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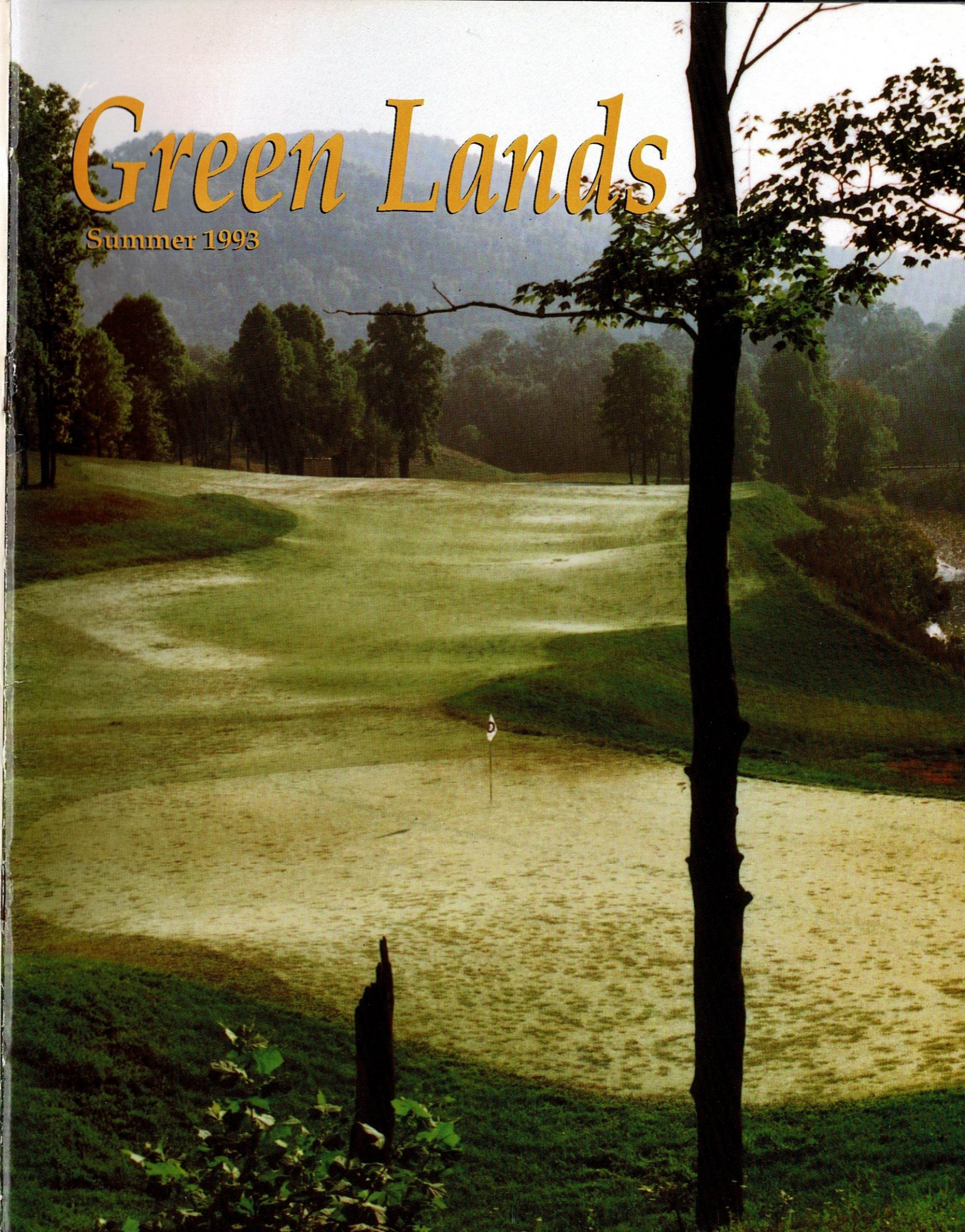
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Summer 1993





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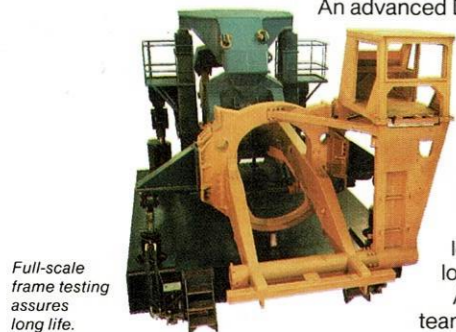
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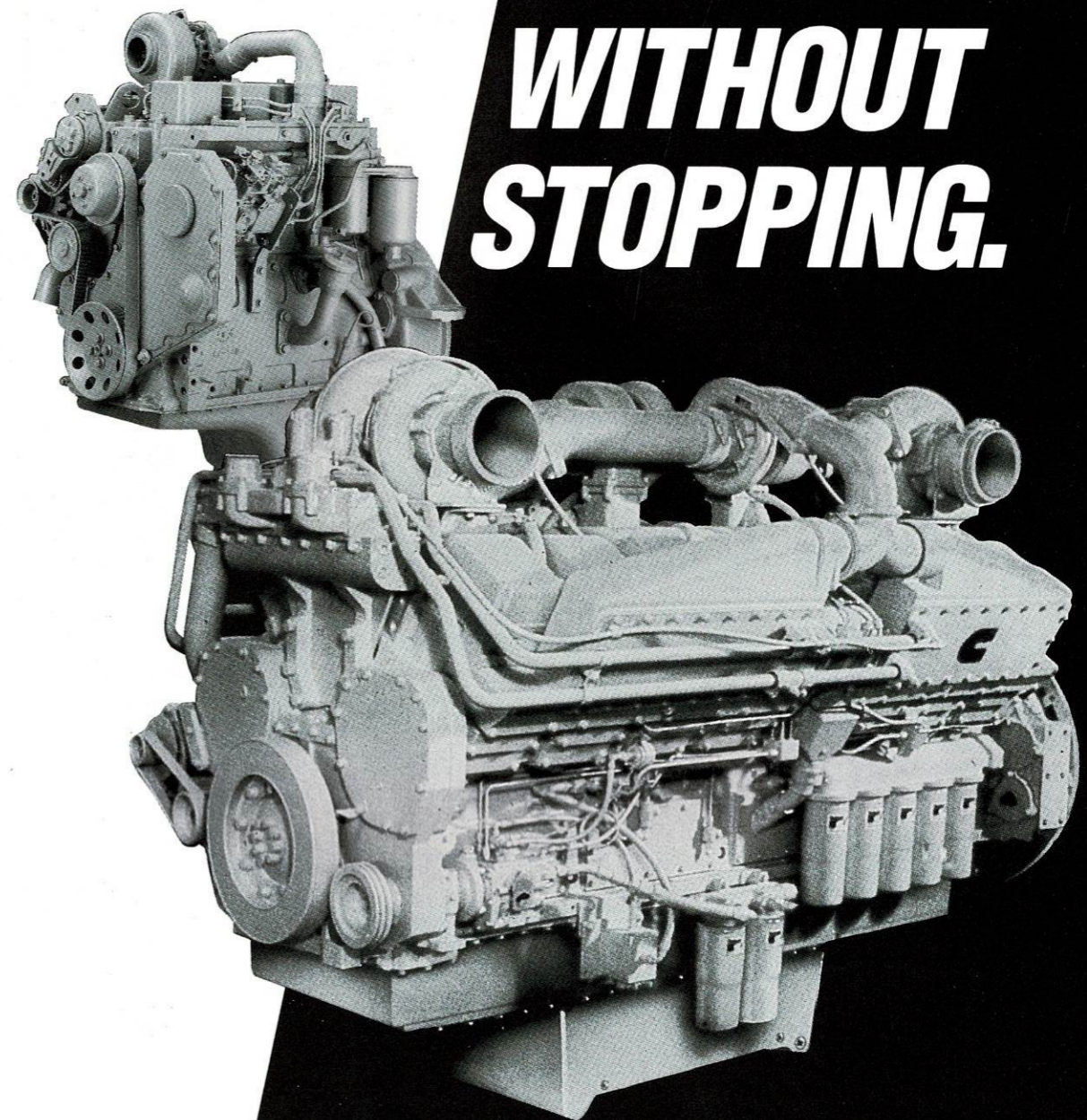
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Green Lands

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Green Lands

is a quarterly publication of the
West Virginia Mining & Reclamation Association,
with offices at 1624 Kanawha Boulevard East
Charleston, West Virginia 25311
(304) 346-5318, FAX 346-5310.



