

NATIONAL MINE LAND RECLAMATION CENTER SUMMARY ACID MINE DRAINAGE RESEARCH PROJECTS

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WEST VIRGINIA UNIVERSITY**

Following is a summary of research projects supported through the National Mine Land Reclamation Center up to June 1992. The Center, as three regional centers: the Eastern Center consists of West Virginia University and Penn State University, the Midwestern Center consists of Southern Illinois University and the Western Center comprises University of North Dakota and North Dakota State University. Each regional center has an advisory committee of industry and regulatory agency staff which directs the activities of the center toward regional problems of greatest impact.

EASTERN REGION

**West Virginia University
The Pennsylvania State University**

ACID MINE DRAINAGE

Removal of Iron and Manganese from Acid Mine Drainage by Cattail Wetlands: Chemical and Microbiological Processes (WV03)

OVERVIEW: Both natural and artificial wetlands have been shown to improve water quality, but the effectiveness of removal has varied. Researchers involved in this project are evaluating the chemistry of metal removal from acid mine drainage in several types of simulated wetlands established in a greenhouse. The experimental wetlands have been receiving concentrated acid mine drainage for a period of 33 months. During spring 1991, emergence of cattail was significantly retarded in troughs receiving acid mine drainage, and there were fewer total plants in these systems. By July, individual plants in treated troughs were less than half the size of those in untreated wetlands. In April 1992 plants were harvested for further study. The researchers are employing several indices of plant stress to compare plant health in treated and untreated systems, including growth measurements of individually tagged plants, leaf fluorometry, and total photosynthesis.

OUTCOME: In the first several years of the project up to 400%, the incoming iron was precipitated in sulfide form. More recent data indicate that nearly 50% of the iron has been removed from the influent water. As the wetlands have matured the oxidation zone has

increased to the point where most iron has precipitated as ferric oxy-hydroxides. At the same time soluble ferrous iron has been produced at the lower depths of the wetland at near neutral pH. In this sense the wetland is beginning to behave like an anoxic limestone drain.

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| INVESTIGATORS: | Alan J. Sexstone, John C. Sencindiver, and Gary K. Bissonnette West Virginia University |
| START DATE: | July 1, 1990 |
| END DATE: | June 30, 1993 |
| STATUS: | Ongoing |
| FUNDING: | NMLRC \$11,300 WVU \$8,760 Industry / Other \$24,094 |

Investigation of Manganese Chemistry in Acid Mine Drainage (WV20)

OVERVIEW: The objectives of this project are to understand the kinetics and thermodynamics of manganese removal from acid mine drainage and to investigate methods to accelerate manganese removal and improve sludge quality. Researchers have conducted studies of manganese removal using a number of chemicals. Calcium hydroxide, sodium hydroxide, sodium carbonate, and calcium carbonate have been used.

OUTCOME: This project is complete and has demonstrated that precipitation of iron and manganese from acid mine drainage are sequential with manganese precipitation occurring only after nearly all iron has been removed from the solution. A new method of evaluating the degree of precipitate oxidation has been developed. This permits evaluation of the chemical stability of precipitates and their susceptibility to resolubilization.

Once iron is removed from acid mine drainage most of the manganese can be removed fairly quickly, corresponding to the quick pH rise associated with the addition of lime or caustic. Resulting pH's are in the range of 7. Limestone, however, reacts slowly and gradually raises the pH to 7; the high localized pH values needed to initiate manganese removal is never created and limestone is thus ineffective for removing manganese.

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| INVESTIGATORS: | Raymond J. Lovett West Virginia University |
| START DATE: | July 1, 1990 |
| END DATE: | June 30, 1992 |
| STATUS: | Project completed. Final report in preparation. |
| FUNDING: | NMLRC \$29,063 WVU \$4,833 |

Tolerance of Wetland Species to Acid Mine Drainage and Long-term Viability of Wetland Plant Communities as Acid Mine Drainage Treatment Systems (WV25)

OVERVIEW: Artificial wetlands have been used to treat acid mine drainage for a relatively short period of time, and there is little information on the stability or longevity of these

systems. Researchers on this project are addressing the following issues: the longevity of wetlands as AMD treatment, the tolerance of wetland species to acid mine drainage, and the efficacy of alternative species compositions in artificial wetlands. Twenty-six "volunteer" wetlands of various ages are being studied. All receive drainage from reclaimed or abandoned mines. A vegetation survey has been carried out at each wetland. Five species have been chosen for further study.

OUTCOME: This project has completed its second year. Data from the original 15 wetlands surveyed in 1990 has been combined with the data from 11 wetlands surveyed in 1992 and is currently being analyzed. Tolerance and stress tests are being used to examine plant performance.

