RESTORATION DESIGN OF COLDWATER FORK FOLLOWING THE OCTOBER 11, 2000 SLURRY SPILL[1]

Michael F. Adams, Jr.,[2] and J. George Athanasakes

Abstract. On Wednesday morning, October 11, 2000, a breach in the 72-acre Big Branch slurry impoundment caused the release of approximately 250 million gallons of coal slurry, a substance consisting of coal fines, other particles and water, into the Coldwater Fork and Wolf Creek Watersheds, through two mine portals ultimately affecting more than 100 miles of stream. Arguably, the most severly impacted section of stream was Coldwater Fork downstream of the portal. During the cleanups, approximately one mile of Coldwater Fork was relocated, resulting in an incised trapezoidal channel over much of the stream. While portions of the stream, particularly sections with good floodplain access, have recovered, other reaches are characterized by headcuts and a lack of riffle-pool sequences. Working for the Martin County Coal Corporation (MCCC), Fuller, Mossbarger, Scott and May, Inc. (FMSM) performed an assessment of the Upper Middle Fork of Coldwater Fork, and prepared a design and directed construction for nearly 6,000 feet of stream restoration.

[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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FINANCIAL COST TO LANDOWNERS ASSOCIATED WITH FORESTLAND CONVERSION TO NON-PRODUCTIVE USES IN THE PROCESS OF SURFACE MINING[3]

Jonathan Aggett[4], Jay Sullivan, Greg Amacher and James Burger

Abstract. Public Law 95-87, the Surface Mining Control and Reclamation Act of 1977 (SMCRA), mandates that mined land be reclaimed to its pre-mining use, and in a fashion that renders the land at least as productive after mining as it was before mining. According to SMCRA requirements, mine operators are responsible for reclaiming mined land. Until recently, mine operators commonly reclaimed previously forested land to hayland/pasture or wildlife habitat. Most of these lands have been abandoned from management and rendered non-productive. This left the landowner with the option or necessity of converting these reclaimed mined lands to forests at a later stage, in order to make them economically viable. Such a land-use conversion, however, comes at a substantial cost to the landowner, which makes the financial feasibility of such a conversion a questionable issue. This paper examines the economic implications of this shift in reforestation burden from the landowner to the mine operator. Results suggest that the reforestation of mined lands as part of the mining operation creates a viable and profitable forest enterprise for landowners.

Additional Key Words: mine reclamation, land-use conversion, reforestation

[3] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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CARBON SEQUESTRATION BY FORESTS AND SOILS ON MINED LAND IN THE MIDWESTERN AND APPALACHIAN COALFIELDS: PRELIMINARY RESULTS[1]

Beyhan Amichev[2], James A. Burger, and Jason A. Rodrigue

Abstract. Reforestation of mined land has the potential to sequester large amounts of atmospheric carbon on sites where carbon-based fuels were extracted. The extent to which reforested mined land captures atmospheric carbon compared to natural undisturbed land is still largely unknown. We compared the amount of carbon sequestered on 14 pre-SMCRA reforested mined sites to 8 adjacent natural sites in the midwestern and eastern coalfields. Rates of carbon sequestration ranged from 0.7 to 6.7 Mg ha^{-1} yr^{-1}, depending on mine soil quality. After 20 to 55 yr, total site carbon levels on mined study sites averaged 161 (± 24) Mg ha^{-1} (hardwood stands) and 148 (± 41) Mg ha^{-1} (pine stands), while total carbon amounts on natural sites averaged 207 (± 36) Mg ha^{-1}. The amount of carbon captured across mined sites was largely a function of forest stand age and forest and site productivity, quantitatively expressed as site index (SI) of white oak at base age 50 years. Ecosystem carbon prediction models on natural and mined sites were generated for a wide spectrum of SI and age, including carbon sequestered in tree biomass, litter layer, and soil. The natural sites' multivariate regression model (P=0.002) explained about 68% of the total variation among natural sites and the mined sites' model (P=0.064) explained 28% of the total variation in measured carbon among mined sites. This study showed that current reclamation procedures and techniques restore carbon sequestration potential on low quality sites, but carbon sequestration potential is degraded on medium to high quality sites. Better reclamation techniques are needed to ensure long-term restoration of the potential of forests and forest soil systems to sequester carbon at pre-mining levels for the entire spectrum of SI and stand age.

Additional Key words: reclamation, reforestation, forest soils, carbon prediction models.

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[1]Paper was presented at the 21st Meeting of the American Society for Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force Symposium, April 18-22, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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INTEGRATING RIPARIAN RESTORATION TO PROMOTE WILDLIFE HABITAT WITH NATURAL STREAM CHANNEL DESIGN ON MINE LAND HABITATS[1]

James T. Anderson, Joseph D. Osbourne, and Ryan L. Ward[2]

Abstract. The role of natural streams and associated riparian habitat in structuring vertebrate communities is an important wildlife management issue in human-impacted environments. Many studies have illustrated the value of healthy riparian ecosystems in providing basic habitat requirements for a broad array of vertebrate taxa. In regions where coal mining is widespread and vital to state and local economies, it is important to address the effects of different mining practices on riparian ecosystems. Two major negative impacts of mining on natural streams and stream corridors is the alteration of physical characteristics of the stream itself and fragmentation of riparian habitat. Natural stream channel design has become a popular means of mitigating for impacts to stream channel structure; however, less emphasis has been placed on the science of creating riparian corridors to connect riparian areas fragmented by human impacts such as mining. This paper provides a background and review of literature regarding the importance of riparian ecosystems to vertebrates, the effects of mining on vertebrate populations in riparian habitats, and the use of natural stream design in riparian restoration. We provide suggestions and recommendations on how to manage riparian corridors on mine lands and outline a research agenda on wildlife in relationship to riparian corridors on mine land sites.

Additional Key Words: amphibians, birds, mammals, reptiles.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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INFLUENCE OF MINELAND RECLAMATION PRACTICES ON MICROBIAL COMMUNITY RECOVERY AND SOIL ORGANIC CARBON ACCUMULATION[5]

J.D. Anderson[6], P. D. Stahl and L. J. Ingram

Abstract: As the nation's leading producer of coal, Wyoming has thousands of hectares of soil that have been affected by surface mining. While the rate of coal production and soil disturbance has increased steadily for the past few years, our knowledge of the long-term sustainability and management of the reclaimed soil systems has remained limited. Preliminary data on soil organic matter content of reclaimed soils collected from a surface coal mine in Wyoming suggests carbon may be an accumulating at a rapid rate. Data collected at the same mine indicates that the productivity of the soil microbial community may take longer than 30 years to recover. An accumulation of soil organic matter and slow recovery of the microbial community may indicate an inhibited nutrient cycling in a reclaimed soil system. We hypothesize that an alteration of the soil structure, as a result of topsoil removal, long-term storage and replacement, may limit the ability of the soil biota to decompose plant litter and result in an accumulation soil organic matter. Reclamation management practices could potentially affect the rate and levels of recovery in these reclaimed soils. By using the most effective management practices, concentrations of soil organic carbon (SOC) and microbial biomass carbon (MBC) could be optimized. To test this hypothesis we are examining the relationship of MBC and SOC in reclaimed soils of different management practices and adjacent undisturbed soils on surface coal mines in the semiarid regions of Wyoming. Preliminary results of these analyses will be presented and discussed.

Additional Keywords: microbial biomass carbon, soil organic matter, management practices, semiarid mineland reclamation soils

[5] Paper was presented at the 2004 National meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd. Lexington, KY 40502.

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OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT APPALACHIAN REGIONAL REFORESTATION INITIATIVE[7]

Patrick N. Angel and Victor M. Davis[8]

Abstract. The Appalachian Regional Reforestation Initiative is a broad-based citizen/industry/government program working to encourage planting trees on reclaimed mined lands and abandoned mine lands. Using a combination of private and governmental resources, the program will facilitate and coordinate citizen groups, university researchers, the coal industry, corporations, the environmental community, and local, state, and federal government agencies that have an interest in creating productive forestland on reclaimed mined lands.

Research by Virginia Polytechnic Institute and State University and the University of Kentucky has confirmed that highly productive forestland can be created on reclaimed mine land by using a forestry reclamation approach. The Office of Surface Mining (OSM) has determined that this technology can be implemented under the current federal regulations. The Forestry Reclamation Approach has five fundamental parts:

1. Create a new soil medium by replacing the original soil with four feet of surface soil, weathered sandstone, or the best available material.
2. Loosely grade the topsoil or topsoil substitutes to create a noncompacted soil growth medium.
3. Use native and noncompetitive ground covers that are compatible with growing trees.
4. Plant two types of trees – early successional species for wildlife and mine soil improvement and commercially valuable crop trees.
5. Use proper tree planting techniques.

Tree planting is documented throughout Appalachia in the regulatory programs in Ohio, Pennsylvania, Maryland, Kentucky, Virginia, Tennessee, and West Virginia. Although trees are being planted, the reclamation plans generally do not reflect the current technology. Our mission is to promote and encourage the use of the Forestry Reclamation Approach technology in both Title IV and Title V programs.

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[7] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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BENTHIC MACROINVERTEBRATE STUDIES CONDUCTED IN MOUNTAINTOP MINING/VALLEY FILL INFLUENCED STREAMS IN CONJUNCTION WITH THE USEPA ENVIRONMENTAL IMPACT STUDY[9]

M.Y. Armstead, J.L. Yeager-Seagle, and L. Emerson[10]

Abstract. Supplemental benthic macroinvertebrate samples were collected in conjunction with the United States Environmental Protection Agency (USEPA) during the implementation of the Mountaintop Removal/Valley Fill Mining Environmental Impact Statement Study (MTR/VF-EIS). Samples were collected over four seasons within the Mud River, Spruce Fork, and Island Creek watersheds. Six Surber samples were collected at each monitoring station sampled by the USEPA to provide quantitative data for analysis in conjunction with the agencies qualitative benthic macroinvertebrate, water chemistry, and habitat data. Drought conditions prevented the collection of representative data during the summer and fall index periods. During the winter and spring index periods, significant differences were seen in both the benthic community and water chemistry between the unmined streams and the streams with fills or fills and residential influences. Differences between the unmined streams and the streams with fills may be related to differences in temperature regimes (and therefore emergence times), the presence of ponds (additional food source), and water chemistry differences between the treatments. The most significant changes in stream biological community are the shifts in the functional feeding groups toward more filter feeding organisms and the reduction of the mayfly community in fill and fill/residentially influenced sites. The changes in community structure may result from the presence of ponds and changes in temperature regimes. The reduced mayfly populations in the fill and fill/residentially influenced sites are not uncommon in areas with mining influence or below impoundments. Sites influenced by mining continue to support an abundant population with representatives of all the functional feeding groups, and stream function does not appear compromised at these sites.

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[9] Paper was presented at the 2004 National meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd. Lexington, KY 40502.

[10]Mindy M. Yeager Armstead and Jessica Yeager-Seagle, Potesta & Associates, Incorporated, 2300 MacCorkle Ave. SE, Charleston, WV 25304, and Larry Emerson, Arch Coal, Incorporated, 10 Kenton Drive, Charleston, West Virginia 25311. This extended abstract **is** a portion of a Technical Report for Arch Coal, Incorporated prepared by Potesta & Associates, Inc. and submitted to United States Environmental Protection Agency in September 2003

INFLUENCE OF SITE FACTORS ON THE SURVIVAL AND GROWTH OF EARLY- AND LATE-SUCCESSIONAL APPALACHIAN HARDWOODS ON RECLAIMED MINED LAND[11]

W. E. Auch[12], J. A. Burger, and D. O. Mitchem

Abstract. In recent years, there has been an upsurge of interest in mined land reforestation with an emphasis on restoring native hardwood species. Research shows that most Appalachian hardwoods could be established on pre-SMCRA sites, but field observations show that many species cannot tolerate the conditions of post-law sites. The purpose of this study was to compare the survival and early growth of hand-planted early- and late-successional timber species (hereafter called softwoods and hardwoods, respectively) as a function of site, specifically slope steepness and slope aspect. This study was conducted on ten sites located in a three-state region of the southern Appalachian coalfields. Four softwoods (American sycamore, green ash, red maple and tulip poplar) and six hardwoods (black cherry, black walnut, northern red oak, sugar maple, white ash, and white oak), all native to the region, were used in the study. Average survival for softwoods was about 50% compared to hardwoods at 38%. Softwoods were also more productive than hardwoods across sites. Softwood survival increased as a function of increasing slope ($P < .0005$) and sunny aspects ($P < .0001$). Softwood tree volume also increased as a function of increasing slope ($P < .0001$) and sunlight ($P < .0008$). Hardwood survival and tree volume were not correlated with either slope or aspect. Because of adverse site conditions, hardwoods as a group did not perform well enough to meet regulatory performance standards. The results of this study demonstrate that hand-planted softwoods, while less viable commercially, survive and grow better than hardwoods. Better reclamation techniques are needed to establish native hardwoods successfully in the Appalachian coalfields.

[11] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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POTENTIAL USE OF PLANTS FOR SELENIUM RECLAMATION

G.S. Bañuelos[2]

Abstract. Seleniferous soils and groundwaters have been identified in many parts of the Western US. Because studies in the late 1980's indicated that excessive selenium (Se) can bioaccumulate to toxic levels in waterfowl and insect biota, ponds used for temporarily storing agricultural drainage effluent produced from Se-laden soils are potentially toxic sites for the biological ecosystem. The purpose of our multi-year field studies was to utilize plants and sometimes trees to manage Se content in waters, soils, and in drainage sediment by plant extraction and biological volatilization of Se. Field plots (ranging from 0.5 to 40 ha in size) were located in Western San Joaquin Valley of Central California. All sites had either Se-laden soils and/or waters with levels of soluble Se that ranging from 0.13 to 0.50 mg L^{-1} that were considered excessive concentrations. Because high levels of salts (6-10 dS m^{-1}) and boron (5-10 mg L^{-1}) are simultaneously present with Se in soils from the Westside of central California, selected boron (B) and salt tolerant plant species were identified and either planted in the Se-laden soil/sediment and/or used as recipients for the disposal of Se-laden water. For each study, soils were monitored for changes in extractable Se throughout the soil profile and plants were evaluated for the accumulation and volatilization of Se. Our results show that although high levels of soluble sulfate reduced plant accumulation of Se (< 12 mg L^{-1} DM), volatilization of Se occurred as high as 100 µg m^{-2} day^{-1} on a daily basis with canola. Both processes resulted in lower soluble Se in the soil. Canola, salado grass, and poplar trees can be used as biological tools for slowly managing soluble Se in soils and waters, however, monitoring the downward movement of soluble Se is recommended.

Additional Key Words: Phytoremediation

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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IN-PLACE SOLIDIFICATION OF COAL TAILINGS FOR EXPRESSWAY SUBGRADE[13]

N. Catherine Bazán-Arias[14]; Stanley R. Michalski, Phillip E. Glogowski, and Frank Howard

Abstract. The Mon-Fayette Expressway is one of the largest highway construction projects undertaken in PA in recent years. A 400-foot long segment with ingress and egress ramps was scheduled for construction over an active 10-acre coal tailings (fine coal refuse) disposal impoundment in Washington County, PA. The coal tailings are deposited by a slurry pipeline, are not traversable, and are over 40 feet thick in the central pond portions. The initial approved Expressway plans included construction of a temporary dike, separating the active slurry pond from the highway right-of-way, followed by complete removal of the tailings upstream of the dike. The remaining void would be raised to highway grade with a structural earth and rock fill followed by removal of the temporary dike. A dam would be constructed on the highway embankment slope to isolate the highway and its supporting embankment from the tailings pond.

Howard Concrete Pumping Company, Inc. and GAI Consultants, Inc. proposed an engineering value, cost saving, novel approach to solidify the tailings in-place providing a stable foundation for construction of the highway embankment and the dam. This approach eliminates the temporary dike and off site disposal of the tailings. Key advantages included lower cost and rapid implementation. In January 2000, following an intensive research and development program, the plan was approved by the concerned parties. Work began in June 2000.

Procedures were developed for both shallow and deep mixing that result in a stable mixture of tailings and fly ash/cement grout. A large backhoe equipped with a custom-designed long-reach dipper stick and hydraulically driven mixing device performed shallow mixing. Deep mixing was conducted with a custom-designed three-auger mix panel supported by a Manitowoc crane. Approximately 320,000 cubic yards of coal tailings were stabilized. The project was successfully completed in March 2001 and Expressway construction remained on schedule.

Key words: fine coal refuse, shallow mixing, deep mixing, fly ash, grout, slurry, Mon-Fayette Expressway

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[13] Paper presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Road., Lexington, KY 40502.

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TOPSOIL CREATION FOR BOND FORFEITED MINED LAND BY USING GREEN SAWDUST AND OTHER SAWMILL BYPRODUCTS[1]

Lawrence T. Beckerle[2]

Abstract: When topsoil is lost during excavation and other construction activities, there is an increased potential for drought and drastic chemical changes in the soil. The reintroduction of large quantities of organic matter can help to restore a balanced moisture regime, to balance soil chemistry, and to improve productivity of the land. Even though the carbon to nitrogen ratio of an organic matter source used in this research (green sawdust) ranged from 300:1 to 500:1, fertilizer nitrogen was not added. Previous reclamation efforts had been failures, which was assumed to be due to acidic soils and the production of acid mine drainage. However, my reclamation technique did not use limestone as an additive. Additions of only magnesium, phosphorus, potassium, and sulfur fertilizers gave positive responses. Up to a dozen wood rotting and some mycorrhizal fungi were used to facilitate the creation of topsoil. Initial revegetation was achieved by seeding several nitrogen-fixing species. The lush vegetation and rich topsoil created by sawdust addition, plus the cessation of acid mine drainage, are drastic improvements over attempts using hydroseeders to apply amendments and to sow seed.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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TECHNIQUES FOR ENCOURAGING NATIVE PLANTS AND CREATING BOBWHITE QUAIL HABITAT ON DRASTICALLY DISTURBED LAND[1]

Lawrence T. Beckerle[2]

Abstract: A number of theories have been advanced as to why many native plants and early successional animal species such as Bobwhite quail do not occur on most lands reclaimed since the enactment of the Surface Mining, Control and Reclamation Act of 1977 (SMCRA). Yet if most native plants and animals are not able to return to the land after it is reclaimed according to SMCRA, is that land truly reclaimed? This paper describes the most effective techniques for reclaiming land to a more natural state. Instead of one-shot revegetation techniques that often favor the seeds of plants that can survive a hydroseeder, the emphasis is on nurse cropping, relay cropping and similar techniques to favor the re-establishment of native plants and provide the diversity needed by butterflies, songbirds, Bobwhite quail, and other game birds. By describing a range of techniques and project results in one paper, regulators may be better able to modify existing regulations to allow improvements in revegetation of disturbed land. In the mean time, land reclamation specialists may be better able to apply for variances to misguided regulations and thus have the freedom and the means to achieve better results, such as reversing the decline of Bobwhite quail and other species dependent on good quality, early successional habitats.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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PASSIVE TREATMENT OF ACID MINE DRAINAGE IN THE MID-CONTINENTAL U. S. – CONSTRUCTION PROBLEMS AND POSSIBLE SOLUTIONS[15].

Paul T. Behum, Jr.[16], and Kwang (Min) Kim

Abstract: Passive treatment technology has been primarily developed in Appalachia for treatment of discharges that lie above drainage. Because of differences in geochemistry, hydrogeology and mining methods in the Illinois and Interior Coal Basins, the application of passive treatment technology for the treatment of Acid Mine drainage (AMD) requires additional design considerations. In the Illinois Basin, most of the surface and underground mines lie below drainage. At a typical discharge, the acidic and metal-laden ground water seeps directly into streams and agricultural ditches as diffuse base flow. In this hydrologic setting AMD impacts are reduced (the "deep and dark" prevention method applies). Many AMD problems in the Midwest are associated with coal refuse disposal areas. These facilities are usually placed above the surface and, as such, above drainage. Common practice for prevention of AMD, where the coarse refuse is net acidic, is to use compaction followed by the construction a soil cap to restrict infiltration.

This paper presents several problems that have restricted application of passive treatment at a number of mid-continent sites and suggest measures needed to remedy these limitations. The problems discussed include: 1) the collection of AMD from diffuse sources and the generation of sufficient hydraulic head for application of a vertical flow pond (VFP), 2) treatment of AMD with high acidity and metal loading, and 3) high aluminum content. Several sites will be discussed, including the Old Bevier, Cedar Creek, and Otter Creek AML projects in Missouri and the artesian Rock Island No.7 mine pool discharge in Oklahoma.

[15] Paper presented at the 2004 National Meeting of the of the American Society of Mining and Reclamation, Morgantown, WV, April 18-22, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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CLIMBING THE LEARNING CURVE IN MINE WATER AQUACULTURE : AN UPDATE FROM WARWICK MOUNTAIN FISHERIES[1]

Charles K. Blankenship [2]

Abstract: Treating acid mine drainage is now a fact of life for coal mine operators. Each year, those companies collectively spend millions of dollars to treat water, releasing it into streams that are often not as clean as the water being placed in them. If ways can be found to derive some benefit from this water treatment, the financial burden of those operations would be reduced. In some cases where state environmental agencies have inherited water problems left by defunct mining companies, some positive cash flow from the treatment process might allow more drainage problems to be tackled.

The market for farm-raised fish and shellfish is real and growing. Aquaculture projects at coal mine water treatment plants are technically feasible and can be moneymakers. Two good examples of this feasibility are the trout propagation project at Mettiki Coal Corporation in western Maryland and the Warwick Mountain Fisheries project in southwestern Pennsylvania. This paper examines the latter and how it has set out to prove financial feasibility as well. The discussion will include challenges encountered, lessons learned, adaptations made to the original plan and financial impacts.

Duquesne Light Company believes that aquaculture at the Warwick Mine is not only an excellent demonstration of the effectiveness of its water treatment program but also an opportunity to offset some portion of its perpetual water treatment costs there. Further, we believe that it holds promise for others who face the same perpetual liability and hope that our experience will be helpful to the industry.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502. While the topic of aquaculture in mine water has been presented in other venues, this paper to be presented orally is an update for the Warwick Project and has not been presented previously.

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REFINEMENT OF ADTI-WP2 STANDARD WEATHERING PROCEDURES, AND EVALUATION OF PARTICLE SIZE AND SURFACE AREA EFFECTS UPON LEACHING RATES: PART 2: PRACTICAL AND THEORETICAL ASPECTS OF LEACHING KINETICS[1]

K.B.C. Brady,[2] W.B. White, R.J. Hornberger, B.E. Scheetz, and C.M. Loop

Abstract: Most previous coal mine drainage leaching studies have not investigated the effect of surface area, effects of elevated Pco_2, which are typical of mine spoil, and solubility constraints on water chemistry. The leaching column and humidity cell tests were designed to evaluate the importance of these parameters. Surface area was examined on three rock types before and after leaching: the Brush Creek shale; a well-indurated calcareous sandstone; and a coal refuse. The surface area, as measured by BET, for the shale was an order of magnitude greater than the other rock types. Surface area after leaching decreased slightly for the shale, and by half for the refuse. The sandstone area remained the same. Plots of sulfate concentration through time closely resemble those expected for diffusion controlled kinetics. Plots of alkalinity through time are characteristic of a material that dissolves quickly at first and then approaches or reaches saturation. Saturation with respect to calcite was confirmed by equilibrium calculations. The water in the leaching columns was undersaturated with respect to gypsum, indicating that sulfate was a conservative parameter and could be used to measure pyrite oxidation rates. The target 10% CO_2 was achieved in the column tests, but not achieved in the humidity cell tests. At the end of 12 to 14 weeks, between 1.5 and 2% of the calcite and between 4 and 6% of the sulfur in the rock had been removed by weathering. Predictions, based on power function equations, indicate that the Brush Creek shale sample would remain alkaline even if weathered for years. Comparisons between leaching chemistry and field data for the Brush Creek shale and the coal refuse sample showed similar water chemistry.

Additional Key Words: weathering tests, acid mine drainage, surface area effects, weathering rates, carbonate dissolution, pyrite oxidation.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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CASE HISTORY OF A COPPER MINE TAILINGS POND RECLAMATION IN DUCKTOWN, TENNESSEE[1]

J L. Branson[2] and J. T. Ammons

Abstract: Cessation of mining operations in Ducktown, TN, left 800-900 acres of barren copper mine tailings. Revegetation activities had met with limited success. In 1998, efforts for revegetation of the tailings materials began anew. The objective of this case history is to provide insight into decision making processes which resulted in conversion of 800-900 acres of barren mine tailings into a vegetated, productive landscape. Phase 1 began with intensive analyses of the tailings materials. Acid-base accounting registered a generally neutral to alkaline pH. Scattered areas were more acid with pH values measuring as low as 1.9. Neutralization potential was adequate in most cases to counteract potential acid formation. Total elemental analysis indicated a maximum of 416 mg kg^{-1} P (total) with essentially none plant available as measured by the bicarbonate P method. Utilizing these data, phase 2 was initiated with the installation of two one-acre plots with variables of 1) P treatments (0, 50, 100, and 200 lb $acre^{-1}$), 2) biosolid/ non-biosolid applications, and 3) fescue/ legumes (birdsfoot trefoil, sericea lespedeza, Korean lespedeza, and Kobe lespedeza). Korean and Kobe lespedeza/fescue on biosolids with 100 lb P $acre^{-1}$ were most productive. Phase 3 was based on data from the test plots. An in situ treatment of 100 lb P $acre^{-1}$ and 2 tons $acre\ lime^{-1}$ (to counter random generations of acids) with no biosolids and additions of standard fertilizers were applied with incorporation to at least 6 inches. Korean and Kobe lespedeza along with Kentucky 31 tall fescue were planted along with sandy bluestem and switch grass. The warm season grasses (sandy bluestem and switch grass) that were included in the seeding mixture were successful in grass test plots on site.

Additional Key Words: Ducktown, phosphorous, copper mine tailings, lespedeza. Biosolids

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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CHEMICAL AND BIOLOGICAL ANALYSIS OF FOX RUN WATERSHED, MERCER COUNTY, PENNSYLVANIA[1]

Fred J. Brenner[2], Shawn Hedglin, Scott Alexander and Shaun Busler

Abstract: The impact of 5 alkaline iron laden discharges was monitored for their impact on water quality and macroinvertebrate communities in Fox Run, Mercer County Pennsylvania. Water samples were collected monthly and analyzed by an independent laboratory and 6 macroinvertebrate surveys were completed over 9 months using the Pennsylvania Environmental Protection Agency rapid assessment protocol to calculate a Biotic Index. At the completion of the study, a Habitat Evaluation Index (HEI) using the Ohio Environmental Protection Agency Protocols was completed at each stream sampling location. The Biotic indexes and the number of individuals and taxa were inversely correlated with total iron concentrations and positively correlated with the overall HEI. Both water quality macroinvertebrate communities improved 1.3 and 3.5 km downstream from the discharges. The reclamation plan for Fox Run will involve the installation of settling ponds and aerobic wetlands to reduce suspended iron loading into Fox Run.

Additional Key Words: Alkaline discharges, macroinvertebrates, biotic indexes

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1. Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Mine Drainage Task Force, April 1824, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE ACID DRAINAGE TECHNOLOGY INITIATIVE[17]

Fred Block, Stephen C. Parsons, R. David Williams and John R. Craynon[18]

Abstract. The Acid Drainage Technology Initiative (ADTI) is a coalition of federal and state agencies, industry, academia, and consulting firms working together to promote communications and technology enhancement in the field of prediction and remediation of acid drainage from mining activities, past and present. This joint effort was formed in recognition of the need to address a range of issues dealing with the technical problems of predicting and controlling acid drainage. These include: the legacy of acid mine drainage/acid rock drainage (AMD/ARD) problems throughout the U.S; the development of consensus on improved test methods, particularly for prediction of mine drainage quality prior to mining; avoidance and remediation technology to prevent, treat and abate AMD/ARD pollution in an effective and economical manner and the application of "best science" methods to accomplish these goals. ADTI is subdivided into a coal mining sector and a metal mining sector. The coal mining sector (http://wvwri.nrcce.wvu.edu/ADTI) is organized into two primary working groups, one focused on prediction and the other on avoidance and remediation methods. The metal mining sector (http://www.unr.edu/mines/adti/) is organized around five major technical areas relevant to the particular technical problems it faces: (1) sampling/monitoring, (2) prediction, (3) mitigation, (4) modeling and (5) pit lakes. This paper discusses the formation, goals and major accomplishments of the ADTI, leading to its current activities.

Additional Key Words: acid mine drainage, acid rock drainage.

[17] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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COMPUTERIZING THE FLUVIAL GEOMORPHIC APPROACH TO LAND RECLAMATION[1]

Nicholas Bugosh[2]

Abstract. The fluvial geomorphic approach to land reclamation is a means of creating the landforms to which the land would naturally tend to erode under the climatic conditions, soil types, and slopes present at the site. The resulting slopes and stream channels are stable because they are in balance with these conditions, and are a reclamation alternative to uniform slopes with terraces and down-drains. Reclamation landscapes created using fluvial geomorphic principles provide stability against erosion with runoff waters that meet water quality criteria, and support a diverse vegetative community. These landscapes offer the benefits of lower initial cost and no long-term maintenance costs. This award-winning fluvial geomorphic approach was successfully introduced to the largest mining company in the world at their New Mexico operations, where the landscapes have remained stable through extreme storms.

Now this innovative fluvial geomorphic approach (presented as a symposium short-course at the 2003 Billings Reclamation Symposium/ASMR Annual Meeting) has been computerized. This "user friendly" computer design software allows many users without advanced training in fluvial geomorphology to use this approach to create stable landscapes. The fluvial geomorphic landscape computer-design software replaces lengthy and tedious manual calculations and allows rapid evaluation of many landscape design alternatives. This allows the user to easily select the optimum landscape design for his needs. The computer design software allows the user to view topographic maps and three-dimensional images of the resulting landscape design. The computer automation is useful for designing reclamation, or for evaluating proposed reclamation designs for bond estimation. Computer automation helps users quickly and cost-effectively designs and build reclamation landscapes from spoil piles to seeded reclamation.

Additional Key Words: bond, channel pattern, cross sectional area, drainage density, longitudinal profile, sinuosity, stable, subwatershed, -width to depth ratio

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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RESTORING FORESTS ON MINED LAND IN THE APPALACHIANS: RESULTS AND OUTCOMES OF A 20-YEAR RESEARCH PROGRAM[1]

James A. Burger[2]

Abstract: The mixed hardwood forest of the central Appalachian coal field region is one of the most diverse, productive, and valuable temperate forests in the world. Strip mining for coal removes the forest ecosystem including the soil and surface geologic strata. Since the implementation of the Surface Mining Control and Reclamation Act in 1978, over 500,000 ha of native forest land have been converted to mine spoils covered with abandoned, unproductive grass and shrub land; less than 10% of these mined lands were reforested due to inadequate technology, economic disincentives, or regulatory constraints. A long-term forestland reclamation program was established in 1980 to develop mined land reclamation techniques specific for reforestation and forestry land uses. Our studies show that forest site quality was routinely degraded in the process of mining, but, if properly reclaimed, forest growth and yield of post mining forests can be as productive as native forests. High site quality is achieved by creating mine soils made from rock strata with properties similar to those of native soils. Soil compaction on mined sites was common; soil building and tillage techniques were devised that greatly increased forest site quality. Tree-compatible ground covers were developed for erosion control, and silvicultural practices were modified for mined land applications. Economic analyses showed that our revised reclamation techniques for forestry were cost effective, while meeting all federal and state regulatory requirements. Our studies also show that productive, reforested mined sites can sequester carbon at a rate of 4 Mt ha^{-1} yr^{-1}, which is important for sequestering and storing carbon released to the atmosphere in the process of burning coal for power production. Based on our research outputs, several states in the Appalachian region have revised their reclamation regulations and guidelines to produce high quality mined sites for restoring native forest ecosystems. With coordination among landowners, miners, and regulators, mined land can be restored for multiple forest values.

