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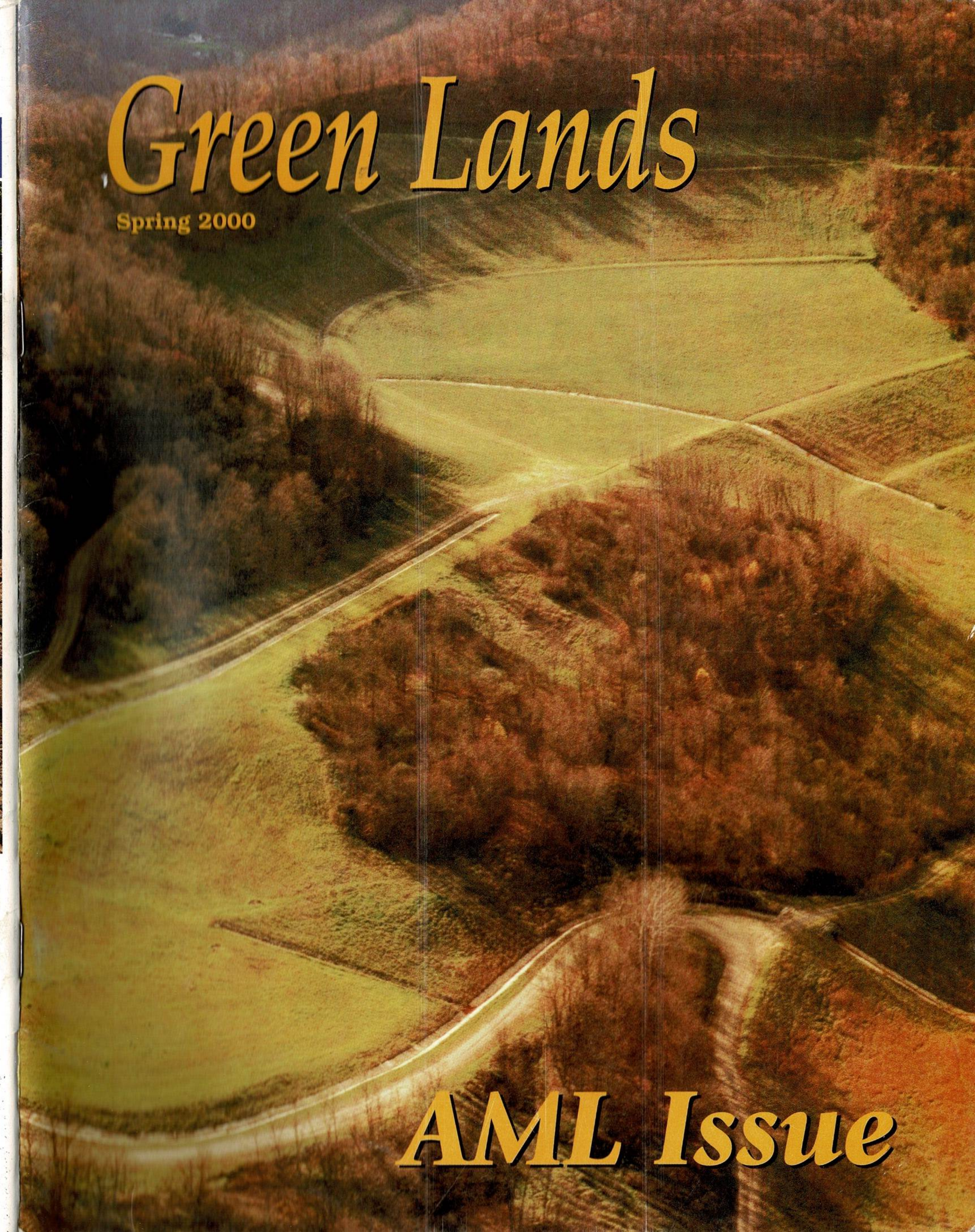

Green Lands

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with offices at 1624 Kanawha Boulevard East
Charleston, West Virginia 25311
(304) 346-5318, FAX 346-5310
E-Mail: wvmra@wvmra.com

On the Cover
An aerial view of the Majesty Mine complex in Barbour County, which shows the outstanding reclamation work through West Virginia's Abandoned Mine Lands program. More AML sites, including other views of Majesty Mine, begin on page 13.

ADVERTISING INDEX

Coal Calendar 2000

April

20 **Tug Valley Mining Institute Meeting,** Logan Country Club, Logan, WV Speaker - WV Coal Association President Bill Raney. Call (304) 664-4006 for dinner reservations.

May

4-6 **2000 Joint Annual Meeting of WVCA and WV CMI** Pipestem Resort. Call (304) 342-4153 for more information.

10-12 **21st Annual Institute,** Westin Cincinnati Hotel, Contact the University of Kentucky's Energy & Mineral Law Foundation (606) 257-7140.

18 **Tug Valley Mining Institute Meeting,** Brass Tree Restaurant, Williamson, WV Call (304) 664-4006 for dinner reservations.

16 **2000 Conference on Unburned Carbon on Utility Fly Ash,** Radisson Hotel Greentree, Pittsburgh, Pa. Contact Karen (412) 386-4763.

22-24 **Kentucky Non-Point Source Conference 2000,** University Plaza Hotel, Bowling Green, KY. Contact Geaunita Taylor (606) 257-2820.

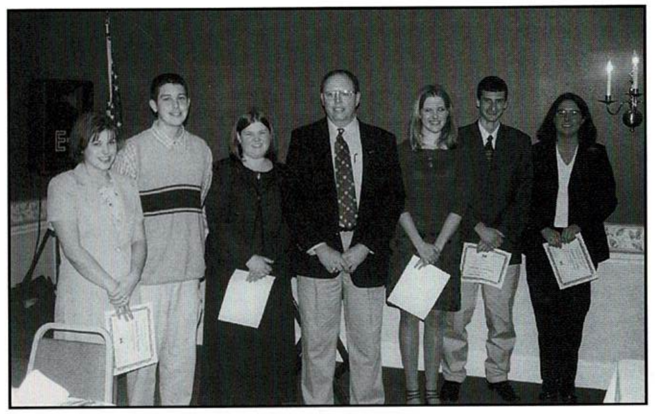
June

15 **Tug Valley Mining Institute Meeting,** Brass Tree Restaurant, Williamson, WV. Speaker - Eliot "Spike" Maynard, Chief Justice, WV Supreme Court, Call (304) 664-4006 for dinner reservations.

21-22 **Electric Power Special Institute**, Westin Great Southern Hotel, Columbus, OH. Contact the University of kentucky's Energy & Mineral Law Foundation (606) 257-7140.

22-23 **Coal Age's Coal Operator's Forum (Coal Ops 2000),** Beckley, WV. Contact Steve Fiscor (312) 726-2802.

Tug Valley Awards $10,000 in Scholarships



Six Students received $10,000 in scholarships from the TVMI recently. Pictured above are: Katrina Sargent, Logan High; Kristopher Fannin, Sheldon Clark High; Christy Roeher, Logan High, Jim Mullins, TVMI president; Ashlee Gibson, Man High; Garreth Hevener, Omega Bible Academy; and Laura Varney, Williamson High.

The Tug Valley Mining Institute awarded $10,000 in scholarships to six students at its March meeting in Williamson.

Students attending high schools in the coalfields of Mingo and Logan counties in West Virginia and Pike and Martin counties in Kentucky are eligible for the awards.

Two $4,000 scholarships and four $500 scholarships are awarded to students.

Although recipients know prior to the meeting they are receiving a TVMI scholarship, they do not know how much until the announcement that evening.

This year, Katrina Sargent, Lohan High and Kristopher Fannin, Sheldon Clark High received the $4,000 scholarships.

Other recipients were Ashlee Gibson, Man High; Garreth Havener, Omega Bible Academy; Christy Roeher, Logan High; and Laura Varney, Williamson High.

Before presenting the awards, Jim Mullins, TVMI president said to the students "eveyone here is a winner" and that he was proud to be presenting TVMI scholarships to a fine group of students.

Since TVMI began presenting scholarships five years ago, a total of $44,500 has been awarded.