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| INVESTIGATORS: | Keith Garbutt and James B. McGraw West Virginia University | |
| START DATE: | July 1, 1990 | |
| END DATE: | June 30, 1993 | |
| STATUS: | Ongoing | |
| FUNDING: | NMLRC | \$14,200 |
| | WVU | \$32,099 |
| | Industry / Other | \$24,094 |

In Situ Removal of Metals and Acidity from Pretreated Acid Mine Drainage Using Typha Wetlands (WV27)

OVERVIEW: Ammonia has been used to treat acid mine drainage. The objective of this project is to evaluate the effectiveness of using wetlands downstream from ammonia treatment ponds as a means of limiting the amount of ammonia that escapes to the receiving stream. Project researchers are investigating the effectiveness of hybrid systems, where wetlands are the terminal step receiving chemically pretreated water. Field and greenhouse model wetlands are receiving ammonia-treated acid mine drainage.

OUTCOME: Researchers are finding that although the ammonia treatment effectively removes metals from the influent, reducing conditions in subsurface sediments are mobilizing existing reduced iron and particularly manganese from the soil used in pond construction. Similar effects have been found at the field site.

Subsurface baffles that force influent waters to lower depths appear to have a positive effect in raising subsurface pH. "Limestone windows" in the treated troughs have been installed to further nitrification.

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| INVESTIGATORS: | Alan J. Sexstone, Jeff G. Skousen, GGary K. Bissonnette, and John C. Sencindiver West Virginia University | |
| START DATE: | July 1, 1990 | |
| END DATE: | June 30, 1993 | |
| STATUS: | Ongoing | |
| FUNDING: | NMLRC | \$53,596 |
| | WVU | \$17,039 |

Fly Ash Seals to Control Acid Mine Drainage (WV28)

OVERVIEW: Many abandoned surface mines produce acid mine drainage. This project explores several methods to identify the source of the acid within the spoils and then treat the problem areas so as to control AMD production. Researchers studied three AMD sites for their applicability for fly ash seals to control acid mine drainage. After careful analysis of spoil location, geology, hydrogeology, and mining practices, they concluded that effective control of acid mine drainage via surface seals was not likely. However, the sites appeared suitable for low-permeability grout containment of acid mine drainage.

OUTCOME: Lab and field work has continued on developing a low-cost, low-permeability grout using waste materials. The work has consisted of testing various grouts for permeability and leaching characteristics and analyzing flow rate measurements and effluent quality.

Amended fly ash mixes were developed with permeabilities as low as 6×10^{-7} cm/sec. These mixes were very ductile and were comprised of 75% fly ash as the primary mix material. A grout has been developed comprised of 10% fly ash and 90% lime-treated AMD sludge. The grout has permeabilities as low as 10^{-5} cm/sec and demonstrated good pumpability characteristics. The grout is being used by the U.S. Bureau of Mines at a field test site. Once grouted, the site will be monitored and a computer model will assess the effectiveness of the grouting scheme in mitigating the AMD problem.

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| INVESTIGATORS: | John J. Bowders, John C. Sencindiver, and William S. Almes West Virginia University |
| START DATE: | July 1, 1990 |
| END DATE: | June 30, 1993 |
| STATUS: | Ongoing |
| FUNDING: | NMLRC \$79,844 WVU \$25,455 Industry / Other \$95,000 |

Trapzene for Treatment of Acid Mine Drainage (WV32)

OVERVIEW: Trapzene, a new chemical for treating acid mine drainage, was developed by researchers at West Virginia University. In conjunction with FIVIC Corporation, this project is moving Trapzene from the lab bench to commercial application. Trapzene is distinguished from conventional AMD treatment chemicals by its ability to remove iron and manganese at low pH: pH 4 for iron removal and pH 7 for manganese removal. In addition Trapzene creates a much more compact sediment than conventional treatment chemicals, generally 50% to 75% volume reductions. This feature increases sludge pond life and decreases the cost of pond cleanout.

OUTCOME: This project is complete.

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| INVESTIGATORS: | Paul Ziemkiewicz and Raymond J. Lovett |
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| | West Virginia University |
| <i>START DATE:</i> | July 1, 1990 |
| <i>END DATE:</i> | June 30, 1992 |
| <i>STATUS:</i> | Project completed. |
| <i>FUNDING:</i> | Industry / Other \$20,229 |

Coating for Underground Mine Acid Drainage Control (WV39)

OVERVIEW: Abandoned underground coal mines commonly discharge acid mine drainage through gravity flow along drift tunnels and through pressure-head spring discharge via fractures near coal barriers and mine seals. At present there is no proven technique to prevent or stop acid mine drainage from forming and flowing from such mines, short of expensive continuous treatment with neutralizing chemicals. The objective of this project is to develop new chemical or mineral coatings to prevent acid mine drainage from exposed rock surfaces in underground coal mines. If such coatings are successful, new coal reserves could be mined in northern West Virginia and elsewhere.