Key Words: Reclamation, mined land, forest management, soil quality

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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PREDICTING VISUAL QUALITY WITH GIS BASED LAND-USE DATA: AN OLD MISSION PENINSULA, MICHIGAN CASE STUDY[1]

Mary Noffke[2] and Jon Bryan Burley

Abstract. Predictive visual quality equations and preference modeling have evolved into important design tools for the landscape architecture profession and reclamation specialists. By using predictive equations, designers and other landscape professionals aim to produce landscape designs that are environmentally sensitive yet effective in terms of improving landscape aesthetics in the post-mining environment. Likewise, new technologies in the area of landscape modeling have brought the computer to the forefront of the design process. By examining and manipulating photographic images of a landscape, one can analyze existing problems and suggest possible solutions with realistic, computer enhanced models and images. However, investigators and practitioners are interested in methodologies which minimize the amount of field work necessary to evaluate visual quality. Many predictive visual quality procedures call for the use of photographic images. In our study we investigated the possibility of using GIS based land-use data to substitute for photographs in a visual quality study. We used the Old Mission Peninsula in Grand Traverse County, Michigan and GIS layers for the study area with 3-dimensional visualization software to determine if computer generated images were similar in visual quality assessment as actual photographs. Through statistical analysis of the data, it was determined that the relationship of the two datasets are in concordance and significant to the 95 percent confidence level. We conclude that visual quality can be assessed through remote, off-site methods.

Additional Key Words: environmental science, post-mining land-use, landscape planning, land-use planning, environmental psychology, 3-D visualization

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[1]Ppaper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24 Morgantown WV. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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VEGETATION PRODUCTIVITY MODEL FOR GRAND TRAVERSE COUNTY, MICHIGAN[1]

Gaelle Le Cleac'h,[2] Marjorie Salles, and Jon Bryan Burley

Abstract. Methods and procedures to evaluate and predict the productivity potential of disturbed soils are of great interest to soil scientists, land planners, and environmental specialists, especially in reclamation and restoration of disturbed landscapes. This study is based upon data collected by the Natural Resource Conservation Service in Grand Traverse County, Michigan. The procedure employs Principal Component Analysis to develop a latent dimension vegetation variable from corn (*Zea mays* L.), silage corn (*Zea mays* L.), oat (*Avena sativa* L.), winter wheat (*Triticum aestivum* L.), grass and legume mixtures, eastern red cedar (*Juniperus virginiana* L.), white spruce (*Picea glauca* L.), red pine (*Pinus resinosa* Ait.), eastern white pine (*Pinus strobus* L.), amur maple (*Acer ginnala* Maxim.), green ash (*Fraxinus pennsylvanica* Marsh.), siberian peashrub (*Caragana arborescens* Lam.), and lilac (*Syringa vulgaris* L.). Soil factors examined in the study include: topographic position, % slope, % rock fragments, % clay, bulk density, hydraulic conductivity, available water holding capacity, soil reaction, % organic matter. A predictive equation for evaluating and reconstructing soil profiles in reclamation applications and in assessing other forms of soil disturbance was generated ($p<0.0001$), explaining 73.72% of the variance.

Keywords: Agro-ecology, soil science, landscape science, environmental planning, environmental design.

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[1]Poster was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24 2004, Morgantown WV. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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LOWER GREY CLOUD ISLAND FOREST PATCH: A 15 YEAR RECLAMATION MONITORING STUDY[1]

J. B. Burley,[2] C.A. Churchward, C.J. Burley, and W. D. Sanders

Abstract. Reclamation specialists are constantly searching for efficient and effective revegetation methods upon xeric sites. In our investigation, we created a small forest patch, densely packed with woody plants and observed the development (expansion and mortality) of individual plants and groups of plants in the patch for 15 years. The patch has expanded from about 0.046 hectares (0.11 acres) to 0.24 hectares (0.58 acres) in area; while the inner core of trees has only slightly expanded from 0.0333 hectares (0.08 acres) to 0.0475 hectares (0.09 acres) in size. The collective basal area of most tree species has increased but is concentrated in fewer individuals. The basal area growth of some of the inner individuals has nearly halted (less then 2.5 mm (0.1 inches) in dbh over 5 years). In contrast, many surviving edge trees have increased their basal area with some individuals growing more than 1.27 cm (0.5 inches) dbh per year. Box elder (*Acer negundo* L.) is the only species that has increased in the number of individual trees (dbh $\geq$ 10 cm). Siouxland Eastern cottonwood (*Populus deltoides* Bart. Ex Marsh. "Siouxland") has gone extinct due to mortality caused by white-tailed deer rubbing against the trees. Woody plant seedling recruitment has occurred for northern red oak (*Quercus rubra* L.), woodbine (*Parthenocissus quniquefolia* (L.) Planch.), riverbank grape (*Vitis riparia* Michx.), Eastern red cedar (*Juniperus viginiana* L.), and common hackberry (*Celtis occidentalis* L.). A small stand of Kentucky Bluegrass (*Poa pratensis* L.) has formed in the understory of the inner core of the stand. Even though changes in the inner core have been slow, we have observed signs that the core may be beginning to expand and expect to observe tree recruitment and increased diversity over the next 10 years.

Additional Key Words: plant ecology, landscape ecology, landscape architecture, planting design, landscape horticulture, urban forestry, landscape planning

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, Morgantown, West Virginia, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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Coal Mine Water Retention Bulkhead Design and Construction[1]

Alan A. Campoli[2]

Abstract: The use water retention bulkheads to impound water and/or fine coal waste in underground workings is increasing in the coal mines of the Eastern United States. Mine Consulting Services Inc. and Minova USA have recently designed and installed two significant bulkhead sets, each with materials specifically selected for the geological and hydrological setting. The first bulkhead set was required in response to water inundation from overlying old workings into a Kentucky mine operating in the Kentucky No. 9 Coalbed. The second bulkhead set was constructed in a deep Mary Lee and Blue Creek Coalbed longwall mine in Alabama to minimize pumping and water treatment costs.

[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 28-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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MAPPING MINESOILS IN THE NATIONAL COOPERATIVE SOIL SURVEY IN APPALACHIA: A BRIEF OVERVIEW OF HISTORY, STATUS, AND DISTRIBUTION[1]

Stephen G. Carpenter, Robert R. Dobos, and Timothy M. Prescott[2]

Abstract. Soil material from surface mine operations is mapped and classified to a comprehensive soil classification system in the United States. This paper outlines the history, development, and spatial distribution of minesoil mapping in the central part of Appalachia with special emphasis on classification, potential use, and data currently available. Several thematic maps depict spatial distribution and differentiation of modern mapping to date. The classification of minesoils is discussed from an historical perspective to the current, modern-day classification of these important soils. The need for more reliable interpretations is also reviewed.

Additional Key Words: Constructed soils, soil classification.

[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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COST-EFFECTIVE ACID ROCK DRAINAGE WATER TREATMENT APPLIED TO MINING-IMPACTED WATERSHEDS[1]

J. A. Chermak[2], B. Wielinga, E. G. Wyatt and J. Taylor

Abstract. The application of three different Acid Rock Drainage (ARD) water treatment technologies will be discussed. The first water treatment technology results discussed are from laboratory and field treatability studies that used low volumes of high Total Dissolved Solids (TDS) ARD water to treat much larger volumes of lower TDS water to reach applicable ecological standards in the effluent stream. The low volumes of high (TDS) lime neutralized water were mixed with the high volumes of low TDS stream water to optimize the removal efficiencies of aluminum, cadmium, cobalt, copper, iron, lead, and zinc. Average removal efficiencies of the metals from the stream water were generally greater than 95%. Flow conditions of the low volume high TDS water tested ranged from 10 to 300 gpm and flow of the low TDS water ranged from 3,000 to over 25,000 gpm. Iron precipitation reactions and pH values in the effluent (ranging from 6 to 8.5) were accurately controlled. The precipitated iron-rich sludge from the neutralization reactions was deposited into a large open pit. Significant cost savings using this water treatment strategy was realized when compared to a conventional lime neutralization ARD water treatment system. The second water treatment technology to be discussed uses a lime mixing apparatus (The Neutra-Mill®) and its application to ARD impacted water-bodies. Results from hydrated lime neutralization of an approximate 90 million gallon ARD impacted tailings impoundment will be discussed. The third water treatment technology describes a system, which grinds limestone to ultra-fine grain sizes (The HALT system) resulting in rapid neutralization reactions occurring in ARD impacted water. Limestone is generally cheaper than most other sources of alkalinity and the maximum pH value that can be reached during dissolution is 8.5.

Additional Key Words: Neutra-Mill®, HALT, acid neutralization

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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BAUXSOL™ TECHNOLOGY TO TREAT ACID AND METALS; APPLICATIONS IN THE COAL INDUSTRY[19]

M. Clark, D. McConchie, J. Berry, W. Caldicott F. Davies-McConchie and J. Castro[20]

Abstract. The mining of coal most often leads to the development of Acid Rock Drainage (ARD) because during peat accumulation anoxic and reducing conditions establish and an availability of sulphate and reducible iron, even at low concentration, leads to the formation of iron sulphides (mostly pyrite). Once exposed oxidation and acid generation occurs, which may mobilize trace metals from the coals. The combination of acid and metals can seep into water ways where it can effectively sterilize many km of stream, and deposit substantial quantities of iron oxy-hydroxides. Frequently waste rock and coal washery tailings are stored where they provide suitable habitat for bacteria that accelerate the oxidation of pyrite and the production of acid.

Aberdare East colliery is a former underground mine located in Cessnock, New South Wales, Australia. Coal washery tailings from the mine are impounded in a series of overlapping stacked cells in a small catchment. Relatively clean water enters the south eastern extent of the tailings and moves to the northwest down the hydrological gradient, and exit the north western batter slope into the a small creek. During flow through the tailings salinity, metal content, redox potential, and temperature all increase; solution pH decreases. Investigations indicate that the impoundment contains 109,445 m^3 of water, 337,793 m^3 saturated fines, 720,113 m^3 of unsaturated fines, and 184,568 m^3 of clay capping.

Treatment rates indicate that the water requires 5.123kg/m^3 of Bauxsol™ Acid B Extra™ C5T5 blend (561 t) and that a further 24,000 t of Bauxsol™ ViroMine™ is required to prevent further acidity at the site being generated. This compares favourably with lime of 0.951 kg/m^3 for the water (104 t) and 32,750 t to prevent further acid production from the tailings. Additional benefits from the Bauxsol™ based treatments are lowered sludge volumes during water treatment, increased chemical stability of the residues and therefore greatly reduced disposal costs, a decreased susceptibility to dissolution of the ANC from the soil/tailings profile that reduces the possibility of having to reapply after 5 or 10 years and, consequently, a reduced safety margin for the Bauxsol™ application is required.

[19] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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SCIENCE, ARTS AND AMD REMEDIATION: BOTH NECESSARY, NEITHER SUFFICIENT[21]

T. Allan Comp[22]

Abstract. AMD remediation and the public support that is often essential to funding that remediation offer the opportunity to reconnect the Sciences and the Arts, to establish a much wider circle of support for our work. Drawing on two examples, one in western Pennsylvania and one in southwestern Virginia, this plenary presentation suggests that science alone may not be sufficient, particularly in places with significant public access or visibility. Engaging what academia traditionally defines as the Arts, whether just good interpretation or broader history, landscape design, even literature, can bring significant improvement to the range of human accessibility of our work in coal country. Good design is more than clean water; it is also an opportunity for public engagement, even delight. Good history opens opportunities for better understanding, of AMD and why it is there, of coal country environments, of our national values and how they have changed over time, even for reflection on the remarkable achievements of our predecessors and our own contemporary role in that continuum of history and environmental concern. Equally important, engaging the Arts also engages a variety of new partners and new sources of support for AMD remediation in coal country, expanding both the community interest in and the support for addressing the most emblematic of environmental problems in the Appalachian coal fields, Acid Mine Drainage.

Additional Key Words: Landscape Design, History, Interpretation, Partnerships, Watershed Assistance

[21] Paper was presented at the 2004 National Meeting of the American society of Mining and Reclamation and the 25th West Virginia Surface mine Drainage Task force, April 18-24, 2004 Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE EFFICIENCY OF PASSIVE TREATMENT SYSTEMS AND THEIR IMPACT ON SEATON CREEK[1]

Emily Coughlin, James Dunne, Candace McClure, Shawn Rummel, Fred J. Brenner, and Shaun Busler[2]

Abstract. The Slippery Rock Creek Watershed has been impact by acid mine drainage for over 100 years. Since 1997, fourteen passive treatment systems have been installed within the watershed treating over 300 million gallons of mine drainage annually. The current study focuses on the impact of mine drainage discharges on Seaton Creek and Murrin Run, the two major tributaries to the head-waters of Slippery Rock Creek. In this study, the efficiencies of six passive treatment systems were analyzed as to their impact on receiving streams. The passive treatment systems installed at Desale I, II, and III are comprised of settling ponds, vertical flow ponds (VFP), aerobic wetland and horizontal limestone beds (HFLB). Two passive treatment systems were installed Goff Station with each system being comprised of two vertical flow ponds and an aerobic wetland. The system at Erico Bridge consists of an anoxic limestone drain that discharges into an aerobic wetland system. For each system monitoring points were located at discharge and above and below each stage in the various systems. At each sampling interval, the pH, alkalinity, and dissolved oxygen were recorded at each monitoring location and water samples were collected for laboratory analysis of acidity, alkalinity, pH, conductivity, total dissolved solids, sulfates, total and dissolved metals (iron, manganese, aluminum). Although each system varied in their efficiency, in all systems the pH increased from <3 to between 6.0 and 7.2 and alkalinity exceed acidity in the final discharge to receiving streams. The systems comprised of a combination of vertical flow ponds and aerobic wetlands were effective in removing iron and manganese and the concentrations of these metals were < 4 mg/l in the final discharge even in those systems where the concentration of iron and aluminum exceeded 50 mg/l in the inflows to the systems. But, only these systems with horizontal limestone beds as the final treatment system were effective in removing manganese from the mine drainages. As a result of the improvement in water quality in the receiving streams, macroinvertebrates and fish are beginning to re-colonize these streams systems. During the last two years, caddisflies, mayflies, dragonflies, damselflies, crayfish and three fish species have been collected in both Seaton Creek and Murrin Run below the discharges from these passive treatment systems.

Additional Key Words: Passive Treatment Systems, water quality, aquatic communities

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004, Published by ASMR, 3134 Montavesta Rd. Lexington, Ky 40502

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ACIDITY AND ALKALINITY IN MINE DRAINAGE: PRACTICAL CONSIDERATIONS[23]

Charles A. Cravotta III[2] and Carl S. Kirby[24]

Abstract. In this paper, we emphasize that the Standard Method hot peroxide treatment procedure for acidity determination (hot acidity) directly measures net acidity or net alkalinity, but that more than one water-quality measure can be useful as a measure of the severity of acid mine drainage. We demonstrate that the hot acidity is related to the pH, alkalinity, and dissolved concentrations of Fe, Mn, and Al in fresh mine drainage. We show that the hot acidity accurately indicates the potential for pH to decrease to acidic values after complete oxidation of Fe and Mn, and it indicates the excess alkalinity or that required for neutralization of the sample. We show that the hot acidity method gives consistent, interpretable results on fresh or aged samples.

Regional data for mine-drainage quality in Pennsylvania indicated the pH of fresh samples was predominantly acidic (pH 2.5 to 4) or near neutral (pH 6 to 7); approximately 25 percent of the samples had intermediate pH values. This bimodal frequency distribution of pH was distinctive for fully oxidized samples; oxidized samples had acidic or near-neutral pH, only. Samples that had near-neutral pH after oxidation had negative hot acidity; samples that had acidic pH after oxidation had positive hot acidity. Samples with comparable pH values had variable hot acidities owing to variations in their alkalinities and dissolved Fe, Mn, and Al concentrations. The hot acidity was comparable to net acidity computed on the basis of initial pH and concentrations of Fe, Mn, and Al minus the initial alkalinity. Acidity computed from the pH and dissolved metals concentrations, assuming equivalents of 2 per mole of Fe and Mn and 3 per mole of Al, was comparable to that computed on the basis of aqueous species and Fe^{II}/Fe^{III}. Despite changes in the pH, alkalinity, and metals concentrations, the hot acidities were comparable for fresh and aged samples. Thus, meaningful "net" acidity can be determined from a measured hot acidity or by calculation from the pH, alkalinity, and dissolved metals concentrations. Together, these water-quality data can be useful for evaluating the potential for toxicity, corrosion, or encrustation and can be helpful for determining the appropriate remediation. By demonstrating the measurements on fresh and aged samples, we hope to encourage (1) consistent use of the hot peroxide treatment procedure for acidity determination and (2) consistent reporting of negative acidity values.

[23]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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OPTIMIZATION OF LIMESTONE DRAINS FOR LONG-TERM TREATMENT OF MINE DRAINAGE, SWATARA CREEK BASIN, SCHUYLKILL COUNTY, PA[25]

Charles A. Cravotta III, Suzanne J. Ward, Daniel J. Koury, and Ryan D. Koch [26]

Abstract. Limestone drains were constructed in 1995, 1997, and 2000 to treat acidic mine drainage (AMD) from the Orchard, Buck Mtn., and Hegins discharges, respectively, in the Swatara Creek Basin, Southern Anthracite Coalfield, east-central Pennsylvania. This report summarizes the construction characteristics and performance of each of the limestone drains on the basis of influent and effluent quality and laboratory tests of variables affecting limestone dissolution rates. Data for influent and effluent indicate substantial alkalinity production by the Orchard and Buck Mtn. limestone drains and only marginal benefits from the Hegins drain. Nevertheless, the annual alkalinity loading rates have progressively declined with age of all three systems. Collapsible-container (cubitainer) testing was conducted to evaluate current scenarios and possible options for reconstruction and maintenance of the limestone drains to optimize their long-term performance. The cubitainer tests indicated dissolution rates for the current configurations that were in agreement with field flux data (net loading) for alkalinity and dissolved calcium. The dissolution rates in cubitainers were larger for closed conditions than open conditions, but the rates were comparable for coated and uncoated limestone for a given condition. Models developed on the basis of the cubitainer testing indicate (1) exponential declines in limestone mass and corresponding alkalinity loading rates with increased age of limestone drains and (2) potential for improved performance with enlargement, complete burial, and/or regular flushing of the systems.

Additional Key Words: limestone dissolution rate, cubitainer tests, armoring.

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[25] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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FUTURE DIRECTIONS OF THE COAL MINING SECTOR OF THE ACID DRAINAGE TECHNOLOGY INITIATIVE AND THE NEEDS FOR ACID DRAINAGE RESEARCH[27]

John Craynon[28]

Abstract. ADTI is a coalition of Federal and State agencies, industry, academia, and consulting firms working together to address a range of issues dealing with the technical problems of predicting and controlling acid drainage. The ADTI is organized into two major groups, a coal mining sector and a metal mining sector. The Coal Mining Sector (http://wvwri.nrcce.wvu.edu/ADTI) is organized into two primary working groups, one on prediction and the other on avoidance and remediation methods. Recently, the Coal Mining Sector met to review its accomplishments, the status of ongoing studies, and to develop a five-year plan for future studies and efforts. This paper discusses the planned activities of the Coal Mining Sector of ADTI and future research needs related to acid drainage.

Additional Key Words: acid mine drainage, acid rock drainage, coal mining sector.

[27] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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MINE SOIL MORPHOLOGY AND PROPERTIES IN PRE- AND POST-SMCRA COAL MINED LANDSCAPES IN SOUTHWEST VIRGINA[1]

W. Lee Daniels, Kathryn C. Haering, and John M. Galbraith[2]

Abstract. Surface coal mining and reclamation methods in the Appalachians have changed dramatically since the passage of the Surface Mining Control and Reclamation Act (SMCRA) of 1977 and subsequent improvements in mining and reclamation technology. In this study, 30 pre-SMCRA mine soil profiles (4-20 yr old) were examined and sampled in 1980 and compared to 20 mine soil profiles (8-13 yr old) described in the same area in 2002 after it had been completely re-mined by modern deep cut methods. Mine soils in both sampling years had high rock fragment content (42 to 81%), relatively well-developed A horizons, and generally exhibited A-C, or A-AC-C horizonation. Although six Bw horizons were described in 1980, only two met all requirements for cambic horizons. The 1980 mine soils developed in overburden dominated by oxidized, pre-weathered material due to relatively shallow mining cuts. The 1980 mine soils had lower rock fragment content, finer textures, lower pH, and tended to be more heterogeneous in horizonation, morphology, and texture than soils observed in 2002, which had formed primarily in unweathered overburden from deeper cuts. Half the pedons sampled in both years had densic materials within 70 cm of the surface. Four poorly to very poorly drained soil profiles were described in each sampling year containing distinct hydric soil indicators in surface horizons. While older pre-SMCRA mine soils do have many properties in common with newer mine soils, their properties are highly influenced by the fact that they generally have formed in more weathered overburden from higher in the geologic column. Overall, Appalachian mine soils are much more complex in subsoil morphology than commonly assumed, and differential compaction greatly complicates their internal drainage and limits their overall productivity potential.

Additional Key Words: Pedogenesis, overburden, weathering, cambic horizon, densic layers.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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MINE SOIL CLASSIFICATION AND MAPPING ISSUES ON PRE- AND POST-SMCRA APPALACHIAN COAL MINED LANDS[1]

W. Lee Daniels, Kathryn Haering, John Galbraith and Jeff Thomas[2]

Abstract. Soils formed on lands mined for coal in the Central Appalachians are currently classified by *Soil Taxonomy* primarily as Typic Udorthents, which does not distinguish these unique anthropogenic soils from other weakly developed natural soils. In this study, we evaluated the effectiveness of currently utilized mine soil series for describing and classifying a range of mine soil pedons in southwest Virginia. Using established series concepts, we mapped and classified approximately 450 ha of mine soils in an area that had been reclaimed in accordance with the U.S. Surface Mining, Control, and Reclamation Act (SMCRA) of 1977. We also used current series concepts to reclassify mine soils in an adjacent and overlapping 250 ha that had been mined prior to SMCRA, and had been mapped using older (non *Soil Taxonomy*) mine soil classification criteria in 1980. Established mine soil series concepts provided adequate information on particle-size and reaction class, but did not adequately describe drainage class, rock type or parent materials. Classification differences occurred on well-drained soils primarily at the family level and below. There were no established series to describe mine soils with impeded drainage, densic layers, and shallow or moderately deep depth classes, all of which commonly occurred in this study area, and are important criteria for separating soil series. Cambic horizons were also described, and generate classification issues at the order level. Using current taxonomic/mapping procedures, none of these dissimilar soils would be considered limiting inclusions to the dominant soil in the map unit. Since reaction class, drainage class, densic contacts, and soil depth directly affect soil management, we feel that it is important to recognize these features by establishing new mine soil series or phases of established series. Older, pre-SMCRA mined lands are much more complex in short-range landform variability than more modern reclaimed landscapes. This pattern of soil landscape variability and associated differences in land use capability is effectively captured by large scale mapping such as that employed by this study.

Additional Key Words: Drainage class, cambic horizon, densic contact.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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PHYSIOLOGICAL OVERVIEW OF RAINBOW TROUT GROWN IN RECLAIMED MINE-WATER[1]

Melody L. Danley[2] and Patricia M. Mazik

Abstract. Rainbow trout (*Oncorhynchus mykiss*) aquaculture in Northern Appalachia is a small-scale industry that produces variable quality and quantity food-fish among farms. Further development and expansion of aquaculture in the region has been prompted by increased global demands for food, abundant local water supplies, and struggling rural economies that have some of the highest unemployment rates in the United States. The following study was conducted as part of the West Virginia University Aquaculture Food and Marketing Development Project. As part of the development project, the objectives of the present study sought to investigate the feasibility of using reclaimed mine-water for aquaculture purposes. Specific questions related to the study included: 1. Can fish be grown successfully (low mortality with economically sufficient growth rates) in reclaimed mine-water? 2. Are the fish grown in reclaimed mine-water healthy (as measured by various physiological parameters)? 3. Are the fish safe for human consumption? 4. Is culture performance in reclaimed mine-water dependent on the rainbow trout strain used? Selected aspects of the second, third and fourth questions of the study will be presented in this abstract.

Three stains of juvenile rainbow trout were grown in a flow-through raceway supplied with reclaimed mine-water (treatment fish) from October 2002 to May 2003. Sibling counterparts (control fish) for each of the strains were grown in flow-through, circular fiberglass tanks at the USDA Center for Cool and Cold Water Research during the same time period. Throughout the study, all fish were fed daily with commercial trout chow. Growth, physiological status, heavy metal content, and water quality parameters were measured at least monthly throughout the study using standard methods and materials. Results for the physiological and heavy metal assessments are presented here. Blood samples were collected using heparinized syringes for assessment of plasma chloride, glucose, and lactate concentrations, and whole fish were collected for assessment of selenium, magnesium, iron, manganese, and aluminum concentrations.

Results of the study show mean plasma glucose and lactate concentrations (indicators of energy-balance and anaerobic activity, respectively) were within the normal physiological ranges of rainbow trout. No differences were noted among the three strains of treatment fish, or between fish grown in reclaimed mine-water

[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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FIRST-YEAR SURVIVAL OF NORTHERN RED OAK SEEDLINGS PLANTED ON FORMER SURFACE COAL MINES IN INDIANA[1]

Anthony S. Davis[2] and Douglass F. Jacobs[2]

Abstract. Surface mining of coal in Indiana is an important industry. Post-mining sites are often characterized by poor soil physical properties, low nutrient availability, and severe compaction 30 cm below the soil surface. hese characteristics can result in poor seedling survival, low productivity, erosion, and therefore low land value, which may ultimately lead to conversion of the land to other uses. For reclamation to forestland to be effective, seedling establishment success must be improved. Myriad studies have assessed the influence of stocktype, mycorrhizae, and fertilization on seedling survival and performance; however, few have studied their influence on northern red oak (*Quercus rubra* L.) planted on reclaimed mined lands. The objectives of this research are to compare the effectiveness of four stocktypes and assess the contribution of controlled-release fertilizer and mycorrhizal inoculation to survival and performance of northern red oak on reclaimed mined lands. Northern red oak is known to survive on a variety of sites and has a high commercial value and was therefore selected as the trial species. The four stocktypes consisted of June-sown and January-sown containerized seedlings, and standard-density (75 seedlings/m^2) and low-density (21 seedlings/m^2) one year old bareroot seedlings. Three treatments were applied to each stocktype: mycorrhizal inoculation (MI), addition of controlled-release fertilizer (CRF), and both MI and addition of CRF. A control, with neither MI nor addition of CRF, was established for each stocktype. Seedlings were planted in April 2003 at two sites and initial height and root-collar diameter were recorded. Survival was assessed in October 2003. Survival for low-density (68%) and standard-density (69%) bareroot seedling stocktypes, and June-sown containerized seedlings that did not receive CRF (64%) was greater than that of June-sown containerized seedlings that received CRF (35%) and January-sown containerized seedlings (30%). That CRF negatively influenced seedling survival in June-sown containerized seedlings indicates that the interactions between seedling development and CRF need further investigation.

[1]Paper presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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OPERATION AND MAINTENANCE CONSIDERATIONS FOR A PASSIVE TREATMENT COMPLEX[1]

Clifford F. Denholm[2], P. J. Shah, Tiff Hilton, Timothy P. Danehy, Shaun L. Busler, and Margaret H. Dunn

Passive systems require no electricity and use environmentally-friendly materials such as limestone aggregate and spent mushroom compost to provide a cost-effective alternative to conventional chemical treatment of mine drainage. Although requiring significantly lower maintenance compared to conventional systems, passive treatment is not a no-maintenance solution. Between 1999 and 2001, a 6-component (Phase I) and a 22-component (Phase II) passive complex were installed at the Harbison Walker Restoration Area (Ohiopyle State Park, Fayette County, PA) to treat numerous mine discharges associated with an old surface clay and coal mine. In combination, the two facilities are treating over 227 million liters (60 million gallons) of severely degraded mine drainage per year, neutralizing ~227 kg/day (~500 lbs/day) of acidity and preventing over 45 kg/day (100 lbs/day) of metals from entering a High Quality Cold Water Fishery. Because of the significant benefit to the stream, development and implementation of an Operation and Maintenance Plan was imperative to insure long-term, consistent, functioning of this facility. To date, periodic site inspections and monitoring have identified the need for flushing of solids from the treatment media, for revegetation of selected areas, for replacement of damaged pipes, and for removal of debris from spillways and ditches. Water monitoring, an integral part of the O & M Plan, has enabled documentation of the individual and combined effectiveness of each component and advancement of passive treatment technology.

Additional Keywords: operation & maintenance, passive treatment system, AMD, mine drainage

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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THE FUTURE OF MINE-WATER DISCHARGES FROM UNDERGROUND COAL MINES OF THE PITTSBURGH COAL BASIN, WV-PA[1]

Joseph J. Donovan[2] and Bruce R. Leavitt

Abstract. Numerous underground coal mines in the Pittsburgh coal basin of West Virginia and Pennsylvania have closed in the period 1980-2003. Of an estimated 1000+ once-active mines, only 11 are currently active, most relatively deep in the basin. These closures have caused flooding of mines and caused new discharges of mine water, of which all are either currently flooding or pumped and treated by mine operators or state agencies.

This newly-created aquifer is a series of semi-interconnected compartments formed by mines separated by barrier pillars of 25->400 feet thickness. The leakage rate through barrier pillars is quite variable spatially and may be either very high (with hydrologically open conditions between adjacent mines) or very low (creating relatively isolated "pools" of one or more mines). Due to this fact and to the various closure dates of mines, the flooding history is complex with mines at a wide variety of water levels and flooding extents. However, experience shows that most mines near the Monongahela River flood within 10 years or less, and thus a new "equilibrium state" is expected to be attained by about 2015. At this time, flooding of most mines will be complete and an estimated 53,000 gpm (85,479 acre-ft/year) of mine discharge – both treated and untreated – will flow into the Monongahela watershed from below-drainage mines. This is in addition to an additional 8000 gpm estimated from above-drainage free-draining mines. At this time, the flooded Pittsburgh coal will become the largest spatially-continuous high-yield aquifer exclusive of Cambro-Ordovician karst aquifers in the Northern Appalachian region.

