NATIONAL MINE LAND RECLAMATION CENTER OVERVIEW OF PROJECTS-1992

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INTRODUCTION

The National Mine Land Reclamation Center (NMLRC) was established by Congress in 1988 to provide a national focus for resolving the outstanding technical challenges still facing the United States mining industry. The Center's programs address reclamation issues for both abandoned and active mine sites. Research areas include acid mine drainage, prime farmland restoration, and soil and groundwater salinization. The Center is committed to serving the needs of both the mining industry and the public, as represented by the government regulatory agencies.

American coal is mined in several different regions, each having particular soil, climate, topography, mining techniques, and research needs. The Center is organized to provide a flexible, responsive means of applying research to the needs of agencies and companies within these regions. To support this concept, three regional centers consisting of five universities have been established. The National Center is located at West Virginia University, which, along with Pennsylvania State University, make up the Eastern Center. Southern Illinois University at Carbondale houses the Midwestern Center, while the University of North Dakota and North Dakota State University comprise the Western Center.

SUMMARY OF PROGRESS 1992

In July 1991, the National Mine Land Reclamation Center entered its fourth year with funding of $1.39 million from the U.S. Congress. We pursued 37 reclamation projects and benefited from the joint support of the coal industry and regulatory agencies. In the Eastern Region, prevention of acid mine drainage continues to be the dominant reclamation issue. Thirteen projects were dedicated to finding solutions to this problem. Our projects looked at both water treatment methods and methods for preventing the formation of AMD. Very promising results were obtained on both fronts.

Previous research at West Virginia University developed methods for identifying and quantifying the acid-producing potential of the rock units associated with coal. This method has been linked with a means for evaluating neutralizing amendments which, when added to the rock, prevent formation of AMD. We also use this procedure to evaluate the leachates which will result from application of the alkaline materials.

Several materials are currently being evaluated: lime kiln dust, steel-making slag, FBC ash and rock phosphate. Each of these materials has been able to prevent AMD formation in pyritic refuse. The theory is simple: as acidity and metal ions are formed by pyrite oxidation the alkaline materials act like a lime, neutralizing the acidity and precipitating the metals before they leave the rock mass. So far, lime kiln dust appears to be the most effective.

Bethenergy Corp. at its Nicholas County operation has been adding kiln dust to its refuse conveyor for two years. Refuse which had previously become strongly acid within six weeks now produces neutral water suitable for discharge without further treatment. Other companies are installing or evaluating alkaline addition systems. We are working with the coal industry and others to identify the most environmentally beneficial and cost-effective alkaline materials.

While there is a great deal of work to be done with alkaline addition, we feel that this method has the potential to become a reliable way to prevent AMD formation in acid-prone areas without resorting to long-term water treatment.

On the subject of water treatment, West Virginia University researchers developed Trapzene, a new environmentally safe chemical for removal of acidity and metals from acid mine drainage. Compared to conventional chemicals, Trapzene has the advantage of removing both iron and manganese within the pH range of 6.5 to 8.5. Manganese removal by conventional chemicals usually requires a pH in the range of 9.5 to 10.5. This project is undertaken in conjunction with FMC Corporation. Trials are currently underway to test its cost-effectiveness under operating mine conditions.

At both West Virginia University and Pennsylvania State University, researchers used industrial wastes such as fly ash and sludge to revegetate surface mined areas and abandoned coal refuse banks. The two universities also conducted research in the areas of slope stability and subsidence.

The NMLRC provided $424,631 for projects at West Virginia University during 1990-91, while the University contributed $560,212. Support from industry and other state and federal agencies totaled $835,703.

At Pennsylvania State University, sources of funding were $282,000 from the NMLRC and $138,685 from the University.

The Midwestern Region focused on the high-priority research needs of the mining industry and regulatory agencies in developing near-term solutions to regional problems. Restoration and preservation of the Midwest's prime agricultural land and water resources were major concerns for this part of the country.

One project investigated soil decompacting techniques that would increase plant-useable soil

volume, pore size, aeration, and infiltration. The goal was to find alternatives to compacting the soil on surface mined lands. In another study, various tree species were being grown and tested on reclaimed land. Researchers want to determine which varieties are best for long-term growth.

In July, SIUC hosted the First Midwestern Regional Reclamation Conference in order to publicize the results of their reclamation research. Technical sessions, workshops and field demonstrations were included in the program which attracted representatives from government, industry and academia.