Our Cover

Where Indians once camped and
coal miners later extracted a living, now a very
special golf course is rising in Harrison County,
reflecting the heritage of bygone days.
Our cover story begins on page 10.

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COAL CALENDAR

August

5-8 **Annual Meeting**, West Virginia Mining & Reclamation Association, The Greenbrier, White Sulphur Springs, WV, contact Patty Bruce, WVMRA, 1624 Kanawha Blvd. E., Charleston, WV 25311, (304) 346-5318, FAX 346-5310.

September

15-17 **Bluefield Coal Show**, Brushfork Armory, Bluefield, WV, contact Greater Bluefield Chamber of Commerce, P.O. Box 4098, Bluefield 24701, (304) 327-7184.

19-22 **AMC Mining Convention** - San Francisco, CA, contact AMC, 1920 N. St. NW, Suite 300, Washington, D.C. 20036, (202) 861-2839.

22-23 **National Coal Association Coal Issues Conference**, Hyatt Regency Capitol Hill, Washington, D.C., contact Gloria Runyon, NCA, 1130 Seventeenth St. NW, Washington, D.C. 20036, (202) 463-2656.

26-29 **Interstate Mining Compact Commission Annual Meeting**, Radisson Plaza-Lord Baltimore Hotel, Baltimore, MD, contact IMCC, 459B Carlisle Dr., Herndon, VA 22070 (703) 709-8654.

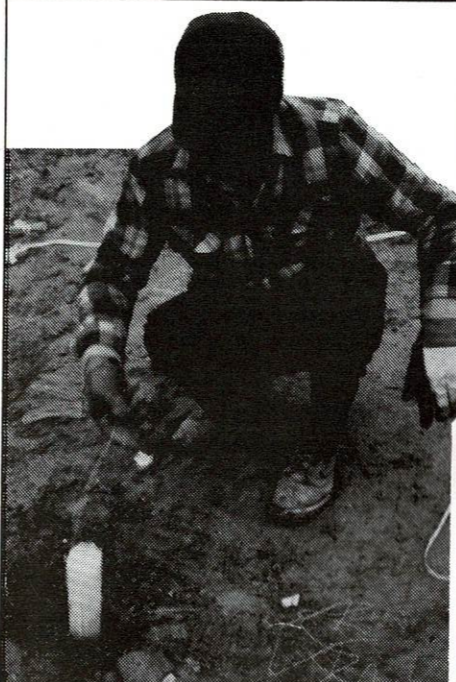
30-1 **Annual Meeting**, West Virginia Coal Association, Lakeview Resort and Conference Center, Morgantown, WV, contact WVCA, 1301 Laidley Tower, Charleston, WV 25301, (304) 342-4153.

October

14-16 **Kentucky Coal Association Annual Meeting**, Marriott Griffin Gate Resort, Lexington, KY, contact KCA, 340 South Broadway, #100, Lexington, KY 40508, (606) 233-4743, FAX 233-4745.

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Association Notebook

James C. Justice, Sr. 1925-1993

The Association was saddened recently by the death of one of the giants of the West Virginia coal industry, Beckley's Jim Justice. He was president of Bluestone Coal Co. and Bluestone Industries, Inc.

"Jim Justice was one of the individuals most closely identified with this Association," said WVMRA President Ben Greene. "Certainly, our stature has been diminished by his passing, but his tremendous contributions to our industry and to the State of West Virginia will be felt for generations to come."

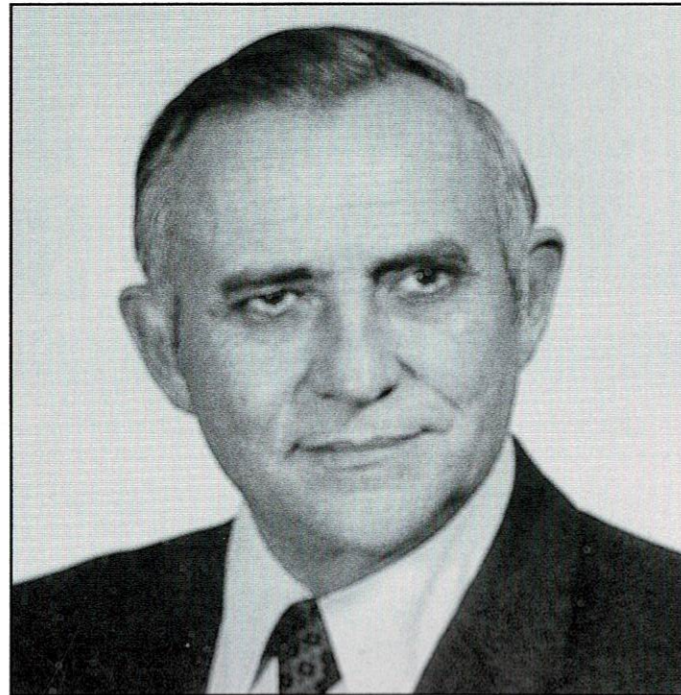
Jim was a native of Pikeville, KY, but was raised in the Wyoming County community of Kopperston. After World War II service in the Army Air Corps, he graduated from Purdue University and entered the coal business in Tennessee in 1947, moving to West Virginia in the 1950's.

As a partner with Leo Vecellio, Sr. in Ranger Fuel Corp., he was heavily involved with the establishment of the West Virginia Surface Mine Institute, forerunner of the modern WVMRA. Jim was elected to the Association's Board of Directors in 1970 and served continuously until his death. He was elected to the Executive Committee for four years and was chairman of the organization in 1974-75.

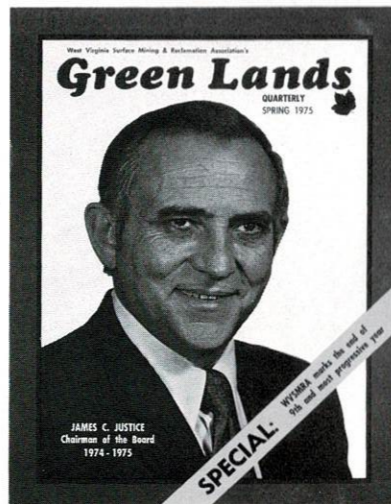
Through the years, his coal interests involved several companies, including Sterling Smokeless Coal Co., Colony Bay Coal Co., and Second Sterling Coal Co. He also diversified with the establishment of Bluestone Farms and Beckley Management, Inc.

In recent years, he had been involved with an innovative mining system. The "Edna Miner," named for Jim's wife, utilizes two powerful hydraulic arms to extract coal from a small auger hole bored into the seam.

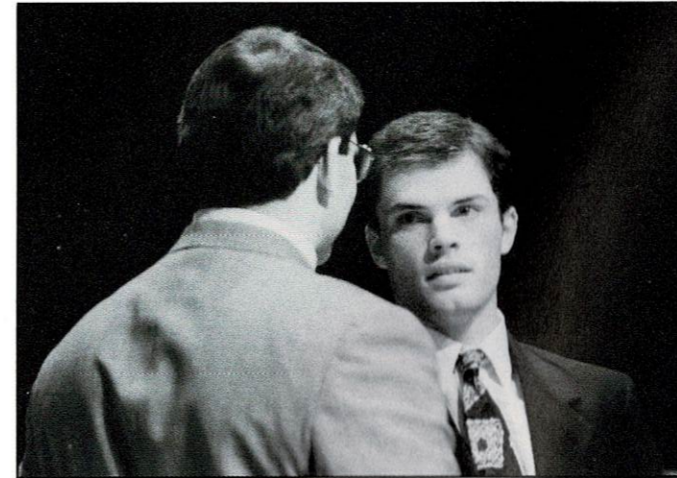
Jim's closest friends also knew him as a quiet philanthropist, with a particular interest in the welfare of children. In keeping with that philosophy, those who wish to memorialize Jim Justice should consider a contribution to the Beckley-Raleigh County YMCA, 121 E. Main St., Beckley, WV 25801.



James Conley Justice, Sr.



Jim was honored in *Time* magazine style with this 1975 *Green Lands* cover



WVCA Chairman Pete Lilly (l) presents a \$1000 scholarship to Steve Ball of Woodrow Wilson H.S.