The locations of discharge from mines are known for 2003, subject to limitations of data availability, and may be speculatively projected for year 2015, subject to numerous assumptions and future circumstances. It is expected that all of the new discharges will require active treatment for metals removal to prevent discharge to the Monongahela and Ohio river watersheds. This resource of treated water may be utilized for other purposes, such as commercial development and aquaculture.

Additional Key Words: Mining hydrogeology, groundwater

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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MINE WATER AQUACULTURE: LINKING COAL MINING, FISH FARMING, WATER CONSERVATION AND RECREATION[1]

Gerard D'Souza and Daniel Miller[2]

Abstract: West Virginia has many active and abandoned mine sites that have plentiful water supplies potentially suitable for raising trout, arctic char or other aquaculture species. While the technical feasibility of raising fish in mine water for food or recreational purposes has been demonstrated and shown to be within acceptable food safety limits, the economic and financial feasibility have not been fully explored, our objective in this analysis.

Additional costs incurred in aquaculture production from mine water can be less than with a conventional aquaculture operation. One reason is because government regulations require mine water to be treated before it is discharged, thus providing an aquaculture production facility access to a relatively low-cost resource and simultaneously contributing to conservation of this resource. We quantify the costs and benefits of mine water aquaculture using standard financial feasibility techniques and data from primary and secondary sources. We also illustrate the potential economic development impacts (i.e., economic multipliers) of growth in the aquaculture industry on statewide output, income, and employment. In general, we find that, under the conditions investigated, mine water aquaculture is financially feasible from the fish farmer's standpoint (feasibility from the mining company's viewpoint is also important, but has not been explored) and, if widely adopted, will result in sizable economic development benefits. The results have implications for the aquaculture and coal industries in Appalachia, and should also be useful to policy makers in other parts of the country where coal mining can be linked to fish farming, water conservation, and recreation.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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EVALUATION OF THE EFFICIENCY OF PASSIVE TREATMENT SYSTEMS ON WATER QUALITY IN THE HEADWATERS OF SLIPPERY ROCK CREEK[1]

James Dunne, Emily Coughlin, Candace McClure, Shawn Rummel,
Fred J. Brenner and Shaun Busler[2]

Abstract: To treat acid mine drainage, both active and passive methods are utilized for the removal of acid and metals. Individual passive technologies target specific aspects of acid mine drainage, and consequently overall efficiency of passive systems can be significantly enhanced with the linking of multiple components. Within the Slippery Rock Creek Watershed, a wide variety of passive systems are being employed to treat acidic mine discharges. Two anoxic limestone drains (ALDs) used in conjunction with aerobic wetlands consistently maintain pHs between 6.4 and 7.2 pH units. Iron concentrations are reduced significantly within these ALD/wetland systems, with an average removal of 32 mg/L at an average flow of 89 gpm, but these systems are generally not effective in removing manganese from acid mine discharges. But, when Vertical flow ponds (VFPs) are used in combination with aerobic wetlands and horizontal flow limestone beds (HFLBs), the discharges to receiving streams are have alkalinity in excess of acidity, alone with a reduction in metal concentrations. For the two VFP/aerobic wetland and HFLB systems, 27 mg/L of alkalinity (as $CaCO_3$) was added to the average flow of 61 gpm to receiving streams and iron, manganese, and aluminum concentrations were reduced by 40 mg/L, 16 mg/L and 27 mg/L, respectively. In addition, pH units were increased from between 2.87 and 3.80 in the inflows to an average of between 6.8 and 7.2. These studies are continuing to analyze the efficiencies of the individual system components.

Additional Key Words: Passive Treatment, Water Quality, Watershed

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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INTERSTATE TECHNOLOGICAL REGULATORY COUNCIL (ITRC) CONSTRUCTED TREATMENT WETLANDS GUIDANCE DOCUMENT[1]

Paul Eger[2]

Abstract. The Interstate Technological Regulatory Council (ITRC) was formed in 1995. Although the ITRC is a state led organization (41 member states), it also includes personnel from the District of Columbia; three federal agencies; and tribal, public, and industry stakeholders. The primary objective is to provide assistance to state regulatory personnel so they can better understand innovative technologies and permit them more quickly, thereby providing less expensive alternatives to standard treatment techniques. Assistance is provided in the form of technical documents and classroom and internet training.

ITRC produces technical and regulatory documents through the use of technical teams, comprised of state agency staff from at least 5 states, and members from universities, industry, federal agencies and public stakeholders. In 2001, a team was formed to examine the use of constructed wetlands to treat a wide variety of wastewater, including: stormwater, municipal and onsite wastewater, mine drainage, agricultural runoff, industrial discharges, landfill leachate, and water from site remediation activities. Although constructed wetlands have been commonly used in some applications, their use in remediation projects is relatively new.

The guidance document was completed in late 2003, and internet training will begin in 2004. The document includes a general description of removal mechanisms, the types of wetland treatment systems, the use of wetlands for each type of wastewater with typical input concentrations and removal efficiencies, design, construction and cost information, regulatory considerations, case studies and a decision tree for each application. The decision trees should help both regulators and applicants work through the process of successfully developing and permitting a wetland for a given application.

The team is currently working on a guidance document on mitigation wetlands; wetlands constructed to replace those impacted by human activity.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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The Use of Sulfate Reducing Bacteria to Remove Sulfate from Iron Mining Tailings Water[29]

Paul Eger,[30] Tom Moe, and John Engesser

Abstract. A column experiment was conducted to evaluate the ability of various substrates to support sulfate reducing bacteria and remove sulfate from iron mining tailings basin water in northern Minnesota. The tailings water has a pH of around 7.5, 800 mg/L of sulfate and low levels of iron and trace metals. Although sulfate was removed in all columns, overall removal rates varied widely between substrates, ranging from 270 to about 3000 mmoles/m^3/day. The best removal occurred in the columns that were fed an organic carbon source, either ethanol or molasses. An organic substrate based column, biosolids + sawdust + hay, also had a high reaction rate but produced unacceptable levels of hydrogen sulfide. Effluent sulfate concentrations in some of these columns were below 50 mg/L and the reaction rate may have been sulfate limited. Methanol was also tried as an organic carbon source but the reaction rate was only about 50% of the rates achieved with ethanol and molasses. Based on the column results, a field pilot cell was designed and constructed in 2002. The cell was built solely with an inorganic iron rich substrate and ethanol was used as the carbon source. Although sulfate reduction occurred, flow problems developed and the system was redesigned in 2003. Through early December 2003, the system was treating about 400 L/minute and reducing sulfate from about 800 to 400 mg/L.

[29] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginaa Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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The New West Virginia Mine Land Reforestation Initiative[1]

Scott D. Eggerud[2]

Abstract. The West Virginia Department of Environmental Protection's Division of Mining and Reclamation has initiated a new effort to promote reforestation of mined lands in West Virginia. The goal of this initiative is to expedite the establishment of commercially valuably native timber stands. Forest productivity, species diversity, and natural invasion and succession will be emphasized. Traditional methods of reclamation have produced sites with decreased productivity compared with the pre-mining conditions. Compaction of the growth media, poor quality overburden materials used in the growth media, competition from ground covers, inferior species of trees planted, and poor tree planting techniques including timing, have all contributed to decreased productivity on many of our past reforestation efforts. The new reforestation technology encourages reforestation of mine sites through developing an optimal growth medium, loosely grading topsoil and topsoil substitutes, establishing less aggressive ground covers, planting commercially valuable crop trees, and using proper tree planting techniques. "The New West Virginia Mine Land Reforestation Initiative" includes regulatory changes, education, training and technology transfer.

Additional Key Words: forestland, commercial woodland, commercial forestry, growth medium, compaction, competition, experimental practices.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE COPPER BASIN RECLAMATION PROJECT[1]

Ben B. Faulkner,[2] Ken L. Faulk, and Franklin K. Miller

Abstract. For more than 150 years, the Copper Basin in southeast Tennessee was the site of extensive copper and other metal mining and sulfuric acid production. It is one of the most dramatically impacted mining areas in the eastern United States. As part of voluntary remediation efforts at the site, Glenn Springs Holdings has committed to remedial actions within the affected tributaries of the Ocoee River with long-range goals of restoring biodiversity and biointegrity. This work follows decades of land reclamation and reforestation efforts on the 9,000 hectare (35 square mile) site by industry, TVA, and other interests. Accomplishments in the comprehensive program include on-going and proposed chemical treatment of acidic surface and underground mine drainage, demonstration land reclamation, demonstration passive treatment systems, restored stream segment, tailings and mine waste reclamation, waste characterization, surface water and storm water study, pit limnology and leak study, PCB removal, lead cap, hazards fencing, subsidence monitoring, stream diversion, and future land use planning.

Additional Key Words: Ducktown TN, acid mine drainage, Ocoee River

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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EVALUATING IMPACTS OF MOUNTAIN TOP REMOVAL/VALLEY FILL COAL MINING ON STREAM FISH POPULATIONS[31]

C. Paola Ferreri, Jay R. Stauffer, and Timothy D. Stecko[32]

Abstract. Little information exists regarding the effects of mountain top removal/valley fill coal mining on stream fish populations in West Virginia and Kentucky. To address this knowledge gap, we conducted a study in cooperation with U.S. Environmental Protection Agency (USEPA) Region III to characterize the fish communities that exist in these regions and to evaluate the effects of these mining operations on fish populations. During 1999-2000, fish assemblages were sampled in 58 sites in West Virginia and in 15 sites in Kentucky. Results from this sampling effort indicated that not enough reference (unmined) sites were included to adequately assess the potential effects of mountain top mining/valley fill operations on fish communities in the area. We found a strong relationship between stream size (as described by stream order) and the total number of fish species present that confounded the effects of mining. As a result, in Fall 2001, we sampled 13 sites in the Guyandotte River drainage, including eight sites in the Mud River that were classified as filled or filled/residential and five reference (unmined) sites in the Big Ugly. Both the number of species and the number of benthic species present were greater in the reference sites than in the filled sites in 2001. Water chemistry analysis revealed that five of the Mud River sites sampled in 2001 had detectable levels of selenium (9.5 – 31.5 µg/l). Sites that were associated with valley fills that had detectable levels of selenium seemed to be more impaired than sites associated with valley fills that had no detectable levels of selenium. Clearly, careful site selection and a multiple year collecting regimen are needed to determine the effects of these mining operations on stream fish assemblages.

Additional Key Words: fish communities, selenium

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[31] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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AN OVERVIEW OF PLANNING AND MANAGEMENT OF THE LAND APPLICATION SYSTEM ON THE GOSLIN FLATS – ZORTMAN AND LANDUSKY MINES, MONTANA[1]

Scott E. Fisher Jr.[2]

Abstract. The Zortman and Landusky gold mines are located on the southern reaches of the Little Rocky Mountains in north central Montana. Gold has been mined and concentrated in the area since the late 1800's. Pegasus Gold Corporation acquired the property and began intensive development in the 1970's with state and federal permits. Gold production was based on extraction of the ore by the cyanide heap leach process. Pegasus filed for bankruptcy in 1998 and reclamation became the state and federal agencies responsibility. Process solutions in the heap leach pads rose and disposal became necessary when the danger of their spilling into surface waters became a real possibility. The pad solutions contained elevated levels of cyanide, nitrates, selenium, sodium, salinity, and several other potentially toxic microelements in concentrations above water quality standards. Land application of the effluent was initiated shortly thereafter on the Goslin Flats south of Zortman, MT. The initial system covered 22.3 hectares (55 acres) but was rapidly expanded to approximately 166 hectares (410 acres) – the majority of which was located on an outwash terrace system and floodplain along Ruby Creek. Treated pad solutions were distributed on the land application area via a main line from the water treatment plants to laterals with risers supporting evaporative sprinkler heads. Inadequate design of the initial LAD system limited distribution and applied evaporation concentrated solution near the sprinkler head limiting application to a small portion of the LAD area. Some of the laterals were up to 90+ meters or more in length – often trending upslope from the main. Effluent application from the pads was concentrated near the riser/sprinkler heads. Modifications to the distribution system have been recently initiated. Collection of additional baseline data and an expanded monitoring program were initiated in 2001 to provide information of modification of the LAD system and to determine the impact of the effluent application on soil and plant systems. Preliminary data suggest that currently there currently is limited forage toxicity. Significant impacts to the soil system have occurred with most soils now being both saline and sodic/alkaline and containing potentially toxic levels of selenium.

Additional Key Words: land application disposal (LAD) systems, salinity, sodicity, selenium, nitrates, cyanide, LAD resource baseline studies, LAD monitoring programs, cyanide heap leach pad solution, irrigation impacts.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Mine Drainage Task Force, April 18-24, 2004. Published by the ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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BIOLOGICAL AND ECONOMIC HURDLES TO PRIVATE FOREST OWNERSHIP OF RECLAIMED STRIP MINES[1]

Victor L. Ford

Abstract. Most mine lands after reclaimed just "hold the world together". While a cover crop of mostly exotic plants provides some wildlife habitat, little of value can be grown to produce wood products. Most ownerships do not seek reclaimed mine lands but purchase or hold them for the value in adjacent lands. Besides hunting leases, these lands do not generally pay their way in acceptable economic returns. If commercial forestry, especially high value timber species, can be grown on these lands, they become more valuable. Mined lands can become important sources of fiber during wet times of the year because of existing all weather access and the characteristics of the soil that allow harvesting during these times. Carbon credits may make these lands very valuable. To create economically viable land, soils; sites; silviculture; regulations; and finances must all must be understood to create a management system.

Additional Key Words: financial return, economic analysis, commercial forestry

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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SOIL RECONSTRUCTION ON SURFACE MINED LAND USING A PROTOTYPE MECHANICAL SYSTEM.[33]

J.P. Fulton and L.G. Wells[34]

Abstract: Soil compaction due to heavy earth moving equipment remains an impediment for the surface mining industry to return prime farmland back to pre-mining performance. The purpose of this investigation was to fabricate and evaluate a mechanism, called the "Soil Regenerator", for constructing the top- and sub-soil profiles without the introduction of machinery traffic in order to minimize compaction during reclamation. The prototype system was mounted on the front of a bulldozer. Windrows of soil were constructed using a scraper or bulldozer for the mechanism to process. The bulldozer engaged the windrows allowing soil to rise up the blade and be agitated, transported, and deposited by a helicoid auger resulting in a 0.9 m deep berm adjacent to the bulldozer. An uncompacted soil medium was built by making successive parallel passes. Testing resulted in processing capacities ranging from 330 to 804 m^3/hr for the prototype, which was much less than the projected theoretical design capacity of 2680 m^3/hr. However, dry bulk densities equal to or less than 1.0 Mg/m^3 were produced along with penetrometer measurements below 0.7 MPa. These results proved that the 'Soil Regenerator' was capable of eliminating soil compaction during reclamation of surface mined land.

Additional Keywords: Reclamation, Surface Mining, Soil Handling System, Soil Profile, Reclamation and Excavating Equipment.

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[33] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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PROPOSED CHANGES TO SOIL TAXONOMY THAT MAY AFFECT MINE SOIL CLASSIFICATION[1]

J.M. Galbraith[2]

Abstract: Mine soils begin developing horizons from natural processes after mining excavation and transportation of spoil ceases. Spoil deposits and altered landforms are easily recognized from a distance but the soils in those landforms seldom contain proof of their origin. *Soil Taxonomy* provides a few diagnostic horizons and materials and classes for mine soils. Most excavated or transported mine soils are identified in one of two suborders (*Arents* or *Orthents*) because they have no currently accepted diagnostic features other than remnant fragments of soil material. Mine soils (excavated and dredged) with *sulfuric horizons* are classified in "Sulf" Great Groups, although dredged deposits without *sulfidic materials* may classify in the *Fluvents* or *Psamments* suborders. There are no provisions in *Soil Taxonomy* to identify human transported material (HTM), human-manufactured or -modified materials, or to identify mine soils that contain those materials separately from natural soils such as in landslides. New designations and diagnostic layers and horizons are needed to establish new classes in *Soil Taxonomy* for HTM such as mine soils. The International Committee for Anthropogenic Soils (ICOMANTH) circulated letters requesting input for changes to describe, map, and manage mine soils. Most respondents would like to identify human-transported material with a special horizon prefix where evidence of mechanical transportation is left behind. Spoils left on the surface after surface mining or dredging presently have little variation in classification above the soil series level. Approximately two dozen soil series are available for identifying mine soils, although some of the series have overlapping properties. Many mine soils deposited following passage of the Surface Mining Control and Reclamation Act of 1977 contain *densic materials* due to compaction during reclamation, although none of the existing series recognize the *densic contact* that is the dominant factor in interpreting their use and management. Proposals to revise Soil Taxonomy will be submitted following recommendations from ICOMANTH with the goal of providing classes for mine soils with unique properties.

Additional Key Words: Spoil, Artifacts, *Densic Contact, Densic Materials*, *Sulfidic Materials*, Anthropogenic Soils, Human-altered soils.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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IMPACTS OF LAND APPLICATION OF SALINE-SODIC COALBED METHANE WATER ON SOIL PHYSICAL AND CHEMICAL PROPERTIES IN WYOMING[35]

Girisha K. Ganjegunte, Lyle A. King and George F. Vance[36]

Abstract: Changes in soil physical and chemical properties due to land application of coalbed methane (CBM) waters were investigated in study sites located in northwest Powder River Basin (PRB) of Wyoming. Samples of CBM water used for land application and analyzed for pH, electrical conductivity (EC), and sodium adsorption ratio (SAR) values. Water quality data indicated that EC and SAR values of CBM water samples were greater than the recommended values for irrigation use (0.75 dS m^{-1} and <10 SAR). Impacts of these poor-quality CBM waters on soil physical and chemical properties were evaluated by collecting soil samples during the 2003 irrigation season from 6 depths (0-5, 5-15, 15-30, 30-60, 60-90 and 90-120 cm) from 6 sites that received CBM water applications for up to 3 years, which were compared to control sites. Changes in soil physical (e.g., infiltration rates, bulk density) and soil chemical (pH, EC, and SAR of saturation paste extracts) properties were determined. Our study indicates that the pH values are significantly ($p = 0.05$) greater in irrigated plots than control plots at depths of 0-5 and 30-60 cm in site 1 and 0-60 cm in site 4. The EC values were significantly greater in irrigated sites than control plots at 0-60 cm depth in sites 1, 4 and 6, 5-30 cm in site 3, and 0-15 cm in site 5. SAR values were significantly greater in irrigated sites than control plots in the upper 60 cm in sites 1 and 5, 0-5 cm site 4, and 5-30 cm in site 6. Irrigated sites 1, 3, and 4 had significantly lower %clay. Hydraulic conductivity in sites 1 and 5 were significantly lower than control plots. Thus, irrigation with poor-quality CBM water had significant impacts on soil chemical and physical properties. It has been estimated that over the next 15 years CBM water production in the PRB will exceed 366,000 ha-m. The results of this study will be useful to understand the potential changes in soil properties due to land application of CBM waters and to develop possible mitigating criteria for preserving impacted PRB ecosystems.

Key Words: Soil, CBM Water, Sodium, Salinity, SAR, PRB, Wyoming.

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[35] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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TWO SUGGESTIONS FOR QUANTIFICATION OF FIELD MORPHOLOGY[37]

Robert B. Grossman, Cathy A. Seybold, and Deborah S. Harms[38]

Abstract. It should be useful for evaluation of the physical condition of mine soils to have field tests that (1) could be made at a narrow range of water suction and (2) stand largely independent of soil survey descriptive approaches. We would improve control of the water state by use of a Mariotte Container to add water. We further propose use of the so called Modified Singleton Blade test to evaluate resistance of the soil to failure against a stress. The test involves insertion of a blade, an established depth into the soil followed by rotation using a Pocket Penetrometer to measure the force required. The width of the blade selected is decreased as the strength of the soil fabric increases.

Additional Key Words: Singleton Blade, Soil Morphology Index, Mariotte Container.

[37] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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SCALING UP DESIGN CHALLENGES FOR LARGE SCALE SULFATE REDUCING BIOREACTORS[1]

James J. Gusek[2]

Abstract: The first large scale, 1,200 gpm capacity, sulfate reducing bioreactor (SRBR) was constructed in 1996 to treat water from an underground lead mine in Missouri. Other large scale SRBR systems have been built elsewhere since then. This technology holds much promise for economically treating heavy metals and has progressed steadily from the laboratory to industrial applications. Scaling-up challenges from bench- and pilot-sized systems include designing for: seasonal temperature variations, minimizing short circuits, changes in metal loading rates, storm water impacts, and resistance to vandalism. However, the biggest challenge may be designing for the progressive biological degradation of the organic substrate and its effects on the hydraulics of the SRBR cells. Due to the wide variability of the organic materials that may be locally available at reasonable costs, the design of organic substrate SRBR systems is not and may never become a "cookbook" approach. Balancing substrate geochemical requirements with intuitive physical resistance to organic decay currently plays a large role in the large scale system design process.

Keywords: Passive Treatment, acid rock drainage, heavy metals, sulfate reducing bacteria

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE LIFE CYCLE OF A PASSIVE TREATMENT SYSTEM:A STUDY OF THE OPEN LIMESTONE CHANNEL AT SOVERN RUN # 62[1]

J. Brady Gutta and Paul Ziemkiewicz[2]

Abstract: Limestone has long been the single most cost effective treatment in efforts to combat acid mine drainage. Over time, the constant degradation and inundation by iron sludge reduces the limestone's ability to neutralize the mine drainage. In September of 2003, a reworking of the open limestone channel at Sovern Run #62 was performed to increase the channel's ability to raise the pH, generate alkalinity, and precipitate metals. We will discuss the life cycle from the channel's initial installation to present day. Aspects including cost, performance, and the chemical parameters such as acidity, alkalinity, pH and metal concentrations will be examined.

[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18 – 24, 2004. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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AN EVALUATION OF HELICOPTER TIME DOMAIN ELECTROMAGNETIC SURVEYS FOR DETECTING DEEP, FLOODED MINE WORKINGS[39]

Richard Hammack[40], Ken Witherly, Mark Zellman, Brian Lipinski, Bill Harbert, and Terry Ackman

Abstract. The recent entrapment of nine coal miners by water at Quecreek Mine has directed national attention to the hazards of mining in proximity to inaccurately mapped or unmapped mine workings. Previous work by the National Energy Technology Laboratory has shown that helicopter frequency domain electromagnetic (FDEM) surveys can detect underground mine workings if: 1) the workings are flooded with conductive water, 2) the overburden conductivity is less than 30 mS/m, and 3) the workings are no deeper than 50 m. Currently, most active mines are at depths greater than 50 m, too deep to be detected with FDEM. This survey attempted to use helicopter TDEM, a technique with greater exploration depth than FDEM, to locate flooded mine workings at 100- to 200-m depths. Four mined areas in southwestern Virginia were selected for study: two areas contained active mines adjacent to flooded, abandoned mines (Quecreek Mine Scenario); two other areas contained abandoned and presumably flooded underground mines that were overlain by water impoundments; a municipal water supply reservoir and a coal slurry impoundment. The selected areas were especially challenging because they contain multiple levels of mining, thin seams, and mine water of relatively low conductivity. The rationale behind the choice of field sites was that if a technology worked in this admittedly difficult region, it could be applied to any coalfield. However, the survey was unsuccessful; mine workings known to be flooded were not detected. This paper discusses problems that were encountered, particularly electromagnetic noise, which rendered 25-50 pct of each flight line unusable.

Additional Key Words: Quecreek Mine, mine pools, mine voids, airborne geophysical surveys

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[39] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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A NATURAL CHANNEL DESIGN APPROACH TO STREAM RESTORATION ON RECLAIMED SURFACE MINE LANDS[1]

William A. Harman, Suzanne J. Unger, and Ronald H. Fortney[2]

Abstract. Natural channel design methods are being considered for the purpose of re-establishing stable stream channels and valleys on reclaimed surface mine lands. Natural channel design is the process of applying fluvial geomorphic principles to transform unstable stream corridors into stable channels that maintain their dimension, pattern, and profile over time. Additional goals include improving aquatic habitats and restoring native riparian vegetation. Natural channel design concepts are reviewed in the context of their application to reclaimed mine lands. A tributary to the Mitchell River in the Blue Ridge Mountains of North Carolina is used as a case study demonstrating techniques that may be applied to reclaimed surface mine land sites.

Additional Key Words: fluvial geomorphology, surface mining, revegetation, channel stabilization, mine land reclamation.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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A PROPOSAL FOR THE CLASSIFICATION OF ANTHROPOGENIC SOILS[1]

B.A. Hartman, J.T. Ammons[2] and N.T. Hartgrove

Abstract. The unique properties of anthropogenic (disturbed) soils have generated a variety of views and proposed taxonomic systems to deal with identification, inventory, and interpretations of these soils. During the soil survey of Knox County, Tennessee, a special study was conducted on two anthropogenic soil profiles. After classifying the two profiles using the three taxonomic methods, it was recognized that no single taxonomic method seemed to be sufficient to properly classify these soils. It was found that current classification schemes for disturbed soils gave different results depending on the system. The objectives of this paper were to combine useable parts from various proposed disturbed soil taxonomy schemes and discuss the implications of a new system made up of combined parts of other proposed systems. *Soil Taxonomy*, anthropogenic soil classification according to Fanning and Fanning, and the proposal for Spolents developed at West Virginia University along with Official Series Descriptions were all evaluated. The result of the study was a new suborder, Anthrents, which could be added to the Entisol order and separated from the other suborders by having at least 3 of the 9 special criteria common to anthropogenic soils. Twenty anthropogenic soil profiles/series using *Soil Taxonomy*, the proposed Spolents, the method of Fanning and Fanning, and the proposed method of classification presented in this paper (Anthrents) were classified to the family level of classification and compared against each other. Using the newest system (proposed in this paper), 16 of the 20 soils were reclassified and the unique soil properties in these soils were readily identified. Amendments should be made to *Soil Taxonomy* to separate anthropogenic soils from other suborders and then structured to convey the unique properties associated with these soils.

Additional Key Words: disturbed soil classification, minesoils, and anthropogenic soils.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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HOW MUCH DO VALLEY FILLS INFLUENCE HEADWATER STREAMS?[1]

Kyle J. Hartman[41], Michael D. Kaller, John W. Howell, and John A. Sweka

Abstract. Valley fill mining has the potential to alter headwater stream habitat in many areas in the eastern United States. In valley fill mining, overburden is removed to expose underlying coal seams. The overburden is then deposited in the adjacent valley. The deposited overburden from mining increases sedimentation, increases stream conductivity, and alters hydrologic regimes downstream of the fill. Changes in downstream communities are not well documented. However, it was suspected the increased sedimentation and conductivity would have deleterious effects upon the downstream macroinvertebrate communities. In southern West Virginia, four pairs of streams, each consisting of a fill and a reference stream, were selected as representative of watersheds experiencing valley fill mining. Stream pairs were selected for similar environmental conditions, with one stream having a valley fill in its headwaters. Each stream was sampled by replicate Surber samples (N = 9 per stream). Water chemistry and sediment measurements also were taken at each location. Valley fill streams had significantly higher specific conductance ($p<0.01$), but did not have elevated levels of fine sediment. Fills also had significantly elevated levels of Na, K, Mn, Mg, Ca, Ni and Fe relative to reference streams. Additionally, valley fill streams had significantly lower densities of Ephemeroptera, Coleoptera, Odonata, Non-insects, Scrapers, and Shredders ($p<0.03$) than reference streams. Further, Ephemeroptera richness was negatively related to specific conductivity and many of the richness metrics were negatively related to metals, both of which were generally elevated in fill streams. It appears that at the minimum, valley fills increase specific conductance and metals in streams and this or some other unqualified factors structure the macroinvertebrate community downstream of the valley fill. However, given the level of disturbance in valley fills, it is surprising how little differences existed between fills and reference stream biota.

Additional Key Words**:** macroinvertebrate, Ephemeroptera, specific conductance.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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USES OF THE BOREHOLE CAMERA IN HYDROLOGIC INVESTIGATIONS RELATED TO COAL MINING[1]

Jay W. Hawkins[2] and Robert S. Evans

Abstract. Use of a borehole camera in a hydrologic investigation, can yield information that may not be otherwise obtainable. The camera permits confirmation of stratigraphy, fracture and bedding plane separation locations, ground water inflow zones, fracture accentuation due to mine subsidence, and other features. A borehole camera also permits viewing of well bore features that otherwise may be unknown to exist, such as the conditions of the well bore, casing, and pumping system, historic water levels indicated by staining or corrosion, presence or absence of bacterial growths, existence of other organisms, the presence of foreign objects, and influx of gases.

Combined with other instruments, the borehole camera can greatly enhance the information derived from either individually. A camera has been used in conjunction with a pump or an electrical specific conductance meter to determine the location of water-bearing and non-water bearing fractures. The flow direction of water within the hole has been determined using the camera with a neutral-buoyancy tape attached. Subsidence features (e.g., fractures, sheared casing, and borehole offsets) have been documented using a borehole camera.

The borehole camera has proved almost indispensable as a tool for several hydrologic investigations conducted by OSM personnel. While not the only piece equipment used during an investigation, it has yielded information that was otherwise unavailable.

Additional Key Words: Water wells, slime bacteria, gases, subsidence fractures, bedding plane separations.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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SOME HYDROLOGIC PROPERTIES OF SURFACE MINE SPOIL IN THE APPALACHIAN PLATEAU[1]

Jay W. Hawkins[2]

Abstract: Prevention of acid mine drainage (AMD) at surface coal mines in the Appalachian region relies greatly on minimizing ground-water contact with acid-forming materials and maximizing ground-water contact with alkalinity-yielding materials. Acid-forming materials (AFMs) are often selectively handled to minimize or prevent contact with ground water. Controlling ground-water contact with acidic- or alkaline materials depends on accurate forecasting of the level and range of fluctuation of the post-mining water table and preferred ground water flow paths within the backfill. Physical measurements and aquifer testing of more than 120 wells from 18 reclaimed mines in Kentucky, Ohio, Pennsylvania and West Virginia have improved forecasting of the post-mining ground-water flow system. Flow regime influencing factors include spoil lithology and particle size, age of reclamation, spoil thickness, distance to the final highwall, and pit floor dip angle and direction. Hydraulic conductivity (K) exhibits a broad range of 7 orders of magnitude about a mean K of 1.69×10^{-5} meters/second. Spoil aquifer saturated thickness is related to the thickness of the spoil, spoil lithology, dip of the pit floor and distance to the highwall. Saturated spoil thickness has a 99% confidence interval of 1.86 to 3.97 meters (m) about a mean of 2.91 m. Spoil saturated zone averages 20% of the total thickness.