NMLRC funding for projects at SIUC during 1990-91 was $366,599 The University provided $294,987 and support from industry and other federal and state agencies totaled $63,177.

The Western Region continued to study groundwater movement and subsidence. The University of North Dakota and North Dakota State University researchers worked together on projects involving water movement, spoil geochemistry, and subsurface water chemical evolution in abandoned mine land sites, currently mined areas, and adjacent unmined settings. The overall goals of this research were to characterize groundwater recharge and to determine topographic controls on recharge. Another purpose was to characterize subsurface water movement and chemical evolution through the root zone and to the water table. Researchers also were determining the practicality of reclaiming the four geologically and geochemically distinct abandoned mine land settings in this region, arid were studying the specific design criteria for current mining areas in the Western Region.

Another project involving subsidence was designed to evaluate a technology for filling and stabilizing abandoned underground mines. Unexpected surface subsidence throughout t coal-bearing region of western North America could result in dangerous or life-threatening situations, such as the collapse of tunnels beneath highways. The project focused on using fly ash to stabilize voids n abandoned underground mines.

In the Western Region, the NMLRC provided $287,974 in funding and the universities contributed $54,644. Industry supported total $86,549.

During 1990-91, we have been encouraged by the increased support from both industry and regulatory agencies for reclamation research. A major aim during our first year of operation in 1988-89 was to create an effective research management organization. Thereafter, our goal has been to work with agencies and companies to develop those technologies which will make mining more competitive while better protecting our environment. Seeing a growing spirit of cooperation between all those interested in developing practical useable reclamation technologies means that this goal is being reached.

EASTERN REGION

West Virginia University
The Pennsylvania State University

In the Eastern Region NMLRC, acid mine drainage continues to be the leading priority. Studies focussed on improved methods of prediction, control and prevention. Following is a brief

outline of Eastern Region projects from our inception in 1988 to the present. Projects are arranged according to priority area.

ACID MINE DRAINAGE

PROJECT WV01 Phosphatic Clay Slurry-Column Studies

OVERVIEW: Phosphatic clay slimes are a waste product of the Florida phosphate industry. The objective of this project was to determine the effectiveness of using this material to restrict the penetration of water into spoils containing pyritic, acid-forming coal mine wastes. In addition to the physical effect of restricting surface water infiltration into the spoils, the reaction of phosphate with the pyrite was monitored to identify any inhibitory effect on pyrite oxidation.

OUTCOME: The project concluded in 1989. Results indicated that phosphatic clay slurry did not make a satisfactory barrier for arresting surface infiltration into spoil piles. However, when the phosphatic clay slurry reduced acid production when mixed with pyritic coal spoils. This appeared to be a result of the high water content of the pure slurries which, upon drying, caused cracking and infiltration. The volume loss on drying and the tendency to crack were lessened by mixing the slurry with spoil.

INVESTIGATOR:	John Bowders West Virginia University
STATUS:	Project completed, June 1989 Final report WV01

PROJECT WV02 Rock Phosphate to Control Acid Mine Drainage

OVERVIEW: Acid mine drainage prediction and prevention have been the focus of research at WVU for several years. Recently, significant improvements have been made in understanding pyrite oxidation chemistry. The researchers have reported a method which appears to prevent pyrite oxidation via apatite addition. They have also developed a model which predicts the rate of pyrite oxidation in mine refuse. This project was to test the performance of phosphate on large scale field trials and to evaluate the factors which affect acid mine drainage leaching rates from refuse piles. Results should lead to improved premining prediction, planning and control methods for mitigation of acid mine drainage.

OUTCOME: This project hinged on construction of six 15,000 ton test piles by a coal company. For a variety of reasons, the piles were never constructed. The project, therefore, became a modeling project only. Subsequent studies by Renton et al. have indicated that less expensive materials such as lime kiln dust perform as well or better than phosphate in controlling acid mine drainage.

INVESTIGATORS:	Alfred Stiller and John Renton West Virginia University	
STATUS:	Project completed, Final report in preparation	
FUNDING 1990/91:	NMLRC	$28,608.00

	WVU	$ 9,862.00

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

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 21 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. 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, arid total photosynthesis.

OUTCOME: In the first several years of the project up to 40'0 of the incoming iron was precipitated in sulfide form. As the wetlands have matured the oxidation zone has increased to the point where most iron is precipitated as ferric oxy-hydroxides. At the same time soluble ferrous iron is being 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.

