we believe that our citizenry and the environment will be well served by state regulatory programs that fully comply with applicable Federal laws and that reflect the results of the laboratories of invention inherent in State primacy. We also believe that an effective regulatory regime for the mine placement of coal combustion wastes will insure that there are effective and safe alternatives to classic land disposal while enhancing the reclamation of both active and abandoned mined lands.

Greg Conrad is Executive Director of the Interstate Mining Compact Commission (IMCC), a multi-State governmental organization representing 20 mineral producing States. Greg has served in his position since 1988 and is responsible for overseeing several issues of importance to the States in the legislative and regulatory arenas including: surface mining and reclamation; mine waste; identification and restoration of abandoned mine lands; and various environmental issues associated with mineral production such as surface and ground water quality and quantity. Prior to joining IMCC, he served for nine years as senior counsel with the American Mining Congress, which is now part of the National Mining Association. While with AMC, he had primary staff responsibility for several coal related issues including transportation, leasing, research and development initiatives, and surface mining and reclamation. He has spoken and presented papers at a variety of conferences hosted by such organizations as the Eastern Mineral Law Foundation, the Conference of Government Mining Attorneys, the Colorado School of Mines, the Office of Surface Mining, the National Mining Association, the Environmental Law Institute and various State

government groups. He has written extensively on mining issues for professional journals and magazines. He graduated from Michigan State University with a degree in business administration and later from the University of Detroit School of Law where he was an associate editor of the law review.

COAL ASH BENEFICIAL USE AT MINE SITES IN PENNSYLVANIA

Roger J. Hornberger[1], Alfred D. Dalberto[2], Michael J. Menghini[1],
Timothy C. Kania[3], Barry E. Scheetz[4], Daniel J. Koury[1], Thomas D. Owen[1]
[1]Pennsylvania Department of Environmental Protection (DEP)
Pottsville, Pennsylvania
[2]PA DEP,
Harrisburg, Pennsylvania
[3]PA DEP
Ebensburg, Pennsylvania
[4]Pennsylvania State University, Materials Research Institute,
University Park, Pennsylvania

Abstract

The beneficial use of coal ash at mine sites in Pennsylvania started in 1986 and is regulated under the State's Solid Waste Management Act and the accompanying coal ash beneficial use residual waste management regulations. Fluidized bed combustion (FBC) coal ash is the type of ash most frequently beneficially used on Pennsylvania's mine sites, but significant amounts of coal ash from pulverized coal fired power plants (PC) are also beneficially used for mine reclamation in Pennsylvania and other States. Pennsylvania benefits from several waste coal burning projects where coal refuse piles are burned by FBC power plants, acid mine drainage and sediment pollution from refuse piles are eliminated, and the alkaline coal ash generated is beneficially used for mine reclamation.

Pennsylvania Department of Environmental Protection (DEP) regulations and technical guidances define types of beneficial uses at mines, coal ash analysis parameters and concentration limits, surface and groundwater monitoring requirements, geologic and hydrologic site evaluations, operational parameters, and mine reclamation plans. During the past eighteen years, coal ash has been beneficially used on over 120 permitted mine sites. Consequently, long-term monitoring data of the chemical and physical characteristics of the coal ash, and the groundwater quality are available for many of these sites, documenting the success of the beneficial use program. The sixteen FBC power plants in Pennsylvania have contributed to the reclamation of approximately 3,400 acres of abandoned mine lands, alone, within the past fifteen years.
Keywords: reclamation, mine drainage abatement, groundwater, ettringite

Introduction: Scope of Coal Ash Beneficial Use in Pennsylvania

This paper is a condensed version of a 442 page book entitled "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania," that was published by the Pennsylvania DEP and the Pennsylvania State University in 2004. DEP developed a contract with the Materials Research Institute (MRI) at Penn State to conduct a series of rigorous scientific studies of three waste demonstration permit sites in the Anthracite Region of Pennsylvania. It was out of the collaboration between the MRI and DEP that the concept for this book originated. The initial intent was to produce a publication that presented the results of the demonstration projects. From there the scope broadened to include the results from other active and abandoned mine sites where coal ash has been beneficially used in Pennsylvania. One reason for broadening the scope of this publication is that the beneficial use of coal ash on mine sites has become somewhat controversial on a national level. That controversy has been fed, in part, by the misreporting and partial reporting of information and data, some of which have been from sites in Pennsylvania. Thus, it became even more important to present the facts and the science behind the beneficial use of coal ash in Pennsylvania.

Since commercial coal mining began in Pennsylvania prior to 1800 (Dodge & Edmunds 2003), the Commonwealth's miners have extracted approximately 16.3 billion tons of coal from the Anthracite and Bituminous Coal Fields combined (PA DEP 2002). Prior to the enactment of the Federal Surface Mining Control and Reclamation Act (SMCRA) in August 1977 and the PA Surface Mining Conservation and Reclamation Act in 1971, laws and regulations governing surface mining and the surface effects of underground mining, were largely ineffective in achieving reclamation of mined lands. However, much of the vast abandoned mine lands (AML) problem from the pre-1977 mining remains. There are more than 5000 abandoned, unreclaimed mine problem areas

encompassing more than 189,000 acres in Pennsylvania, according to the DEP Bureau of Abandoned Mine Reclamation (BAMR). It is estimated that Pennsylvania suffers from up to 3,100 miles of streams degraded by acid mine drainage (AMD) as a result of abandoned mines. AMD is Pennsylvania's most serious stream pollution problem. The BAMR-estimated price tag to eliminate Pennsylvania's AML problems is a staggering $14.6 billion.

One approach Pennsylvania has taken to help address the AML problem is to encourage re-mining of abandoned mine lands in settings where technical data show that additional problems are unlikely to occur, and, where in the normal course of re-mining, abandoned mine features will be reclaimed. Waste coal piles represent a significant subset of AML remining sites in Pennsylvania. These sites present both some unique problems and opportunities. The piles are typically toxic to plant life, and thus are barren and highly erosive. The bituminous piles in particular can leach highly concentrated AMD with acidity values in the thousands of mg/L, and which can include, in addition to typical AMD parameters, elevated levels of some trace metals such as arsenic, lead, copper, and chromium. The cost of reclaiming these piles using conventional AML techniques is high, and the extremely poor water quality is often beyond the reach of current passive treatment technology. However, the key to reclamation of many of the piles may be in the fuel-value of the material.

The significant growth in the use of coal ash in mine reclamation in the anthracite and bituminous coal regions of Pennsylvania in the past 20 years is principally due to three regulatory developments: 1) the enactment of the Federal Public Utility Regulatory Policies Act (PURPA) in 1978 and related regulations of the Federal Energy Regulatory Commission (FERC), which facilitated the development of the culm burning cogeneration plants, 2) the development of DEP policies and procedures in 1986 authorizing the Bureaus of Mining and Reclamation (BMR) and District Mining Operations (DMO) to issue permits for the use of coal ash in reclaiming active and abandoned mine lands within Surface Mining Permits (SMP) boundaries, pursuant to the Solid Waste Management Act of 1980, and 3) the promulgation of specific regulations for the beneficial use of coal ash in 1992 by the Pennsylvania Environmental Quality Board (25 Pa. Code Sections 287.661 through 287.666). These regulatory enhancements resulted in the construction of 16 waste coal plants in Pennsylvania shown on Figure 2, and the issuance of 122 permits for coal ash use in mine reclamation by DEP from 1986 through 2004. The permitted coal ash placement sites are shown on Figure 1.

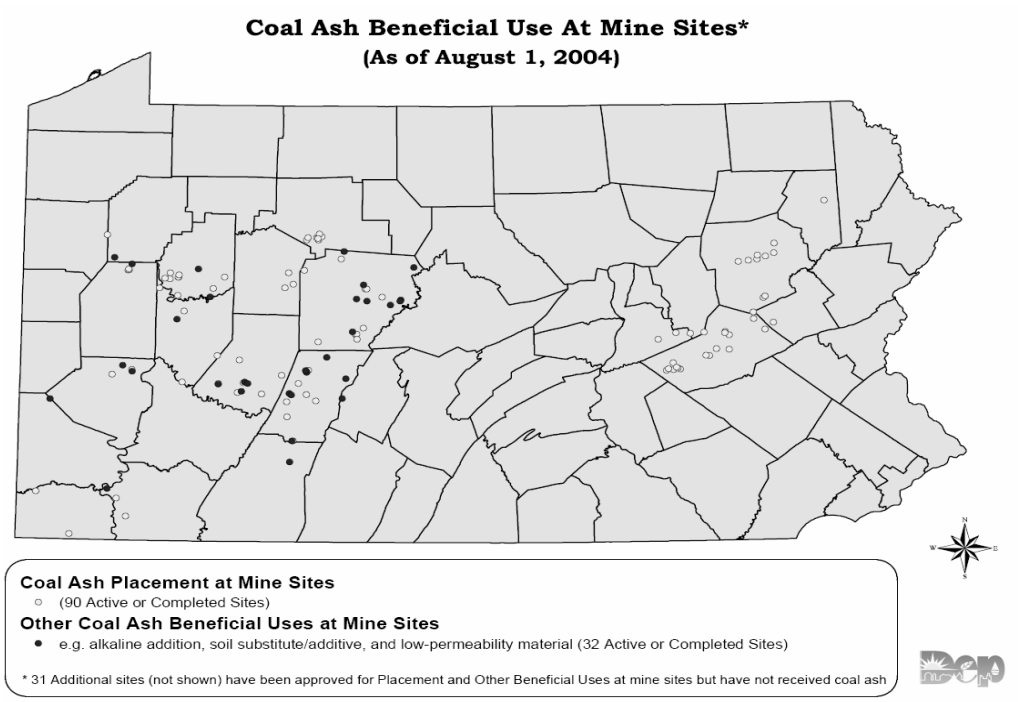

Figure 1. Location of coal ash beneficial use mine sites in PA.

The cogeneration plant concept is perfectly suited to Pennsylvania because these facilities remove abandoned coal refuse banks, mix the culm with limestone in their circulating fluidized-bed combustors, producing an alkaline coal ash, and use the coal ash to reclaim abandoned pits and other AML features. Therefore, multiple environmental benefits accrue from the removal of unsightly, acid-producing culm banks, the backfilling of AML features and the reduction of acid mine drainage pollution. In addition, social and economic benefits result from jobs related to the production of electrical power and by-product usage of steam (e.g. growing hydroponic flowers and tomatoes) in areas with a depressed economy. The cogeneration plants would be impossible without the development of the circulating fluidized bed boilers. PURPA created the business opportunity, and the circulating fluidized bed technology made it possible to burn the waste coal material. The new combustion technology was also capable of emissions control that enabled these combustion units to meet the most stringent of the emissions regulations mandated by the Clean Air Act of 1970.

There have been sixteen fluidized bed combustion (FBC) power plants constructed in Pennsylvania in the past seventeen years. The locations of these plants are shown on Figure 2. The Kimberly Clark FBC plant is an industrial site-power plant, and the remaining plants are all commercial power producers. Some are also cogeneration facilities in that they supply heat to one or more customers. (An FBC power plant is also considered a cogeneration project if it markets at least five percent of its steam to a thermal energy user.) The Archbald power plant was decommissioned in June 1997, and the Reliant Energy Seward FBC power plant started operating in the spring of 2004, so there currently are 15 FBC plants operating in Pennsylvania. Fifteen of the sixteen FBC plants range in size from 18 megawatts to 107 megawatts, however the most recent FBC plant (Seward) to come on line is 520 megawatts.

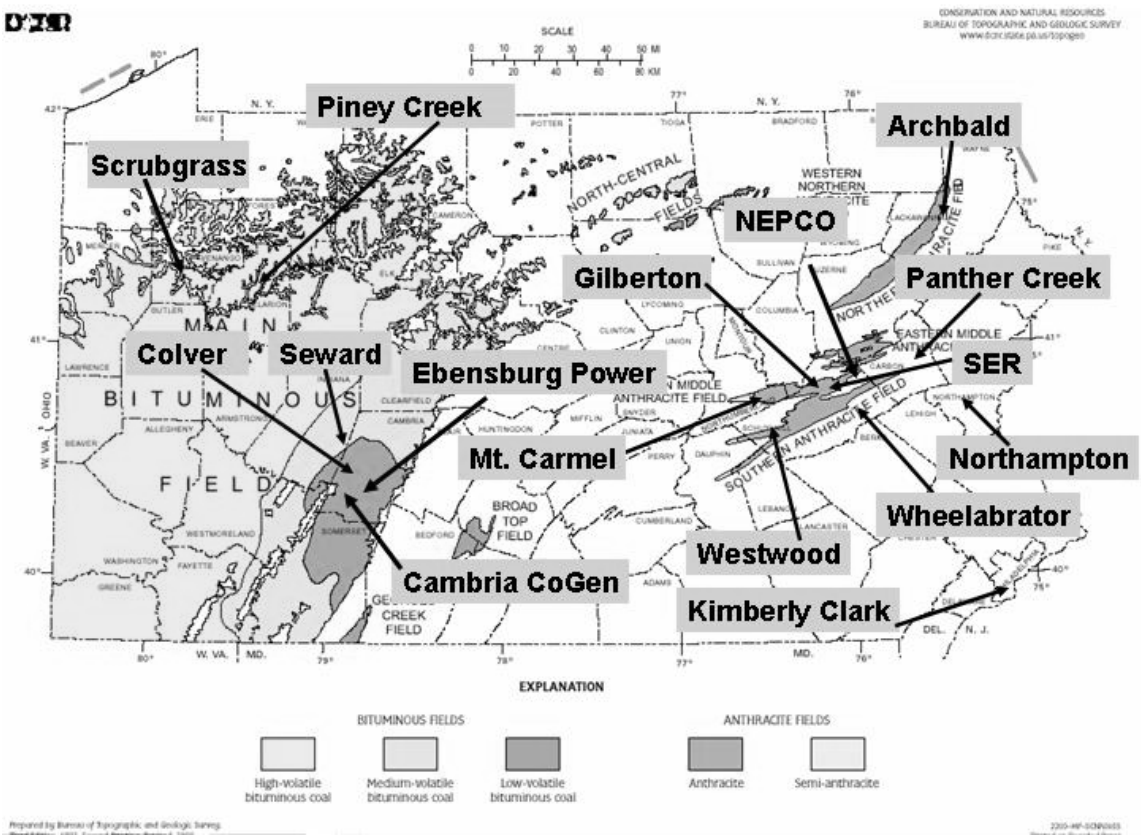

Figure 2. Distribution of the 16 FBC power plants in Pennsylvania

In Pennsylvania, there are 21 pulverized coal-fired (PC) electric generating power plants ranging in size from 100 megawatt (Mw) to 2700 Mw. The locations of the power plants are shown in Figure 3. These PC power plants burn about 45 million tons of coal annually, resulting in the production of about 5 million tons of coal ash (Bidden, personal communication 2004). Pulverized coal-fired plants produce much less ash per ton of fuel burned than do waste coal plants because waste coal contains much more noncombustible (inorganic mineral) material, and because the FBC process includes the addition of lime into the boiler.

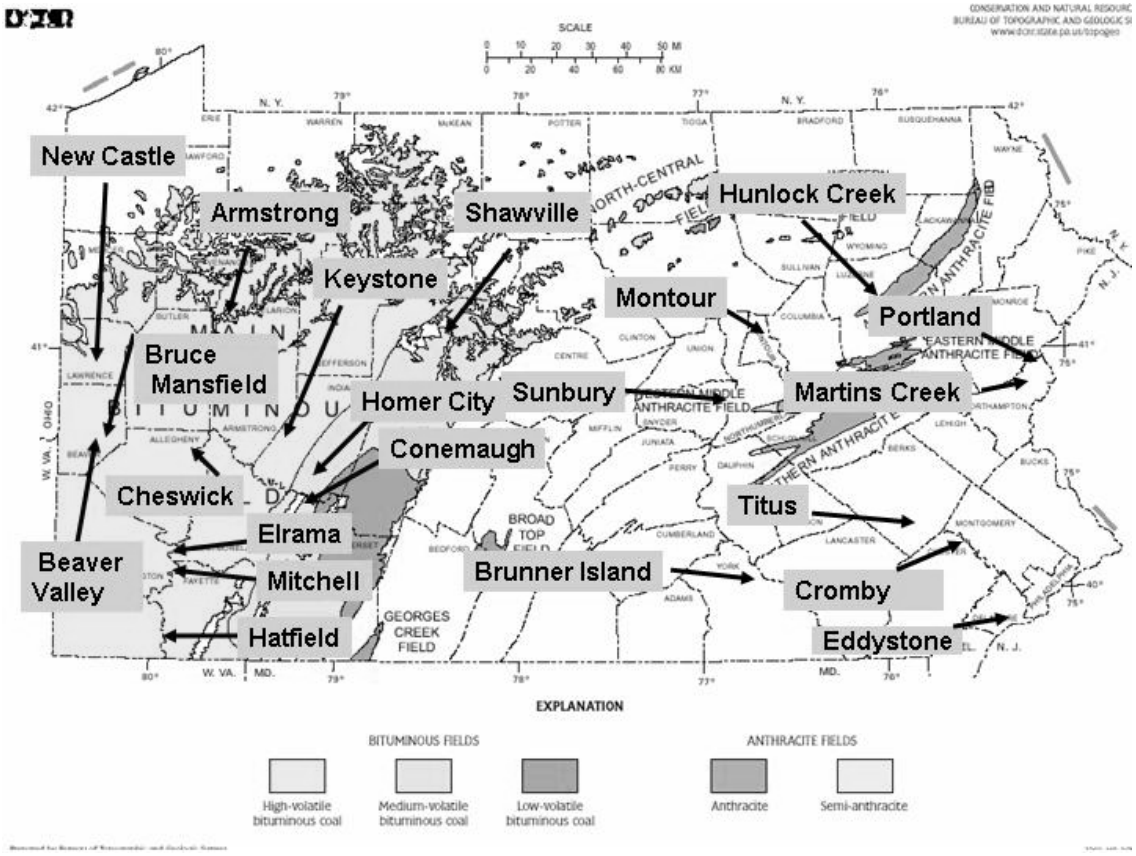

Figure 3. Distribution of 21 conventional PC coal-fired power plants in Pennsylvania

Each year Pennsylvania's power plants presently generate approximately ten million tons of coal ash, with about half coming from traditional plants and half coming from FBC plants. Currently, the FBC plants consume an average of 7,500,000 tons of coal refuse annually. However, with the addition of Reliant Energy Seward's FBC power plant, another 4,000,000 tons of coal refuse will be burned yearly, which is about a 50% increase to 11,500,000 tons per year. The FBC power plants in Pennsylvania collectively have burned more than 88,551,000 tons of refuse up through 2002, the last full year for which figures are currently available. The FBC industry in Pennsylvania has generated over 58,188,000 tons of ash between 1988 and 2002.

In 2002, about 6.4 million tons of ash were beneficially used on mine sites, of which about 5 million tons were FBC ash. Of the approximate 5,000,000 tons of conventional coal ash produced that year in Pennsylvania, only a little over 1,000,000 tons or twenty percent was used beneficially. However, opportunities do exist for the beneficial use of traditional PC ash on mine sites, where the ash has appropriate chemical and physical properties.

The sixteen FBC power plants in Pennsylvania have contributed to the reclamation of approximately 3,400 acres of abandoned mine lands within the past fifteen years. See Figure 4 for the annual number of acres reclaimed by the ten anthracite FBC power plants and the six bituminous FBC power plants as of the end of 2002. In the Anthracite

Region, where the abandoned mine pits are significantly deeper than in the Bituminous Region, the number of acres of abandoned mine acres reclaimed is less, but the depth of the pits are greater.

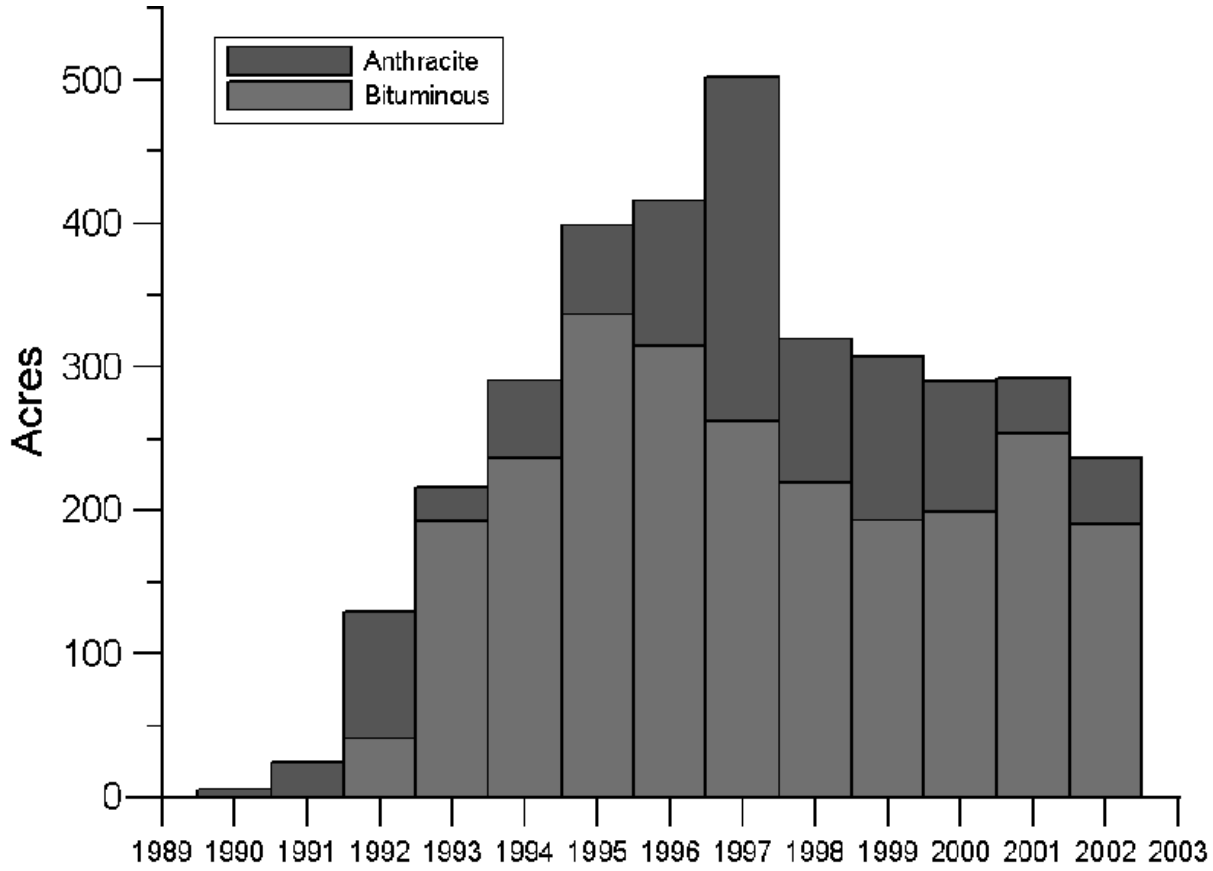

Figure 4. Acres of abandoned mine lands reclaimed by FBC plants in the Anthracite and Bituminous Regions.

Regulatory Framework for Coal Ash Placement at Mine Sites

Coal ash is defined in Pennsylvania's Solid Waste Management Act (SWMA) as fly ash, bottom ash, or boiler slag resulting from the combustion of coal. The beneficial use of coal ash in Pennsylvania is regulated under the SWMA, the Surface Mining Conservation and Reclamation Act, the Coal Refuse Disposal Act, the Clean Streams Law, and the Air Quality Control Act.

Beneficial use of coal ash was authorized under the 1986 amendment to the SWMA, which authorized the beneficial use of coal ash for mine site reclamation along with other beneficial uses. Prior to 1986, DEP required a waste disposal permit for the use of coal ash at mine sites. In 1992, the residual waste management regulations were amended in accordance with SWMA to regulate the beneficial use of coal ash at mine sites (under 25 Pa. Code Sections 287.661 to 287.666). The regulations were further revised in 1997 in regard to water monitoring, volumes of ash that may be used at mine sites, and certification guidelines for ash. In addition, the DEP developed a Memorandum of Understanding between its waste and mining programs and three technical guidance documents to further coordinate and manage the beneficial use of coal ash on both active and abandoned mine sites.

Pennsylvania currently defines the following four uses of coal ash on active mine sites as beneficial uses: 1) alkaline addition; 2) low permeability material; 3) soil substitute or additive; 4) placement. Alkaline addition takes advantage of the potential for some coal ashes to generate alkaline leachate and is used to offset the potential for on-site materials to generate acid mine drainage. According to Pennsylvania's current guidelines, to qualify for use as an alkaline addition agent the ash should have a neutralization potential (NP) of at least 100 parts per thousand and a pH of between 7.0 and 12.5. Using ash as a low permeability material usually entails sealing or

encapsulating materials on site that have the potential to produce acid mine drainage. For use as a low permeability material on a mine site, an ash should have pozzolonic characteristics and should be capable of achieving permeability equal to or less than 1.0×10^{-6} cm/sec under laboratory conditions. As a soil supplement, alkaline coal ash is used as a liming agent and also to improve the physical characteristics of the soil or soil substitute being used as site cover, as described in more detail in Strock and Stehouwer (2004). In some re-mining settings soil is not readily available, especially on coal refuse reprocessing operations, and coal ash can be used to enhance the characteristics of other on-site material to produce an acceptable growth medium. The soil/ash mixture must result in a pH between 6.5 and 8.0 to be considered suitable, and the amount of ash used must otherwise be commensurate with the need to establish a growth medium. The term "ash placement" involves the use of coal ash on a mine site to backfill pits or re-contour refuse piles on re-mining sites. The pH of the coal ash must be in the range of 7.0 to 12.5 at the generator's site for placement approval. In practice, coal ash use on a mine site typically fulfills more than one of the above beneficial use criteria. For example, coal ash being returned to a refuse reprocessing site may serve as an alkaline addition agent, an encapsulating agent (capping), as a soil additive, and for re-contouring.

Beneficial use of coal ash on a surface mine site can be requested as part of an original permit application or as a permit amendment. Either way, public notice and public participation are an integral part of the review process for all beneficial uses of coal ash on mine sites. The application for use of coal ash on a mine site must include a detailed operational plan, which includes: identification of the ash source(s); a certification from the ash generator(s); amount of ash to be used; purposes(s) of ash utilization; operational details of how the ash is to be handled and incorporated into the site; a demonstration that the ash is chemically and physically suitable for the proposed use; documentation of the hydrogeology of the ash-use area; and a monitoring program, including background data collection, designed to show any influence of ash use on surface and groundwater quality.

An application for use of coal ash on mine sites must include chemical analyses of the ash proposed for use. Analyses are performed on a dry-weight basis for pH plus sixteen metals. A SPLP (Synthetic Precipitation Leach Procedure) leachate analysis is required for pH, sulfate, chloride, plus seventeen metals. Coal ash must meet the maximum acceptable leachate limits for contaminants, based on the minimum requirements for an acceptable waste at a Pennsylvania Class III residual waste landfill. Periodic (typically biannual) re-certification and/or monitoring of the ash quality are required as long as the ash is being used on the mine site. The ash shipped from most power plants usually includes proportions of both fly ash and bottom ash, and analyses are provided of both for the mixture to be beneficially used. When the proposed use of ash on a site is as a soil supplement or additive, the applicant must also provide a soil analysis for pH, PCB's, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc so that potential plant up-take levels may be considered as part of the permitting process.

Groundwater monitoring is required for all ash applications on mine sites, except for sites where the only application is as a soil amendment. The volume of ash used on soil application sites is so small as to negate the need for water monitoring. For all other applications of coal ash on mine sites, groundwater monitoring is required before, during, and after ash placement on the site. Monitoring points are chosen so as to best show the effects, if any, of ash placement on the site. On many sites, especially re-mining sites, directly downgradient groundwater seeps, springs, and discharges may provide the most representative monitoring points for the site. The monitoring program should include monitoring wells where existing groundwater discharge points are inadequate in number or character to fully monitor the site. Upgradient wells, while they may not need to be as numerous as the downgradient points, are important, especially in an area where potential upgradient influences on water quality, such as other mine sites are present. In some upland or minepool settings, upgradient groundwater monitoring is not possible. For most mine sites, Pennsylvania requires a minimum of six monthly background samples for each monitoring point, and ash monitoring points are no exception. The ash monitoring points must be sampled for a suite of standard mine drainage parameters plus aluminum, arsenic, cadmium, calcium, chloride, chromium, copper, lead, magnesium, mercury, nickel, potassium, selenium, sodium, and zinc. During operations, monitoring must be done, at a minimum, quarterly for the mine drainage parameters and annually for the additional metals and chloride. More frequent monitoring is required on some sites. Once the site is completed, monitoring continues until the site is judged stable. Coal ash generally must be placed no closer than within eight feet of the top of the regional groundwater table. However, this requirement may be waived under the regulations if DEP approves the placement as part of a demonstration project.

The beneficial use of coal ash for mine reclamation is addressed in Sections 287.663-664 and subject to the requirements outlined in Table 1, Coal Ash Special Conditions. Coal ash may be beneficially used at active coal

mine sites and abandoned mine sites to improve water quality or prevent degradation. In addition, coal ash is capable of eliminating public health and safety hazards at mine sites. Basically, the ash must be placed in approved areas, spread and compacted in two-foot lifts, covered with four feet of suitable material and graded to a 3% minimum final slope.

Table 1. Key Items of Coal Ash Special Conditions used in DEP Permits

KEY ITEMS OF COAL ASH SPECIAL CONDITIONS

- Grade the disposal area to create a stable base.
- Keep the coal ash disposal area free of standing, running, or impounded water at all times.
- All coal ash must be within the acceptable moisture content range in order to achieve a minimum compaction of 90% of the maximum dry density.
- Coal ash is not to be deposited within eight feet of any coal outcrop, vein or seam, pit floor, high wall, low wall or highest regional groundwater elevation.
- Complete chemical analysis and leachate analysis of the coal ash shall be conducted on a semiannual basis.
- Modified Proctor or Standard Proctor tests of each separate source of coal ash to be disposed shall be conducted on a semiannual basis, to determine the optimum moisture content and the acceptable moisture range needed to achieve a minimum compaction of 90% of the maximum dry density as determined by the Modified Proctor Test or 95% of the maximum dry density as determined by the Standard Proctor Test.
- Approved monitoring points shall be analyzed on a quarterly basis for Coal Ash Groundwater Quality Parameters.
- The final cover layer on the coal ash disposal area shall be a minimum of four feet.
- Field density tests (minimum of one test per acre of active coal ash disposal areas) shall be conducted to insure that proper field compaction is being achieved within the disposal area.
- All coal ash conveyed or hauled to the coal ash disposal area must be spread and compacted in lifts of two feet or less.

Physical Properties of Coal Ash at Mine Placement Sites

Earthen materials are widely variable in physical and chemical properties and “in-place” strata conditions. Soil engineering methods have been developed that can be applied to coal ash as shown by decades of academic evaluation and practical experience. For purposes of engineering, uniformly placed coal ash can be considered as an artificial “soil” type that is usually more uniform than a natural soil layer. Engineering methods to determine particle size distributions generally classify a soil or coal ash by the percentages of particles that can pass through standardized sieve opening sizes via comparison to a USDA Soil Triangle Classification Chart. Coal ash generally contains approximately 60 to 70 percent silt, and 30 to 40 percent sand size particles depending on the characteristics of the fuel burned by the plant. The coal ash classification is normally that of a silt loam.

In coal ash monofills at both conventional ash disposal sites and demonstration ash sites, nationally recognized engineering standard tests are conducted and data is gathered. From this, an estimate of the ash's strength or bearing capacity can be made. The coal ash strength and bearing capacity sets the upper limit on potential building types, and other future uses. A laboratory Proctor Density Test must be conducted on the coal ash (either standard or most commonly the modified version). From this test, the theoretical Maximum Dry Density and the Optimum Moisture Content can be determined. Figure 5 illustrates a laboratory compaction test adapted from Bowles (1970).

DEP requires that field compaction results achieve 90 percent of this laboratory maximum density of 107.5 pcf, in this example. By projecting a line through the curve at this point it is seen that, the acceptable moisture range needed in order to achieve the required compaction in the field is between 12.5 and 17.3 percent for the example in Figure 5. Therefore, the moisture content of the ash can be adjusted in order to place it on site within this moisture range**.** These numbers can then be used to ensure that the material is brought to the placement site at a moisture content that will allow adequate on-site compaction. In short, the test method usually shows a narrow range of density and optimum moisture for coal ash that has the desired engineering qualities for the proposed usage of the material**,** however the results can be different for fly ash and bottom ash.

The maximum dry density is that point where there is little potential for additional compaction. Therefore, long-term settlement of the coal ash is minimized if the coal ash is already near or at maximum density. An analysis of the maximum density, optimum moisture content, and field compaction test results for fly/bottom ash for four

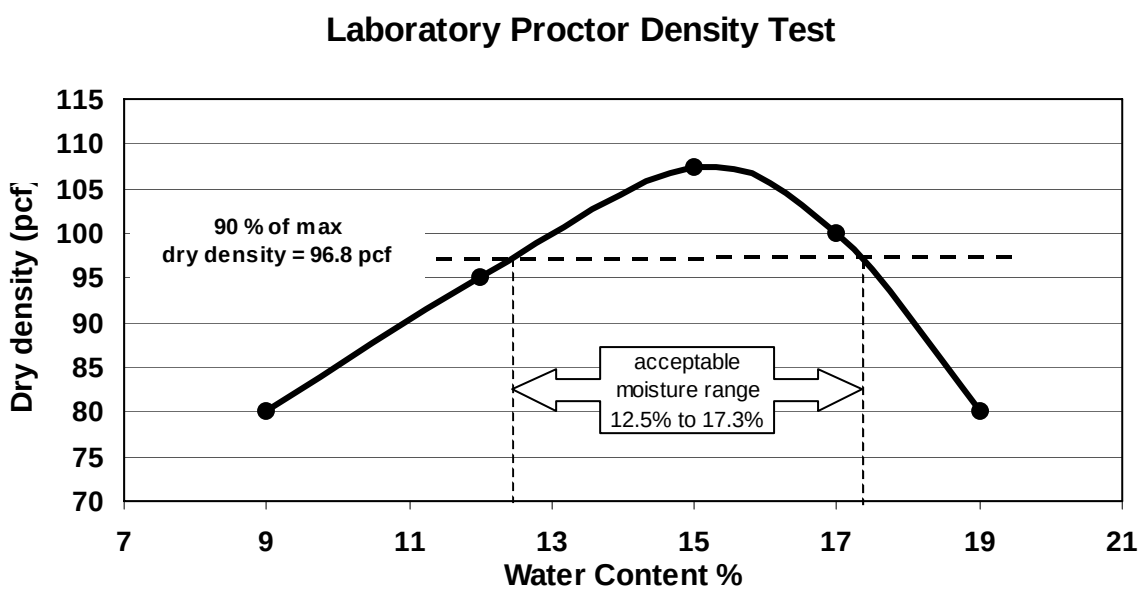

Figure 5. Typical display of compaction test data.

different ashes over time (Figs. 6a to 6c) indicates the maximum dry density varies from approximately 70 lbs/cu.ft. to 105 lbs./cu.ft. (mean value of 85 pcf), and the optimum moisture content varies from approximately 16% to 38%, (mean value of 25%). Field compaction tests reveal that compaction percentages are almost always 90% or higher (Fig. 6c). Other engineering properties can often then be correlated to the same maximum range of dry density, compaction and optimum moisture due to the uniformity of the coal ash materials.

After the ash is spread and compacted, field density tests can be performed with a nuclear densometer or other test method to determine or verify that the ash fill is meeting the 90% requirement. Results of these tests are summarized in a report from a certified testing laboratory. Analysis of the field density tests taken at conventional ash disposal sites has shown that their compaction consistently meets 90% or greater of the modified proctor

densities with minimal compactive effort (i.e. dozers, trucks, etc.), without the need for the usual steel drum, rubber tire, or sheeps foot roller equipment**.** The use of this extra equipment and labor are not routinely needed to achieve the required compaction and density for most sites. There may be some sites, however where compaction equipment may be needed.

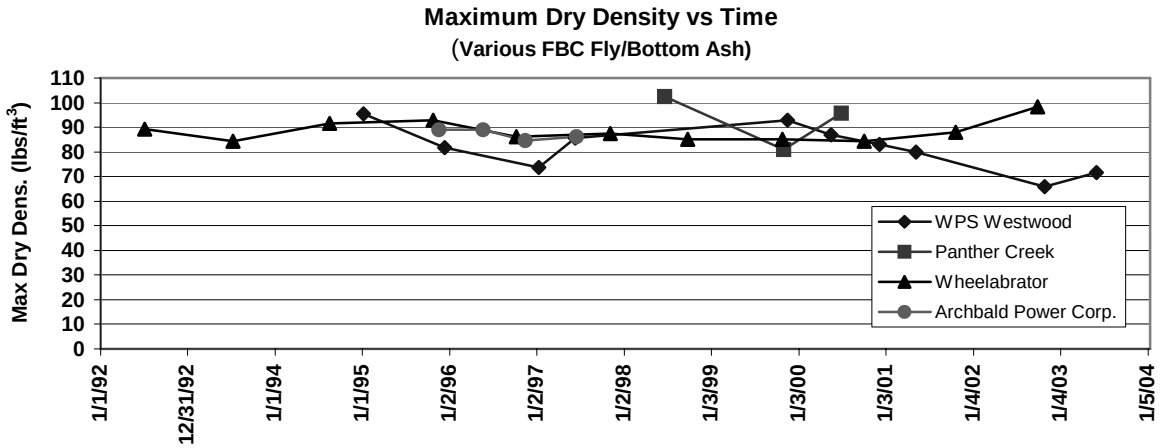

Figure 6(a). Plot of Maximum Dry Density.