Additional Key Words: acid mine drainage, hydraulic conductivity, saturated thickness, ground water, water table, selective materials handling.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE USE OF MEASURED AND CALCULATED ACIDITY VALUES TO IMPROVE THE QUALITY OF MINE DRAINAGE DATASETS[1]

Robert S Hedin[2]

Abstract: The net acidity of a water sample can be measured directly by titration with a standardized base solution or calculated from the measured concentrations of the acidic and basic components. For coal mine drainage, the acidic components are primarily accounted for by free protons and dissolved ferrous iron, ferric iron, aluminum, and manganese. The base component is primarily accounted for by bicarbonate. A standard calculation is: $Acid^{calc} = 50*(2*Fe^{2+}/56 + 3*Fe^{3+}/56 + 3*Al/27 + 2*Mn/55 + 1000*10^{-pH}) - Alkalinity$, where acidity and alkalinity are measured as mg/L $CaCO_3$ and the metals are mg/L. Because these methods of estimating acidity are derived by independent laboratory procedures, their comparison can provide a valuable QA/QC for AMD datasets. The relationship between measured and calculated acidities was evaluated for fourteen datasets containing 1,484 sample analyses. All datasets consisted of samples collected from mine drainage discharges or polluted receiving streams. The datasets were variable in nature, ranging from watersheds where most of the discharges contained alkalinity to ones where all of the discharges were acidic. Good relationships were found to exist between measured and calculated acidities. The average acidity measurement was 239 mg/L $CaCO_3$ and the average acidity calculation was 226 mg/L $CaCO_3$. Linear regressions were calculated for individual datasets and for the entire dataset. The linear regression for the entire dataset was: $Acid^{calc} = 0.98 * Acid^{meas} - 8$, $r^2 = 0.98$. The good correlation between calculated and measured acidity is the basis for an easy and inexpensive QA/QC for AMD data. Substantial variation between measured and calculated acidities can be used to infer sampling or analytical problems and allow data corrections, when appropriate.

[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18 – 24, 2004. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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MONITORING AT THE ABANDONED ELIZABETH AND ELY MINES IN EASTERN VERMONT[1]

James V. Holmes,[2] Daniel E. Lawson, Kathleen D. White, and Scott E. Acone

Abstract. The complexities of remediation and restoration of abandoned mine lands with acid mine drainage require cost effective investigations that are coupled with in situ parameter measurements and monitoring, sometimes in near real-time. Off-the-shelf as well as innovative, state-of-the-art instrumentation and equipment can be readily adapted to site characterization and monitoring, and can be linked to various digital data transmission technologies for remote sites lacking power and easy access. Data, once received, can be readily displayed on web sites or incorporated into a GIS. At the Elizabeth and Ely abandoned mine sites in Vermont, we have employed various types of instrumentation to monitor surface and ground water hydrology, meteorology and water chemistry, depending on the application. To characterize temporal variations in drainage sources and metal loading during spring runoff at Ely Mine, we used Hydrolab data sondes for in situ measures of water temperature, conductivity and pH at 20-minute intervals. For laboratory chemical analyses, we obtained water samples at timed intervals automatically using an ISCO suction sampler in conjunction with water level measurements using a pressure transducer in a calibrated weir. Stage, along with air and water temperatures and rainfall, were measured at 5-minute intervals and stored on a Campbell data logger powered by a battery charged by solar panels. At the Elizabeth Mine, acid mine discharge and various water quality parameters are monitored continuously at five remote sites, three near the points of discharge of seeps from tailings. Data are stored on Campbell data loggers and periodically transmitted via radio to a cell phone for transmission and rapid graphical display on a web site. In addition, we used ISCO samplers triggered by intense rainfall to collect water samples in 15-minute intervals, allowing us to characterize the total storm loading during summer thunderstorms.

Additional Key Words: in-situ measurements, copper mine, surface water hydrology, ground water hydrology, meteorology, acid runoff

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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REFINEMENT OF ADTI-WP2 STANDARD WEATHERING PROCEDURES, AND EVALUATION OF PARTICLE SIZE AND SURFACE AREA EFFECTS UPON LEACHING RATES: PART 1: LABORATORY EVALUATION OF METHOD PERFORMANCE [1]

Roger J. Hornberger, Keith B.C. Brady, Joan E. Cuddeback, William B. White, Barry E. Scheetz, William A. Telliard, Stephen C. Parsons, Caroline M. Loop, Timothy W. Bergstresser, Carlton R. McCracken Jr., and Duane Wood.[2]

Abstract. The second year of method development work was conducted on the ADTI-WP1 (Humidity Cell) and the ADTI-WP2 (Leaching Column) standard test methods. The performance of the leaching column method was superior to the humidity cell method. In making improvements to the leaching column method, variations in column diameter and water-handling/gas-handling procedures were evaluated. Two commercial laboratories and a university research lab participated in the study. Relative percent differences between duplicate samples and relative standard deviations between laboratories were evaluated.

Surface area measurements, using BET methods, were conducted on each of 8 particle size classes, before and after weathering tests on 4 different lithologic samples. Observed alkalinity concentrations were consistent with the elevated PCO_2 and approached saturation with respect to calcite for calcareous rocks. The maximum concentrations of acidity (33,700 mg/L), sulfates (37,404 mg/L) and iron (9,120 mg/L) for the high-sulfur coal refuse sample were consistent with the maximum concentrations observed in the field. The measured surface areas of the shale samples were significantly higher than the sandstone, limestone and coal-refuse samples. However, the surface area measurements post-weathering were not significantly different from the pre-weathering measurements for most rock samples and most particle size classes.

Additional Key Words: kinetic test, leaching column, humidity cell

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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STUDY ON SOIL IMPROVEMENT FOR RECLAIMED SUBSIDED LAND WITH FLY ASH AND ORGANIC FERTILIZER[1]

Zhenqi Hu[2], Shili Chu, Shan Zhao, J.R. Zhang and Z.J. Zhao

Abstract. Reclaimed land usually has some problems such as poor soil structure and nutrients shortage. The man-made improvement treatments could accelerate soil development of reclaimed soil and increase soil productivity. This study was conducted to determine the effectiveness of soil improvement with fly ash and organic fertilizer for reclaimed subsided land. A 0.23 ha of experimental site was chosen in Jiawang coal mining area, Jiangsu province, and 6 treatments were used in the design with 3 types of materials such as 1% fly ash, 5% fly ash and poultry litter. The results showed that the application of fly ash could improve the reclaimed soil, but the amount of the fly ash should be more than 1%. The treatment of 1% fly ash had the lowest yield of soybeans, even lower that of the reference plot. As fly ash has fewer nutrients, some organic fertilizers are needed for higher yield. The treatment with 5% fly ash with poultry litter had the highest yield of soybeans. All the treatments of soil amendments were lower or equal to the concentrations of metal elements found for the control plot. The addition of organic fertilizer (D, E, F treatments) resulted significant decreases in the concentrations of Zn and Cu in the soybeans while the addition of 5% fly ash had only a slight decrease of the concentration of Zn and Cu in the beans. The pH and available nutrient contents of soils after harvest of the soybean were not affected by the application of fly ash.

Key words: reclaimed soil, soil improvement, fly ash, subsidence land, coal mine

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502. This study is supported by the National Natural Science Foundation of China (40071045)

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CHANNEL DEVELOPMENT ON UNRECLAIMED SURFACE MINES IN THE BEAVER CREEK WATERSHED, TUCKER COUNTY, WEST VIRGINIA[1]

Wendy D. Igo[2] and Jeffrey Skousen

Abstract: Mining in the early to mid 1900's has degraded streams within the Beaver Creek watershed in Tucker County, West Virginia. Channels have incised to bedrock and banks suffer from severe erosion. The sediment supply surpasses the stream's transport capacity, which has resulted in channel alterations. In a preliminary study, the headwater regions of two streams within the Beaver Creek watershed were assessed geomorphologically to define similarities in channel development on disturbed mine soils. These streams were composed of primarily aggradading sections and fewer degradating sections. Channel gradient and width were the primary factors used to separate the stream into distinct geomorphic units. Channel morphologies did not correlate consistently with the Rosgen Stream Classification System. Preliminary results indicate refinements to this system are needed to delineate streams on disturbed lands. Further research that quantifies and describes primary channel alterations that have developed since mining, may reveal the natural responses these streams are taking to reestablish equilibrium. Continued work on these streams may provide further information on how streams respond to comparable alterations.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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FORESTRY: A PRACTICAL LAND USE FOR SURFACE MINING?[1]

Mike W. Isabell[2]

Abstract: Fola Coal Company, LLC, is a mountain top, surface coal mine operation in Clay and Nicholas Counties in West Virginia employing over 300 people. Using six spreads of equipment to mine twelve seams, Fola produces about 4.5 million clean tons of low sulfur coal, which is sold on the steam market. Changes in the West Virginia surface mining regulations have made Commercial Forestry one of the post-mining land uses acceptable on mountain top surface mines that seek a variance from returning the land to AOC. The new regulations call for saving the top five feet of material on the surface, including the topsoil and other brown weathered sandstone at the surface, and replacing that material on the reclaimed backfill. Rough grading is also encouraged in the regulations, along with seeding a tree-compatible ground cover that will not present competition to the trees. The reclamation goal of Fola is to implement Commercial Forestry as a PRACTICAL land use for reclaimed areas. Fola has devoted 900 + acres to this land use. Our experience shows that there are several hurdles that must be overcome in order to make Commercial Forestry a viable post-mining land use, and among the most important is changing the perceptions of engineers and state regulatory inspectors that have been accustomed to smooth backfills and lush green grass, both of which are detrimental to tree establishment and growth. The techniques and costs associated with soil and brown sandstone special handling, grading, tree planting, and ground cover establishment will be presented.

Key Words: Forest establishment, forest management, reclamation, topsoil

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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SUCCESS OF RECLAMATION PRACTICES TO SUPPORT AMPHIBIAN POPULATIONS[1]

K.P. Jansen, C.M. Oakes, and F.D. Colyer[2]

Abstract: Many semi-aquatic organisms often require multiple ecotopes for reproduction, hibernation, aestivation, metamorphosis and/or feeding. For example, numerous salamanders and anurans breed in temporary wetlands yet maintain juvenile and adult populations in the surrounding uplands. The primary goal of this study was to assess the ability of modern restoration practices to support sustainable populations of native amphibian species, particularly anurans. The Powell River Project's Education Center (PRP-EC) in Wise County, Virginia, was used as the principle study site because of its diversity of terrestrial and wetland habitat types, and history of mining and restoration. Anuran call surveys and point-quarter surveys of vegetation for each of fourteen distinct wetlands/ponds were used to understand the effects of the distribution of habitat types within the landscape on resident amphibian populations, the characteristics of restored habitats conducive to reestablishment of these populations, and the sustainable nature of native amphibians in restored habitats. The PRP-EC is home to constructed and accidental wetlands/ponds, as well as retained settling ponds, that differed markedly in characteristics that affected species diversity. Importantly, some species did well in relatively deep, permanent ponds (e.g., *Rana catesbeiana*, *R. palustris*), whereas others required relatively shallow, temporary ponds (e.g., *Bufo* spp., *Hyla chrysoscelis*). In addition to the differences in permanence of ponds, the presence and structure of vegetation in and around ponds correlated with anuran diversity. A restoration plan that fails to account for these differences ultimately would support fewer amphibian species than one that does. Further, current methods of restoring mined lands (whether for productivity or suburban development) often do not design landscapes (e.g., connected wetlands and uplands) to accommodate future populations of the species formerly inhabiting the site.

Additional Key Words: wetlands, amphibians, biodiversity.

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[1] Paper to be presented at the Joint Conference, 21st American Society for Mining and Reclamation Meeting and 25th West Virginia Surface Mine Drainage Task Force Symposium, Morgantown, West Virginia, April 18-22, 2004.

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THE STATUS OF THE PASSIVE TREATMENT SYSTEMS FOR ACID MINE DRAINAGE IN SOUTH KOREA[1]

S.W. Ji [2], J.I. Ko , and S.J. Kim

Abstract. This study has been carried out to investigate the operating status, evaluate their problems, and discuss the possible improvement methods of passive treatment systems for acid mine drainage in South Korea. 35 passive treatment systems in 29 mines have been constructed since 1996 using SAPS as a main process.

Out of 29 systems investigated (two for metal mines), 19 systems revealed various problems. Overflows of drainage from SAPS or wetland or oxidation pond were caused by flow rate exceeding the capacity of the facility or the low permeability of the organic substance layer. At various places in systems leakages happen. Sometimes clogged and broken pipes at the mouths of the mine adits made the whole system useless. Some systems showed very low efficiencies without apparent leakage or overflow. Even though systems show fairly good efficiencies in metal removal (mainly iron) and pH control, sulfate removal rates were very poor except for three systems, which may indicates very poor sulfate reductions by SRB.

As an alternative method In-Adit-Sulfate-Reducing System, the method of placing the SAPS inside the adit, to keep the temperature constant about 15°C was suggested.

Additional Key Words: acid mine drainage, SAPS, SRB, In-Adit-Sulfate-Reducing System

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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PROPERTIES AND GENESIS OF MINESOILS ON SITES MINED FOR BAKERSTOWN AND UPPER FREEPORT COALS[1]

Jennifer R. Jones and John C. Sencindiver[2]

Abstract: Appalachian Corridor H will pass through Beaver Creek watershed in Tucker County, West Virginia. This is a sensitive area because numerous wetlands and reclaimed mined lands are located in the vicinity of the proposed highway. The West Virginia Division of Highways funded a project to assess the effects of the highway on the watershed. The two major coal beds in the watershed were Bakerstown, a member of the Conemaugh Formation, and Upper Freeport, a member of the Allegheny Formation. Bakerstown was mined and reclaimed in the 1970s, and Upper Freeport was mined and reclaimed in the 1960s. The dominant vegetation on the Bakerstown sites was grasses and legumes with scattered trees, while Upper Freeport sites were uniformly covered with red pine (*Pinus resinosa* Ait.). In order to document the existing conditions prior to the construction of the highway, a study was initiated to evaluate the properties and genesis of minesoils in the watershed. Six minesoil sampling points were located on Bakerstown sites and six were located on Upper Freeport sites. In addition, six sampling points were located on contiguous native soils. Soil profiles were described and horizons were sampled for laboratory physical and chemical analyses. The native soils were well drained to very poorly drained Inceptisols or Ultisols developed in alluvium or colluvium. Three of the six sampling points had fragipans. Minesoils developing on the Bakerstown sites had A horizons ranging from 3 to 16 cm thick. Sola of these soils ranged in thickness from 15 to 49 cm. Five of the six points had sola ranging from 15 to 33 cm thick. Minesoils on the Upper Freeport sites had A horizons that were 4 to 11 cm thick. Five of the six sampling points had sola ranging from 9 to 35 cm thick. One point had an uncommonly thick solum with Bw horizons described to 99 cm. Minesoils on both sites were classified as Entisols and Inceptisols. Although the depth of minesoil sola forming on the Upper Freeport and the Bakerstown sites was similar, fewer horizons were described per profile in Bakerstown minesoils. We attributed this horizonation difference to differences in parent materials. The rock fragments in Bakerstown minesoils were predominantly sandstones, whereas rock fragments in the Upper Freeport minesoils were a mixture of shale and sandstone.

Additional Key Words: Reclamation, soil development, *Soil Taxonomy.*

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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Assessing Reclamation Features and Estimating Reclamation Costs on Abandoned, Inactive, and Permitted Mines Using Real-Time GPS and Tablet Computers[1]

Len Meier, William Joseph, and Kevin Garnett [2]

Abstract. Real time mobile mapping is now a reality for natural resource professionals such as Abandoned Mine Land (AML) Reclamation Specialists, Mine Inspectors, and Permit Reviewers. During the early 1990's, lightweight global positioning system (GPS) receivers first opened the door for field professionals to accurately locate geographic features and environmental problems without traditional surveying crews and equipment. Further developments in GPS technology during the late 1990's enabled improvements in accuracy of GPS data with the introduction of real-time GPS correction equipment such as portable beacon receivers and Wide Area Augmentation System (WAAS) enabled GPS units. However, standard GPS receivers and even the higher-end GPS mapping equipment lacked the power and capabilities to seamlessly move from the office to the field and back without multiple data conversion and correction exercises. Recent innovations in Tablet computers, card type GPS receivers, integrated GPS technologies along with Geographic Information System (GIS) and Computer Aided Drafting and Design (CAD) software make it possible to use existing aerial photography, satellite imagery, and electronic permitting data to easily and accurately locate natural resource problem features, produce ready-to-use GIS data and maps, conduct in field CAD design, and seamlessly extract the data back in the office. The Office of Surface Mining (OSM) continues efforts in applying mobile computing devices and software to permitting and AML field work. This technology allows Inspectors to take maps and permit data to the field for inspection and verification of mining and permitting activities. The application of AML design and re-design in the field is also being applied along with traditional methods to eventually integrate mobile computing as a tool in AML and Regulatory work. This technology will result in a more efficient means of implementing the Surface Mining Control and Reclamation Act (SMCRA).

Additional Key Words: mobile computing, GIS, GPS, CAD, electronic permitting, and digital mapping.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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RUSLE C-FACTORS FOR SLOPE PROTECTION APPLICATIONS[42]

R.D. Karpilo, Jr.[43] and T.J. Toy

Abstract: Despite the fact that the Universal Soil Loss Equation (USLE) was originally developed to estimate erosion rates for agricultural lands, both the USLE and its successors (RUSLE Versions 1.06, 2.0) are increasingly applied to non-agricultural land disturbances. For these non-agricultural applications there is little consensus in the erosion-science community concerning which cover-management factor (C-factor) values should be used to account for the effects of various slope-protection materials. The purpose of this study is to derive appropriate RUSLE C-factor values from the rainfall-simulation study data collected at the Texas Department of Transportation – Texas Transportation Institute, Hydraulics and Erosion Control Laboratory (TTI) and the San Diego State University, Soil Erosion Research Laboratory (SERL), and to evaluate the utility of such values. RUSLE C-factor values were calculated for over 50 erosion-control products, straw mulch, and several vegetation types for various research conditions. The C-factor values were then compared with the few values provided by the manufacturers of erosion-control products. The C-factor values for straw mulch and the several vegetation types were compared with analogous USLE C-factor values found in *Agricultural Handbook 537* (Wischmeier and Smith, 1978) and values calculated using RUSLE2. One-way ANOVA tests and a Tukey test identified a significant difference between the C-factors calculated with the SERL methods and the USLE C-Factors and a second significant difference between the SERL method C-factors and values provided by product manufacturers. To test the spatial and temporal variability of C-factors, monthly values were calculated using RUSLE2 for 49 U.S. cities. A two-factor, without replication, ANOVA test was used to determine that the temporal and spatial variability of C-factor values is statistically significant. As a result of the lack of available C-factors for specific products, the SERL method at best provides a "quick and dirty" C-factor estimation. These values provide a soil-loss ratio useful for comparing the surface protection of similar erosion control products. The results of this study should assist USLE and RUSLE users by increasing awareness of the high variability of available C-factor values and highlight the need for product-specific C-factor values in RUSLE2.

Additional Key Words: USLE, Erosion-Control Products

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[42]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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MONDAY CREEK: A CASE STUDY IN SUCCESSFUL PARTNERING[44]

Mark D. Kessinger[45]

Abstract. The U.S. Army Corps of Engineers, in partnership with the Ohio Department of Natural Resources (ODNR), Division of Mines and Reclamation, is conducting a Feasibility Study to evaluate the applicability of various restoration solutions to the overall degradation of the ecosystem of the Monday Creek Watershed. In addition to the Corps and the ODNR, seven other federal, state and local agencies are actively involved in the project. The watershed encompasses 116 square miles (74,240 acres) of Athens, Perry and Hocking Counties, Ohio. Extensive portions of the Monday Creek watershed have been subjected to underground and surface mining since the mid-1800s and a number of stream reaches in the watershed are sterile and unable to support diverse, aquatic life due to acid mine drainage. The objectives of this paper are to explain the various roles and responsibilities of each of the agencies involved ant to show how a cooperative partnership among the agencies has been instrumental in the success of this complex and challenging project.

[44] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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A PROCESS FOR DEVELOPING AND EVALUATING DESIGN OPTIONS FOR LARGE-SCALE WATERSHED REMEDIATION[46]

Dr. Paul Ziemkiewicz[47] Dr. James Stiles[48] Mark D. Kessinger[49]

Abstract. The U.S. Army Corps of Engineers, in partnership with the Ohio Department of Natural Resources (ODNR), Division of Mines and Reclamation, is conducting a study to evaluate the applicability of various restoration solutions to the overall degradation of the ecosystem of the Monday Creek Watershed in southeastern Ohio. Extensive portions of the watershed have been subjected to underground and surface mining since the mid-1800s and a number of stream reaches in the watershed are sterile and unable to support diverse, aquatic life due to acid mine drainage. In addition to the Corps and the ODNR, seven other federal, state and local agencies are actively involved in the project including West Virginia University (WVU). WVU's primary role in the project was to develop and use a computer model called the Total Acid Mine Drainage Loading (TAMDL) model to simulate the evolution of stream water quality affected by acid mine drainage. WVU then used the data from the model to design passive and active treatment structures to meet the remediation goals. The objectives of this paper are to explain how the model works, its strengths and weaknesses, and its results.

[46] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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MONDAY CREEK ECOSYSTEM RESTORATION FEASIBILITY STUDY[50]

Mark D. Kessinger[51]

Abstract. The U.S. Army Corps of Engineers, in partnership with the Ohio Department of Natural Resources, Division of Mines and Reclamation, is conducting a Feasibility Study to evaluate the applicability and feasibility of various restoration solutions to the overall degradation of the ecosystem of the Monday Creek Watershed. The watershed encompasses 116 square miles (74,240 acres) of Perry, Athens and Hocking Counties, Ohio. Extensive portions of the watershed have been subjected to underground and surface mining since the mid-1800s and a number of stream reaches are sterile and unable to support diverse, aquatic life due to acid mine drainage (AMD). In addition to the Corps and the ODNR, seven other federal, state and local agencies are actively involved in the project. West Virginia is one of the agencies and its primary role was to develop and use a computer model called the Total Acid Mine Drainage Loading (TAMDL) model simulate the evolution of stream water quality affected by acid mine drainage. The objectives of this paper are to describe the Corps' processes for addressing AMD projects, to presents the results of the model study, and to explain how the stakeholders have worked together to develop a comprehensive plan to address the problems in the Monday Creek Watershed.

[50] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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PROGRESS REPORT ON THE OLD BEVIER PASSIVE TREATMENT WETLAND, MACON COUNTY, MISSOURI[52]

Kwang "Min" Kim[2] and Paul T. Behum, Jr.[2]

Abstract. The Old Bevier Aerobic Wetland in Macon County, Missouri, was constructed between 1990 and 1991 by the Missouri Department of Natural Resources' Land Reclamation Program for the purpose of treating acid mine drainage (AMD). The principal source of the AMD is from an underground mine that operated during the 1920's through 1950's, which was partially exposed during surface mining in the 1950's. Limestone bedding of an AMD collection system provided alkalinity similar to an anoxic limestone drain (ALD). Because the original aerobic wetland failed when a critical dilution water supply became unavailable, the total acidity of the AMD overwhelmed the limited neutralization ability of the aerobic wetland. The aquatic vegetation deteriorated and treatment became ineffective. The Missouri Land Reclamation Program with the assistance of the Office of Surface Mining, Mid-Continent Regional Coordinating Center rehabilitated the Old Bevier Aerobic Wetland in 2001, incorporating newer technologies to improve the performance. The new system, Old Bevier II treatment facility, consists of a 2-stage vertical flow pond (VFP) with associated oxidation cells and aerobic wetlands. This paper discusses the performance of this passive AMD treatment system, updating an earlier report. The new treatment system has operated with nearly continuous net alkaline discharge and a high iron removal rate. Also discussed are measures to improve AMD collection and treatment by the facility.

Additional Key Words: Acid Mine Drainage, Vertical Flow Pond, Anoxic Limestone Drain, Aerobic Wetland, Anaerobic Wetland, and Water Sampling

[52]Paper presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, Morgantown, WV, April 18-22, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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LAND APPLICATION OF COALBED METHANE WATERS: WATER MANAGEMENT STRATEGIES AND IMPACTS[1]

L.A. King, G.F. Vance, G.K. Ganjegunte and B. Carroll[2]

Abstract: Saline/sodic waters derived from wells associated with coalbed methane (CBM) gas production are being applied to rangelands and to lands used for production agriculture within the Powder River Basin (PRB) of Wyoming and Montana. Our study areas represent variable vegetation types, soil textures, treatment strategies and water application methods on sites impacted by up to 3 years of land application of saline/sodic CBM water. Vegetation parameters evaluated were forage quality, above ground biomass production, aerial cover, species diversity and infectivity of arbuscular mycorrhizae (AM) fungi. Soil data from six depth intervals to 120 cm were collected early summer, mid/late summer and fall during the 2003 water application season. Samples were analyzed for texture, bulk density, pH, electrical conductivity (EC), and sodium adsorption ratio (SAR). Infiltration and hydraulic conductivity rates were also measured. Waters from CBM gas wells in the PRB vary in quantity and quality, with average flows of around 30 liters per minute, salinity levels of about 2 dS/m and SAR's ranging from low (e.g., 5) to extremely high (e.g., 70) levels. Variable water application methods including center-pivot and side-roll irrigation and "mister" evaporation systems are utilized for land application. Common CBM water treatment strategies include: 1) varying application rates; 2) chemically treating water to adjust for SAR, salinity, pH and bicarbonate levels; and 3) chemically treating soil surfaces to minimize sodicity and salinity conditions. Potential advantages and disadvantages of various management strategies are discussed based on soil and vegetation data analyses. With about 20,000 CBM gas wells currently permitted or drilled in the PRB and estimates of at least 50,000 future new wells, proper CBM product water utilization is warranted.

Additional Key Words: saline-sodic water, infiltration rates, Powder River Basin, sodium adsorption ratio.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 28-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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ACIDITY AND ALKALINITY IN MINE DRAINAGE: THEORETICAL CONSIDERATIONS[1]

Carl S. Kirby[2] and Charles A. Cravotta, III

Abstract: Acidity, net acidity, and net alkalinity are widely used parameters for the characterization of mine drainage, but these terms are not well defined and are often misunderstood. Incorrect interpretation of acidity, alkalinity, and derivative terms can lead to inadequate treatment design or poor regulatory decisions. We briefly explain derivations of theoretical expressions of three types of alkalinities (caustic, phenolphthalein, and total) and acidities (mineral, CO_2, and total). Theoretically defined total alkalinity is closely analogous to measured alkalinity and presents few practical interpretation problems. Theoretically defined "CO_2-acidity" is closely related to most standard titration methods used for mine drainage with an endpoint pH of 8.3, but it presents numerous interpretation problems, and it is unfortunately named because CO_2 is intentionally driven off during titration of mine-drainage samples. Using the proton condition/mass-action approach and employing graphs for visualization, we explore the concept of principal components and how to assign acidity contributions to solution species, including aqueous complexes, commonly found in mine drainage. We define a comprehensive theoretical definition of acidity in mine drainage on the basis of aqueous speciation at the sample pH and the capacity of these species to undergo hydrolysis to pH 8.3. This definition indicates the computed acidity in milligrams per liter (mg L^{-1}) as $CaCO_3$ (based on pH and analytical concentrations of dissolved Fe^{III}, Fe^{II}, Mn, and Al in mg L^{-1}):

$$\text{Acidity}_{\text{computed}} = 50\cdot(10^{(3\text{-pH})} + 3\cdot C_{Fe^{III}}/55.8 + 2\cdot C_{Fe^{II}}/55.8 + 2\cdot C_{Mn}/54.9 + 3\cdot C_{Al}/27.0)$$

underestimates contributions from HSO_4^- and H^+, but overestimates the acidity due to Fe^{3+}. These errors tend to approximately cancel each other.

We demonstrate that "net alkalinity" is a valid mathematical construction based on theoretical definitions of alkalinity and acidity. We demonstrate that, for most mine-drainage solutions, a useful net alkalinity value can be derived from: 1) alkalinity and acidity values based on aqueous speciation, 2) measured alkalinity - computed acidity, or 3) taking the negative of the value obtained in a standard method "hot peroxide" acidity titration, *provided that labs report negative values*. We recommend the third approach; ***i.e.***, Net alkalinity = - Hot Acidity.

Additional Key Words: calculated and measured acidity.

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[1]Paper presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18 – 24, 2004. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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LONG-TERM DOWNSTREAM IMPACTS OF SURFACE MINING AND VALLEY FILL CONSTRUCTION TO BENTHIC MACROINVERTEBRATES AND WATER QUALITY[1]

Ed J. Kirk[2] and Randall Maggard[2]

Abstract. Argus Energy (formerly Pen Coal Corporation) has been conducting spring and fall seasonal monitoring of water chemistry and benthic macroinvertebrates since 1995 on the Trough Fork watershed to determine the long-term downstream impacts of mining operations.

Conductivity, TDS, and sulfates have remained relatively low at the upstream site since 1995 with the exception of October data since 2000. Although there was a noticeable increase in these parameters at the downstream site during active mining from October 1997, April levels have appeared to stabilize at levels about 3 times pre-mining levels. October levels have continued to "spike" since 2000 at both the upstream and downstream sites.

Total individuals collected have been lower at the downstream site since October 2000, whereas prior to October 2000, total individuals had been higher at the downstream for 8 of the previous 10 sampling events. Although sporadic prior to October 1999, total taxa, EPT taxa, and percent mayflies has remained lower at the downstream site since April 2000.

Pre-mining and early active mining upstream and downstream communities consisted of relatively equal proportions of sensitive, facultative, and tolerant individuals. Extremely large proportions of tolerant individuals were noted during the droughts of October 1998 and April 1999 at both sites. Since October 2002, the downstream site has become more facultative, and less sensitive.

WV-SCI scores have ranged from pre-mining scores of 73 and 79, to lows of 47 and 41 during the drought years, to highs of 91 and 89 for the upstream and downstream sites, respectively. Usually, the downstream site has scored less than the upstream site in 10 out of 16 sampling seasons. Regression data does not show any trends correlating WV-SCI score to conductivity, TDS, sulfates, or aluminum at either the upstream or downstream sites utilizing data over 6 ½ years. Some correlation between these parameters and mayfly abundance appear to exist.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavista Rd., Lexington, KY 40502.

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IMPACTS OF SURFACE MINING AND "AOC" RECLAMATION ON SMALL STREAMS AND DRAINAGE NETWORKS[53]

J. Steven Kite, Jocelyn Smith, Francis K Rengers, and Jennifer C. Walker[54]

Abstract. Many Appalachian drainage networks have been extensively altered by surface mining and reclamation. Mine sites reclaimed after passage of the Surface Mine Control and Reclamation Act (SMCRA) of 1977, must meet SMCRA Approximate Original Contour (AOC) requirements. However, investigations at three north-central West Virginia study show AOC is far removed from original landscape form and function. Specific drainage transformation varies greatly with reclamation style. Small stream drainage density decreased in all cases, but declines were less where sediment trenches act as low-gradient streams. Many reclaimed slopes lack small streams, relying on groundwater and overland flow to deliver water to larger streams. Thus, many headwater streams in unmined uplands are severed from the rest of the drainage system.