Selection is based on criteria including the students' grade point average, ACT scores and activities in and outside of school.

West Virginia Receives Financial Increase For Abandoned Mine Lands Program, First time in 10 years

Throughout the next 15 pages are examples of how well the Abandoned Mine Lands program is working, when the money is available to clean up these sites.

Areas of abandoned surface mined land are from many years ago and have increasingly become a major issue more every year.

Yet, even as state and coal industry officials continue to request increased funding to reclaim old mining sites from the Interior Department's Office of Surface Mining Reclamation and Enforcement, it wasn't until fiscal year 2000 that such an increase was granted.

That is a 10 year lapse from the last increase in AML funding for West Virginia or any other state.

In late November, 1999, Congress passed an omnibus appropriations bill (H.R. 3424) that approved funding for the OSM.

As a part of the bill, Title IV abandoned mine land reclamation grants were increased $10.55 million over last year's appropriation.

In 1981, the Office of Abandoned Mine Lands & Reclamation was created by West Virginia's Department of Natural Resources to clean up these areas. The office is now under the state's Division of Environmental Protection.

This office manages the reclamation of eligible lands and waters affected by mining prior to passage of the Surface Mining Control and Reclamation Act in 1977.

As a part of SMCRA, Congress created Title IV that requires coal companies to fund the AML program by placing fees on every ton of coal mined in the United States.

Currently, 35 cents for every ton of surface-mined coal, and 15 cents for every ton of coal mined underground is paid into the AML fund.

Allocations from the AML fund are then made to state and tribal agencies through the congressional budgetary process.

On October 1, 1977, the first fees were paid, and the fund has collected more than $5 billion nationwide since that time.

West Virginia's portion accounts for more than $600 million into the AML fund during that same time period.

In fact, the West Virginia coal industry has a 99 percent contribution rate to the AML fund which is higher than any other state in the nation.

Making sure money is paid into the fund is not the only way today coal companies clean up abandoned sites. Many West Virginia companies clean up area themselves saving the fund millions of dollars which can be allocated for other AML projects.

For example, Catenary Coal Company received a reclamation award from the West Virginia Mining and Reclamation Association for its voluntary elimination of more than 25 miles of abandoned highwall and the total reclamation of two abandoned refuse piles totaling more than 150 acres.

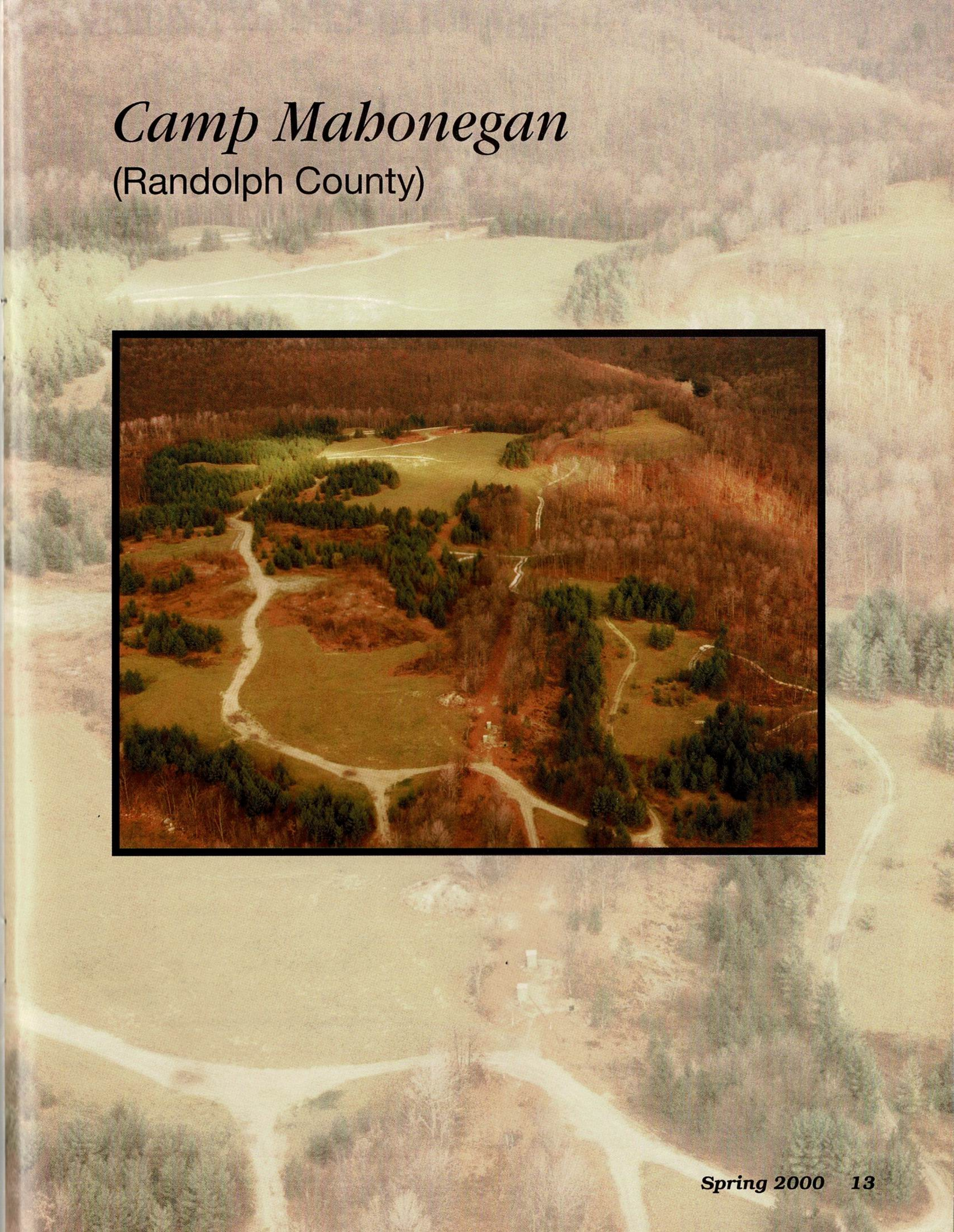
This project alone saved the Division of Environmental Protection and the AML fund more than $30 dollars.

Two other companies, Anker Coal Group and C&W Coal Company also were recognized for the cleanup of abandoned mine sites.

These are just three quick examples how many of present-day coal companies make a sincere and concentrated effort in environmental stewardship.

Although the state provides the funding, it is usually private contractors who are the ones who take pride in the cleanup work. Work that is so important that the WVMRA

Please take the time and review the "before" and "after" photographs of the AML sites located throughout West Virginia. Many people with the DEP, coal companies and contractors are very proud of the reclamation completed here.



Camp Mahonegan

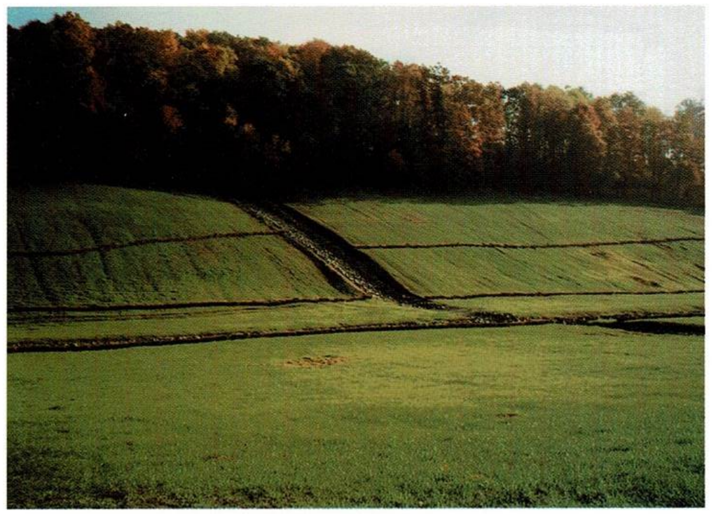
(Randolph County)

Everettville

(Monongalia County)