OUTCOME: Of the 15 coatings studied so far, eight have passed all durability lab tests, and four of these eight are economical and convenient for mine spraying. These four also appear to be successful in preventing acid mine drainage based on early results of soxhlet experiments,

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| <i>INVESTIGATORS:</i> | Henry W. Rauch |
| | West Virginia University |
| <i>START DATE:</i> | July 1, 1991 |
| <i>END DATE:</i> | June 30, 1993 |
| <i>STATUS:</i> | Ongoing |
| <i>FUNDING:</i> | NMLRC \$27,046 |
| | WVU \$5,109 |
| | Industry / Other \$15,900 |

Hydrological Modeling for Watershed Restoration (WV43)

OVERVIEW: This research will determine the most cost effective means of treating acid mine drainage and abandoned mine land problems in a watershed. The approach is to develop a comprehensive plan for treating the Sovern Run watershed in West Virginia. The benefits of restoring a fishery to the lower six-miles of the Big Sandy River will be examined.

OUTCOME: Water quality samples have been collected and flow measurements have been taken at consistent sampling points. Sampling has been continued through fall 1992, and the costs of various alternative approaches to treatment have been studied.

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| <i>INVESTIGATORS:</i> | Jerald J. Fletcher, Tim T. Phipps, |
| | Jeff G. Skousen |
| | West Virginia University |
| <i>START DATE:</i> | July 1, 1991 |
| <i>END DATE:</i> | June 30, 1993 |
| <i>STATUS:</i> | Ongoing |

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| FUNDING: | NMLRC | \$45,322 |
| | WVU | \$21,270 |
| | Industry / Other | \$12,874 |

Chemical Risk Assessment of Sediments from Mining Operations: Characterization of Sludge from Acid Mine Drainage (WV46)

OVERVIEW: This project will evaluate the relative efficiency with which the various AMD treatments remove metals from a solution. The study will improve the understanding of metal removal and evaluate the rates of metal remobilization when sludge is mixed with different pH solutions.

OUTCOME: The research consists of four phases. Phase 1 consisted of collecting acid mine drainage and sludges from four field sites representing different AMD compositions and treatment materials. Phase 2 has consisted of experiments exposing the four field AMD solutions to four treatment materials. Phase 3 will analyze the data. Phase 4 will be statistical analysis and the generation of a mathematical model.

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| INVESTIGATORS: | John J. Renton West Virginia University | |
| START DATE: | July 1, 1991 | |
| END DATE: | June 30, 1993 | |
| STATUS: | Ongoing | |
| FUNDING: | WVU | \$15,704 |
| | Industry / Other | \$80,374 |

Analytical Testing for Acid Mine Drainage (WV51)

OVERVIEW: The center is providing funds to establish and maintain an analytical facility to evaluate acidic rock.

OUTCOME: A laboratory has been established using the soxhlet-oven reoxidation procedure. The laboratory will evaluate the AMD-producing potential of any rock materials submitted by university researchers and the coal industry. Rocks are subjected to the soxhlet procedure and the solutions are analyzed by the NRCCE aqueous analytical facility. An existing mathematical model evaluates the acid potential of the rock material. The lab and soxhlet procedure allows the coal industry to make adequate pre-mining plans for the treatment and ameliorization of acid mine drainage based on scientifically sound criteria.

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| INVESTIGATORS: | John J. Renton West Virginia University | |
| START DATE: | July 1, 1991 | |
| END DATE: | June 30, 1993 | |
| STATUS: | Ongoing | |
| FUNDING: | Industry / Other | \$10,907 |

Prediction and Amelioration of Acid Mine Drainage (PSU02)

OVERVIEW: The main objectives of this project are to develop a basic knowledge of the processes generating acid mine drainage from reclaimed surface coal mines, to investigate the efficiency of possible methods of predicting future acid generation, and to prevent acid drainage from proposed mines. Researchers are conducting field studies at two mine sites. Piezometers and gas samplers have been installed within boreholes drilled at both mine sites. Hundreds of shallow holes are being used for the near surface temperature investigation, and the holes have been monitored monthly.

OUTCOME: This project has thus far confirmed the significance of spoil gas exchange, temperature, and bacterial action in controlling the rate of pyrite oxidation. A transit it 2-numerical model (HOT) that simulates AMD generation has been completed. Theoretical considerations included boundary conditions, hydraulic parameter estimations of mine spoil, and kinetic modeling of acid reaction-is.

INVESTIGATORS: Richard R. Parizek, Michael L. Machesky,
and Arthur W. Rose
Pennsylvania State University

START DATE: July 1, 1988

END DATE: June 30, 1992

STATUS: Project completed.
Final report received.

FUNDING:

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| NMLRC | \$35,000 |
| PSU | \$69,570 |
| Industry / Other | \$113,240 |

Mine Water Renovation in Wetland Environments (PSU03)

OVERVIEW: Two constructed wetlands in Pennsylvania are being used in this project to reveal the factors which influence the removal and retention of mine water pollutants. Researchers have been characterizing the chemicals of the wetland sediment, interstitial water, and surface water, and are now developing a predictive quantitative model describing diagenetic changes in the sediments. The necessary model parameters have been identified and organic matter decomposition chambers for determining first-order reaction rate parameters have been constructed.

OUTCOME: A stoichiometric model based on decomposition kinetics that describes the removal of ferrous iron from mine drainage has been developed. Additional sediment characterization involving the determination of sediment texture and color has been accomplished.