Teresa Diamond (l) of Burch H.S. accepts her scholarship from WVMRA Vice President K. O. Damron.

Industry awards two 'Coal Classic' scholarships

The West Virginia coal industry has awarded two scholarships of \$1000 each to students from state high schools.

WVMRA and the West Virginia Coal Association provided the scholarship money in conjunction with the "West Virginia Coal Classic" basketball tournament, held in Charleston last December. Woodrow Wilson High School of Beckley and Burch High School of Delbarton were the winners of the two-tiered tournament and thereby earned the scholarships for their schools.

The scholarships were made available to all students at the schools, based on academic achievement and extra-curricular activities. The recipients were selected by committees within the schools.

The winner at Burch H.S. is Teresa Diamond, senior class president, co-valedictorian and a member of the basketball team. She will attend Alice Lloyd College in Kentucky this fall as a pre-pharmacy student, with plans to complete pharmacy school at the University of Kentucky.

Association Vice President K. O. Damron, a native of nearby Lenore, presented the scholarship to Ms. Diamond at a school awards program. K. O. characterized the scholarship as a key element of the industry's sponsorship of the basketball event. "We hope this award, presented as a result of a highly visible athletic event, will draw the attention of all students to the importance of academics. We are pleased to be able to participate in furthering the education of outstanding young West Virginians who have demonstrated an ability to balance academic achievement with success outside the classroom."

The scholarship winner at Woodrow Wilson H.S. is Steve Ball who, in addition to compiling an outstanding academic record, was a key player on the school's state

championship basketball team and also a member of the baseball team. He will attend Clemson University in the fall.

Eastern Associated Coal Corporation President Peter B. Lilly, a Beckley native, presented the \$1,000 scholarship to Ball during the school's annual award ceremony. Lilly sees Ball's scholarship as emblematic of the industry's objectives for the tournament. "The West Virginia coal industry is proud of Steve Ball's outstanding record of academic success at Woodrow Wilson High School, and is pleased to honor him today with the 'Coal Classic' scholarship."

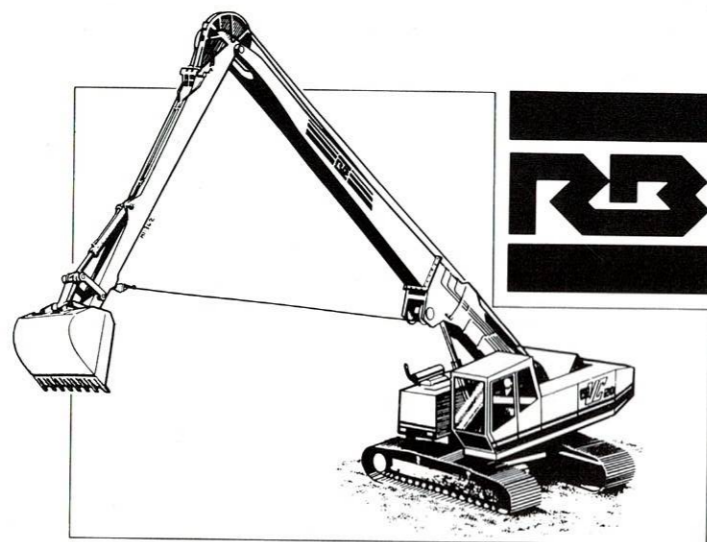
"Our state's future lies in achieving continued educational advancements. The coal industry remains committed to emphasizing educational excellence through our many partnerships with individual schools, and with our 'Coal Classic' scholarship program."

New members

Six companies were approved for membership at the March meeting of the Board of Directors.

The newest General members are **Old Dominion Mining, Inc.** of Pound, VA, Steven R. Mullins - representative; **Pickands Mather Coal Co.**, Cleveland, OH, Scott F. Brown - representative; and **The Ridge Land Co.**, Thorpe, WV, William G. Skewes, Jr. - representative.

Joining the Associate Division are **Acord Surveying Inc.** of Summersville, WV, Wayne Acord - representative; **Paul Weir Co.**, Charleston, WV, Robert E. Golkosky - representative; and **Resource Associates Group, Inc.**, Lexington, KY, Donald W. Hunter - representative.



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The Pete Dye Golf Club logo retains the mining heritage of the property

. . . .and the course itself perfectly reflects West Virginia's natural beauty.



Almost Heaven — Golf Division

A right turn off the Meadowbrook exit of I-79 northbound, at mile marker 121, in Bridgeport, West Virginia brings travelers to a blossoming commercial area which was mostly meadowland a decade ago.

To the left, the road turns country, wandering past the Meadowbrook Mall and on into the woods. A couple of miles down that path stands a little white country church. At Smith Chapel, things change again. Turn left at the church, and the road leads quickly to what is probably the most innovative golf course anywhere.

The ambitiously named "Pete Dye Golf Club" is coming to life amid half a thousand acres of an ancient Indian hunting ground, more recently a West Virginia coal mine.

The Club is the pet project of father and son coal operators James D. and James J. LaRosa. It has been in the works since 1980. Pete Dye, already famous as a golf course architect, was among several designers invited to evaluate LaRosa property along old Route 50, between Bridgeport and Clarksburg. Jim LaRosa recalls Dye's reaction. "He said, 'I can build you a good average golf course on this property.'"

Of course, he wasn't really anxious to spend his efforts on a average course. But when he saw the property behind Smith Chapel, he fell in love with it.

"Here," said Dye, "we can build a world class golf course." And that's just what the developers have in mind. Midway through construction, Dye was sufficiently pleased with the direction of the project that he offered to lend his name to the Club. Though he is the architect on ten of Golf Digest's top 100 American courses, this is the first club named for Pete Dye. Intrigued by the rolling valley countryside set between majestic hills and a picturesque creek, he calls it "the most dramatic piece of property I've ever built a course on."

Clarksburg native Billy Pulice is the marketing director for the fledgling enterprise, and his enthusiasm is catching. "This is a very special place. We intend to create a very special golfing atmosphere here. We want to appeal to golfers on a national, even a global, scale. We want to bring tournaments here. Most of all, we want to offer to our members an experience that they just can't get anywhere else."



The blend of careful land sculpting with natural settings have created many scenes that can only be described as "picturesque."

Operating a course designed by Pete Dye is a big step in that direction. Another was luring Jim Jamieson from the Florida sunshine to serve as golf director. Jamieson is a 10 year veteran of the PGA tour and a former winner of the Western Open. He also served as the golf pro at the famed Greenbrier resort in White Sulphur Springs.

But the course itself will be the star. It covers 235 acres and sits in the middle of a 500 acre tract, leaving a privacy buffer zone of 265 acres.

The heritage of the land as a former coal property is readily apparent. Lumps of coal serve as tee markers. Cart paths are paved with red dog. From the 5th tee, the red and white towers of the coal-fired Harrison Power Station are visible at a distance of more than three miles.

The 6th, 7th 8th and 10th holes will utilize crushed coal in place of sand traps. Between the 6th green and the 7th tee, golfers can pass through a 140 foot stretch of an authentic underground mine shaft. The 10th fairway is defined by 22 coal-filled rail cars on an old track.

The course is picturesque in other ways as well. A venerable haystack sits near antique farm implements along the 3rd fairway. A 25 foot waterfall fronts the 10th green. Simpson Creek winds its way through a mile and a half of the course, complementing three lakes, one of which covers 11 acres.

By any standard, the course will be challenging. But it is designed for golfers of many levels. Each hole features five sets of tees. The course plays anywhere from 5200 to 7100 yards.

The flag is visible from the tee on 17 of the 18 holes and each hole has a landmark "target" from which to aim the tee shot.