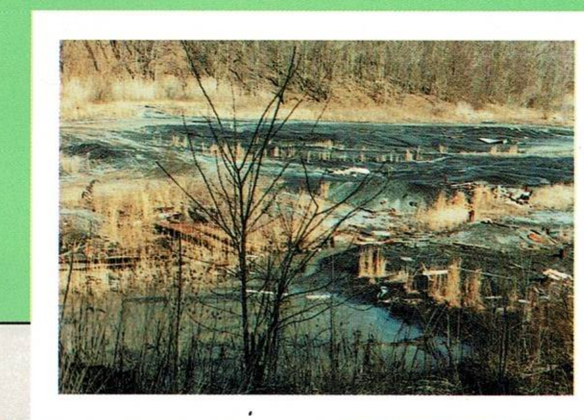
Masontown #4

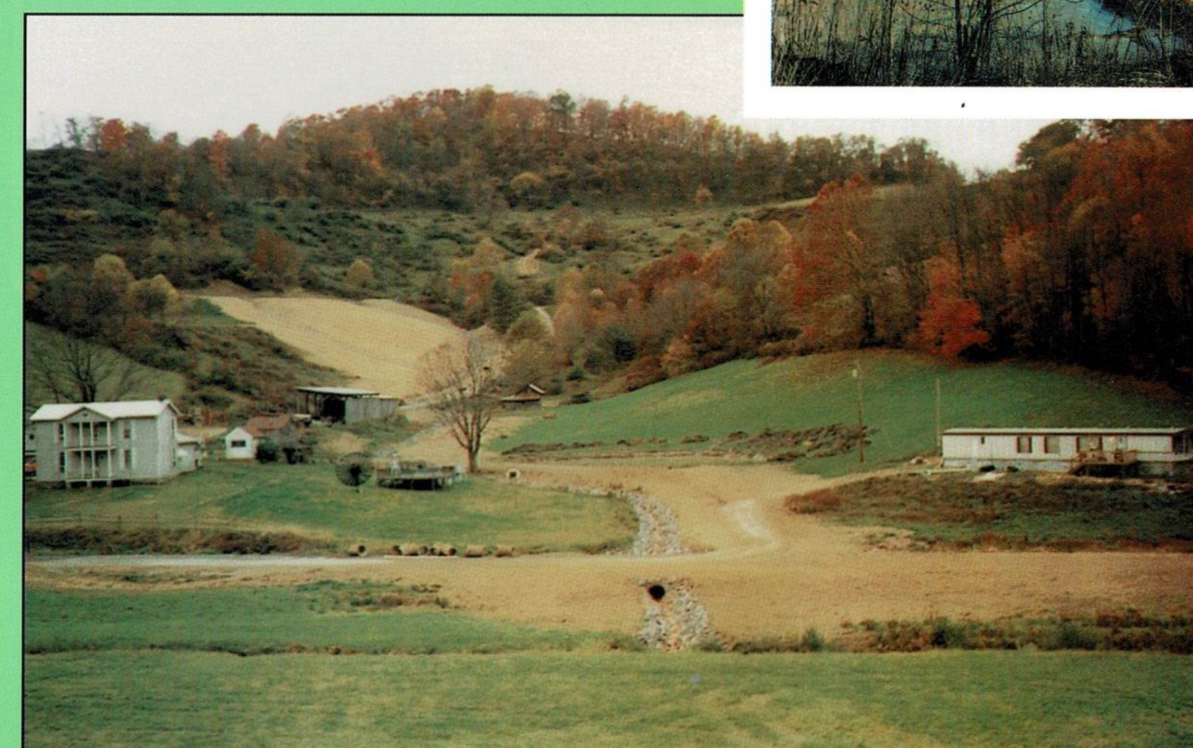
(Preston County)



Majesty Mine

(Barbour County)





Piney Creek

(Raleigh County)

Bradford Brothers, Inc. was awarded the James E. "Pete" Pitsenbarger award by the West Virginia Mining and Reclamation Association for its work on this AML site that included making major aesthetic improvements in the regrading and restoring topsoil of the abandoned refuse.

Owings Mill Complex

(Harrison County)

Green Mountain Company was awarded the James E. "Pete" Pitsenbarger award by the West Virginia Mining and Reclamation Association for its work on this AML site that included the removal of hazardous materials and the installation of a major drainage system to correct environmental degradation at the long abandoned complex.

Wahoo Refuse

(Marion County)

Turkey Wallow

(Wyoming County)

Family Values at work.

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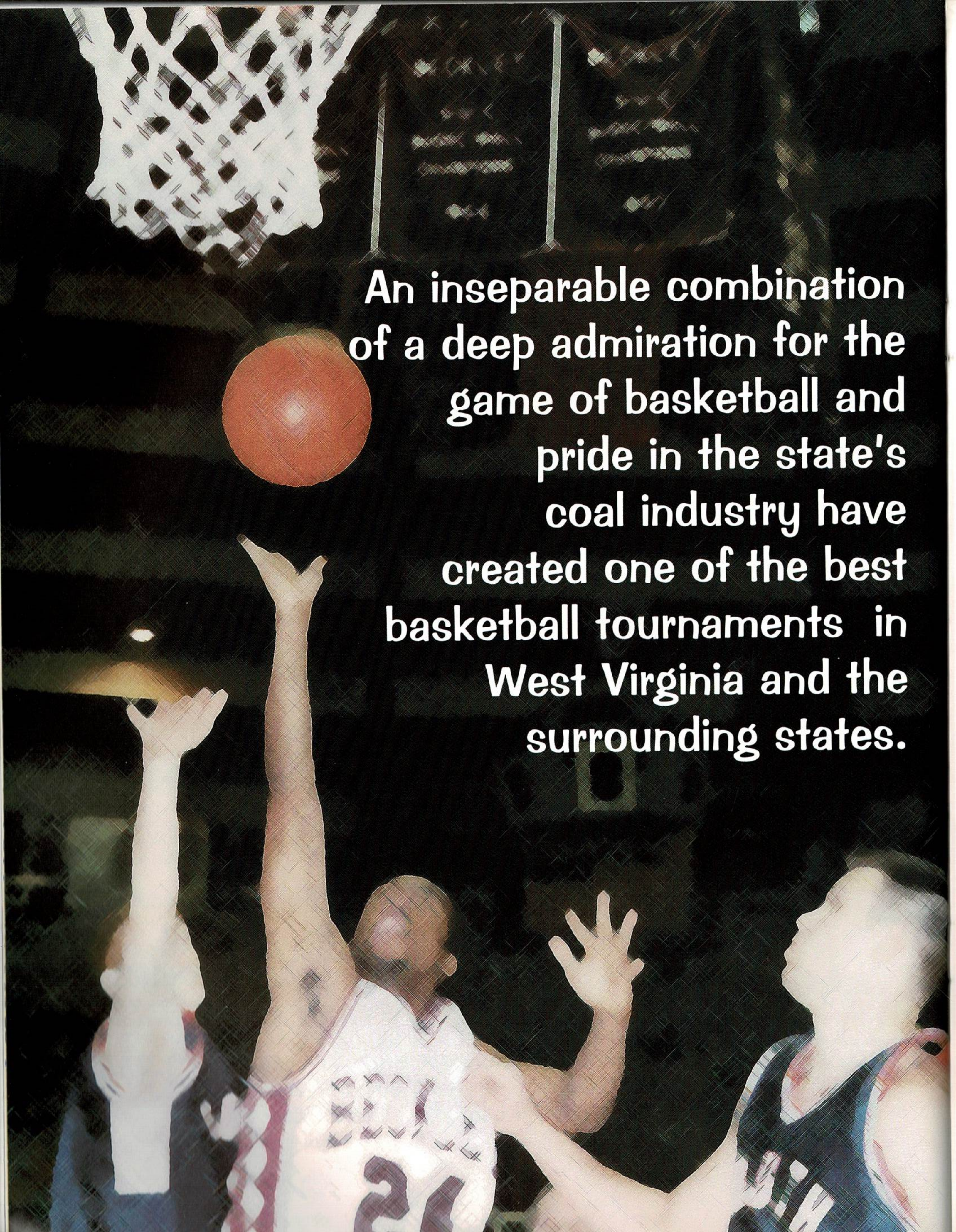
Layland Refuse

(Fayette County)

Black Wolfe

(McDowell County)



An inseparable combination of a deep admiration for the game of basketball and pride in the state's coal industry have created one of the best basketball tournaments in West Virginia and the surrounding states.