INVESTIGATORS: R.F. Unz and R.P. Brooks
Pennsylvania State University

START DATE: July 1, 1998

END DATE: June 30, 1993

STATUS: Project completed.
Final report received.

FUNDING:

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| NMLRC | \$45,934 |
| PSU | \$13,620 |

Treatment of Coal Wastes for Reduction of Acid Generation (PSU07)

OVERVIEW: This project is investigating waste treatment methods for reducing and eventually preventing acid mine drainage at its source. Experiments are underway to determine the effect of various reagents on the weathering characteristics of pyrite. A series of test reagent-, have been selected to determine their influence on the rate of oxidation of pyrite in coal. Based on these results, researchers are identifying the type of reagents likely to have a significant effect on the rate of pyrite oxidation

OUTCOME: Humic acids from various coal sources and other commercial reagents have been used to treat pyrite waste. The acid generation potential of treated pyritic waste has been determined using accelerated weathering tests in an unsaturated column. Such tests have simulated the conditions of oxidation in a vadose zone. Additional studies have been carried out to determine interfacial properties-,s of pyrite in the presence of various reagents.

INVESTIGATORS: Steve Chander
Pennsylvania State University

START DATE: July 1, 1990

END DATE: June 30, 1992

STATUS: Project completed.
Final report received.

FUNDING: NMLRC \$36,520
PSU \$29,394

Modeling the Dynamics of Metal Retention in Simulated Freshwater Wetlands (PSU08)

OVERVIEW: A principal aim of this research is to determine the chemical and biological processes in metal removal by analyzing metals trapped in the substrate. These are determined by sequentially extracting different forms of the metals from the wetland substrates. Substrates both from simulated wetlands and a functioning constructed wetland are being analyzed. The results provide information plant species, density and biomass, inlet pH, flow rate, carbon amendment, substrate type, and surface water depth.

OUTCOME: A major finding from the manganese extractions has been that, unlike iron, reducing conditions in compost yield manganese predominately in water soluble and exchangeable forms. From the standpoint of long-term manganese retention, a compost treatment does not, therefore, represent the ideal option. Researchers are currently extracting substrates sampled from a constructed wetland that has been successfully treating iron for seven years. Mathematical modeling has begun that may help predict the longevity of constructed wetland effectiveness.

INVESTIGATORS: Frederick M. Williams and Lloyd R. Stark
Pennsylvania State University

START DATE: July 1, 1991

END DATE: June 30, 1993

STATUS: Ongoing

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| FUNDING: | NMLRC | \$40,719 |
| | Industry / Other | \$40,972 |

ASH DISPOSAL

Modeling Environmental Impact of Coal Ash Disposal in Mine Environment on Water Quality (WV17)

OVERVIEW: The project is designed to evaluate the quality of water emerging from those areas where coal combustion residues are presently disposed or are used for revegetation purposes. Researchers have conducted a literature search on information from industries and regulatory agencies relating to the identity of trace elements from fly ash leaching that are potential surface and groundwater pollutants. They are also evaluating changes in the chemical composition of several coal ashes sampled at periodic intervals.

OUTCOME: During the past year, different extraction procedures to predict the mobilization of trace elements from coal ash have been compared. Data collected from over 100 ash samples have shown that none of the ashes investigated qualified as hazardous waste. However, standard TCLP tests have extracted significantly larger concentrations of barium than the extraction with acid mine drainage.

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| INVESTIGATORS: | Rabindar N. Singh and Robert F. Keefer West Virginia University | |
| START DATE: | July 1, 1990 | |
| END DATE: | June 30, 1993 | |
| STATUS: | Ongoing | |
| FUNDING: | NMLRC | \$ 12,614 |
| | WVU | \$111,540 |
| | Industry / Other | \$ 15,000 |

GENERAL STUDIES

Evaluation and Preparation of Reclamation Technologies (WV10)

OVERVIEW: Reclamation technologies have been developed, evaluated, rejected or adopted in an often undocumented process over the past 50 years. Many apparently new technologies have already been tried and rejected. The reasons lie in the nature of the mining and reclamation industries. Innovative companies tend to apply a variety of technologies until one proves successful. They have little incentive to report their findings. Researchers have conducted approximately 50 interviews from a list of coal operators, consultants, and regulatory personnel.

OUTCOME: The project has developed handbooks titled "Chemicals for Treating Acid Mine Drainage" and "Use of Ammonia for Treating Acid Mine Drainage." The following papers have been published: "Acid Mine Drainage Treatment Alternatives," "Prevention of Acid Mine Drainage by Alkaline Addition," "A Field Example of Alkaline Addition to Acid Mine Drainage," "An Ounce of Prevention is Worth a Pound of Water Treatment," "Preliminary Results of Anoxic Limestone Drains in West Virginia," and "A Methodology for Evaluation of the Costs of

Selective Handling."