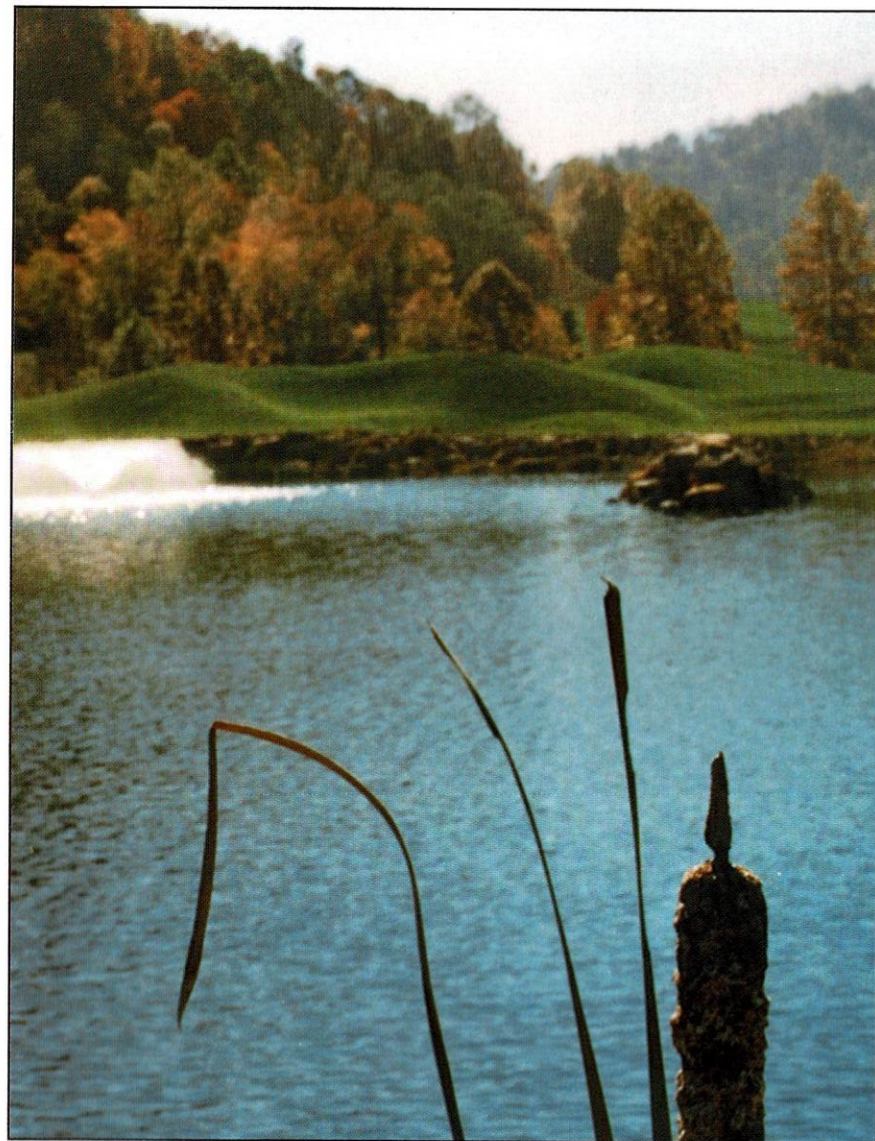
With future tournament play in mind, the hillside along the 18th fairway was sculpted to accommodate up to 30,000 spectators and several other holes are flanked by natural viewing areas. The Club will also be geared to accommodating corporate outings and tournaments.

A modest but comfortable clubhouse sits on the shaded entrance grounds, where valet parking will be in place for members and guests. More extensive and elaborate facilities are planned for the near future.

Some 40 workers put the finishing touches on the front nine in time for the July 3 startup date. The back nine is scheduled for play next spring.

Pulice has not planned a "grand opening." "We're going to invite our members to come out and play some golf."

After previous lives as the home of hunters, coal miners and farmers, that's what the valley behind Smith Chapel is all about.



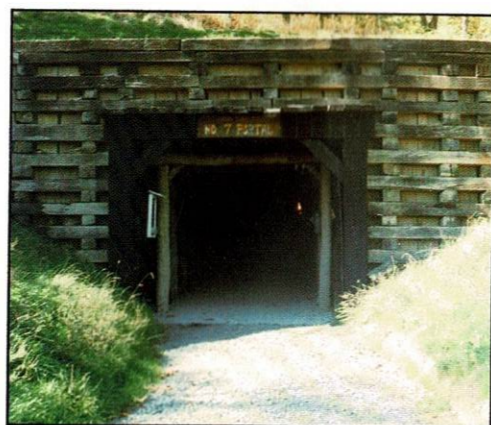
The course features three lakes, including this 11 acre beauty.



The 235 acre course is surrounded by an additional 265 acres of peaceful woodland.



The Club's manicured fairways have a "greens-like" quality.



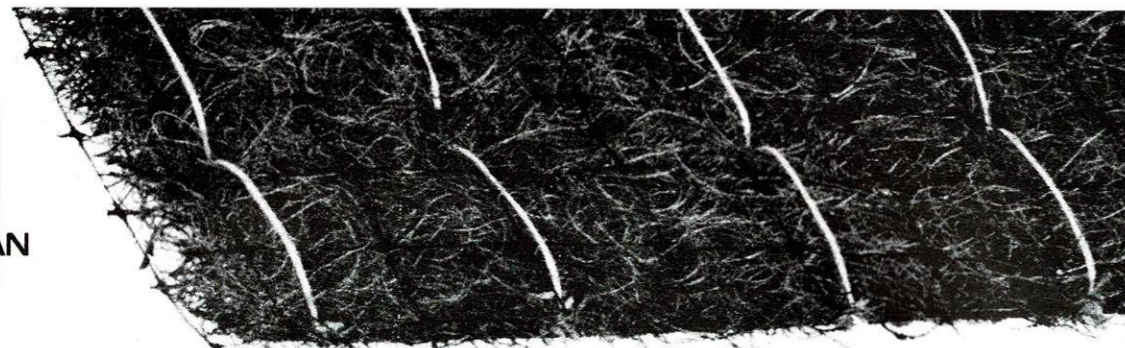
A unique detour between holes 6 & 7.



Harrison County's rolling countryside lends itself to the kind of golf course Pete Dye had in mind.



Undisturbed relics of a bygone era add character and distinction to the layout of the Pete Dye Golf Club.