MOUNTAIN STATE COAL CLASSIC

When it's January in Beckley, W.Va., it can only mean two things: it's going to snow and the Mountain State Coal Classic basketball tournament is in town.

In this southern West Virginia town, they seem to be as certain as death and taxes.

The Classic, however, is a little different than most basketball tournaments. It begins with a kickoff banquet having a keynote speaker that is always a nationally recognized. This year, the speakers were Marshall University's quarterback and Heisman candidate, Chad Pennington and head coach, Bob Pruett.

Previous speakers have included Kareem Abdul-Jabbar, Terry Bradshaw, and Jerry West.

Games run for next six days with 52 teams playing more than 50 games ranging from elementary school to college.

Quite a feat.

And even above all that, the Classic consistently attracts some of the state's and the nation's best high school basketball talent.

Yet, why would teams who are accustom to playing in high power tournaments in South Carolina, Florida, California and even Alaska and Hawaii, come to Beckley, West Virginia?

"The tournament has good competition and that's a big draw for us," said Bobby Jones, head coach for Charlotte Christian Academy who played in the Classic for the first time. "The Classic draws large crowds and it is a well run tournament."

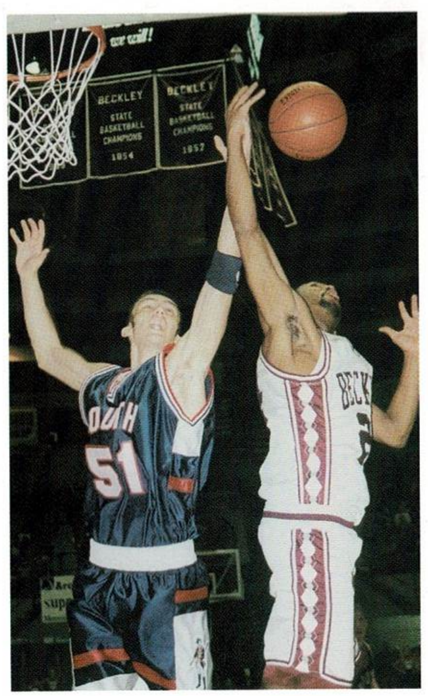
Apparently Oak Hill Academy's Head Coach Steve Smith agrees. "I look for things like good competition, how the tournament is run and how they take care of you. Hospitality is as important as anything for us in a tournament and in Beckley, they do a lot of nice things for you."

Steve Kominar (D-Mingo) presents the high school boys AA division Coal Classic championship trophy to Tug Valley after they defeated Richwood.

It is evident that Smith think's highly of the Classic as Oak Hill has already committed to play in the tournament again next year.

Smith arguably can be considered one of the top coaches in the nation. He has spent 15 years at the helm for Oak Hill and 68 of his players have gone to Division I colleges on scholarships and 12 players have advanced one step farther to play in the NBA.

To have Smith and his team in the Classic is obviously a gigantic plus.



(Left) Woodrow Wilson's Leon Smith takes a rebound from Parkersburg South's Chris Squires during the Classic's AAA semifinal game. (Right) Chris Clark of Charlotte Christian Academy, tries to stop Oak Hill's Luke Whitehead. Oak Hill won the Coal Classic for the second year in a row by later defeating Woodrow Wilson in the championship game.

This is the 11th season for the Mountain State Coal Classic which is becoming more dominating with each passing year. It's the sixth year the Classic tournament has been showcased in Beckley since moving from Charleston.

This year, the Mountain State Coal Classic was played during January 24-29 at the Raleigh County Armory and again boasted of having the top ranked high school team in the nation.

At the time of the Classic, Oak Hill was ranked as the nation's top team and had won the Beach Ball Classic in Myrtle Beach, S.C. just prior to coming to Beckley.

However, with a loss a week later in a tournament in Long Beach California, Oak Hill dropped out of the top spot, but finished its season as number two of the nation's top 25 teams.

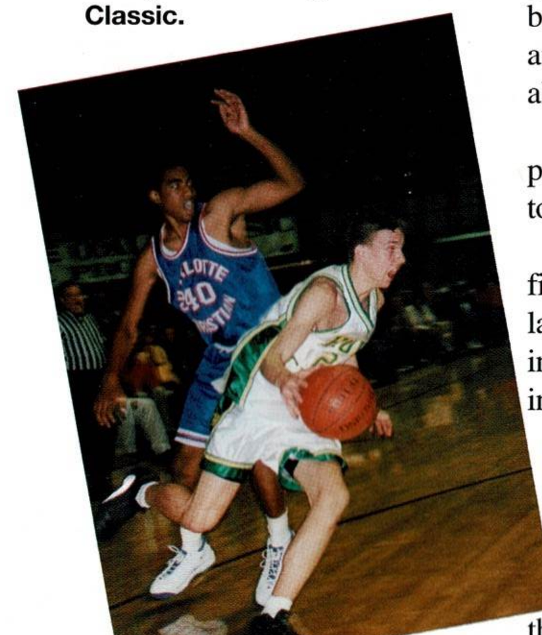
Earlier in the Classic, in front of a packed house, Beckley's Woodrow Wilson upset Parkersburg South in a nail biter to earn the right to challenge Oak Hill in the AAA tournament championship.

Although Smith said that the Armory is a tough place to play for any team, Oak Hill easily defeated Woodrow Wilson to claim the Classic crown for the second year in a row.

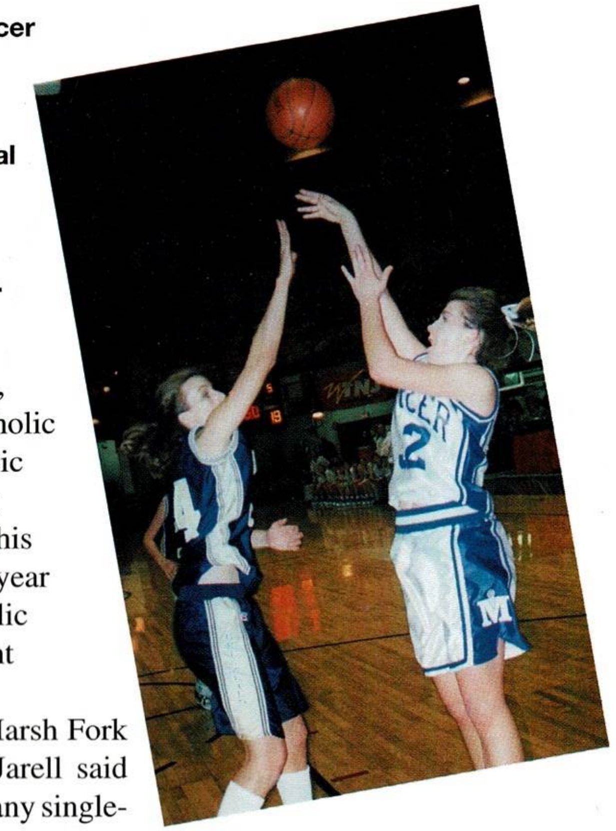
In the AA high school boys division, it was Tug Valley who defeated Richwood to become tournament champions.

Tug Valley's point guard, Greg Davis, was named player of the week by the Associated Press for the state boys high school basketball for averaging 23 points during the Classic.

Michael Howell of Holy Cross, Flushing N.Y., dribbles past Charlotte Christian's Jake Helms in a losing effort during the Coal Classic.



Hollie Gillespie of Mercer Christian Academy shoots over Brandy Roberts of Nicholas County, during the Coal Classic High School Championship. Nicholas won in a 32-29 defensive battle.



In the high school boys Class A division, it was Charleston Catholic that grabbed the Classic Crown by hammering March Fork 63-44. This is the second straight year that Charleston Catholic was named tournament champions.

After the game, Marsh Fork Head Coach Buddy Jarell said "it's going to hard for any single-A team to beat them."

He was right as Charleston Catholic also captured the state tournament championship later this year.

In the Classic's high school girls division, it was a defensive battle between Nicholas County and Mercer Christian Academy all the way.