INVESTIGATORS:	Alan J. Sexstone, John C. Sencindiver, and Gary K. Bissonnette West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	NMLRC	$19,802.00
	WVU	$46,790.00

PROJECT WV08 Criteria for Remining and Reclamation of Abandoned Mine Lands (AMLs)

OVERVIEW: The objective of this study was to develop a list of criteria to be used by state regulatory authorities (SRAs) in helping to designate priority 2 AML sites for remining and reclamation. For each site, the mining history and geology determined; the general site conditions were assessed; the physical and chemical properties of the mine soils were analyzed and classified; and the plant communities were sampled and evaluated. Researchers analyzed the data using principal component analyses and other ordination methods.

OUTCOME: A method for assessing the health of volunteer vegetation on AML sits has been developed. In addition, a relationship between spoil factors and vegetation longevity will enable inspectors to evaluate which sites are likely to be problematic in the future.

INVESTIGATORS:	Jeffrey Skousen and Curt Johnson West Virginia University	
STATUS:	Field work complete final report in preparation	
FUNDING 1990/91:	NMLRC	$19,276.00
	WVU	$131360.00

PROJECT WV11 Evaluation of Parameters Affecting Acid Mine Drainage Production on a Micro, Field, and Regional Scale

OVERVIEW: Coal mining in high sulfur areas has traditionally produced acid mine drainage, which has resulted in decreasing permitability and increased need for knowledge as to what factors are responsible for acid mine drainage. Researchers have developed a mathematical model which, when applied to rock samples accurately predicts the rate of acid mine drainage. Current work involves collecting core samples from several consulting and coal companies, and grinding and separating the samples into four sizes. Roof shale and sandstone samples are also being prepared for bacterial study.

OUTCOME: None as yet

INVESTIGATORS:	Alfred Stiller and John Renton West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	OSMRE	$46,517
	WVU	$25,075

PROJECT WV12 Phosphate Field Tests for Acid Mine Drainage Control

OVERVIEW: The use of a variety of apatite rock called Code 31 has been evaluated in the laboratory as being a very effective acid mine drainage ameliorant. The intention was to construct several large refuse test piles in conjunction with a West Virginia Coal company. The test piles were never built. As a result, the phases of the project leading up to test pile construction were completed but the critical step was never taken.

OUTCOME: Documentation and source codes for the SSPE/PSM model were produced and are available for distribution and validation.

INVESTIGATORS:	Alfred Stiller and John Renton West Virginia University	
STATUS:	Project terminated 30 June 1991	
FUNDING 1990/91:	WVDOE	$17,927

PROJECT WV15 Electrolytic Control of Acid Mine Drainage

OVERVIEW: Researchers developed an electrolytic process, known as the AMD-CELL SYSTEM, as an alternative to chemical neutralization of acid mine drainage. Electrolytic processes have been attempted in the past but have usually failed to operate economically due to their high current consumption. This process differs because it operates on a low current (<2 amps) format. it has been run as a laboratory bench demonstration unit and researchers are now evaluating the scale-up potential of this technology, its effectiveness and practicality under operational field conditions.

OUTCOME: Although positive results had been -reported from early prototype work, they could not be duplicated. A series of alternative lab-scale designs was tested and none were successful. Since no successful prototype could be developed the project never moved to

field scale. The project was therefore terminated.

INVESTIGATORS:	Alfred Stiller	
	West Virginia University	
STATUS:	Project terminated 30 June 1991	
FUNDING 1990/91:	NMLRC	$13,716
	WVU	$ 3,774
	Industry/Other	$10,514

PROJECT WV20 Investigation of Manganese Chemistry in Acid Mine Drainage

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 were used.

OUTCOME: The project has thus far 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 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 AMD 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.

INVESTIGATORS:	R.J. Lovett	
	West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	NMLRC	$42,412
	WVU	$11,129

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

OVERVIEW: Artificial wetlands have been used to treat AMD 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 AMD, and the efficacy of alternative species compositions in artificial wetlands. Fifteen "volunteer" wetlands of various ages are being studied. All receive drainage from reclaimed or abandoned mines. A vegetation survey was carried out at each wetland. Five species have been chosen for further study.

OUTCOME: This project has completed its first year. Thus far, wetlands aged 3 to 25 years have been selected and vegetation surveys have been performed. Also, inflow and outflow

water samples have been collected for analysis so that performance changes over time can be characterized.