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| INVESTIGATORS: | Jeff Skousen, Ben Faulkner, Jerry Fletcher, and Tim Phipps West Virginia University |
| START DATE: | July 1, 1991 |
| END DATE: | June 30, 1993 |
| STATUS: | Ongoing |
| FUNDING: | NMLRC \$37,465 WVU \$54,806 |

SOIL RECONSTRUCTION / REVEGETATION

Use of Reclaimed Surface Mines for Horticultural Crop Production (WV38)

OVERVIEW: In West Virginia and along the Eastern United States surface mine sites are abundant. Those that have been reclaimed may be usable for horticultural crops. One company has given financial support to demonstrate crop production on a site in West Virginia.

OUTCOME: Researchers are performing a greenhouse study using soil from the field site and soils from surface mine sites from central and northern West Virginia. The field study will include the cultivation of 18 annual and perennial crops. With further research the investigators may be able to recommend sewage sludge as an amendment to make mine soils horticulturally productive.

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| INVESTIGATORS: | Juanita Popenoe, Bradford Bearce, Jeff Skousen West Virginia University |
| START DATE: | July 1, 1991 |
| END DATE: | June 30, 1993 |
| STATUS: | Ongoing |
| FUNDING: | NMLRC \$3,440 Industry / Other \$35,753 |

Revegetation of Abandoned Coal Refuse Banks (PSU01)

OVERVIEW: Abandoned coal refuse banks are found throughout the Appalachian region. Most have remained barren and defy revegetation by natural processes. Many are on steep slopes and subject to erosion. Refuse is generally black resulting in high surface temperatures during the summer. It is also low in nutrients, water, and is acidic. The refuse banks are not only unsightly and unstable but may also pose a threat to health and safety.

OUTCOME: Sewage sludge/fly ash mixtures significantly have improved grass and legume cover. Perhaps as a result, tree survivorship and growth rates have been somewhat lower on the treated sites for all six species. Nonetheless, tree performance data suggest that establishment will be vigorous, while the herbaceous cover will minimize erosion and develop a stable soil on the site.

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| INVESTIGATORS: | William E. Sopper Pennsylvania State University | |
| START DATE: | July 1, 1988 | |
| END DATE: | June 30, 1992 | |
| STATUS: | Project completed. Final report received. | |
| FUNDING: | NMLRC | \$21,278 |
| | PSU | \$7,636 |

Establishment of Native Hardwoods on Mined Lands Revegetated under Current Regulations (PSU11)

OVERVIEW: When reclaiming a surface mine, replacing original contours, saving and replacing topsoil, and reseeding are practices used to reduce erosion and sedimentation. Regardless of the reasons, native hardwoods typical of the region are not used for reseeding. Red pine, black locust, and Japanese larch are species that survive best on current mine sites. This research seeks to evaluate methods for establishing native hardwood tree species on newly-reclaimed areas.

OUTCOME: Approximately 4,200 tree seedlings were planted on reclaimed land during spring 1991. Tree species planted included red oak, red maple, black birch, quaking aspen, and black locust. Three additional sites have been added to the project in 1992. Over 5,400 tree seedlings have been planted in spring 1992.

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| INVESTIGATORS: | H. Glenn Hughes and Gerald L. Storm Pennsylvania State University | |
| START DATE: | July 1, 1991 | |
| END DATE: | June 30, 1993 | |
| STATUS: | Ongoing | |
| FUNDING: | NMLRC | \$31,922 |
| | Industry / Other | \$4,350 |

SUBSIDENCE

Development of Technology to Control Longwall Subsidence Damage to Surface Structures and Renewable Resources (WV23)

OVERVIEW: The two main objectives of this project are to develop, test, and evaluate new and existing techniques to control subsidence damages to surface structures and renewable resources over active longwall panels, and to collect data about the complete surface subsidence process. The data will be used to refine the current subsidence prediction model, CISPM, into a more reliable and more comprehensive model for industry applications. When the model is completed, it will be used to perform the premining damage potential assessment of the dynamic subsidence process, and to perform post-subsidence damage analysis. This includes assessment of the effectiveness of damage mitigation techniques and analysis of the causes of damage.

OUTCOME: Much of the structural damage from longwall mining comes from the compression

of the foundation by the surrounding soil. So far, four houses have been protected from damage primarily by excavating a trench around the foundations. This allowed soil deformation without direct contact with the foundations. A number of feasibility studies of undermining highways, railroad, residential structures, industrial installations, and bodies of water have been performed. The development of a new version of CISPM is near completion.

INVESTIGATORS: Syd S. Peng and Yi Luo
West Virginia University
START DATE: July 1, 1990
END DATE: June 30, 1993
STATUS: Ongoing
FUNDING: NMLRC \$35,347
WVU \$32,964
Industry / Other \$59,496

Potential for Alleviating Longwall Mining Concerns Through the Use of Backstowing (PSU09)

OVERVIEW: The overall objective of this research is to evaluate the potential for controlling longwall-induced subsidence using backstowing as a unit operation in coal mines. Particular attention will be focused on effectiveness and potential costs.

OUTCOME: During the current period, researchers have gathered background information from government, industry, and public interest groups. Based on this information, a site has been chosen in southwestern Pennsylvania for conducting a hypothetical case-study.