While both teams average 60 points a game, it was Nicholas that topped Mercer in a 32-29 thriller.

The game came down to the final buzzer as Mercer missed a last second three point shot keeping Nicholas' undefeated streak in tack.

Beckley media has always had outstanding coverage of the Classic and this year, it seemed even more prominent. Jody Murphy, sports writer for the Beckley *Register-Herald* even selected a personal Classic all tournament team: Luke Whitehead, Oak Hill, Patrick Crum, George Washington; Mike Ross, Woodrow Wilson; Chris Meeks, Charlotte Christian and Patrick Jones, Capitol.

According to *USA Today* Whitehead has already signed to advance his basketball career at Louisville.

Thanks to Jim Justice, Terry Miller, Byrd White, Pam Rhodes and so many other people at Bluestone Industries, the Classic truly lives up to its name. It is a top notch tournament that is not only known through West Virginia, but in the surrounding states as well.

The Mountain State Coal Classic, a good way to promote West Virginia and good way to promote the state's coal industry.

Mountain State Coal Classic - An Event That Keeps Giving Even After the Last Whistle is Blown

There is more to the Mountain State Coal Classic than just a basketball tournament.

It is also provides college scholarships to the student/athletes participating in the tournament. A gift that goes way beyond the last whistle.

Since its beginning 11 years ago, the Classic is responsible for more than $130,000 in college scholarships. This year alone, $22,000 in scholarships were presented to the student/athletes.

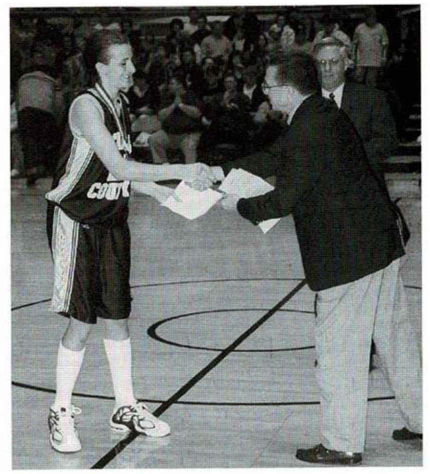
Every year, one player and one cheerleader from each high school team and one cheerleader from a college team, is awarded a $500 college scholarship. An award that helps the students continue their education at the college level.

Any other industry would be touted for awarding this amount of money to benefit future educations.

Unfortunately, the West Virginia's coal industry, does not get to enjoy that luxury.

Nonetheless, the games will continue, the crowds will roar and the scholarships will be presented, silently.

As Jim Justice, president of Bluestone Industries, Inc. says, "It's for the kids."



Brandy Roberts of Nicholas County High School, is awarded a $500 college scholarship by West Virginia Coal Association President, Bill Raney, as Terry Miller of Bluestone Industries, Inc. looks on.

Below is the list of students receiving a $500 scholarship

Leon Smith	Woodrow Wilson	Brittany Weddington	Tug Valley
Adrianne Lewis	Woodrow Wilson	David Gibbons	Charleston Catholic
Jonathan Crum	George Washington	Erin Liberatore	Charleston Catholic
Lindsey Tyree	George Washington	Bryan Cosby	Montcalm
Maitland Bailey	Princeton	Charlie Mahon	Burch
Tina Jones	Princeton	Clyde McKnight	Marsh Fork
Chris Squires	Parkersburg South	Jessica Eads	Marsh Fork
Noelle Young	Parkersburg South	Sarah Stowers	George Washington
Jessica Gray	Oak Hill	Amanda Kuhn	George Washington
Patrick Jones	Capitol	Nikki Jackson	Summers County
Sara Funk	Capitol	Ashley Meador	Summers County
Chris Meeks	Charlotte Christian	Brandy Roberts	Nicholas County
Adam Frederic	Holy Cross	Merilee Mullins	Nicholas County
Matt Donahue	Richwood	Jessica Southers	Russell County (KY)
Kissy Derito	Richwood	Sarah Johnson	Woodrow Wilson
Laurie Meszaros	Richwood	Crystal Lovell	Woodrow Wilson
Josh Allen	Independence	Dori Glance	Fairmont
Jenny Dickerson	Independence	Tracy Wyatt	Mercer Christian
Antoine Hickman	Bluefield	Cristy Bennett	Mercer Christian
Kelly Jarrell	Bluefield	Anna Connolly	Princeton
Dennis Ooten	Tug Valley	Candice Farrington	College of W.Va.

Use of Coal Combustion Products for Reclamation

Paul F. Ziemkiewicz and Jeff Skousen
West Virginia University

Introduction

About 105 million tons of coal combustion products (CCP) were produced by American power generating utilities in 1997 (ACAA, 1998). Of that total, about 2 million tons were used in reclamation applications. Twenty years ago, almost all coal ashes were either bottom ash or fly ash. With the shift to new emission control technologies at power plants, large volumes of new products are being generated. Many of these new products are not suited to traditional ash applications (such as cement additions), so other uses have been investigated.

Filling of mine voids has the potential to dispose of substantial quantities of CCPs, and state and federal policies encourage the beneficial use of CCPs. Beneficial uses in mining include acid drainage control, subsidence control, and soil reconstruction. States such as Pennsylvania and West Virginia have developed policies that define and regulate beneficial use of CCPs for coal mine reclamation. These successful policies will be summarized.

Types of Coal Combustion Products

Coal combustion products are grouped into four main classes: 1) Class F, 2) Class C, 3) Fluidized Bed Combustion, and 4) Flue Gas Desulfurization. Class F and C ashes are produced in large coal boilers where pulverized coal is injected as fuel. These two ash types still comprise the bulk of CCPs produced in the U.S. They are distinguished by their free lime (CaO) content. Class F ashes have less than 10% lime, while Class C ashes have more than 10% lime.

Nearly all ashes produced by coal boilers in the eastern U.S. are Class F, while those burning western U.S. coal are typically Class C. Table 1 shows typical chemical compositions for both Class F and Class C ashes.

Fluidized Bed Combustion (FBC) ashes and Flue Gas Desulfurization (FGD) solids (also sometimes referred to as sludges) result from relatively new, clean coal technologies. Both use lime or limestone ($CaCO_3$) to generate CaO to capture sulfur oxides in the boiler exhaust gas stream.

FBC ashes are produced when high sulfur coal and coal waste materials (gob, coal partings or binders, black shales, etc.) are burned with limestone in a fluidized bed boiler. Sulfur oxides are precipitated as gypsum ($CaSO_4$) along with unreacted lime in a strongly alkaline ash (typically 25 to 30% free lime).

Flue Gas Desulfurization solids are produced when lime or limestone slurries are injected into the exhaust gas downstream of the boiler. Sulfur oxides are precipitated either as gypsum or calcium sulfite ($CaSO_3$). Some utilities combine FGD solids with fly ash to increase the solids content, so FGD solids may or may not contain fly ash. In either case, sulfites may then be converted to gypsum by forced oxidation.

Currently, 25 million tons of FGD solids are produced each year with 9% of that total being beneficially used in reclamation. The remainder is landfilled. FGD solids normally have little inherent lime. However, they are often amended with lime (CaO) for solidification, but if not amended, they have the consistency of a thin paste.

Beneficial CCP Applications in Coal Mines

CCPs are typically used in the following beneficial applications at coal mines:

1. Neutralization or encapsulation of acid-producing materials,
2. Barriers to acid mine drainage formation/transport,
3. Alkaline amendment to neutralize acid-producing rock,
4. Subsidence control in underground mines,
5. Filling underground mine voids to control acid drainage,
6. Pit filling to reach approximate original contour in surface mines,
7. Soil amendment or substitute.

This report will only discuss the first six scenarios since soil reclamation is an agricultural application.

Coal Mine Environments and Their Implications for CCP Use

Mine environments are complex, and any given mine will contain zones of high groundwater flux and nearly stagnant areas. Mine groundwater can be oxidizing or reducing. Reducing conditions are often found in saturated zones, while unsaturated zones tend to be oxidizing. Some metals and anions of elements tend to be more soluble under reducing conditions.