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Actual Size

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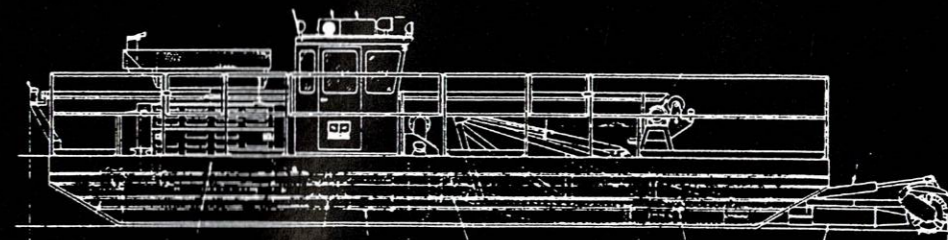
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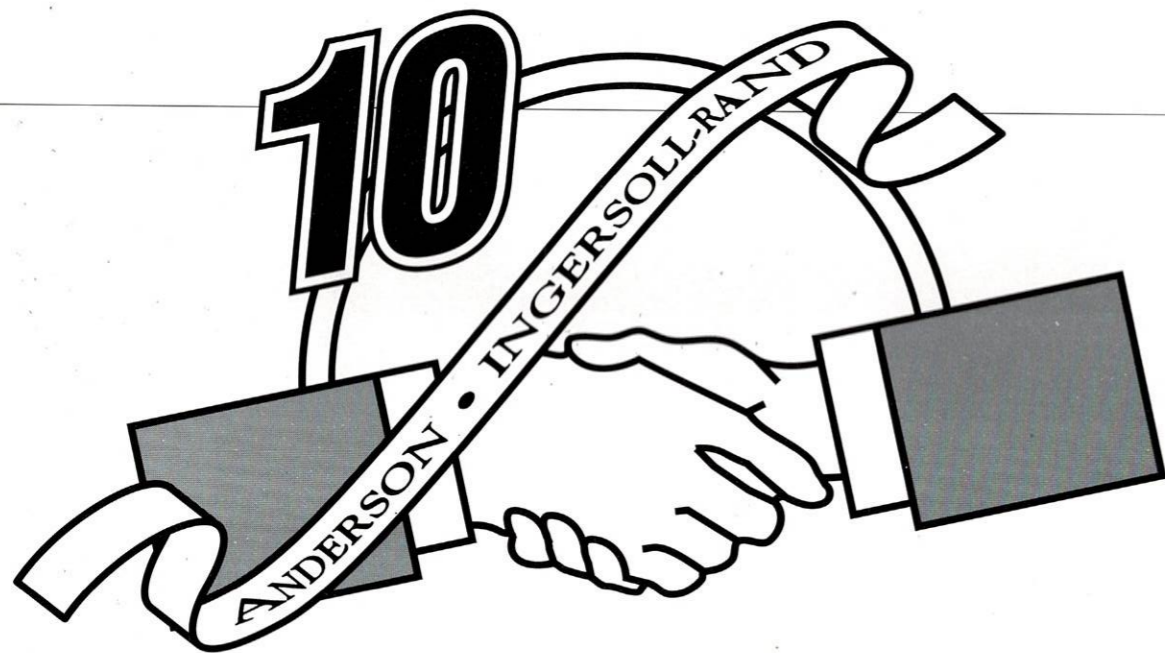
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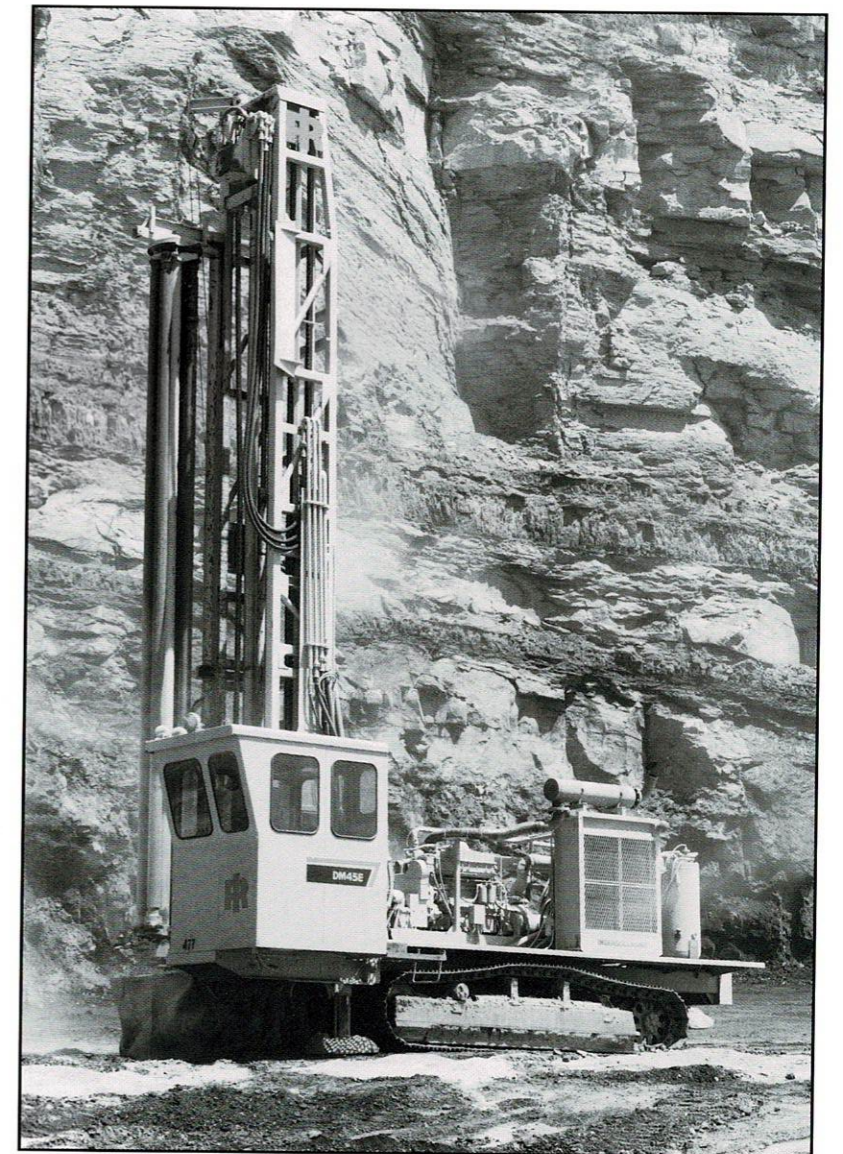
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Buffalo Coal's award winning wetlands construction project., adjacent to Blackwater Falls State Park.

Buffalo Coal hosts 'Horseshoe campers'

Buffalo Coal Co., always a popular "tourist attraction" within the West Virginia coal industry, brought more than one hundred students from around the state to its Tucker County operations late this spring for a practical demonstration of how the industry works.

The students were at nearby Camp Horseshoe for the week at a Youth in Government "Free Enterprise Camp" sponsored by the West Virginia-Ohio YMCA organization.

For the past three years, Buffalo Coal has generously offered to interrupt its operations long enough to demonstrate state-of-the-art mining and reclamation. Buffalo has won numerous awards for both reclamation and safety and is generally regarded as a model mining operation.

Mining successfully in the very shadow of Blackwater Falls State Park, Buffalo is a popular stop with all sorts of groups interested in mining tours.

"There is a certain amount of disruption when we have visitors," concedes company President Don Cussins. "But, I think it's important that people find out what's going on with the mining industry and showing them firsthand is the best way to do that. We're especially gratified to have young people out here, and this particular group is a real pleasure because they are bright, inquisitive and well behaved."

Campers got a good look at Buffalo's award winning wetland construction project, saw a bulldozer up close and personal, visited fly ash disposal reclamation, witnessed a blasting procedure and toured the company's modern preparation plant.

At midday, Kingsford Charcoal grilled lunch for all, preceded by an historical lecture on the area by Buffalo Vice President Steve Shaffer and a question and answer session on the coal industry.



WVMRA's Ben Greene joins Don Cussins and Steve Shaffer of Buffalo Coal Co. (background l-r) for a field lecture and q & a session.



Students got "hands on" experience with a Buffalo bulldozer.



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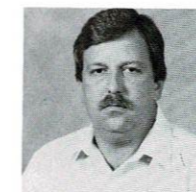


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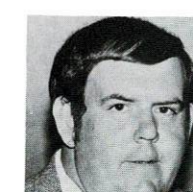
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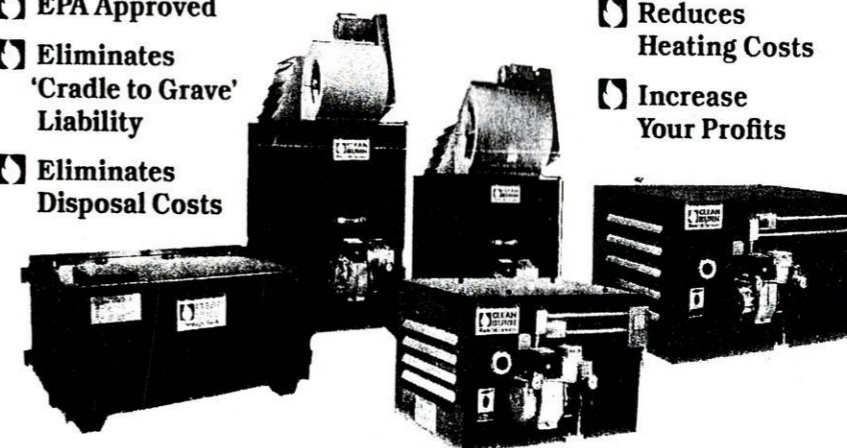