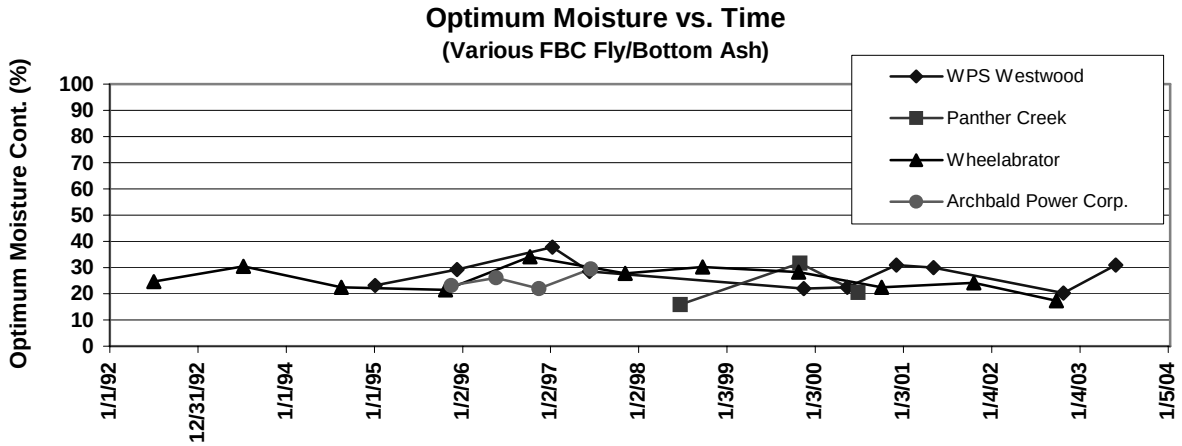

Figure 6(b). Plot of Optimum Moisture Content.

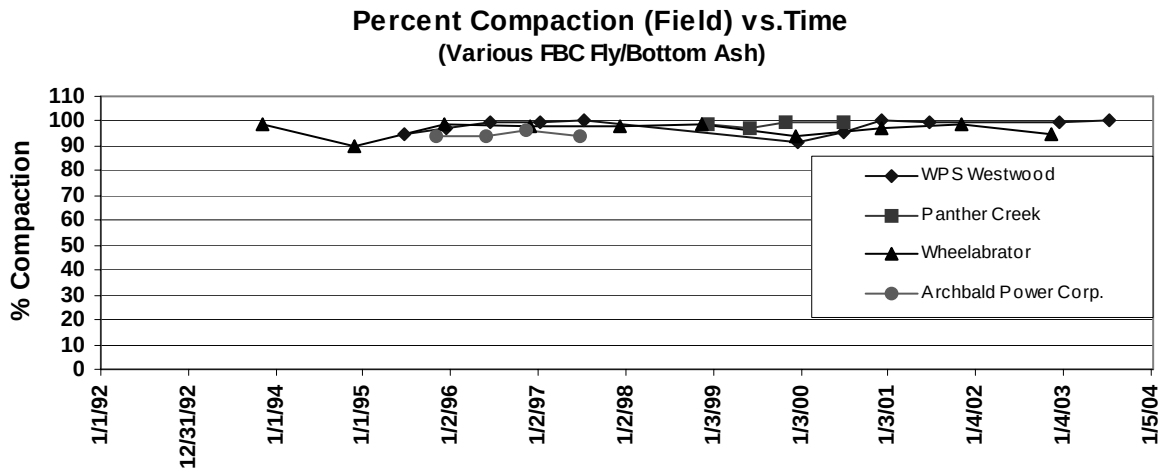

Figure 6(c). Field compaction tests of ash from various ash sources.

Occasionally direct readings are taken with a hand held pocket penetrometer (Sowers and Sowers 1970), which gives a rough estimate of the bearing capacity of the material at the surface (e.g. in tons/square foot). This type of testing is primarily useful as a spot check for the surface layer of the placed ash. It must be supplemented with the Troxler nuclear moisture density gauge or other test methods giving results that are accurate for below the exposed surface of the coal ash. At the demonstration permit sites described in the last section of this paper, the soil penetrometer results consistently met or exceeded 3.0 tons/square foot (tsf) and commonly **"**maxed out**"** on the penetrometer gauge at 5.0 tsf, which more than satisfies the accepted minimum standard of 2.0 tsf listed in the permit. The physical properties of coal ash and engineering practices of coal ash placement at mine sites in Pennsylvania are described in more detail in Owen et al. (2004).

Finally, in some cases, and for the demonstration permit sites, Soil Boring Tests are performed which utilize a split-spoon for sampling at depth intervals (usually 5 feet) and Standard Penetration Tests (U.S. Department of the Interior, Bureau of Reclamation 1974) are performed at these same intervals which measure the number of times (i.e. the blow count) it takes to drive the spoon through a specified vertical interval with a standard weight hammer and drop distance on the drill rig (i.e. the "blow"), (ASTM Standard Penetration Test – ASTM D 1586-2003). From these numbers, the engineer can use technical literature (Tschebotarioff 1974) in order to estimate the "in-place" bearing capacity of the material at depth, and can make recommendations as to design of footing foundations for structures. Available data from other test methods were compared to the penetrometer test results, and appear to support the high bearing capacities. The penetration results on the soil boring logs showed a sufficient value of "Blows/Foot" to adequately support a spread footing foundation at a design parameter of 2.0 tsf.

In summary, the ash fills, whether at conventional or demonstration sites are more than suitable for construction purposes for residential or commercial buildings, roads, and most other engineering applications, with perhaps the exception of "super-structures" such as heavy bridges or tall buildings, but even these uses could be investigated on a case by case basis. Ash has been utilized in other cases either with or without additives, such as Portland cement or cement kiln dust, in a slurry form to fill in mine voids, narrow crop falls, etc. where equipment access is a problem. Flowable fill is produced by mixing fly ash and a small amount of cement, hydrated lime or other binder material with water to a flowable consistency. Flowable fill is defined by the American Concrete Institute Committee as "controlled low-strength material" (ACI Committee 229). Since fly ash is a pozzolan, it reacts with calcium hydroxide and water to form cementitous compounds. Flowable fill is virtually self-leveling with the consistency of pancake batter. DEP has found these types of ash grout cement uses to be successful and continues to look at other possible uses within the same realm.

Chemical Characteristics of Coal Ash, Leachate, and Groundwater Quality at Mine Sites

The physical and chemical properties of coal ash are monitored and evaluated by DEP through permitting and inspection activities at coal ash placement sites. The general chemical monitoring requirements for the solid ash

samples, SPLP leachate, and groundwater samples are described in the preceeding section of this paper on the regulatory framework and in the book chapter by Dalberto et al. (2004). The purpose of this section is to use site-specific data from an anthracite case study described in Hornberger et al. (2004) to illustrate the relationships among the chemical parameters in the solid ash, SPLP leachate, and groundwater monitoring points. Groundwater monitoring associated with coal ash placement at anthracite mine sites generally depends upon an understanding of the minepool hydrology. Almost all of the refuse bank reprocessing and strip mine sites overlie abandoned underground mines, and these individual collieries have minepools with gravity discharges, or are hydrologically interconnected to other minepools and downgradient discharge points.

The large B-D Mining coal refuse reprocessing and coal ash placement site is located in Mahanoy and West Mahanoy Townships and Gilberton Borough in Schuylkill County. The SMP #54850202 is for a total of 1,590 acres, including 809 acres of coal refuse removal and 175 acres of coal ash placement areas. This SMP was issued in December 1985 as a repermitting operation that encompassed five previous surface mining permits. The permit boundary and active and abandoned mine features are shown on Figure 7. This site consists of a large area of abandoned mine lands containing extensive waste coal (refuse material) and coal silt deposits that are consumed in the Gilberton Power Cogeneration Plant. While the ash placement site overlies a single abandoned underground mine (Boston Run Colliery), the SMP overlies a total of 8 abandoned collieries, and the Gilberton Shaft minepool monitoring point within the SMP receives mine drainage from at least 11 upgradient collieries and interconnected minepools. This case study site was selected because it represents a large volume coal ash placement area within a large-scale refuse reprocessing operation with a complex groundwater monitoring scenario.

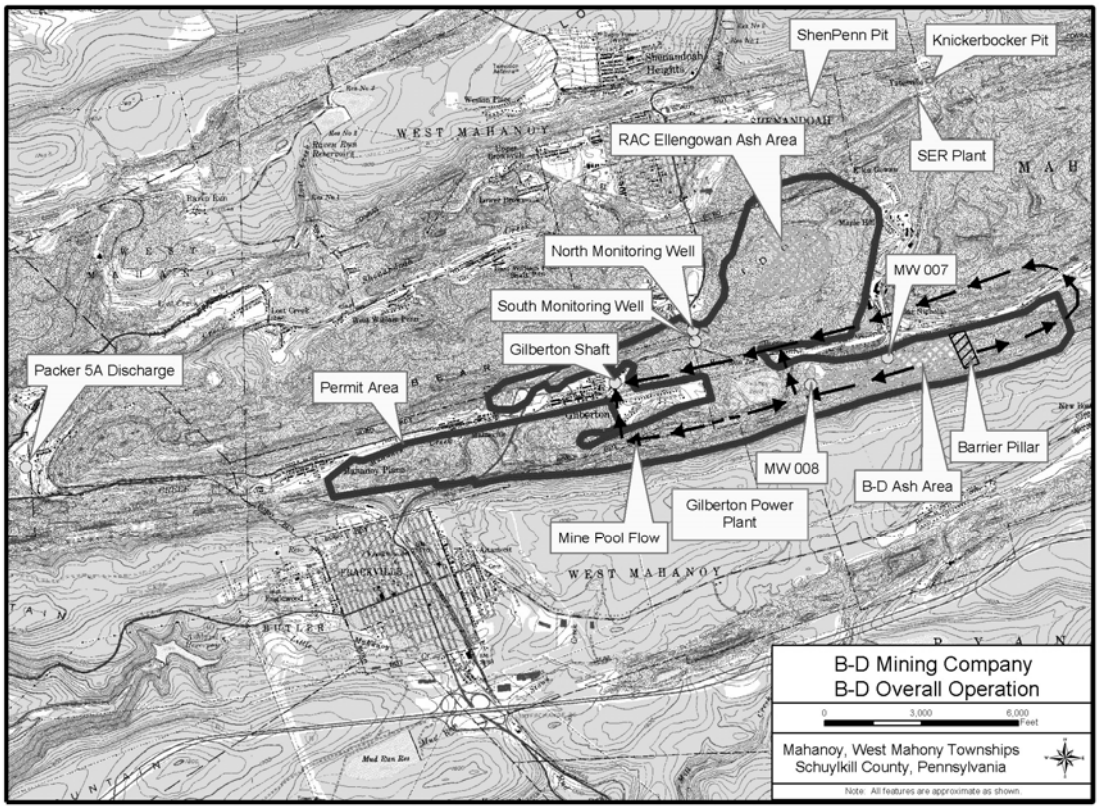

Figure 7. Map of B-D Mining site showing permit boundary, ash placement areas and monitoring locations.

Before describing the monitoring points and monitoring data, it is useful to put the B-D Mining site in perspective with the other coal mining and ash placement activities in the watershed. The 1,590 acre B-D Mining SMP shown on Figure 7 is adjacent to the 3,038 acre Reading Anthracite Co. Ellengowan SMP located to the northeast. That Reading Anthracite SMP contains the Schuylkill Energy Resources (SER) cogeneration plant and its large coal refuse bank fuel supply, plus the Shen Penn and Knickerbocker pits, and the Ellengowan silt dam coal ash site

within the SMP boundaries. Thus, there are three significant coal ash placement sites in the area as shown in Figure 7, the Knickerbocker pit to the north, the Ellengowan silt dam in the middle, and the B-D ash placement site to the south of the other two. The entire area underlying these two large surface mining pits is a series of interconnected abandoned underground mines. Surface mining activities within this area consisted of numerous small pits, several large open pit mines including the Shen Penn and Knickerbocker pits, and extensive coal refuse disposal and refuse reprocessing operations. Annual records of refuse consumption and ash production from the Gilberton Power and SER cogeneration plants, show that more than 22 million tons of coal refuse have been removed from the permit areas, and more than 15 million tons of coal ash have been beneficially used from 1988 to 2002. All of these mining and ash placement areas drain to the Gilberton Shaft and ultimately the Packer V discharge at Girardville, shown on Figure 7.

The coal ash material placed within permit areas shown on Figure 7 has been regularly monitored and tested since 1988 for solid ash bulk chemistry and leachate analyses in accordance with the DEP's Module 25 requirements, and monitoring has shown that the solid ash and leachate parameters are consistently within allowable limits. Table 2 shows the chemical analyses for the solid ash expressed in milligrams per kilogram (i.e. parts per million) for the ash from the SER plant. The bottom half of the table shows the leachate concentrations from the Synthetic Precipitation Leachate Procedure (SPLP) test, expressed in milligrams per liter (i.e. parts per million), for the ash samples shown in the top half of the table. The samples included in the table are representative samples of the 25 samples contained in the permit file resulting from the semiannual testing requirements. The samples selected for inclusion in Table 2 represent the range in concentrations, the medians, the range in time, or sampling events when bottom ash or fly ash were separately tested. The writers determined that to include all available analyses in these tables would make them too voluminous for inclusion in the body of this paper; plus, all of this data is public file information within the permit files. However, the concentration plots of the ash, leachate, and monitoring data in Figure 8 and 9 show the entire range and median values of all of the data within the permit files. Another table in Hornberger et al. (2004) shows the chemical analyses for the solid ash and SPLP leachate from the Gilberton Power Plant in the same format as Table 2.

The elements in the columns of Table 2 are arrayed in the approximate order of their abundance in the solid ash samples. The major elements, aluminum, iron and potassium shown in the table are present in the range of thousands to tens of thousands of mg/kg. Other major elements in coal, coal refuse and overburden rock minerals (e.g. calcium, magnesium, sodium and silica) are not included in the table, because they are not routinely required in the Module 25 list of analytes; but they are known to be present in these approximate ranges (i.e. thousands of mg/kg) from other analyses discussed in Scheetz et al. (1997) and other sources. Barium is relatively abundant in the hundreds of mg/kg range, followed by manganese, chromium, copper, zinc, nickel, boron, molybdenum, and arsenic, generally in the tens of mg/kg range. Finally, the elements of selenium, cobalt, mercury, cadmium, and silver are generally present in the range of a few mg/kg to trace quantities of a few hundredths of a mg/kg.

Table 2. Chemical analyses of SER coal ash and SPLP leachate. (0.00 values = below detection limit).

Solid Ash - Dry weight concentrations in mg/kg																			
SAMPLED	**pH**	**Al**	**Fe**	**K**	**Ba**	**Mn**	**Cr**	**Cu**	**Zn**	**Ni**	**B**	**Pb**	**Mo**	**As**	**Se**	**Co**	**Hg**	**Cd**	**Ag**
Combined Fly and Bottom Ash																			
4/30/91	10.6	22100	8520		229	57	24	24	35	*10*	34	19	*12*	11	5.8		0.42	1.20	0.00
12/7/92	9.2	23150	16170		163	70	28	18	14	8	9	17	23	12	0.8		0.33	0.00	0.00
10/28/98	9.6	27900	24500	10600	287	62	47	48	23	15	0	45	13	13	0.0	11	0.00	0.00	1.00
11/30/99	10.2	13000	8360		121	50	16	10	8	38	0	0	0	7	0.0		0.41	0.00	
11/10/00	10.4	45600	26700		243	84	27	17	14	25	17	*10*	*10*	42	1.2		*0.02*	*0.50*	
4/17/02	9.1	10300	13200		108	87	25	14	17	10	45	18	*1*	10	*0.5*		0.15	*2.00*	
Bottom																			
1/10/90	11.3	17568	11160		156	59	23	21	19	9		0	62	206	0.0		0.00	0.70	1.80
Conditioned Fly																			
1/10/90	11.3	42470	28140		473	101	52	31	35	22		46	47	158	0.2		0.00	1.00	2.00
SPLP Leachate Concentration in mg/L																			
SAMPLED	**pH**	**Al**	**Fe**	**K**	**Ba**	**Mn**	**Cr**	**Cu**	**Zn**	**Ni**	**B**	**Pb**	**Mo**	**As**	**Se**	**Co**	**Hg**	**Cd**	**Ag**
Combined Fly and Bottom Ash																			
4/30/91	5.4	5.12	0.20		0.27	0.27	0.00	0.00	0.07	0.18	ns	0.09	0.05	0.01	0.12		0.00	0.00	0.00
12/7/92	5.4	9.88	0.04		0.00	0.40	0.00	0.00	0.14	0.08	0.37	0.00	0.23	0.02	0.01		0.00	0.00	0.00
10/28/98	10.1	1.72	0.00	10.40	0.24	0.03	0.08	0.02	0.00	0.04	0.00	0.12	0.15	0.01	0.08	0.00	0.00	0.01	0.01
11/30/99	8.8	2.85	0.12		0.00	0.02	0.07	0.03	0.00	0.20	0.22	0.00	0.45	0.05	0.01		0.00	0.00	
11/10/00	10.3	1.67	*0.03*		*0.10*	0.07	*0.05*	0.02	*0.01*	*0.04*	*0.20*	*0.10*	*0.10*	*0.01*	*0.01*		*0.00*	0.02	
4/17/02	10.2	1.64	0.02		0.03	0.01	*0.01*	*0.01*	0.06	*0.01*	*0.07*	0.05	*0.01*	*0.04*	*0.01*		*0.00*	*0.01*	
Bottom																			
1/10/90	5.00	13.82	4.26		0.00	0.56	0.00	0.12	0.17	0.00	0.40	0.42	0.63	0.00	0.00		0.00	0.30	0.04
Conditioned Fly																			
1/10/90	5.10	14.38	4.30		0.00	0.56	0.00	0.10	0.21	0.00	ns	0.44	0.54	0.00	0.00		0.00	0.32	0.03

While some of these elements are not abundant in the solid ash or the SPLP leachate, they are included in Table 2, and are routinely required in the Module 25 analyses because they are elements of concern in the Federal RCRA program (i.e. As, Ba, Cd, Cr, Pb, Hg, Se, Ag). The leachate concentrations of all of these major, minor, and trace elements in the bottom half of the table can easily be compared to the solid ash analyses, and it is evident that the relative abundance of certain elements in the solid ash is not matched by their relative abundance in the leachate. For example, aluminum, and potassium are more concentrated in the leachate than iron, and barium concentrations in the leachate are no higher than manganese or zinc. In the 15 columns from barium to silver, none of the leachate concentrations are greater than 1.0 mg/L. The analyses for some of these elements that are shown as 0.00 in Table 2 were reported that way in the monitoring data submitted to DEP, but actually should be expressed as less than a specified analytical detection limit for that element.

The ranges of concentrations of constituents in the solid ash samples from the Schuylkill Energy Resources FBC plant are shown in Figure 8. All of the 25 solid ash analyses for the SER power plant were used in computing the range and median for these data sets. The bold vertical lines express the range of concentrations and the bold horizontal lines represent the median values in these frequency distribution diagrams. These figures are graphed on a log scale because the range of concentrations of elements in the coal ash extends over 7 orders of magnitude for this coal ash source, and the patterns of variations for all these elements can then be viewed simultaneously as an "ash fingerprint" or chemical signature for that ash. These data plots are essentially simplified box plots, following the concepts developed by Tukey (1977) and McGill et al. (1978) for comparing batches of data, and used in the statistical analysis of mine drainage data by Griffiths et al. (2001), Fox et al. (2001), Smith et al. (2004), and Brady et al. (1998). If these diagrams were truly box plots, the interquartile range of the data would be contained in a box. While the boxes are very useful in evaluating the shape of the frequency distribution of the data and in comparing large data sets, it was determined that the boxes were not essential in these diagrams.

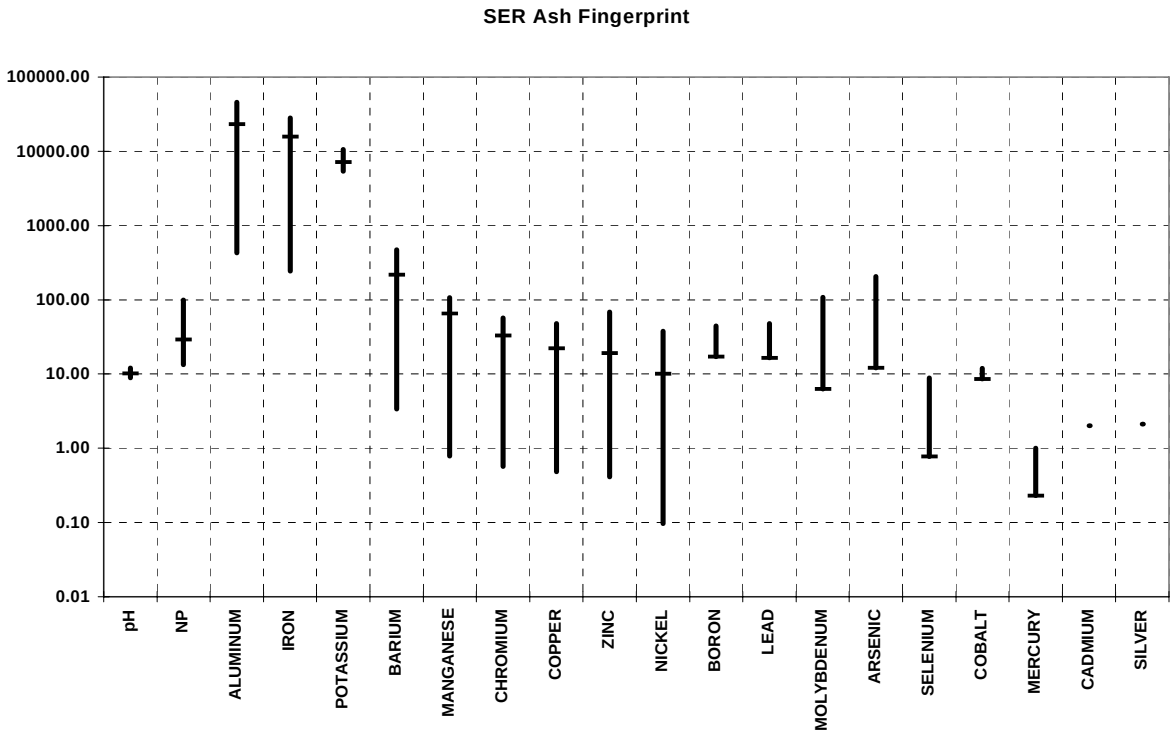

Figure 8. Ranges and medians of elements in SER coal ash. (all parameters except pH and NP are expressed as mg/kg).

Similar diagrams were constructed to evaluate the patterns of variation for several analytes of concern (i.e. aluminum, iron, and arsenic) in the solid ash, the SPLP leachate, and an array of groundwater monitoring points, as described in more detail in Hornberger et al. (2004). Figure 9 shows the patterns of variation for iron in the solid ash, the leachate, and the downgradient groundwater monitoring points occur over seven orders of magnitude. The three monitoring wells (South BH, MW7, MW8) are located downgradient of the B-D and SER ash sites and they were mostly installed after ash placement commenced and it was determined that these additional monitoring points were needed. Thus, the data from the first few years of monitoring were compared to the data for all of the later years to determine if there were any noteworthy changes. The data from the early years is shown as MW7-e, for example, and the later years as MW7-1. The median iron concentrations in the solid ash are similar at 19,995.5 mg/kg for the Gilberton Power ash and 15,750 mg/kg for the SER ash. The SPLP leachate medians for iron are both relatively low at 0.16 mg/L for Gilberton and 0.07 mg/L for SER. The three downgradient monitoring wells had interesting differences between median iron concentrations. MW007 had no significant change between the first 3 years of data and the remaining 6 years, because the median for the early years (MW7-e) is 66.7 mg/L and the median for the later years (MW7-l) is 69.5 mg/L. The median iron concentrations in the South BH and MW008 on Figure 9 show very substantial differences between the early and later years of monitoring. The first 2 years of data for the South BH downgradient of the SER ash site have a median of 168.5 mg/L (n=14), compared to the median for the later 14 years of 22.6 mg/L (n=80). The first 2 years of data for MW008 downgradient of the Gilberton ash site have a median of 121.5 mg/L, compared to the median for the later 5 years of 9.65 mg/L. The Gilberton Shaft pumped minepool discharge point is the key downgradient groundwater monitoring point for both coal ash placement sites and the median iron concentration for the first 4 years of monitoring is 55.83 mg/L (for 24 samples from 1986 to 1990), while the median for the last 12 years is 43.92 mg/L (for 49 samples from 1991 to 2003). The Packer V minepool overflow point further downgradient has a median iron of 18.5 mg/L. The conclusion that can be made for the entire data set of iron values shown on Figure 9 is that although more than 15 million tons of coal ash were placed in the drainage basin with high concentrations of iron in the solid ash samples, the median iron concentration at the downgradient Gilberton Shaft monitoring point decreased by 12 mg/L, and the median iron

concentrations in two monitoring wells immediately downgradient of the two coal ash placement areas decreased by an order of magnitude (i.e. from >160 mg/L to <25 mg/L in South BH, and from >120 to <10 mg/L in MW008).

The median aluminum concentrations in the Gilberton Power and SER ash samples were 31,608 and 23,150 mg/kg respectively, while the medians of the SPLP leachate from these ash samples were both 2.2 mg/L, and the median aluminum concentrations for the Gilberton Shaft and Packer V downgradient groundwater monitoring points were both less than 1.0 mg/L. The median arsenic concentrations in the Gilberton Power and SER solid ash samples were 11.6 and 12.17 mg/kg respectively, the medians of the SPLP leachate were 0.02 mg/L or less, and the medians of all groundwater monitoring points were less than 0.01 mg/L. Additional diagrams and data for aluminum and arsenic are shown in Hornberger et al. (2004).

The anthracite minepool interconnections are described above to provide illustrations of the potential difficulties and complexities of developing realistic groundwater monitoring plans for some anthracite surface mine and coal ash placement sites. The simplified residual-waste monitoring concept of an upgradient monitoring well to document ambient groundwater quality of the aquifer, and one or more downgradient monitoring wells to detect and capture any groundwater pollution emanating from the site, is not applicable to many anthracite mine sites. Thus, the configuration of voids within the underground mine workings (i.e. gangways, cross-cut rock tunnels, slopes, shafts, etc.) is evaluated to select potential upgradient and downgradient monitoring well locations and the presence of breaches in barrier pillars is considered in determining groundwater (minepool) flow patterns.

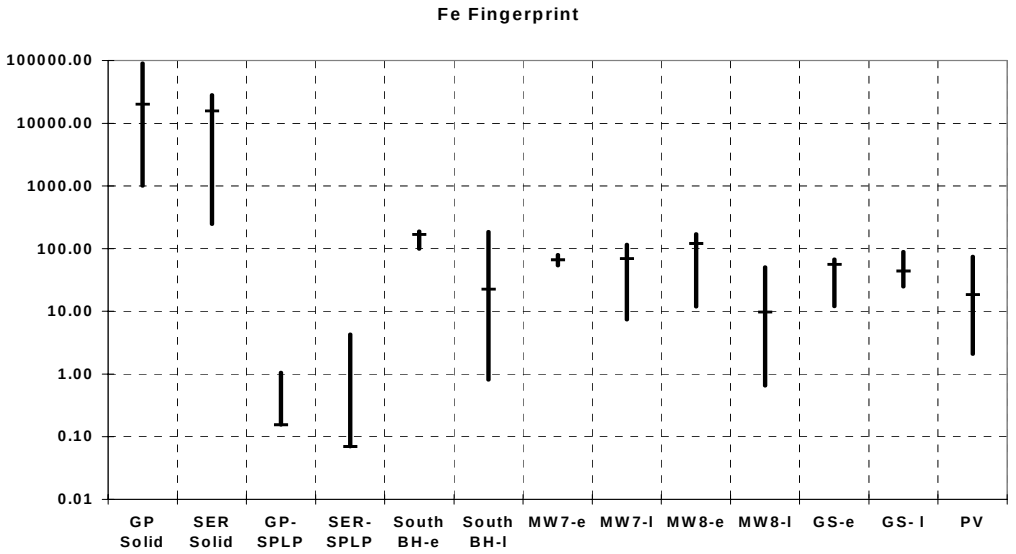

Figure 9. Iron content of solid ash, SPLP leachate and groundwater monitoring points.

Conventional Ash Placement Practices in the Bituminous and Anthracite Regions

Bituminous Coal Region

Beneficial use of coal ash on bituminous coal mine sites in Pennsylvania is not a new concept and has been practiced for at least 15 years. Abandoned coal refuse piles, large and small, dot the landscape of Pennsylvania's bituminous coal region. Coal refuse (also known as gob) is the nonmarketable material that was removed from mines along with the coal. Many of the piles occur near old mine mouths or cleaning plants; most, but not all, are associated with deep mines. Surface mined coal that was cleaned prior to being marketed also contributed to some piles. The aboveground piles typically are toxic to any colonizing vegetation and are highly erosive. Often the refuse was deposited in the lowland areas, below mine entries or cleaning facilities, frequently on stream banks, and sometimes directly in the stream channel. Even decades after refuse placement, each significant precipitation event washes fresh refuse onto adjacent properties and into streams. Most coal refuse contains relatively high percentages of sulfur and, therefore, leaches severe quality AMD. Because the oxidation of pyrite is exothermic, some refuse piles catch fire and burn for decades, adding air pollution to the list of problems they create for the small mining communities that often exist next to them.

The Ebensburg Power Company Revloc site is located directly east of the village of Revloc and south of highway US 422 in Cambria County, Pennsylvania. The South Branch of Blacklick Creek, a tributary of the Conemaugh River, bisects the pile as shown on Figure 10. The South Branch supports a native brook trout population directly upstream of the Revloc pile, but has been virtually devoid of aquatic life below the pile for decades. Refuse in the pile is from the Bethlehem Mines Corporation Mine 32 Lower Kittanning deep mine that operated during the middle decades of the twentieth century. The refuse was placed in a lowland area where an unnamed tributary entered the South Branch; the refuse actually dammed the South Branch, producing a pond on the upstream side of the pile. Ebensburg Power Company obtained separate mining permits on the northern and southern sections of the Revloc pile, which are separated by the South Branch. The company permitted the larger northern pile under SMP #11880201 (Revloc 1), which DEP issued in 1989. Revloc 1 contained approximately 3.8 million tons of coal refuse spread over approximately 56 acres. In 1997, the company obtained SMP #11960202 (Revloc 2), which included 0.7 million tons of coal refuse.

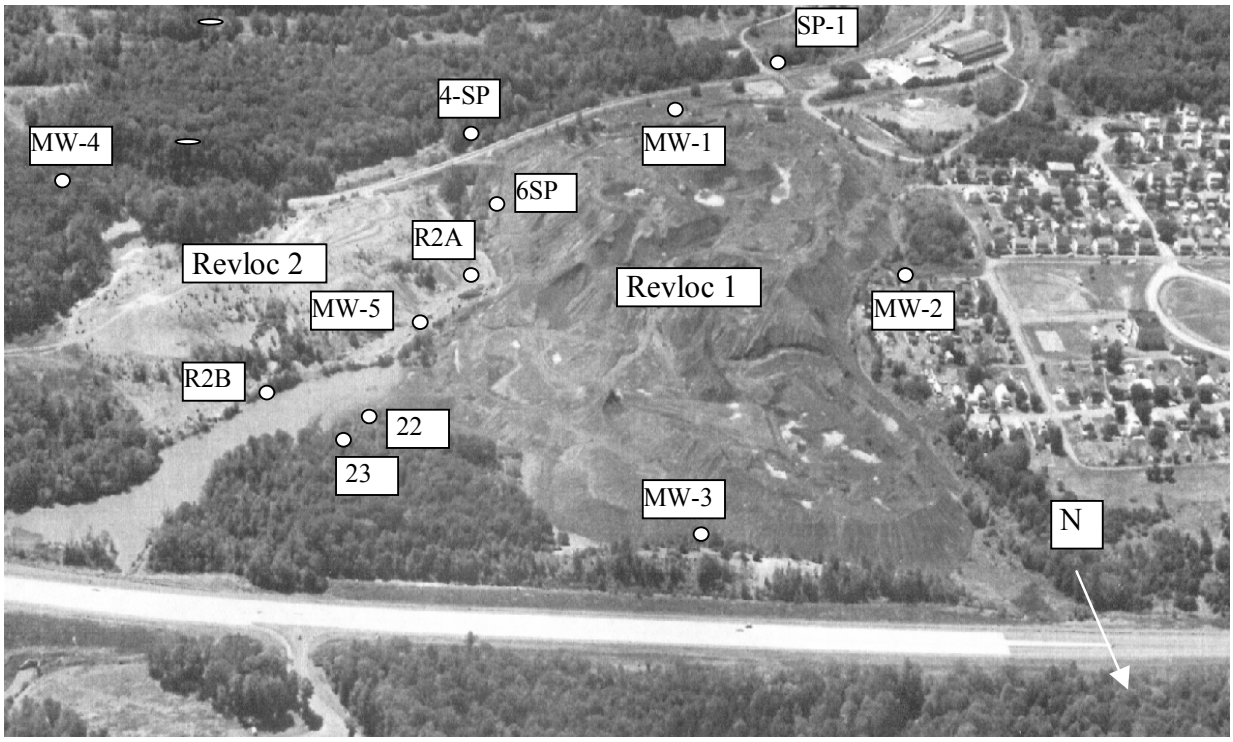

Figure 10. Aerial photo circa 1988 showing the Revloc sites and key associated monitoring reports. The photo was obtained from the permit application for Revloc 1.

Ebensburg Power Company began removing refuse from the Revloc 1 site at the end of 1990 and began bringing ash back to the site in very early 1991, when its 50-megawatt fluidized bed cogeneration facility, located in Ebensburg, PA, went online. Mining began on the northern end of the site adjacent to Route 422 and has advanced toward the southwest on multiple working faces. The company activated the Revloc 2 site in the fall of 1997; excavation on Revloc 2 began on the eastern side of the pile, in the area known to be burning. Thus, the fire was extinguished early in the operations to end that source of air pollution and to preserve the useable fuel in the pile. The company operates the two piles concurrently as fuel needs warrant.

Because the Revloc 1 site has been active for ten years, there is a large body of data available from the site. (The approximate locations of the monitoring points discussed herein are shown on Figure 10). Well MW-1 is a downgradient well, located just off the south-central edge of pile and between the pile and the South Branch. MW-2 is located along the western side of the pile, between the pile and the village of Revloc, and is located upgradient of the site. Well 3 is located along the north central edge of the pile, between, the pile and US Route 422, and MW-3 is located transverse to the direction of groundwater flow. The shallow groundwater flow direction at the site is from the northwest toward the southeast, from an upland recharge area in and to the north of the village of Revloc toward the discharge area at the South Branch.

Figure 11 is a photograph of the Revloc 1 site taken from the Revloc 2 site looking toward the village of Revloc to the northwest. The lighter green area in the center of the photo is recently planted area, while the darker green area on the right side of the photo is area that has been planted for at least two years. The dark area on the left of the photo is an area awaiting soil and vegetation. The refuse in the foreground is a yet-to-be-reclaimed area on the Revloc 2 site, and the small tree line at the base of the reclaimed pile marks the location of the South Branch.

Figure 11. Photograph of the reclaimed portions of the Revloc 1 refuse site. Note the contrast with Figure 10.

Data from MW-1, and other monitoring points from the Revloc site are discussed herein and in Kania and Tarantino (2004). Figure 12 displays the historical results for acidity, iron and sulfate, three of the parameters most commonly elevated in mine drainage. The data show that groundwater downgradient of the pile was, not surprisingly, severely degraded by acid mine drainage prior to the Ebensburg Power Company operation. The data show a steady trend of declining concentrations for acidity, iron, and sulfate throughout the monitoring period. The decline appears to have

begun prior to initiation of Ebensburg Power Company's operations in early 1991. The site had been disturbed by another operation approximately 10 years before Ebensburg Power Company permitted the site. It is possible that some of the earlier declines in concentrations are due to the natural attenuation of the results of that earlier disturbance of the pile. The data for MW-1 also show that specific conductance, aluminum, zinc, and TDS have declined at MW-1 during the monitoring period, which is consistent with the decline in mine drainage parameters.

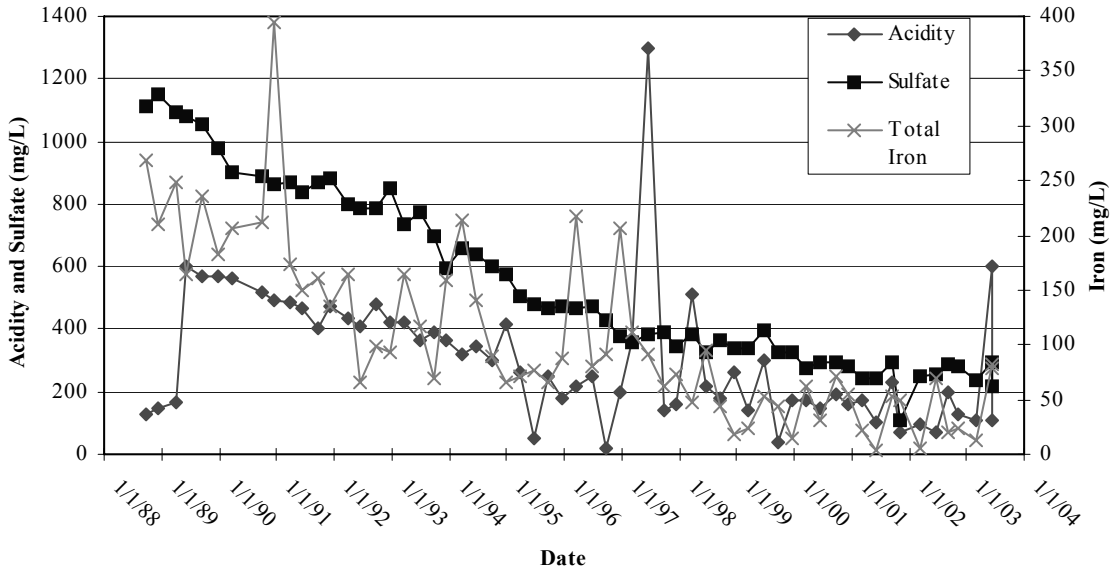

Figure 12. Graph of acidity, sulfate, and iron at MW-1.

When the median values of the early years of monitoring data are compared to the median values of the recent data, significant pollutant load reductions to the South Branch Blacklick Creek are evident. Sampling Point SP-1 is located on the South Branch below the Revloc 1 and Revloc 2 sites. This point is influenced by the direct discharges and groundwater baseflow from the piles into the stream. Table 3 compares the data in terms of median values collected from SP-1 prior to 1992 (N=14) to the 14 most recent samples at the time of this writing. The reductions in aluminum, acidity, and sulfate at SP-1 are evident when the background data medians are compared to the most recent data medians. The data from SP-1 show the improvement to date in terms of mine drainage pollution in the South Branch that has resulted directly from the Ebensburg Power Company operations at the two Revloc sites. Note especially the reduction in aluminum and acidity concentrations along with the increase in pH. During times of low flow, the stream still experiences spikes in pollutant concentrations, but that condition should only improve as re-mining and reclamation continues.