INVESTIGATORS: Christopher J. Bise
Pennsylvania State University
START DATE: July 1, 1991
END DATE: June 30, 1993
STATUS: Ongoing
FUNDING: NMLRC \$40,811
PSU \$19,370

Long-term Impact on Domestic and Farm Groundwater Supplies Under Pennsylvania's Longwall Mining Conditions (PSU10)

OVERVIEW: The goal is to determine the long term post-longwall mining impacts on domestic and farm groundwater supplies. In particular, researchers are studying permanent loss in levels and yield and transient short term disturbances associated with longwall subsidence waves. Remedial measures and their success are being reviewed.

OUTCOME: Analysis of well and spring water supply data has indicated that significant fluctuations in static head and flow valves have occurred from mining in the vicinity of the well locations. This also coincides with the drought of 1991. A method has been devised to separate mining influences on water levels from drought influences on control wells. Conclusions on stream baseflow changes related to longwall mining are still being evaluated as are modeling results.

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| INVESTIGATORS: | Richard R. Parizek and R.V. Ramani | |
| | Pennsylvania State University | |
| START DATE: | July 1, 1991 | |
| END DATE: | June 30, 1992 | |
| STATUS: | Project completed. | |
| | Final report received. | |
| FUNDING: | NMLRC | \$28,338 |
| | PSU | \$11,350 |
| | Industry / Other | \$25,000 |

MIDWESTERN REGION

Southern Illinois University at Carbondale

ACID MINE DRAINAGE

Concentrated Alkaline Recharge Pools for Acid Seep Abatement (SIUC12)

OVERVIEW: The primary objective of this project is to implement a full-scale field demonstration of the alkaline groundwater recharge approach to ameliorate the effects of -a chronic acid seep. Researchers are monitoring the effects of alkaline surface loading on a shallow groundwater recharge area using seasonally inundated alkaline wetlands constructed upslope of the subsurface acid generation zone.

OUTCOME: Surface and groundwater samples have been collected and analyzed. Monitoring in both the upper and lower basins documented no significant changes during this quarter. Based on the trends recorded during the previous three annual cycles, it is apparent that groundwater quality improvements should persist unless acid seeps develop from unforeseen conditions. Two new recharge pool areas have received alkaline amendments.

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| INVESTIGATORS: | J.R. Nawrot and W.B. Klimstra | |
| | Southern Illinois University at Carbondale | |
| START DATE: | July 1, 1989 | |
| END DATE: | June 30, 1992 | |
| STATUS: | Project completed. | |
| | Final report in preparation. | |
| FUNDING: | NMLRC | \$37,391 |
| | SIUC | \$14,655 |
| | Industry / Other | \$15,800 |

Surface Mine Land Reclamation Enhancement through Disposal of Coal Processing and Utility Wastes (SIUC14)

OVERVIEW: After the surface coal of the Illinois Basin has been extracted, a filler may be needed in some areas to return the land to its original elevation and surface quality. Researchers believe that appropriate combinations of coal processing and utility wastes can be used as an environmentally acceptable filler for reclaiming both pre-SMCRA abandoned

mine lands and post-SMCRA surface mine lands.

OUTCOME: The field study pit has been dug six inches below the water table and three feet of slurry mix has been spread. Wells for monitoring groundwater have been constructed upstream and downstream of the pit, along with a leachate monitoring system. Groundwater from each well has been tested twice for 20 chemicals. There is no evidence thus far that the pit is significantly affecting the downstream well.

INVESTIGATORS: P.K. Davis and J.G. Smith
Southern Illinois University at Carbondale
START DATE: July 1, 1990
END DATE: June 30, 1993
STATUS: Ongoing
FUNDING: NMLRC \$38,344
IUC \$77,968
Industry / Other \$16,000

Application of Analytic Models to Predict Hydrologic Conditions Associated with Refuse Injection Into Underground Coal Mines (SIUC17)

OVERVIEW: Refuse from coal mining and coal use is generally buried in mined-out areas or landfills, a disposal practice that may adversely affect groundwater quality. Abandoned underground mines offer an attractive disposal option from an environmental perspective, and, as the cost of surface disposal rises, underground disposal may be attractive from an economic standpoint. Pumping refuse into a mine as a slurry is one option under consideration; however, this procedure may later after the hydraulic potential in the coal and the strata adjacent to the coal.

OUTCOME: From the results of this project, researchers are completing a hydrology manual. Significant achievements to be included are: a working two-dimensional finite difference model in radial coordinates; complete tables for an analytical model that predicts the effects of slurry injection on hydrologic potential in strata bounding the mine; and new analytic contaminate transport models that predict contaminant migration as a result of slurry injection. Preliminary response to a questionnaire sent to 135 coal companies in the Midwest indicates strong interest in a short course designed around the manual.

INVESTIGATORS: Steven Esling and Sidney W. Jones
Southern Illinois University at Carbondale
START DATE: July 1, 1991
END DATE: June 30, 1993
STATUS: Project completed.
Final report in preparation.
FUNDING: NMLRC \$26,237
SIUC \$15,291
Industry / Other \$ 2,500

Prevention of Pyrite Dissolution in Acid Mine Drainage (SIUC18)

OVERVIEW: This project evaluated pyrite corrosion in acid mine drainage.