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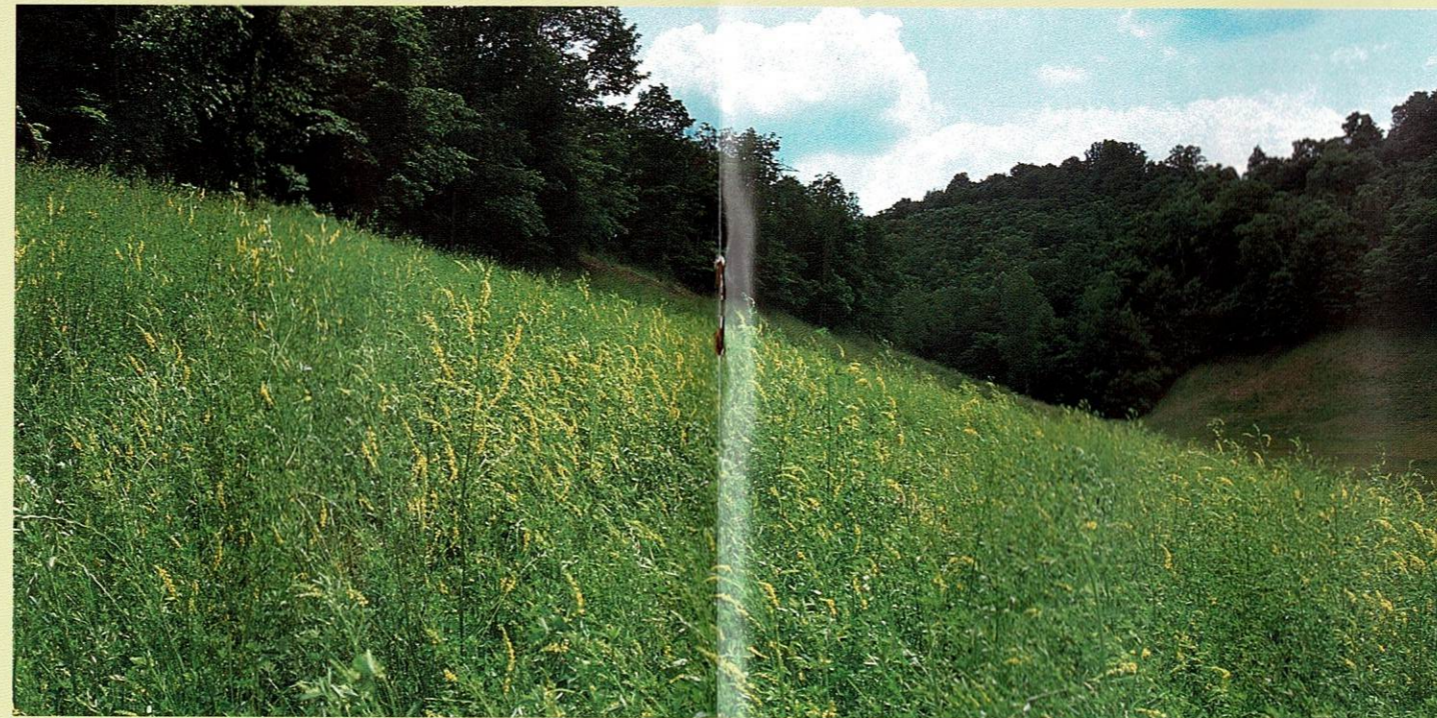
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Their effort was part of the Federal Abandoned Mine Lands program

that will pump over \$350 million dollars into West Virginia's economy. This means jobs while improving the environment.

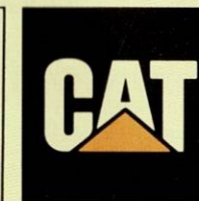
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Earth Day '93

Beckley students boost state tree population



Bob Monarchy of Petroleum Products, Inc. assisted members of the Woodrow Wilson H.S. Conservation Club in their tree planting efforts.



Smokey the Bear paid a visit to Red Warrior Mine as part of Catenary Coal's Earth Day celebration.

The Conservation Club of Woodrow Wilson High School in Beckley is into trees. Not literally, of course.

They've just taken it upon themselves to make an impact on West Virginia's woody population.

In January, led by Bob Monarchy of Petroleum Products, Inc., four members of the Club braved winter winds and frozen ground to initiate an experimental planting of chestnuts, walnuts, hickory nuts and acorns on Elk Run Coal Co.'s Black Castle Surface Mine in Boone County.

In preparation for the experiment, the Club gathered nuts and stored them until they germinated. Members will now monitor the Elk Run site over the next several years. If successful, the planting will result in a valuable food source for wildlife.

This spring, under more congenial conditions, the Conservation Club returned to the field, this time helping Catenary Coal Co. celebrate Earth Day '93 at its Red Warrior Mine near Leewood. by planting 1500 white pine, Siberian crab apple, black walnut, Chinese chestnut, chestnut oak and chingapin seedlings.

Petroleum Products, Inc. purchased the trees on behalf of the Conservation Club. The actual planting was done by employees and families of Red Warrior, Petroleum Products and members of the Kincaid 4-H Club joined the Woodrow Wilson students for the planting session.

Red Warrior Engineer Rick Morgan designed a grid pattern for the project to correspond with the company's overall reclamation plan. Project Coordinator Frank Robinette arranged for flags to mark tree planting locations.

The trees were arranged in patterns to allow for wildlife feeding areas, staging areas and cover. Chestnut, crab apple and chestnut oak trees were planted on benches and slopes affording the greatest potential for growth. Pines were arranged near the top of the slope for cover and wind breaks and on benches with average soil conditions.

According to Club President Keri Monarchy, "Our main objective in planting trees is the prevention of soil erosion, but, with the help of the host companies, the planting is done in a manner that will be helpful in promoting wildlife habitat."



As part of its Earth Day '93 celebration, Arch of West Virginia conducted public tours of its Ruffner operation.



Arch hosted hundreds of employee family members as well as the local community with its open house, complete with food and entertainment

Earth Day at Arch of WV

Arch of West Virginia goes all out for Earth Day, opening its operations to the public, serving lunch to all comers and even sweetening the pot with door prizes.

Employees manned the gates at the Ruffner job near Yolyn, passing out information packets and directing fishermen to well stocked sediment ponds on the property.

On top of the hill, a huge tent was erected to provide relief from the spring sun, a picnic place and a venue for Earth Day entertainment, as well as brief remarks by company officials and the presentation of a wide array of gifts and prizes.

Through its efforts on May 8, Arch demonstrated that "Every Day is Earth Day for West Virginia miners."



"Callaghan Award" winner Mingo Logan Coal Co. has brought further honor to West Virginia's industry, winning a national "Excellence in Mining" award..

Mingo Logan wins national award

Mingo Logan Coal Co. of Wharncliffe, Mingo County, has become the first West Virginia operation to win the national "Excellence in Mining" award. Mingo Logan, a two-time winner of the "Callaghan Award" as West Virginia's best overall operation, was recognized in the national program for "innovative design of a preparation plant."

The awards are sponsored by the federal Office of Surface Mining Reclamation and Enforcement. Judging is done first at the state level, then by a national panel of experts from OSM, the U. S. Bureau of Mines and the U.S. Geological Survey.

R & F Coal Co.'s Hart Mine in Ohio won the Director's Award as the nation's outstanding operation. Other winners were from Illinois, Indiana, Kentucky, Montana, North Dakota, and Texas.

Acting OSM Director W. Hord Tipton presented the awards at the National Coal Association's Annual Meeting at The Greenbrier in White Sulphur Springs, WV.

Mingo Logan's Award Citation

Mingo Logan Coal Company, Black Bear Preparation Plant, Wharncliffe, West Virginia, selected by the West Virginia Division of Environmental Protection, for innovative design of a preparation plant. Located in steep Appalachian terrain, the preparation plant was constructed within a box-cut on a multi-seam contour mine. A complex network of roadways and drainage channels was constructed to control runoff and carry it to ponds. Main access to the site required a specially designed valley fill. A unique road was constructed down the face of the fill. Each section of the road goes down and across the face of each lift, with drainage diverted into side ditches.

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Special Chemicals for Treating Acid Mine Drainage

By Jeff Skousen, Ron Lilly and Tiff Hilton

Introduction

In 1990, a paper was published in *Green Lands* entitled "Acid Mine Drainage Treatment Systems: Chemicals and Costs" (Skousen et al., 1990). In that paper we described four commonly-used chemicals in neutralizing acid mine drainage (AMD). Hydrated lime (calcium hydroxide), soda ash briquettes (sodium carbonate), caustic soda (sodium hydroxide), and ammonia (anhydrous ammonia) were related to situations, both in terms of water flow and metal composition, where they were best suited. Costs for each chemical treatment system were broken down into equipment installation, repair, and salvage costs, along with annual chemical reagent costs over four AMD flow and acid concentration cases. These tables were recently updated with 1992 costs and projected over 5- and 20-year operation periods (Fletcher, Phipps and Skousen, 1992).