Table 3. Comparison of background median flow and mine drainage pollutant concentrations at SP-1, the monitoring point on the South Branch directly down stream of the Revloc 1 and 2 sites.

	Flow (gpm)	pH (su)	Acidity (mg/L)	Iron (mg/L)	Mn (mg/L)	Al (mg/L)	Sulfate (mg/L)
1988-91 Data	3261	4.30	134	1.61	1.03	21.0	191
2000-03 Data	2427	5.55	16	0.50	0.55	1.50	73

The use of FBC ash in the re-mining and reclamation of two large refuse piles at Revloc, PA has resulted in a large reduction in pollution load from site discharges and in a substantial improvement in downstream quality on the South Branch Blacklick Creek. Both flows and concentrations of pollutants have declined at the largest discharge points. Remining and reclamation are ongoing at these sites, and further water quality improvements are expected.

Monitoring data show no significant negative impacts to downgradient water quality from the use of FBC ash on the sites.

Two additional bituminous surface mine sites are described in Kania and Tarantino (2004), but the water quality results related to the beneficial use of coal ash are less significant than the Revloc site. At the Laurel Land Development, Inc. McDermott site in Cambria County, the use of FBC ash as an alkaline addition agent was unsuccessful in preventing mine drainage formation. Water quality data indicate that the large quantity of ash placed in the backfill may be neutralizing some AMD, but has not prevented the formation of AMD, and has not generated net alkaline water. Several downgradient monitoring points have been degraded with AMD at the McDermott site. While operational complications, such as an intermittent ash supply, stockpiling of ash before incorporation into the backfill, and delayed and incomplete site reclamation may have contributed to the site problems, they likely are not the sole cause of the problems. At the Abel-Dreshman site in Clarion County, the use of FBC ash in the reclamation of an abandoned surface mine resulted in an improvement in downgradient water quality. The use of ash appears to have increased the net alkalinity of downgradient monitoring points, increased the pH, and decreased metal concentrations. Net alkalinity appears to have declined recently, but remains above pre-ash placement levels. The coal ash did not cause groundwater pollution or degradation in either of these two cases, but the results were not as favorable as the Revloc site.

Anthracite Coal Region

The spatial distribution of permitted beneficial use coal ash sites in the Anthracite Region is closely related to several key aspects of the mining history of the region. Underground mining accounted for most of the coal production prior to 1950, and surface mine production increased steadily from the 1920's and surpassed deep mining by around 1950. Underground mining in the Anthracite Region started out small in the late 1700's, but by 1850, there were 1000-foot deep shafts and extensive lateral development of gangways and rock tunnels in numerous collieries of the anthracite coal fields. Historical accounts of this early mine development in the region are found in Miller and Sharpless (1985) and Wallace (1981). The Department of Mines and Mineral Industries of the Commonwealth of Pennsylvania produced annual reports of coal production from 1870 to 1972, and its successors, the Pennsylvania Department of Environmental Resources and the Pennsylvania Department of Environmental Protection, produced these statistical reports from 1972 to the present. Those reports state that anthracite production peaked in 1917, at 100,445,299 tons.

In addition to the extensive network of colliery development features underground, the effects of all of this anthracite mining on the landscape of the anthracite region included thousands of large coal refuse (or culm) banks, and many thousands of mine subsidence features. By the 1940's advances in the development of large surface mining equipment, and the demand for anthracite related to World War II industrial development efforts, facilitated the development of large open-pit surface mines several hundred feet deep. Many of these large open-pit mines and thousands of smaller surface mine pits were abandoned prior to the enactment of laws requiring surface mine reclamation.

The nine anthracite region FBC plants account for 38.14 million tons of the coal ash beneficially used for abandoned mine reclamation described in a previous section of this paper (see Figure 4). The coal ash placement sites associated with these 9 FBC plants represent the greatest volume of coal ash and the largest acreage of abandoned mine land reclamation with coal ash in the anthracite region. However, many of the 51 permits issued by the Pottsville District Office were for the use of coal ash from pulverized coal power plants in Pennsylvania and other States, which is transported to the anthracite region by truck and rail for use in the reclamation of active and abandoned pits on these surface mining permits. Many of the yellow dots on Figure 1 represent coal ash placement mine sites that are not located at or near a FBC plant. Several case study sites of conventional ash placement in the Anthracite Region are described in Hornberger et al. (2004) and Menghini et al. (2005, this volume). Figure 13 shows the Westwood FBC plant under construction in 1985 and the large coal refuse pile adjacent to Interstate 81 in Schuylkill County. Figure 14 shows the Westwood site in 2003 after the large coal refuse pile was removed and consumed in the FBC plant, and a significant amount of coal ash was placed on site.

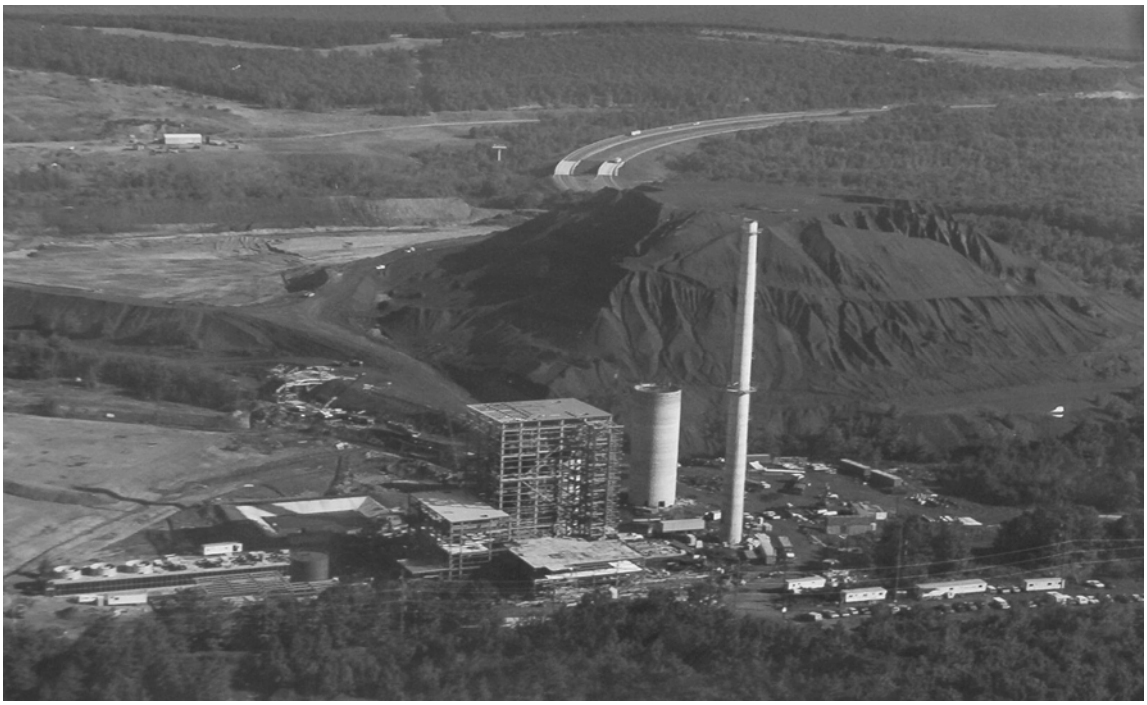

Figure 13. Westwood FBC plant near Tremont in Southern Anthracite Field (1985).

Figure 14. Westwood FBC plant 2003 – culm pile has been consumed .

Some anthracite coal ash sites exhibit a distinct effect upon minepool chemistry (e.g. reduction in acidity/increased alkalinity) at downgradient minepool discharge sites; for other coal ash sites any effects are more subtle. The following characteristics of the coal ash placement site and the minepool system are believed to determine the magnitude of any water quality effects: the size of the minepool drainage area, the flow volume of the minepool discharge, the size of the coal ash placement area and ash volume (a 10 acre ash site may not produce a detectable change in the typical minepool discharge, but a 100 acre site might), the ratio of the coal ash site acreage to the minepool drainage area acreage, the thickness and permeability of the coal ash deposit, the bulk chemistry and mineralogy of the coal ash deposit, the acidity to alkalinity ratio in the minepool, the geologic structure underlying the surface mine coal ash site and the associated minepool, and the configuration of underground mine development features.

Three possible interpretive scenarios emerge from interactions of the coal ash site and minepool characteristics listed above: (a) significant improvement in water quality parameters at minepool monitoring points from beneficial use of coal ash in mine reclamation, (b) no significant change in minepool chemistry associated with the coal ash, and (c) a significant degradation in minepool chemistry and pollution loading at downgradient minepool discharge locations attributable to the coal ash placement. Fortunately, for the interests of the coal mining/electrical power production industry, the environmental regulatory agencies, and the environmental/citizens groups, none of the type (c) environmental damage scenarios have been found in more than 15 years of compliance monitoring and inspections of anthracite ash sites by DEP staff. The Westwood site and the Mount Carmel cogeneration site (described in Hornberger et al. (2004) and Menghini et al. (2005, this volume) exhibit significant improvement in alkalinity (type (a) behavior) at downgradient minepool monitoring points (see Fig. 15), presumably due to a relatively small ratio of minepool drainage area size to coal ash placement area acreage, bulk chemistry of the FBC ash, and favorable geologic structure and underground mine development features, to convey groundwater flow from the coal ash site to the minepool monitoring points. Figure 15 shows that the alkalinity in the downgradient monitoring well increased significantly after the start of ash placement, while the upgradient monitoring well was essentially unchanged. The Wheelabrator site described in Menghini et al. (2005), and the B-D/SER sites exhibit the type (b), no significant change, behavior in varying degrees, for a variety of known and unknown reasons. However, when hundreds of acres of abandoned mine lands on these sites are reclaimed (at no cost to the government or taxpayers) with millions of tons of FBC coal ash that contains large amounts (tens of thousands of mg/kg) of aluminum and iron, and there is no discernable degradation of downgradient minepool discharge points with these metals or other analytes of concern, the overall project still represents a significant environmental benefit. For example, the Wheelabrator cogen site has reclaimed 123 acres of abandoned mine lands and the Mount Carmel cogen site has reclaimed 209 acres. Several sites discussed in Hornberger et al. (2004) and Menghini et al. (2005) showed no significant change in groundwater/minepool water quality, despite extensive ash placement and land reclamation – although these sites significantly reduced infiltration to the minepool, and thus should represent a reduction in the flow and thereby the pollution load of acidity, iron, and other metals in these high volume minepool discharges. The groundwater monitoring data for some of the case study sites and the hydrologic budget discussion below demonstrate that the "high and dry" concept of placing relatively dry (optimum moisture content) coal ash into a relatively dry mine environment is working well.

The purpose of this hydrologic budget discussion is to briefly evaluate the effects of coal ash placement in abandoned surface mine reclamation as a component in the post-reclamation hydrologic budget. The Wheelabrator case study site described in Menghini et al. (2005) and Hornberger et al. (2004) is selected for this purpose because it is near Hazleton, and the surface water/groundwater relationships are very similar to the hydrologic budget components in Ballaron (1999) for the pre-reclamation site conditions. The site description documents that there was very little surface runoff from the permit area because the tributary to Mill Creek entering the eastern end of the permit, goes subsurface to the minepool, and most of the permit area was covered by extensive abandoned surface mine pits and spoil piles prior to remining and coal ash placement by Wheelabrator. Using the values from Ballaron (1999) to evaluate the before-remining conditions of a 10 acre phase of the Wheelabrator permit area, the annual precipitation of 48.5 inches falling on that 10 acres equals 13.2 million gallons, the surface runoff would be 0.94 million gallons, and the evapotranspiration would be 3.5 million gallons. Therefore the amount of water infiltrating to the minepool from that unreclaimed 10 acre phase would be 8.76 million gallons. In the post-reclamation hydrologic budget for the Wheelabrator 10 acre site area with the presumed annual precipitation of 48.5 inches (13.2 million gallons); the surface runoff term in the hydrologic budget equation would be 9.7 inches (2.64 million gallons) and the evapotranspiration would be 20 inches (5.44 million gallons) with the remainder in groundwater

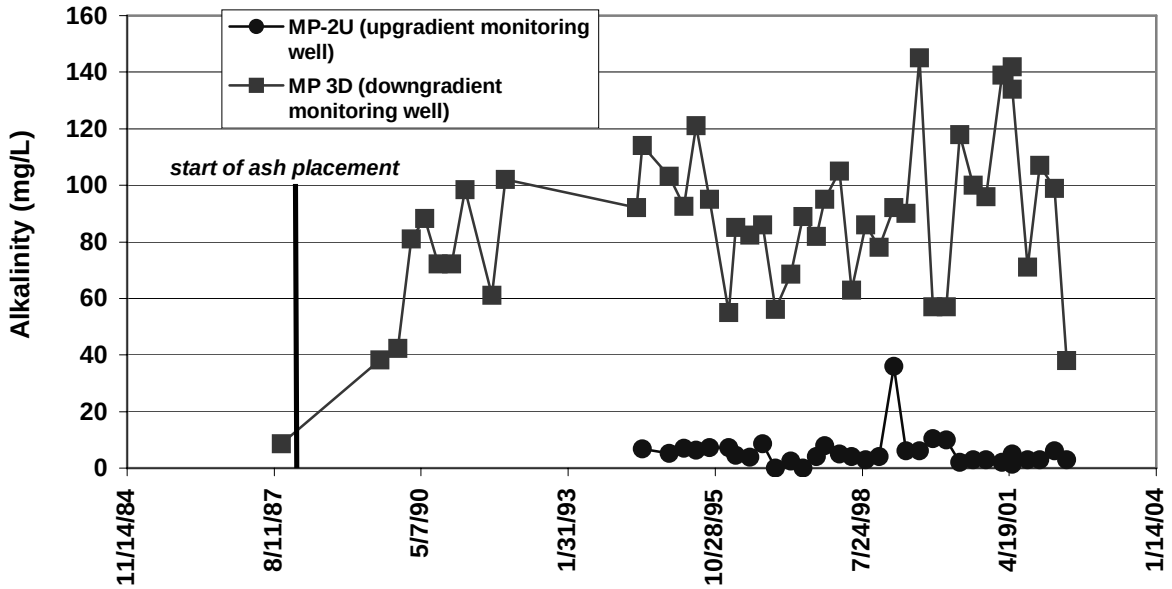

Figure 15. Alkalinity in upgradient and downgradient monitoring wells at the Westwood FBC power plant site.

runoff/minepool discharge of 18.8 inches (5.12 million gallons). Total reduction in mine recharge was 3.64 million gallons per year. Given the assumption that recharge to the minepool equals discharge, the flow of the Morea/New Boston minepool discharge at the downgradient monitoring point should decrease by about 41.6 percent, after the entire site is reclaimed.

There may be some zones of saturation within the backfilled mine spoil or the coal ash deposit (i.e. groundwater storage), but the minepool is the regional groundwater table of the area, and pursuant to the residual waste regulations and permit conditions, the coal ash must be at least 8 feet above the regional groundwater level (i.e. the "high and dry" concept). A cross-section through the relatively shallow abandoned pits (40 ft depth) on the Wheelabrator site would show a lens-shaped compacted ash deposit of about 20 to 25 feet thickness, with an estimated permeability in the range of 10^{-5} to 10^{-6} cm/sec groundwater flow, surrounded by more coarse mine spoil (bottom, side, and top cover material), with an estimated permeability in the range of 10^{-1} to 10^{-3} cm/sec. These permeability estimates for the mine spoil are based upon summary statistics of hydraulic conductivity (K values) reported in Hawkins (2004) and related data in Hawkins (1998) and Hawkins and Aljoe (1991). Thus, most of the groundwater flow from the point of recharge to the minepool should be under unsaturated conditions, and given the permeability contrast between the compacted ash lenses/layers and the surrounding mine spoil, most of the infiltrating groundwater should run off of the upper ash surface or flow around the ash deposit (with mine spoil permeability 2 to 6 orders of magnitude greater than compacted ash) before entering the minepool flow system. Nevertheless, some groundwater will flow through the coal ash deposit, with a substantial residence time, and discharge to the minepool.

From the hydrologic budget calculations described above, a rough estimate is made here, that of 5.12 million gallons of recharge in the 10-acre reclaimed area, less than 0.5 million gallons per year would flow out of the ash deposit with a high alkalinity concentration. However, that high alkalinity groundwater flow component would commingle with the many millions of gallons of groundwater in the minepool and would result in a modest acidity reduction in the downgradient groundwater monitoring point, rather than a significant alkalinity increase in the minepool discharge. The purpose of this discussion has been to document that the "high and dry" coal ash placement concept is apparently working well on mine sites like the Wheelabrator site, although alkalinity benefits may not be maximized with this method of ash placement.

Innovative Coal Ash Placement Methods (Demonstration Project Sites) in the Anthracite Region

Pennsylvania's residual waste regulations include the requirement that any waste, which is placed on a site, must be a minimum of 8 feet above the regional groundwater table and 4 feet above any perched water table. The regulations concerning waste demonstration permits enable DEP to issue permits that deviate from these required separation distances (among other things), providing that the demonstration project is a justifiable evaluation of alternative methods of solid waste management, and that an economic and technical analysis of benefits is considered as well as potential environmental effects. Under requirements of 25 Pa. Code Sections 287.501-287.506, waste management permit applications have been approved as Waste Management Demonstration Permits which may allow the demonstration of new or unique technologies for the processing or disposal of residual waste at permitted facilities.

Three such demonstration project permits have been issued in the Anthracite Region of Pennsylvania as alternatives to the conventional coal ash beneficial use requirements of placing relatively dry (optimum moisture content) ash in a relatively dry mine environment. One project is for the placement of high-density ash/water slurry into standing mine water (wet-to-wet placement) in the Shen Penn Demonstration Project. The second is for placement of a high-density ash/water slurry into a dry mine pit (wet-to-dry placement) in the Knickerbocker Demonstration Project. The third is for dry ash placement into standing mine water (dry-to-wet placement), the Big Gorilla Demonstration Project. If DEP determines that these demonstration facilities adequately achieved their objectives and satisfactorily protected public health, safety, welfare, and the environment, the agency subsequently may revise the regulations to allow the use of the new or unique technologies where the characteristics and potential interactions of the specific coal ash, specific mine water chemistry, and mine site (i.e. configuration, geology, hydrology) are all favorable.

Shen Penn Demonstration Permit Site

The Shen Penn Pit is located within the town of Shenandoah on the eastern end of town and encompasses approximately 39 water-filled acres with a measured depth of 240 feet. Associated with the pit is an exposed highwall approaching 600 feet. Figure 16 is an aerial overview of the pit and its relationship to the cogeneration facility and the town of Shenandoah. The Shen Penn Pit represents a significant public health and safety problem directly to the city of Shenandoah and surrounding communities because it is often used as a recreational swimming hole and is the site of multiple drowning fatalities. The most recent being an 11-year old boy triggered a renewed interest in eliminating the safety problem with the water-filled pit. The objective of the demonstration was to show that ash could be transported in the form of a slurry and placed in the deep standing waters of the Shen Penn Pit. The significance of the Shen Penn Pit to mineland reclamation in the Commonwealth cannot be over stated. The sheer volume of the pit limits direct AML funding to backfill it. It is estimated that for just backfilling with rock, the cost would be between $20 and $28 million, comparable to the Pennsylvania Bureau of Abandoned Mine Reclamation's annual budget. A Waste Management Demonstration Permit (No. 301289) was issued to Reading Anthracite Company on August 6, 1996, that included details on testing and monitoring the physical and chemical properties of the coal ash slurry and its interactions with the mine pool impoundment. Unfortunately, Waste Management Demonstration Permit No. 301289 was never activated, due to the impediment of a $5 per ton coal ash tax imposed by the local school district. Scheetz et al. (2004) describes the small-scale demonstration project completed within the permitted ash placement area on the Ellengowen permit (at the SER cogen site) that was conducted as a precursor to the Shen Penn project, and also provides additional information on the mine pool chemistry and monitoring data relevant to the Shen Penn and Knickerbocker sites.

Figure 16. Aerial photograph of the Shen Penn Pit in relation to the Schuylkill Energy Resources Cogeneration facility and to the town of Shenandoah to the west of the pit.

The Ellengowan demonstration project was a necessary precursor to the three Waste Demonstration Permits in order to develop tangible data on a small scale before embarking on the full-scale demonstration projects. The Ellengowan silt dam was within the approved ash disposal area on the Reading Anthracite surface mining permit, and it contained about 9 ft. of water wherein two ash placement techniques were evaluated: direct dry-to-wet end dumping of ash into the water, and slurry delivered, wet-to-wet placement. Both placement techniques were successful in the shallow water impoundment. Slurry placement of the ash was found to be an adequate approach if the slurry is allowed to flow into shallow standing water in a slow delta-like spreading flow of material.

Knickerbocker Demonstration Permit Site

On July 21, 1998, DEP issued Waste Demonstration Permit No. 301301, to Reading Anthracite Co. (RAC) for the 44-acre Knickerbocker pit area within the Ellengowan surface mining permit near the Schuylkill Energy Resources FBC power plant site. The Knickerbocker pit is a dry abandoned surface mine above the mine pool level, located on the same surface mine permit as the Shen Penn pit to the east along the strike of the syncline, and in West Mahanoy Township (outside of the boundaries of the school district and the ash tax). This permit approval authorized RAC and SER to demonstrate their coal ash slurry concept in a dry pit. It also enabled DEP to obtain scientific and engineering data on a relatively large-scale slurry project, for possible future use into a water-filled pit (i.e. the original wet-to-wet alternative). The results of the Knickerbocker demonstration project, including an evaluation of the effectiveness of the use of various percentages of a cement kiln dust (CKD) admixture as an activator for cementitious behavior of the ash in test cells, are described in Loop et al. (2004 a). The Knickerbocker project was implemented in 1997 with the placement of approximately 4 million cubic yards of ash placed by 2005, and the completion of reclamation back to approximate original contour is anticipated in 2007.

A water/ash slurry consisting of a mixture of 60% (by volume) deep minepool water pumped from the Maple Hill shaft and 40% ash was delivered to the placement site, a distance of approximately 1 km, in a 10 inch diameter high-density polyethylene pipe (Fig. 17). Discharge of the slurry into the pit was controlled so that laminar flow conditions were maintained. As observed in the Ellengowan demonstration, turbulent mixing of the slurry would result in unnecessary turbidity in the transporting water, which could percolate into the minepool or be recycled

back to the ash slurrying operation. Neither outcome was desirable. When placed in a manner that allowed the transport water to flow in a slow and laminar fashion, the ash dropped out of suspension rapidly and resulted in a dense, strong compacted fill onto which equipment could immediately drive (Fig. 18). Semi-annual characterization of the proctor densities of the ash and size distributions are reported. These data show that compaction of the ash was routinely above 90% with enough structural strength to support wheeled vehicles.

Test cells in Knickerbocker pit

Figure 17. Aerial photograph of the Schuylkill Energy plant and the Knickerbocker Pit.

Figure 18. Truck parked on recently placed ash.

A subset of the principal wet-to-dry demonstration was a study intended to evaluate the potential for the enhancement of the mechanical properties of the cogeneration ash by the additions of CKD. CKD, depending upon its storage history, can contribute significant alkalinity to an ash/CKD mixture to enhance the cementitious reactions and/or it can serve as a fine filler to enhance packing within structural fills. Schuylkill Energy slurried both bottom and fly ash approximately 2900 feet to a blending tank beside four test cells. Keystone Cement Company delivered 20 ton truckloads of CKD to the test cell area, which were then stockpiled. The four test cells were at the northwest end of the Knickerbocker Pit. They were carved from ash originally slurried into the pit. The cells can be seen in the foreground of the demonstration pit in Figure 17. Test cells 1 and 2 contained a mix of 20% CKD and 80% ash. Cells 3 and 4 contained 10% and 5% CKD, respectively, with ash as the remainder.

Soil borings and split-spoon samples were collected by the Borings, Soils, and Testing Company of Harrisburg, PA on the four cells in both August and November, 2000. At this time, the necessary blow counts were recorded. Dry density, wet density, and moisture measurements were collected by the DEP with a Troxler nuclear density moisture gauge. Weight bearing capacity measurements were collected with a penetrometer. Wet chemical, fertility, x-ray diffraction (XRD), moisture loss, grain size, and scanning electron microscope (SEM) analyses also have been performed on the ash/CKD mixture from the Knickerbocker test cells as described in Loop et al. (2004 a). The number of blows per 6 inches of depth from Split-spoon sampling were noted by the Borings, Soils, and Testing Company as they drilled into the test cells and a control area in August and November. In each cell, one boring was drilled close to the inlet pipe location and another drilled toward the center of the cell, but on the ash platform. The mean and standard deviations of the blow count values from cells 1 through 4 are presented in Table 4.

Table 4. Mean and standard deviation data for blow counts per foot recorded at the center of cells 1 – 4 in November 2000.

	Cell 1	Cell 2	Cell 3	Cell 4
Mean	12.07	7.93 4.	67 2.	87
Standard Deviation	1.94	1.53 2.	29 1.	96

The economic benefit to the Commonwealth is that abandoned mine lands are reclaimed at no cost to the Commonwealth. The company benefits due to the reduction of materials handling costs, from the minimal amount of equipment, maintenance and labor requirements.

Big Gorilla Demonstration Permit Site

On June 16, 1997, DEP issued Waste Demonstration Permit No. 303104 to Northeastern Power Co. (NEPCO). This project placed optimum moisture content ash into an abandoned water-filled pit known as the Big Gorilla pit, a 16.6 acre area within the 876 acre surface mining permit site at the NEPCO FBC power plant site near the borough of McAdoo. The mine water impoundment in the Big Gorilla pit was 80 feet deep in most places. Cogeneration ash was first placed in contact with the surface mine pool in August 1997, which was entirely filled by 2004. Over 3 million tons of ash were placed from two platforms, and will eventually be brought to pre-mining contour and re-seeded. The Big Gorilla had an estimated volume of approximately 120 million gallons when the water level was at 1570 feet msl. It was approximately 1,400 feet long, 400 feet wide, and about 80 feet deep before ash placement began (Fig. 19a).

The use of trucks and bulldozers in regular placement activities provided the only mechanical compaction of the ash platforms. When driving or walking on the ash, there is no indication of soft areas or water accumulation. (Fig. 19c) NEPCO is required to submit ash samples to undergo a Proctor test (ASTM, 2001) every six months. The results from the Proctor test provide a theoretical maximum density, as well as an optimum moisture content. Also, the DEP Pottsville office staff regularly monitored the density and moisture content of the ash platform using a Troxler nuclear moisture density gauge. Based on both procedures, the density of the ash placed on the platform is consistently 90-100% of the theoretical maximum. The weight bearing capacity is measured in the field with a penetrometer by DEP, and is routinely over 69 MPa (5 tons per square foot).

The data evaluated in the Big Gorilla demonstration project as described in more detail in Loop et al. (2004 b) and Scheetz (2005, this volume) suggest that the presence of free lime ($Ca(OH)_2$) is necessary for placement of ash in standing mine water. Lime serves to immobilize labile heavy metals but more importantly, it is the activator that

initiates chemical reactions among the fly ash phases. These hydration reactions not only contribute to the immobilization of metals but also to the development of cementitious chemical reactions that will influence the development of favorable mechanical and physical properties of the ash. As the hydration reactions mature with time, the resulting microstructure of the mass will continue to develop leading to a decrease in permeability to external fluids. Lime from the ash in contact with the pit waters will result in an elevated pH, the driving factor in the chemical reactions. The aluminosilicate structures of the glass or meta-clay phases are activated by elevated pH values to initiate the hydration reactions which begin to dissolve their structures. The presence of aluminum and silica in solution in the presence of calcium results in the precipitation of tobermorite (a fiberous mineral that acts like the glue in Portland cement).

Figure 19(a). Big Gorilla – pre-ash placement.

19(b). Ash placement in 80 feet of water.

19(c). Ash placement equipment.

19(d). Water filled pit eliminated.

The high pH and alkalinity also results in a large amount of meta-clay undergoing pozzolanic reactions with the formation of hydrous calcium silicate phases. Thermodynamic modeling described in Loop et al. (2004 b) has confirmed the existence of 14Å tobermorite. This phase is the crystalline equivalent of C-S-H, the glue in Portland cement. In Portland cement, calcium-silicate-hydrate (C-S-H) forms as an amorphous hydration product of both di- and tri-calcium silicate. It is the morphology of this phase that imparts the mechanical properties that are attributed to concrete. Although the thermodynamic calculations have been conducted for a phase that contains no aluminum, C-S-H that forms under real world cement hydration conditions always contains a finite amount of aluminum substitution that is at the maximum solubility limits (Barnes and Scheetz 1989). In the ash fill, clays in the culm and coal are thermally altered to the point where the clays give off their water and dehydroxylate. It is the reaction of

these meta-clays with Ca at elevated pH that forms C-S-H, as described in more detail in Scheetz et al. (2005, this volume).

SEM characterization of placed ash has visually confirmed the development of the mineral ettringite. Ettringite is an important component of the alteration of the ash since it has been demonstrated thermodynamically that it is not only responsible for limiting control of the solubility of aluminum in the mine-pit lake waters at high pH, but it is also an important component in the cementitious reactions that are taking place within the ash fill and an important control for arsenic sequestration. The observation that ettringite formation limited the solubility of aluminum in the pit waters suggests that the sulfate content of the pit water/ash mass is also an important controlling component.

In summary, the Big Gorilla demonstration project described in Loop et al. (2004 b) and Scheetz (2005, this volume), is the Waste Demonstration Permit issued to evaluate alternative ash placement technology of placing relatively dry (optimum moisture content) ash into a water-filled abandoned surface mine pit (i.e. dry-to-wet placement). Early in the process of filling the pit with FBC ash from the NEPCO power plant, two significant findings were recognized: a) the pH of the 80 ft. deep mine water impoundment had changed from a background water quality of pH 3.6 to a pH of approximately 11, homogeneously throughout the impoundment, due to the unreacted calcium hydroxide in the FBC ash, and b) the physical properties of the completed ash terrace, resulting from the placement technique of end-dumping the ash into the standing water, had adequate stability and bearing capacity to support heavy equipment, meet the DEP compaction requirements, and allow an orderly advancement of the dumping face from east to west, without causing turbidity in the western portion of the impoundment. Detailed scientific research produced three additional significant conclusions: c) the pore water chemistry within the completed coal ash fill closely resembles the chemistry of pore water solutions in conventional Portland cement (i.e. C-S-H) and concrete products, d) the mineral ettringite has formed and is abundant in the completed ash fill, which is an important component in the cement formulation process, and e) the relatively high sulfate concentrations of the mine pool chemistry were necessary to promote the formation of the ettringite, and then the ettringite provides an additional environmental benefit by sequestering heavy metals.

Sharp Mountain Demonstration Agreement Site

The Sharp Mountain cropfall abatement project in the city of Pottsville is an innovative project using coal ash and other materials to create a cementitious grout mixture for filling dangerous subsidences (cropfalls) that are prevalent in the Southern and Western Middle Anthracite Coal Fields of Pennsylvania. The purpose of the project was to conduct a demonstration to employ new technology to reclaim the cropfall mine subsidence features that were previously filled and re-subsided and to develop a strategy that could be implemented on other cropfalls adjacent to the project area. Due to the complex nature of cropfall features described below, a structural plug was created using a grout mixture to form a cement-like plug to bridge a void. The beneficial use of FBC coal ash as the major component in the grout cement mixture, and pulverized coal PC power plant ash as the bulk fill material for more extensive backfilling of the cropfalls is an excellent example of solving a significant public health and safety problem, as well as associated environmental problems. The beneficial use of coal ash and cement kiln dust in this mine subsidence abatement project was authorized by an Agreement executed by DEP and the City of Pottsville pursuant to 25 PA Code Section 287.665b(6). Various mixtures of FBC ash and Portland cement or CKD were evaluated to determine their relative strengths, bearing capacities, and cost-effectiveness. As the project advanced, the cement grout mixtures using CKD were unable to meet the compressive strengths in the laboratory tests and the CKD was replaced with Portland Cement.

The result of the surface outcrop of coal falling into the abandoned underground mine voids below is known as a *cropfall*. Cropfalls are dramatic features that often occur with little warning, resulting in deep narrow voids with near vertical walls. Many of the cropfalls occur as result of the work of "bootleg miners" who operated after the major collieries closed, or by geological and climatological processes over a number of years that weaken the support until it fails abruptly. This type of cropfall feature frequently develops in the spring of the year, following freeze-thaw cycles, and can be very dramatic, considering that the gaping hole may extend downdip as much as 900 feet depth, or deeper, depending on how many lifts were mined and whether the chain pillars between the lifts were robbed during retreat mining. The magnitude of the extensive underground mine void system connected to the cropfall feature may make the abatement of the subsidence with coal ash or any other material problematic, as described in Koury et al. (2004). In the years following the initial dramatic collapse of a cropfall, rock and soil materials gradually fall into the gaping hole and develop a weak or strong bridging system. This represents a

mitigating factor in developing subsidence abatement plans (or may fool the unsuspecting hiker of lurking dangers beneath the rock and soil bridging material).

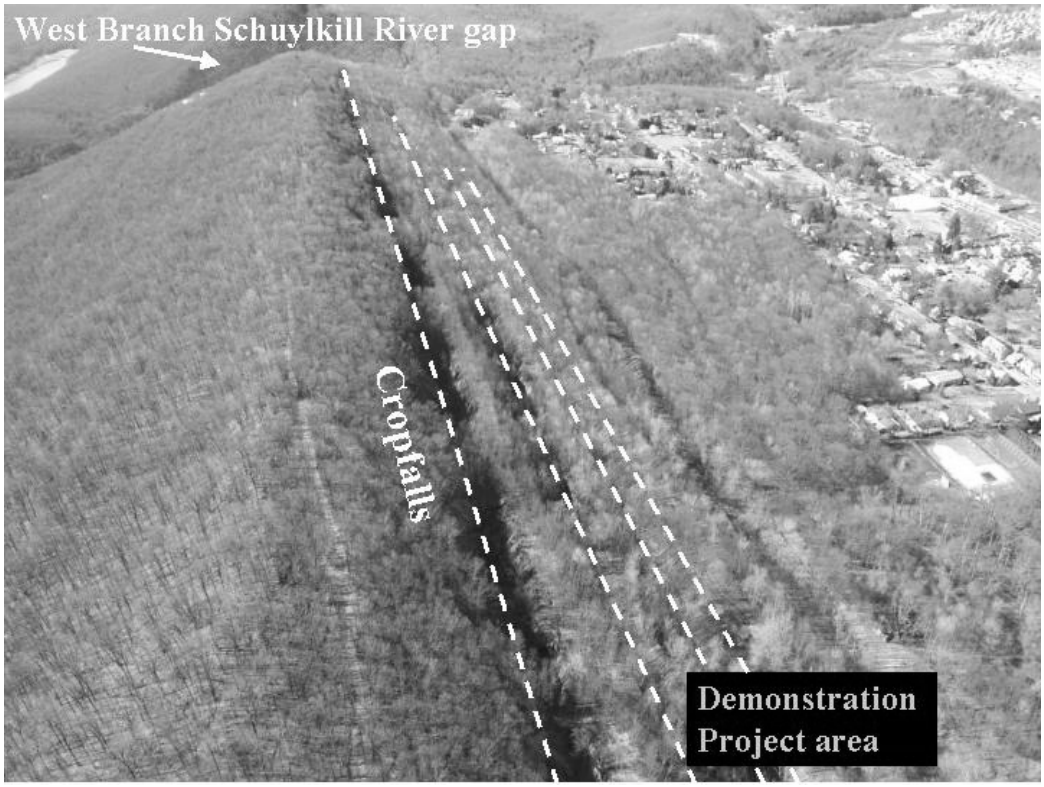

Figure 20. An aerial view of cropfalls on Sharp Mountain in the city of Pottsville.

The City of Pottsville lies on the northern exposure of Sharp Mountain along the southern boundary of the Southern Anthracite Coal Field. Although cropfalls occur throughout the Southern & Western Middle Coal fields, the cropfalls in Pottsville area are unique in that they are very close to residential areas. Cropfall features have existed on Sharp Mountain in Pottsville and are shown on maps of the Sherman Coal Company as early as 1925 and many of them have been dormant since that time and they appear stable with overgrown vegetation. In the 1990's however, several areas that extend over 1,000 linear feet began to collapse significantly. The subsidences have continually occurred and expanded causing an imminent danger to the safety of the public. There are 4 distinct continuous lines of subsidence that are dramatic and unstable, as seen in Figure 20. The active subsidences are within 300 feet of residences, including a community baseball field, swimming pool, and cemetery. There are many challenges to addressing the cropfalls in Pottsville in that the only established access to the mountain is through residential areas and the fact that since they are a collapse, there is no available on-site material available to use as fill. The demonstration project addressed cropfalls in a 2.5 acre area. The project area shown in Figure 21 consists of Pit A East and Pit A West. The area referred to as Pit A originally subsided in 1999, was backfilled with dirt and rock in 2000, and re-subsided in 2001. Pit A consisted of 2 subsidences which were separated by a vertical support pillar of coal that remained intact, as displayed in Figure 21b. In order to install the structural plug, the subsidences were further excavated and prepared. Approximately 2,250 cubic yards of material were removed from Pit A to locate solid competent rock adjacent to the subsided coal vein.

The method of backfilling in Pit A was to develop a structural wedge so if the false bottom of the pit would fail, the wedge would become lodged and would not undergo catastrophic failure. Concrete panels were placed on the floor of the excavated pit in both the eastern and western portion of Pit A. The purpose of the concrete panels was to retard the flow of the grout until it had time to cure and to create an additional structural member of the plug. The concrete panels were originally manufactured to be used as sound barriers along major highways. The panels were flawed or damaged and they were donated by Schuylkill Products, Inc. a nearby concrete fabrication operation. In

the eastern portion of Pit A an inverted steel truss was fabricated to act as a structural support member that spanned the void and was wedged into the competent solid rock on the north and south end of the pit (Fig. 21b). The self leveling cementitious grout mixture, not unlike controlled low strength flowable fills, was then placed in the eastern portion of Pit A covering the steel member. The grout mixture of FBC ash, approximately 9% Portland cement, and water was blended at Quandel Concrete, Minersville and imported to the site in cement mixers (Fig. 21b). The consistency of the grout mixture allowed it to flow throughout the east pit and it hardened relatively quickly allowing the vehicles to travel on the grout mixture (Fig. 21c).