Mine groundwater also varies according to its acidity/alkalinity. Many mine waters, particularly in the eastern U.S., are slightly to strongly acidic with significant concentrations of iron, aluminum and manganese. These ions are more soluble in acid conditions and alkalinity from CCPs can be used to neutralize acid mine drainage. The resulting metal hydroxides formed through neutralization will scavenge trace elements, such as arsenic and zinc, from the water.

In a given underground mine, one might encounter acid/oxidizing, acid/reducing, alka

Table 1. Typical composition of Class F and C ashes as defined by ASTM (1997).

Parameter	Class F	Class C
SiO_2	54.9%	39.9%
Al_2O_3	25.8%	16.7%
Fe_2O_3	6.9%	5.8%
CaO	8.7%	24.3%
SO_3	0.6%	3.3%
Moisture content	0.3%	0.9%
Loss on Ignition (LOI)(@750C)	2.8%	0.5%
Available alkalies as Na_2O	0.5%	0.7%
Specific gravity	2.34	2.67
fineness, retained on #325 mesh sieve	14%	8%

line/oxidizing and alkaline/reducing conditions. Care must be taken to ensure that CCPs are matched to zones which take advantage of their beneficial properties and which minimize their exposure to conditions that will mobilize toxic element concentrations.

The CCPs can have permeable or impermeable properties. At one end of the spectrum, bottom ashes have the hydraulic conductivity of gravel, while most fly ashes have the hydraulic conductivity of a silt-textured, soil-like material. Class F ashes tend to be more permeable than Class C ashes due to the texture differences and some Class C ashes have a high enough lime content to form very weak cements. At the opposite extreme, FGD solids and FBC ashes have very low hydraulic conductivity and are virtually impermeable like strong cement.

Nearly all CCPs contain soluble and insoluble salts. If exposed to water, soluble salts in the ash and attached to its surface will dissolve in the water. On the other hand, sulfate salts and calcium or magnesium carbonates in the ash may not be dissolved because their concentration may already be high in the water. It is not unusual to find mine waters that are already saturated with respect to gypsum or calcium carbonate. In such cases, little or no net dissolution will occur. Care should be taken that CCPs containing substantial amounts of soluble salts are not placed in areas where significant groundwater flux occurs.

Beneficial Use Policies for CCPs

The quality of CCPs must also be tested when used in mine applications according to West Virginia's coal ash policy (13 Jan 1998). For example, beneficially used CCPs must pass the USEPA's Test Methods for Evaluating Solid Waste, SW-846, Method 1311 (Toxicity Characteristic Leaching Procedure or TCLP) for non-organics. They must also have at least 0.5% alkalinity (calcium carbonate equivalent) and be applied at a rate needed to treat any acidity that could be generated by the acid-producing rock. The latter is calculated by the following formula:

$$A = ((W \times \%S \times 3.125) / \%NNP) \times 1.1$$

Where:
- A = Required amendment (tons)
- W = Amount of waste rock to be neutralized (tons)
- %S = Percent sulfur in waste rock
- %NNP = Percent net neutralization potential of amendment (e.g. %NP - %MPA)

The West Virginia ash policy calls for a 10% safety factor. Hence, the total is multiplied by 1.1.

As an example, assume 1,000 tons of waste rock containing 1% S is to be neutralized with limestone (100% NNP). So the equation shows that about 34.5 tons of the alkaline material (100% limestone in this case) would be required to neutralize this 1,000 tons of rock with the 10% safety factor.

Under Pennsylvania's Certification Guidelines for Beneficial Uses of Coal Ash (30 Apr 1998), beneficial ash applications include:

1. Coal Ash Placement. pH between 7.0 and 12.5 at the generator's site.
2. Soil substitute or soil additive. For use as a liming agent, the calcium carbonate equivalent must be at least 100 tons/1000 tons of ash. For use as a soil substitute or soil additive, the generator must provide a description and justification for the intended use. Certification would be granted on a site-specific basis.
3. Alkaline addition. For use as an alkaline amendment, the pH must be in the range of 7.0 to 12.5 at the generator's site. Also, the calcium carbonate equivalent must be at least 100 tons/1000 tons of ash.
4. Low-permeability material. To be certified as a low-permeability material, the pH of the coal ash must be in the range of 7.0 to 12.5 at the generator's site. However, if an additive is used, the mixture can be adjusted to the pH range of 7.0 to 12.5 at the site of beneficial use. To be certified as a low-permeability material, the hydraulic conductivity of the coal ash/additive mixture must be 1.0×10^{-6} cm/sec or less, based on ASTM D5084-90 or other test approved by the state and using compaction and other preparation techniques that will duplicate expected conditions at the site of the beneficial use.

Pennsylvania also requires leaching tests prior to approval of beneficial uses for CCPs. Extracts from the USEPA's Test Methods for Evaluating Solid Waste, SW-846, Method 1312 (Synthetic Precipitation Leaching Procedure or SPLP) are evaluated prior to approval of beneficial use.

Table 2 summarizes the concentrations of elements by West Virginia and Pennsylvania test methods.

Case Studies of CCPs used in Mine Environments

Eastern U.S. Projects

Case Study 1. Winding Ridge.

The Maryland Department of Natural Resources Power Plant Research Program and the Maryland Department of the Environment initiated a project in 1995 to demonstrate the use of CCPs for acid mine drainage abatement in an underground mine (Rafalko et al., 1999). The strategy was to completely fill the mine voids and replace mine water with CCP grout.

The demonstration occurred at the Frazee Mine on Winding Ridge, near Friendsville, Maryland. The mine was abandoned in the 1930s and has produced acid drainage for decades.

By filling the mine voids, the grout was intended to minimize contact between groundwater and pyrite remaining in the mine. A grout was developed consisting of solid phase CCPs with acid mine water used for slurry makeup water. The grout was injected into both dry and inundated portions of the mine.

The grout consisted of FGD material and Class F fly ash from Virginia Power Company's Mount Storm power plant and FBC ash from Morgantown Energy Associates' Morgantown power plant. The FGD material, containing mostly calcium sulfite and calcium sulfate and no free lime, was used as an inert filler.

The Class F ash was used as a pozzolon, while the FBC ash was used as the cementing agent. The grout contained approximately 60% fresh FBC (<24 hours old), 20% FGD, and 20% Class F fly ash.

The FBC ash arrived from the power plant containing about 15% moisture. The final design mix yielded 8 inches of spread using ASTM PS28-95, and a 28-day unconfined compressive strength of 520 pounds per square inch (psi) as determined by ASTM C39-94.

Prior to injection, the grout was subjected to the Toxicity Characteristic Leaching Procedure for non-organics. None of the element concentrations in the leaching solution exceeded their respective regulatory limits for characterization as a hazardous waste.

During fall 1996, more than 5,600 cubic yards of grout were injected into the mine. The original design was for 3,900 cubic yards, but additional void space was encountered in the mine and also grouted. During the injection, it became apparent that the Frazee Mine was larger and more complex than originally determined during the mine characterization phase. As a result, the mine was not completely filled and the mine continues to produce acid mine drainage.

The mine's discharge pH remained around 3.0 during and after grout injection, while Ca, Na, and K concentrations increased by nearly an order of magnitude (Aljoe, 1999). Sulfate, Cu, Ni, Zn, and Cl all nearly doubled with both Ni and Zn in excess of water quality discharge limits. Both Ni and Zn had exceeded water quality limits prior to injection. Two years after injection, however, concentrations of both Ni and Zn were at or slightly above pre-injection levels (Table 3).

In September 1997, nine bore holes were drilled into the Frazee Mine to recover grout material. The bore hole locations targeted wet and dry sections of the mine. The grout samples from core drilling were submitted to the laboratory for testing of density, permeability (hydraulic conductivity), and unconfined compressive strength. In general, the grout showed little sign of in-situ weathering and displayed good mine roof and pavement contact.

Grout cores after one year yielded permeabilities between 1.89×10^{-6} and 6.02×10^{-8} cm/sec. Grout from one core matched the target compressive strength in the 28-day laboratory test. The other grout cores all had approximately twice the strength achieved in the laboratory after 28 days.