Slopes below truncated headwater streams are prone to instability. Groundwater and sheet flow lack capacity to handle moderate- to high-magnitude runoff from intense rainfall. Steep slopes commonly showed significant gully erosion very soon after reclamation and these gullies fore-tell long-lived channel paths across reclaimed slopes. Most constructed drainage was designed for extreme runoff, and lacks the "channel within a channel" cross-sections that promote stability during formative bankfull flows that occur every year or two. Constructed channels are poor matches to natural streams with respect to gradient, sinuosity and bed materials. Oversize channels may not fail during the reclamation bond period, but inevitably most will face sedimentation or lateral erosion problems.

Existing reclamation practices inadequately address the important roles of small streams in storm-water conveyance and sediment transport, and virtually eliminate ecological functions critical to the biological viability of all streams throughout a watershed. Long-term stability of reclaimed slopes and ecological sustainability of streams will require designs that accommodate both moderate bankfull flows and large infrequent floods.

Additional Key Words: fluvial geomorphology, hydraulic geometry, drainage density, stream restoration, slope stability, Appalachian Plateaus, West Virginia.

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[53]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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RECOGNITION OF NOOGENIC SOIL MATERIALS IN CLASSIFYING MINE SOILS[1]

Alan Kosse[2]

Abstract. Proposals for a separate order of Noosols have been advanced to include soils where anthropogeomorphic processes predominate. Although a number of soil series for mine soils are established in the United States, these soils have not been fully incorporated in the U.S.D.A. taxonomic system. Problems in separating mine soils from "natural" soils remain, and these soils are inevitably placed in Entisols (Orthents or Arents). Proposals for recognizing a separate suborder of Spolents have not been approved, while attempts to distinguish mine soils at the subgroup level (using dominant lithology) seem inconsistent with family criteria. Recognition of a separate suborder (Spolnos) in Noosols to accommodate mine soils is discussed, and proposals to define noogenic materials using field criteria are presented as a basis for distinguishing other suborders. Provisional classes for spolic materials based on dominant lithology are proposed for loamy- skeletal families in Spolnos. Use is made of the so-called clastic ratio in distinguishing relative abundance of rock types as an aid in reclamation and management. Additional characterization of spolic materials will be required to recognize other types of spolic materials, and eventually it may be necessary to introduce unique families to accommodate mine soils.

Additional Key Words: Noosols, Spolnos, Spolents, anthropogeomorphology

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[1] Paper presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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FACTS AND MYTHS ON THE EFFECTIVENESS OF WATER COVERS TO SUPPRESS SULFIDE OXIDATION AND METAL LEACHING – FIELD AND LABORATORY EVIDENCE[1]

Y.T. John Kwong[2]

Abstract. Largely due to the low diffusivity of dissolved oxygen in water, reactive tailings are often rendered harmless upon disposal underwater. However, both field observations and results of simulated weathering studies in the laboratory have shown that as long as a water cover remains oxygenated, sulfides exposed at the tailings/water interface are susceptible to oxidation. The two primary factors that determine whether or not net acid generation is to occur are the alkalinity balance in the water cover and the rate of deposition of a more efficient oxygen scavenger like organic matter to further isolate the submerged tailings. Even if net acid generation may not materialize, metal leaching can still occur as a result of galvanic interaction. Moreover, because of the changing redox conditions, many potentially deleterious trace elements with multiple oxidation states like arsenic and antimony are subject to remobilization from mine wastes disposed underwater. Thus, the choice of a proper management alternative for the long-term disposal of reactive mine wastes must duly consider the composition of the mine wastes as well as the environmental settings of the site after mine closure.

Additional Key Words: alkalinity balance, oxygen scavenger, galvanic interaction, base metals, arsenic and antimony.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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ANAEROBIC BIOREMEDIATION OF ACID MINE DRAINAGE USING EOS[1]

Nicholas L. Lindow and Robert C. Borden[2]

Abstract: Recent laboratory and field studies have shown that injection of Edible Oil Substrate (EOS®) into the subsurface can provide an effective, low-cost alternative for the enhanced anaerobic bioremediation of a variety of pollutants including acid mine drainage (AMD). EOS® is prepared from a mixture of slowly biodegradable emulsified oil (e.g. soybean oil) and easily biodegradable substrates. As AMD impacted water flows thought the treated zone, EOS® stimulates growth of iron and sulfate reducing bacteria, increasing the pH, reducing sulfate, and immobilizing iron, copper, nickel, zinc and related toxic metals. All materials used in the process are Generally Recognized As Safe (GRAS), food-grade materials (21 CFR 184.1400) for *in situ* application.

The impact of EOS® treatment on AMD was evaluated in both batch and flow-through column experiments. Batch microcosms were constructed with AMD generating spoils from a former coal mine in Sequatchie Valley, TN, simulated acid mine drainage, and a small liquid inoculum from an anaerobic treatment wetland. Sulfate declined from 1,800 mg/L to 10 mg/L, pH increased from 2.6 to 6.4 and iron was precipitated in a 2:1 molar ratio with sulfate removal. These results demonstrate that EOS® addition can be very effective in treating AMD and the initial pH does not significantly inhibit microbial growth.

Laboratory columns were also packed with mine spoils and received a one time treatment of EOS® with a microbial inoculum. Simulated AMD was then pumped through the columns with a four-day hydraulic retention time. During passage through the EOS® treated columns, pH increased from less than 3 to near 6, SO_4 was reduced by 75%, and aluminum, copper and zinc were reduced to below the analytical detection limit. In this system, effluent dissolved iron concentrations appear to be controlled by the amount of dissolved sulfide available for precipitation.

Additional Key Words: Sulfate reducing bacteria, heavy metals immobilization, in situ acid rock remediation

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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DEPARTMENT OF ENERGY'S PROGRAM ON THE RECLAMATION OF MINE LANDS FOR CARBON SEQUESTRATION AND OTHER ANCILLARY BENEFITS[1]

J.T. Litynski[2]

Abstract. Increasing concentrations of CO_2 and other greenhouse gases in the Earth's atmosphere have the potential to enhance the natural greenhouse effect, which may result in climatic changes. The main contributor to the increased atmospheric CO_2 level is fossil fuel combustion. Consequently, an important component of the United States Department of Energy's (DOE) research and development program is dedicated to avoiding a detrimental increase in the CO_2 concentration in the atmosphere by developing technologies to capture and sequester CO_2. An option being researched is to enhance natural sinks for CO_2, such as terrestrial ecosystems, which can potentially increase the carbon stored in these systems. Enhancing such natural sinks could make a significant contribution to long term CO_2 management strategies. Of particular interested are sites that have been surfaced mined for coal. Surface mining for coal not only results in the release of millions of ton of carbon from subsequent power generation at power plants burning the coal, it also releases carbon that was stored in the form of above ground biomass and in soils. Lands that were previously forested are routinely converted to pasture after mining and not managed for agricultural productivity. Therefore, carbon storage on these lands is minimal. Over 1.6 million acres of documented abandoned mine lands exist in the United States today. With proper management, these lands have the potential to sequester several million of tons of carbon each year in the form of grasses, trees, and soil organic matter in soils.

The DOE Carbon sequestration program is working to meet the current Administration's goals for climate change to reduce the greenhouse gas intensity of the United States by 18% by the year 2012. Sequestration of carbon in terrestrial sinks promises to play a major role in meeting this goal since technologies for increasing carbon in these systems is well understood

Additional Key Words: Reforestation, carbon sequestration, carbon measurement, project selection tools.

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1 Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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Carbon sequestration requires a new look at the old problem of mine land reclamation and could influence how these lands are treated. Carbon will become not only a product that mining companies remove from these lands in the form of coal, but also replace in the form of natural vegetation. Obviously, the price of carbon may not drive whether a site is mined. Future commodity markets are being developed today that will trade carbon credits to offset greenhouse gas emissions from the energy industry. These markets will demand that project plans be developed that include methods to measure, monitor and verify that these carbon credits are valid.

The Department of Energy (DOE) National Energy Technology Laboratory (NETL) program for Carbon Sequestration has partnered with several universities, non-government organizations, industry, and national laboratories to identify promising approaches to terrestrial carbon sequestration on mine lands. The projects focus on a variety of topics including: the demonstration and measurement of carbon sequestered on mine lands via reforestation incorporating various soil amendments and best management practices; improved technologies for the measurement of soil carbon; remote sensing applications to measure above ground carbon in forests; development of terrestrial carbon sequestration project management tools; economic analyses of carbon sequestration via reforestation of mined lands; and assessing the ancillary benefits of carbon sequestration on mine lands. This presentation will focus on DOE's program to assess and demonstrate the potential of using mine lands for carbon sequestration projects that will offset anthropogenic greenhouse gas emissions.

THE OCCURRENCE AND IMPACTS OF SELENIUM IN AQUATIC SYSTEMS DOWNSTREAM OF A MOUNTAINTOP MINING OPERATION IN CENTRAL APPALACHIA[55]

R.R. Maggard[56]

Abstract: The occurrences of low levels of selenium (<25 µg/l) were detected in central Appalachian streams during the data collection for the Mountaintop Mining Environmental Impact Study. The study was conducted as part of a settlement in a lawsuit alleging "Clean Water Act" and "SMCRA" violations related to the construction of valley fills. Most of the areas east of the Mississippi River have been characterized as being low or even deficient in selenium. During the past twenty-five years the role of selenium has changed from being considered a toxic element to now being considered a necessary micronutrient that is important for biological functions. The current water quality standard for selenium is 5 µg/l, which is lower than the levels measured in some streams in the study area of central Appalachia. Typically, areas west of the Mississippi River have higher naturally occurring soil selenium concentrations. In a few areas some streams have selenium concentrations as high as 500 to 1000 µg/l. The sources of selenium in the central Appalachian area are related to several anthropogenic activities. These sources can range from the weathering of exposed soil and rock created from various surface disturbance activities to runoff from domestic animal feedlots. The concentrations in soil, rock, and coal can range from < 0.5 mg/kg to as high as 21 mg/kg. The exact path in which the selenium becomes part of the water column is currently being evaluated. The impacts of these low levels of selenium on aquatic life are nearly indistinguishable from other contaminants (high suspended solids or high total dissolved solids), which also occur in these streams. Elevated levels of these parameters will usually result in more significant aquatic degradation than can be correlated with low selenium concentrations.

Additional Key Words: valley fill, total suspended solids, total dissolved solids, anthropogenic activities, coal mining.

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[55] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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ESTIMATION OF HYDRAULIC CONDUCTIVITY OF COAL MINE BARRIERS, PITTSBURGH COAL, NORTHERN WEST VIRGINIA, 1992-2000[1]

Kurt J. McCoy,[2] Joseph J. Donovan, and Bruce R. Leavitt

Abstract. Unmined coal barriers separate adjacent coal mines and restrict horizontal leakage between mines. Understanding the leakage rate across such barriers is important in planning mine closure and strongly affects recharge calculations for post-mining flooding. This study presents maximum estimates for intact (non-compromised) barrier hydraulic conductivity (K) in two closed mines at moderate depth (100-350 meters) in the Pittsburgh coal basin. The estimates are based on pumping rates from these mines 1992-2000 associated with leakage across common barriers from upgradient flooded mines. Both the pumped mines were maintained nearly dry, and so had dry seepage faces downdip from flooded mines, allowing accurate estimates of hydraulic gradient. The two mines do not approach the outcrop and are sufficiently deep that vertical infiltration is thought to be negligible. Similarly, there are no wetted barriers facing on other mines, and therefore pumping is the only discharge. The length of barriers totals 24 kilometers for the two mines, generally ranging in thickness from 15 to 50 m, and so the K test was large-scale. These test conditions are ideally suited to K estimation. K values from the test ranged from 0.03 m/d to 0.15 m/d using an isotropic model, and 0.05 to 0.27 (face cleat K_f) and from 0.03 to 0.15 m/d (butt cleat K_b) using an anisotropic model.

Additional Key Words: mining hydrogeology, coal barriers, aquitards

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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EARLY DEVELOPMENT OF A SPECIES TEST ESTABLISHED ON SURFACE MINES THIRTY YEARS POST-RECLAMATION[57]

David W. McGill[58], Victor L. Ford, and Joseph F. McNeel

Abstract. Three reclaimed surface mine sites are part of a surface mine reforestation species test to assess opportunities for planting previously-mined and recontoured lands. Located in southeastern West Virginia on MeadWestvaco property, these sites were mined just over 30 years ago. In 2001, a reforestation species test was established on one site per year through 2003. Site preparation consisted of a fall, aerial application of 9.4 liters ha^{-1} of Accord (glyphosate) to control the thick herbaceous cover of crown vetch and panicum grass and a "bedding" treatment for the planting rows. Species tests in the research areas included plantings of black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), hybrid aspens, hybrid poplars, pitch×loblolly hybrid pine (*Pinus rigida×taeda*), white pine (*P. strobus*), and Norway spruce (*Picea abies*).

First year survival values varied by species and year of planting. At the end of the second growing season, *P. trichocarpa×deltoides* (TD) clones were statistically taller than all other species in the test. The clone TD184 averaged 2.9 m and 2.1 cm diameter at breast height (dbh) at the site planted prior to the harsh environmental conditions experienced in the second year of this project. However, TD52 appears to be more sensitive to environmental conditions during the initial year of establishment as its first year survival was only 43% when established in the difficult 2002 planting season, whereas its survival was high in the 2001 (97%) and 2003 (98%) planting seasons.

[57] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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USE OF DATABASES IN CHARACTERIZATION AT MINE SITES[1]

Virginia T. McLemore[2], Gretchen K. Hoffman, Maureen Wilks, J. Steven Raugust, and Glen R. Jones

Abstract: Mining companies and their consultants generate large amounts of data at mine sites today. One of the most effective tools to enter, store, report, and utilize these data are by relational databases. The New Mexico Bureau of Geology and Mineral Resources has developed a database, the Mine Rock Pile database, to incorporate the characterization of mine rock piles for potential acid-mine drainage and rock pile stability. This database is being applied to an investigation at Molycorp's Questa mine in New Mexico. There are six main tables in the database: Samples, Drillholes, Test pits, Analytical data, Photographs and Bibliography, with more than 100 supporting tables. The data to be incorporated in this database includes locational data, climatic data, mineralogy, chemical analyses, geologic data on drill holes and test pits, historical and recent photographs, and other data. Existing data as well as newly collected data will be incorporated into the database. The purposes of this database are 1) to provide easy access to computerized data that will aid in the physical, mineralogical, chemical, and geotechnical characterization of the mine rock piles and 2) to create links to other databases at the mine and at NMBGMR. Forms allow for standard collection and input of data in the field and laboratory. Standard Operating Procedures (SOPs) are incorporated throughout the database to insure acceptable quality of sample collection and laboratory procedures. Once the data are entered into the database with locations, the data can easily be converted to GIS format for displaying on maps. The data can be imported into spreadsheets and used in most commercial software for data manipulation and interpretation.

Additional Key Words: chemistry, mineralogy, databases, Molycorp, Questa

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV, April 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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COMPARISON OF THREE METHODS TO MEASURE ACIDITY OF COAL-MINE DRAINAGE[1]

Brent Means[2] and Tiff Hilton

Abstract. Although the Standard Methods 2310 hot peroxide acidity procedure is widely used for measuring the acidity of mine drainage, little work has been done to determine if "hot acidity" data actually describe the base requirement for neutralization of mine drainage. This study compared three methods for estimating the acidity of net-acidic waters emanating from the Manor, Millerstein, Ike, and Morris coal mines in Pennsylvania: Standard Methods 2310 hot acidity titration to pH 8.2 endpoint, cold acidity titration to treatment endpoint pH as high as 11.0, and calculated acidity. The results showed poor agreement between hot acidity and calculated acidity for three of the four waters. For two of the waters, Mg hydrolysis during the hot-acidity titration indicated greater acidity than that computed based on pH and dissolved Fe, Mn, and Al. The poor agreement for the other water resulted from incomplete hydrolysis of Mn during the hot acidity titration. The agreement between the acidity measured by the treatment acidity titration and the other two acidity methods was within 16 mg/L (as $CaCO_3$) for the Manor and Millerstein waters, but greater than 200 mg/L (as $CaCO_3$) for the Ike and Morris waters. The fair agreement between all methods for Manor and Millerstein is a result of pH, Al, Fe, and Mn being the main source of acidity in the waters. The poor agreement between the acidity methods for the Ike and Morris waters is a result of the treatment acidity titration measuring a large amount of additional "acidity" at high pH from the hydrolysis of Mg and other constituents. While the exact sources of acidity measured by a treatment titration is unknown, results from PHREEQC aqueous speciation calculations showed that the formation of cation-hydroxl complexes in the Morris water at pH 11.0 contributed 40 mg/L of acidity. The authors hypothesize that Mg hydrolysis and the formation of base-consuming complexes are the reason why acidity measured by treatment titrations at high pH is often greater than that measured by hot acidity titrations to pH 8.2 or 8.3. The authors also hypothesize that the neutralization of carbonic acid is the reason why the acidity measured by "cold" titrations at low to mid pH is often greater than that measured by hot acidity titrations. The results of this study have practical importance because they show hot acidity titrations should not be used to universally describe the acidity of mine drainage. This is especially true when estimating the acidity produced when Mg-rich mine drainage is chemically treated to high pH. This study also showed that over treating Mg-rich mine drainage not only increases chemical costs but also increases sludge production.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 19-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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A COMPUTER-BASED MODEL FOR ESTIMATING MINE DRAINAGE TREATMENT COSTS[1]

Brent Means, Bob McKenzie, and Tiff Hilton[2]

Abstract. In the last 20 years, coal mining in Appalachia has produced approximately 1500 pollutional discharges. State and Federal agencies are developing a strategy, which includes consideration of treatment costs, to ensure long-term treatment of these discharges. The U.S. Office of Surface Mining Reclamation and Enforcement (OSM), in cooperation with the states of Pennsylvania and West Virginia, developed a free Windows-based computer program, termed AMDTreat, designed to estimate the capital and annual costs to abate pollutional mine discharges. AMDTreat uses a three-step approach to estimate treatment costs: 1. Users enter water quality and quantity data, 2. Users "build" an active and/or passive treatment system by selecting the applicable treatment components from the software menu, and 3. Users customize each treatment system to site-specific conditions by controlling the size, quantity, and unit cost of treatment components. Treatment types for which AMDTreat can estimate costs include vertical flow pond, anoxic limestone drain, Mn removal bed, anaerobic and aerobic wetlands, oxic limestone channel, hydrated lime, caustic soda, anhydrous ammonia, pebble quicklime, and soda ash. The model combines costs from these treatment methods with costs of ancillary treatment components, such as settling ponds and ditching, to calculate a site-specific capital cost. Similarly, AMDTreat calculates annual costs by taking into account user-provided information regarding sampling, labor, maintance, pumping, chemical consumption, and sludge removal. Capital and annual costs can be used in conjunction with AMDTreat's financial forecasting utility to evaluate the economics of long-term treatment. Additional features of the application include the ability to forward predict or back calculate costs, and an extensive help system. AMDTreat was designed for anyone interested in mine drainage treatment; including State and Federal agencies, industry, and watershed groups.

Additional Keywords: Treatment Costs, Cost, Passive Treatment, Chemical Treatment, AMD

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[1] Paper to be presented at the Joint Conference, 21st American Society for Mining and Reclamation Meeting and 25th West Virginia Surface Mine Drainage Task Force Symposium, Morgantown, West Virginia, April 18-22, 2004.

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EFFECTS OF AMD POLLUTANT LOADING ON STREAMS IN THE HAZLETON PA AREA[1]

Justin J. Mendinsky[2] and Brian A. Dempsey

Abstract. A baseline water quality study of streams impacted by acid mine drainage (AMD) within the Hazleton, PA area was undertaken to determine sources of acidity, aluminum, iron, manganese, and sulfate with the long-term objective of development of regional abatement strategies. Sample site locations were identified for the Black Creek, Little Nescopeck and Nescopeck Creek watersheds, consisting of main-stem locations and tributaries both upstream and downstream of suspected AMD sources. Flow measurements were conducted at each sample location to calculate mass loadings of AMD contaminants. Data will be used to prepare Total Maximum Daily Load (TMDL) reports to determine the required percent removals of acidity and total Al, Fe, and Mn in order to comply with PA water quality standards. Discharge from the Jeddo Tunnel was found to be the largest source of AMD contamination in the Little Nescopeck and Nescopeck Creek watersheds, with an average pH of 4.30 and contributing average mass loadings exceeding 7750 kg/day (17,000 lb/day) of acidity, 1350 kg/day (2900 lb/day) Al, 390 kg/day (860 lb/day) Fe, and 630 kg/day (1350 lb/day) Mn to the Little Nescopeck Creek based on two sampling expeditions. Discharge from the Jeddo Tunnel was compared to historic water quality data for this source, demonstrating improvement in water quality over time. Discharge from the Gowen Mine was the major source of AMD contamination to Black Creek, which also flows into Nescopeck Creek. This discharge had pH less than 4.0 and contributed average mass loadings of 4820 kg/day (10,600 lb/day) of acidity, 715 kg/day (1575 lb/day) Al, and 480 kg/day (1050 lb/day) Mn to Black Creek based on four rounds of sampling and flow measurement. AMD from Jeddo Tunnel and Gowen Mine are among the largest sources of pollutants in the Middle Susquehanna River system. Continued monitoring and field sampling of the streams and discharges within the study area is recommended so that seasonal variations in water quality and flow can be determined in order to evaluate AMD abatement strategies.

Additional Key Words: Acid mine drainage, water quality

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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MITIGATING THE PERCY MINE FIRE[59]

Stanley R. Michalski, Phillip E. Glogowski, and William J. Marks[60]

Abstract. Mining has occurred in the Uniontown Syncline (coal basin) in Fayette County, Pennsylvania for over one hundred years. The thirty-year old Percy Mine Fire, a legacy of past mining, underlies approximately fifty acres on the eastern flank of the Uniontown Syncline.

To establish how to extinguish the fire, it was necessary to understand the geology and the fire's potential, if left unabated. The Pittsburgh Coal was extensively mined in the basin with interconnecting mine workings extending from Uniontown on the south to Connellsville on the north. Three mine pools, flooding most of the underground workings, are defined within this basin. The coal in the center of the basin can not burn in its current submerged condition. Along the rim or outcrop zone, the mine workings rise out of the mine pool and extend to the outcrop where they become susceptible to burning. This zone encompasses a perimeter of outcropping coal encircling the syncline. The Percy Mine Fire, lies within this perimeter. It has been a threat to the health, safety and welfare of those living near and over the fire and effectively lowers property values of those living in the vicinity of the fire.

This paper reports on the history of mitigation actions and future planning to extinguish the Percy Mine Fire using Low Permeability Cementicious Material® (LPC_{TM}), a coal combustion product (CCP), in a joint effort headed by Bureau of Abandoned Mine Reclamation (BAMR), Reliant Energy, GAI Consultants, Inc., and Howard Concrete Pumping, Inc.

Additional Key Words: mine fire, low permeability cementicious material, coal combustion product, Percy Mine Fire.

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[59] Paper was presented at the 2004 21st National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004, Morgantown, WVA. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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METHODS USED TO DETERMINE IF MINE SITE ARE SUITABLE FOR AQUACULTURE[1]

Daniel Miller and Ken Semmens[2]

Abstract: There are a number of critical characteristics needed for a mine site to be developed for the commercial production of fish. These characteristics include physical and chemical attributes, as well as a history of water flows during all seasons of the year. In many cases state agencies have already collected years of discharge data in order to be in compliance with the mining permit.

The "economy of size" principle is an economic principle that was used to limit the number of mine sites being investigated. Only mine discharges with larger flows (1000 gpm) were chosen to be visited and sampled for water analysis. The physical attributes of each site that were noted during the visit included: area, slope, vegetation, security issues, distance to paved roads and electrical lines, distance to markets and processing plant, and identifying the receiving stream. Sampling included measuring the flow with a flow meter, and analyzing the water for pH, Ca, Mg, Mn, Fe, Al, ammonia, alkalinity, hardness, CO_2 and sulfates.

Photos were usually taken and the lab results from the water samples were used to determine if there were any serious health threats. Local people were found to be valuable in remembering how droughts affected the flow of the site. If at this point there were no obvious obstacles to fish health an effort was made to get permission to conduct a simple bioassay with a marketable species of fish, usually trout.

Based on the infrastructure of the site the method of conducting a bioassay was chosen. Where ponds were present, cages were chosen to house the fish. In one case where CO_2 was an issue, a trickling filter was used to remove CO_2 and an untreated tank was employed as a control. Failures were often associated with fish in cages located in polishing ponds directly downstream from acid mine discharge treatment plants. Electronic monitoring devices (sondes) collected water quality data from the remote sites and uploaded to computers. When fish died, the monitors were useful in determining if pH or dissolved oxygen was responsible for the deaths. Security at the research sites continues to be a challenge, especially when the fish are larger.

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1 Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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PROPERTIES OF CONSTRUCTED SOILS ALONG FOUR-LANE HIGHWAYS IN WEST VIRGINIA[1]

Rosa Lee Miller and John C. Sencindiver[2]

Abstract. Four-lane highways have been constructed in West Virginia since the 1960's. During the early construction periods of four-lane highways, geologic information was not assessed, nor was the effect of the disturbance of these geologic materials on soil quality established prior to construction activities. Due to the mountainous topography of the Central Appalachian region, the construction of four-lane highways requires large, expansive cut and fill areas that may contain acid or alkaline producing materials. The disturbance and mixing of these materials with the original soil produces "new" soil that differs considerably from the surrounding native soil. In order to evaluate highway substrate conditions and the development processes of these new soils, study areas along sections of highways have been selected for comparison based on differences in age and geologic parent materials. The long-term goal of this research is to improve selective soil handling of earth excavated during highway construction similar to that of mine overburden materials. Cut, fill and on-grade areas within sections of Interstates 68, 79, and 81 and Corridor H (U.S. Route 33 and State Route 55) have been randomly selected as sampling sites. Soil pits located at 10- m increments along transects perpendicular to these four-lane highways have been sampled at 0-10 cm and 10-20 cm depths and described according to USDA methods. Surface samples also were taken near the edge of the highway. Field pH values of all sites ranged from 5 to 8. Preliminary analysis of the data suggests that thin A horizons develop within 1 to 2 years in rapidly weathering surface materials. In these young soils, little development is observed beneath a weakly developed A horizon, commonly creating an A-C1-C2 or A-AC-C horizon sequence. Soils of intermediate ages (9-12 yrs) were similar to young soils, although at some sites a more developed soil profile was occasionally observed (A-Bw-C1-C2). The most developed soil profiles were observed on sites where soils had been constructed 25 to 43 years ago. At these locations, multiple B horizon sequences were common creating A-Bw1-Bw2-C or A-Bw-BC-C horizons.

Additional Key Words: Soil quality, soil development, disturbed soils, minesoils, soil genesis.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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WATER QUALITY CHANGES IN A COMBINED ALKALINE INJECTION TECHNOLOGY-REDUCING AND ALKALINITY PRODUCING SYSTEM (AIT-RAPS)[1]

Robert W. Nairn, Clint M. Porter and Geoffrey A. Canty[2]

Abstract. Alkaline injection technology (AIT), the introduction of coal combustion products (CCP) into an underground mine pool, is a novel *in situ* treatment process for remediating acid mine drainage (AMD). The highly alkaline nature of some CCPs neutralizes acidity and precipitates metals prior to discharge. Also, for certain net acidic waters, reducing and alkalinity producing systems (RAPS) successfully sequester metals and generate alkalinity. Water quality improvement has been demonstrated for each of these stand-alone technologies. However, no information exists about the possible effects of their use in combination, i.e., an "AIT-RAPS". AIT has treatment limitations and a finite lifetime; RAPS may serve as a complimentary and backup system. To address an AMD problem in eastern Oklahoma, 2,200 mtons of fluidized bed ash was injected into an underground coal mine in early 2002. In late 2002, a five-cell RAPS (total surface area 3100 m^2) received the now treated discharge. Water quality samples were collected at the mine discharge and at multiple locations in the RAPS for analysis of total metals, major anions, sulfide, and oxygen demand. After 20 months, AIT has reduced metals loading and acidity while increasing pH and alkalinity, but certain metal concentrations in the mine discharge have noticeably increased recently. The RAPS positively affected the metal load it received and significantly lowered sulfate concentrations. However, the vertical flow cell components of the RAPS produced significant biochemical oxygen demand and dramatically increased concentrations of hydrogen sulfide. These changes may be due to a combination of decreased metal loading and specific design parameters (i.e., use of an exceedingly labile carbon source). The combined AIT-RAPS may serve to prolong the life of any single passive treatment technology. However, specific design guidelines must be developed and the monitoring of atypical non-target water quality parameters must be considered in its application.

Additional Key Words: mine drainage treatment, water quality improvement

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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MINE DRAINAGE DISCHARGE QUALITY AND HYDROLOGY OF AN ABANDONED HARD-ROCK MINING WATERSHED[1]

Robert W. Nairn and Niki J. Iverson[2]

Abstract. Abandoned mine drainage water quality and discharge hydrology were examined in the Beaver Creek watershed, a 17 km^2-drainage basin located within the Tar Creek Superfund Site of northeastern Oklahoma. From approximately 1902-1970, the watershed was the site of extensive underground lead and zinc mining. Mine drainage discharges currently emanate from abandoned boreholes, air vents, shafts and other seepage points. Mine drainage water quality (pH, conductivity, dissolved oxygen, total alkalinity, turbidity, temperature, Fe, Zn, Pb, Cd, As, Ca, Mg, Na, Mn, SO_4^{-2}, and Cl^-) and discharge rates were determined monthly for a full year. Of the 20 mine drainage discharges identified as part of this study, 11 sites flowed at various times from February 2002 through January 2003. Measurable discharge rates ranged from 2 to >1500 L/minute. All mine drainage discharges were characterized as net alkaline (by 91-208 mg/L as $CaCO_3$) with variously elevated concentrations of iron (<1-32 mg/L), zinc (1.1-7.4 mg/L), lead (0.004-5.1 mg/L), cadmium (0.005-0.015 mg/L) and arsenic (0.005-0.019 mg/L). Overall, although contaminant concentrations for most discharges were relatively modest, metal concentrations did exceed appropriate requirements for maintenance of aquatic communities. In addition to mine drainage discharges, in-stream seeps contributed to contaminant loading. Based on a tiered evaluation approach, a single discharge was prioritized and recommended for treatment. However, the wide spatial and temporal variability of mine drainage discharge rates indicated a need for more comprehensive and thorough hydrological analyses. Mine drainage discharge rates responded to both seasonal changes in the regional water balance and to single storm events, demonstrating a possible direct link between the mine pool and surface waters. Although passive treatment of specific discharges appears to be both reasonable and desirable from a stream health perspective, the closing of open surface connections to the mine pool may eliminate or decrease impacts from mine drainage discharges.