As shown in Table 1, caustic had the lowest annualized costs during the 5-year time period for the low flow (50 gpm) and low acidity (100 mg/l acidity) situation, even though it had the highest reagent cost. Ammonia had the next lowest annualized costs, soda ash was third because of its high labor and reagent costs, and hydrated lime was fourth because of its high installation costs. In the intermediate flow and acidity cases, ammonia became the most cost effective, with hydrated lime second. Soda ash and caustic soda were the most expensive alternatives for all but the low flow and acidity case. In the highest flow and acidity category, hydrated lime was clearly the least costly treatment system, with an annualized cost \$230,000 less than ammonia, the next best alternative.

Over a 20-year operation period (Table 2), caustic soda and ammonia were still the least expensive choices for the low flow and acidity situation, and hydrated lime was still clearly the least expensive alternative for the high flow and acidity condition. Ammonia, as in the 5-year budgets, was the cheapest treatment system for the intermediate flow and acidity conditions and was second for the highest flow and acidity combination.

Special AMD Treatment Methods

Since AMD treatment began, most companies simply used one of the above chemical treatment systems for acid neutralization and metal precipitation. Raising the pH of the water usually caused precipitation of the metals and if the metals did not precipitate adequately to meet effluent limits, more chemical was added.

While the same four acid neutralization chemical treatment systems are still predominately used by the coal industry, several other chemicals have become available during the past five years (Table 3). Limestone was found to successfully treat AMD in anaerobic (oxygen-free) environments such as anoxic limestone drains where the limestone does not armor with metal hydroxide deposits. (Faulkner and Skousen, 1993; Skousen, 1991). Pebble quick lime (calcium oxide) has been recently used in conjunction with the Aquafix Water Treatment System utilizing a water wheel concept (Jenkins and Skousen, 1993).

Several operators have used potassium hydroxide, magnesium hydroxide, and magna lime with good success. These products behave similarly to the calcium-type products and their use depends on the price. Ammonia is used in many locations in West Virginia with good success and cost savings. Some problems and cautions associated with its use were outlined in Faulkner and Skousen (1991). Trapzene has been tried at several AMD treatment sites (Lilly and Ziemkiewicz, 1992). Trapzene is a calcium peroxide material which oxidizes the water as well as neutralizes the acidity. Kiln dust and fly ash have been used less often because of impurities in each material which creates more sludge.

Today's AMD treatment situations often require more than one chemical or system in order to find the most cost effective method, and in order to meet more stringent effluent limits. Some sites have an array of hoses and valves connected to drums and tanks with several chemical products being dispensed (Figure 1).



Figure 1. Sometimes several chemicals are necessary for suitable treatment of AMD. This site required the addition of an acid neutralizing reagent and also a flocculant to aid in precipitation of the metals.

Numerous products are available for water treatment and the selection of the appropriate product, its specific role or function, and its cost should be considered carefully.

Metal Sludge Precipitation

Once metal sludges are formed by the addition of alkaline reagents, adequate retention time in a settling basin is necessary for metal hydroxide precipitation. In areas where water retention time in a pond is insufficient due to high flow or pond size constraints, a variety of chemicals (coagulants, flocculants and oxidants) are available to improve the settling efficiency of metal flocs in retention ponds.

Coagulation and Flocculation

Coagulation and flocculation are terms that refer to two different processes to facilitate colloid settling in water. Coagulation reduces the net electrical repulsive forces at particle surfaces, thereby promoting consolidation of small particles into larger particles. These larger particles are then able to settle.

Flocculation aggregates or combines small particles by bridging the space between particles with chemicals. Bridging occurs when segments of a polymer chain adsorb suspended particles causing larger particles. Both processes result in the formation of larger particles which promote precipitation (Figure 2).

Aluminum sulfate (alum) is the standard coagulant used in water treatment. It reacts with alkalinity in the water to form aluminum hydroxide flocs which attract other metals for precipitation. Ferrous sulfate also reacts with alkalinity but is slower reacting than alum. Ferric sulfate coagulates

particles over a larger pH range than ferrous sulfate and the precipitate is a heavy, quick-settling floc. Ferric chloride is more frequently used as an oxidant but reacts similarly as ferrous sulfate. Sodium aluminate is alkaline instead of acidic like the other coagulants. The limited use of sodium aluminate is due to its high cost.

Activated silica has been used as a flocculant since the 1930's to strengthen flocs and to reduce the potential of deterioration. The resulting floc with silica is larger, denser, faster-settling, and more stable. Clays and metal hydroxides are also called weighing agents so when added to water they add bulk to the water enhancing floc formation.

Naturant flocculants are used only in specialized situations. They are expensive and usually used when specific water parameters or effluent limits must be met. They have not been used in AMD treatment situations to this date.

Synthetic flocculants are a recent and popular addition to the field of water treatment. These flocculants are also sometimes called polyelectrolytes and are extremely large molecules that, when dissolved in water, produce highly-charged ions. Anionic polymers dissolve to form negatively-charged ions, and are used to remove positively-charged solids. The reverse occurs with cationic flocculants. Nonionic polymers or polyampholytes are neutral but when dissolved in water release both positively- and negatively-charged ions. Compared with other mineral and natural flocculants, the synthetic polymers are needed in much smaller quantities. Synthetic flocculants may be added to water as a liquid, or more commonly, placed in water as a solid ("floc" logs).

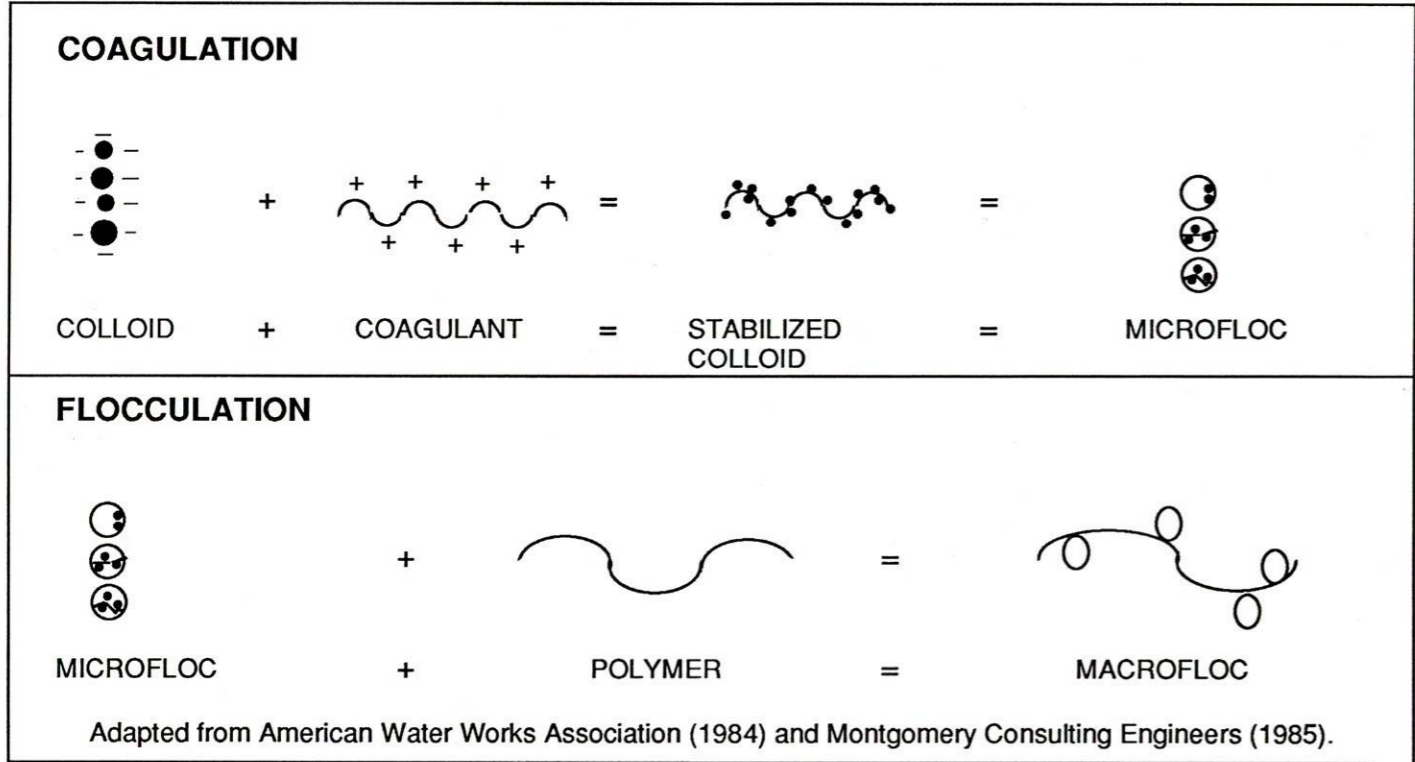


Figure 2. Coagulation is the process of reducing the net electrical repulsive forces at particle surfaces causing consolidation into larger particles. Flocculation is the process of bridging small particles into larger particles. Both processes promote larger particle formation to enhance settling efficiency.