OUTCOME: Three different sources of pyrite used in this study have indicated that the addition of humic acids prevented pyrite corrosion.

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| INVESTIGATORS: | Shashi B. Lalvani Southern Illinois University at Carbondale | |
| START DATE: | July 1, 1991 | |
| END DATE: | June 30, 1993 | |
| STATUS: | Ongoing | |
| FUNDING: | NMLRC | \$15,014 |
| | IUC | \$12,940 |

ASH DISPOSAL

Evaluation of the Feasibility of Using Mixtures of Fluidized Bed Combustion Waste and Coal Refuse in Mine Reclamation Embankments and Road Beds in Mining (SIUC15)

OVERVIEW: Researchers are evaluating the feasibility and environmental factors of using mixtures of fluidized bed combustion fly ash and coal refuse in mine reclamation. To achieve this goal, geotechnical characteristics of coarse coal refuse and FBC waste residues will be determined. Leaching and shear strength will also be evaluated.

OUTCOME: The first year has been devoted to a literature review and laboratory investigations. A design and fabrication of a large shear box have been completed. Trial tests are complete and large shear tests on mixtures of coal refuse and FBC fly ash are in progress.

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| INVESTIGATORS: | Vijay K. Puri and Zhangzing Yu Southern Illinois University at Carbondale | |
| START DATE: | July 1, 1991 | |
| END DATE: | June 30, 1993 | |
| STATUS: | Ongoing | |
| FUNDING: | NMLRC | \$34,451 |
| | SUIC | \$36,468 |
| | Industry / Other | \$9,091 |

Development of Guidelines in Selecting an Underground Waste Disposal Technology for the Midwest (SIUC16)

OVERVIEW: Coal cleaning is essential before it is burned in utility plants, especially for high-sulfur coal. Approximately 25 to 30% of mined coal is rejected as refuse in preparation plants. Current estimates indicate that coal waste is produced at a rate of 150 to 200 million tons a year. These wastes must be disposed in an environmentally safe manner. Currently, the most widely used waste disposal method is surface disposal. This project examines underground disposal as an alternative.

OUTCOME: An underground waste disposal operation for the Midwest has been conceptualized. Calculations for technical specifications and overall economics of the

operation have been performed.

INVESTIGATORS: Hasan Sevim
Southern Illinois University at Carbondale
START DATE: July 1, 1991
END DATE: June 30, 1992
STATUS: Project completed.
Final report in preparation.
FUNDING: NMLRC \$30,005
SIUC \$12,582

SOIL RECONSTRUCTION/REVEGETATION

Advanced Management for Revegetation with Trees (SIUC02)

OVERVIEW: Much of the Illinois coal reserves are overlain by prime agricultural land. Restoration of this land has been a key issue in successful reclamation in this region. Conventional soil handling methods are capable of identifying appropriate soils and subsoils. The major difficulty lies in reestablishing structure to the replaced soils. Structure determines the extent to which roots, oxygen, and moisture can penetrate the reclaimed soil. This project is evaluating the use of trees to establish structure on reconstructed soils.

OUTCOME: Tree plots have been established and soil conditions are being monitored. The best growth so far is by the cottonwoods.

INVESTIGATORS: W. Clark Ashby
Southern Illinois University at Carbondale
START DATE: July 1, 1988
END DATE: June 30, 1993
STATUS: Ongoing
FUNDING: NMLRC \$18,001
SIUC \$20,774
Industry / Other \$9,350

Evaluation of Mined Land Reclamation Strategies and Management Techniques for Enhanced Soil and Crop Productivity (SIUC03)

OVERVIEW: Federal law requires surface mined farmland be reclaimed to pre-mine, row crop productivity levels. Since enactment of the law, achievement of the necessary levels of crop production for bond release has proven to be difficult. However, significant research advancements in mine land reclamation have been made. For example, segregation and reapplication of subsoils and topsoil horizons is now common practice. Most of the soil productivity issues relate to compaction of these reconstructed soil profiles. This project evaluates soil handling and tillage methods that will minimize soil compaction.

OUTCOME: Field test plots consisting of various slopes and tillage methods were established last year. Minor drainage damage has been corrected and corn and soybean crops planted. Depressions caused by uneven settling have been filled. Reduced tillage plots have been field

cultivated twice to prepare a suitable seedbed. Soil moisture will be monitored using a neutron probe while bulk density samples and root samples will be obtained using a Giddings probe. Other activities will include crop stand counts and crop monitoring throughout the coming summer.