Additional Key Words: water quality, watershed restoration, stream ecology

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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COAL TAILINGS RECLAMATION PRACTICES: SOIL COVER VARIANCES - THE AYRSHIRE ALTERNATIVE[1]

Jack R. Nawrot[2]

Abstract. Reclamation of potentially acid producing coal processing waste generally requires 4 feet (1.2 m) of soil cover to comply with most state and federal requirements (Surface Mining Control and Reclamation Act of 1977 (PL 95 - 87)). Soil cover variances for acid coal slurry (tailings) have included alkaline amendments (agricultural limestone) and reduced soil cover depths. Direct seeding of alkaline amended coal tailings substrates has been demonstrated on more than 1,800 acres throughout the midwest since the late 1970's. Slurry reclamation practices have included upland cool season grasses and legumes, warm season native prairie grasses, and emergent and open water wetlands. Direct seeded slurry demonstrations implemented by the Cooperative Wildlife Research Laboratory - SIUC during the 1980's and 1990's have received regulatory approval (bond release), as well as state and national (OSM) reclamation awards. Reclamation monitoring has documented vegetative cover, water quality, and substrate geochemistry through the period up to bond release. This annual monitoring has established a > 25-year database supporting the principles and practices of acid coal tailings reclamation. A recent soil cover variance at the Amax Ayrshire Mine (southwest Indiana) incorporated the principles of pyrite aging and weathering, and incremental limestone amendment to establish warm season grasses and shallow water wetlands on a ~170 acre (70 ha) acid producing slurry basin. Pre-treatment (1995) and post-treatment (1996 - 1999, 2003) substrate monitoring identified differential pyrite oxidation in unsaturated surface, and saturated subsurface profiles within the Ayrshire slurry basin. Agricultural limestone amendment (~100 - 150 tons/ac (225 - 335 Mg/ha)) has restored and maintained a favorable (alkaline) acid-base balance for seven years since the initial (1995) application. Warm season grass establishment provided > 87% aerial coverage in the direct seeded upland zones. Pre-treatment acid (pH 2.6) surface water quality in the shallow wetland zone has been restored to post-treatment alkaline (pH 7.8) conditions.

Additional Key Words: pyrite oxidation, acid abatement, acid-base balance, limestone amendment, warm season grass, direct seeding

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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GEOCHEMICAL CHARACTERIZATION OF SPOIL MATERIAL TO ASSESS SUITABILITY FOR USE AS A COVER IN TAILINGS REHABILITATION[1]

R.R.P. Noble, D.W.G.T. Oldmeadow, R.T. Watkins and J.T. Ammons[2]

Abstract. Twenty-four samples of waste rock material from the Mt. Micke stockpile were collected for chemical characterization. Mount Micke is spoil that was removed from the Wonga pit gold mine in Stawell, Western Victoria, Australia. Tentative plans at the Stawell mine are to use this material as a rehabilitative cover in conjunction with other materials to prepare the mine tailings for revegetation. The objective of this study was to assess the chemical properties of the Mt. Micke spoil to establish future land use potential and investigate the possibilities for future environmental problems. The following elements were targeted for ICP-MS/AES analysis following a nitric:perchloric acid digest: Al, As, Ca, Cd, Co, Cr, Cu, K, Mg, Mn, Mo, Na, Ni, P, Sb, Se, Sn and Zn. Total C and S were also determined. Acid-base accounting (ABA) was used to identify samples with significant acid producing potential (APP). Results indicate most samples have a low APP and are not prone to acid mine drainage. Three of the samples did have high total sulfur concentrations between 0.1-0.18 % and some APP, but the buffering capacity was sufficiently high to neutralize the potential acidity. The composition of transition metals is also relatively low, with ranges typically <500µg kg^{-1} in all samples. Interestingly, there were elemental concentration variations between the samples, which are attributed to the distinct regions in the open pit from where the material was originally mined. To accurately assess the characteristics of the spoil, it is essential to sample the different mined zones and not assume the stockpile is homogenous. A nutrient analysis for plant growth should be completed before any attempt is made at rehabilitation. Laboratory data revealed the Mt. Micke material is relatively low in P. Applications of biosolids and commercial fertilizers or the planting of low P tolerant plants will enhance success of rehabilitation on these tailings by compensating for the low P in these materials. Waste Rock from Mt. Micke should not pose any significant environmental problems and should be a beneficial cover supplement to the tailings rehabilitation.

Additional Key Words: Stawell, gold, Victoria, Australia.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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RECLAMATION OF DISTURBED SULFIDIC COASTAL PLAIN SEDIMENTS USING BIOSOLIDS AT STAFFORD REGIONAL AIRPORT IN VIRGINIA[1]

Zenah W. Orndorff and W. Lee Daniels[2]

Abstract. Excavation through sulfidic geologic materials during construction activities has resulted in acid rock drainage (ARD) related problems across the state of Virginia. The most extensive documented disturbance at a single location resulted from construction of the Stafford Regional Airport in Stafford, Virginia. Beginning in 1998 over 150 ha of sulfidic Coastal Plain sediments were disturbed, including steeply sloping cut surfaces and spoils. This disturbed area remained barren for over two years before being recognized as sulfidic. In addition to the development of acid sulfate soils, the generation of ARD degraded metal and concrete structures and heavily damaged a receiving stream with water quality effects noted over 1000 m downstream from the site. In December 2001 the existing surface soils were composite sampled from 32 map units across the site. In February 2002 a water quality monitoring program was established with 16 locations in and around the airport. In the spring and fall of 2002, after determining liming requirements using potential peroxide acidity (PPA), the site was treated with lime-stabilized biosolids, straw-mulch, and acid- and salt-tolerant grasses. By October 2002 the site was fully revegetated (≥ 90% living cover) with the exception of a few highly acidic outcrops and seep areas. Water quality quickly responded to treatment, although some N release was noted as a secondary effect. Surface soil sampling in September 2003 indicated that post-amendment pH values across the site increased from values < 3.5 to values typically > 7.0. Continued monitoring of the water and soils will be used to evaluate the multi-year efficacy of this treatment. Stafford Regional Airport illustrates the importance of accurately assessing sulfide hazards, and establishing optimal handling and treatment procedures prior to construction.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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MECHANISMS OF HETEROGENEOUS FE(II) OXIDATION IN ACID MINE DRAINAGE[1]

Byungtae Park and Brian A. Dempsey[2]

Abstract. The objective of the study was to investigate the sorption and abiotic oxidation of ferrous iron at ferric oxide surfaces at pH 6.8 and 7.0, and to identify changes in ferric oxide phase during the sorption and oxidation processes. Our group previously reported on mechanisms for sorption and heterogeneous oxidation at pH less than 6.5 and on the characteristics of ferric oxide sludge. We have also reported on transformations from amorphous to crystalline ferric oxides as a function of pH and solution composition. Sorption experiments were conducted at room temperature in an anaerobic chamber with 97% N_2 and 3% H_2. An additional oxygen trap was used to ensure an anoxic environment. The Fe(II)/Fe(III) ratio and pH were varied. The rate and extent of sorption of Fe(II) were monitored. Changes in solid phases were monitored using ^{57}Fe-Mössbauer Spectroscopy. Subsequent to sorption, oxidation rate constants and mechanisms were evaluated after exposure to very low partial pressures of O_2. The results showed that oxidation processes that occurred with high Fe(III) to Fe(II) ratios were more complicated in the neutral pH range compared to pH < 6.5, due to phase transformations that resulted in short-term sorption anomalies, such as decreased sorption after conversion from amorphous ferric oxide to goethite or precipitation of mixed Fe(II)/Fe(III) phases that slowly became inert to oxidation. These results are important in the context of treatment processes for AMD that depend on the presence of a ferric oxide phase, that is for high-density sludge processes that result in heterogeneous oxidation of Fe(II) and that are conducted at slightly acid to alkaline pH values.

Additional Key Words: HFO, iron oxide, phase transformation, sorption

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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ACID DRAINAGE TECHNOLOGY INITIATIVE: CONTINUING PROGRESS IN COAL RELATED TOPICS[61]

Stephen C. Parsons, Paul F. Ziemkiewicz, Fred Block, Roger J. Hornberger
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Abstract. In 1995, the U.S. Office of Surface Mining (OSM) and the National Mine Land Reclamation Center (NMLRC) joined with the Interstate Mining Compact Commission, the National Mining Association, academia, and other Federal agencies to form the Acid Drainage Technology Initiative (ADTI). The ADTI partnership seeks to identify, evaluate and develop "best science" based practices to prevent new acid mine drainage sources and eliminate existing sources. The ADTI partnership developed a management structure to oversee the program and developed action plans to address key technical areas. The ADTI organization consists of a coal mining sector, a metal mining sector and a secretariat, overseen by an Operations Committee. The coal mining sector of ADTI is divided into a prediction working group and an avoidance and remediation working group to implement and coordinate the research strategy. This paper summarizes the results of the coal mining sector efforts since the completion of the avoidance and remediation, and prediction handbooks in 1998 and 2000, respectively, and the status of current activities. The activities have included field verification of acid drainage predictions using acid-base accounting, monitoring and follow up evaluation of acid mine drainage passive and in-situ treatment systems, developing standardized kinetic testing protocols, flooded underground mine pools, and issues related to elevated selenium in streams associated with surface mines.

Additional Key Words: acid mine drainage, coal mining sector.

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[61] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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EFFECTS OF WILDLIFE UTILIZATION ON WYOMING BIG SAGEBRUSH GROWTH AND SURVIVAL ON RECLAIMED MINE LANDS[1]

Kristene A. Partlow[2], Gerald E. Schuman*, Richard A. Olson, and Scott E. Belden

Abstract: Ensuring Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) survival remains a challenge on many mines even years after initial establishment. Wildlife utilization may be a major influence on its survival. A wildlife exclosure was erected in June 2001 on a portion of a study initiated in 1990 at the North Antelope/Rochelle Mine in northeastern Wyoming. Investigations focused on the influence of wildlife utilization on big sagebrush survival and growth under 3 grass seeding rates, inside and outside of the exclosure. Growth, browsing, and survival were evaluated on 72 marked sagebrush plants inside and outside of the exclosure. Permanent 1 m^2 quadrats established in 1990 and 2 x 12 m belt transects were utilized to estimate big sagebrush density both inside and outside of the wildlife exclosure. Big sagebrush mortality, based on the 72 marked plants, was 24 outside the exclosure and 8 inside the exclosure for 2001-2002. Grass seeding rate had no effect on mortality inside the exclosure; however, mortality outside was lowest in the highest grass-seeding rate, 32 kg ha^{-1}. The higher grass-seeding rate appears to have enhanced big sagebrush survival although a specific ecological explanation is not clear from our data. Other research has shown similar responses whether browsed by livestock or wildlife. Big sagebrush browsing outside of the exclosure was 100% on the marked sagebrush plants and no browsing was evident inside the exclosure. Fecal pellet group and individual pellet data along with bite characteristics on the sagebrush leaders indicated that rabbits were the major browsers. Annual leader length (new growth on sagebrush) averaged 44.3 mm inside the exclosure and only 16.8 mm outside the exclosure for the 2 years. Findings of this research has shown that wildlife utilization can significantly impact shrub growth and survival on reclaimed mine lands, making it difficult to achieve the shrub density requirement for bond release.

Additional Key Words: Reclamation, deer, rabbits, browse, shrubs

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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LONG-TERM WATER QUALITY TRENDS IN A PARTLY FLOODED UNDERGROUND COAL MINE[1]

Eric F. Perry[2] and Henry W. Rauch

Abstract. Water quality trends for an 8 year period were analyzed for two acidic springs draining from a partially flooded underground coal mine, and the composite mine-pool outflow of 10 discharges. Time series analysis was used to separate long-term data trends from short-term noise. Short-term variation usually constituted less than 30 percent of the trend concentration. Exponential functions were fitted to the trend data, and time estimates (t_{50C}) for concentration to decline 50% were generated for Total Acidity, Fe, Al, SO_4, Co, Ni, and Zn concentrations. Iron decline is similar at two springs with an estimated t_{50C} of 60 months. Sulfate t_{50C} is about 60 to 70 months at one spring and for the aggregate mine-pool. Cobalt, Ni and Zn declines are more rapid, with estimated t_{50C} of about 30 to 50 months. Aluminum decline is 2 to 3 times slower than rates for other parameters, and mine-waters are near apparent equilibrium for the mineral jurbanite, $Al(SO_4)OH*5H_2O$. Constituent fluxes are controlled mostly by flow, and decline with time. Estimated time (t_{50F}) for flux to decline 50% for the composite mine-pool outflow is about 85 months for Fe, 80 months for SO_4 and 105 months for acid flux. Fluxes are 1.5 to 3 times greater in spring than fall, and reflect seasonal distribution of precipitation and recharge to the mine. Most of the improvement in mine-pool discharge results from declining pollutant concentrations. These trends suggest a slow decline in pyrite oxidation, with significant water quality improvement occurring on the order of years to decades.

Additional Key Words: acidity, flux, jurbanite.

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[1] Paper was presented at the 2004 National meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington KY 40502

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GROUND-WATER FLOW AND QUALITY IN A FULLY FLOODED UNDERGROUND COMPLEX[1]

Eric F. Perry [2] and Jay W. Hawkins

Abstract Water quantity and quality conditions are described for a mine-pool aquifer in a fully flooded complex of underground mines in northern West Virginia. Abandoned mines in the Pittsburgh coal bed are contiguous, and separated by coal barrier pillars ranging from as little as 9 to about 60 meters thick. Barrier pillars are transmissive enough to circulate significant quantities of water between mines, yet they control head distribution and flow direction within the aquifer. The mine-pool acts as a partly confined to confined aquifer, and recharge is approximately balanced by withdrawal of about 5700 Liters/minute, leakage to adjacent mines, and unquantified outflow to unmined areas. Resulting drawdown prevents the mine-pool from discharging directly into overlying streams. A centrally located subgroup of mines within the aquifer currently acts as a ground-water sink, but water levels are slowly increasing in the sink, and in some outflow areas. Mine waters are highly reduced, with circumneutral pH, and variable Fe concentrations from 5 to over 100 mg/L. Total alkalinity averages about 200 mg/L with a mixed Ca-Na-HCO_3-SO_4 composition in recharge areas. End of flow path waters contain up to 600 mg/L alkalinity, and are Na-SO_4 type waters with higher dissolved solids and metals concentrations. The shift from Ca to Na dominated waters is attributed mainly to cation exchange. Potentiometric head is increasing in the aquifer, and mine-pool withdrawal may have to be increased to prevent discharge to the surface. Mine-pool quality remains poor, and has shown slow improvement in 6 years of monitoring.

Additional Key Words: barrier pillar, leakage, confined aquifer, cation exchange

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[1]Paper was presented at the 2004 National meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington KY 40502

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ASSESSMENT OF WATER QUALITY IN A WATERSHED IMPACTED BY NATURAL ARD USING MINERALOGY AND REMOTE SENSING

Douglas C. Peters[2], David A. Bird, Phoebe L. Hauff, Matthew A. Sares, David W. Coulter, Eric C. Prosh, and Frederick B. Henderson III

Extended Abstract

In many areas of the Western U.S. containing mineralization that includes large sulfide bodies, natural acid rock drainage (ARD) from sulfidic alteration adversely affects the water quality of the host watershed. This occurs regardless of whether any mining has occurred in the watershed, but mining activity can exacerbate ARD production. The Colorado Geological Survey and a team of remote sensing experts from industry are conducting a National Aeronautics and Space Administration (NASA) -funded study of the ARD impacted Lake Creek watershed in the upper Arkansas River basin of Colorado (Fig. 1) using remote sensing technology to characterize, map, and monitor water quality in such watersheds.

Hyperspectral remote sensing technology is used to identify the mineralogy of the stream precipitates, which form the connection between pH, the type of ARD present and subsequent water quality. The mineralogy of these metal precipitates is directly determined by the stream water chemistry. Thus, remote sensing can indirectly assess water quality by linking the precipitate mineralogy to the water chemistry necessary for its formation. Water chemistry and streamflow data provide a detailed picture of metals transport and solubility in the watershed (Bird et al., 2003). Oxidizing, hydrothermally derived alteration and sulfide minerals are the source of the ARD. Secondary iron sulfates, iron oxides and oxyhydroxides, and aluminum hydroxides precipitate from the acidic stream waters in distinct pH zones. This is a function of dilution (i.e., changing pH conditions) by mixing with less acidic to neutral tributaries downstream from the ARD sources (Fig. 2). Image maps of mineralogy from the remote sensing data show a distinct correlation between the precipitates and water quality and can be used to predict and map the extent of ARD impacts.

Additional Key Words: water chemistry, hydrothermal alteration, metals, hyperspectral, precipitates.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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WATER QUALITY VARIABILITY IN TRIBUTARIES OF THE CHEAT RIVER, A MINED APPALACHIAN WATERSHED[63]

J. Todd Petty and Jennifer Barker[64]

Abstract. An understanding of the dynamics of metals and other solutes from mine drainage is essential to successful planning and stream remediation in mined Appalachian watersheds. Consequently, we conducted a study designed to quantify the spatial and temporal dynamics of trace metals and other water chemistry variables across a range of mining impairment. Water chemistry was monitored every three weeks in 34 stream segments of the lower Cheat River basin in northeastern West Virginia. Water sampling was conducted regardless of flow levels over a period from May 2002 – October 2003 and produced data on spatial and temporal variation in water temperature, dissolved oxygen, pH, conductivity, alkalinity, acidity, hardness, total dissolved solids, and dissolved concentrations of sulfates, iron, aluminum, manganese, cadmium, chromium, and nickel. Our study produced the following results. 1) Water chemistry was temporally variable in all streams examined; however, variability was generally highest in the moderately impaired streams. 2) Severely impaired waterbodies experienced poorest water quality during periods of extended low flows, whereas moderately impaired streams experienced poorest water quality under a variety of moderate and high flow conditions. 3) Elevated trace metal concentrations (chronic and acute) were common in moderately impaired streams and may provide an explanation for biological degradation in these streams. Our results suggest that water samples must be taken during late winter and late summer seasons in order to properly quantify chemical conditions in moderately impaired streams. Furthermore, full restoration of mining impacted watersheds may not be possible unless remediation approaches target reductions in trace metals and control temporal variability in water quality.

Additional Key Words: acid mine drainage, aquatic chemistry, coal mining, streams, trace metals

[63] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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IMPACTS OF REMEDIATED ACID MINE DRAINAGE ON BIOLOGICAL SYSTEMS WITHIN A SUCCESSIVE ALKALINITY PRODUCING WETLAND TREATMENT SYSTEM[65]

C. M. Porter[66] and R. W. Nairn

Abstract: Exposure to heavy metals can lead to increased mortality and decreased normal physiological function in aquatic organisms. Acid mine drainage (AMD) contains a mixture of different inorganic contaminants including heavy metals. The impacts from untreated AMD on macroinvertebrate communities within natural waterbodies have been investigated extensively, and a number of different processes have been designed for the treatment of AMD. To address an AMD discharge from an underground mine in eastern Oklahoma, injection of an alkaline coal combustion product (CCP) was coupled with a five-cell reducing and alkalinity producing system (RAPS). This study was conducted to examine resulting water quality changes and biological responses. Grab samples were collected at multiple locations for metal, anion, sulfide, and oxygen demand analyses. Chlorophyll *a* concentrations were determined throughout the system to estimate trophic status. Artificial substrate samplers were deployed to quantify and evaluate colonizing macroinvertebrate assemblages within each cell of the system. *Corbicula fluminea* and *Lepomis macrochirus* were exposed to waters within each treatment cell. Mantel, foot, and visceral mass tissues were harvested for metals content analysis in *C. fluminea*, and liver tissues were collected from *L. macrochirus*. Water quality data indicated positive changes in quality of mine drainage. Productivity between treatment cells varied significantly. The cells receiving effluent from anoxic organic substrate conditions had elevated nutrient levels, which lead to elevated productivity. Chlorophyll *a* levels reached hypereutrophic conditons into final treatment cells. Macroinvertebrate community structured was significantly different among treatment cells. Primary cells produced more diverse and evenly distributed taxa, including the presence of moderately intolerant taxa. Organismal responses, such as heptaosomatic index, condition factor, and condition index, did not significantly vary among organisms exposed within different treatment cells. Trends of metal tissue accumulation, compared to water concentrations, were observed for a limited number of metals. Exposure and colonization experiments indicated that the RAPS were functioning by removing metals from the water column and decreasing potential impacts from mine drainage to biological systems.

Additional Key Words: coal combustion products, *Lepomis macrochirus*, *Corbicula fluminea, in situ* exposures

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[65] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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ACID MINE DRAINAGE AND COAL COMBUSTION PRODUCTS AFFECT *CORBICULA FLUMINEA* AND *GAMBUSIA AFFINIS*[67]

C. M. Porter[68] and R.W. Nairn

Abstract: Toxicity tests and exposure experiments define the impacts of different metals on terrestrial and aquatic organisms. However, few examinations have evaluated the impacts of combined metals, similar to acid mine drainage (AMD), on fish and invertebrates. Toxicity associated with some selenium rich coal combustion products (CCP) has been identified, but little work has been done to identify toxicity associated with low sulfur, high alkalinity fluidized bed ash (FBA). Because FBA has been used to remediate AMD it is important to identify any potentially negative impacts from FBA to aquatic organisms. In this study, *Corbicula fluminea* and *Gambusia affinis* were exposed to synthetic AMD and an FBA extract in a controlled laboratory environment to complement *in situ* exposures at a current FBA injected AMD treatment site. Exposure periods were intermediate lasting 21 days. Synthetic mine drainage was created to mimic pre and post-injection metal concentrations and *C. fluminea* and *G. affinis* were exposed to different treatments. Test organisms were also exposed to a diluted concentration of FBA extract. Mantel, foot, and visceral mass tissues were harvested from *C. fluminea* and whole fish samples were prepared from *G. affinis* for metal content analysis. Organismal responses, such as condition factor and condition index, did vary among organisms exposed within different experimental treatments. Significantly greater condition index values were observed with *C. fluminea* exposed to post-FBA injected synthetic mine drainage. Trends of metal tissue accumulation, compared to water concentrations, were observed for a limited number of metals. Although FBA injections have proven to have positive impacts on water quality, biological examinations are necessary to holistically evaluate impacts to the environment.

Additional Key Words: synthetic acid mine drainage, fluidized bed ash extract, controlled metal exposure.

[67] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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LITTLE BOYD COAL CO., INC. REMINING NO.'S 1 AND 2 MINES

Lantz G. Rankin

Abstract. Little Boyd Coal Co., Inc. is now operating the largest remining operation in the State of West Virginia. With approximately 5.0 miles of highwall currently under permit and another 1.5 miles of high wall awaiting final regulatory permit approval, this operation has the potential to positively effect the West Virginia environment by the remining of a large portion of area negatively impacted by mining that occurred before the implementation of the current mining regulations in 1977. Collection and analysis of premining baseline data is critical because it allows a gauge to environmental control during mining and is key to understanding post mining water quality. This paper will present the information gathered during these periods and will help to provide assurance of the success of the operation for future mining permit applications. Since the submittal of an additional remining permit application will occur in 2004, documentation of the conditions, improvements or short comings of the current mining operation is appropriate to give the regulatory agencies confidence in the viability and success of the projects. This also allows Little Boyd Coal Co., Inc. economic confidence that the operation will be a financial success. The changes to the overall environment are also to be documented to quantify the environmental benefits to the State of West Virginia of this remining operation.

[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE NATURAL DEFENSES OF COPPER FLAT SIERRA COUNTY, NEW MEXICO[1]

J. Steven Raugust[2] Virginia T. McLemore

Abstract. Copper Flat, located in southwestern New Mexico, approximately 23 miles southwest of Truth or Consequences, is a porphyry copper deposit with associated gold, silver, molybdenum, and sulfide minerals. The stock contains a 75 million-year-old quartz monzonite breccia pipe forming the center of an eroded andesite strato-volcano. Quintana Minerals Corporation mined the property for three months in 1982 producing 7.4 million pounds of copper, 2,306 ounces of gold, and 55,966 ounces of silver. Mining activities ceased because of low copper prices. The mining equipment was dismantled and sold.

Since no mining activities have occurred since 1982, the site is an excellent field laboratory for studying the behavior of metals and sulfide minerals exposed with waste rock and tailings in the arid southwest. There is a 12.8-acre pit and pit lake on site that is located near the center of the breccia pipe. The entire study undertaken at Copper Flat focused on the potential impact of the pit lake, the waste rock piles, and the tailing impoundment on the local surface and groundwater quality; however, this paper focuses on the pit lake.

The pit lake has been sampled at least 65 times between 1989 and 1997. The pH of the lake is typically neutral to alkaline, with exception occurring in 1992 and 1993, where the pH dropped as low as 4.4. At least one intermittent seep from the pit wall has been sampled and the results reported a pH of 2.64, a total dissolved solid concentration (TDS) of 12,770 milligrams per liter (mg/L), and a sulfate concentration of 790 mg/L. The andesitic host rocks surrounding the ore body and groundwater inflow have a high acid buffering capacity as shown by the partial dissolution of calcite and the precipitation of gypsum and goethite. The alkalinity of the groundwater and host rocks quickly neutralizes and dilutes acidic discharges into the pit lake. Groundwater samples collected from monitoring wells located down gradient from the pit lake indicate groundwater chemistry is similar before and after the excavation of the pit.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Forces, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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RECLAMATION OF A TAILINGS IMPACTED STREAM CORRIDOR[1]

Patrick L. Redmond, George E. Austiguy, and Michael A. Rotar[2]

Abstract: A history of environmentally insensitive tailings disposal practices across the U.S. has resulted in large-scale ecological disruptions caused by acid mine drainage, surface and groundwater contamination, nutrient-poor soil with little or no vegetation, and prevalent erosion. Reclamation of stream corridors impacted by tailings must consider the transport mechanisms inherent to fluvial systems, and the geomorphic processes that occur at the interface between the stream and its boundary material. Case histories of two stream reclamation projects located along Silver Bow Creek are presented. Contamination in the basin is the result of more than 125 years of copper, silver and associated base metal mining and processing in Butte and Anaconda, Montana. In 1992, the U.S. Environmental Protection Agency (EPA) and the Atlantic Richfield Company began reclamation activities within the Lower Area One Operable Unit, through an Expedited Response Action under the EPA's Superfund program. Major work elements included removal of mine waste material and reconstruction of the creek using an elevated gradient. The elevated channel, in conjunction with ground water hydraulic controls, minimized the potential for stream flows to collect potentially contaminated ground water. The second project involved remediation of a 1.25-mile reach of Silver Bow Creek within the Streamside Tailings Operable Unit, located immediately downstream of the Lower Area One Operable Unit. The Montana Department of Environmental Quality, in conjunction with EPA, managed this project. Design work for this project began in 1997, and construction was completed during 1999-2000. Major work elements included tailings/impacted soils removal, placement of the tailings/impacted soils in an adjacent mine waste repository, reconstruction of a natural stream channel with deformable banks, floodplain reconstruction and associated groundwater dewatering, a flow regulation control structure and high-flow diversion channel, and one county road crossing. Due to the presence of geologic controls at the boundary between the two projects, the potential for contaminated groundwater to contact stream flows was minimal in the Streamside Tailings Operable Unit. Therefore, the stream was reconstructed at a new gradient that was dictated by the post-tailings removal surface, and general channel stability and sediment transport competence criteria.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE ROLE OF POLITICS, COMMUNITY INVOLVEMENT AND PUBLIC PARTICIPATION IN THE RECLAMATION OF AN ABANDONED IRON MINE IN WYOMING[1]

Timothy C. Richmond and James J. Gusek[2]

Abstract. The reclamation of a tailings impoundment, waste rock dumps, and a railroad grade associated with a taconite operation in Wyoming was a political and public relations challenge. Several stake-holders had strong personal agendas and objectives to be achieved through the reclamation project. Thorough newspaper coverage, numerous public meetings, and interaction with local landowners regarding innovative reclamation techniques were some of the methods used to combat the project's complicated web of miscommunication and misinformation that hindered the public's acceptance of the proposed construction plans and progress of the work.

Additional Key Words: tailings, organic soil amendments

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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AN "AUTOPSY" OF THE FAILED TANGASKOOTACK #1 VERTICAL FLOW POND, CLINTON CO., PENNSYLVANIA[69]

Arthur W. Rose, David Bisko, Amidea Daniel, Mary Ann Bower and Scott Heckman[70]

Abstract. The Tangascootack #1 passive treatment system was constructed in 1998 to treat an acid discharge from an abandoned surface mine in Clinton Co., PA. The discharge averaged about 155 L/min with pH 4.0, acidity 235 mg/L $CaCO_3$, Fe 3.7 mg/L, Al 24 mg/L and Mn 68 mg/L. The vertical flow pond had dimensions of 48 x 20 m and was preceded by a wetland and followed by an oxidation/settling pond. The system produced net alkaline effluent for a few months, but by 1 year after construction, the effluent acidity was 120 mg/L, and flows decreased to 20-60 L/min. Plugging by Al precipitate was suspected, despite occasional flushing.

In 2003, investigation showed partial plugging by cattail roots in the effluent pipe, but after removal of the roots, head loss across the VFP was less than 2 cm at flows of about 20 L/min, indicating that plugging was not severe. The VFP was drained and the compost and limestone (2.5 cm dia..) were excavated along several trenches. Compost, originally designed as 30 cm thick, varied markedly from 8 to 25 cm thick. In thick zones, basal compost was coated by black Fe sulfides. The limestone was coated nearly everywhere for at least 25 cm beneath the compost with gelatinous white Al-bearing precipitate mixed with quartz-rich silt. A layer of gypsum beneath the Al precipitate covered the limestone in places. An open joint in the underdrain may have somewhat concentrated flow. The limestone layer retained considerable pore space and permeability. In spite of the flushing and open joint, Al coating was approximately the same over underdrain pipes as elsewhere. Also, the Al coating was present nearly everywhere, under both thick and thin compost, indicating that channeling was minimal. Measurements in 1999 and 2003 show that the system was removing acidity at reasonable rates of 45 to 60 g/m^2/day.

Additional Key Words: Acid mine drainage, passive treatment, SAPS

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[69] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd, Lexington, KY 40502.

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VERTICAL FLOW SYSTEMS – EFFECTS OF TIME AND ACIDITY RELATIONS[71]

Arthur W. Rose[72]

Abstract. The characteristics of the 29 vertical flow systems reported on by Rose and Dietz (2002) have been reevaluated based on 2 years additional experience and revised understanding of acidity. Data on several additional systems have been collected. If measured hot acidity is interpreted as net acidity that includes the effects of alkalinity (vs. net acidity = acidity minus alkalinity), many systems remove slightly less acidity and fewer VFS produce net alkaline water. Rates of acidity removal ($g/m^2/d$) are somewhat lower, and the typical value is about 34 rather than 40 $g/m^2/d$. If non-Mn acidity is taken as the critical parameter, the sizing parameter for non-acid effluent is about 35 $g/m^2/d$. Systems with fine limestone in the compost do about twice as well and appear to be a solution for high-Al discharges.

Over the past 2 years, at least 5 of the systems have markedly decreased in effectiveness. Problems have been accumulation of excess ferric hydroxide precipitate on top of the compost, pipe plugging, channeling, and Al coating causing decreased reaction rate with limestone.

Additional key words: Passive treatment, SAPS, performance, problems.