The west side of Pit A was prepared similarly in that reject concrete panels were placed in the floor of the pit. Instead of the fabricated steel trusses, recycled reinforcement bar (rebar) was imported from Glasgow, Inc. to form a wire mat in the grout mixture for structural support (Fig. 21c). The rebar was loosely packed and it allowed the grout to flow through it. The grout was placed and leveled with the eastern portion of Pit A. Grout depth in all of Pit A was approximately 10 feet. The remainder of the pit was then filled with coal ash from PPL Montour Station to serve as a bulk fill material that will also be beneficial due to its cemetitious properties (Fig. 21d). As with the Northampton FBC ash, PPL donated the PC ash and delivered it to the site. Once the area was backfilled and graded to the adjacent contours, topsoil was added and the area was vegetated, Figure 21d.

Figure 21(a). Cropfall resubsidence.

21(b). Grout mixture poured on steel truss.

21(c). FBC ash grout mixure pour with rebar.

21(d). Cropfall reclamation completed.

The cropfall type of mine subsidence features present a significant challenge in abandoned mine reclamation efforts because of the general lack of adjacent backfill materials. Conventional backfill materials, or concrete, have resubsided shortly after completion of previous reclamation projects. The Sharp Mountain cropfall project is an innovative approach to abating the mine subsidence problems, utilizing FBC ash in formulating ash cement grout mixtures, and using PC ash as a bulk fill material.

Conclusions

This paper has presented descriptions of a variety of permit and project sites in Pennsylvania where coal ash has been beneficially used in mine reclamation and mine drainage remediation. Most of these sites have been clear success stories: abandoned mine lands and their associated safety and environmental hazards have been reclaimed at no cost to the taxpayer; water quality has been improved; a waste material has been recycled to a useful end rather than being landfilled. None of these sites represent environmental damage groundwater pollution cases attributable to the coal ash quality.

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Roger J. Hornberger has been District Mining Manager of the Pottsville District Office of the Pennsylvania Department of Environmental Protection since 1987. From 1978 to 1986, he was hydrogeologist with the Pennsylvania's Bureau of Mining and Reclamation. Prior to working for the Commonwealth, he was employed at Pennsylvania State University in the Department of Landscape Architecture (1973-1976) and at the Institute for Research on Land and Water Resources (Sep. 1974 – Aug. 1975 and Jul. 1976 - Nov. 1978). He is the author of publications on coal mine drainage prediction and prevention and is the Interstate Mining Compact Commission's representative on the Operations Committee of the Acid Mine Drainage Technology Initiative. Roger has a bachelor's degree in landscape architecture and an M. S. in geology, both from Pennsylvania State University.

STATE REGULATION OF CCPs & CCBs IN TEXAS

Michael J. Nasi
and
Rebecca L. Fink
Lloyd Gosselink Blevins Rochelle & Townsend, P.C.

Abstract

The talk will cover the use of coal combustion products (CCPs) in the reclamation of large mine sites and the pending Texas initiative aimed at clarifying and streamlining the regulatory process governing the use of CCPs and disposal of Coal Combustion By-Products (CCBs) at Texas mines. The numerous beneficial purposes for which CCPs can be used at a mine site in both the active mining operation and during the reclamation process will be addressed and will include: construction and maintenance of haul roads; ancillary roads; pit ramps; equipment pads; drainage control structures and erosion control structures; and for use as fill material to achieve Approximate Original Contours (AOC) in reclamation activities.

The current status of regulations governing these activities at the State and Federal level will be discussed, with an emphasis on the on-going Federal evaluation of the need (or lack thereof) for Federal regulation of CCP mine site uses. The Federal evaluation involves a cooperative effort between the Environmental Protection Agency (EPA) and Office of Surface Mining (OSM) of the Department of the Interior, with critical input by the Department of Energy (DOE) and the Interstate Mining Compact Commission (IMCC). The recent developments in the National Academy of Science (NAS) review of current placement practices, including their public meeting and site tour in Texas will also be addressed.

Finally, the State-level rulemaking initiated by Texas coal-ash producers and users to create a regulatory framework that facilitates the beneficial use of CCPs by recognizing the potential beneficial uses for CCPs at Texas mine sites during operations and as a component of the reclamation process will be discussed. The key issues that have arisen in the pending rulemaking and how stakeholders have worked to resolve those issues will be presented. The talk will conclude with the author's thoughts on why it is critical that all mining States have explicit rules capable of being reviewed by the Federal government as EPA and OSM finalize their assessment of existing regulatory framework governing mine placement of CCPs and disposal of CCBs.

Introduction

Over the past decade, coal combustion residues have been used at Texas mine sites for a variety of beneficial uses under a regulatory framework administered by the Texas Commission on Environmental Quality (TCEQ) and the Railroad Commission of Texas (RCT). TCEQ is the Texas agency with delegated authority from EPA to administer Federal hazardous waste laws, including the Resource Conservation and Recovery Act (hereinafter referred to as RCRA). The RCT is the Texas agency with delegated authority from OSM to administer federal mining regulations, including the Surface Mining Control and Reclamation Act (hereinafter referred to as SMCRA).

In 2001, TCEQ promulgated explicit regulations (the "Non-waste Criteria") governing whether a given mine site use of a coal combustion residue qualifies as a "beneficial use," thereby rendering the residue a Coal Combustion Product (CCP), or "disposal," thereby rendering the residue a Coal Combustion By-product (CCB).[1] The practice of the RCT, up until the 2001 TCEQ rulemaking, was to authorize CCP mine site use based upon site-specific letters from TCEQ confirming the beneficial use status of a given residue and use. When the TCEQ practice of issuing site-specific letters ended with the promulgation of the self-implementing Non-waste Criteria, RCT staff began to express reluctance about approving mine site uses of CCPs. To ameliorate that situation and further encourage the beneficial use of CCPs, the Texas Coal Combustion Product Coalition (Texas CCP Coalition) initiated discussions

[1] 30 Tex. Admin. Code 335.1(131)(H).

with the RCT staff and management which culminated with the filing of a petition for rulemaking in 2002 to clarify and streamline the RCT regulation of CCPs in Texas. After an initial notice and comment period and OSM review, that rulemaking remains pending at the RCT while changes are made to address issues raised during the review process.

After reviewing the CCP mine site uses currently employed in Texas, this paper will review in detail the Texas regulatory framework governing those uses. As part of this review, the paper will identify and discuss the remaining issues to be resolved in the pending RCT rulemaking governing CCP use and CCB disposal at Texas mine sites. The paper will conclude with the Texas CCP Coalition's perspective on the appropriate resolution of those issues and a reemphasis on the critical importance of a clear regulatory framework governing CCP mine site use and CCB disposal at mine sites.

Production of Coal Combustion Residue in Texas

Texas is the fifth largest coal-producing State in the nation and depends on coal for roughly 50 percent of the electricity consumed in Texas. According to the Energy Information Administration's 2004 report, Texas consumed 105,376 short tons in 2003, making it the largest consumer of coal in the United States. Not surprisingly then, Texas is the largest producer of coal combustion residue in the United States. Texas alone produces about 15 million tons of coal ash per year, which equates to about 12% of the national total. Approximately 60%–70% of coal ash produced in Texas is currently being beneficially used. This number has increased from 15% in 1992. In some cases, Texas electricity generating facilities are able to use 100% of the ash they produce and are even reclaiming material previously disposed of in order to beneficially reuse it. Notwithstanding these numbers, there is significant room to improve: it has been reported that 83% of the Texas industrial solid waste stream is made up of coal ash that was, for whatever reason, not beneficially reused.

Use of CCPs at Mine Sites in Texas

Most of the coal mines in Texas have electricity generating facilities situated adjacent to the mine; the mine and the adjacent electric generating facilities are often referred to as "mine-mouth operations." This set-up facilitates the use of CCPs at mine sites by creating a natural partnership between each mine and its adjacent electricity generating facility. Also, the proximity of the operations means that the distance CCPs have to be transported to be beneficially used is minimal. In fact, vehicles transporting coal to the electricity generating facility can, instead of returning empty for another load of coal, return with CCPs for beneficial use at the mine site.

Texas mine operators and the RCT have recognized that CCPs can be used for numerous purposes at a mine site in both the active mining operation and during the reclamation process. CCPs have been used at Texas mine sites to construct and maintain haul roads, ancillary roads, pit ramps, and construction projects such as equipment pads, drainage control structures, and erosion control structures. CCPs have also been used as fill material to achieve AOC in reclamation activities. In fact, all of the following beneficial uses have been approved and implemented at Texas mine sites:

- Roads: CCPs have been used as a structural fill layer to bring both primary haul roads and ancillary roads to necessary grade in place. CCPs have also been used in the road base in place of clay and aggregate. CCPs have also been used as a traction agent on primary haul roads and ancillary roads, instead of the limestone rock and other aggregate materials that are generally used.

- Ramps: CCPs have been used for structural fill in the construction of ramps in active pit areas in place of the use of virgin dirt or spoil material. In addition, CCPs have been used to surface the ramps to provide the necessary traction to efficiently access the pits during inclement weather conditions (i.e. when the ramps are slippery, wet, and/or frozen).

- Construction: CCPs have been used as a substitute for aggregate or soil and as an ingredient in cement or grout in on-site construction projects. Such projects include equipment construction and repair pads, well pads, drainage control structures, and erosion control structures.

- Reclamation: CCPs have been used in areas where there are low volumes of available spoil material and in order to minimize additional disturbance during the project for pit reclamation or, ultimately, at the end of the project for final pit reclamation. For Abandoned Mine Land (AML) projects, CCPs could also be used to complete reclamation for pit areas which previously had little to no reclamation performed.

Existing Texas Regulations Governing CCP Use

As noted above, the two regulatory bodies governing the use of CCPs at mine sites in Texas are the TCEQ and the RCT. As the RCRA-delegate agency in Texas, the TCEQ is responsible for making the initial determination of whether the coal-combustion residue is "waste." Material produced from coal-combustion in utility boilers may be exempted from the definition of "waste" by the TCEQ if it qualifies as a "product." To qualify as a product—and thereafter be properly referred to as a CCP—the material must meet certain "Non-waste Criteria" (discussed further below).

Once a material is deemed to be a CCP, then the TCEQ regulation of the material is reduced to an enforcement/oversight role and the specific approvals necessary for the material to be used at Texas mine site are governed by the RCT.[2] If the material does not qualify as a product, then it is considered to be a waste and is considered to be a coal combustion by-product (CCB), as opposed to a CCP. The TCEQ continues to regulate the handling and disposal of CCBs and, to the extent the disposal activity occurs within a RCT-permitted mine, the TCEQ and RCT retain concurrent jurisdiction over the activity, much as they do, for example, over sedimentation ponds (which the TCEQ regulates as the general Clean Water Act delegate agency in Texas in coordination with RCT, which retains primary day-to-day oversight of the ponds).[3]

Historically, generators of coal combustion residue would submit information to the TCEQ to demonstrate that the material was a product and not a waste. The operator of the mine at which the material was proposed to be used would additionally specify the intended uses of the material. The TCEQ (formerly called the TNRCC) would then apply the "non-waste criteria" (then contained in guidance document – RG-240), and determine if the material was appropriate for exemption from being considered "waste" and, if so, issue individual letters confirming that the material was not "waste" when used for the specified purposes. The RCT staff then relied upon these confirmation letters to issue site-specific approvals for the use of CCPs at Texas mine sites.

In 2001, the TCEQ formally adopted a rule that codified, with some changes, the non-waste criteria guidance into the definition of "solid waste." Specifically, the TCEQ adopted an amendment to Title 30, Chapter 335 of the Texas Administrative Code to exempt from the definition of "solid waste" material that meets all of the following criteria:

1. A legitimate market exists for the recycling material as well as its products.

2. The recycling material is managed and protected from loss, as would be raw materials or ingredients or products.

3. The quality of the product is not degraded by substitution of raw material or product with the recycling material.

4. The use of the recycling material is an ordinary use, and it meets or exceeds the

[2] *See* 26 Tex. Reg. 3807 (2001) ("The rule adds a self-implementing exemption from the definition of "solid waste" for certain recycling activities involving application of nonhazardous materials to the land or involving their use in materials which are applied to the land. The rule also eliminates the need to perform case-by-case determinations in every instance that such an exemption applies.").

[3] See Chapter 361 of the Texas Health & Safety Code; Chapter 26 of the Texas Water Code.

specifications of the product it is replacing without treatment or reclamation. Or if the recycling material is not replacing a product, the recycling material is a legitimate ingredient in a production process and meets or exceeds raw material specifications without treatment or reclamation (note: treatment may impact future flue gas desulfurization (FGD) utilization; this is in another section of the report).

5. The recycling material is not burned for energy recovery, used to produce a fuel, or contained in a fuel.

6. The recycling material is a legitimate ingredient in a production process and meets or exceeds raw material specifications without treatment or reclamation.

7. The recycling material must not present an increased risk to human health, the environment, or waters of the State when applied to the land or used in products which are applied to the land and the material, as generated:

   - Is a Class 3 Waste under the TCEQ waste classification rules[4]; or
   - Is a Class 2 Waste solely due to elevated concentrations of arsenic, cadmium, chromium, lead, mercury, nickel, selenium, and total dissolved solids and does not exceed a specified concentration limit, which is tied to the application rate of the material.[5]

8. The recycling material is, in fact, recycled at a rate of at least 75% per year (by weight or volume) of the annual production rate or is transferred to a different site and recycled on an annual basis. If the recycling material is placed in protective storage, the operator is allowed a two-year period to realize the above-referenced recycling rate.

When the TCEQ adopted the Non-waste Criteria Rule, the TCEQ made it clear that the previously issued CCP authorizations would remain in effect. *See* 26 Tex. Reg. 3807, 3811-3812 (2001). The TCEQ also indicated in the preamble to the rule that the criteria were self-implementing as to uses not previously approved and that additional site-specific or use-specific letters were not necessary. *See id.* at 3807.

The TCEQ was also clear in explaining that it was not going to issue site-specific letters, but would rather depend on the individual generators and users to apply the criteria and make the waste-determination themselves. This meant that the RCT no longer had site-specific letters from the TCEQ upon which to depend in issuing approvals. It became apparent from correspondence and discussions with the RCT Surface Mining and Reclamation Division (SMRD) staff, that the SMRD staff was reluctant to encourage CCP use at mines sites due to the self-implementing

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[4] 30 Tex. Admin. Code 335.1(131)(H)(vii)(I), referencing Subchapter R of Chapter 330 of Title 30 of the Texas Administrative Code for purposes of determining whether the material is a Class 3 waste. In contrast to EPA regulations and several other states which end the waste classification analysis after a material is deemed non-hazardous, TCEQ regulations further define non-hazardous industrial solid wastes as belonging to one of three categories:

Class I: Any industrial waste that is toxic; corrosive; flammable; a strong sensitizer or irritant; a generator of sudden pressure by decomposition, heat, or other means; or may pose a substantial present or potential danger to human health or the environment. To be a CCP, material cannot be a Class I waste.

Class II: Any industrial waste which cannot be described as hazardous under Class I or does not meet the criteria for Class III. The majority of CCPs produced in Texas are categorized as Class II wastes.

Class III: Inert and essentially insoluble industrial waste. The TCEQ rules allow that Class III wastes of any kind can be used without any specific approval as fill to bring land to natural grade for development.

[5] 30 Tex. Admin. Code 335.1(131)(H)(vii)(II)(-b-), referencing 30 Tex. Admin. Code 312.43(b)(3), Table 3 for the metals limits.

nature of the TCEQ rule. This apparent reluctance on the part of SMRD staff has temporarily deterred many operators from proposing new or continued CCP uses at mine sites in Texas.

Texas CCP Coalition Rulemaking Petition

In response to the above-referenced reluctance of the RCT SMRD staff, a group of electric generating facilities that produce CCPs banded together with mine operators that used CCPs or hoped to use CCPs at their mine sites to form the Texas CCP Coalition. The Texas CCP Coalition met with RCT staff and management to determine the most appropriate regulatory approach to facilitate the beneficial reuse of CCPs in Texas. It was ultimately decided that the best approach was for the Texas CCP Coalition to petition the RCT to adopt a revised set of rules that would standardize the process by which the SMRD staff would review applications to beneficially use CCPs. It was also decided that additional clarity should be brought to issues surrounding the disposal of CCBs within or adjacent to RCT-permitted mine sites.

The Texas CCP Coalition's petition proposed specific regulatory provisions to accomplish the goals set out above. The petition additionally noted that it was appropriate—if not critical—for Texas to clarify its regulations as soon as possible because a host of Federal agencies[6] was then in the process of finalizing their evaluation of whether any additional Federal oversight was needed with regard to the regulation of CCP uses or CCB disposal at mine sites across the U.S. The Coalition reasoned and publicly asserted that, in order to reassure the Federal government and eliminate any perceived need for EPA regulation of CCPs or CCBs, it was necessary for States such as Texas to have clear and explicit rules in place governing the waste and mine issues that are capable of being efficiently reviewed by the Federal government.

The original rule petition drafted by the Texas CCP Coalition aimed to rectify the uncertainty associated with the existing regulations by defining CCBs and CCPs, affirming the several beneficial uses of CCPs at Texas mine sites, and confirming that the disposal of CCBs and the use of CCPs are mining-related activities that may be retained by a permittee in a RCT-issued mine permit. The proposed rule also attempted to reduce uncertainty by requiring an operator to submit extensive documentation so that the RCT staff would have adequate information to review and the RCT would have an adequate administrative record to support all approved mining and reclamation plans that contemplate the use of CCPs or disposal of CCBs. The Texas CCP Coalition proposed that once the proposed rule changes were in effect, RCT staff would be able to conduct more timely and efficient reviews of applications that involve the use of CCPs or disposal of CCBs at mine sites in Texas.

The language of the rule, as petitioned by the Texas CCP Coalition and proposed by the RCT in the Texas Register on November 28, 2003 is included as Appendix II to these proceedings.

Net Environmental Benefits of CCP Use at Texas Mine Sites

The proposed rule language was not intended to relax any environmental standards applicable to the practice of using CCPs and CCBs at mine sites. Rather, the Texas CCP Coalition showed that the rule would provide more certainty, due to the additional documentation requirements, and positive environmental benefits by facilitating the use of CCPs in lieu of other raw materials. The Texas CCP Coalition explained that this reduction in the need for other raw materials would lead to a reduction in the amount of disturbed land and reduce a number of other environmental impacts associated with the use of non-CCP materials.

For example, with regard to the use of CCPs in the construction of haul roads at Texas mines, the Texas CCP Coalition explained that, absent the use of CCPs, the structural fill layer used to bring the primary roads to the necessary grade would be comprised of clay. The road base and the surface layers would be comprised of clay, aggregate, and quick lime. The use of bottom ash in place of clay and the use of fly ash and stabilized scrubber sludge in place of lime could provide several environmental benefits. First, less total land would have to be

[6] The Federal evaluation of the need (or lack thereof) for Federal regulation of CCP mine site uses is a cooperative effort between the Environmental Protection Agency (EPA) and Office of Surface Mining (OSM) of the Department of the Interior, with critical input by the Department of Energy (DOE) and the Interstate Mining Compact Commission (IMCC).

disturbed since less clay and aggregate will need to be extracted. There are numerous ancillary benefits to disrupting less land. For example, there is less potential for disturbing ecologically valuable habitat. Second, the use of CCPs, which are readily available on-site or immediately adjacent to the mine site (at the power plant), will reduce potential diesel and particulate matter emissions and noise and safety issues associated with blasting, extracting, crushing, sizing, and hauling non-CCP materials. Third, CCPs are typically transported by truck over existing mine roads. In some operations, the transportation network not only enables the haulage of coal or lignite to the power plant, it also allows a reverse trip to haul CCPs from the power plant to the mine area. Therefore, vehicular diesel emissions are reduced by the utilization of an otherwise empty haul truck.

The Texas CCP Coalition also advanced the environmental benefits of facilitating the use of CCPs for other beneficial uses, to include to assist in achieving AOC by providing an additional volume of material that could be used to enhance AOC activities at certain mine sites. The Texas CCP Coalition explained:

1. CCPs can be essential to ensuring and enhancing AOC in ongoing reclamation when there are periodic shortages of overburden (spoil) available for reclamation purposes in the immediate vicinity.

2. CCPs can greatly enhance the flexibility of achieving AOC by allowing the operator to lessen steeper slopes in areas where low volumes of available spoil material typically result in steeper postmine slopes.

3. Use of CCPs in other conditions of pit reclamation enable placement of the CCPs to create slope diversity and enhance postmine contours while maintaining compliance with the regulatory permitting requirements. Typically in active mine areas, CCPs are placed in pits at depth below the approved topsoil and subsoil depth increments.

4. Use of CCPs in the manners described above may reduce landowner concerns at the time of Reclamation Performance Bond release by improving the attractiveness of land features created during the reclamation process.

5. Use of CCPs for final pit reclamation provides benign material in situations where the material from a boxcut has low pH. In those situations, the CCP material would be better quality and more protective of the environment than the low pH material. Minimizing low pH conditions in the final pit would minimize that potential condition in surface water drainage and groundwater thereby minimizing or eliminating environmental degradation.

6. Use of CCPs for final pit reclamation would decrease the amount of disturbed acreage, therefore potentially decreasing disturbance acreage of vegetation and habitat by not having to re-disturb the initial boxcut area, which has been covered, revegetated, and stabilized (pursuant to RCT regulations) for several years.

7. Although final pit impoundments may be appropriate in some cases, they may not always be an option, thereby making it necessary for permittees to fill in the final pit to achieve AOC. In addition, in some cases, creation of final pit impoundments may require disturbance of additional acreage to achieve the necessary side slopes depending on the intended use of the impoundment following release of the reclamation performance bond, i.e. flatter side slopes than if sloped for final pit reclamation.

8. Use of CCPs improves the material balance for reclamation of the project and provides operational flexibility, which increases the efficiency of the operation.

9. Use of CCPs in final reclamation results in reduced emissions from diesel equipment by having less acreage that needs to be disturbed.

10. Use of CCPs in some operations enables direct haul-back of CCP material from a nearby facility, i.e. electric generating facility to the mine, which results in reduced diesel emissions and also increases the efficiency of the operation.

11. Use of CCPs for final pit reclamation may eliminate significant impacts to the reclamation timetable when not re-disturbing the boxcut area. This would ultimately result in minimizing delays in release of the Reclamation Performance Bond by not having to "start the clock" over for reclamation of a re-disturbed boxcut area.

12. By using CCP material to fill the majority of the final pit, the volume (and distance) of material required from the highwall side may be greatly reduced.

In sum, there are a number of benefits to be achieved from the use of CCPs in achieving approximate original contours—even at a side where there is technically enough soil to achieve AOC without the use of CCPs. CCPs would not be used when excess spoil would have to be landfilled, but can be used when the soil balance is marginal and utilizing the soil available requires redisturbing an original boxcut spoil pile that has likely been reclaimed years before it is needed. Redisturbing the original cut-area, moving the soil, and then reclaiming both the redisturbed area and the newly filled area can all be avoided by the use of CCPs.

Note that the net environmental benefits described above formed the foundation for a table that was included in EPA's background documents in preparation for their facilitated stakeholders meeting on minefill practices for coal combustion residue on May 19 and 20, 2003. That table is included as Appendix III to these proceedings.

In addition to environmental benefits associated with the mine site use of CCPs in Texas, the Texas CCP Coalition urged in its petition the practical and economic benefits to be derived from a more efficient process for reviewing plans that contemplate CCP use and CCB disposal. In particular, the flexibility afforded by the ability to use CCPs and CCBs instead of procuring alternative products or managing the material in other locations would result in a significant cost-savings to the operator of a mine, the generator of the CCPs and CCBs, and, ultimately, the consumers of electricity in Texas. The Texas CCP Coalition argued that the cost-savings could be a critical component to the continued economic use of coal, which is the cornerstone of sound energy policy in Texas and throughout the U.S.

OSM Response to Rulemaking

As required, the RCT submitted the proposed rulemaking to the Office of Surface Mining (OSM) for their comments. OSM's response, which is included as Appendix IV, requested clarification on a number of points relating to mine site use of CCPs and generally sought from the RCT a more clear "road map" on how the TCEQ and RCT concurrent jurisdiction over CCB disposal operates in Texas.

Pending RCT Response to OSM – Current Status of Regulations

The RCT is currently in the process of deciding how it must revise the pending rule to be responsive to OSM's comments. The SMRD staff drafted a set of revised rule language and narrative explanations designed to be responsive to the OSM comments. The Texas CCP Coalition has stated its concern to the RCT Commissioners, in a public meeting on January 13, 2005, that the SMRD staff made more wholesale changes than were required by OSM's comments. For example, the OSM wrote: "By policy OSM views the disposal of coal combustion by-products as disposal of noncoal mine waste. Texas needs to clarify in its regulations or a policy document that it will require disposal operations to adhere to Texas' noncoal mine wastes disposal regulations as well as any special and/or additional requirements that site-specific conditions may require." In response to this request that Texas clarify that CCBs are noncoal mine waste, SMRD staff's response defined both CCBs and CCPs as noncoal mine waste and stated that it considered the use of CCPs as fill to be a use "constituting disposal."

It is the Texas CCP Coalition's position that this revision to the rules goes beyond what is necessary to be responsive to OSM and the language used by the SMRD staff contradicts TCEQ regulations. The Texas CCP Coalition noted that OSM is aware of the significance of the terms "disposal" and "coal combustion by-products" as contrasted with "use" and "coal combustion products" and used its language precisely, therein not indicating any need for any change relevant to the use of CCPs.

The Texas CCP Coalition further believe that the TCEQ regulations determine whether a material is legally characterized as a "waste" or a "product" – that is, to be considered coal combustion "products" (CCPs) and not coal

combustion "by-products" (CCBs) – and that inherent in the TCEQ criteria is that a material may not be considered a "product" if it is used in a manner that constitutes disposal. The Texas CCP Coalition, therefore, is pressing the issue with the RCT that it is legally inconsistent to characterize CCPs (which, by definition, meet the TCEQ non-waste criteria) as "waste" or the beneficial use of CCPs as "constituting disposal." The Texas CCP Coalition recommends, therefore, that the definition of "non-coal mine waste" should be revised to explicitly reference CCBs, but not CCPs.

There are a number of other concerns that the Texas CCP Coalition has with the RCT SMRD's initial proposed response to OSM that will be the subject of extensive public deliberations among the RCT Commissioners in the very near term. At the time this paper is going to press, no RCT Commissioner Public Meeting has been set to deliberate the issues, but a resolution is expected very soon and, in fact, may be finalized before this paper is presented at the 2005 conference.

Conclusion

As the producer of more coal combustion residue than any other State in the union, it is critical for Texas to have a regulatory program in place that facilitates the beneficial mine site use of CCPs and clarifies the concurrent jurisdiction of the TCEQ and RCT over CCB disposal at Texas mine sites. When the RCT completes its pending rulemaking, Texas will finally have both TCEQ and RCT regulations that are clear and express so that operators, the public, and EPA can be assured of the process and the measures in place to protect human health and the environment. Especially as it relates to the beneficial mine site use of CCPs, easily discernable regulations are critical if we hope to accomplish EPA and Department of Energy goals regarding the increased beneficial reuse of CCPs.

Michael J. Nasi is an equity partner with Lloyd Gosselink, *et al* P.C., a law firm with over twenty attorneys specializing in environmental law in Austin, Texas. (Website: lglawfirm.com) He has over 12 years of experience as a compliance counselor in waste permitting, air permitting, corrective action, and surface mining and reclamation. He serves on several environmental agency advisory/guidance committees representing the interests of local governments, publicly traded corporations, and other members of the regulated community. He has developed significant expertise in coal combustion product (CCP) issues as environmental counsel to many electric generating utilities and mining companies, as well as the Texas Mining & Reclamation Association (TMRA) and the Texas Coal Combustion Products Coalition (Texas CCP Coalition). On behalf of TMRA and Texas CCP Coalition, he has been significantly involved with the EPA's ongoing review of mine-site use of CCPs and coordinated efforts to provide EPA with extensive information regarding existing mine-site CCP use and CCB disposal practices. He has worked closely with the Texas Commission on Environmental Quality (TCEQ) and the Railroad Commission of Texas (RCT) on CCP-focused rules such as the TCEQ's "Eight Non-Waste Criteria Rule" and the RCT's proposed rulemaking governing mine-site use of CCPs and disposal of coal combustion byproducts (CCBs). He also represents the Gulf Coast Lignite Coalition (GCLC) focusing on mercury and interstate air quality regulations, including the potential impact of air quality regulations on coal combustion products. He is the Chairman of the Education Committee for the State Bar of Texas Section on Environmental and Natural Resources Law. He is also a member of the American Bar Association Section of Environment, Energy, and Resources. He maintains three chapters for West's Texas Practice Series on Environmental Law. He has authored numerous articles on coal combustion product use, management, and regulation. He is also published in numerous publications, including the Texas Environmental Law Journal, on a wide range of environmental topics. He received a B.A. majoring in Government and History from the University of Texas at Austin and a J.D. from the University of Houston Law Center with focused studies in environmental law. Prior to joining Lloyd Gosselink, he worked for the Attorney General of Texas in the Environmental Protection Division (currently referred to as the Natural Resources Division).

THE USE OF COAL ASH AND DREDGED MATERIALS IN LARGE SCALE ABANDONED MINE RECLAMATION

Andrew S. Voros
Executive Director
NY/NJ Clean Ocean And Shore Trust
Columbia University
New York, New York

Abstract

The human and environmental impacts of Abandoned Mines Lands are well known, creating falling, drowning and asphyxiation hazards, mine void collapses, stream and groundwater diversion, and the acidification of thousands of miles of waterways. They are the number one cause of water pollution in many States. Surface mines despoil hundreds of thousands of acres while underground mine fires burn for decades. The reclamation of America's 560,000 abandoned mine features will require billions of tons of fill. At the same time, environmental regulations seeking cleaner air and water are redirecting millions of tons of bulk materials to the land. Cleaner-burning coal means adding tons of lime during combustion, and collecting more of the ash that used to go up the stack. Mud dredged from navigation channels, dams, and reservoirs may no longer be disposed of in the ocean. This country annually produces 130 million tons of coal combustion products and 500 million tons of dredged materials. This project set out to demonstrate that dredged materials, amended with alkaline activated ash wastes, undergo a cementitious reaction that can be used beneficially to: (1) replace the devastated geology of Abandoned Mine Lands, (2) remove physical hazards, (3) return surface waters to their watersheds, (4) prevent the formation of Acid Mine Drainage, and (4) restore natural vegetation and habitat, without harm to the environment. Nearly one million tons of amended fill was used to return a double high wall along 11,000 feet of a hillside in western Pennsylvania to its original contours. Over 100,000 surface and groundwater analyses have been performed since 1998. The results of which has lead the Pennsylvania Department of Environmental Protection (PADEP) to permit this application for the remediation of a 30,000,000 cubic yard strip pit in eastern Pennsylvania. The permitting, monitoring, operations, and results of this project will be summarized.
Keywords: dredged materials, contaminated sediments, coal ash, mine reclamation.

Introduction

Both unconsolidated coal ash and loose sediments dredged from navigation channels may not *by themselves* be suitable for large scale mine reclamation applications. But the mixing of the two can provide structural fill engineered to virtually any requirement while improving the material handling properties of both: dusting can be eliminated on the part of coal ash while dredged materials become stiffer and more easily handled because of the binding of any free water in the mixture.

Dredging projects can produce volumes on the order of 10,000 cubic meters per day (a cubic meter is approximately one metric ton). Depending on the application, an equivalent amount of coal ash may be employed in the mix as well. Besides utilizing volumes on this order, meaningful results can be achieved in reclaiming many Abandoned Mine Lands (AML) features otherwise 'written off' as impossible to reclaim. Twenty-nine US States have catalogued over one-half million AML features: shafts, tunnels, strip pits, crop falls, high walls and more, many individual features exceeding one billion (1,000,000,000) cubic meters in fill requirements. In Pennsylvania alone there are dozens of actively burning underground mine fires. At many of these sites the overburden has been used to fill wetlands and is no longer available. Even where major refuse piles do exist nearby, in many instances the disturbed rock must be encapsulated when used as mine fill to prevent generation of acid mine drainage (AMD). Nearly every industrialized country in Europe and Asia have similar abandoned mine problems, as well as major volumes of coal ash and dredged sediments to deal with.

The remediation of these mine features not only provide beneficial use for these large scale would-be-wastes while fulfilling their massive volume needs, but properly engineered and placed mixtures of dredged material and coal ash

seal the features from further exposure to water, preventing leaching of metals and acids while returning runoff to their pre-mining water sheds, reducing the acid drainage that sterilize thousands of miles of US waters and allow the regeneration of wetland habitat, and eliminate falling, drowning, and asphyxiation hazards and mine void collapses that cost dozens of lives each year at abandoned mine sites.

The addition of dredged materials into a manufactured fill, rather than using coal ash alone, allows the leveraging of significant economic resources towards the mutual benefit of dredging projects, mine reclamation efforts, and coal ash utilization. The proper combination of a strategically chosen reclamation site or sites, perhaps with economic development potential, and appropriately located dredging projects and sources of coal ash can create a project with significant environmental remediation and economic benefits. In the future, the configuration of power generating facilities, rail connections, and mine sites required by such projects, may lend this application to large scale carbon sequestration.

The following briefly describes the project that demonstrated this concept, followed by a discussion of practical considerations in organizing such work. The complete final report with charts, graphs and data are available online at www.nynjcoast.org.

Volumes of Dredge, Ash, and Mine Voids

Abandoned Mine Lands

The Pennsylvania Department of Environmental Protection (PADEP) has designated over 5,600 abandoned mine features as human health hazards in need of remediation. These features, responsible for several fatalities each year, include dangerous shafts, high-walls, and submerged pits, 36 underground mine fires, 800 annual incidents of land subsidence over deep mines, 250,000 acres of unreclaimed mine lands and the production of Acid Mine Drainage (AMD) that impacts 3,000 miles of Pennsylvania's rivers and streams. Pennsylvania has individual strip mine features with fill requirements estimated at up to one billion cubic yards[1], while the total cost of these reclamations is estimated to be $15 billion. Twenty-nine (29) US states and tribal lands have catalogued over 560,000 abandoned mine land features.

Dredged Materials

An issue of similar scale is the disposal of the 500 million tons of sediments dredged on average each year from the nation's navigational channels, lakes, dams, harbors and marinas. These volumes, which are mostly composed of water, silt, sand, and clays, were typically disposed of in off-shore waters, and generally contain trace amounts of contaminants from agricultural and industrial sources. This should not be confused with the minority of highly contaminated or hazardous materials associated with 'environmental dredging' operations from industrial sites that require decontamination, and which make up a small percentage of the total volumes dredged nationally. There is however legitimate concern over the disposal of even trace-contaminated materials in open water because loose sediments in aquatic habitats are literally consumed by bottom dwelling creatures, which over time may bioaccumulate contaminants and could provide their entry into the food chain. For this reason, dredged materials are increasingly being used world-wide in upland applications where they are solidified and used as structural fills with no threat to the environment.

While many upland uses of dredged materials have been developed, from the construction of port islands to airport runways and use in landfill closures, sufficient portside areas are not available for the volumes involved. The cost of dredging has skyrocketed, threatening to rearrange national shipping patterns with dire consequences for road traffic, employment, and consumer prices in the entire mid-Atlantic region. In some instances, shoreline placements of dredged materials have smothered valuable wetlands. On the Delaware River, the long standing practice has been to hydraulically pump dredged materials onto what were originally wetland areas of Delaware, New Jersey, and Pennsylvania, covering thousands of acres. The proposed deepening of the Delaware channel would generate 93

[1] While many mine sites have millions of tons of coal wastes in local piles (overburden and rock originally surrounding the coal seams and removed during mining) much of these wastes are acid generating and should be replaced as encapsulated fill to prevent acid drainage. Other mines have had their spoil widely scattered, while some, like vertical outcrops, are massive voids that have no spoil associated with them at all.

million yards of sediments, mostly destined for existing facilities in New Jersey, as well as an additional 670 acres of presently existing wetlands in that State.

Coal Ash

Another large scale problem is the annual production of 130 million tons of coal ashes in the US, largely from coal burning power plants, which provide over 50% of the nation's electricity. These ashes are the mineral residue of coal and lime (added during combustion to reduce acid rain production) and the captured 'fly ash' that used to exit from smokestacks. They have cementitious (or *pozzolanic*) properties and are similar to the volcanic ashes used by the Romans to perfect concrete twenty centuries ago. Under alkaline conditions, these mineral products of burning react to form cementitious bonds. Modern coal ashes have been used in US construction since 1948, and 20% of the total ash generated is used in the manufacture of Portland cement. But the remainder is largely land filled or stockpiled. Their sheer volume and the portion placed in unconsolidated stockpiles are themselves causes of environmental concern. The coal ash specifically used in this project was fluidized bed combustion coal ash from the burning of bituminous coal waste ('gob') which is noted for being high in lime (up to 30%) and formed under a moderate heat environment.

The Bark Camp Demonstration Project

Initiated in 1995, the Bark Camp Demonstration Project is a public-private partnership among the Pennsylvania Department of Environmental Protection, the New York/New Jersey Clean Ocean And Shore Trust (a bi-State marine resources legislative commission), and Clean Earth Dredging Technologies, Inc (a Pennsylvania environmental contracting and recycling firm). The project sought to join port economies, the need to dredge navigation channels, and the would-be waste products of coal combustion and dredging with the vast fill requirements of dangerous abandoned mine land features.

Historic proposals for the use of abandoned mines often focused on the planned dumping of bulk materials simply as a means of disposal, in the absence of present day environmental sensibilities, however there is a real need for safe mine reclamation fill materials where such materials are not economically available, and for funding mechanisms to address that $15 billion problem. The concept tested here is straightforward: along with their ability to form cements, the contaminant binding properties of alkaline activated coal ashes are well established, making them an appropriate binder for dredged sediments, so as to form an extremely low permeability manufactured fill as the replacement for the underlying rock of stripped mine lands.