INVESTIGATORS: E.C. Varsa, S.K. Chong, B.P. Klubek, F.J. Olsen, L.L. Bledsoe, D.A. Farquhar, and D.J. Stucky
Southern Illinois University at Carbondale

START DATE: July 1, 1988

END DATE: June 30, 1993

STATUS: Ongoing

FUNDING:

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| NMLRC | \$89,664 |
| SIUC | \$50,844 |
| Industry / Other | \$2,500 |

Establishment, Water Relations, and Growth of Selected Tree Species on Reclaimed Mine Soil (SIUC10)

OVERVIEW: The Surface Mining Control and Reclamation Act of 1977 required return of surface-mined land to premining vegetation types. In Illinois only about 10% of lands reclaimed to forest and wildlife habitat have been released of bonding. The main problem is tree and shrub establishment and survival on reclaimed soils. This project seeks to understand the reasons for poor performance and to identify means by which desirable trees and shrubs can be established at acceptable survival rates. Treatments include tillage, species selection, and post-planting management.

OUTCOME: Statistical analysis has been collected regarding tree species with survival rates that meet bond release requirements. In addition data on spring survival of both the tillage and handling, and tillage and species experiments have been collected.

INVESTIGATORS: R. Kjelgren and B. Claveland
Gary K. Bissonnette
Southern Illinois University at Carbondale

START DATE: July 1, 1989

END DATE: June 30, 1992

STATUS: Project completed.
Final report in preparation.

FUNDING:

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|------------------|----------|
| NMLRC | \$26,679 |
| SIUC | \$12,786 |
| Industry / Other | \$ 9,630 |

WESTERN REGION

University of North Dakota North Dakota State University

SODIC SPOIL RECLAMATION

Groundwater Movement and Chemical Evolution from the Root Zone to the Water Table (ND02)

OVERVIEW: The overall objectives are to provide data for evaluating the long term effects of lignite surface mining on subsurface hydrology and geochemistry and to identify the critical variables affecting subsurface water quality, plant growth potential, and surface stability. This project involves detailed hydrogeologic and geochemical studies at several different sites having adjoining areas of abandoned mine lands, areas of recent mining, and undisturbed lands. Results from this project will be used to identify reclamation procedures that optimize groundwater quality and stability of post mining landscapes, as well as biological productivity. The initial focus has been on abandoned mine lands.

OUTCOME: Three field project sites have been established: Indian Head Mine, Velva Mine, and the Fritz Mine. Work to date has focused on completing water analyses, data compilation, and graphical illustrations of water quality trends in the various parts of the mine.

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| INVESTIGATORS: | R.D. Butler, G.H. Groenewold, F.W. Beaver, and D.J. Hasset Energy and Environmental Research Center, University of North Dakota |
| START DATE: | July 1, 1988 |
| END DATE: | June 30, 1993 |
| STATUS: | Ongoing |
| FUNDING: | NMLRC \$149,507 NDSU \$ 11,997 |

SOIL RECONSTRUCTION / REVEGETATION

Surface and Root Zone Hydrology of Mined Lands (ND01)

OVERVIEW: Much of North Dakota's coal is overlain with sodic clay overburden. Its physical properties make it difficult to work with as it tends to swell and absorb great volumes of water when wet while drying to a hard, nearly impenetrable mass when dry. The overall purpose of this project is to identify landscape design and soil reconstruction criteria for surface-mined agricultural land in North Dakota. Specifically the project will quantify surface and root zone hydrologic factors by measuring water infiltration, movement, and retention in soil and spoil materials as a function of topographic position in abandoned and reclaimed mine lands. Other elements of this project will look at genetic influences on reconstructed soils and the distribution and intensity of summer storms.

OUTCOME: Findings have shown significant effects of pre-and post-mine soil materials and topographic positions in determining infiltration, movement, and retention of water in various profiles.

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| INVESTIGATORS: | Gary A. Halvorson, Padam P. Sharma, Kevin C. Vining, and F. Scott Carter Energy and Environmental |
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| | Research Center | |
| | University of North Dakota | |
| <i>START DATE:</i> | July 1, 1988 | |
| <i>END DATE:</i> | June 30, 1992 | |
| <i>STATUS:</i> | Project completed. | |
| | Final report in preparation. | |
| <i>FUNDING:</i> | NMLRC | \$95,414 |
| | NDSU | \$26,709 |

SUBSIDENCE

Stabilization of Underground Mine Voids by Filling with Coal Conversion Residual Materials (ND03)

OVERVIEW: The objectives of this project are: 1) to characterize the physical, chemical, mineralogical, and leaching properties of the fill material to find the optimum mix for injection; 2) to characterize the geology, hydrogeology and hydrogeochemistry of the fill setting; 3) to determine the long-term physical and chemical changes in the injected fly ash grout and local groundwater, and monitor future subsidence.

OUTCOME: Work is concentrating on the selection of the proper leaching procedure for simulating environmental conditions anticipated at the site.

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| <i>INVESTIGATORS:</i> | Frank Beaver, R.D. Butler G.H. Groenewold, and D.J. Hassett Energy and Environmental Research Center University of North Dakota |
| <i>START DATE:</i> | July 1, 1988 |
| <i>END DATE:</i> | June 30, 1993 |
| <i>STATUS:</i> | Ongoing |
| <i>FUNDING:</i> | NMLRC \$48,473 NDSU \$3,330 |