[71] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE KENTUCKY REFORESTATION INITIATIVE[73]

Paul F. Rothman[74]

Abstract. In an effort to aggressively promote and encourage "Forest Land" as the "Post Mining Land Use" of choice on Kentucky coal mines, the Department for Surface Mining Reclamation and Enforcement (DSMRE) began the Kentucky Reforestation Initiative in the fall of 1995. The Reforestation Initiative is a collaborative effort between the DSMRE, University of Kentucky (UK), federal Office of Surface Mining (OSM), environmental groups, the coal industry and other interested parties, assembled for the purpose of developing reclamation guidelines that would provide for the establishment of healthy productive forests on coal mined lands. Suggestions from members of these groups were incorporated into Reclamation Advisory Memorandum (RAM) #124, which was issued on March 10, 1997. This document provides guidance on the selection of growth medium, grading techniques, selection of tree compatible ground covers, soil amelioration, tree selection, and planting recommendations. Interestingly, it was field inspection personnel who initially exhibited the greatest aversion to the new reclamation techniques. This was largely due to the ingrained belief that a site was not stable if it wasn't repeatedly graded, or was not properly reclaimed unless it had a pasture-like appearance. As a consequence, the mining industry was hesitant to embrace this guidance – even if it resulted in reduced reclamation costs and increased tree survival and growth. Ongoing reforestation research by the University of Kentucky utilizing, in part, the reclamation techniques outlined in RAM #124 is demonstrating that high-value hardwood forest can be successfully established on strip-mined land. The emphasis of this research has been on the establishment and growth of desirable hardwood and pine species (white oak, red oak, white ash, black walnut, yellow poplar, royal paulownia and eastern white pine). The ongoing field research has been very successful and thoroughly supports the reclamation techniques contained in RAM #124. Since issuance of RAM #124 there has been a growing interest in reforestation. There has been an increase in the number of permit applications that propose a post-mining land use that requires the establishment of trees and shrubs.

Key words: Tree planting, mined land, reclamation

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[73] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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PA DEP-BUREAU OF ABANDONED MINE RECLAMATION'S BRANDY CAMP AMD TREATMENT PLANT A CASE STUDY[1]

Daniel Sammarco[2]

Abstract. On January 5, 1999 the Pennsylvania Bureau of Abandoned Mine Reclamation began construction of a semi-active acid mine drainage treatment plant in Horton Township, Elk County. Extensive water quality and flow data was obtained within a sampling period of 1969 to 1997. A net acidic discharge was characterized as an average flow of 600 gpm, pH 4.5, acidity 200 mg/l, total iron 75 mg/l, ferrous iron 70 mg/l, aluminum 8 mg/l, and manganese 10 mg/l. Plant design consisted of a 35 ton hydrated lime silo, natural aeration, a sedimentation pond, and an aerobic wetland. Upon plant startup in late summer 1999, flow quantities had increased to 2000 gpm. Inefficient natural aeration resulted in a ferrous hydroxide based sludge accumulation in the sedimentation pond. Geophysical studies identified subsidence in two upper watershed tributaries. The increased flows were consistent throughout year 2000 and on February 1, 2001, a DEP growing greener grant was awarded to the Toby Creek Watershed Association to retrofit the plant to an active treatment plant. A treatment building was constructed which houses an aeration tank, polymer make down system, two (2) 500 gpm inclined plate clarifiers, and a belt press. The plant was dedicated on May 18, 2002. Approximately six (6) tons of 20% solids sludge is belt pressed daily with effluent pH 7.5, total iron <1 mg/l, aluminum < 1 mg/l. This paper discusses the operational experiences since plant startup and a sludge resource recovery metallurgical application.

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[1] Paper to be presented at the Joint Conference, 21st American Society for Mining and Reclamation Meeting and 25th West Virginia Surface Mine Drainage Task Force Symposium, Morgantown, West Virginia, April 18-22, 2004.

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EVALUATION OF AERATION TECHNIQUES FOR MINE WATER TREATMENT IN PASSIVE SYSTEMS[1]

Terry W. Schmidt[2]

Abstract. Removal of metals from mine drainage involves a host of chemical and biological processes including oxidation and hydrolysis reactions. The rate of reactions is dependent on mine water pH, presence of bacterial catalysts, and the availability of oxygen. Oxygen availability becomes particularly important in treatment systems using aerobic processes such as settling ponds and wetlands. Although oxygen is readily available in the atmosphere, encouraging the transfer of oxygen to mine water can be a challenge. Applicability of the various methods to increase oxygen levels in mine water is dependent on mine water chemistry and the availability of treatment area, hydraulic head, and power. Innovative aeration techniques have been developed which use wind, water, and electricity as power. The suitability of techniques must be evaluated on a site-by-site basis. Wind energy has been harnessed using windmill aeration techniques at the Sagamore site in Fayette County, Pennsylvania. Water energy has been utilized through manipulation of available hydraulic head to improve aeration as demonstrated at the Kolb site in Indiana County, Pennsylvania. In cases where adequate aeration cannot be accomplished by passive methods, such as the Kempton site in Garrett County, Maryland, active mechanical aeration using electric power may be a cost-effective alternative.

Additional Key Words: abandoned mine lands, acid mine drainage, best management practices.

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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ELECTRONIC DATA MANAGEMENT SYSTEM FOR WATERSHED ASSESSMENT AND RESTORATION PLANNING [1]

A. Edward Sciulli, and David G. Minnear [2]

Abstract. Watershed Restoration Plans (WRP) and subsequent restoration activities are generally only as good as the data and data analyses on which they are based. Until recently, watershed assessments in Pennsylvania have generally not incorporated a watershed-wide approach. Portions of a given watershed may have been assessed several times over the years by various groups, organizations and agencies, each collecting and analyzing their own data without coordinating efforts, techniques, or interpretations. This usually resulted in an incomplete assessment of the watershed as a whole and subsequent allocation of funding to projects that may not efficiently lead to watershed restoration. This paper presents the development and use of an Electronic Data Management System (EDMS) designed specifically for watershed groups to manage and evaluate water quality and other physical data for the preparation of a WRP.

The EDMS consists of two separate but linked components. The first is a relational database designed for both functionality and ease of use. Key to the database structure is the ability to conduct comparative analyses across several discharges, as well as comparative analyses within individual watersheds and between watersheds. More importantly, the EDMS provides a means for quick and efficient input of water quality and other physical data as well as providing a final repository for the data. The second component is a geographic information system (GIS) which provides the spatial relationship lacking in the database. Key to the GIS structure is the development of routines to display and analyze the spatial distribution of discharge loadings and levels of specific contaminants.

The EDMS has been found to significantly increase the ability of local watershed groups to conduct watershed-wide assessments and data analysis. The system allows less technical users to conduct more thorough evaluations of data and data trends and assists in the spatial analysis of contaminant loadings. Incorporation of widely available GIS data themes and layers provides additional data tools to evaluate local land use, topography, and land ownership, if available.

Additional Key Words: database, GIS, restoration plan, prioritization.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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UTILIZING MINE WATER FOR AQUACULTURE - AN OVERVIEW OF PRODUCTION FORMATS, 2003[1]

Ken Semmens and Daniel Miller[2]

Abstract. Treated and untreated water originating from coal mines in Appalachia has been utilized to produce harvestable size salmonids for the past decade. Abundant sources of well oxygenated water with a pH between 6.5 and 8.5, and stable water temperatures between 40 and 70 F are required. Stability of water temperature between 55 and 60 F year round allows the grower to feed all year long, something not possible in surface waters. Suitable infrastructure (seed stock, feed, processing plant, market demand) exists to support continued growth of this industry. Rainbow Trout are the predominant species cultured, but brown trout, and arctic char are also grown. It has been estimated that nearly 4 million pounds can be produced if 30 % of available mine water is utilized for this purpose. This presentation will describe the production system at five locations utilizing treated and untreated mine water and the potential use of a retired Acid Mine Discharge (AMD) treatment plant as a marketing tool for farm raised fish.

Acid mine water, found in the northern part of West Virginia (WV), is usually treated with aeration, lime, and flocculants, before passing through a polishing pond. Infrastructure created in this process effectively reduces the investment costs for salmonid production. Net pens have been used successfully by the Maryland Department of Natural Resources at the Mettiki AMD treatment plant near Oakland, Maryland for the past decade. West Virginia University installed a modular composite raceway near Morgantown, WV for research. It utilizes effluent from the polishing pond at Consol Energy's Dogwood AMD treatment plant.

In southern WV, groundwater flowing from coal mines does not require treatment to remove metals and acidity. Two production facilities which rely on gravity flow of aerated mine water to grow food size rainbow trout have been operating near Sophia, WV for about 6 years. High Appalachia, Inc. grows about 200,000 lb of rainbow trout at these facilities for its processing plant near Sophia, WV. West Virginia Aqua, Inc. has two facilities devoted to the production of Arctic Char in southwestern West Virginia which began marketing product in 2002. The capacity of their production facility is estimated to be 500,000 lb and features a design that recirculates mine water with approximately 80% reuse.

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1 Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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EVALUATING SOIL QUALITY ON RECLAIMED COAL MINE SOILS IN INDIANA[75]

C.A. Seybold, R.B. Grossman, H.R. Sinclair, K.M. McWilliams, G.R. Struben, and S.L. Wade[76]

Abstract. On cultivated cropland, soil quality of reclaimed soils after surface mining for coal can be lower than that of the quality before mining. The objectives of the study were to evaluate near surface and profile soil quality on eight soils reclaimed to agricultural land in southwestern Indiana. Several near-surface properties were measured and a soil quality index score calculated from a minimum data set (MDS) of six indicators. The scoring function ranges were based on the soil condition before mining. The near-surface properties of bulk density, soil strength, aggregate stability and particulate organic matter (POM-C) were within the limits observed for cultivated surface horizons. However, surface properties could be improved through best management practices. The profile soil quality was lower on all eight reclaimed sites. The index scores ranged from 68 to 87 on a scale from 0 to 100. The properties that were a major factor in lowering the soil quality of the reclaimed soils were a poor or massive soil structure, lower available water capacity, and increased bulk densities. Organic C, CEC, and soil pH on most sites were generally comparable to the condition before mining. The poor or massive structure, higher bulk densities, and lower AWC of the reclaimed soils could result in water stress and/or lower productivity. Under doughty conditions especially under doughty conditions compared to the reference soil condition before mining.

Additional Key Words: soil quality index, POM, near surface properties.

[75]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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SUCCESS AND PROBLEMS AT ACID MINE DRAINAGE ABATEMENT PROJECT COLD STREAM SITE A CONTRACT NO. AMD 14(0850)101.1 RUSH TOWNSHIP, CENTRE COUNTY[1]

P. J. Shah[2]

Abstract. A series of sedimentation basins and vertical flow wetlands (VFWs) were constructed on approximately 1.6 hectares (4 acres) of ground at a cost of $239,000 in the fall of 1998. The sedimentation basins remove metals precipitates and the VFWs neutralize acidity through neutralization (limestone) and sulfate reduction (spent mushroom compost). The system was designed to handle flows of about 450 L/minute (120 GPM) of highly acidic water (pH 2.6, 70 mg/L of iron, and an acidity of 900 mg/L) but has experienced flows ranging from 0 to 5300 L/minute (1400 GPM). The treated water has averaged pH 7.0, iron concentrations less than 1 mg/L, and no net acidity. There have been problems with aesthetics and odor complaints, and these have been dealt with. Based on our experience at this and other sites, some pre-and post-construction recommendations are provided.

Additional Key Words: passive treatment, vertical flow wetlands.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington KY 40502**.**

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SUMMARY OF NORTHERN BOND FORFEITURE AMD TREATMENT SITES[1]

Mike Sheehan and Jimmie Seckman[2]

Abstract: The West Virginia Office of Special Reclamation (WVOSR) is funded through section eleven; article three of chapter twenty-two of the Code of West Virginia, one thousand nine hundred thirty-one. Beginning January 1, 2002, section eleven increased the reclamation tax from three cents per ton of coal mined to fourteen cents. Seven cents of which is to be collected for a period not to exceed thirty-nine months. Funds allocated under section eleven are administered by an eight member advisory council created under section seventeen of article one, chapter twenty-two of the state code. The primary purpose of the advisory council is to ensure that the funds are utilized in the most effective, efficient, and financially stable manner.

The WVOSR is mandated to meet technology-based effluent standards at all bond-forfeited sites. To accomplish this task WVOSR has designed treatment facilities that utilize water driven dispensing units (Aqua Fix®) to dispense pebble quicklime (CaO) directly into the AMD, thereby neutralizing the mine drainage and precipitating out pollutant metals. Each treatment facility consists primarily of four components:

1. The dispensing unit, which includes a silo to store the lime, and various mixing mechanisms

2. Settling ponds

3. Sludge cells

4. A pipeline adapted for a portable pump to pump the sludge to the cells for disposal.

The size of the silo is based on the required amount of CaO. This amount is either derived based on acid load calculations or titration results (to Mn endpoint pH) whichever is available. The use of titration results is the preferred approach since these results are also useful in sizing the settling ponds and sludge disposal cells. The configuration of the settling ponds is an important consideration as well. For pumping purposes it is necessary to have at least two settling ponds with the capability of bypassing one pond to another. Periodic pumping of the settling ponds is required to maintain the design capacity of the ponds. It is highly recommended to pump the sludge from each settling pond before reaching 60% of its holding capacity. This ensures adequate retention time and simplifies pumping procedures. As the sludge accumulates, it forms a hardened mass that may need broken up either by mechanical means and/or hydraulic pressure, forcing the sediment toward the pump.

To date, this approach has been implemented at seven locations throughout northern West Virginia, with four other facilities currently under construction. As with other types of treatment, problems do present themselves. Problems encountered thus far include; extreme fluctuations in flow, leaves and algae clogging the intake lines to the dispenser, undissolved CaO accumulating in ditches or clogging valves, mixers malfunctioning, or a clogged dispenser due to moisture. These problems are easily remedied but do require attention on a continuous basis.

The use of pebble quicklime in this type of application has proven to be an effective method of AMD remediation. Water quality results are promising. Monthly sampling results indicate that the WVOSR is meeting effluent requirements.

[1] Paper to be presented at the Joint Conference, 21st American Society for Mining and Reclamation Meeting and 25th West Virginia Surface Mine Drainage Task Force Symposium, Morgantown, West Virginia, April 18-22, 2004.

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CHARACTERIZATION OF RECLAIMED SOILS IN SOUTHWESTERN INDIANA AFTER SURFACE MINING FOR COAL[77]

H. R. Sinclair, Jr., K. M. McWilliams, S. L. Wade, and G. R. Struben[78]

Abstract. The study was to document some laboratory soil properties, soil classifications, and selected morphological characteristics of soils reclaimed after surface mining for coal in southwestern Indiana. The reclamation of these soils range from 6 to 17 years. Scraper placement reclaimed all sites except Daviess 001. It used shovel-truck placement during reclamation. Seven of the eight soils sampled for laboratory characterization in southwestern Indiana were reclaimed using prime farmland rules and regulations developed by the State Regulatory Authority as set forth in the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87). Since being reclaimed all the soils have been in cropland or hayland for the last 6 to 17 years. The soils were sampled for laboratory characterization in November 2002. All the soils were fine-silty Alfisols before they were disturbed for mining. The reclaimed soils classify in either fine-silty or loamy Udarents. Five of the undisturbed soils had fragipans. Six of the undisturbed soils had aquic or oxyaquic conditions, which are indicated, in their classification. Selected laboratory data for the reclaimed soils are compared to properties in the National Cooperative Soil Survey Database for the premined soils. Through current reclamation techniques, most the reclaimed soils have similar soil properties to the pre-mined soils. Soil structure and bulk density are two of the properties that will be different than the premined soils.

Additional Key Words: Available water capacity, bulk density, Land-Capability Classification, National Cooperative Soil Survey Database, Public Law 95-87, soil morphological properties, structureless, and water retention difference.

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[77] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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USDA-NRCS's ROLE FOR SOILS INFORMATION IN THE SURFACE MINING CONTROL AND RECLAMATION ACT OF 1977 (PUBLIC LAW 95-87)[1]

H. Raymond Sinclair, Jr.[2]

Abstract. The Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) authorizes the Secretary of the Interior to implement a regulatory program to control the environmental impacts of mining operations. The Secretary of Interior administers this program through the Office of Surface Mining Reclamation and Enforcement (OSM) with assistance from state and other federal agencies as specified in the law. All functions and responsibilities assigned to USDA by Public Law 95-87 were delegated by the Secretary of Agriculture to the Chief of USDA-NRCS (formerly the SCS), except those that relate to the National Forest Service System Lands and to the USDA-Agriculture Research Service. This paper briefly presents the role USDA-NRCS had in the development of the rules, regulations, and guidelines to comply with Public Law 95-87 that pertained to soils before, during, and after surface mining for coal.

Additional Key Words: Historically used as cropland, Soil Conservation Service, State Regulatory Authority, Prime Farmland, Code of Federal Regulations, High Capability Land, policy and procedures[3], and Proof of Restoration.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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[3] The history presented in this paper happened when the agency's name was the Soil Conservation Service (SCS). It seems only appropriate that the event during the SCS era be shown as SCS in this paper. So, events that happened before the name changed to the Natural Resources Conservation Service (NRCS) will be shown as SCS. The several and long quotes will hopefully help the reader appreciate the style of writing during that era and the force those written words had on the SCS employees working at that time. Some of the early SCS policy and procedures contained in various SCS documents are paraphrased or occasionally the exact wording is used in this paper.

REMOTE SENSING, VISUALIZATION AND MODELING OF THE DIAMOND COAL MINE IN HAZLETON, PA[1]

Daniel Sirkis[2], Glendon Stevens, Dr. Timothy Bechtel

Abstract: More than two hundred homes in Hazleton, Pa. were found to have benzene vapors (a known carcinogen) from one of the largest underground gasoline storage tank spills in PA history. Remediating this site became the number one priority of USEPA Region III (EPA). A relic underground coal mine situated along a 3000 ft long plunging syncline beneath the Laurel Gardens neighborhood complicated site geology. The U.S. Army Corps of Engineers (USACE) determined if air filled mine voids existed and contained gasoline and gasoline vapors. The plan called for four study phases: Determining the mine location, Visualizing the geology and water table, Modeling mine pool effects on plume behaviors, and Field sampling to verify study results.

Mine Location: GIS was used to georeference and compare a 19th century mine map of unknown datum and coordinate system with old aerial photos, boreholes data and microgravity survey results. Extremely accurate location of the mine was critical for locating potential gas filled voids.

Visualization: A three dimensional geologic model was constructed from the GIS data and available site data depicting the relationship between site geology, the mine void, the mine pool elevation and the surrounding groundwater table. This predicted air filled mine voids in the upper areas of the syncline.

Modeling: A finite element groundwater model (FEMWATER) was developed to study mine pool effects on gasoline plume movements. Two different approaches were compared for modeling the mine pool. In one approach the mine void was modeled as high conductivity aquifer. In the adopted approach, it was modeled as an interior boundary with assigned heads. The model showed dissolved gasoline contaminants migrating to the mine.

Field Sampling**:** Using the gravity data and 3 dimensional mine model, several target areas for drilling were identified. Gas vapor explosion was a concern during drilling. The drilling plan incorporating the use of on-demand nitrogen gas connected to a drill rig. A gas filled mine void was encountered and an aqueous sample confirmed gasoline contamination in the mine.

Key Words: GIS, Microgravity, Mine Pool, FEMWATER

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

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LONGEVITY OF ACID DISCHARGES FROM UNDERGROUND MINES LYING ABOVE THE REGIONAL WATER TABLE[1]

J. Skousen, L.M. McDonald, and J. Demchak[2]

Abstract: The duration of acid mine drainage flowing out of underground mines is important in the design of watershed restoration and abandoned mine land reclamation projects. Past studies have reported that acid water flows from underground mines for hundreds of years with little change, while others state that poor drainage quality may last only 20 to 40 years. More than 150 above-drainage (those not flooded after abandonment) underground mine discharges from Pittsburgh and Upper Freeport coal seams were located and sampled during 1968 in northern West Virginia, and we revisited 44 of those sites in 1999-2000 and measured water flow, pH, acidity, Fe, sulfate, and conductivity. We found no significant difference in flows between 1968 and 1999-2000. Therefore, we felt the water quality data could be compared and the data represented real changes in pollutant concentrations. There were significant water quality differences between year and coal seam, but no effect of disturbance. While pH was not significantly improved, average total acidity declined 79% between 1968 and 1999-2000 in Pittsburgh mines (from 66.8 to 14 mmol H^+ L^{-1}), and 56% in Upper Freeport mines (from 23.8 to 10.4 mmol H^+ L^{-1}). Iron decreased an average of about 80% across all sites (from an average of 400 to 72 mg/L), while sulfate decreased between 50 to 75%. Pittsburgh seam discharge water was much worse in 1968 than Upper Freeport seam water. Twenty of our 44 sites had water quality information in 1980, which served as a midpoint to assess the slope of the decline in acidity and metal concentrations. Five of 20 sites (25%) showed an apparent exponential rate of decline in acidity and iron, while 10 of 20 sites (50%) showed a more linear decline. Drainage from five Upper Freeport sites increased in acidity and iron. While it is clear that surface mines and below-drainage underground mines improve in discharge quality relatively rapidly (20-40 years), above-drainage underground mines are not as easily predicted. In total, the drainage from 34 out of 44 (77%) above-drainage underground mines showed significant improvement in acidity over time, some exponentially and some linearly. Ten discharges showed no improvement and three of these got much worse.

Additional Key Words: Above-Drainage Underground Mines, Acid Mine Drainage, Metals, Sulfate, Water Quality.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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SOIL PROPERTIES IMPORTANT TO STREAM DEVELOPMENT ON MINED LANDS[1]

J. Skousen and J. Sencindiver[2]

Abstract: Fluvial processes and channel development on landscapes have recently received more attention as designers attempt to establish or replace natural streams on disturbed or degraded sites. Several approaches using similar parameters have been developed to evaluate stream development and erosion processes on natural soils and landscapes. Such approaches include the Manning's and stream power equations for stream development, and the Universal Soil Loss Equation (USLE) and the Bank Erosion Hazard Index (BEHI) for erosion. Soil properties used in these methods to evaluate erosion potential include texture (clay, silt and sand contents), bulk density, aggregate stability, rock fragments, soil horizons, rooting density and vegetation cover. Soil scientists have developed a well-known descriptive system for identifying and classifying disturbed soils and this information should be used to more fully evaluate the process of channel development on new landscapes. Therefore, the soil properties used in classification can be evaluated in designing channels and streams on disturbed lands, and refinements on interpreting these physical properties in the context of stream design need to be made.

Additional Key Words: minesoil properties, minesoil classification, reclamation, rehabilitation, stream restoration,

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE DEVELOPMENT OF A NATIONAL PROGRAM TO ABATE ACID MINE DRAINAGE THROUGH THE REMINING OF ABANDONED MINE LANDS[1]

Michael W. Smith[2], Roger J. Hornberger, Keith B.C. Brady, Jay Hawkins,
William A. Telliard, Joan Cuddeback, and Ken Miller

Abstract. Acid mine drainage (AMD) pollution from abandoned mine lands has long been recognized as one of the most serious causes of water pollution in the Appalachians. With reclamation to current-day standards and the use of appropriate best management practices (BMPs), remining can be an effective method for improving water quality. Passage of the Rahall amendment to the Clean Water Act and experience with remining in Pennsylvania and other states lead to EPA's development of a nationwide water quality rule for remining operations. EPA studied the effectiveness of BMPs in abating AMD and developed methods for establishing baseline pollution loads and evaluating postmining water quality. The nationwide rule encourages remining by establishing standardized permitting requirements and encourages pollution abatement through the implementation of effective BMPs.

[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mining Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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GEOCHEMISTRY, HYDROGEOLOGY, AND EFFECTS FROM THE PLUGGING OF ARTESIAN FLOWS OF ACID MINE DRAINAGE: CLARION RIVER WATERSHED, NORTHWESTERN PENNSYLVANIA [1]

Sherry L. Stafford, Theodore J. Weaver, and Robert S. Hedin[2]

Abstract. Numerous abandoned gas wells drilled during the late 1800's through the mid 1900's in the Clarion River watershed are acting as conduits for the artesian flow of iron-polluted waters to the surface. These shallow wells are located near surface mines, which were mined during the 1940's through the 1970's and had little if any surface reclamation. The geochemistry of the artesian well discharges suggests that they are originating in the open pit mine spoils located at the headwaters of tributaries to the Clarion River. Surface water filters through exposed mine spoils and weathers pyrite (FeS_2) producing water with low pH and elevated sulfate, acidity, and Al. The polluted water flows down through the fractured pit pavement into lower stratigraphic units and then flows laterally and down the synclinal structures through moderate to high productivity aquifers. The contaminated groundwater artesians to the surface through natural fissures or abandoned gas wells. Samples collected from twenty artesian discharges had pH values of 4.7 to 6.1, alkalinity concentrations of 26 to 110 mg/L as $CaCO_3$, sulfate concentrations of 33 to 1254 mg/L, and iron concentrations of 10 to 215 mg/L. Aluminum concentrations were less than 1 mg/L. Eighteen of the twenty samples were strongly acidic due to the presence of high concentrations of Fe. The change in chemistry between the surface mines and the artesian discharges is attributed to reaction with iron carbonate minerals such as siderite. The effect of plugging efforts on eight artesian flowing gas wells was monitored. Four wells were successfully plugged. Flow shifted rapidly from plugged wells to unplugged wells. The rapid response suggests that the wells drain a shallow contaminated aquifer. Because of the flow transfer, the plugging program had minimal remedial effect on the targeted watershed.

Additional Key Words: gas wells

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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GEOCHEMICAL CLUSTER ANALYSIS OF MINE WATER QUALITY WITHIN THE MONONGAHELA BASIN[79]

James M. Stiles,[80] Joseph Donovan, David A. Dzombak, Rosemary C. Capo, and Larry Cook

Abstract. The objective of this research was to conduct a cluster analysis of mean water quality data of 1,624 samples collected from 84 mine discharge sites within the Monongahela River basin over a 10 year period. This analysis produced four basic clusters. These four clusters were distinguished primarily by three factors: total dissolved solids, degree of acid neutralization, and mine discharge maturity. Most of the mine discharge sites (84%) were classified into a single cluster by the level one cluster analysis. Most of the discharges in this dominant grouping were older discharges from mines abandoned more than 15 years prior to discharge sampling. The discharges in the other three level one clusters exhibiting higher TDS levels tended to be more acidic and also to be from active mines, mines in the process of flooding, or mines flooded for less than 15 years

Future research should be devoted towards identifying the discharge maturity and flooding status of the various mine sites within the dataset, as well as the coal seam and overburden characteristics. The identification of these characteristics for all of the mine discharge sites would permit the analysis of separate datasets with comparable characteristics.

[79] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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HYDROLOGY OF THE ABANDONED UNDERGROUND CORNING COAL MINE, PERRY COUNTY, OHIO[81]

Mary W. Stoertz, Parameswar Sahu, Benny McCament, and Jennifer S. Bowman[82]

Abstract. The Corning mine complex, a suite of abandoned partially flooded room-and-pillar mines in Perry County, Ohio, contributes nearly 100% of the annual acidity load to upper Sunday Creek. Discharge, which issues from a single hole, averages 73 liters/s (2.6 cfs); acidity load averages 590 kg/day; and metal (Fe, Al and Mn) loads average 260, 2 and 13 kg/day respectively. The discharge is a high priority for remediation, but is not well suited for treatment by passive systems. Source-control strategies require knowing recharge sources, flow paths, underground pool interconnections, and mine residence times. This paper describes the development of both conceptual and quantitative models of the mine system, based on mine and soil water budgets, an equivalent-porous-medium numerical model, a barometric efficiency model, and a chemical mixing model. The models were based on monthly water sampling, continuous mine-pool and discharge hydrographs, borehole logs, meteorological data and mine maps.

The recharge rate is 20 cm/yr (13% of precipitation). Stream capture contributes 13% of the mine's annual recharge, with diffuse recharge accounting for 87%. During intense rainfall events, however, 50% of recharge can occur by stream capture. Mine storage varies seasonally, depending on recharge, which in turn depends on not just precipitation but also evapotranspirative demand and soil-moisture storage. Consequently, mine storage and discharge are highest in the late spring and lowest in the late summer and early fall. The mine aquifer is a gently dipping grid of rooms and tunnels that collectively provide hydraulic resistance to flow, and it does not form a single hydrostatic pool. Assuming that mines are fully interconnected and that water is well mixed yields a residence time of 5.1 years. However, barometric pressure response shows that the eastern 40% of the mine is separate and partially confined, with exceptionally poor water quality. The eastern portion accounts for only 10% of the flow, but contributes 50% of the chemical load. Excluding the weakly-connected eastern 40%, residence time is 3.9 years. Barometric responses of heads in various parts of the mine show unconfined behavior, confined behavior, or "displacement" behavior, in which heads increase with barometric pressure.

Additional Key Words: barometric efficiency, storativity, beach location

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[81]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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BIOGEOCHEMISTRY OF SELENIUM ON REMEDIATED PHOSPHATE-MINE TAILINGS IN SOUTHEASTERN IDAHO[1]

Daniel Strawn[2], Amy Ryser, Jodi Johnson-Maynard, Greg Möller, Brian Hart, Mathew Marcus

Abstract. Selenium (Se) occurs in a wide variety of oxidation states and is a common element present in sedimentary geologic materials such as shale. Phosphate mining activities in southeastern Idaho have left shale materials near the surface, thus releasing the natural Se into a new weathering environment. In this study we are investigating the biogeochemistry of Se at remediated phosphate mining sites. Soil samples were collected from the rhizosphere of remediated sites and analyzed using microscopically focused X-ray absorption fine structure (XAFS) spectroscopy. A greenhouse study to measure the impacts of sulfate and manure amendments on plant bioavailability is also discussed in this paper. XAFS spectroscopy results provide knowledge of mineralogy and Se-oxidation state in the soils. XAFS spectroscopy revealed that Se exists in several different reduced forms in the parent shale materials, including elemental Se and ferroselite-type minerals. In weathered soils, Se was present as Se(IV) and reduced Se minerals. All of the Se(IV) species were associated with iron, likely goethite. Soil pore water analysis revealed that the soil solution contained both Se(IV) and Se(VI), the most soluble and plant-available forms. We hypothesize that the reduced Se in the shale-parent materials is weathering to Se(IV)-goethite type minerals, which further oxidize to Se(VI) in the rhizosphere and is taken up into the plant foliage. The mechanism that rhizosphere oxidation occurs is unknown, and may be biotic or abiotic. Results from this study provide insight into the weathering mechanism by which Se is made plant available, and will help in developing improved management strategies that will reduce Se exposure to animals.