The behavior of calcium and sulfate after injection was significantly different than that of acidity, iron and aluminum. Calcium concentrations increased three to six times and remained at these levels for more than 16 months after injection. Sulfate levels remained at about twice the pre-injection level. These increases in calcium and sulfate are due to the dissolution of these ions from the injected FBC and FGD materials.

Trends in sodium, potassium and chloride concentrations were similar to those of calcium. It is likely that their elevated concentrations result from some grout dissolution.

Prior to injection, the grout itself was subjected to a TCLP. The results showed that arsenic and barium were found at levels of 0.13 and 0.11 mg/L, respectively. Post-grouting quality of the mine discharge did not detect these constituents (the detection limit for arsenic in the mine water was 0.2 mg/L, but the detection limit for barium is one order of magnitude below the TCLP result). The data

Table 2. Comparison of West Virginia and Pennsylvania standards for CCP leachate concentrations.

	Maximum Acceptable Leachate Concentrations (mg/L)	
State:	West Virginia	Pennsylvania
Test Method:	TCLP	SPLP
Al		5.0
Sb	1	0.15
As	5	1.25
Ba	100	50
Be	0.007	
B		31.50
Cd	1	0.13
Cr	5	2.5
Cu		32.5
Fe		7.5
Pb	5	1.25
Mn		1.25
Hg	0.2	0.05
Mo		4.38
Ni	70	2.5
Se	1	1.00
Ag	5	
Tl	7	
Zn		125
SO4		2500
Cl		2500

Table 3. Summary of pre- and post-injection water quality at the Frazee Mine, Friendsville MD. All values in mg/L.

RCRA Element	TCLP Limit	EPA Drinking Water	Pre-CCP n=18	Post-CCP n=15
Sb	1	0.006	<0.2	<0.2
As	5	0.05	<0.2	<0.2
Ba	100	2	0.029	<0.02
Be	0.007	0.004	<0.02	<0.02
Cd	1	0.005	<0.02	<0.02
Cr (6+)	5	0.1	0.03	0.04
Pb	5	0.015	<0.02	<0.02
Ni	70	0.01	0.62	1.13
Se	1	0.05	<0.5	<0.5
Al			37	56
Ca			25	223
Cl			2.3	7.3
Co			0.3	0.5
Cu			0.08	0.25
Fe			67	67
Mg			26	32
Mn			2.7	2.8
K			0.9	13.3
Zn			1.4	2.3
Na			1	8
SO4			564	1182

showed that with the exception of a short term increase in Ni and Zn, no high levels of elements were leached from the ash even though the ash is dissolving due to acid attack.

The grout was placed under nearly worst case conditions in this application. There was insufficient grout to neutralize acid in the mine water, so the grout was subjected to continuous weathering by pH 3.0 water. Further, the flow of this water through the mine was unhindered. The objectives of such mine grouting projects are to occlude voids and eliminate mine drainage. This project, however, represents a case where this objective was not achieved and the grout was subject to a high flow, chemically aggressive mine water.

Case Study 2. Mettiki Coal, Underground Mine Back Stowing.

In December 1996, Metikki Coal Corporation began injecting a mixture of non-fixated (non-hardening and low lime content) FGD solids, acid mine drainage metal precipitates (floc), and fine coal refuse into its underground coal mine near Redhouse, Maryland. Materials are mixed in a specially designed building with slurry water. The slurry is injected into the mine at about 15% solids content. There is some unreacted lime in both the FGD and the floc, which would dissolve in the thin slurry.

The mixture is injected into inactive sections of the mine and to date about 320,000 tons of this mixture have been injected. The slurry is injected at the low point in the mine and displaces an otherwise acid mine pool. The FGD solids are not fixated, so they are not expected to solidify.

On the other hand, since the slurry is placed in the low point of the mine and well below regional drainage, the mine pool is expected to be relatively stagnant. Thus, stratification of water above the slurry mixture is likely to occur with minimal mixing. Water has been sampled and analyzed both prior to and after injection of the slurry and these data are summarized in Table 4.

Chloride was expected to be the most sensitive ion as the FGD solids have between 10,000 and 30,000 mg/L Cl. Since chloride is an anion and extremely soluble, it has been monitored closely. Maryland set a discharge limit of 860 mg/L on chloride.

Chloride concentrations remain well below the Maryland limit of 860 mg/L, averaging about 200 mg/L. This is, however, above the pre-injection level of 2.2 mg/L. Other than a 50% increase in sulfate concentrations, the injection has had little effect other than to increase the alkalinity in the mine pool. This has caused the pH to increase from about 3 to 4.5, while Al and Fe have both dropped substantially. Prior to discharge, mine water is treated in a high-density lime treatment system and discharged through a polishing pond to the NPDES monitoring point. Trout are successfully raised in the polishing pond.

Case Study 3. Clinton County, PA. Surface Mine Grouting and Capping for AMD Control.

Between 1974 and 1977, a 37-acre surface coal mine was mined and reclaimed in Clinton County, Pennsylvania. Pyritic pit cleanings and refuse were buried in the backfill, producing severe acid mine drainage. The pyritic material was located in discrete piles or pods within the backfill. The pods and initial contaminant plumes were identified using geophysical techniques confirmed by drilling.

Three approaches were taken to abate acid mine drainage. On one area of the mine, a direct injection of an FBC ash grout into and around the pyritic pods was conducted. On a second area, the affected area was capped with FBC ash. On a third area, a combination of the first two approaches was conducted. The first approach was initially attempted at every acidic pod. If the pod was unable to accept the grout, the area directly above the pod was capped to minimize contact between surface water and pyritic waste. In several cases, the area around the non-receptive pod was grouted to divert groundwater flow. The project has been described in detail by Schueck et al., 1996.

For performance monitoring, 42 wells were drilled on and adjacent to the site. Well locations were guided by the results of geophysical mapping techniques. Wells located on the site were drilled through the spoil to the pit

Table 4. Water quality data from Metikki FGD underground injection. All values in mg/L.

RCRA Element	TCLP Limit	EPA Drinking Water	Pre-CCP injection Tons added 0	Post-CCP injection Tons added 51,716
Sb	1	0.006	<0.05	<0.05
As	5	0.05	<0.025	<0.025
Ba	100	2	0	0.03
Be	0.007	0.004	<0.002	<0.002
Cd	1	0.005	<0.002	<0.002
Cr (6+)	5	0.1	<0.007	<0.007
Pb	5	0.015	<0.025	<0.025
Hg	0.2	0.002	na	na
Ni	70	0.01	0.14	0.19
Se	1	0.05	na	na
Ag	5		<0.002	<0.002
Tl	7	0.002	<0.13	<0.13
Al			0.4	1.3
Ca			224	541
Cl	860		2.2	200
Co			0.1	0.14
Cu			0	0.01
Fe			39	34
Mg			50	84
Mn			2.7	4.8
K			7.4	10.2
V			<0.005	<0.005
Zn			na	0.27
Na			77	79
SO4			830	1346

floor, while wells located adjacent to the site were drilled to the unmined lower split of the Lower Kittanning coal seam. The initial drilling confirmed the locations of the pods previously identified by geophysical methods.

Pressure grouting resulted in reductions of acid mine drainage. Acidity from the pods was reduced by 23 to 52%. Significant reductions in trace metal (Cd, Cu, and Cr) concentrations from 42 to 88% were also observed. Wells down gradient of the grouted pods exhibited 16 to 37% reductions in mean concentrations of the common acid mine drainage parameters (Fe, Al, SO4). The exception was sulfate, which remained unchanged. Significant trace metal reductions were also noted in down gradient wells.

Where a surface cap of FBC ash was applied, results were mixed. Decreased infiltration from the cap may have abated some of the acid mine drainage in the upper portion of the pod, but the lateral flow of water along the pit floor was sufficient to create acid mine drainage. Wells down gradient of capped pods displayed significant reductions in mean concentrations of acid mine drainage parameters (29 to 34%).

Where both grouting and capping were employed, significant decreases in mean concentrations (42 to 64%) of acid mine drainage parameters were measured. The data suggested a reduction in acid mine drainage production within the pod and reduced migration of mine drainage down gradient of the pods.