This project sought to demonstrate the potential for the combined beneficial use of these wastes, or by-products of US shipping and power generation while leveraging the economies of scale of each of the problems addressed and directing their financial resources towards mine reclamation. The high cost of dredged material management along with ever increasing volumes of coal ash generated to reduce air emissions, have made their beneficial use for mine reclamation economically feasible. Over 19 million dollars was provided to accomplish this project, of which about seven and one-half million were spent at Bark Camp. The determination to be made was whether it was truly beneficial without negative consequences for the environment.

Project Planning

In 1995, the New York / New Jersey Clean Ocean And Shore Trust, the biState marine resources commission known as COAST, approached the Pennsylvania Department of Environmental Protection (PADEP), Bureau of Abandoned Mine Reclamation with a proposal to test the feasibility of using dredged materials from the Hudson and Raritan estuaries and the Delaware River in abandoned mine reclamation. Facing the legacy of 300 years of coal mining, PADEP has been a national leader in mine reclamation research and applications, and saw the potential for using dredged sediments as an aggregate in a coal ash amended grout. The department determined that in spite of the negative public perception of dredged materials, the levels of contaminants involved were not excessive and well within their regulatory experience. Furthermore, the contaminant binding capacity and low permeability of coal ash grouts were perfectly suited to immobilize any contaminants present. In order to ensure that only acceptable materials were used, the Bureau of Land Recycling and Waste Management applied regulatory limits for contaminant levels from existing programs and forbade the use of any hazardous materials whatsoever.

Over the next year and a half, many meetings were held with State and Federal agencies, scientists, regulators and mine reclamation field staff to sketch out a basic project design, identify potential demonstration sites, and to obtain funding for the project.

The Bark Camp Mine Reclamation Laboratory

PADEP identified the existing Bark Camp Mine Reclamation Laboratory in Clearfield County as a good candidate for the demonstration site. It was an abandoned mine in a State Forest owned by the Commonwealth, with the responsibility for its reclamation having reverted to the State.

Bark Camp as a whole is an abandoned coal mining complex that included abandoned surface and underground mines, preparation facilities and operating equipment, all with their attendant residual problems. Given that the facilities operated from the 1950s through the early 1980s, substances commonly used there included electrical transformers and a variety of fuels, solvents, and other materials no longer in use today. Several reclamation and acid mine drainage abatement methods had been and continue to be tested and evaluated there, including the use of coal ash and municipal waste incinerator ash grouts.

The permitting process was begun and discussions were entered into with the nearby community of Penfield in Huston Township. The township governing board formed an Environmental Committee to work with PADEP as full partners to inspect and monitor site activities. In June 1997, PADEP approved an amendment for the inclusion of dredged materials to the existing permit for ongoing reclamation activities at Bark Camp.

The Site

Bark Camp Run is a small stream that runs northward down a narrow headwater stream valley for about a mile and a half before entering a six foot diameter culvert under a former coal processing facility. It emerges and continues another 1.75 miles to where it joins a larger stream. The entire inside rim of the valley upstream of the culverted area was strip mined about 50 feet above the valley floor to reach thin layers of coal outcropping there. A bench was cut about 100 feet into the hillside, exposing the coal seam and creating a vertical cliff or 'highwall.' The pyritic overburden was simply dumped directly downhill, and has since become overgrown in trees and shrubs. The project area is that bench and highwall along the west side of the stream stretching from near the stream's headwaters almost to the culverted area. Approximately one third of this stretch of highwall has a second bench above the first one at the downstream end. The reclamation achieved in this project involved replacing the stripped out overburden with the manufactured fill, placed in lifts until the original contours of the hillside were restored, then covered with topsoil and planted.

Since the stripped pyritic overburden ringing the valley lies below the project level and was not remediated, it has and will continue to impact the upper portion of the stream with acid drainage contaminants. Prior to the project, surface and groundwater in the project area exceeded Pennsylvania Chapter 93 water quality criteria and/or drinking water standards for lead, cadmium, aluminum, Iron, manganese, sulfate, pH, and phenols. The area's coal beds, exposed in the valley walls by the strip mine, tilt down northwestward at twice the pitch of the descending streambed, intersecting the valley floor at the processing area and continuing underground beyond it. Two deep mines had been historically tunneled into the hills on either side of the valley at the processing site, and were now flooded and daily generating 180,000 gallons of acid mine drainage into the stream below the former entrances, heavily impacting the downstream portion of Bark Camp Run. The use of materials with minimal contamination during the demonstration was never likely to further degrade the already impacted stream.

During the course of the project, many interested people visited the site and discussed the various activities and their merits. They represented a wide range of backgrounds and interests that included State and Federal agencies both within and outside of Pennsylvania, news media, elected officials (municipal, State, and Federal representatives), national and State environmental organizations and watershed groups, academic researchers, private business concerns, and local citizens.

Analyses were regularly posted and available on the PADEP website during the course of the project.

Permitting, Sampling, and Analysis

Every step of the process, beginning prior to dredging through the processing and placement of dredged materials, and including all components of the fill materials used, was regulated by permits and approvals issued by the relevant State and Federal authorities. Dredged materials and all additives had to meet specific bulk chemistry and leachate testing standards to gain approval for their use. Prior to the acceptance of any sediments, core samples from proposed dredging projects were analyzed for bulk chemistry, volatile and semi-volatile organic compounds, pesticides, PCBs, dioxins, and metals before being approved for use in the demonstration. A single proposed dredging project was rejected for exceeding allowable contaminant limits. All admixture elements were also required to meet regulatory standards.

In addition to the minimum testing standards for inclusion of any materials in the project, a series of confirmatory tests were also required to ensure that no unauthorized materials were being included anywhere along the processing line. Samples were regularly obtained at the port-side dredged material processing facility after pre-amendment and just prior to shipping and random samples were also obtained from rail cars upon arriving at Bark Camp. Samples were taken of the final pugmill mixture as well, before emplacement in the highwall. These samples were subjected to the entire chemical testing protocol for all analytes.

Over 50 surface and ground water monitoring points have been established in various places at the mine reclamation laboratory over the past decade. These include the monitoring of a mine pool, multiple acid drainage seeps, and a collection system beneath a lined area of municipal waste incinerator ash grout. Several of these were established for, or continued to be monitored during, this project. Surface water monitoring points were established in Bark Camp Run and its tributaries above, along, and downstream of the demonstration project, and 6 monitoring wells were drilled along its length at the toe of the lower highwall to monitor groundwater. A small ravine separated the project near its middle into two phases, with three of the wells along each phase. Additionally, domestic wells in the general vicinity of the off-loading site on the rail siding were monitored to detect any changes during operations. Water samples were taken at the monitoring points at first monthly, and then quarterly, beginning prior to operations on the site. The samples were tested for a comprehensive suite of organic compounds and metals, which are listed in the report appendix.

Operations

Coal Ash Amended Dredged Material

Dredging was accomplished by using clam shell buckets mounted on cranes. The sediments are grabbed from the bottom of the waterway and placed in hopper scows for transfer to Clean Earth Dredging Technology's (CTI) port side processing facility. Dredged sediments are over 60% water, and must be stabilized for shipping. After decanting excess water rising to the surface of the scows, the material is screened to remove debris and blended with approximately 15% coal ash (by volume) before being loaded into 110 ton gondola railcars and covered with tarpaulins for transport to the mine site. This addition of coal ash is sufficient to bind any free water in the material. CTI processed and shipped up to 4300 tons of amended dredged materials per one-shift day.

Although Bark Camp was an appropriate site for demonstration purposes, it was never logistically ideal, requiring a long haul from the port and multiple re-handling of materials. On arrival at Bark Camp, the railcars were unloaded into off-road mining trucks for the nearly two mile trip from the rail siding to the processing pad at the mine site. The now pre-amended dredged material was further mixed with coal ash and lime kiln dust in proportions necessary to initiate cementitious reactions, taken to the high walls and placed in piles while they began the curing process. The material was then spread in one to two foot lifts and roller compacted. In this project the fill was engineered to: achieve a minimum compressive strength of 35 pounds per square inch within 28 days (enough to support construction machinery); achieve permeability of less than 1×10^{-6} centimeters per second (nearly the low permeability of a clay cap) and; to withstand freezing and thawing cycles.

Each lift was placed in a width slightly narrower than the one immediately below it to reconstruct the original contours of the hillside. When that was accomplished, the surface was covered in approximately 18-20 inches of

manufactured topsoil made from local shale, paper fiber cellulose, organic material from a vegetable-process tannery, coal ash, and lime. The surface was planted in a mixture of grasses.

The first manufactured fill to be placed was a total of 40,000 tons of coal-ash amended dredged material in May, 1998. Placed on the upper bench, its side slope was covered and planted, but the entire top surface was left uncovered to monitor the effects of weathering. The site was monitored for two years from initiation before additional materials were brought to the project. In two years of surface and groundwater monitoring there was not a single detection of a volatile or semi-volatile organic compound, pesticide, PCB, or dioxin. No metals were detected other than those previously present due to mine drainage. Yet the flat expanse of bare shale and the severe drop of the highwall were diminishing through the reclamation efforts. The planted slope had established a lush growth, and there was no detectable change in the stream below the length of the project. A negligible amount of chloride (34 mg/L) from the salt water (sodium chloride) in the material was detected in the lowest elevation monitoring well, indicating that project impacts were being captured by the monitoring system. However, no chlorides were detected beyond background levels in the surface water monitoring point below the site.

Manufactured fill placement resumed in July, 2000. In May 2001, three years after the project began, and after the emplacement of over a quarter million tons of dredged sediments, a biological survey by the Pennsylvania Fish and Boat Commission showed over-wintering trout in the stream below and along the site. In spite of the fact that the entire Commonwealth is under a fish consumption advisory due to airborne contaminants like mercury and PCBs, the fish sampled from Bark Camp Run met the standard for unlimited consumption. A total of 435,000 cubic yards of dredged materials were amended and emplaced by spring 2002, with a three month winter hiatus in operations.

Municipal Waste Incinerator Ash

As previously noted, there were ongoing reclamation projects on the site before this demonstration was proposed, including projects seeking low cost fill materials in significant volumes. Permits had been issued for the use of coal ash, manufactured soil and finally, municipal waste incinerator ash (MWIA) as a cementitious fill material. MWIA went through a full permitting process in 1996 and was shown to exhibit low permeability and pozzolanic activation. Regional competition for qualifying, bidding, and contracting for dredged material delayed completion of this project long enough that MWIA began arriving at the site in April, 2001. CTI began amending the alkaline activated ash and dredged material mixtures with MWIA in May, placing most of that material in Phase Two and at another site away from the project. For several months in 2002 after final placement of dredged materials, MWIA grouts were used to complete the final sections of the Phase Two highwalls.

Physical and Chemical Processes

The factor that makes this application safe and beneficial for mine reclamation is the physical and chemical changes undergone by the constituent materials. More than 20 years of increasingly sophisticated scientific investigations have established an understanding of the long known ability of alkaline activated bituminous coal ashes to form very strong cementitious bonds. Cementitious properties occur among the mineral fraction remaining after coal combustion because they are converted by the heat of combustion (in the presence of lime- calcium carbonate- injected to reduce the generation of acid rain) into highly reactive compounds with stored chemical energy. When mixed with water, they initiate cementitious reactions breaking their chemical bonds and forming new ones. Most of the water present (H_2O) becomes divided into oxygen (O) and hydroxyl (OH), and is chemically bound into the newly formed minerals of the hardening cement matrix. Both coal ashes and dredged sediments (sand, silt, and clay) are mostly composed of silicon, aluminum, and oxygen compounds, which along with calcium, are the core constituents of cementitious reactions.

Cement mineral structures or matrices are extremely tight and leave only tiny pore spaces that may contain some liquid water of a highly alkaline pH in excess of 12. Because of chemical reactions with calcium, this pore water remains extremely alkaline, and maintains a very strong buffering capacity, being able to neutralize acids over long periods of time. Several things happen to metals and organic compounds present during these reactions, including:

> Precipitation: most metals that are in soluble form are transformed in the high pH environment into insoluble forms that precipitate out of solution, just as iron dissolved by acid drainage precipitates out in

streams when the mine drainage is diluted and neutralized by fresh water. Since the pore water has the capacity to buffer acids, these substances remain immobilized and less vulnerable to leaching out of the matrix.

Isomorphic Substitution: contaminants may be chemically incorporated into the new compounds formed as the solid mineral phase develops from the slurry, they may also stick to the surface of the new compounds or be absorbed into their three dimensional structure (*adsorption* and *absorption*).

Physical Encapsulation: contaminants are surrounded by a strongly bonded matrix from which they can not escape.

Metal and organic contaminants are therefore physically and chemically bound at the molecular level and are not released when the concrete matrix is broken up. Once a contaminant is incorporated into the mineral phase of the cement, that matrix must be chemically destroyed to release them. The specific regulatory testing that the manufactured fill in this demonstration must pass is the Toxicity Characteristic Leaching Procedure (TCLP) testing, where a sample is pulverized, then tumbled in acidic solution for 18 hours, the equivalent to an extremely long duration of exposure to acid rain attack.

Aside from these complex mineral interactions at work, a more commonplace effect is taking place as well: the massive reduction in surface area. When disposed of in the ocean, dredged materials are literally consumed in large quantities over time by mud-dwelling marine organisms; their digestive systems processing every grain of sediment, and any contaminants thus available. But when solidified into a low permeability monolithic cemented mass, the surface area that is available to chemical attack is infinitely reduced in relation to the massive volume enclosed. The fine particle sizes of both ashes and sediments make for very low permeability materials when compacted, and water can only move through them at a very minute rate. When considering the ability of these mixes to buffer naturally mildly acidic rainfall, along with their extremely low hydraulic conductivity, they are calculated to remain stable through geological time.

The final effect is that of creating a material that is graded steeply enough to easily shed water and prevent its pooling, low enough in permeability to absorb very little of it, and chemically resistant enough to protect the small amount of material exposed to it at the surface at any one time. For all of the complex molecular reactions taking place in the final engineered fill, its main effect is no more complicated than the roofing that protects a house. Only in this case, the entire 'house' is composed of the roofing material.

Results and Conclusions

1) Analysis of sediments before dredging and along the processing train showed that trace contaminants within permitted levels were present in the fill material prior to placement. Yet in the more than five years of monitoring ground and surface water impacts after placement began, the substances of public health concern - PCB's, pesticides, volatile and semi- volatile organic compounds, dioxins, and furans- were not detected in any of the surface and groundwater monitoring points. Similarly, metals remained at the levels present before the project and were not impacted by the manufactured fill. No hazardous levels of substances were ever detected in regular confirmatory and random sampling of transported materials.

2) The demonstrated effects were predicted by an extensive body of research and are due to the well established physical and chemical binding properties of pozzolanic materials, the low permeability of the fill, a relatively low level of commonplace contaminants in the manufactured fill constituents, and the small surface area to volume ratio of the restoration. Correctly proportioned blends of dredged sediments, coal combustion ash, and kiln dusts, properly applied, will not leach contaminants to ground or surface waters due to their inherent physical characteristics and the chemical bonds formed upon their proper blending.

3) This demonstration has proven the feasibility of this application on a practical basis; the material can be handled, processed, treated, transported, and emplaced while keeping up with the production capacity of dredging operations.

4) The only statistically significant water monitoring impact detected over the course of the entire project was the appearance of chlorides from common salt (sodium chloride) in the marine dredged materials, which fluctuated in relation to project activities and demonstrated the effectiveness of the water monitoring plan. The presence of chlorides were expected due to the release of some salt water from marine dredged materials during handling, and a period of surface washing off the hardened material. But elevated chlorides were correlated with the use of municipal waste incinerator ash (MWIA) as a pozzolanic amendment in the later stages of the project and its placement as a grout, its use having been permitted prior to this project. Much of the material dredged in the United States comes from fresh water sources, and this single outstanding effect would not be a consideration in the use of that material.

5) At the height of activity during exclusive placement of dredged material fill, chloride levels in the area of Bark Camp Run affected only by the project (and not a source of drinking water) briefly reached 44 mg/L, well below impact levels for fish and other aquatic organisms. During placement of MWIA grout, chlorides briefly exceeded the EPA suggested drinking water standard (for taste and not health reasons) of 250 mg/L in a single round of testing (282 mg/L) and then declined. While such projects are typically done near acid drainage impacted waters that require time to recover after remediation, a short period of elevated chlorides would be inconsequential. However, projects in potentially sensitive freshwater areas must be designed and managed to take this phenomenon into account, employing appropriate sediment and runoff management. Careful mix design and project management can reduce the amount of free water remaining un-bound by hydrating reactions in the cured material, thereby reducing any mobilization of chlorides. PADEP will continue to closely monitor the project to quantify this trend.

In the fall of 2004, sampling was carried out along the control stream above and away from the demonstration project. Chloride levels increased the further *upstream* the samples were taken, indicating that chlorides were still present in the vicinity of historic gas wells along the top of the hill and could be contributing detected chlorides in Bark Camp Run.

6) Analysis of Domestic Wells in the vicinity of the rail siding where materials were off-loaded indicate that there is a source of contamination originating at some far distance away from the siding and migrating toward it. The affected wells are all within the influence of multiple residential sewage discharges and several are within the influence of a large farm field that has had contamination issues in the past. Further, the wells closest to the railroad, indeed the one directly below and adjacent to the unloading area, have lower values of detected elements. No effects were detected from the project operations.

7) A dangerous high wall in a State forest, adjacent to State game lands was eliminated. Water is now flowing overland to the stream rather than back into and along the highwall. Flat expanses of bare shale and pyritic rock have been restored to a meadow habitat frequented by bear, deer, bobcat, turkey, and elk. The survey of Bark Camp Run by the Pennsylvania Fish and Boat Commission in May 2001, three years after the project began, cited significant water quality improvements with increasing numbers of macroinvertebrate taxa and some common fishes at a downstream station in Bark Camp Run which was formerly sterile due to the mine drainage impacts left behind by the bankrupt mining operation.

8) The survey further reported over wintering trout in the upper section of Bark Camp Run, directly below the fill project area. Pennsylvania has a State-wide precautionary one meal per week fish consumption advisory due to the prevalence of trace contaminants in the environment. And while there is a one meal per month advisory for PCB contaminated fish and a two meal per month advisory for mercury contaminated fish, all the fish tissue samples from Bark Camp met the standards for unrestricted consumption, including for mercury and PCBs.

9) Community outreach and participation were vital to the success of this project. Local communities must be worked with closely and included in the projects to dispel misconceptions and build cooperation. The sampling and analysis plan for the Demonstration Project, as detailed below, was specifically designed and modified to answer the community's concerns regarding the addition of unauthorized materials, including the addition of a series of random 'confirmatory' testing of materials: after portside processing but before shipping; upon arriving at Bark Camp, as well as, unannounced random sampling by the community and the PADEP site inspector. As would any major reclamation project, this work also provided significant employment and financial resources to the host area.

10) The appearance of moderately elevated chlorides during this demonstration corresponds with the introduction of municipal waste incinerator ash (MWIA) into the manufactured fill as a pozzolanic material. About 253,000 tons of MWIA was placed in Phase 2 of this demonstration, and another area separate and distinct from the dredge demonstration project. MWIA ash is known to contain sodium chloride and as such, the manufactured fill would be expected to release a finite amount of chlorides as well. Chlorides are commonly released as brines from gas wells in this portion of the State, (which is underlain by a vast salt-dome) and are widely applied during winter road-salting operations, and a period of elevated chlorides has never posed any problems at Bark Camp. The extent and degree to which the chloride levels have increased in various monitoring points at Bark Camp over time with the placement of material containing MWIA, indicates a clear need for caution in the use of this material in a similar project. PADEP, therefore, has decided that Municipal Waste Incinerator Ash will no longer be considered for use in mine reclamation projects. Any other potential use of this material would require a more extensive review and separate examination with the appropriate permitting agency which is not within the scope of this report.

11) The key to the successful use of coal ash amended dredged materials is thoroughness. The capabilities of properly made ash mixes were utilized in ancient times, and over the last 70 years. Over 80% of the surface and groundwater analytes tested for, at significant cost, were reported as undetected. The proper characterization of raw materials, and the imposition and monitoring of appropriate performance criteria for compressive strength and low permeability, along with sound project design and operations, are more important than continually analyzing bulk chemistry for contaminants during operations.

12) The use of dredged materials, amended with alkaline activated coal ash, is found to be feasible, safe, and beneficial for use in abandoned mine reclamation.

GIS Feasibility Analysis of a National Application

Environmental Management published our (*Gorokhovich, Voros et al*, vol. 32, issue 4, October 2, 2003) national Geographic Information Systems (GIS) analysis correlating the location of abandoned mine features with the proximity of coal ash generators, dredging projects, and the rail connections among them in the contiguous United States, in order to gauge their feasibility for such a project. The analysis examined mine land areas according to the proximity of all four constituent factors ranked according to where all factors were present within 20, 40, 60, 80, and 100 kilometers. The State rankings in terms of the most areas where these factors come together are listed in table x. Besides the major coal mining States of Pennsylvania and West Virginia, Alabama, Ohio, Illinois, and Kentucky were major confluences of the four parameters examined.

Considerations on Siting Projects

Parochialism and Paroxysms

The existence of individual States with unique laws and identities create special considerations in large regional projects. While all the necessary elements exist entirely within the boundaries of many individual states, maximization of the economic factors involved will often require crossing state boundaries. The original project, for example, involved three States, utilizing the $20 billion-a-year economic engine of the bi-State Port of New York / New Jersey and the extensive abandoned coal mines of the Commonwealth of Pennsylvania.

But the depth of feeling local residents can have about an issue involving out-of-State interests can transcend any project reality no matter how locally advantageous environmentally and even economically. Pennsylvanians have many reasons to be wary of any projects surrounding abandoned coal mines, with everything from garbage to other wastes having been proposed for wholesale dumping in them. And in an issue that involves such massive volumes of materials and amounts of money, there is also no shortage of organized interests, economic and environmental, who are willing to exploit the weaknesses of this situation to their advantage and are willing to manipulate facts to mislead local residents, even after being shown to be wrong.

The only approach to such a situation is extensive outreach, education and willingness to devote time to the local communities involved well in advance of proposing any project.

Steps in Considering Projects

GIS Inventory

Several factors lend themselves to analysis with Geographic Information Systems:

> Inventory of dredging needs; not overlooking small marinas, including information on the relative degree of contamination;
> Inventory of ash generators, mine sites and rail connections;
> Analysis of timing needs: Group multiple dredging projects;
> Look for a constellation of sites that can be remediated from a central project site.

The identification of the four project requirements (mines, dredging projects, ash generator, and rail links among them) is a first step, but further work needs to be done on timing requirements and groupings of both dredging and reclamation projects within regions. Multiple marines can be piggy-backed onto a regional channel dredging project, reducing costs for the participants by 30% over single projects. Similarly, a large mine reclamation project can be located with a constellation of smaller pits, hazards, and AMD outflows that can be stemmed with materials processed at the central site.

Permitting Guidelines

The myriad requirements for State, Federal, and local permits need to be examined and if possible, coordinated and streamlined. Permitting guidelines can be created for group projects, perhaps leading to a multi-state MOU.

Regional Facilities

A regional transfer facility placed on a brownfields site could remediate a known contributor of contamination while creating a large regional facility for dredged material dewatering, handling and transport. It would require water access, rail access, and enough area for moving material on site, crust management, and transferring material. Such a site would eliminates pre-amendment handling considerations, as the dry material (about 90% solids) require no pre-amendment for shipping, and effectively moves three times the volume of wet material, which coming out of a channel is only about 36% solids.

For Further Information

See the final bark Camp Report at www.nynjcoast.org. COAST may be contacted at coast@columbia.edu as well as 212-854-2910.

Andrew Voros is the Executive Director of the NY/NJ Clean Ocean And Shore Trust (COAST), a bistate, marine and coastal resources commission between the State legislatures of New York and New Jersey. He has worked as a consultant to the US Dept. of State, the United States Agency for International Development (USAID), The Center for Strategic and International Studies, Louis Berger International, and the International Union for the Conservation of Nature, among others, and served on the Committee on the African Environment for United Nations Environmental, Scientific and Cultural Organization (UNESCO). He holds visiting appointments at Columbia University's Department of Earth and Environmental Engineering in New York City and Rutgers University's Institute of Marine and Coastal Sciences in New Brunswick, NJ. He has appeared as a guest on National Public Radio and CNN's Larry King Live. He worked as a Park Ranger in Yosemite National Park and completed federal law enforcement training at the Northern California Criminal Justice Training Center of the Department of the Interior, for which he worked as a Park Ranger in Yosemite National Park. He has degrees in biology and psychology from Rutgers University in New Jersey.

THE STATE OF INDIANA'S EXPERIENCE IN REGULATING THE DISPOSAL OF COAL ASH AT SURFACE MINES

Deborah A. Dale
Indiana Department of Natural Resources
Division of Reclamation
Jasonville, Indiana

Abstract

The Indiana General Assembly exempted coal combustion waste (CCW) from regulation by the Solid Waste Management Board of the Indiana Department of Environmental Management (IDEM) in 1988, when the disposal facility is regulated under a Surface Mining Control and Reclamation Act permit. Annually, it is estimated that Indiana generates as much as 7 million tons of Coal Combustion By-Products (CCBP). During the 15 years since authority for CCW disposal at surface coal mine sites was initiated, the State has generated somewhere between 90 and 105 million tons of CCBP. During this same period, a cumulative total of approximately 7 million tons of CCW's have been disposed at Indiana surface coal mines. Regardless of this low percentage of CCBP's placed at Indiana mines, the Indiana Department of Natural Resources, Division of Reclamation has worked hard to develop a program that ensures adequate controls and safeguards that are protective of the public and the environment. The program contains three different waste characterization tests prior to disposal for as long as disposal continues. These include: (1) hydrologic and geologic site characterization, (2) performance surface and groundwater monitoring during and after waste placement, and (3) siting criteria. This presentation will discuss the requirements, philosophy, and rationale of the Indiana program.
Keywords: coal ash, surface coal mines, Indiana, regulation

Background

The State of Indiana, after Texas, is the largest producer of coal combustion materials (coal ash) in the nation. The quantity of coal ash produced is directly related to the fact that 98 percent of all the State's electrical generation comes from the burning of coal. Indiana's dependence on coal fired utilities for electrical production is the highest in the nation. In an attempt to level the playing field for Indiana coal operators in competition with low sulfur Western coals caused by expanding clean air limitations, the Indiana General Assembly intervened to provide legislative relief. In a like manner, Indiana utilities were seeking a cost effective alternative to current methods of coal ash disposal and storage as expanded use of clean coal technologies were causing a corresponding increase in the quantity of coal ash produced. With coal ash production in the State estimated at 6 to 7 million tons annually the question of how best to manage this issue has been no small task. Even as of this date, the issue of coal ash placement, disposal, and utilization are subjects of a considerable public policy debate within the State.

The Indiana Department of Natural Resources – Division of Reclamation has been involved in the placement, i.e., disposal as well as use of coal ashes (CCW's, CCM's, CCB's, CCP's, CCBP's, CUB's FGD's, FBC's, fly ash, bottom ash, boiler slag, scrubber sludge, flue gas desulfurization materials, etc.) since 1988. In that year, in response to a recommendation from the Governor appointed Indiana Coal Commission, the Indiana General Assembly passed Public Law 103. A relatively uncomplicated piece of legislation, the new law simply exempted coal ash disposal from solid waste regulations administrated by the Indiana Department of Environmental Management (IDEM) when disposal occurred at surface coal mines regulated by the Indiana Department of Natural Resources (IDNR) under the Surface Mining Control and Reclamation Act (SMCRA). The underlying rationale behind the switch in authority to regulate coal ash was that for a material that is generally non-hazardous, existing solid waste requirements associated with normal landfill regulations were viewed to be excessive. There was the view that disposal of coal ash in the volumes being generated was an unwise use of otherwise precious municipal landfill space. Additional arguments were also advanced that massive storage cells and holding ponds located in close proximity to the powerplants was also not necessarily the best location for placement of this material. Moreover, neither was it considered a wise use of land as the expansion of these holding cells continued to take up ever increasing acreages of otherwise productive

land. In Indiana characteristically many powerplants are located in floodplain areas immediately adjacent to rivers and lakes. These hydrologic environments can often be highly favorable to the conductance of pollutants through the ground water. To some it seemed logical to dispose of coal ash in a hydrologic environment already substantially disturbed by surface coal mining, represented typically by highly mineralized ground water. There also seemed to be a sort of symbiotic logic in returning these burned coal residues to their place of origin. As has been learned, to others this choice did not appear to be so logical or wise.

With the passage of Public Law 103-88 several attempts at administrative rule making were made by IDNR in the late 1980's and early 1990's. None of these attempts met with any measure of success. The Natural Resources Commission (NRC), which serves as IDNR's policymaking body overseeing the agency's programs, held hearings on proposed CCM disposal regulation. Unfortunately, the hearings proved to be highly contentious. Representatives from both the coal industry and the electrical utilities claimed that the early draft versions of the rules proposed by IDNR were far too stringent. Opponents to CCM disposal at surface coal mines claimed them to be not strict enough. A review of several of these early drafts revealed that they were based largely on the State's existing solid waste disposal regulations administered by the IDEM.

In an effort to resolve the issue, an attempt was made to get the various multi-interest stakeholders together to agree on an approach to regulate coal ash disposal. As a result, a group was created among the stakeholders that agreed to have the University of North Dakota (UND) conduct a study to characterize Indiana coal. The group also agreed on how the study was to be conducted and what parameters were to be examined. The UND report was to serve as basis for determining what level of risk CCM presented to the environment. It was hoped that corresponding regulations could be developed commensurate to the degree of risk.

Unfortunately, the completion of the UND's report itself proved to be contentious. To a more or lesser extent the various parties used the study to declare that it had gone to prove their point for or against disposal at coal mines. With the breakdown of further progress toward a solution, IDNR acted unilaterally to get the program moving. Using the UND study to justify its initiative, IDNR approached the NRC with a suggested solution that would circumvent the need for drafting specific coal ash disposal regulations. It was IDNR's position that current SMCRA rules regulating surface mining were by themselves adequate to accommodate coal ash disposal and protect the environment. To that end IDNR drafted "Memorandum 92-1" as a policy guidance document instructing applicants for coal ash disposal what they must do to secure permit approval and comply with existing SMCRA law and regulations. After more than four years since the passage of Public Law 103-88 authorizing coal ash disposal at surface mines, and otherwise no end in sight to the debate, the NRC approved IDNR's *Memo 92-1* as Indiana's coal ash disposal program.

Program Requirements

Among other requirements the highlights of *Memo 92-1* include; a characterization of the disposal sites hydrogeologic setting (pre and post-mining and disposal), a qualitative and quantitative analysis of the effects of coal ash placement within that setting, waste characterization determined through bulk analysis and both an 18 hour and 30 day neutral leachate analysis in compliance with ASTM standards. Coal ash is analyzed for 22 different constituents, including all 8 RCRA metals, plus pH, potential acidity, neutralization potential, and net neutralization potential. *Memo 92-1* also carried with it the provision that any coal ash leachate result that exceeded 25 percent of the limit for any RCRA element would be rejected for disposal. All sources of coal ash proposed for disposal were required to undergo these tests as well as the requirement to representatively sample and analyze each active waste stream on a quarterly basis.

Other factors considered in IDNR's review included, proximity to public and private water supplies, maximum possible concentrations of constituents, site characteristics such as type and extent of aquifers, spoil characteristics, expected impacts of attenuation, dispersion and dilution, direction of ground water flow, volume proposed for disposal, baseline water quality and quantity data. Plans also are required to include provisions for handling and placement of coal ash during disposal, control of dust and plans for final reclamation and ground water monitoring both during and after the completion of disposal activities through final SMCRA bond release.

In July 1999 the department issued a second policy document, *Memo 99-2* specifically intended to provide guidance

to coal operators that were intending to utilize coal ash on permitted coal mine sites, pursuant to the State's regulatory exemption at Indiana Code 13-19-3-3. While the use of coal ashes for certain functions has been lawfully exempted from regulation in Indiana, the department felt it was essential to provide guidance to coal operations in order to clearly differentiate between coal ashes on mine sites for purposes of utilization from coal ashes subject to disposal and regulatory jurisdiction. *Memo 99-2* closely mirrors the Indiana statute, but emphasizes communication between the coal operator and the department in order to avoid misunderstanding and potential enforcement.

Litigation

Since the approval of *Memo 92-1* by the NRC in April 1992, the State of Indiana has received a total of 19 permit applications for coal ash disposal with the IDNR issuing its first permit for disposal in May 1994. Subsequently, of the 19 disposal applications received, 16 have been approved and three applications were withdrawn. Of the 16 approved permits, disposal has occurred at only 9 permitted sites. Currently, active coal ash disposal is occurring at only three mine sites and 6 have now officially terminated disposal. Seven of the 16 approved mine sites have never received any coal ash disposal. The State currently has one pending coal ash disposal permit application under review and one recently issued permit is currently under administrative appeal.

Of the 16 issued permits only three have not undergone some form of legal challenge. A single environmental group, the Hoosier Environmental Council (HEC), has filed all but one of the legal challenges. Some of the challenges filed by HEC have included individually named adjacent landowners. Only two permits of all those which were challenged have completed the administrative appeal process. Both of these permits were subsequently appealed to the Indiana Circuit Courts for judicial review.

Of the two permits that completed the administrative appeal process, the first completed the process with no changes to the permit. Active coal ash disposal is currently taking place at this mine. The second permit, however, did not pass through the process unscathed and was subjected to additional conditions imposed by the Administrative Law Judge (ALJ). As conditioned, the ALJ reduced the amount of coal ash disposal that had been approved by IDNR in the permit by 75 percent. The initial permit approved the disposal of approximately 7.0 million tons of coal ash over the permit term. The IDNR approved plan also called for the mining of approximately an equivalent amount of coal to a ratio of 1:1 between tons of coal mined and coal ash disposed. In limiting coal ash disposal by 75 percent, or one quarter of the amount of coal removed, the ALJ found that this ratio represented approximately the amount of coal ash produced by the amount of coal mined under the permit. The ALJ further stated the 25 percent figure represented approximately the same amount of RCRA elements being returned to the mine site as originally present in the coal.

The permit was further conditioned by the ALJ to require a disclosure affidavit be filed in the County Recorder's office providing a legal description of land parcels where coal ash disposal occurred. Additional requirements were also imposed requiring the full recharge of ground water, as determined by monitoring wells, prior to the release of final SMCRA bond. Highly controversial, all parties appealed the ALJ's decision to the NRC, including IDNR. In administrative appeals the NRC serves as the final arbiter in permit dispute cases. As a result of the appeal, the NRC modified the ALJ's decision by revising the disposal limit upward to 50 percent of the amount of coal mined by the permittee. This increased amount, however, represented a reduction of 50 percent from the original amount approved by IDNR. The NRC otherwise maintained all other ALJ imposed conditions on the permit.

Subsequent to the NRC's final administrative determination both the coal operator and the Hoosier Environmental Council (HEC) filed for judicial review. The coal operator requested a full restoration of the department's initially issued permit and HEC argued that the NRC was in error for not denying the issuance of the disposal permit in total. As a party to the suit, but not appealing the NRC decision, the State filed a proposed "Findings of Fact and Conclusions of Law" document with the court. In a decision based virtually identical to the suggested "findings" document submitted by the State, the Circuit Court ruling upheld the NRC decision in total and in support of the viability of the State disposal permit. No appeals were filed by any of the parties.

In a very recent development, a State ALJ eliminated all pending permit challenges, citing a lack of prosecution by litigants. Currently only one permit appeal involving coal ash disposal at coal mines in Indiana is pending, as is an issue of legal fees involving an earlier case before the Court of Appeals. The "relative" quiet of the coal ash disposal

at coal mines, cannot be said for the issue of coal ash utilization at non-mine sites where the Hoosier Environmental Council has very recently challenged a floodway construction permit. This "floodway permit" issued to Indianapolis Power and Light intends to utilize coal ashes as a structural fill. Although the use of coal ash is not regulated, the placement of fill in a stream floodway is and has been subjected to legal challenge.

The obvious fallout from the legal challenges filed on most of Indiana's coal ash permits has been to complicate an already complex and lengthy permitting process. As of the last quarter of 2004, a total of approximately 7.2 million tons of coal ash has been disposed of at Indiana surface coal mines since 1989, with 1.64 million tons being the most disposed at any single mine site. In contrast, since that same year, the State of Indiana has generated an estimated almost 100.0 million tons coal ash with about 7.0 percent of what has been produced disposed at coal mines.

While no projections have ever been done to estimate the tonnage expected to be returned to mines, the amount would undoubtedly be higher without the concern over litigation. Regardless of the litigation, however, more practical economic factors, such as transportation costs related to haulage distance and handling expenses, increasingly viable and profitable recycling initiatives and other disposal options, serve to inhibit coal ash disposal at mines. Realistically, it is unlikely that an amount greater than two to three million tons per year would be placed at Indiana surface coal mines due to these economic limitations. To date, most coal ash disposed of in Indiana coal mines in a single year has been slightly more than 1.0 million tons in 2003 and again in 2004. Litigation and the continued lingering controversy involving the seemly perpetual review by the U.S. EPA and now the National Academy of Sciences, deserved or otherwise, also served as an effective constraint to disposal as well as utilization well below levels otherwise anticipated.

Opposition

The arguments brought forward by the opponents of coal ash disposal have been numerous and varied. One of the underlying philosophies is that coal ash which is otherwise classified as a solid waste is best left to the regulation of the agency responsible for solid waste disposal in the State, the Indiana Department of Environmental Management. It has been argued that based on legal precept of "equal protection under the law," that it is not equal to have coal ash disposed of in a non-mining location subject to one set of rules, while disposal at coal mines are subject to a different set, argued to be less protective. This "double standard" is asserted to be less protective of citizens living in the coalfields than those living near landfills.