Additional Keywords: Selenium, Speciation, Bioavailability, XAFS

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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TRACE METAL RETENTION IN LBOS-AMENDED, VERTICAL-FLOW CONSTRUCTED WETLANDS TREATING LOW PH, FERRIC IRON-DOMINATED ACID ROCK DRAINAGE[1]

Robert C. Thomas, Christopher S. Romanek, and Lindy S. Paddock [2]

Abstract. Remediation strategies employed for mitigation of low-pH, metal-sulfate drainage (i.e., acid rock drainage, ARD) may include passive treatment systems. While shown effective for neutralization of acid and removal of major ions (e.g., iron, aluminum, and manganese), trace element removal during acid neutralization in passive systems is rarely investigated. Therefore, in this presentation, we will focus on the fate of trace metals in one common type of passive treatment system, the vertical flow wetland (VFW). Our experimental VFW contained a limestone buffered organic substrate (LBOS) and received low pH (<3), ferric iron-dominated ARD for two years. During this time, trace elements (As, Cd, Cr, Cu, U, Co, Ni, and Zn) were removed along a pH gradient controlled by a series of reaction zones that developed above a dynamic limestone dissolution front. Therefore, for the practical purpose of implementing LBOS to treat low pH, ferric iron-dominated ARD, high trace element removal efficiency can be expected as long as the limestone dissolution front does not pass completely through the substrate. With the exception of uranium, trace metal attenuation largely occurred above the limestone dissolution front in the transitional and oxide reaction zones. Moreover, trace metal removal exhibited a strong dependence on pH. Based largely on increasing pH with depth, trace metal removal within the LBOS follows the sequence:

$$As > Cu > Cr > Co = Ni = Zn = Cd > U.$$

Cadmium, copper, chromium, cobalt, nickel, zinc, and uranium were subject to remobilization as the pH decreased over time, although the degree of mobilization was trace element-dependent; arsenic was not remobilized. The following general order of trace element mobility can be applied to the LBOS:

$$U > Co = Zn \geq Cd = Ni > Cu > Cr > As.$$

Additional Key Words: trace element removal, sorption selectivity, arsenic, cadmium, chromium, copper, uranium, cobalt, nickel, zinc.

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AN UPDATE ON THE CHEAT RIVER RESTORATION[1]

Bill Thorne[2] and Keith Pitzer

Abstract. Extensive coal mining in the Cheat watershed that started in the early 20th century has left many streams and parts of the river severely degraded by acid mine drainage. Very little water treatment was conducted until 1977, when the Surface Mining Control and Reclamation Act (SMCRA) was enacted to prevent degradation from water quality from existing mines and funds were created to restore the abandoned mine sites. This was accomplished through bonding and a tax on coal tonnage. Since SMCRA, several once-active sites have been forfeited to the state to pay for the remediation from the bonding program and several of these contribute to the overall problem. The AML fund from the coal tax addresses the pre-law or previous to 1977 sites by funding reclamation on sites that have no legally responsible party.

The headwaters that had escaped damage from mining began seeing the effects of acid precipitation in the late 20th century from Midwest coal fired power plants and many streams lost all alkalinity because of poorly buffered soils. Poor water quality from these streams contributed to the degradation of the river. Because of these activities, much of the lower 25 miles of the watershed were without significant aquatic life by the early 1980s. Reclamation started in the watershed in the early 1980s and many projects have been completed. Not all of the projects addressed AMD; however, water quality has steadily improved over this period and some stream segments have shown significant increases in aquatic life in the past few years. This watershed has been the focus of state and federal agencies, watershed and conservation groups, and efforts are ongoing to further improve the water quality. The Cheat hosts a multitude of recreational activities and this makes continued restoration a high priority.

Additional Key Words: watershed, conservation, water quality.

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[1] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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ENVIRONMENTAL SELENIUM AND LAND DISTURBANCE: SOIL, VEGETATION, WATER AND ANIMALS[1]

George F. Vance[2]

Abstract. Selenium (Se), an element of interest and concern, is recognized for its environmental impact to soils, plants, and waters in native and disturbed ecosystems in western U.S. because of its natural occurrence and potential toxicity to wildlife and livestock (Vance & Schuman 1996). This presentation will address issues related to Se analysis and levels in soils, plants, waters, and wildlife. Information presented will be based on several Se-related research projects conducted by the author that examined analytical methods for Se analysis; methods of sampling; Se analytical procedures for soil, overburden, backfill, vegetation, and water; identification of Se levels in native and disturbed environments; and organism Se concentrations. Objectives of this research were to identify: 1) what extraction procedures are better indicators of "soluble" (plant available) soil or backfill Se; 2) what forms of Se are present in seleniferous soil and backfill materials, and how are these related to plant Se uptake; 3) what impacts do chemical, physical and biological soil characteristics have on plant Se uptake; 4) how does Se content of native and reclaimed plant species vary; 5) what effect does soil depth have on plant uptake of Se; and 6) what Se suitability limits should be recommended for reclaimed topsoil and vegetation?

Additional Key Words: Selenite; Selenate; Extractable Se; Hot water Se; AB-DTPA Se; Phosphate Se; Saturated paste Se; Bioavailable Se; Soil-plant Relationships; Site Characteristics; Standard Operating Procedures; Statistical Analysis; Atomic Absorption Spectroscopy; Hydride Generation; Ion Chromatography; Sediments; Vegetation Life-forms; Grasses; Forbs; Shrubs

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HELICOPTER FREQUENCY DOMAIN (FDEM) SURVEYS FOR CHARACTERIZING ENVIRONMENTAL PROBLEMS RELATED TO MINING: OBSERVATIONS AND CONCLUSIONS FROM 30 SURVEYS[83]

G. Veloski[84], R. Hammack, J. Sams, T. Ackman, and W. Harbert

Abstract. Since 1999, the National Energy Technology Laboratory has conducted helicopter frequency domain electromagnetic (FDEM) surveys of 30 sites to identify hydrologic problems that have resulted from mining activity. The FDEM data from these surveys was processed to generate conductivity maps and conductivity/depth images (CDI), which together show the lateral and vertical distribution of ground conductivity. This information has been used to determine: 1) the location, depth, and thickness of regional water tables and perched water tables, 2) the location of infiltration zones, 3) the location of pyritic wastes either on the surface or at depth, 4) the location of flooded mine workings (if filled with conductive water and located at depths less than 50 m), and 5) the likely locations for springs or mine discharges. Helicopter FDEM results have been validated using down-hole geophysical measurements, traditional hydrologic measurements from dense networks of groundwater monitoring wells, ground-based electromagnetic surveys, airborne thermal infrared imagery, and field reconnaissance.

Helicopter FDEM surveys cannot be used in heavily populated areas or areas near power lines. The exploration depth will be reduced in areas with conductive cover such as contaminated surface impoundments or clay layers.

Successful and unsuccessful FDEM surveys will be discussed.

[83] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd. Lexington, KY 40502.

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EFFECTS OF FERTILIZATION AND DISTURBANCE ON NATIVE SPECIES ESTABLISHMENT ON HIGHWAY CORRIDORS IN WEST VIRGINIA[1]

Christina Venable and Jeff Skousen[2]

Abstract. Introduced and invasive species have been recognized as potential threats to natural plant communities. Many such plant species are introduced along roadways, which then can spread to adjacent fields and forests. The West Virginia Division of Highways is required to develop seeding mixtures comprised of native plants for revegetating highway corridors and thereby reducing the potential for introduction of non-native species along roads. Therefore, the objectives of this project were to identify native plants that are suitable for seeding on highway sites and to document the establishment of these species after seeding on highway cut and fill areas. Phase 1 of the project began in April 2002, when three sites (Baker, Hazelton, and Parkersburg) were seeded with five seed mixes (Control, Native, DOH, DOH-Native, and DOH½-Native) into fertilized and unfertilized plots. Plots were 2m by 2m and each treatment (seed mix and fertilizer) was replicated four times (40 plots per site). Phase 2 of the project began in March 2003 when a native seed mix was sown on three sites (Weston, Buckhannon, and Elkins) into five different surface treatments and two fertilizer rates. After 2 years, Phase 1 results show that fertilizer and seeding mixture have a significant affect on plant growth and ground cover. The fertilized DOH and DOH-Native plots had the highest ground covers while the unfertilized Control and Native plots had the lowest. Unseeded, unfertilized plots generally had more weedy species than other plots. Native species establishment was poor and plots seeded to native species were mostly colonized by non-native and non-seeded species from adjacent areas. Native species were seen minimally by the second year. Phase 2 first year results also show that fertilizer and surface treatment had a significant affect on plant growth and ground cover. Tilled and herbicided plots tended to promote the establishment of native species best. In subsequent years, it is anticipated that the native species will emerge and become a more prominent contributor to the ground cover.

Additional Key Words: fertilization, highway construction, invasive species, revegetation, seed mixtures.

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[2] Christina Venable, Graduate Research Assistant, and Jeff Skousen, Professor of Soils and Reclamation Specialist, Division of Plant and Soil Sciences, West Virginia University, Morgantown, WV 26506.

A PRELIMINARY STUDY ON THE SPECIATION OF SELENIUM IN A WEST VIRGINIA WATERSHED[85]

Dorothy J. Vesper[86], Gary Bryant, Paul F. Ziemkiewicz

Abstract. The presence and chemistry of selenium (Se) has undergone considerable investigation in the western U.S. coal mining regions and in irrigated agricultural lands. Se is also present in West Virginia coals but its distribution and transport has received little attention to date. The recently completed Environmental Impact Statement (EIS) on Mountaintop Mining and Valley Fills (MTM/VF) reported Se in stream waters at concentrations up to 50 µg/L (USEPA, 1999). The streams with the elevated Se concentrations are located in watersheds impacted by MTM/VF in south-central West Virginia. Our ongoing work reviews the literature on Se in mine settings, and applicability of this largely western U.S. literature to the Appalachian geologic setting. This paper also reports our preliminary data for Se speciation in streams in southern West Virginia.

Additional Key Words: trace metals, coal mining

[85] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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DEVELOPMENT OF TREATED MINE WATERS FOR AQUACULTURE: OVERVIEW OF WATER QUALITY FROM DOGWOOD LAKES, 2002-2003[1]

Dr. Roger C. Viadero, Jr. & Aislinn E. Tierney[2]

Abstract: In October 2002, a production-scale experiment was initiated to assess the feasibility of using treated acid mine waters to rear rainbow trout (*Oncorhynchus mykiss*). The following were identified as major ionic constituents of the treated water: iron (Fe^{3+}), aluminum (Al^{3+}), manganese (Mn^{2+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), and sulfate (SO_4^{2-}). On average, dissolved ion concentrations exceeded levels recommended for freshwater aquaculture. Further, alkalinity, acidity, water temperature, turbidity, dissolved oxygen, nutrients (NO_2^-, NO_3^-, total ammonia nitrogen, and total phosphorus), BOD_5, and TSS were monitored. Of these parameters, un-ionized ammonia concentrations were in excess of recommended limits. However, the fish exhibited no signs of stress and grew well. A low mortality of ~1.4% was observed. The lack of impact by metals and ammonia loading was explained as a combination of high ionic strength impacts on "active" ion concentrations and on the formation of less bioavailable metal-ligand species such as $MgSO_4(aq)$ as opposed to the free magnesium ion.

In contrast, temperature was identified as a primary productivity-limiting water characteristic, based on the period of time water temperatures at the site were outside the optimum growth range for rainbow trout (~13 – 21°C). In general, fish growth changed in direct proportion to water temperature, where maximum growth was observed at temperatures within the optimum range for trout. However, growth rates were slower at the beginning of the study due to stress from handling and acclimation. Feeding was halted in the winter due to sustained low water temperatures (<4 °C), and operation was discontinued when the fish were harvested in the summer (June and July 2003) as temperatures approached lethal levels.

The total net production was 3,657 kg, with a calculated feed conversion rate of 1.4, and an average absolute growth rate of 1.55 g/day. Further, a condition factor of 0.0005 was determined, where a typical value for trout is ~0.0004. Thus, the trout grown in mine water exhibited normal growth.

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DEVELOPMENT OF TREATED MINE WATERS FOR AQUACULTURE: NON IDEAL WATER CHEMISTRY EFFECTS AT DOGWOOD LAKES[1]

Dr. Roger C. Viadero, Jr. & Aislinn E. Tierney[2]

Abstract: Water quality criteria have long been established for freshwater aquaculture, in which the effects of high ion concentrations are neglected, though similar criteria have not been developed for high ionic strength water sources such as treated mine waters. Consequently, this study was initiated to assess the opportunity of using treated mine waters to rear rainbow trout (*Oncorhynchus mykiss*).

Concentrations of dissolved metals were measured in excess of recommended freshwater limits at the study site; however, the trout stocked in the treated mine water had near normal growth patterns, little instance of disease, and low mortalities (~1.4%). Consequently, a rational for the lack of impacts was sought by examining the effects of the high ionic strength and speciation of dissolved metals in the treated mine water. The average active concentration of divalent and trivalent ions at the study site were 32% and 8%, respectively, of analytic concentrations, of the concentration predicted in low ionic strength, "fresh" waters. Consequently, the active concentrations of iron, aluminum, manganese, and calcium were actually below recommended limits, even though analytic concentrations exceeded recommended limits.

In the case of magnesium, the free Mg^{2+} ion is considered to be the most bioavailable species. However, free Mg^{2+} ions have a strong affinity for inorganic ligands such as SO_4^{2-} and OH^-, which are common in treated mine water. Thus, through complexation, soluble magnesium hydroxides and sulfates can be created. To determine Mg speciation, simulations of metal-ligand interactions were preformed under average conditions using *CHemical Equilibria for AQuatic Systems* software. At pH = 8.1 with a specific conductance of 6.7 mS/cm, only 53% of active magnesium was available as free Mg^{2+}, while ~47% was present as the less bioavailable $MgSO_4$. Consequently, non ideal effects of high ionic strength and coordination chemistry of treated mine waters must be considered when assessing the suitability of such waters for aquaculture.

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TECHNOLOGY AND DESIGN ADVANCES IN PASSIVE TREATMENT SYSTEM FLUSHING

Kimberly R. Weaver, P.E.[2], Kathleen M. Lagnese, P.E., and Robert S. Hedin, Ph.D.

Abstract: A common goal of passive mine drainage treatment is the removal metals such as iron and aluminum from contaminated water. However, these metals form solid particles that can clog pipes and limestone aggregate, increasing operational costs and decreasing treatment system longevity. To combat this problem, a wide variety of flushing systems have been installed in passive treatment systems. Flushing systems usually consist of a network of perforated pipes buried in limestone, which drain via valved header pipes. Periodically, the valves are opened to allow large amounts of water to flush through the system and, ideally, remove accumulated solids. This theoretically extends the useful life of passive systems by restoring porosity. Unfortunately, flushing system design is poorly understood and most systems are not designed using scientific or engineering principles. Four existing systems were examined from an engineering standpoint and an engineering method for designing these systems was developed. The purpose of this paper is to provide a survey of flushing technologies currently being used, detail one method of using engineering principles to design flushing networks, and discuss the implications of this analysis on future flushing technologies.

Additional Key Words: mine drainage treatment

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MINING INFLUENCED WATERS: THEIR CHEMISTRY AND METHODS OF TREATMENT[1]

T. R. Wildeman[2], and R. Schmiermund

Abstract. More and more often, in treating waters associated with mining projects, it is not acid rock drainage that is the focus of concern. Consequently, we have coined a new phrase "mining influenced waters" to include all the types of water that can be encountered. These waters can be divided into four categories. For acid rock drainage (ARD) the primary treatment problem is the elimination of mineral acidity in the form of soluble iron and aluminum. For mineral processing waters, the water is usually basic and the primary treatment problem is usually the elimination of cyanide, arsenic and selenium. For marginal waters, the water is circum-neutral but contains contaminants slightly above aquatic standards. For these waters, the treatment problem is often reducing small concentrations of contaminants in high flows of water. Finally, for residual waters, the primary treatment problem is the removal of high levels of total dissolved solids. For residual waters, there are few treatment options and these waters are becoming a serious environmental problem in some mining operations.

Additional Key Words: aquatic chemistry, acid mine drainage, water treatment, mineral processing, and total dissolved solids

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THE USE OF A PRIORITIZATION INDEX TO RANK MINE DISCHARGES AND TRIBUTARY STREAMS FOR REMEDIATION CONSIDERATION[87]

Donald R. Williams[88]

ABSTRACT. The Pittsburgh, Pennsylvania, project office of the U.S. Geological Survey (USGS) has been involved in various studies of the effects of mine drainage on stream water quality. Two of these studies focused on prioritizing the severity of mine discharges and the relative impairment of streams. One study located and sampled abandoned coal-mine discharges in the Stonycreek River Basin in Pennsylvania and prioritized the mine discharges for remediation. This priority ranking system, or prioritization index (PI) developed for mine discharges, also was used to prioritize tributary streams and reaches of the mainstem throughout the lower Cheat River Basin in northern West Virginia. The major difference between the PIs of the studies was that the Stonycreek River Basin index was applied to chemical loadings of point-source mine discharges, whereas the Cheat River Basin index was applied to mainstem river sites, tributary stream sites, and subbasin stream sites within the major tributaries in terms of chemical yields. The PIs for both studies were based on a site-to-site water-quality comparison of the loads and yields of selected chemical constituents that included total iron, total manganese, dissolved aluminum, total heated acidity, and dissolved sulfate. Water discharge was an important physical measurement used to calculate the loads and yields of the chemical constituents. Water discharge and pH were used as "tiebreakers" in developing the PI. All of these factors are related either directly or indirectly to the effects of coal-mine drainage on water quality. A computerized spreadsheet of the water-quality data was used to simplify the PI calculations. The PI, developed to assist water-resource managers in considering remediation possibilities at specific mine discharges in the Stonycreek River Basin or in the many tributary basins and subbasins throughout the lower Cheat River Basin, is suitable for application in other watersheds affected by mine drainage. Some potential modifications to improve the index method are discussed.

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[88] Donald R. Williams is a Hydrologist at the U.S. Geological Survey, 1000 Church Hill Road, Suite 200, Pittsburgh, PA 15205.

STREAMSIDE SALAMANDERS IN VALLEY FILL AND REFERENCE STREAMS IN SOUTHERN WEST VIRGINIA[89]

Jennifer M. Williams and Petra Bohall Wood[90]

Abstract. We sampled stream salamanders in southern West Virginia during 2001 in streams below head-of-hollow valley fills and in reference streams to determine if there were differing trends in relative abundance between these treatments. Head-of-hollow valley fill construction can cover headwaters, first-order, second-order, and higher order reaches with excess spoil materials; valley fills in southern West Virginia are often hundreds of hectares in size. Total salamander captures were higher in 3 reference streams (RS; N=389) than in 4 valley fill streams (VFS; N=289) and mean abundance was significantly greater in reference streams. Number of salamanders captured was positively related to number of rocks in the stream substrate. We suggest that alterations in water chemistry, substrate composition (greater silt cover), and fewer rocks below valley fills all may have contributed to reduced salamander densities in VFS.

Additional Key Words: streamside salamanders, mountaintop removal mining, head-of-hollow valley fills, water chemistry

[89] Paper presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE RELATIVE MERITS OF NATIVE TRANSPLANT PLUGS AND TOPSOIL ISLANDS IN THE ENHANCEMENT OF UNDERSTORY BIODIVERSITY ON RECLAIMED MINELANDS[91]

Keith Winterhalder[92]

Abstract. In northeastern Ontario, Canada, mine tailings and lands rendered barren by smelter emissions are commonly revegetated using a grass-legume mixture, then planted with native trees, mostly conifers such as Red, White and Jack Pine. Vigorous colonization by native pioneer tree species such as White Birch and Trembling Aspen occurs, as well as that of native herbs associated with forest openings, such as Asters and Goldenrods. However, it is rare for the herbs and shrubs found in the understory of a mature pine forest to colonize these artificially wooded sites. Native understory species have been transplanted from natural habitat at an experimental level over a number of years on grassed smelter-affected barrens and grassed tailings, to determine whether such transplants survive and spread. Small islands of forest topsoil have also been established on grassed tailings. The source of native plugs has been predominantly mature Jack, Red and White Pine forest, but species adapted to naturally exposed sites such as sand dunes have also been transplanted with success. Not surprisingly, the species that spread most readily are those possessing rhizomes or stolons, such as Canada Mayflower (*Maianthemum canadense*) and Starry False Solomon's Seal (*Smilacina stellata*) in the case of plugs, and Spreading Dogbane (*Apocynum androsaemifolium*) in the case of topsoil islands. Since results so far suggest that both approaches are valid, the relative advantages of each are critically appraised.

Additional Key Words: tailings, revegetation, restoration

[91] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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NUMERICAL MODELING OF A LARGE MINED SYNCLINAL COAL BASIN, WESTMORELAND COUNTY, PENNSYLVANIA[93]

William R. Winters and Rosemary C. Capo[94]

Abstract. The Irwin Syncline bituminous coal basin has been extensively underground mined with numerous complexes (>95% mined over a 240 km^2 area; Pullman-Swindell, 1977). Earlier work in the Irwin Syncline demonstrated the benefit of dividing the basin into smaller sub-basins based on equilibrium flow conditions established over the past 30 years (Winters et al. 1999; Winters and Capo, in press). MODFLOW numerical modeling was undertaken to quantify the hydraulic relationships within the basin and to corroborate sub-basin delineation over time (~ 5-15 yrs) as post-mining equilibrium hydraulic conditions develop. Boundary conditions are imposed by (1) the coal outcrop, which limits hydraulic influence, (2) the low hydraulic conductivity of the coal seam floor (typically clay, $K \sim 10^{-8}$ cm/sec), and (3) large surface water bodies. Because of these constraints, recharge can be assumed to emanate primarily from infiltration through the overburden rocks. Basin discharge can be directly measured from the large discharges that developed following basin flooding.

In the Irwin basin, the overburden rocks range in thickness from 0 m at the outcrop to 200 m in the interior. Overburden units were modeled as four distinct hydraulic conductivity zones that correspond to classic mine subsidence profile models (Singh 1992). Initial model results indicated that mine water is discharging through the intervening overburden to the Youghiogheny River, which overlies the southwestern portion of the basin. To calibrate the model, 15 mine pool monitoring points from the 1970's were used to establish known hydraulic head elevations in the northern 2/3 of the basin. Hydraulic head elevations in the southern 1/3 were determined from current pumping elevations at two treatment plants in the area. Preliminary results from the calibrated model demonstrate the hydrologic impact of interior coal mine barriers on the flow regime and confirm that the largest discharges ($Q > 0.18$ m^3/s) are the dominant influence on the flow system. Future modeling efforts will concentrate on sensitivity analysis of recharge and other hydraulic parameters and on refinement of methods used for modeling the mine-void aquifer system.

Additional Key Words: AMD, hydrology, MODFLOW

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[93] Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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THE ROLE OF AIRBORNE REMOTE SENSING AND GEOPHYSICS IN ACID MINE DRAINAGE ASSESSMENT OF THE LOWER KETTLE CREEK WATERSHED, CLINTON COUNTY, PENNSYLVANIA[1]

Amy G. Wolfe[2]

Abstract. The Kettle Creek watershed in north central Pennsylvania is home to one of the state's most renowned trout fisheries and has attracted anglers nationwide since the late 1800s. However, historic practices of coal mining have left behind a tragic legacy of acid mine drainage (AMD) emanating from unreclaimed surface mines and abandoned deep mines that pollute over fifteen miles of stream in the lower watershed, leaving them essentially lifeless. Since 1998, Trout Unlimited (TU) has been working through its Home Rivers Initiative to restore and conserve this important coldwater fishery. Kettle Creek is TU's third Home Rivers Initiative project, which are multi-year projects in which significant staff and financial resources are committed to certain watersheds across the country to take a science-oriented, community-based, collaborative approach to river and fishery restoration. Through funding provided by the Pennsylvania Growing Greener Grants Program, TU partnered with the U.S. Department of Energy National Energy Technology Laboratory to conduct an airborne remote sensing and geophysical survey on 80 km^2 of the lower Kettle Creek watershed. This survey used a combination of thermal infrared (TIR) imagery and helicopter-mounted electromagnetic (HEM) surveys to locate: 1) abandoned deep mine pools, 2) recharge zones for mine pools, 3) contaminated groundwater discharge points, and 4) areas of acid-generating mine spoils. Of the 53 AMD polluted groundwater seeps identified by the TIR imagery, field reconnaissance determined that 26 were known sites and 27 were previously unknown. The HEM survey identified approximately 12 mine pools in shallow underground coal mines and successfully located AMD seeps, acid-generating spoils, and groundwater recharge zones. Overall, TIR and HEM survey data yielded beneficial data for a large area in a short amount of time, thereby significantly reducing costs associated with the typical means of manpower for obtaining the same large-scale data collection.

Additional Key Words: thermal infrared imagery, airborne electromagnetic surveys, watershed assessment, mine drainage remediation.

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[1] Presented at the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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RECLAMATION OF ABANDONED COAL MINE WASTES USING LIME CAKE BYPRODUCTS IN KOREA[1]

Jae E.Yang, H.J. Kim, J.Y. Choi, J.P. Kim, Y.S. Shim, J.M. An and Jeffrey G. Skousen[2]

Abstract. In Korea, hundreds of abandoned and closed coal and metallic mines are present in the steep mountain valleys due to the depression of the mining industry since the late 1980s. From these mines, enormous amounts of coal waste were dumped on the slopes, which causes sedimentation and acid mine drainage (AMD) to be discharged directly into streams causing detrimental effects on soil and water environments. A limestone slurry by-product (lime cake) is produced from the Solvay process in manufacturing soda ash. It has very fine particles, low hydraulic conductivities ($10^{-8} \sim 10^{-9}$ cm/sec), high pH, high EC due to the presence of CaO, MgO and $CaCl_2$ as major components, and traces of heavy metals. Due to these properties, it has potential to be used as a neutralizer for acid-producing materials. A field plot experiment was used to test the application of lime cake for reclaiming coal wastes. Each plot was 20 x 5 m (L x W) in size on a 56% slope. Treatments included a control (waste only), calcite ($CaCO_3$), and lime cake. The lime requirement (LR) for the coal waste to pH 7.0 was determined and treatments consisted of adding 100%, 50%, and 25% of the LR. The lime cake and calcite were also applied in either a layer between the coal waste and topsoil or mixed into the topsoil and coal waste. Each plot was hydroseeded with grasses and planted with trees. In each plot, surface runoff and subsurface water were collected. The lime cake treatments increased the pH of coal waste from 3.5 to 6, and neutralized the pH of the runoff and leachate of the coal waste from 4.3 to 6.7. Surface cover of seeded species was significantly increased with lime cake and the 25% LR plots were sufficient to neutralize the acidity in the coal waste.

Additional Key Words: abandoned mine land, acid mine drainage, runoff, revegetation, water quality

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force, April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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BUTTE MINE FLOODING WATER TREATMENT FACILITY: IMPLEMENTATION OF MAJOR COMPONENT OF SELECTED REMEDY FOR HISTORIC CONTAMINATION AT BERKELEY PIT SITE[95]

Robert L. Zick[96], David A.Velegol, Jr., Mark W. Hess, and Martin Foote

Abstract. The Anaconda Mining Company was founded in 1891, and it soon absorbed the independent underground copper mines in Butte, Montana. The underground mining operations continued through the mid-1950s when open-pit mining at the now famous Berkeley Pit site began. Over the years, the pit grew into a crater 1.5 miles across and 1,800 feet deep. By 1977, Anaconda Mining was struggling and ripe for takeover by Atlantic Richfield Oil Company, which was diversifying into hard-rock mining. Within a few years following the purchase, the Berkeley Pit operations began to fail and by the early 1980s, the remaining shafts were closed and the mine pumps were de-energized, allowing the pit to begin filling. In 1983, the Environmental Protection Agency declared that Butte was a high-priority Superfund site[97]. The Butte Mine Flooding Operable Unit (BMFOU) is located within the Butte Mining District in the upper Silver Bow Creek (SBC) drainage area. Atlantic Richfield and Montana Resources, LLP, the Potentially Responsible Parties (PRPs), have liabilities for this operable unit, and under the selected remedy they will continue into perpetuity. A key component of the site remediation activities involved the design and construction of a two-stage, high-density sludge water treatment facility using calcium oxide for neutralization of the Horseshoe Bend (HSB) seep. The process primarily removes metals. Those of concern include aluminum, arsenic, copper, cadmium, iron, manganese, and zinc. The paper provides a timeline for major events and other developments relating to the site including the Record of Decision, a Unilateral Administrative Order, Remedial Investigation/Initial Feasibility Study, Pilot Studies, Contingency Treatment Plant Design, Final Design/Report Documents (EPA Region 8), Site Inflow Control, Sludge Disposal Method, Monitoring Program, Interim/Final Discharge Requirements, and Features/ Benefits/Performance of the Water Treatment Facility.

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[95] Paper to be presented at the Joint Conference, 21st American Society for Mining and Reclamation Meeting and 25th West Virginia Surface Mine Drainage Task Force Symposium, Morgantown, West Virginia, April 18-22, 2004.

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[97] William Langewiesche, *The Profits of Doom*, The Atlantic Monthly, April 2001.

ATTENUATION OF SELENIUM IN MINE SPOIL [1]

P.F. Ziemkiewicz [2] and A.S. Knox

Abstract: Coal Combustion Byproducts (CCBs) are attractive for filling abandoned coal mines because they may constitute a source of low cost alkalinity and favorable economics. The environmental risk of mine filling with CCBs is currently evaluated by either the Toxic Characteristics Leaching Procedure (TCLP) or the Synthetic Precipitation Leaching Procedure (SPLP). However, these tests include only one leach cycle and there is doubt regarding their applicability to long-term CCBs leaching behavior in groundwater environments: particularly those associated with coal mines. The Mine Water Leaching Procedure (MWLP) was developed to provide a site specific risk assessment tool. In this study we added increasing proportions of coal mine spoil to MWLP fly ash leachings to evaluate the potential of a given mine spoil to sorb selenium ions.

Selenium has emerged as a significant mine drainage issue associated with placement of coal ash in exhausted coal pits in the eastern U.S. coal fields. This study indicated that significant attenuation may be realized by selectively placing selenium source materials upgradient of fine grained mine spoils. To evaluate the attenuation potential of spoils, a series of experiments were conducted using the Mine Water Leaching Procedure (Ziemkiewicz et al., 2003). Tumbling flasks were filled with acid mine drainage and varying proportions of a silty/clay spoil and a selenium-producing coal ash. The class F coal ash had a neutralization potential of 1.5% and three leaching cycles of 18 hours were conducted. This was adequate to exhaust the ash's inherent alkalinity allowing the leach water to return to its original pH. At the end of each leach cycle solid residues were collected and subjected to a fresh aliquot of mine water. The results indicated selenium mobility in pure ash leaches and at low spoil addition rates but at a ratio of 100 g spoil: 50 g ash and above selenium was immobile (Table 1.). This is consistent with findings that selenium in eastern U.S. class F ashes tends to be in the reduced, selenite form. Selenite is more strongly sorbed to clays while the oxidized form: selenate is only weakly sorbed by clays (Guo, et al., 1999).

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[1]Paper was presented at the 2004 National Meeting of the American Society of Mining and Reclamation and The 25th West Virginia Surface Mine Drainage Task Force , April 18-24, 2004. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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