INVESTIGATORS:	Keith Garbutt and James B. McGraw West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	NMLRC	$ 7,200
	WVU	$45, 713

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

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 which escapes to the receiving stream. Project researchers are investigating the effectiveness of hybrid systems, where wetlands are the terminal step receiving chemically pretreated water. Both 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. They are waiting to determine whether this result is transitory.

INVESTIGATORS:	Alan J. Sexstone, Jeffrey G. Skousen, Gary K. Bissonnette, and John C. Sencindiver West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	NMLRC	$21,040
	WVU	$27,599
	Industry/Other	$ 6,260

PROJECT WV28 Fly Ash Seals to Control Acid Mine Drainage

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 to treat the problem areas so as to control AMD production. Researchers studied three acid mine drainage sites for their applicability for fly ash seals to control AMD. After careful analysis of spoil location, geology, and hydrogeology, and mining practice, they concluded that effective control of AMD via surface seals was not likely. However, the sites appeared suitable for low-permeability grout containment of AMD and acidic materials.

OUTCOME: Lab and field work has commenced on developing a low-cost, low-permeability grout utilizing waste materials. The work has consisted of testing various grouts for permeability and leaching characteristics and analyzing flow rate measurements and effluent quality. In the field, sites suitable for grouting and been located and geophysical surveys have been performed.

INVESTIGATORS:	John J. Bowders, John C. Sencindiver, and William S. Lames West Virginia University	
STATUS:	Ongoing K.L. Harshberger MSCE Thesis "Fly Ash Grouts for Remediation of AMD at reclaimed Surface Mines" 218	
FUNDING 1990/91:	NMLRC	$25,561
	WVU	$36,304
	Industry/Other	$55,000

PROJECT WV31 Modeling of Hydrological Impact of Mines

OVERVIEW: The objective of this project was to develop and document computer software that will link a water quality database for a particular watershed, display this information on a map of the watershed, and allow the user to interact with the data. The software's goal is to aid in the preparation of Probable Hydrological Consequences (PHC) and Cumulative Hydrological Impact Assessment (CHIA) requirements.

OUTCOME: The researchers have worked with the West Virginia Department of Energy in developing the software. The software now being evaluated by WVDOE field offices.

INVESTIGATORS:	Alan Donaldson and Tom Rymer West Virginia University	
STATUS:	Project completed, Final Report received	
FUNDING 1990/91:	NMLRC	$27,700
	WVU	$ 5,220

PROJECT WV32 Trapzene for Treatment of Acid Mine Drainage

OVERVIEW: Trapzene, a new chemical for treating acid mine drainage was developed by researchers at West Virginia University. In conjunction with FMC 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 50~1'1 to 75~ volume reductions. This features increases sludge pond life and decreases the cost of pond cleanout.

OUTCOME: The project has focussed on better understanding the chemistry of Trapzene's reaction with metals in AMD and at the same time is running a series of field trials in cooperation with the coal industry. Results thus far are very promising with costs in a range between those of lime and caustic soda.

INVESTIGATORS:	R.J. Lovett and Paul Ziemkiewicz West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	FMC Corp.	$46,129

PROJECT WV34 Prediction and Control of Acid Mine Drainage: A Pre-Mining Evaluation

OVERVIEW: Methods for prediction and control of acid mine drainage have been developed at West Virginia. This project assembled several of these methods into a package for use by the coal industry in evaluating the acid producing potential rock units within a prospective lease. In addition, the package permits evaluation of methods for controlling acid production in identified rock units. The project was funded and carried out in conjunction with Shell Mining Company, a major coal producer. In addition to fulfilling a planning role for the company, the project was the first step toward tailoring our prediction and control technologies to meet the needs of the coal industry and the regulatory agencies.

OUTCOME: The project identified acid producing rock units within the property. These were mainly the refuse materials from the various coal seams to be mined. Three AMD control methods were tested: lime kiln dust, high-lime CFBC ash and rock phosphate. All were tested at 2 and 4"~15 additions by weight.. Lime kiln dust was successful in preventing acid production in all rock units within the application rates tested. Phosphate and CFBC ash generally required higher application rates than kiln dust and in several cases did not control acid production at the 4% rate.

INVESTIGATORS:	J.J. Renton and Paul Ziemkiewicz West Virginia University
STATUS:	Completed Final Report Submitted to Company
FUNDING 1990/91:	Shell Mining Company $79,796

PROJECT PSU02 Prediction and Amelioration of Acid Mine Drainage

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 preventing 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 were 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. The researchers are investigating means of translating this understanding to a practical technology for controlling AMD.