Arguments have also been made that the requirements of the program itself as expressed in *Memo 92-1*, as a "non-rule policy" are not enforceable and are therefore not protective. Criticism was made that coal ashes were also not being properly characterized. Critics stated that the leachate medium of distilled water, pursuant to ASTM standards was improper. Testimony given at the administrative hearings by experts representing the opponents of coal ash disposal advocated that TCLP was the only correct method to properly determine the degree a waste might be a danger to the environment. The coal ash disposal opponents also wanted the list of constituents tested to include a quantification of radionuclides and polyaromatic hydrocarbons (PAH) as possible mutagens and carcinogens. An article written by a member of the U.S. Department of Energy's Oak Ridge National Laboratory alleging that coal ashes could be used to extract sufficient quantities of weapons grade plutonium was touted as proof of the nuclear danger. Informational bulletins distributed by coal ash disposal opponents, containing such quotes from this article as; "significant quantities of fissionable material..." and "potentially employable as weapon fuel by any organization so inclined." At public hearings held on coal ash disposal, citizens stated that they did not wish to live adjacent to "a weapons grade nuclear facility." Others expressed fear over the potential for radioactive coal ashes from some "hot" Colorado coals finding their way into Indiana for disposal.

The Indiana program has also been attacked under the allegation that its regulation of coal ash disposal was far weaker in comparison to its neighboring states of Illinois, Kentucky, and Ohio. This allegation fed a corollary allegation that because Indiana's program was lax, it would inundate the State with as much as 200 millions tons coal ash, most coming from "out-of-State," over the next five years. The argument played upon recent emotional battles fought within the State over the import of out-of-State garbage into Indiana landfills. This concern has been continually raised despite the fact *Memo 92-1* strictly limits the disposal of out-of-state coal ash's to materials generated from the burning of Indiana coal. Pursuant to *Memorandum 92-1*, coal ash from out-of-State sources may equal an amount no more than the tonnage of coal ash generated from exported Indiana coal. As the State exports

only about four million tons annually, the return of coal ash's for those same out-of-State sources would not in all probability exceed one million tons at most. These facts, however, were not sufficient to quell the specter of out-of-State coal ash as a basis to criticize the agency. As the reality has proven, the dire 200 million tons of coal ash in 5 years prediction has in fact turned out be only 7.2 million tons in the fifteen years.

Opponents of the Indiana disposal program frequently use the fact that program tests run on these materials produce a leachate that exceeds U.S.EPA's primary drinking water standards for a variety of one or more test constituents as proof that coal ash is dangerous. Information is also distributed to the public with descriptions of how the various constituents such as lead, mercury arsenic, cadmium and others can impact human health. U.S.EPA's February 1988 "Report to Congress" is also frequently referenced as evidence of the pervasive nature of ground water contamination from improper coal ash disposal. Together these issues are used to justify strict regulation of disposal at surface coal mines and arguments for the need for synthetic liners and leachate collection and treatment systems.

One of the observations that can be made by watching this process is that the primary entities involved, not surprisingly, view the issue from very different conceptual perspectives. The paradigm for some in the Indiana environmental community has been developed as a result of dealing with issues like coal ash from purely a "landfill" perspective. This is not surprising considering the extensive history of these individuals in working with solid waste laws in comparison to their understanding of SMCRA and the environment found at a "typical" surface coal mine. In their view, coal ash is a solid waste and as such it must be disposed of in a typical solid waste landfill. Correlating with this viewpoint is the opinion that waste materials must be maintained completely separate from the groundwater. Conversely, IDNR mine regulators view the coal ash problem through their SMCRA paradigm. Knowing the post-mining ground water environment, the nature of mine spoils, and how materials such as coal processing wastes are successfully disposed under SMCRA, the addition of coal ashes have always been considered a manageable problem by IDNR. Placing coal ash in direct contact with the ground water did not present the agency with any undo concern in many situations. The effects of attenuation, dispersion, dilution, chemical interaction and the beneficial impacts of coal ash mineralization within the surface mine ground water environment, plus many of its physical characteristics did not appear to warrant the additional costs associated with total isolation as characteristic of a landfill approach. Moreover, given Indiana's nearly century of surface mining and the history of non-use of mine ground water (spoil water) for domestic or irrigation purposes, the department has an extremely high confidence level that potential receptors of "spoil water," much less "ash water" would continue to be virtually nonexistent. To the agency charged with administering SMCRA, a certain symbiotic/logical relationship exists between coal originating from a mine and the return of coal ash. In a differing analogy, the opponents to disposal have described coal as differing from coal ash as does the food you eat from the wastes you produce and a direct threat to domestic and agricultural sources of useable ground water.

Groundwater monitoring requirements imposed by the program were criticized. The number of wells were considered to be too few to characterize the mines hydrologic environment and determine flow direction, and too far removed from the disposal areas to detect any potential contamination. Again, in the paradigm of the landfill with numerous closely sited monitoring wells, no justification for anything less was acceptable. The water monitoring issue led to criticism that the program did not contain groundwater standards and neither specific requirements nor remediation plans should the groundwater become contaminated**.** However, with the recent adoption of Statewide groundwater standards by the Indiana Department of Environmental Management (IDEM), which includes waters impacted by mining and coal ash disposal at mines along with implementation of these standards through surface mining regulations, overall criticism has been less.

State Response

On behalf of the State's position, IDNR has attempted to respond to what it viewed as inaccurate or misrepresentative information or to just provide the public an explanation of how the program worked whenever and wherever possible. As an example of some specifically debated points, such as the use of distilled water instead of TCLP to test coal ash, the agency responded that TCLP was designed for landfill environments and not at all representative of a mining environment. While IDNR recognized that distilled water also did not necessarily represent a mining environment either, it is consider by the agency to be a closer representation of coal ash characterization and in-situ leachability than TCLP. However, it would appear that the debate over TCLP has lessened with both sides agreeing that the test is not appropriate for the circumstance of coal ash placement at coal

mines. Unfortunately however, there has been no corresponding agreement on what is the best test medium or method of testing.

Concerning the issue of radionuclides, IDNR pointed to substantial mainstream scientific literature that indicated that radioactivity from coal ashes were well within background radiation levels for many commonly occurring earth materials. That the possibilities of hot coals or coal ashes from Colorado coming to Indiana was not realistic. Moreover, IDNR has indicated that it was unaware of the Federal government or any State, regardless of its disposal program, that tested for either radioactivity or PAH's.

In responding to attacks on *Memo 92-1* as "non-enforceable," IDNR responded that while the memo itself may not be enforceable, the SMCRA regulations protective of the environment and the specific conditions placed on the permits were. The agency also responded that *Memo 92-1* was never intended to do anything more than to provide guidance to operators as to what specifically must be done to comply with the SMCRA regulations when disposing of coal ash and secure permit approval.

In defending the program, very often the sources of information and documents used to "prove" the soundness of the State's coal ash approach were the same sources of information and documents used by the coal ash opponents to "prove" the program's inadequacies. Not surprisingly, in the public opinion arena IDNR's attempts to scientifically respond to often-emotional arguments have not always played well. However, despite this fact the individual numbers of concerned citizens have been relatively small, given the length of time and the intensity of the effort by coal ash opponents to raise public consciousness. Media coverage has been generally light and most press coverage has been overall fair and balanced, with only a few isolated exceptions. For the most part, the intensity of concern expressed by the public appears to be directly proportional to the individual's proximity to the mine.

Conclusion

In conclusion, after nearly seventeen years of controversy the issue of coal ash disposal may hopefully be drawing to a conclusion with the on-going review by the National Academy of Sciences (NAS) requested by Congress and the current review by the U.S. EPA, which will certainly draw guidance from the NAS study. Whether this process will finally put an end to future litigation or the practice of mine placement remains to be seen. Whether the final regulations will be within industry's means to "live" with economically, and coal ash opponent's demand for environmental protection, is uncertain. Whatever the final "product" is, it is the "process" that in today's reality must be gone through to get there. There must be ownership of the process. There hopefully will be ownership of the product as well.

Deborah A. Dale has been employed as a hydrogeologist with the Indiana Department of Natural Resources, Division of Reclamation since 1998. As a hydrogeologist with the Technical Services Section, she is involved with geological and hydrogeological reviews of surface and underground coal-mining permit applications, surface and groundwater data interpretation, coal combustion by-product issues, regulatory issues, outreach programs and training. She is also involved in various research projects utilizing stable isotopes in evaluating hydrologic regimes. Prior to joining the Division, she worked as an environmental consultant and as instructor for DePauw University in Greencastle, Indiana. She has a M.S. (Geoscience/Hydrogeology) from the University of Nevada, Las Vegas and a B.S. (Geology) from Nicholls State University in Thibodaux, Louisiana. She is also a Licensed Professional Geologist in the State of Indiana.

SURVEY RESULTS
REGULATION, RISK, AND RECLAMATION WITH CCBS AT MINES: A TECHNICAL INTERACTIVE FORUM
PARTICIPANT COMMENTS AND RECOMMENDATIONS

CATEGORY OF PARTICIPANTS	PARTICIPANTS #	PARTICIPANTS %
TOTAL PARTICIPANTS	73	
TOTAL COMPLETING THE SURVEY	18	100
LEVEL OF SATISFACTION WITH THE FORUM **EXTREMELY SATISFIED** **VERY SATISFIED** **SATISFIED** **DISSATISFIED** **VERY DISSATISFIED**	 8 8 1 0 1	 44 44 6 0 6

WHERE DID THE PARTICIPANTS COME FROM? AND WHO DID THEY REPRESENT?

PARTICIPANT AFFILIATION	PARTICIPANT #	PARTICIPANT %
Electric Utility	12 16	
Consultant	11 15	
University	9 12	
Mining	8 11	
DOE	8 11	
State Agency	6 8	
International	6 8	
OSM	3 4	
U.S EPA	3 4	
Other State	3 4	
Attorney	2 3	
CCB Organization	1 1	
US Geologic Survey	1 1	

REGIONAL REPRESENTATION	PARTICIPANT #	PARTICIPANT %
WEST	10 16	
EAST	32 51	
MID-CONTINENT	14 22	
INTERNATIONAL	7 11	

PARTICIPANT RATING ON USEFULNESS OF TALKS
4.0=EXCELLENT
3.0=GOOD
2.0=FAIR
1.0=POOR

SESSION 1 CASE STUDIES OF CCB MINE PLACEMENT DESIGN, IMPLEMENTATION, AND MONITORING

PRESENTER	AVER	AGE RATING	RATING RANGE
James Luther	**3.2**		**4-1**
Harold Walker	**2.7**	**4-**	**1**
Barry Scheetz	**3.5**	**4-**	**1**
Michael Menghini	**3.3**	**4-**	**2**
George Hawkey	**3.2**	**4-**	**2**
Robin Guynn	**2.9**	**4-**	**1**
OVERALL SESSION 1 AVERAGE	**3.1**		

SESSION 2 LEACHING PROTOCOLS AND STUDIES SUPPORTING CCB RISK ASSESSMENT AT MINES

PRESENTER	AVER	AGE RATING	RATING RANGE
David Hassett	**3.5**	**4-**	**2**
Paul Ziemkiewicz	**3.2**	**4-**	**1**
Greg Helms	**3.1**	**4-**	**2**
Ann Kim	**3.5**	**4-**	**3**
Michael Menghini	**3.5**		**4-3**
Deborah Dale	**3.3**		**4-2**
OVERALL SESSION 2 AVERAGE	**3.4**		

SESSION 3 REGULATION OF CCB PLACEMENT AT MINES

PRESENTER	AVER	AGE RATING	RATING RANGE
Greg Conrad	**3.4**	**4-**	**3**
Richard Sweigard	**3.3**	**4-**	**3**
Roger Hornberger	**3.6**	**4-**	**3**
Michael Nasi	**3.2**	**4-**	**3**
Andrew Voros	**3.3**	**4-**	**2**
Deborah Dale	**3.5**		**4-2**
OVERALL SESSION 3 AVERAGE	**3.4**		

SUGGESTIONS FOR IMPROVEMENT

CCB CHARACTERIZATION AND LEACHING

- Need more projects that focus on leachate formation in CCBs at mines and the attenuation of various leachate components in surrounding strata.
- Need more information on leachate studies and ash physical characteristics.
- Disagreement in the scientific community on appropriate leachate methods is problematic for mines and states in risk assessment.

- Need a short overview of the chemistry of Boron, Arsenic, and sulfates and their relative mobility.
- Need more on coal ash testing criteria and the difference between AMD and ash leachate.

OTHER

- Biological surveys of CCB reclaimed mines
- Need more field trips like the Harrisburg Forum.
- Need more information from the State Regulatory Authorities on mine placement.
- Need more mining company presentations on CCB beneficial use and disposal with leachate assessments.
- Need more information on the use of CCBs for road base and structural fill.

APPENDIX 1: RECORDED DISCUSSIONS

Edited by
Kimery C. Vories
USDI Office of Surface Mining
Alton, Illinois

The following are the edited discussions that took place at the end of each speaker presentation and at the end of each topic session. The actual comments have been edited to translate the verbal discussion into a format that more effectively and efficiently communicates the information exchange into a written format. The organization of the discussion follows the same progression as that which took place at the forum. The topic of each question is arranged in alphabetical order for ease of access. A topical outline has been developed to aid in accessing the information brought out in the discussions.

The topic of each question is shown in alphabetical order in **bold.** The individual speaker questions are listed in outline format under the appropriate topic session and presentation title. Questions during the interactive discussions are listed at the end of the session in the following format.

SESSION # AND TOPIC AREA
1. Presentation Title
   - **Subject of Question or Comment**

SESSION #: INTERACTIVE DISCUSSION
Subject of Question or Comment

OUTLINE OF DISCUSSION TOPICS

SESSION 1: CASE STUDIES OF CCB MINE PLACEMENT DESIGN, IMPLEMENTATION, AND MONITORING

1. The Relationship Between Water Quality and Coal Combustion By-Product Placement in an Arid Western Coal Mine
   - **Length of CCB Monitoring**
2. Short- and Long-Term Behavior of Fixated FGD Material Grout at the Roberts-Dawson Mine
3. Diagenesis of FBC Ash in an Acid Pit Lake
   - **Changes in Water Quality**
   - **Measurement of Calcium**
   - **Proportion of CSH structure**
4. Beneficial Use of FBC Coal Ash for Mine Reclamation in the Anthracite Region at the Wheelabrator Frackville and Mount Carmel CoGen Sites
   - **Calculations of Acid Load**
   - **Length of the Permitting Process**
   - **Metals Concentrations**
5. Beneficial Applications of CFB Ash At Mississippi Lignite Mining Company's Red Hills Mine
   - **Evidence of Swelling in Ash**
   - **Reclamation of Ash Haul Roads**
   - **Trends in Ash Use for Roads in SE**
6. Use of a CCP Grout to Reduce the Formation of Acid Mine Drainage: An Update on the Winding Ridge Project
   - **Expansive Grouts to Seal the Mine**
   - **Geophysical Systems for Locating Mine Voids**
   - **Improving Grouting Efficiency**
   - **Mineralogical Studies**
   - **Project Cost**

SESSION 1 INTERACTIVE DISCUSSION

- **Bore Hole Camera**
- **Final Filling for Big Gorilla Pit**
- **Guidelines for Underground Mine Injection**
- **Peer Review of Longevity for Big Gorilla Pit**
- **Public Reaction to Ash Projects**
- **Public Reaction to Ash Projects**
- **Set Up Strength at Big Gorilla Pit**
- **Total or Dissolved Values for Heavy Metal Analysis**

SESSION 2: LEACHING PROTOCOLS AND STUDIES SUPPORTING CCB RISK ASSESSMENT AT MINES

1. Using Laboratory Leaching Methods to Evaluate CCBs
2. Leaching Methods Applied to the Characterization of Coal Combustion By-Products
3. US EPA Leach Testing of Coal Combustion Residues
4. Mine Water Leaching Procedure

LEACHATE PANEL DISCUSSION OF ABOVE

- **ASTM Guide to Test Methods**
- **Coal Refuse with MWLP Test**
- **Consensus Test**
- **Cost for EPA Leach Method**
- **Effect of High Cost EPA Test on Beneficial Use**
- **One Size fits all Test**
- **Regulatory versus Research Tests**
- **Standard versus Site Specific Tests**
- **Western versus Eastern Tests**
- **Worst Case Scenario**

5. Prediction of Coal Ash Leaching Behavior in Acid Mine Water: Comparisons of Laboratory and Field Studies
6. The Use of Leachate Data and Other Factors in Evaluating CCBs for Placement at Coal Mine Sites in Pennsylvania
   - **Amendment of Pulverized Coal Ash**
   - **Annual Samples**
   - **Ash Placement in Flooded Mines**
   - **Projects with Fluidized Bed Ash**
7. The Use of Neutral Leachate Test Data in Indiana's Coal Combustion By-Product Disposal
   - **Opponents Criticism of Indiana Program**

SESSION 2 INTERACTIVE DISCUSSION

- **CCB Damage Cases**
- **CCB Permeability**

SESSION 3: REGULATION OF CCB PLACEMENT AT MINES

1. A State Perspective on Regulation of Mine Placement of Coal Combustion Wastes
   - **A Next Step for EPA**
   - **Guidance from EPA**
   - **Role of OSM**
2. Coal Ash Beneficial Use at Mine Sites in Pennsylvania
3. State Regulation of CCPs and CCBs in Texas
4. The Use of Coal Ash and Dredged Material in Large Scale Abandoned Mine
5. The State of Indiana's Experience in Regulating the Disposal of Coal Ash at Surface Mines
   - **Bond Release Requirements**

SESSION 3 INTERACTIVE DISCUSSION

- **Environmental Testing Cost Dredging Project**
- **Total Cost Dredging Project**

DISCUSSION BY SESSION

SESSION 1: FLUIDIZED BED COMBUSTION MATERIAL AND MINE RECLAMATION

1. The Relationship Between Water Quality and Coal Combustion By-Product Placement in an Arid Western Coal Mine *James G. Luther, Brent Musslewhite, and Collette Brown, San Juan Coal Co., Waterflow, New Mexico*

Question: **(Length of CCB Monitoring)** You said that you have been monitoring the CCB placement area for about 20 years. How long will you be monitoring prior to bond release?

Answer: Although a ball park estimate would be a total of 40 to 50 years of ground water and surface water data, it really depends upon a lot of factors. Currently, the mining contract runs through 2017. There are sufficient coal reserves to continue after that, but it would be up to the power plant to extend the contract. Some of the wells would definitely be monitored throughout the life of the operation. The State Mining Regulatory authority requires us to keep these wells at least until the end of Phase II liability release and in some cases the State may require the wells to remain in place even after Phase III liability release. The Bureau of Land Management and the State actually own most of the land where the coal has been mined. They have already indicated that they may want to see some of the wells remain after final bond release and then it would be up to a different agency to conduct monitoring.

2. Short- and Long-Term Behavior of Fixated FGD Material Grout at the Roberts-Dawson Mine *Harold W. Walker, Pawpanuwat Taerakul, Mikko Lamminen, Earl Whitlatch, Ohio State University, Columbus, Ohio; Yongpian He, Virginia Tech; Samuel Traina, The University of California.*

3. Diagenesis of FBC Ash in an Acid Pit Lake *Dr. Barry E. Scheetz and William B. White Pennsylvania State University, University Park, Pennsylvania, Dr. Carolyn M. Loop, Groundwater Management Associates, Greenville, North Carolina and Roger J. Hornberger and Michael J. Menghini, Pennsylvania Department of Environmental Protection, Pottsville District Mining Office, Pottsville, Pennsylvania*

Question: **(Changes in Water Quality)** Did you see changes in the water quality as you started to add the ash?

Answer: The water quality went from a pH of 3.4 to just below 12. With the exception of the pH and a slightly elevated sulfate level, the water almost met drinking water standards.

Question: **(Measurement of Calcium)** Do you have any measurements of calcium in the pond and is it consistent with this model?

Answer: The calcium content in the pond was used in the model. If you look at the mathematics, you have the chemical activity inside the ash and the water. There is an activity gradient that you are taking into consideration in this calculation.

Question: **(Proportion of CSH structure)** What proportion of the total mass of the ash is in the form of CSH structure?

Answer: We don't know that and at this point it is very difficult to go back and try to calculate it. That is why I stuck with my calculation to the stage t0 to t1. We know how far it is potentially possible but do not know how far it has progressed.

4. Beneficial Use of FBC Coal Ash for Mine Reclamation in the Anthracite Region at the Wheelabrator Frackville and Mount Carmel CoGen Sites *Michael J. Menghini, Roger J.Hornberger, Sharon Hill, and Thomas D. Owen, Pennsylvania Department of Environmental Protection, Pottsville District Mining Office, Pottsville, Pennsylvania and Dr. Barry E. Scheetz, Pennsylvania State University, University Park, Pennsylvania*

Question: **(Calculations of Acid Load)** One of the benefits of the program is just taking this enormous mass of pyretic refuse out of the landscape and even if you didn't reclaim the areas with ash I would think you would get a substantial environmental benefit over time. Have you ever made any calculations of what the reduction in acid load would be by just the removal of the coal waste?

Answer: We have looked at that at some sites but not at this one. This is a win/win situation where we remove the easily leachable material and replace it with alkaline material, cap it and cover it. I don't know how you can use logic to not see that that is better.

Question: **(Length of the Permitting Process)** How long did the permitting process take and what were some of the major issues?

Answer: Initially when these projects came on line, we worked with the Bureau of Land Recycling and Waste Management. Initially it was probably a one year process. Currently, it takes about 6 to 9 months depending upon site complexity. Unless it is a very complicated one like the Big Gorilla where there was a joint permitting process with the Waste Division, it took 18 months to complete. The major issue with the Big Gorilla was the ash placement in water. Most of our sites are high and dry and we know where the mine pools are so you don't have to worry about it.

Question: **(Metals Concentrations)** What were your metals concentrations?

Answer: We have not seen any increase in metals concentrations in the ground water.

5. Beneficial Applications of CFB Ash At Mississippi Lignite Mining Company's Red Hills Mine *George M. Hawkey, Mississippi Lignite Mining Co., Ackerman, Mississippi*

Question: **(Evidence of Swelling in Ash)** Have you seen any swelling with this ash and is that an issue with your application?

Answer: We have not seen any swelling with our ash. We did expect to see some of this material break down over time especially in our most intensively used roads. What we have found is that we never have to maintain the roads, we do not have to blade it, it is hard and rain doesn't affect it, it doesn't pound out. We have seen no breakdown of these roads despite heavy use by 40 ton haul trucks.

Question: **(Reclamation of Ash Haul Roads)** From a post mining perspective, will the haul roads constructed with fly ash remain after mining?

Answer: All of the haul roads will remain but will be reclaimed and be covered with a minimum of ten feet of material.

Question: **(Trends in Ash Use for Roads in SE)** Do you think the use of fly ash as road base construction material in the south east will increase with time?

Answer: We have found that in our part of Mississippi, that our mine is not the only place where roads suffer due to the lack of good road base material. The counties and the State highway department both have difficulty finding good road base materials. I would speculate that there will be a trend to increase the use of ash in these markets over time. I don't think it will be suitable for highway concrete but it would be suitable for road base. However, since the mine must be continually building new haul roads to support the mining, we will probably be able to use most of the ash produced at the power plant.

6. Use of a CCP Grout to Reduce the Formation of Acid Mine Drainage: An Update on the Winding Ridge Project *Robin L. Guynn, Leonard G. Rafalko, ERM, and Paul Petzrick MarylandDepartment of Natural Resources, Power Plant Research Program, Annapolis, Maryland*

Comment: **(Expansive Grouts to Seal the Mine)** You have to look very carefully at the flow patterns. An aperture at the interface of your wall and the grout of only a few hundred microns is enough to carry huge quantities of water. In order to do a better job of filling the voids you would have to use an expansive grout.

Question: **(Geophysical Systems for Locating Mine Voids)** Is there any possibility of using surface geophysical systems to detect these mine voids so they can be treated?

Answer: We actually attempted to find the unmapped mine voids prior to grouting. The methods we used however, were not very successful in helping us to find these voids.

Question: **(Improving Grouting Efficiency)** You made the observation that grouting was incomplete within the mine works. It would seem that if you have been able to grout more of the mine you could have further reduced or eliminated the possibility of further oxidation and acid production. Do you have any suggestions for improving the efficiency of these grouting systems?

Answer: We do know that there are unmapped voids in the mine. We are looking into the possibility of grouting these unmapped voids in order to reduce acid generation further.

Question: **(Mineralogical Studies)** Did you conduct any mineralogical studies on the cores that you removed?

Answer: We have not done any mineralogical studies on the cores.

Question: **(Project Cost)** What did the project cost?

Answer: There was a fairly large research and development phase. This is a very small mine with no mine maps. A lot of effort went into using geophysical methods to locate the mine voids. I do not have the costs involved.

SESSION 1 INTERACTIVE DISCUSSION

Question: **(Bore Hole Camera)** Did you use a bore hole camera during grouting to determine how the material was filling the voids?

Answer: Yes, we used a bore hole camera and it showed that the grout flowed very well. It was the views we saw with the camera that convinced us we were getting good flow with the grout. However, there must have been some type of physical barrier that we did not see with the camera that prevented the flow of the grout to certain parts of the mine.

Question: **(Final Filling for Big Gorilla Pit)** Has the Big Gorilla in Pennsylvania been completely filled and if so what was it covered with?

Answer: It has been filled to the point of eliminating all of the water. It is still being filled with ash to bring it up to approximate original contour. After it has been completely filled, it will be covered with soils and seeded. We will not use an artificial soil made with ash because there are suitable spoil materials available to use as a final soil cover. We do however plan to use a spoil ash mixture on other sites where there is not sufficient material available to make the soil cover. Since we use primarily FBC ash, it has a very high pH and would not be suitable for most plants without mixing with other materials

Question: **(Guidelines for Underground Mine Injection)** We have seen variable results in deep mine coal ash injection. Is anyone developing engineering guidelines for these types of projects?

Answer: As a representative of industry, I would prefer that there not be any national guidelines. I would prefer that guidance be State driven. In our operation, we are going from surface mining to underground mining and may

someday desire to place CCBs in the mine. Since we are not concerned about treatment of acid mine drainage I would not want to be constrained by guidelines that were created to treat acid mine drainage. In our application, our concerns may be more related to subsidence prevention and improving the economics of mining and ash handling. I would prefer that this type of guidance be left to the States.

Question: **(Peer Review of Longevity for Big Gorilla Pit)** For the Big Gorilla pit, you used three different cases to determine how long the high pH condition would remain. The values you determined in the millions of years were so high they approached the geological time scale. Have you had a chance to present this data to the public?

Answer: This is actually the first public presentation of this data. The data is also in the recent "Coal Ash Beneficial Use in Mine Reclamation and Mine Drainage Remediation in Pennsylvania" publication by Pennsylvania DEP in chapter 11. This publication was peer reviewed. The mathematical formula was borrowed from Walton in INEL who used it to describe and model the behavior of low level cementitious nuclear waste and has received a significant amount of peer review.

Question: **(Public Reaction to Ash Projects)** How have these projects been received by the public?

Answer: Concerning the Mississippi project, it is a very rural area where the public knows that ash is used to build roads on the mine and is also being used by the surrounding counties as a road building material. We did extensive analysis of the ash prior to using it so that we understood what it was and had answers for the public when asked.

Answer: In New Mexico, we have not had any public concerns except for one individual who seems to be very anti-mining and anti-power plant.

Answer: In Ohio, we had public meetings to discuss the project.

Question: **(Set Up Strength at Big Gorilla Pit)** What was the set up strength at the Big Gorilla pit?

Answer: They were initially in the range of 100 to 125 psi.

Question: **(Total or Dissolved Values for Heavy Metal Analysis)** In your analysis of ground water for heavy metals were you using totals or dissolved?

Answer: Maryland and New Mexico use dissolved. Pennsylvania and Ohio had done both. For Mississippi they used dissolved for the major ions and cations and did totals for the metals except for Iron and Manganese where dissolved was used. One of the observations that has come from the civilian nuclear waste program at Yucca Mountain is that the primary movement of radionuclides is through colloidal movement in ground water flow. The difference between the dissolved and totals is the colloidal behavior of those elements. The colloidal behavior could be significant so that it is preferred to have both.

SESSION 2: LEACHING PROTOCOLS AND STUDIES SUPPORTING CCB RISK ASSESSMENT AT MINES

1. Using Laboratory Leaching Methods to Evaluate CCBs *David J. Hassett, University of North Dakota, Energy & Environmental Research Center, Grand Forks, North Dakota*

2. Leaching Methods Applied to the Characterization of Coal Combustion By-Products *Dr. Ann Kim, US DOE National Energy Technology Laboratory, Pittsburgh, Pennsylvania*

3. US EPA Leach Testing of Coal Combustion Residues *Gregory Helms, U.S. EPA, Office of Solid Waste, Washington, D.C.*

4. Mine Water Leaching Procedure *Dr. Paul Ziemkiewicz, West Virginia Water Research Institute, West Virginia University, Morgantown, West Virginia*

LEACHATE PANEL DISCUSSION OF ABOVE

Comment: **(ASTM Guide to Test Methods)** ASTM is in the early stages of trying to develop a standard method on how to select the most appropriate leachate test or group of tests.

Question: **(Coal Refuse with MWLP Test)** Have you done any tests with the MWLP where you incorporated coal refuse and if so what?

Answer: Normally when we look at coal refuse, there is always the potential for the oxidation of additional pyrite so you add a whole new element to the test. I have not done this yet. If you did it, you would have to run a separate test without the ash to see how much acid you would generate just from tumbling the refuse.

Comment: **(Consensus Test)** I would agree that we will probably not have a one size fits all test. Whatever approach gains consensus will have to be flexible to consider the range of factors that affect leaching. It must however give a useful estimate of the likely environmental impacts for disposal or reuse.

Question: **(Cost for EPA Leach Method)** What are the costs of the EPA Leach Method currently being developed?

Answer: The EPA costs have been in the range of $10,000 to $20,000 per sample. Part of the flexibility is that after the first test at 12 pH ranges you can back off to about 3 to 4 pH ranges to determine that the material is leaching consistently. Although this test will probably not replace TCLP, EPA may recommend it for some applications.

Answer: EPA is looking at this from a very broad perspective. We are not just looking at the east or the west and we are not just looking at coal ash. Taking ground water from a specific site and testing a specific material with it may be useful and appropriate to determine what the resulting leachate may be. It may not however be predictive when conditions change at the site. If you have a situation where you are using several different materials such as building a road with coal ash and you are also using foundary sand and some biosolids for embankments and vegetative growth you need a leaching approach that you can use with all of these materials so that you can do an overall site assessment. You need this so that you can walk away from the road and know that it will not eventually become a superfund site.

Question: **(Effect of High Cost EPA Test on Beneficial Use)** Concerning the EPA Kosin test, if that becomes a regulatory requirement, I have some concerns that small beneficial uses might be precluded because it would just be too expensive to do the testing?

Answer: I am not sure that EPA is intending to make this a regulatory test to replace TCLP. If you are going to evaluate a material for use you need to do some kind of testing and you usually want more than one data point. The EPA Kosin test would be more appropriate for 50 miles of highway that you want to ensure is not going to be a superfund site. You could do a much reduced availability test that would be less expensive for smaller applications.

Comment: **(One Size fits all Test)** I think we are getting closer to an understanding about what leachate tests to use and I am going to bet that it will not be a one test fits all scenario.

Comment: **(Regulatory versus Research Tests)** There is a tendency for half formed ideas to find their way into the regulatory process. There are some things that are research tools and others that are regulatory in nature and they are not necessarily the same.

Comment: **(Standard versus Site Specific Tests)** I would like to compare some pros and cons with site specific leachate tests versus a standard test. There has been a lot of concern about using standard tests such as the TCLP. If you use a site specific test it may provide good data but you also have to do a lot more work. In addition, I have found that when you are trying to explain what you did to the regulators or to your management you may find that you have to do a lot more educating to make someone else comfortable with your results. A standard test should give comparable results when used on different ashes or from different parts of the country. NETL is involved in a comparison of four tests which happen to be the EPA Kosin's, Paul Ziemkiewicz's, Dave Hassett's, and the NETL test.

Comment: **(Western versus Eastern Tests)** In geochemical modeling, it is extremely difficult to account for multiple ion and species interactions. This is to a very large extent what we see dominating the process. I think we are at the very early stages of understanding what kinds of interactions and chemistry are involved when you add CCBs to mine spoil. I think we are on very divergent paths based on whether we are dealing with an alkaline or acid material. I am not sure that the logic that would work in the western environment would work in the east.

Question: **(Worst Case Scenario)** If someone did not do long term leaching, and they did an 18 hour test, wouldn't you look at those results and say they were a worst case scenario because long term leaching would actually act to attenuate some of the metals?

Answer: It would be a worst case scenario for some things and a not worst case for others. Not everything decreases with time. Whenever anyone asks me for a worst case scenario, my response is "wouldn't you rather know what is actually happening?"

5. Prediction of Coal Ash Leaching Behavior in Acid Mine Water: Comparisons of Laboratory and Field Studies *Dr. Paul Ziemkiewicz, West Virginia Water Research Institute, West Virginia*

6. The Use of Leachate Data and Other Factors in Evaluating CCBs for Placement at Coal Mine Sites in Pennsylvania *Michael J. Menghini, Pennsylvania Department of Environmental Protection, Pottsville District Mining Office, Pottsville, Pennsylvania*

Question: **(Amendment of Pulverized Coal Ash)** Do you amend the pulverized coal ash and if so how?

Answer: We require the pulverized coal ash to have a minimum of pH 7. In the cases where proposals have come in where the ash was below pH 7 the supplier has had to amend the ash with lime in order to obtain approval. In such a case, the application would not be suitable for alkaline addition. There are additional requirements if the ash is utilized for a soil amendment or as an alkaline addition.

Question: **(Annual Samples)** How do you take an annual sample of the mine waters for the Pennsylvania report?

Answer: The operator will take a routine sample and analysis it for the other metals. Annual means that once a year they must analyze for all of the parameters.

Question: **(Ash Placement in Flooded Mines)** If you have a flooded mine, what are the criteria for deciding whether you put in a dry or wet ash?

Answer: Under the current program, we do not allow placement in a flooded mine. We require a minimum of 8 feet between the ash and regional ground water table. What we look at is the quantity of water coming in and its flow path. Most of the western offices have some issues with ground water and this is what they look at in association with acid mine drainage production in order to place the ash out of the path of the water. It is very site specific. Based on our SMCRA program, site characterization is one of the most important things we look at. Because of this over 99% of our sites don't result in acid mine drainage. We try to use the same data and process for our ash placement.

For the experimental sites that we did that were totally wet, those were done in stages beginning with a small scale bench, then a small scale field test, and then a large scale. We built within this system safeguards so that if at any time something happened we could stop the whole project. At one of the sites there was a $5 million bond required for remedial measures if the material were required to be removed, capped, or otherwise corrected if an unforeseen problem arose.

Question: **(Projects with Fluidized Bed Ash)** Are most of your projects with Fluidized Bed Ash?

Answer: Some of our projects are with Fluidized Bed Ash and some are with pulverised coal ash. We take ash in Pennsylvania from across the whole country. Although most of our sites are reclaimed with FBC we have a lot of data on sites with pulverized coal.

7. The Use of Neutral Leachate Test Data in Indiana's Coal Combustion By-Product Disposal Program *Deborah Dale, Indiana Division of Reclamation, Jasonville, Indiana*

Question: **(Opponents Criticism of Indiana Program)** What would the Indiana opponents of CCB placement at coal mines consider to be the weakest part of the Indiana program?

Answer: They have voiced concerns that there are not enough monitoring wells, wells are in the wrong location, wrong leachate test, samples are not frequent enough, too much under the influence of the industry.

SESSION 2 INTERACTIVE DISCUSSION

Question: **(CCB Damage Cases)** Are there CCB damage cases in Indiana?

Answer: There have been numerous claims about CCB damage case sites in Indiana. When I look at data concerning CCB placement at mines, I look at the eight RCRA metals and Boron. I don't focus on parameters that are normally associated with coal mining such as sulfates, TDS, iron, and manganese. Boron is probably the best indicator of ash placement. Based on my investigations of these parameters, I have not found much that shows up with the exception of Boron showing up at the Universal site. Indiana differs from Pennsylvania in that it does allow disposal below the water table.

Comment: **(CCB Damage Cases)** After extensive investigation by EPA, EPA are found no proven CCB damage cases related to coal mining in Indiana or in the entire US. EPA is now working with the National Academy of Science that is studying mine filling with CCBs and they should complete their investigation by the end of 2005.

Comment: **(CCB Permeability)** Don't always assume that all CCBs are not permeable. CCBs have different characteristics. In Pennsylvania, we look at the ash source and its characteristics in order to determine its suitability for placement at a particular site. You can probably get all ashes to compact but sometimes you need an activator and sometimes you need physical modification like in Mississippi where they use a vibratory roller. Depending upon the placement situation and the head involved you can get water movement. Horizontal permeability may be different than vertical permeability because of stratification.

SESSION 3: REGULATION OF CCB PLACEMENT AT MINES

1. A State Perspective on Regulation of Mine Placement of Coal Combustion Wastes *Gregory E. Conrad, Interstate Mining Compact Commission, Herndon, Virginia*

Question: **(A Next Step for EPA)**Assuming that the National Academy has the same or similar findings as EPA, what would be the next step for EPA?

Answer: Then EPA will have to go back to the drawing board about whether or not they need additional Federal regulations or guidelines under RCRA and/or SMCRA to cover mine placement in addition to existing Federal and State law. EPA had never come to this point prior to the involvement of the National Academy. Perhaps with the further guidance and thought provided by the National Academy, that job will be made easier.

Question: **(Guidance from EPA)** If EPA is not been able to find any damage cases at mine sites, what further guidance could they provide?

Answer: If EPA does further detailed analysis, and makes a comparison of SMCRA to RCRA requirements, which has already been done by IMCC and OSM as part of the four year process we have been through. If in the course of that analysis, and taking into consideration real if not proven concerns with regard to mine filling, I could see them identify several key areas in State programs that need to be enhanced or shored up through some combination of adjustment to RCRA programs or SMCRA programs. The one possible example that I gave was concerning long term financial assurance.

Question: **(Role of OSM)** What part does OSM play in this process?

Answer: OSM has always had an excellent handle on this issue. They have been very open and honest about what SMCRA does and does not do and how the State SMCRA programs cover the regulatory environment for mine placement of CCBs. OSM has been an incredible ally. The have provided IMCC and EPA really good information through their technical forums and their analysis of applicable regulations. They have given a very succinct and comprehensive analysis of what SMCRA already has in place to address this issue.