The pods, which were treated by injection and capped, produced the most favorable results, followed by injection only. Capping alone produced the least favorable results. The combined approach inhibits contact among water, oxygen and pyrite by limiting infiltration and diverting lateral flow around the pods. Injection limits contact via lateral flow, but vertical infiltration may not be inhibited.

Although percent reductions in mean concentrations varied, concentrations of acid mine drainage parameters generally decreased by 30 to 40% and the reduction of trace metals was typically higher. This is significant given that only 5% of the site was grouted. Any change in water quality is expected to be permanent due to the pozzolanic nature of the FBC grout. It was known that the entire site generated acid mine drainage and there was no intention of eliminating acid mine drainage production.

The objective was to prove the effectiveness of the FBC in reducing pollutant loads discharging from the site, while evaluating the potential for decreasing concentrations of toxic elements. Table 5 summarizes pre- and post-CCP monitoring data at well T-34, which is down gradient of a section of the mine that had been capped and grouted with FBC ash.

Despite less than total success at acid mine drainage abatement, the investigators concluded that injection grouting is a viable acid mine drainage abatement technique worthy of application on sites with certain criteria.

The technique would be most appropriate at reclaimed surface mines where the spoil is net alkaline, but where improper placement of acidic materials (pit cleanings or refuse) resulted in an acidic discharge. In addition to reclaimed sites, FBC ash is recommended on active surface mines and refuse disposal sites as a preventative measure.

FBC ash can be directly applied to or mixed with refuse and pit cleanings to create monolithic structures capable of diverting water away from pyritic materials.

Case Study 4. Chaplin Hill Mine, WV. FBC Ash for Pit Floor Sealing and Surface Capping

At the Chaplin Hill Coal Mine near Morgantown, WV, a series of surface mine pits were treated with FBC ash to control acid mine drainage. Pits in the same geological sequence had historically produced acid mine drainage due to a pyritic pit floor and pyritic units within the overburden.

In 1991, the company adopted the practice of laying a 1-ft-thick layer of FBC ash on the pit floor and compacting it prior to backfilling. In addition, another 1-ft lift of FBC ash was placed on the graded spoil and compacted prior to topsoil application. All pits thus treated have not generated acid mine drainage and do not require water treatment.

Table 6 summarizes the water quality from pits completed prior to FBC ash application and after ash application. The data indicate elimination of acid mine drainage with no significant increase in toxic element concentrations.

Midwestern Project

Case Study 5. Illinois direct water treatment using FBC ash.

A project investigated by Paul et al. (1996) introduced 150 tons of FBC ash into a two-million-gallon pond of pH 2 mine water. The pond was carefully monitored during and after the dose of FBC ash. Iron and aluminum precipitated and the pH rose. Metal concentrations in the water fell about an order of magnitude. No toxic metal contamination from the ash was detected. The same result was observed for arsenic, which can be mobilized by acidic conditions even though the solubility of arsenic decreases very little as water is neutralized.

Table 5. Pre-grouting mean water quality at the Clinton County, PA spoil site capped with FBC ash. In addition, an FBC ash grout was used to isolate pyritic pit cleanings from groundwater. All values in mg/L.

RCRA Element	TCLP Limit	EPA Drinking Water	Pre-CCP n=7	Post-CCP n=14
Sb	1	0.006		
As	5	0.05	0.18	0.04
Ba	100	2	0.03	0.04
Cd	1	0.005	0.130	0.006
Cr (6+)	5	0.1	0.43	0.04
Al			425	28
Ca			76.4	42.7
Cu			1.84	0.08
Fe			1193	124
Mg			87	14
Mn			63	50
Zn			7.5	0.6
Na			1.3	3.7
SO4			5513	430

This experiment indicates that acidified mine waters already containing toxic metals can be precipitated by FBC ash treatment of the water. The ash effectively neutralized the acid and metals in the water, but also scavenged other metals from the water as metal hydroxides formed and precipitated.

Conclusions

The use of CCPs in reclamation has been beneficial in some settings, neutral in others, and harmful in some other settings. While each setting and CCP form a unique set of circumstances requiring individual analysis and evaluation, several generalizations can be made.

1. As a mine filling material, CCPs can be used to neutralize acid groundwater, encapsulate toxic materials, bring the land surface to approximate original contour, prevent subsidence, and control hydraulic pressure buildup in underground coal mines.

2. CCP-filled areas introduce an alkaline component into the mine fill. By neutralizing acid and metal laden water in the backfill or underground mine, CCPs tend to cause metals to precipitate, lowering the concentrations of nearly all metal ions in solution. No case was found where metal loads increased beyond either TCLP or drinking water limits due to the application of CCPs in mine backfills. Neutralization of mine spoil or refuse is best accomplished by blending the CCP with pyritic materials in appropriate ratios.

Table 6. Summary of pre- and post-CCP application water quality at the Chaplin Hill Mine, Morgantown WV. The data are for samples taken and analyzed by Anker Energy Corporation and reported to the state of West Virginia. All values in mg/L.

RCRA Element	TCLP Limit	EPA Drinking Water	Pre-CCB	Post-CCB
Sb	1	0.006	0.94	0.40
As	5	0.05	1.28	<0.1
Ba	100	2	<0.1	<0.1
Be	0.007	0.004	0.96	<0.1
Cd	1	0.005	<0.1	<0.1
Cr (6+)	5	0.1	0.0001	0.0001
Pb	5	0.015	0.72	<0.1
Hg	0.2	0.002	<0.0005	<0.0005
Ni	70	0.01	1.16	<0.1
Se	1	0.05	1.29	<0.1
Ag	5		<0.1	<0.1
Tl	7	0.002	2.68	1.21
Al			36	<0.1
Ca			450	750
Fe			4	<0.1
Mg			296	450
Mn			47	0.2
SO4			2022	1500

3. In already neutral or alkaline groundwater environments, CCPs can exacerbate soil salinity problems if chlorides or sodium are a problem.

4. The extent of positive or negative impacts is a function of the groundwater flux through the CCP, its chemistry, and the chemistry of the mine groundwater.

5. Water flux is governed by local hydrology and the permeability of the CCP. In arid regions, water flux due to precipitation may be negligible, while flux along the mine pit floor may be high and regional. In humid areas, precipitation can be very high and groundwater flux is high, but localized.

6. Some CCPs can be compacted or formulated as grouts so that they are nearly impermeable to water.

Non-fixated FGD materials contain almost no neutralization potential and are presently not very useful in mine land reclamation. The non-fixated materials typically exhibit a high permeability, as well. However, fixated FGD contains excess alkalinity with low permeability. Fixated FGD materials can be useful in acid mine drainage abatement, subsidence control, and used as a barrier material to encapsulate acidic materials or seal pit floors on surface mines. Both materials can contain high chloride levels that are concentrated in the FGD units.

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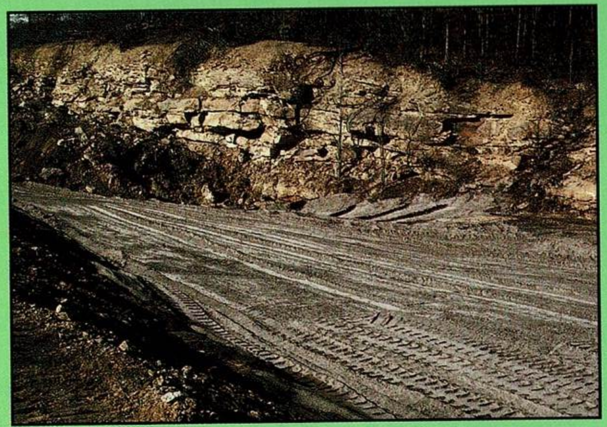
Injection of coal combustion products down a borehole to fill underground mine voids.

The slurry injected into the underground mine hardened into cement-like material. This aids in reducing mine pool size and decreases contact between acid-producing materials and water.



Coal combustion products can be used as a fill material to the backfill. It can help to eliminate acid mine drainage and bring the landscape back to approximate original contour.

Alkaline coal combustion products can be placed on coal mine pavements to neutralize acid-producing materials and eliminate the potential for acid mine drainage formation.