INVESTIGATORS:	Richard R. Parizek, Michael L. Machesky, and Arthur W. Rose Pennsylvania State University
STATUS:	Completed, Final report in preparation
FUNDING 1990/91:	NMLRC $38,912

PROJECT PSU03 Mine Water Renovation in Wetland Environments

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 chemical 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 which describes the removal of ferrous iron from mine drainage has been developed.

INVESTIGATORS:	R.F. Unz and R.P. Brooks Pennsylvania State University	
STATUS:	Completed, Final report in preparation	
FUNDING 1990/91:	NMLRC	$54,914

PROJECT PSU04 Inverse Modeling of Groundwater Flow and Contaminant Systems: Reliability and Accuracy

OVERVIEW: The primary objective of this project is to develop inverse solution techniques to the groundwater flow and transport equations to facilitate rapid and accurate appraisal of contamination problems associated with abandoned mine land. A large sandbox has been constructed and a series of tests involving transport in pluviated sand aquifers using a saline solution tracer are planned.

OUTCOME: A technique has been developed to evaluate aquifer transmissivities through an iterative direct method using the square error as the convergence criterion. The method shows some promise in its ability to accurately evaluate transmissivity magnitudes in the absence of noise.

INVESTIGATORS:	Derek Elsworth Pennsylvania State University	
STATUS:	Completed, Final report received	
FUNDING 1990/91:	NMLRC	$34,762

PROJECT PSU07 Treatment of Coal Wastes for Reduction of Acid Generation

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 reagents 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 that are likely to have a significant effect on the rate of pyrite oxidation.

OUTCOME: First year project, no results thus far.

INVESTIGATORS:	S. Chander Pennsylvania State University	
STATUS:	Ongoing	
FUNDING 1990/91:	NMLRC	$34,271
	PSU	$28,206

SUBSIDENCE

PROJECT WV04 Mine Land Prediction of Surface Subsidence Over Abandoned

OVERVIEW: This project uses finite element analysis to model abandoned underground coal mine layouts. Researchers have defined: the influence of progressive failure of pillars; material bulking and pillar punching.

OUTCOME: Results showed that most of the subsidence occurred after the first pillar failed. Depending on overburden height and seam thickness, subsidence after the first stage of failure ranged from 60',.'~ to 85','~ of the maximum possible subsidence. Regarding pillar punching, results showed that this most likely occurs when the mine floor has a lower strength than the coal.

INVESTIGATORS:	H.J. Siriwardane and S.S. Peng West Virginia University	
STATUS:	Completed, Final Report in preparation	
FUNDING 1990/91:	NMLRC	$19,740
	WVU	$31,496

PROJECT WV05 Development of Quality Grouts for Subsidence Control: Phase 3

OVERVIEW: The objectives for this phase are to assess mechanical characteristics of grouts required in subsidence control and to continue assessment of the durability of grouts subjected to an acidic environment. Mine structures and factors influencing subsidence were investigated. Stresses in grout backfill were calculated for various subsidence scenarios representative of the eastern region of the United States.

OUTCOME: Researchers have found that using grout columns becomes decreasingly desirable as depth to cavity increases due to high grout strength requirements. Conversely, total backfill of cavities required relatively low-strength grout. Regarding grout durability, a mixture containing a small amount of sand and a low cement content was developed and subjected to an acid media. A minimum strength of 250 psi at seven days was attained. This mixture appeared to be durable on the basis of laboratory tests and was achieved with a low cement content; namely four percent of the total weight of the ingredients.

INVESTIGATORS:	W.J. Head and H.J. Siriwardane West Virginia University
STATUS:	Completed,

	Final Report in preparation	
FUNDING 1990/91:	NMLRC	$23,520
	WVU	$52,240

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

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 comes from the compression of the foundation by the surrounding soil. So far, a house has been protected from damage primarily by excavating a trench around the foundation. This allowed soil deformation without direct contact with the foundation.

INVESTIGATORS:	S.S. Peng and Y. Luo	
	West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	NMLRC	$ 33,001
	WVU	$ 15,443
	Industry/Other	$127,443

PROJECT PSU05 Abandoned Mine Lands Management Information System

OVERVIEW: Within the abandoned mine lands (AML) program, there is a need to monitor and assess all potential reclamation sites so that the projects funded provide maximum benefits to the public. Following the high priority sites which affect heath and safety, sites which impact the environment only are considered for funding. This project involves setting criteria for ranking this latter group. Researchers have completed interviews with ten Pennsylvania Department of Environmental Resources experts who are directly involved with AML project selection. Eleven representative sites have been chosen and ranked.