2. Coal Ash Beneficial Use at Mine Sites in Pennsylvania *Roger J. Hornberger and Michael J. Menghini, Pennsylvania Department of Environmental Protection, Pottsville District Mining Office, Pottsville, and Alfred Dalberto, Bureau of Mining and Reclamation, Harrisburg, Pennsylvania*

3. State Regulation of CCPs and CCBs in Texas *Michael J. Nasi, Lloyd, Gosselink, Blevins, Rochelle, & Townsend, Austin, Texas*

4. The Use of Coal Ash and Dredged Material in Large Scale Abandoned Mine Reclamation *Andrew Voros, NY/NJ Clean Ocean and Shore Trust (OCEAN), New York, New York*

5. The State of Indiana's Experience in Regulating the Disposal of Coal Ash at Surface Mines *Deborah Dale, Indiana Division of Reclamation, Jasonville, Indiana*

Question: **(Bond Release Requirements)** What is the time period required for monitoring before final bond release and the permit expires and what corrective actions are required if monitoring detects ground water problems?

Answer: For ash disposal at a permitted site, the permittee is required to maintain monitoring of the surface and ground water through final liability bond release. Final bond release for coal mining is normally eligible for release when it is proven that the vegetation has been adequately established for 5 years in the East and 10 years in the Western U.S. In Indiana, we have found that most final bonds are not actually released until after the vegetation has been established for 8 to 12 years. This means that on average we have 8 to 12 years of quarterly ground water monitoring prior to final bond release. Concerning corrective actions, we have received public criticism that the Indiana surface mining program does not have any corrective actions that could protect the public after final bond release. Indiana has passed, within the last year, a set of ground water quality standards. These standards have to be adhered to by all coal companies regardless of whether they are disposing of ash. If data at any of the monitoring wells indicates there will be a negative impact on this ground water standard, the permittee must immediately submit a plan to the Indiana Division of Reclamation for review and approval on how they are going to address this problem.

Comment: As a point of clarification, all SMCRA programs are required to not only be able to prove revegetation success at final bond release but are also required to demonstrate that all requirements of the permit and regulatory program are in compliance at the time of final release. The reason this has not impacted any State programs to date is that so far there have not been any proven cases of where a premining use of ground or surface water has been negatively impacted due to CCB placement at a SMCRA mine. Because of this, there has never been any reason to delay final bond release once revegetation success has been proven.

SESSION 3 INTERACTIVE DISCUSSION

Question: **(Environmental Testing Cost Dredging Project)** What were the environmental testing costs for the dredge/ash mixing project?

Answer: The characterization of dredge material is done in place before any material is actually excavated. If you know the properties of your materials and what your mix is then you know what will come out of it. If we trusted this, then repeated testing would not be necessary. In working with the local community, we learned that one of their main fears was not contaminated dredge material but that some unscrupulous person was going to dump in toxic materials somewhere in the mixing or transportation process. In order to address this, we set up a protocol that funds were made available to the local community so they could have their own inspector who could come on site at

any time and take unannounced grab samples and have them tested at a laboratory of their choice. There was a huge amount of confirmatory testing. The dredge material was tested before it was dredged, the coal ash was tested by the utilities as per their regulatory requirements, it was tested again after the materials were mixed to insure that nothing had be inappropriately added to the mix, it was tested again in Pennsylvania once it arrived on the train to ensure that nothing had been added, and finally it was tested after it was placed at the mine. All of this testing was not required by environmental regulation but because it was necessary to convince the locals that the materials had not be tampered with at some point in the process.

Question: **(Total Cost Dredging Project)** Is there a ball park cost per ton for mixing fly ash and dredging material from New York and delivering it to Pennsylvania for placement in an abandoned mine?

Answer: The figure we use for planning purposes is $36/ton. This assumes you do a demonstration project similar to what we did. It assumes a $16/ton rail cost because we were only shipping 30 cars at a time. If you were using a unit train with 100 cars, you could reduce the shipping cost by one third. In looking at the various economic contributors to a project like this, like a dredging project, a coal ash disposal, and an economic development project you could do this over significant distances for less than $20/ton. The majority of that contribution would come from the dredging project. There is possibly room for tipping fees to be given to local communities. If you could do the right project with the right materials in the right mixes you could achieve a significant environmental benefit as well. With the right cost benefit analysis you could bring the numbers way down.

Attachment A

(3) the state-sponsored inspection and dispute resolution process;

(4) the procedures by which complaints or requests are filed with and resolved by the Commission; and

(5) any other information designated by the Commission.

This agency hereby certifies that the proposal has been reviewed by legal counsel and found to be within the agency's legal authority to adopt.

Filed with the Office of the Secretary of State on November 17, 2003.

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Stephen D. Thomas
Executive Director
Texas Residential Construction Commission
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For further information, please call: (512) 463-9524

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TITLE 16. ECONOMIC REGULATION

PART 1. RAILROAD COMMISSION OF TEXAS

CHAPTER 12. COAL MINING REGULATIONS

The Railroad Commission of Texas (Commission) proposes amendments to §§12.3, 12.142, 12.145, 12.187, 12.197, 12.384, 12.385 and 12.552 (relating to Definitions; Operation Plan: Maps and Plans; Reclamation Plan: General Requirements for Surface Mining; Reclamation Plan: General Requirements for Underground Mining; Operation Plan: Maps and Plans; Backfilling and Grading: General Requirements; Backfilling and Grading: General Grading Requirements; and Backfilling and Grading: General Grading Requirements). The Commission proposes the amendments pursuant to its October 21, 2003, vote in open conference to initiate a rulemaking wholly consistent with the petition for rulemaking filed on September 4, 2003, by the Texas Coal Combustion Products Coalition (CCPC). The CCPC comprises representatives from Alcoa, American Electric Power, Texas Genco, LP, San Miguel Electric Cooperative, Inc., Twin Oaks Power, TXU Mining Company LP, and Walnut Creek Mining Company.

The Commission proposes to amend §12.3 to add new paragraphs (33) and (34) defining coal combustion by-products and coal combustion products, respectively. The remaining paragraphs currently designated as paragraphs (33) - (193) will be renumbered (35) - (195).

Coal combustion by-products (CCB) are defined as any material resulting from the combustion of lignite or coal in utility boilers or industrial boilers that is not exempt from the definition of "solid waste" under 30 TAC §335.1(131)(H) (relating to Definitions), or through letter-authorizations related to surface mining and specifically identified in Table 1 in paragraph (33). In the past, the Texas Commission on Environmental Quality (TCEQ) issued letter authorizations for reuse and recycling materials identified as solid waste. When TCEQ amended its definition of solid waste in 30 TAC §335.1(131)(H) to include provisions for reuse and recycling, it discussed letter authorizations in the adoption preamble provided in the May 25, 2001, issue of the *Texas Register* at 26 TexReg 3811-3812. The proposed definition in §12.3(33) goes on to state that coal combustion by-products may be disposed of within the Commission's permitted mining areas so long as the disposal operation complies with applicable TCEQ regulations at 30 TAC §§335.2 - 335.8 (relating to Permit Required; Technical Guidelines; General Prohibitions; Deed Recordation of Waste Disposal; Notification Requirements; Financial Assurance Required; and Closure and Remediation) and 30 TAC Chapter 335, Subchapter R (relating to Waste Classification). The proposed definition provides that where the disposal of coal combustion by-products is proposed to result in approximate original contour before the end of mining operations within the Commission's permitted area, both the disposal operation and all ancillary features (e.g., sediment control structures, roads, and other infrastructure) and activities associated with the operation shall be considered mining-related and the permittee may retain them within the Commission's mining permit for the life of the mining project. The proposed definition further provides that where the disposal of coal combustion by-products is not proposed to result in achieving approximate original contour within the life of the mining project, the disposal area shall be removed from the Commission's mining permit area, but all ancillary features associated with the disposal operations shall be considered mining-related features that the permittee may retain within the Commission's mining permit for the life of the reclamation project until final bond release.

Proposed new §12.3(34) defines coal combustion products (CCP) as fly ash, bottom ash, fluidized bed combustion ash, and flue gas desulfurization solids or sludge resulting from the combustion of lignite or coal in utility boilers or industrial boilers that is exempt from the definition of "solid waste" under 30 TAC §335.1(131)(H) (relating to Definitions) or through letter authorization which TCEQ has issued as referenced at 26 TexReg 3811-3812 and specifically identified in Table 1 in paragraph (33). The proposed definition provides that the utilization of coal combustion products at a Commission-permitted mining area for any of the purposes noted in the definition shall be considered a mining-related activity that the permittee may retain within the Commission's mining permit for the life of the reclamation project until final bond release. The proposed definition further provides that all associated ancillary features and activities (e.g., sediment control structures, roads, and other infrastructure) shall be considered mining-related, and which the permittee may retain within the Commission's mining permit for the life of the reclamation project until final bond release, even if the area of ultimate coal combustion products use is not retained within the mining permit for the same period of time. The proposed definition lists the specific purposes for which coal combustion products may be used, and provides references to other rules in Chapter 12 that pertain to some of the authorized uses for coal combustion products.

The proposed amendments to §12.142(2) add subparagraph (L) to require that each permit application contain maps and plans of the proposed permit and adjacent areas which show the approximate location of any area in which coal combustion by-products have been disposed or will be disposed.

The proposed amendments to §12.145(b) add paragraph (10) to require each reclamation plan for the proposed permit area to include a description of any planned use of coal combustion products designed to achieve approximate original contour, or any proposal to dispose of coal combustion by-products in a manner that achieves approximate original contour. Proposed paragraph (10) states that when additional time to conduct rough backfilling

as soon as practicable to foster informed discussion of the proposed amendments. The Commission intends to post all comments on its web site so that interested persons will have access to them. The Commission would like to have as many comments and replies as possible available for discussion at the public hearing. Final reply comments must be filed by February 26, 2004, and should address initial written comments as well as comments offered at the January 27 meeting. The Commission cannot guarantee that comments submitted after this deadline will be considered. For further information, call Melvin Hodgkiss, Director, Surface Mining and Reclamation Division, at (512) 463-6901. The status of Commission rulemakings in progress, and a link to comments on this proposal, will be available at http://www.rrc.state.tx.us/rules/proposed.html.

SUBCHAPTER A. GENERAL

DIVISION 1. GENERAL

16 TAC §12.3

The Commission proposes the amendments under Texas Natural Resources Code, §134.013, which authorizes the Commission to promulgate rules pertaining to surface coal mining operations.

Statutory authority: Texas Natural Resources Code, §134.013.

Cross-reference to statute: Texas Natural Resources Code, §134.013.

Issued in Austin, Texas, on November 13, 2003.

§12.3. Definitions.

The following words and terms, when used in this Chapter (relating to Coal Mining Regulations), shall have the following meanings unless the context clearly indicates otherwise:

(1) - (32) (No change.)

(33) Coal combustion by-products--Any material resulting from the combustion of lignite or coal in utility boilers or industrial boilers that is not exempt from the definition of "solid waste" under 30 TAC §335.1(131)(H) (relating to Definitions), or TCEQ letter-authorization identified in Table 1 of this paragraph. Coal combustion by-products may be disposed of within the Commission's permitted mining areas so long as the disposal operation complies with applicable TCEQ regulations at 30 TAC §§335.2 - 335.8 (relating to Permit Required; Technical Guidelines; General Prohibitions; Deed Recordation of Waste Disposal; Notification Requirements; Financial Assurance Required; and Closure and Remediation) and 30 TAC Chapter 335, Subchapter R (relating to Waste Classification). Where the disposal of coal combustion by-products is proposed to result in approximate original contour before the end of mining operations within the Commission's permitted area, both the disposal operation and all ancillary features and activities associated with the operation shall be considered mining-related and the permittee may retain them within the Commission's mining permit for the life of the mining project. Where the disposal of coal combustion by-products is not proposed to result in achieving approximate original contour within the life of the mining project, the disposal area shall be removed from the Commission's mining permit area, but all ancillary features (e.g. sediment control structures, roads, and other infrastructure) associated with the disposal operations shall be considered mining-related features which the permittee may retain within the Commission's mining permit for the life of the reclamation project until final bond release.

Figure: 16 TAC §12.3(33)

(34) Coal combustion products--Fly ash, bottom ash, fluidized bed combustion ash, and flue gas desulfurization solids or sludge resulting from the combustion of lignite or coal in utility boilers or industrial boilers that is exempt from the definition of "solid waste" under 30 TAC §335.1(131)(H) (relating to Definitions) or TCEQ letter-authorization as referenced in Table 1 of paragraph (33) of this section. The utilization of coal combustion products at a Commission-permitted mining area for any of the purposes noted in this paragraph shall be considered a mining-related activity which the permittee may retain within the Commission's mining permit for the life of the reclamation project until final bond release. All associated ancillary features and activities (e.g. sediment control structures, roads, and other infrastructure) shall be considered a mining-related activity which the permittee may retain within the Commission's mining permit for the life of the reclamation project until final bond release, even if the area of ultimate coal combustion products use is not retained within the mining permit for the same period of time. Coal combustion products may be used for the following purposes:

(A) surfacing material, traction agent, road base material, and structural fill material used to bring roads to necessary grade and for primary or ancillary roads in compliance with §§12.154, 12.198, 12.400, 12.401, 12.569, and 12.570 of this title (relating to Road Systems and Support Facilities; Road Systems and Support Facilities; Roads: General; Primary Roads; Roads: General, and Primary Roads) and any other sections providing requirements relating to road construction and maintenance;

(B) surfacing material, traction agent, road base material, and structural fill material used in the construction of ramps in active pit areas;

(C) fill material to be used to achieve approximate original contour in accordance with §§12.145, 12.187, 12.383 - 12.388, and 12.550 - 12.558 of this title (relating to Reclamation Plan: General Requirements for Surface Mining; Reclamation Plan: General Requirements for Underground Mining; Contemporaneous Reclamation; Backfilling and Grading: General Requirements; Backfilling and Grading: General Grading Requirements; Backfilling and Grading: Covering Coal and Acid- and Toxic-forming Materials; Backfilling and Grading: Thin Overburden; and Backfilling and Grading: Thick Overburden; Contemporaneous Reclamation, Backfilling and Grading: General Requirements; Backfilling and Grading: General Grading Requirements; Backfilling and Grading: Covering Coal and Acid- and Toxic-forming Materials; Stabilization of Surface Areas for Underground Mining; Revegetation: General Requirements; Revegetation: Use of Introduced Species; Revegetation: Timing; and, Revegetation: Mulching and Other Soil Stabilizing Practices), and any other sections providing requirements relating to the use of fill material in achieving approximate original contour;

(D) substitute for aggregate/soil or an ingredient in cement/grout used in on-site construction of such projects as equipment construction pads and repair pads, well pads, and drainage and erosion control structures in compliance with §§12.139, 12.140, 12.148, 12.185, 12.186, and 12.190 of this title (relating to Operation Plan: General Requirements; Operation Plan: Existing Structures; Reclamation Plan: Ponds, Impoundments, Banks, Dams, and Embankments; Operation Plan: General requirements; Operation Plan: Existing Structures; Reclamation Plan: Ponds, Impoundments, Banks, Dams, and Embankments) and any other sections providing requirements relating to on-site construction projects;

(E) soil stabilization additive to reduce the shrink and swell factors as water either evaporates from the soil or infiltrates into the soil in compliance with §§12.145, 12.187, 12.201, 12.338, 12.389 - 12.393, 12.508 and 12.554 - 12.558 of this title (relating to Reclamation Plan: General Requirements for Surface Mining; Reclamation Plan: General Requirements for Underground Mining; Prime

(50) [(48)] Cumulative impact area--The area, including the permit area, within which impacts resulting from the proposed operation may interact with the impacts of all anticipated mining on surface-water and ground-water systems. Anticipated mining shall include, at a minimum, the entire projected lives through bond release of:

(A) the proposed operation;

(B) all existing operations;

(C) any operation for which a permit application has been submitted to the Commission; and

(D) all operations required to meet diligent development requirements for leased federal coal for which there is actual mine development information available.

(51) [(49)] Cumulative measurement period--As used in §§12.25 - 12.33 of this title (relating to Exemption for Coal Extraction Incidental to the Extraction of Other Minerals), the period of time over which both cumulative production and cumulative revenue are measured.

(A) For purposes of determining the beginning of the cumulative measurement period, subject to Commission approval, the operator must select and consistently use one of the following:

(i) for mining areas where coal or other minerals were extracted prior to August 3, 1977, the date extraction of coal or other minerals commenced at that mining area or August 3, 1977; or

(ii) for mining areas where extraction of coal or other minerals commenced on or after August 3, 1977, the date extraction of coal or other minerals commenced at that mining area, whichever is earlier.

(B) For annual reporting purposes pursuant to §12.33 of this title (relating to Reporting Requirements), the end of the period for which cumulative production and revenue is calculated is either:

(i) for mining areas where coal or other minerals were extracted prior to the effective date of §§12.25 - 12.33 of this title, the first anniversary of that date, and each anniversary of that date thereafter; or

(ii) for mining areas where extraction of coal or other minerals commenced on or after the effective date of §§12.25 - 12.33 of this title, the last day of the calendar quarter during which coal extraction commenced, and each anniversary of that date thereafter.

(52) [(50)] Cumulative production--As used in §§12.25 - 12.33 of this title, the total tonnage of coal or other minerals extracted from a mining area during the cumulative measurement period. The inclusion of stockpiled coal and other mineral tonnages in this total is governed by §12.31 of this title (relating to Stockpiling of Minerals).

(53) [(51)] Cumulative revenue--As used in §§12.25 - 12.33 of this title, the total revenue derived from the sale of coal or other minerals and the fair market value of coal or other minerals transferred or used, but not sold, during the cumulative measurement period.

(54) [(52)] Department--The U.S. Department of the Interior.

(55) [(53)] Direct financial interest--Ownership or part ownership by an employee of lands, stocks, bonds, debentures, warrants, partnership shares, or other holdings and also means any other arrangement where the employee may benefit from his or her holding in or salary from coal mining operations. Direct financial interests include employment, pensions, creditor, real property and other financial relationships.

(56) [(54)] Director--The Director or Acting Director, Office of Surface Mining Reclamation and Enforcement, U.S. Department of the Interior, or the Director's representative.

(57) [(55)] Disturbed area--An area where vegetation, topsoil, or overburden is removed or upon which topsoil, spoil, coal processing waste, underground development waste, or noncoal waste is placed by surface coal mining operations. Those areas are classified as disturbed until reclamation is complete and the performance bond or other assurance of performance required by Subchapter J of this chapter (relating to Bond and Insurance Requirements for Surface Coal Mining and Reclamation Operations) is released.

(58) [(56)] Diversion--A channel, embankment, or other manmade structure constructed to divert water from one area to another.

(59) [(57)] Division--The Surface Mining and Reclamation Division of the Railroad Commission of Texas.

(60) [(58)] Downslope--The land surface between the projected outcrop of the lowest coal bed being mined along each highwall and a valley floor.

(61) [(59)] Embankment--An artificial deposit of material that is raised above the natural surface of the land and used to contain, divert, or store water, support roads or railways, or for other similar purposes.

(62) [(60)] Employee--Shall include:

(A) any person employed by the Commission who performs any function or duty under the Act, including the Commissioners; and

(B) Advisory board or Commission members and consultants who perform any function or duty under the Act, if they perform decision making functions for the Commission under the authority of state law or regulations. However, members of advisory boards or commissions established in accordance with state law or regulations to represent multiple interests are not considered to be employees.

(63) [(61)] Ephemeral stream--A stream which flows only in direct response to precipitation in the immediate watershed or in response to the melting of a cover of snow and ice, and which has a channel bottom that is always above the local water table.

(64) [(62)] Essential hydrologic functions--The role of an alluvial valley floor in collecting, storing, regulating, and making the natural flow of surface or ground water, or both, usefully available for agricultural activities by reason of the valley floor's topographic position, the landscape and the physical properties of its underlying materials. A combination of these functions provides a water supply during extended periods of low precipitation.

(A) The role of the valley floor in collecting water includes accumulating runoff and discharge from aquifers in sufficient amounts to make the water available at the alluvial valley floor greater than the amount available from direct precipitation.

(B) The role of the alluvial valley floor in storing water involves limiting the rate of discharge of surface water, holding moisture in soils, and holding ground water in porous materials.

(C) The role of the alluvial valley floor in regulating:

(i) the natural flow of surface water results from the characteristic configuration of the channel flood plain and adjacent low terraces; and

outside the specific 5-years-in-10 criterion, in which case the regulations for prime farmland may be applied to include more years of cropland history only to increase the prime farmland acreage to be preserved; or

(C) lands that would likely have been used as cropland for any 5 out of the last 10 years, immediately preceding such acquisition but for some fact of ownership or control of the land unrelated to the productivity of the land.

(86) [~~(84)~~] Historic lands--Historic, cultural, or scientific resources. Examples of historic lands include archeological sites, National Historic Landmarks, properties listed on or eligible for listing on a state or National Register of Historic Places, properties having religious or cultural significance to Native Americans or religious groups, and properties for which historic designation is pending.

(87) [~~(85)~~] Hydrologic balance--The relationship between the quality and quantity of water inflow to, water outflow from, and water storage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake, or reservoir. It encompasses the dynamic relationships among precipitation, runoff, evaporation, and changes in ground and surface water storage.

(88) [~~(86)~~] Hydrologic regime--The entire state of water movement in a given area. It is a function of the climate and includes the phenomena by which water first occurs as atmospheric water vapor, passes into a liquid or solid form, falls as precipitation, moves along or into the ground surface, and returns to the atmosphere as vapor by means of evaporation and transpiration.

(89) [~~(87)~~] Imminent danger to the health and safety of the public--The existence of any condition or practice, or any violation of a permit or other requirements of the Act in a surface coal mining and reclamation operation, which condition, practice, or violation could reasonably be expected to cause substantial physical harm to persons outside the permit area before such condition, practice, or violation can be abated. A reasonable expectation of death or serious injury before abatement exists if a rational person, subjected to the same condition or practices giving rise to the peril, would not expose himself to the danger during the time necessary for abatement.

(90) [~~(88)~~] Impoundment--A closed basin, naturally formed or artificially built, which is dammed or excavated for the retention of water, sediment, or waste.

(91) [~~(89)~~] Indian lands--All lands, including mineral interests, within the exterior boundaries of any federal Indian reservation, notwithstanding the issuance of any patent, and including rights-of-way, and all lands including mineral interests held in trust for or supervised by an Indian tribe.

(92) [~~(90)~~] Indian tribe--Any Indian tribe, band, group, or community having a governing body recognized by the Secretary.

(93) [~~(91)~~] Indirect financial interest--The same financial relationships as for direct ownership, but where the employee reaps the benefits of such interests, including interests held by his or her spouse, minor child and other relatives, including in-laws, residing in the employee's home. The employee will not be deemed to have an indirect financial interest if there is no relationship between the employee's functions or duties and the coal mining operation in which the spouse, minor children or other resident relatives hold a financial interest.

(94) [~~(92)~~] In situ processes--Activities conducted on the surface or underground in connection with in-place distillation, retorting, leaching, or other chemical or physical processing of coal. The term includes, but is not limited to, in situ gasification, in situ leaching, slurry mining, solution mining, borehole mining, and fluid recovery mining.

(95) [~~(93)~~] Intermittent stream--A stream or reach of a stream that:

(A) drains a watershed of at least one square mile; or

(B) is below the local water table for at least some part of the year, and obtains its flow from both surface runoff and groundwater discharge.

(96) [~~(94)~~] Irreparable damage to the environment--Any damage to the environment that cannot be or has not been corrected by actions of the applicant.

(97) [~~(95)~~] Knowingly--With respect to §§12.696 - 12.699 of this title (relating to Individual Civil Penalties), that an individual knew or had reason to know in authorizing, ordering, or carrying out an act or omission on the part of a corporate permittee that such act or omission constituted a violation, failure, or refusal.

(98) [~~(96)~~] Land use--Specific uses or management-related activities, rather than the vegetation or cover of the land. Land uses may be identified in combination when joint or seasonal uses occur. Changes of land use or uses from one of the following categories to another shall be considered as a change to an alternative land use which is subject to approval by the Commission.

(A) Cropland. Land used for the production of adapted crops for harvest, alone or in a rotation with grasses and legumes, and includes row crops, small grain crops, hay crops, nursery crops, orchard crops, and other similar specialty crops. Land used for facilities in support of cropland farming operations which is adjacent to or an integral part of these operations is also included for purposes of these land use categories.

(B) Pastureland or land occasionally cut for hay. Land used primarily for the long-term production of adapted, domesticated forage plants to be grazed by livestock or occasionally cut and cured for livestock feed. Land used for facilities in support of pastureland or land occasionally cut for hay which is adjacent to or an integral part of these operations is also included.

(C) Grazingland. Includes both grasslands and forest lands where the indigenous vegetation is actively managed for grazing, browsing, or occasional hay production. Land used for facilities in support of ranching operations which are adjacent to or an integral part of these operations is also included.

(D) Forestry. Land used or managed for the long-term production of wood, wood fiber, or wood derived products. Land used for facilities in support of forest harvest and management operations which is adjacent to or an integral part of these operations is also included.

(E) Residential. Includes single- and multiple-family housing, mobile home parks, and other residential lodgings. Land used for facilities in support of residential operations which is adjacent to or an integral part of these operations is also included. Support facilities include, but are not limited to, vehicle parking and open space that directly relate to the residential use.

(F) Industrial/Commercial. Land used for:

(i) extraction or transformation of materials for fabrication of products, wholesaling of products, or for long-term storage of products. This includes all heavy and light manufacturing facilities, such as lumber and wood processing, chemical manufacturing, petroleum refining, and fabricated metal products manufacturing. Land used

(115) [(~~113~~)] Perennial stream--A stream or part of a stream that flows continuously during all of the calendar year as a result of ground-water discharge or surface runoff. The term does not include intermittent stream or ephemeral stream.

(116) [(~~114~~)] Performance bond--A surety bond, collateral bond or self-bond or a combination thereof, by which a permittee assures faithful performance of all the requirements of the Act, this chapter, and the requirements of the permit and reclamation plan.

(117) [(~~115~~)] Performing any function or duty under this Act--Those decisions or actions, which if performed or not performed by an employee, affect the programs under the Act.

(118) [(~~116~~)] Permanent diversion--A diversion remaining after surface coal mining and reclamation operations are completed which has been approved for retention by the Commission and other appropriate state and federal agencies.

(119) [(~~117~~)] Permanent impoundment--An impoundment which is approved by the Commission and, if required, by other state and federal agencies for retention as part of the postmining land use.

(120) [(~~118~~)] Permit--A permit to conduct surface coal mining and reclamation operations issued by the Commission.

(121) [(~~119~~)] Permit area--The area of land and water indicated on the map submitted by the operator with his application, as approved by the Commission, which area shall be covered by the operator's bond as required by §§134.121 - 134.127 of the Act and shall be readily identifiable by appropriate markers on the site. This area shall include, at a minimum, all areas which are or will be affected by the surface coal mining and reclamation operations during the term of the permit.

(122) [(~~120~~)] Permittee--A person holding or required by the Act or this chapter to hold a permit to conduct surface or underground coal mining and reclamation operations issued by the Commission.

(123) [(~~121~~)] Person--An individual, partnership, society, joint stock company, firm, company, corporation, business organization, governmental agency, or any organization or association of citizens.

(124) [(~~122~~)] Person having an interest which is or may be adversely affected or person with a valid legal interest--Shall include any person:

(A) who uses any resources of economic, recreational, esthetic, or environmental value that may be adversely affected by coal exploration or surface coal mining and reclamation operations or any related action of the Commission; or

(B) whose property is or may be adversely affected by coal exploration or surface coal mining and reclamation operations or any related action of the Commission.

(125) [(~~123~~)] Precipitation event--A quantity of water resulting from drizzle, rain, snow, sleet, or hail in a limited period of time. It may be expressed in terms of recurrence interval. As used in these regulations, precipitation event also includes that quantity of water emanating from snow cover as snowmelt in a limited period of time.

(126) [(~~124~~)] Previously mined area--Land affected by surface coal mining operations prior to August 3, 1977, that has not been reclaimed to the standards of this Chapter.

(127) [(~~125~~)] Prime farmland--Those lands which are defined by the Secretary of Agriculture in 7 CFR 657 and which have been historically used for cropland.

(128) [(~~126~~)] Principal shareholder--Any person who is the record or beneficial owner of 10% or more of any class of voting stock.

(129) [(~~127~~)] Probable cumulative impacts--The expected total qualitative, and quantitative, direct and indirect effects of mining and reclamation activities on the hydrologic regime.

(130) [(~~128~~)] Probable hydrologic consequences--The projected result of proposed surface coal mining and reclamation operations which may reasonably be expected to change the quantity or quality of the surface- or ground-water flow, timing and pattern; the stream-channel conditions; and the aquatic habitat on the permit area and other affected areas.

(131) [(~~129~~)] Professional specialist--A person whose training, experience, and professional certification or licensing are acceptable to the Commission for the limited purpose of performing certain specified duties under this chapter.

(132) [(~~130~~)] Prohibited financial interest--Any direct or indirect financial interest in any coal mining operation.

(133) [(~~131~~)] Property to be mined--Both the surface estates and mineral estates within the permit area and the area covered by underground workings.

(134) [(~~132~~)] Public building--Any structure that is owned or leased, and principally used by a governmental agency for public business or meetings.

(135) [(~~133~~)] Publicly-owned park--A public park that is owned by a federal, state or local governmental entity.

(136) [(~~134~~)] Public office--A facility under the direction and control of a governmental entity which is open to public access on a regular basis during reasonable business hours.

(137) [(~~135~~)] Public park--An area or portion of an area dedicated or designated by any federal, state, or local agency primarily for public recreational use, whether or not such use is limited to certain times or days, including any land leased, reserved, or held open to the public because of that use.

(138) [(~~136~~)] Public road--Any thoroughfare open to the public for passage of vehicles.

(139) [(~~137~~)] Qualified jurisdiction--A state or federal mining regulatory authority that has a blaster certification program approved by the U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, in accordance with the Federal Act.

(140) [(~~138~~)] Qualified laboratory--A designated public agency, private firm, institution, or analytical laboratory that can provide the required determination of probable hydrologic consequences or statement of results of test borings or core samplings or other services as specified at §§12.236 and 12.240 of this title (relating to Program Services, and Data Requirements), and that meets the standards of §12.241 of this title (relating to Qualified Laboratories).

(141) [(~~139~~)] Rangeland--Land on which the natural potential (climax) plant cover is principally native grasses, forbs, and shrubs valuable for forage. This land includes natural grass lands and savannahs, such as prairies, and juniper savannahs, such as brushlands. Except for brush control, management is primarily achieved by regulating the intensity of grazing and season of use.

(142) [(~~140~~)] Recharge capacity--The ability of the soils and underlying materials to allow precipitation and runoff to infiltrate and reach the zone of saturation.

(160) [(158)] Soil horizons--Contrasting layers of soil parallel or nearly parallel to the land surface. Soil horizons are differentiated on the basis of field characteristics and laboratory data. The four master soil horizons are:

(A) A horizon. The uppermost mineral layer, often called the surface soil. It is the part of the soil in which organic matter is most abundant, and leaching of soluble or suspended particles is typically the greatest;

(B) E horizon. The layer commonly near the surface below an A horizon and above a B horizon. An E horizon is most commonly differentiated from an overlying A horizon by lighter color and generally has measurably less organic matter than the A horizon. An E horizon is most commonly differentiated from an underlying B horizon in the same sequum by color of higher value or lower chroma, by coarser texture, or by a combination of these properties;

(C) B horizon. The layer that typically is immediately beneath the E horizon and often called the subsoil. This middle layer commonly contains more clay, iron, or aluminum than the A, E, or C horizons; and

(D) C horizon. The deepest layer of soil profile. It consists of loose material or weathered rock that is relatively unaffected by biologic activity.

(161) [(159)] Soil survey--A field and other investigation, resulting in a map showing the geographic distribution of different kinds of soils and an accompanying report that describes, classifies, and interprets such soils for use. Soil surveys must meet the standards of the National Cooperative Soil Survey.

(162) [(160)] Spoil--Overburden that has been removed during surface coal mining operations.

(163) [(161)] Stabilize--To control movement of soil, spoil piles, or areas of disturbed earth by modifying the geometry of the mass, or by otherwise modifying physical or chemical properties, such as by providing a protective surface coating.

(164) [(162)] Steep slope--Any slope of more than 20 degrees or such lesser slope as may be designated by the Commission after consideration of soil, climate, and other characteristics of a region or state.

(165) [(163)] Subirrigation--With respect to alluvial valley floors, the supplying of water to plants from underneath or from a semi-saturated or saturated subsurface zone where water is available for use by vegetation. Subirrigation may be identified by:

(A) diurnal fluctuation of the water table, due to the differences in nighttime and daytime evapotranspiration rates;

(B) increasing soil moisture from a portion of the root zone down to the saturated zone, due to capillary action;

(C) mottling of the soils in the root zones;

(D) existence of an important part of the root zone within the capillary fringe or water table of an alluvial aquifer; or

(E) an increase in streamflow or a rise in ground-water levels, shortly after the first killing frost on the valley floor.

(166) [(164)] Substantial legal and financial commitments in a surface coal mining operation--Significant investments that have been made on the basis of a long-term coal contract in power plants, railroads, coal-handling, preparation, extraction or storage facilities and other capital-intensive activities. An example would be an existing mine, not actually producing coal, but in a substantial stage of development prior to production. Costs of acquiring the coal in place or the right to mine it without an existing mine, as described in the above example, alone are not sufficient to constitute substantial legal and financial commitments.

(167) [(165)] Substantially disturb--For purposes of coal exploration, to significantly impact land, air or water resources by such activities as blasting; mechanical excavation; drilling or altering coal or water exploratory holes or wells; removal of vegetation, topsoil, or overburden; construction of roads or other access routes; placement of structures, excavated earth, or waste material on the natural surface of land; or by other such activities; or to remove more than 250 tons of coal.

(168) [(166)] Successor in interest--Any person who succeeds to rights granted under a permit, by transfer, assignment, or sale of those rights.

(169) [(167)] Surface coal mining and reclamation operations--Surface coal mining operations and all activities necessary or incidental to the reclamation of such operations. This term includes the term surface coal mining operations.

(170) [(168)] Surface coal mining operations--Includes:

(A) activities conducted on the surface of lands in connection with a surface coal mine or, subject to the requirements of §134.015 of the Act, surface operations and surface impacts incident to an underground coal mine, the products of which enter or the operations of which directly or indirectly affect interstate commerce. Such activities include excavation for the purpose of obtaining coal, including such common methods as contour, strip, auger, mountaintop removal, box cut, open pit, and area mining; the use of explosives and blasting; in situ distillation or retorting; leaching or other chemical or physical processing; the cleaning, concentrating, or other processing or preparation of coal; and the loading of coal for interstate commerce at or near the mine-site. Provided, however, that such activities do not include the extraction of coal incidental to the extraction of other minerals, where coal does not exceed 16 2/3% of the tonnage of minerals removed annually from all sites operated by a person on contiguous tracts of land for purposes of commercial use or sale, or coal exploration subject to §134.014 and §134.031(d) of the Act; and provided further, that excavation for the purpose of obtaining coal includes extraction of coal from coal refuse piles; and

(B) areas upon which the activities described in subparagraph (A) of this definition occur or where such activities disturb the natural land surface. Such areas shall also include any adjacent land the use of which is incidental to any such activities, all lands affected by the construction of new roads or the improvement or use of existing roads to gain access to the site of those activities and for haulage and excavation, workings, impoundments, dams, ventilation shafts, entryways, refuse banks, dumps, stockpiles, overburden piles, spoil banks, culm banks, tailings, holes or depressions, repair areas, storage areas, processing areas, shipping areas, and other areas upon which are site structures, facilities, or other property or material on the surface, resulting from or incident to those activities.

(171) [(169)] Surface mining activities--Those surface coal mining and reclamation operations incident to the extraction of coal from the earth by removing the materials over a coal seam, before recovering the coal, by auger coal mining, or by recovery of coal from a deposit that is not in its original geologic location.

(172) [(170)] Surface operations and impacts incident to an underground coal mine--All activities involved in or related to underground coal mining which are either conducted on the surface of the land, produce changes in the land surface or disturb the surface, air or water resources of the area, including all activities listed in

relied upon to establish property rights. If no applicable state law exists, custom and generally accepted usage at the time and place that the documents came into existence will govern their interpretation.

(B) Additional demonstrations. Except as provided in subparagraph (C) of this paragraph, a person claiming valid existing rights must also demonstrate compliance with one of the following standards:

(i) Good faith/all permits standard. All permits and other authorizations required to conduct surface coal mining operations have been obtained, or a good faith effort to obtain all necessary permits and authorizations has been made, before the land came under the protection of §12.71(a) of this title or §134.022 of the Act. At a minimum, an application must have been submitted for any permit required under Subchapter G of this chapter (relating to Surface Coal Mining and Reclamation Operations, Permits, and Coal Exploration Procedure Systems); or

(ii) Needed for and adjacent standard. The land is needed for and immediately adjacent to a surface coal mining operation for which all permits and other authorizations required to conduct surface coal mining operations have been obtained, or a good faith attempt to obtain all permits and authorizations has been made, before the land came under the protection of §12.71(a) of this title or §134.022 of the Act. To meet this standard, a person must demonstrate that prohibiting expansion of the operation onto that land would unfairly impact the viability of the operation as originally planned before the land came under the protection of §12.71(a) of this title or §134.022 of the Act. Except for operations in existence before August 3, 1977, or for which a good faith effort to obtain all necessary permits have been made before August 3, 1977, this standard does not apply to lands already under the protection of §12.71(a) of this title or §134.022 of the Act when the Commission approved the permit for the original operation or when the good faith effort to obtain all necessary permits for the original operation was made. In evaluating whether a person meets this standard, the Commission may consider factors such as:

(I) the extent to which coal supply contracts or other legal and business commitments that predate the time that the land came under the protection of §12.71(a) of this title or §134.022 of the Act depend upon use of that land for surface coal mining operations;

(II) the extent to which plans used to obtain financing for the operation before the land came under the protection of §12.71(a) of this title or §134.022 of the Act rely upon use of that land for surface coal mining operations;

(III) the extent to which investments in the operation before the land came under the protection of §12.71(a) of this title or §134.022 of the Act rely upon use of that land for surface coal mining operations; and

(IV) whether the land lies within the area identified on the life-of-mine map submitted under §12.136(3) of this title (relating to Maps: General Requirements) or §12.182(3) of this title (relating to Maps: General Requirements) before the land came under the protection of §12.71(a) of this title.

(C) Roads. A person who claims valid existing rights to use or construct a road across the surface of lands protected by §12.71(a) of this title or §134.022 of the Act must demonstrate that one or more of the following circumstances exist if the road is included within the definition of "surface coal mining operations" in this section:

(i) the road existed when the land upon which it is located came under the protection of §12.71(a) of this title or §134.022 of the Act, and the person has a legal right to use the road for surface coal mining operations;

(ii) a properly recorded right of way or easement for a road in that location existed when the land came under the protection of §12.71(a) of this title or §134.022 of the Act, and, under the document creating the right of way or easement, and under subsequent conveyances, the person has a legal right to use or construct a road across the right of way or easement for surface coal mining operations;

(iii) a valid permit for use or construction of a road in that location for surface coal mining operations existed when the land came under the protection of §12.71(a) of this title or §134.022 of the Act; or

(iv) valid existing rights exist under subparagraphs (A) and (B) of this paragraph.

(190) [~~(188)~~] Valley fill--A fill structure consisting of any material other than coal waste and organic material that is placed in a valley where side slopes of the existing valley measured at the steepest point are greater than 20 degrees or the average slope of the profile of the valley from the toe of the fill to the top of the fill is greater than 10 degrees.

(191) [~~(189)~~] Violation, failure, or refusal--With respect to §§12.696 - 12.699 of this title, a violation of or a failure or refusal to comply with any order of the Commission including, but not limited to, a condition of a permit, notice of violation, failure-to-abate cessation order, imminent harm cessation order, order to show cause why a permit should not be suspended or revoked, and order in connection with a civil action for relief, except an order incorporated in a decision issued under §134.175 of the Act.

(192) [~~(190)~~] Violation notice--Any written notification from a governmental entity of a violation of law, whether by letter, memorandum, legal or administrative pleading, or other written communication.

(193) [~~(191)~~] Water table--The upper surface of a zone of saturation, where the body of ground water is not confined by an overlying impermeable zone.

(194) [~~(192)~~] Willfully--With respect to §§12.696 - 12.699 of this title, that an individual acted:

(A) either intentionally, voluntarily, or consciously; and

(B) with intentional disregard or plain indifference to legal requirements in authorizing, ordering, or carrying out a corporate permittee's action or omission that constituted a violation, failure, or refusal.

(195) [~~(193)~~] Willful violation--An act or omission which violates the Act, state, or federal laws or regulations, or any permit condition required by the Act or this chapter, committed by a person who intends the result which actually occurs.

This agency hereby certifies that the proposal has been reviewed by legal counsel and found to be within the agency's legal authority to adopt.

Filed with the Office of the Secretary of State on November 13, 2003.

TRD-200307792
Mary Ross McDonald
Managing Director
Railroad Commission of Texas
Earliest possible date of adoption: December 28, 2003
For further information, please call: (512) 475-1295

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and to plug, case or manage exploration holes, other bore holes, wells and other openings within the proposed permit area, in accordance with §§12.501-12.503 of this title (relating to Casing and Sealing of Exposed Underground Openings: General Requirements; [; to] Casing and Sealing of Underground Openings: Temporary; and [; and to] Casing and Sealing of Underground Openings: Permanent); [and]

(9) a description of steps to be taken to comply with the requirements of the Clean Air Act (42 U.S.C. 7401 et seq.), the Clean Water Act (33 U.S.C. 1251 et seq.), and other applicable air- and water-quality laws and regulations and health and safety standards; and[.]

(10) a description of any planned use of coal combustion products designed to achieve approximate original contour or any proposal to dispose of coal combustion by-products in a manner that achieves approximate original contour. When additional time to conduct rough backfilling and grading is requested to allow for the use of coal combustion products or the disposal of coal combustion by-products, the description shall include a planned time frame for those activities. The proposed time frame may include extensions of the time frames under §12.551(a) of this title (relating to Backfilling and Grading: General Requirements) to facilitate the cost-effective utilization of coal combustion products and by-products considering generation rates, transportation issues, market conditions, and other relevant factors. Ancillary features (e.g., sediment control structures, roads, and other infrastructure) associated with the use of coal combustion products or coal combustion by-products shall be considered mining-related activities which the permittee may retain within the Commission's mining permit for the life of the reclamation project until final bond release.

§12.197. Operation Plan: Maps and Plans.

Each application shall contain maps, plans, and cross sections of the proposed permit and adjacent areas as follows:

(1) (No change.)

(2) the following shall be shown for the proposed permit area unless specifically required for the permit and adjacent area by the requirements of this section:

(A) - (K) (No change.)

(L) location of each water and subsidence monitoring point; [and]

(M) location of each facility that will remain on the proposed permit area as a permanent feature, after the completion of underground mining activities; and[.]

(N) the approximate location of any area in which coal combustion by-products will be disposed.

(3) - (4) (No change.)

This agency hereby certifies that the proposal has been reviewed by legal counsel and found to be within the agency's legal authority to adopt.

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SUBCHAPTER K. PERMANENT PROGRAM PERFORMANCE STANDARDS

DIVISION 2. PERMANENT PROGRAM PERFORMANCE STANDARDS--SURFACE MINING ACTIVITIES

16 TAC §12.384, §12.385

The Commission proposes the amendments under Texas Natural Resources Code, §134.013, which authorizes the Commission to promulgate rules pertaining to surface coal mining operations.

Statutory authority: Texas Natural Resources Code, §134.013.

Cross-reference to statute: Texas Natural Resources Code, §134.013.

Issued in Austin, Texas, on November 13, 2003.

§12.384. Backfilling and Grading: General Requirements.

(a) Timing of backfilling and grading.

(1) Contour mining. Rough backfilling and grading shall follow coal removal by not more than 60 days or 1,500 linear feet. The Commission may grant additional time for rough backfilling and grading if the permittee can demonstrate, through a detailed written analysis under §12.145(b)(3) or (b)(10) of this title (relating to Reclamation Plan: General Requirements for Surface Mining), that additional time is necessary.

(2) Open pit mining with thin overburden. Rough backfilling and grading shall occur in accordance with the time schedule approved by the Commission, on the basis of the materials submitted under §12.145(b)(3) or (b)(10) of this title (relating to Reclamation Plan: General Requirements for Surface Mining), which shall specifically establish in stated increments the period between removal of coal and completion of backfilling and grading.

(3) Area strip mining (cyclic excavation). Rough backfilling and grading shall be completed within 180 days following coal removal and shall not be more than four spoil ridges behind the pit being worked, the spoil from the active pit being considered the first ridge. The Commission may grant additional time and/or distance for rough backfilling and grading if the permittee can demonstrate, through a detailed written analysis under §12.145(b)(3) or (b)(10) of this title (relating to Reclamation Plan: General Requirements for Surface Mining), that additional time and/or distance is necessary.

(4) Area strip mining (continuous excavation). Rough backfilling and grading shall occur in accordance with the time schedule approved by the Commission, on the basis of a detailed written analysis by the permittee under §12.145(b)(3) or (b)(10) of this title (relating to Reclamation Plan: General Requirements for Surface Mining), and any additional information which the Commission may require.

(b) (No change.)

§12.385. Backfilling and Grading: General Grading Requirements.

(a) - (e) (No change.)

(f) In the case of a reclamation plan in which coal combustion products are designed to achieve approximate original contour or coal combustion by-products are proposed to be disposed of in a manner that achieves approximate original contour, the following information shall be submitted as applicable:

Figure: 16 TAC §12.3(33)

TABLE 1: LETTER AUTHORIZATIONS FOR REUSE OF BOTTOM ASH AT TEXAS LIGNITE MINES[1]			
Company Mine (Pmt. No.)	[2]Bottom Ash Disposal/Reuse	Disposal/Beneficial Reuse Method	TCEQ Letter Date
Alcoa Inc.			
Sandow (1E)	**D, R**	Roads, Fill[3]	8/25/1995
Three Oaks (48)	**R**	Roads	8/25/1995
The Sabine Mining Company			
South Hallsville No. 1 (33E)	**R**	AOC, Ramp Advance, Roads	12/17/1998
TXU Mining Company LP			
Big Brown (3D)	**R**	Roads, Fill	3/31/1999
Martin Lake (4H)	**R**	Roads	4/21/1992
Oak Hill (22D & 46A)	**R**	Roads	4/21/1992
Walnut Creek Mining Company			
Calvert (27F)	**R**	Roads	3/25/1998

[1]The information in this table was obtained largely from the portion of the permit application files concerning general requirements for operations plans, as provided in 16 TAC §12.139(2)(D) (relating to Operation Plan: General Requirements).

[2]Title 30 of the Texas Administrative Code (TAC) addresses environmental quality. According to 30 TAC §335.506 and §335.507, fly ash is a Class II waste, and bottom ash is a Class III waste unless classed as a coproduct. These rules are enforced by the Texas Commission on Environmental Quality (TCEQ).

[3]Class III Waste Disposal ceased as of April, 1999, when the 2C and 3C pits were reclaimed. Reuse in A Mine Area continues.

Attachment B

WORKING DRAFT 3 - COAL COMBUSTION ASH PRODUCTS			
BENEFICIAL USES	**INDUSTRIAL STANDARDS**	**ENVIRONMENTAL AND PRACTICAL BENEFITS**	**REGULATORY SAFETY NET**
ON-SITE CONSTRUCTION APPLICATIONS CCA is used to replace cement, sand and aggregate in various grout/ concrete projects on site including: -Equipment pads - Foundations -Grouted rock rip-rap spillways -Bricks - Asphaltic concrete	By reference, Transportation Department Quality Control Standards as well as ASTM Standards	CCA exhibits pozzalanic properties which make it an effective substitute for cement in certain concrete and grout applications., with the following environmental benefits: - Conservation of energy & materials. The process of cement uses significant energy and raw materials and substituting CCA helps conserve these resources. - Reduced CO2 Emissions. Every ton of CCA substituted for cement avoid 1 ton in CO2 emissions which would have been generated in the production of the cement.	State & Federal Requirements: -Surface Water (NPDES) -Clean Air Act - Superfund
SOIL STABILIZATION CCAs are used for soil stabilization to reduce the shrink and swell factors as water either evaporates from the soil or infiltrates into the soil.	By reference, Transportation Department Quality Control Standards as well as ASTM Standards	One example of soil stabilization is to mix CCA with soils underlying a road in lieu of lime and concrete. By doing so, the plasticity index is reduced, maintenance requirements are decreased and the life of the road is extended. The effective substitution of CCA for lime and cement component of concrete provides environmental benefits, as follows: Conservation of energy & materials. The process of cement uses significant energy and raw materials and substituting CCA helps conserve these resources. Reduced CO2 Emissions. Every ton of CCA substituted for cement avoid 1 ton in CO2 emissions which would have been generated in the production of the cement.	State&Federal Requirements: -Surface Water (NPDES) - Clean Air Act - Superfund

Source: Document Prepared for EPA in Preparation for Minefill Practices for Coal Combustion Residue Facilitated Stakeholders Meeting
May 19 & 20, 2003
U.S. EPA East Building, Room 1153

WORKING DRAFT 3 - COAL COMBUSTION ASH PRODUCTS

BENEFICIAL USES	INDUSTRIAL STANDARDS	ENVIRONMENTAL AND PRACTICAL BENEFITS	REGULATORY SAFETY NET
SOIL AMENDMENT / ACID MINE DRAINAGE CCAs are used as agricultural soil amendments at a mine site for a variety of purposes including: -providing a soil cover to prevent water infiltration into mined areas, - controlling acid mine drainage, and -as additives to soil to prevent potential acid mine drainage by effectively adjusting the pH balance.	See Also, Draft ASTM Standard for CCA Used as Soil Amendment and U.S. Department of Agriculture, Natural Resources Conservation Service Soil Survey Documents	The CCAs are a substitute for agricultural lime, which would typically be relied upon from off-site sources. The effective substitution of CCA for lime and cement component of concrete provides environmental benefits, as follows: - Conservation of energy & materials. The process of cement uses significant energy and raw materials and substituting CCA helps conserve these resources. - Reduced CO_2 Emissions. Every ton of CCA substituted for cement avoid 1 ton in CO_2 emissions which would have been generated in the production of the cement. In addition to the environmental benefits realized from not relying upon off-site agricultural lime to accomplish the same purpose, the use of CCAs as a soil amendment to neutralize acidic soils has been a critical component to Acid Main Drainage projects in the Eastern U.S. and effectively prevents future acid mine problems through its use in the reclamation process at sites in the Western U.S.	State & Federal Requirements: -Surface Water (NPDES) -Clean Air Act - Superfund

WORKING DRAFT 3 - COAL COMBUSTION ASH PRODUCTS

BENEFICIAL USES	INDUSTRIAL STANDARDS	ENVIRONMENTAL AND PRACTICAL BENEFITS	REGULATORY SAFETY NET
STRUCTURAL FILL / COMPACTION (To fix underground subsidence) CCAs are used for construction fill material, including: - structural fills as a substitute for aggregate / soil - injection into underground mines, where coal or lignite has been removed, in order to minimize the occurrence of subsidence	Engineering Standards By reference, Transportation Department Quality Control Standards as well as ASTM Standards See Also, Draft ASTM Standard for CCA Applications at Mine Sites.	CCA materials replace soils, aggregate and cement materials routinely used as construction fill material (for structural support) and the cement or grout materials which would be injected into underground mines to prevent subsidence. In the absence of CCA materials, these materials would be excavated (either on or off site), processed to meet the engineering specifications and hauled to the mining site. The effective substitution of CCA in place of soils, aggregate and cement provides several environmental benefits, as follows: - Land / Habitat Conservation. Less land would be disturbed to excavate / extract the clay and aggregate. As a result more ecologically valuable habitat remains undisturbed. - Reduced VOC and PM Emissions. The use of CCA, (which is usually available from the power plant on-site or close to the mine site), will reduce the distance required to haul the clays, limestone rocks and aggregate materials from off site and will eliminate the additional excavation (and therein the use of heavy equipment) of these materials from on site, reducing the emissions associated with these activities. Also for some operations, the same trucks are used not only to haul coal or lignite to the power plant, but also for the reverse trip to haul CCA from the power plant to the mine area. Diesel truck emissions are reduced by this efficient use of vehicles. - Reduced Noise & Improved Safety. The reduction in driving distances for the diesel haul trucks and the reduced operations of heavy equipment also reduces the noise / potential safety issues associated with blasting, extracting, crushing, sizing, and hauling new clays and rocks for use in roads. - Conservation of energy & materials. The process of cement uses significant energy and raw materials and substituting CCA helps conserve these resources. - Reduced CO_2 Emissions. Every ton of CCA substituted for cement avoid 1 ton in CO_2 emissions which would have been generated in the production of the cement.	State & Federal Requirements: -Groundwater (SMCRA) -Surface Water (NPDES) (SMCRA) -Air (CAA) -Waste (RCRA) -Clean-up (CERLCLA)

WORKING DRAFT 3 - COAL COMBUSTION ASH PRODUCTS			
BENEFICIAL USES	**INDUSTRIAL STANDARDS**	**ENVIRONMENTAL AND PRACTICAL BENEFITS**	**REGULATORY SAFETY NET**
RAMP ADVANCEMENT (Surfacing and Fill) CCAs are used for the construction of ramps in the active pit areas which would otherwise require the use of virgin dirt or spoil material.	30 United States Code Sections 1201-1309b) (Surface Mining Control & Reclamation Act [SMCRA]) Implemented by Detailed Regulations and Engineering / Design Review and Approval Implemented at State Level and Inspected by Office of Surface Mining (OSM) and State Agencies See Also, Draft ASTM Standard for CCA Applications at Mine Sites	Using CCAs for ramp construction provides increased operational flexibility as well as minimizing the need to disturb additional ground at the end of the project. In addition, surfacing the ramps with CCAs provides the necessary traction to efficiently access the pits during inclement weather conditions, i.e., slippery, wet, and/or frozen. The CCAs also provide a good surface for equipment required to operate on roads located on the pit floor (effective as structural fill). The effective substitution of CCA in place of soils provides several environmental benefits, as follows: - Land / Habitat Conservation. Less land would be disturbed to excavate / extract the soils. As a result more ecologically valuable habitat remains undisturbed. - Reduced VOC and PM Emissions. The use of CCA, (which is usually available from the power plant on-site or close to the mine site), will reduce the distance required to haul the soils from off site and will eliminate the additional excavation (and therein the use of heavy equipment) of these materials from on site, reducing the emissions associated with these activities. Also for some operations, the same trucks are used not only to haul coal or lignite to the power plant, but also for the reverse trip to haul CCA from the power plant to the mine area. Diesel truck emissions are reduced by such efficient use of vehicles. - Reduced Noise & Improved Safety. The reduction in driving distances for the diesel haul trucks and the reduced operations of heavy equipment also reduces the noise / potential safety issues associated with the excavation and transportation of the soils.	State & Federal Requirements: -Groundwater (SMCRA) -Surface Water (NPDES) (SMCRA) -Air (CAA) -Waste (RCRA) -Clean-up (CERLCLA)

WORKING DRAFT 3 - COAL COMBUSTION ASH PRODUCTS

BENEFICIAL USES	INDUSTRIAL STANDARDS	ENVIRONMENTAL AND PRACTICAL BENEFITS	REGULATORY SAFETY NET
ACHIEVING APPROXIMATE ORIGINAL CONTOUR (AOC) -Pits -Final Pits, and -Abandoned Mine Land (AML) Projects) CCAs are used in reclamation of pits, final pits and AML projects. It is used selectively in areas where there are low volumes of available spoil material and in order to minimize additional land disturbance (extraction of rock and /or soils for the purposed of refilling pit areas.)	30 United States Code Sections 1201-1309b (Surface Mining Control & Reclamation Act [SMCRA]) Implemented by Detailed Regulations and Engineering / Design Review and Approval Implemented at State Level and Inspected by Office of Surface Mining (OSM) and State Agencies See Also, Draft ASTM Standard for CCA Applications at Mine Sites	The use of CCA in place of soils /overburden spoils provides several environmental benefits, as follows: - Land / Habitat Conservation. Less land would be disturbed to excavate / extract the soils. As a result more ecologically valuable habitat remains undisturbed. - Reduced VOC and PM Emissions. The use of CCA, (which is usually available from the power plant on-site or close to the mine site), will reduce the distance required to haul the soils from off site and will eliminate the additional excavation (and therein the use of heavy equipment) of these materials from on site, reducing the emissions associated with these activities. Also for some operations, the same trucks are used not only to haul coal or lignite to the power plant, but also for the reverse trip to haul CCA from the power plant to the mine area. Diesel truck emissions are reduced by such efficient use of vehicles. - Reduced Noise & Improved Safety. The reduction in driving distances for the diesel haul trucks and the reduced operations of heavy equipment also reduces the noise / potential safety issues associated with the excavation and transportation of the soils. In addition, the use of CCAs to assist in achieving AOC provides a critical additional volume of material that enhances AOC activities in several ways: 1) Provides alternative source of fill when there are shortages of overburden (spoil) available for reclamation purposes in the immediate vicinity of the pit being reclaimed. 2) Allows operators to lessen steeper slopes in areas where low volumes of available spoil material typically result in steeper post mine slopes and create slope diversity and enhances post mine contours while maintaining compliance with the regulatory permitting requirements. [Typically in active mine areas, CCAs are placed in pits at depth below the approved topsoil and subsoil depth increments.] 3) Because of 1) and 2) above, may reduce landowner concerns at the time of reclamation performance bond release by improving the attractiveness of land features created during the reclamation process.	State & Federal Requirements: -Groundwater (SMCRA) -Surface Water (NPDES) (SMCRA) -Air (CAA) -Waste (RCRA) -Clean-up (CERCLA)

Attachment C

United States Department of the Interior

OFFICE OF SURFACE MINING RECLAMATION
AND ENFORCEMENT
5100 East Skelly Drive, Suite 470
Tulsa, Oklahoma 74135-6547

May 7, 2004

Melvin B. Hodgkiss, Director
Surface Mining and Reclamation Division
Railroad Commission of Texas
Post Office Box 12967
Austin, Texas 78711-2967

Dear Mr. Hodgkiss:

The Mid-Continent Regional Coordinating Center and my office have completed our review of the comments received in response to our February 3, 2004, and March 3, 2004, **Federal Register** notices announcing receipt of your December 9, 2003, Regulatory Program amendment (69 FR 5102) and the comments received at the March 1, 2004, public hearing conducted in Del Valle, Texas (Administrative Record Nos. TX-656.05, TX-656.29, and TX-656.31, State Amendment Tracking System No. TX-051-FOR).

After reviewing public comments and the policy and procedures used by other States for disposal of coal combustion by-products, we determined that the enclosed list of concerns needs to be addressed either in your regulations or by a policy document referenced in your regulations.

Please advise me within 30 days of this letter whether you want to address these concerns before we proceed to a final decision on the amendment package. If you want to discuss the concerns with OSM or if you have any questions, contact me at (918) 581-6431, extension 23, or Dwight Thomas at extension 24. You may also reach me by e-mail at mwolfrom@osmre.gov.

Sincerely,

Mike Wolfrom

Michael C. Wolfrom, Director
Tulsa Filed Office

Enclosure
cc: Charles E. Sandberg, MCRCC
Knoxville Field Solicitor's Office

TX-051-FOR
TEXAS CCB AMENDMENT
CONCERNS/ISSUES

OSM's policy is that coal combustion by-products disposal at a mine site is not precluded so long as such disposal is consistent with the environmental protection standards of SMCRA, its implementing regulations, and Federal and State solid waste disposal requirements. After reviewing the public comments and the policy and procedures used by other States for disposal of coal combustion by-products, we determined that the following concerns need to be addressed by Texas either in its regulations or by a policy document referenced in its regulations.

1. Air Pollution Control Plan – 30 CFR 780.15 and 816.95 [16 TAC §§12.143, 12.379, and 12.389]

Texas needs to clarify that the fugitive dust control practices in the air pollution control plan will specifically address the coal combustion by-products transportation and disposal operations and the coal combustion products transportation and use.

2. Hydrologic Information – 30 CFR 780.21 [16 TAC §12.146]

Texas needs to clarify that the probable hydrologic consequences analysis and hydrologic reclamation plan in the permit application and the cumulative hydrologic impact assessment prepared by Texas will specifically address the coal combustion by-products disposal operations and coal combustion products use, including the probability of adverse impacts on the hydrologic balance, contamination of surface- or ground-water supplies, and the time for manifestation of impacts to surface- or ground-water supplies. This should include a ground-water monitoring plan and surface-water monitoring plan that address the monitoring of potential leachable parameters that are normally associated with coal combustion by-products, such as arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, boron, sulfate, vanadium, nickel, zinc, molybdenum, and manganese (Murarka, Environmental Performance of CCPs, Proceedings of Coal Combustion By-Products and Western Coal Mines: A Technical Interactive Forum, p.p. 231-234, Edited by Vories & Throgmorton, 2002).

3. Release of Performance Bond – 30 CFR 800.40 [16 TAC §§12.312 - 12.313]

The definition of "Coal combustion by-products" at §12.3(33) provides that "where the disposal of coal combustion by-products is not proposed to result in achieving approximate original contour within the life of the mining project, the disposal area shall be removed from the Commission's mining permit area . . . ." Neither the definition nor other provisions in the proposed rule specify how the removal of the disposal area is to be accomplished. Texas needs to clarify in its regulations or in a policy document the procedures for removing a coal combustion by-products disposal area from the Commission's mining permit area and returning complete jurisdiction to the Texas Commission on Environmental Quality (TCEQ). Texas also needs to clarify what "within the life of the mining project" means.

Would this portion of the permit area be released as an industrial/commercial land use and then be regulated by TCEQ under the Texas Solid Waste Program? If so, how would this be accomplished? For example, Texas would need to consider the requirements in its rules at 16 TAC §§12.312 and 12.313 concerning bond release; §12.395(b)(4) concerning Revegetation standards for areas to be developed for industrial, commercial, or residential use; and §12.399(c) concerning alternative land uses. Texas would also need to consider the requirements in its rules at 16 TAC §12.226 concerning permit revisions, §12.400 concerning access road(s) to the disposal area, and §§12.505 and 12.506 concerning topsoil and subsoil to ensure that sufficient topsoil and subsoil will be set aside to spread on the disposal areas upon site closure to ensure a good vegetative cover to provide long term site stability.

The definition of "Coal combustion by-products" at §12.3(33) also provides that when the disposal area is removed from the permit, "all ancillary features (e.g. sediment control structures, roads, and other infrastructure) associated with the disposal operations shall be considered mining-related features which the permittee may retain within the Commission's mining permit for the life of the reclamation project until final bond release." Texas needs to clarify that if these roads and structures are only being used for active solid waste disposal operations and the surrounding permit area has been reclaimed, they will be released as a part of the coal combustion by-products disposal area that was removed from the permit.

For your information, we are attaching the current policy document of the North Dakota program for the release of mined acreage used for the disposal of ash, the current policy documents used by Illinois and the OSM Western Region for the beneficial use and disposal of coal combustion by-products, and the current regulations used by Kentucky for coal combustion by-products.

4. <u>16 TAC §12.145 – Reclamation Plan: General Requirements for Surface Mining and §12.187 – Reclamation Plan: General Requirements for Underground Mining</u>.

Texas needs to clarify what it will require at §§12.383 and 12.550 concerning contemporaneous reclamation when considering an operator's request for additional time to conduct rough backfilling and grading to allow for the use of coal combustion products or the disposal of coal combustion by-products.

5. <u>16 TAC §12.3(34) – Definition of Coal Combustion Products</u>.

Since the use of coal combustion products at a permitted mining area will be considered a mining-related activity, Texas should clarify how it will determine which of the identified coal combustion products (fly ash, bottom ash, fluidized bed combustion ash, and flue gas desulfurization solids or sludge) will be used for the specific purposes listed in §12.3(34)(A) through (G). For example, will paragraphs (A) and (B) concerning roads be limited to the use of bottom ash? Bottom ash is the only product that TCEQ ever approved in its letter authorizations for roads and TCEQ limited its approval of fly ash to disposal in mine pits and fill. What type of demonstrations must the operators provide to aid in your determinations?

6. Disposal of Noncoal Mine Wastes – 30 CFR 816.89 [16 TAC §12.375]

By policy OSM views the disposal of coal combustion by-products as disposal of noncoal mine wastes. Texas needs to clarify in its regulations or a policy document that it will require disposal operations to adhere to Texas' noncoal mine wastes disposal regulations as well as any special and/or additional requirements that site-specific conditions may require.

7. Backfilling and Grading – 30 CFR 816.102 (a) and (b) [16 TAC §§12.384(a) – 12.385]

The Federal regulation at 30 CFR 816.102(a)(1) requires that disturbed areas be backfilled and graded to achieve the approximate original contour (AOC) with certain limited exceptions. The Federal regulations at 30 CFR 816.102(b) require that spoil, except excess spoil disposed of in accordance with 30 CFR 816.71 through 816.74, shall be returned to the mined-out area. It is not clear why coal combustion products fill and coal combustion by-products disposal is needed to achieve AOC at the typical lignite mine in Texas. Therefore, Texas needs to clarify that it will not allow coal combustion products to be used as fill or coal combustion by-products to be disposed of in those mined-out areas where spoil would be displaced and have to be disposed of as excess spoil.

8. Recordkeeping and Annual Reporting

It does not appear that the proposal addresses any record keeping requirements. Will the generators who ship coal combustion by-products to the mining areas for disposal be required to comply with applicable TCEQ regulations at 30 TAC §335.9 (relating to Recordkeeping and Annual Reporting Procedures Applicable to Generators)? Will Texas require the operator to include information in the operation plan and/or reclamation plan on the locations for the coal combustion by-products disposal operations and quantities to be disposed and the locations and quantities of coal combustion products to be used?

REGULATION, RISK, AND RECLAMATION WITH CCBs AT MINES: A TECHNICAL INTERACTIVE FORUM PARTICIPANT LIST

William Aljoe US DOE National Energy Technology Lab P.O. Box 10940 Pittsburgh, PA 15236-0940 (412) 386-6569	Lonnie Barrier Mississippi Dept of Environmental Quality Office of Geology Jackson, MS 39289-1307 (601) 961-5519
Richie Benninghoven Underground Services Co., LLC 1201 N. W. Briarcliff Parkway, Suite 250 Kansas City, MO 64116 (816) 741-8540	James A. Berg Basin Electric Power Cooperative 1717 E Interstate Ave Bismarck, ND 58501-0564 (701) 223-0441
Robert D. Bessette Council of Industrial Boiler Owners 6035 Burke Centre Pkwy Burke, VA 22015 (703) 250-9042	Tracy Branam Indiana Geological Survey 611 N Walnut Grove Bloomington, IN 47405 (812) 855-2687
Lynn Brickett US DOE National Energy Technology Lab P.O. Box 10940 Pittsburgh, PA 15236-0940 (412)386-6574	Charles Burdick Western Maryland Resource Conservation & Development Council, Inc. 431 Dual Highway, Suite 104 Hagerstown, MD 21740 (301) 733-2973
Dr. Tarunjit S. Butalia Ohio State University 470 Hitchcock Hall, 2070 Neil Ave. Columbus, OH 43210 (614) 688-3908	Gregory E. Conrad Interstate Mining Compact Commission 445 - A Carlisle Drive Herndon, VA 20170 (703)709-8654
Kevin Creagh Rio Tinto P.O. Box 2207 Milton QLD 4064 Australia	Mac Crosby Pacificorp 1407 West North Temple, Suite 330 Salt Lake City, UT 84116 (801) 220-4829
Deborah A. Dale IN DNR Division of Reclamation RR2, Box 129 Jasonville, IN 47438 812-665-2207	Dr. W. Lee Daniels Virginia Polytechnic Institute CSES Department 0404 Blacksburg, VA 24061-0404 (540) 231-7175
Yvonne Dedrickson Constellation Energy 1005 Brandon Shores Rd. Baltimore, MD 21226 (410) 787-5456	Matthew W. Erbe Environmental Resources Management 200 Harry S. Truman Parkway, Suite 400 Annapolis, MD 21401 (410) 266-0006
David G. Erickson Basin Electric Power Cooperative 1717 East Interstate Ave. Bismarck, ND 58503-0564 (701) 223-0441	Thomas H. Ewing Kay, Casto, & Chaney 50 Clay St. Morgantown, WV 26501 (304) 296-1100

William E. Giles Freeman Energy PO Box 259 Farmersville, IL 62533 (217) 627-2161	David C. Goss American Coal Ash Association 15200 E. Girard Ave Aurora, CO 80014-3955 (720) 870-7897
Thomas A. Gray GAI Consultants 385 East Waterfront Drive Homestead, PA 15120-5005 (412) 476-2000 x 1406	Richard E. Gray DiGioia, Gray & Associates, LLC 11 Wisteria Drive Pittsburgh, PA 15235 (412) 372-4500
Fredrick H. Gustin Kansas City Power & Light P.O. Box 418679 Kansas City, MO 64141-9679 (816) 556-2108	Robin L. Guynn Environmental Resource Management 200 Harry S. Truman Pkwy, Suite 400 Anapolis, MD 21401 410-266-0006
Gary P. Haney First Energy 76 S. Main St. Akron, OH 44308 (330) 384-4676	David J. Hassett Univ. of North Dakota, Energy & Env. Res Center P.O. Box 9018 Grand Forks, ND 58202-9018 701-777-5192
George M. Hawkey Mississippi Lignite Mining Company Route 3, Box 98 Ackerman, MS 39735 (662) 387-5260	Greg Helms U.S. Environmental Protection Agency Office of Solid Waste 1200 Pennsylvania Ave. NW Mail Code 5304W Washington, DC 20460 703-308-8845
Dr. Peter A. Hesbach US. DOE, National Energy Technology Laboratory P.O. Box 880 Morgantown, WV 26507-0880 (304) 285-4443	Claudette Bonham Horn PNM 2401 Aztec NE, MS Z110 Albuquerque, NM 87101 (505) 855-6393
Dell Jaggers Poplar Ridge Enterprise, Inc. 305 Old Coach Road Nicolasville, KY 40356 (859) 223-4879	Roger Hornberger Pennsylvania Dept. of Environmental Protection 5 West Laurel Blvd. Pottsville, PA 17901 570-621-3118
Dr. Ann Kim US Dept. of Energy, National Energy Tech. Laboratory P.O. Box 10940 Pittsburgh, PA 15236-0940 412-386-6724	Dr. Richard A. Kruger Ash Resources P.O. Box 3017 Randburg, South Africa 2125 (11) 886-6200
Larry L. LaBuz PPL Generation, LLC 2 North 9th St. Allentown, PA 18101-1179 (610) 774-5340	Howard S. Lewis Cinergy Power Generation Services 1000 E. Main St. Plainfield, IN 46168-1782 (317) 838-1661
Dr. Henry Liu Freight Pipeline Co. 2601 Maguire Blvd. Columbia, MO 65201 (573) 442-0080	James G. Luther BHP Coal New Mexico, San Juan Coal Co. P.O. Box 561 Waterflow, NM 87421 505 598-2110

James MacLean Dominion Ash P.O. Box 1470 Stn. A, Fredericton, New Brunswick, Canada E3B 5E3 (506) 452-7933	Michael J. Mehghini PA Department of Environmental Protection Pottsville District Mining Office 5 W. Laurel Blvd. Pottsville, PA 17901-2454 570-621-3118
Lin Jin Mei Niigata University, Civil Engineering 8050 Ninocho Igarashi, Niigata City, 950-2181 Japan	Dana G. Meier Indianapolis Power & Light Co. One Monument Circle, Rm 771 Indianapolis, IN 46204-2936 (317) 261-8792
Marcelo P. Merino The North American Coal Corp. Signature Place II 14785 Preston Rd., Suite 1100 Dallas, TX 78254-7891 (972) 239-2625	Peter R. Michael Office of Surface Mining ARCC Three Parkway Center Pittsburgh, PA 15220 (412) 937-2867
E. Cheri Miller Tennessee Valley Authority 1101 Market St., LP 5G Chattanooga, TN 37402-2801 (423) 751-4419	Harry R. Miller PPL Generation, LLC P.O. Box 128 Washingtonville, PA 17884-0128 (570) 437-1276
Vaughn Miller Anker Coal Group, Inc. 2708 Cranberry Square Morgantown, WV 26508 (304) 288-2280	Randall Mills Office of Surface Mining MCRCC 501 Belle St. Alton, IL 62002 (618) 463-6460
Dr. Ishwar P. Murarka ISH Inc 690 W Fremont Ave., Ste 9C Sunnyvale, CA 94087 (408) 720-0474	Michael J. Nasi Lloyd, Gosselink, Blevins, Rochelle, Baldwin, & Townsend 111 Congress Ave., Suite 1800 Austin, TX 78701 (512) 322-5859
Lynn E. Nelson Dominion Generation Mt. Storm Power Station HC 76, Box 430 Mt. Storm, WV 26739 (304) 259-4142	Tony Palumbo Oak Ridge National Laboratory P.O. Box 2008 Oak Ridge, TN 37831-6638
Harold M. Parsons, Jr. West Virginia DEP, Mining & Reclamation 105 S. Railroad St., Suite 301 Philippi, WV 26416 (304) 457-3219 x 3250	Paul A. Petzrick Maryland DNR Power Plant Research Program Tawes State Office Bldg., B-3 Annapolis, MD 21401 (410) 260-8669
Debra Pflughoeft-Hassett Univ. of North Dakota, Energy & Env. Res Center P.O. Box 9018 Grand Forks, ND 58202-9018 (701) 777-5261	Kelley Reynolds Technology Services International Lower Germiston Road, Rosherville, Gauteng Private Bag 40175 Cleveland, 2022 South Africa
Bonnie B. Robinson US EPA 1200 Pennsylvania Ave NW MS 5306W Washington, DC 20460 (703) 308-8429	James R. Roewer USWAG 701 Pennsylvania Ave., NW Washington, DC 20004 (202) 508-5645

Dr. Barry Scheetz Penn State Univiversity 107 Materials Research Lab University Park, PA 16802-5000 (814) 863-3539	Todd J. Stong Golder Associates 44 Union Blvd., Suite 300 Lakewood, CO 80228 (303) 980-0540
Damini Surender ESKOM Lower Germiston Road, Private Bag 40175 Cleveland, 2022 Gauteng South Africa	Karl T. Schroeder US DOE, National Energy Technology Laboratory P.O. Box 10940 Pittsburgh, PA 15236-0940 (412) 386-5910
Takao Tanosaki Taiheiyo Cement Corporation 2-4-2, Osaku, Sakurashi, Chiba Prefecture, 285-8655 Japan	Michael J. Tate Graymont Dolime (OH) Inc. P.O. Box 158 Genoa, OH 43430 (419) 855-8336 x 212
Kimery Vories Office of Surface Mining 501 Belle St. Alton, IL 62002 (618) 463-6463 x 103	Andrew Voros Columbia University, Earth Engineering Center 500 W. 120th St. New York, NY 10027 732-932-4673
Peter J. Vuljanic Anker Coal Group, Inc. 2708 Cranberry Square Morgantown, WV 26508 (304) 594-1616	Dr. Harold W. Walker The Ohio State University, Civil Engineering 2070 Neil Ave., 470 Hitchcock Hall Columbus, OH 43210 614-292-8263
Colin R. Ward The University of New South Wales School of Biological, Earth, and Environmental Sciences Sydney NSW 2052, Australia	Daniel T. Wheeler Illinois Office of Coal Development 620 East Adams Street Springfield, IL 62701 (217) 558-2645
David J. Wickens Mississippi DEQ, Office of Geology/Mining & Reclamation P.O. Box 20307 Jackson, MS 39289-1307 (601) 961-5521	Erick J. Zacher Energy & Environmental Research Center University of North Dakota P.O. Box 9018 Grand Forks, ND 58202-9018 (701) 777-5131
Robert A. Zielinski US Geological Survey P.O. Box 25046, MS 973, DFC Denver, CO 80225 (303) 236-4719	Dr. Paul Ziemkiewicz National Mine Land Reclamation Center P.O. Box 6064 Morgantown, WV 26506-6064 304-293-2867