OUTCOME: Researchers have prepared a detailed analysis of the results, which have been included on a software database. They are now working to integrate the fuzzy logic development system and the database management software tools into an interactive model.

INVESTIGATORS:	Eric K. Albert and Jan M. Mutmansky	
	Pennsylvania State University	
STATUS:	Completed	
	Final report received	
FUNDING 1990/91:	NMLRC	$42,086

SOIL RECONSTRUCTION/REVEGETATION

PROJECT PSU01 Revegetation of Abandoned Coal Refuse Banks

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 acid. 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 improved grass and legume cover. Perhaps as a result tree survivorship and growth rates were 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 help to develop a stable soil on the site.

INVESTIGATORS:	William E. Sopper	
	Pennsylvania State University	
STATUS:	Completed	
	Final report in preparation	
FUNDING 1990/91:	NMLRC	$61,744

ASH DISPOSAL

PROJECT WV06 A Model for Revegetating Abandoned Mine Land Using Industrial Wastes

OVERVIEW: Researchers applied various rates of three fly ash types to several abandoned mine land sites. The purpose was to evaluate the best fly ash applications for restoring productivity to the spoil. The quality of agricultural crops grown on these treated sites was also evaluated.

OUTCOME: The field experiments show that fly ashes differ in their ameliorative properties and that the suitability of a given fly ash is governed by its physio-chemical characteristics and by the chemistry of the soil on which it is mixed. A method for identifying appropriate applications for various spoil types was developed. Plant samples were collected for both plant analysis and computation of dry product matter. Plant and soil analysis was completed and data will be included in this project's final report.

INVESTIGATORS:	Robert F. Keefer, Rabindar N. Singh,	
	John Sencindiver, David W. Patterson,	
	and Donald J. Horvath	
	West Virginia University	
STATUS:	Completed,	
	Final Report in preparation	
FUNDING 1990/91:	NMLRC	$42,367
	WVU	$35,145

PROJECT WV17 Modeling Environmental Impact of Coal Ash Disposal in Mine Environment

on Water Quality

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 from revegetation purposes. Researchers are conducting a literature search on information from industries and regulatory agencies relating to the identity of trace elements from fly ash leaching which are potential surface and groundwater pollutants. They are also evaluating changes in the chemical composition of several coal ashes sampled at periodic intervals.

OUTCOME: Three fly ash types and an FBC ash have been subjected to leaching according to the TCLP test and by acid mine drainage. It was found that AMD is a more aggressive leaching environment than TCLP. Large-scale disposal sites in the field have been instrumented with lysimeters and leachates are being collected for each of the above combustion wastes.

INVESTIGATORS:	Rabindar N. Singh and Robert F. Keefer West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	NMLRC	$ 1, 800
	WVU	$72,468
	Monongahela Power	$15,000

GENERAL STUDIES

PROJECT WV10 Evaluation and Preparation of Reclaimation Technologies

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 involved in this project have developed a list of coal operators, consultants, regulatory personnel, and researchers, and have interviewed approximately 50 of them.

OUTCOME: The project has developed handbooks titled "Chemicals for Treating AMD," and "Use of Ammonia for Treating AMD." Future topics include revegetation with sewage sludge and overburden sampling and analysis

INVESTIGATORS:	Jeffrey Skousen, Ben Faulkner, Jerry Fletcher, and Tim Phipps West Virginia University	
STATUS:	Ongoing	
FUNDING 1990/91:	NMLRC	$38,928
	WVU	$66,871
	Industry/Other	$15,000

PROJECT PSU06 Design Analysis for Time Dependent Stabilization of Abandoned Mine Slopes Under Groundwater Pressure

OVERVIEW: This project was to develop a numerical modeling technique to predict the time dependent behavior of spoil pile stability under groundwater pressure. The programs required for hydrological simulation (UNSAT2) and stability analysis (SLPFAL and REAMS) are being used.

OUTCOMES: A model has been developed which consists of spoil material and represents the spoil slope conditions over most mining interval. The model is being extended to predict groundwater rebound from the pit floor. In addition, ponding behind abandoned spoil on steep slopes is being modeled.

INVESTIGATORS:	L. Barry Phelps	
	Pennsylvania State University	
STATUS:	Completed	
	Final report received	
FUNDING 1990/91:	NMLRC	$15,311
	PSU	$21,770