Figure 3. Ultrion is a product that oxidizes metals and also promotes coagulation of particles for settling.



Oxidants

Aeration is the process of introducing air into water. Oxidation occurs when oxygen in air combines with metals in the water. Once oxidized, substances such as iron and manganese come out of solution and precipitate at neutral pH (7 to 8) versus higher water pH (9 to 12) when oxidation levels are lower. For this reason, oxidation is a major limiting factor in the efficiency of many AMD treatment systems. In most cases, chemical treatment costs could be reduced substantially if aeration and oxidation were incorporated or improved in the treatment system.

Oxidants aid in the completion of the oxidation process to enhance metal hydroxide precipitation and reduce sludge volume. Oxygen can be used as an oxidant but we are unaware of anyone actually bubbling oxygen into AMD. More commonly, the hypochlorite products and hydrogen peroxide are used and have demonstrated very effective oxidation. Potassium permanganate is also an effective oxidant and used on many sites where extra oxidation is needed. Ultrion oxidizes metals and speeds up coagulation of metal hydroxides (Figure 3).

Case Studies

Case #1 - A mine in northern West Virginia originally used only anhydrous ammonia for acid neutralization and metal precipitation. The water being treated has a flow of 125 to 400 gpm, 2.5 pH, 4,000 mg/l acidity, and 3,200 mg/l iron. Using only anhydrous, the cost of water treatment averaged \$12,000 per month. Also the ponds had to be pumped and cleaned 5 days a week.

The company later decided to use anhydrous and hydrogen peroxide together. Currently, the total cost of both chemicals is \$11,000 per month and the ponds are only pumped 2 or 3 days per week. Using both chemicals reduced overall chemical usage, and pond cleaning frequency and associated labor costs were decreased (cost estimates are not available for sludge removal). The metal flocs currently produced with both products precipitate faster and are denser. Dissolved iron (reduced Fe) is less than 3 mg/l after peroxide treatment.

Case #2 - A sealed deep mine in southern West Virginia produces a drainage of 200 to 500 gpm, 6.5 pH, no acidity, and 30 to 50 mg/l iron in the ferric form. Raising the pH to higher levels had little effect on ferric iron precipitation and pond retention time was insufficient for the iron to precipitate on its own. A coagulant and flocculant mixture was selected (NALCO's 7883 (Ultrion) or Stockhausen's 190 coagulant along with NALCO's 8877 or Stockhausen's 262 flocculant) in order to meet the iron effluent limitation.

A cost evaluation showed that ferrous iron treated by acid neutralization chemicals vs ferric iron treated by coagulants/flocculants were almost equivalent (with costs of ammonia at \$.28/lb. and 20% sodium hydroxide at \$.50/gal). A positive aspect with regard to the coagulant/flocculant treatment was a reduction in sludge volume. Conversely, higher costs were associated with increased labor for mixing two products and maintaining chemicals during winter.

Summary

As can be seen from Tables 3 and 4, many chemicals are available for treatment of AMD. Bench testing in a laboratory will indicate the level of treatment that a certain chemical may induce on a specific AMD. The Jar Test is also an effective way of determining the right chemical or combination of chemicals which will treat the water and settle the flocs. Jar tests can be done very simply with quart canning jars and stirring devices. Experiments may be conducted to determine the effectiveness of various acid neutralizers and coagulants/flocculants, optimum dosage for precipitation, optimum pH for floc generation, and the most effective order in which to add various chemicals. However, a field trial is recommended to demonstrate treatment during real conditions. A product may look expensive on paper but it may be diluted in the field or modified by physical application to enhance treatment and greatly reduce costs associated with water treatment.

Contacts

American Cyanamid (CYTEC)	304-744-3454
Dubois Chemical Co.	800-438-2647
Dupont Chemical Co.	919-282-9772
Envirotech	304-855-4437
FMC Corp.	800-523-5005
MineTek, Inc.	304-253-2923
Nalco Chemical Co.	304-768-7388
Stockhausen Chemical Co.	800-768-7388

Acknowledgements

This paper is a contribution from West Virginia University National Mine Land Reclamation Center through Project WV-10, and also from the WVU Cooperative Extension Service.

Table 1. Costs of alternative technologies to treat acid mine drainage in West Virginia, 5-year operation period.

Flow and Acidity Conditions		50	1000	250	1000
Flow (gpm)		100	100	500	2500
Acidity (mg/l)					
Chemical					
Soda Ash					
reagent costs	\$ 3,248	\$64,955	\$ 81,194	\$1,623,876	
repair costs	0	0	0	0	
annual labor	14,040	14,040	14,040	14,040	
installation costs	229	229	229	229	
salvage value	0	0	0	0	
NPV	73,051	332,985	401,3886,	899,728	
Annualized cost	\$ 17,343	\$ 79,049	\$ 95,288	\$1,637,971	
Ammonia					
reagent costs	\$ 1,116	\$ 22,323	\$ 27,904	\$ 558,071	
repair costs	495	495	495	495	
tank rental	480	1,200	1,200	1,200	
annual labor	7,020	7,020	7,020	7,020	
electricity	600	600	600	600	
installation costs	5,936	6,357	6,357	6,357	
salvage value	0	0	0	0	
NPV	46,843	139,627	163,135	2,396,392	
Annualized cost	\$ 11,120	\$ 33,147	\$ 38,728	\$ 568,895	
Caustic Soda					
reagent costs	\$ 3,852	\$ 77,036	\$ 96,295	\$1,925,891	
repair costs	0	0	0	0	
annual labor	7,020	7,020	7,020	7,020	
installation costs	283	5,478	5,478	5,478	
salvage value	0	0	0	0	
NPV	46,079	359,551	440,676	8,147,602	
Annualized cost	\$ 10,939	\$ 85,356	\$104,615	\$1,934,211	
Hydrated Lime					
reagent costs	\$ 526	\$ 10,527	\$ 13,158	\$ 263,169	
repair costs	1,000	3,100	3,500	10,500	
annual labor	6,500	11,232	11,232	11,232	
electricity	3,500	11,000	11,000	11,000	
installation costs	38,400	102,000	106,000	204,000	
salvage value	5,750	6,500	7,500	25,000	
NPV	82,656	248,193	264,216	1,431,760	
Annualized cost	\$ 19,622	\$ 58,920	\$ 62,724	\$ 339,895	

Table 2. Costs of alternative technologies to treat acid mine drainage in West Virginia, 20-year operation period.

Flow and Acidity Conditions		50	1000	250	1000
Flow (gpm)		100	100	500	2500
Acidity (mg/l)					
Chemical					
Soda Ash					
reagent costs	\$ 3,248	\$ 64,955	\$ 81,194	\$1,623,876	
repair costs	0	0	0	0	
annual labor	14,040	14,040	14,040	14,040	
installation costs	229	229	229	229	
salvage value	0	0	0	0	
NPV	198,518	906,296	1,092,553	18,787,000	
Annualized cost	\$ 17,308	\$ 79,015	\$ 95,254	\$1,637,936	
Ammonia					
reagent costs	\$ 1,116	\$ 22,323	\$ 27,904	\$ 558,071	
repair costs	495	495	495	495	
tank rental	480	1,200	1,200	1,200	
annual labor	7,020	7,020	7,020	7,020	
electricity	600	600	600	600	
installation costs	5,936	6,357	6,357	6,357	
salvage value	0	0	0	0	
NPV	119,397	371,316	435,326	6,516,302	
Annualized cost	\$ 10,410	\$ 32,373	\$ 37,954	\$ 568,121	
Caustic Soda					
reagent costs	\$ 3,852	\$ 77,036	\$ 96,295	\$1,925,891	
repair costs	0	0	0	0	
annual labor	7,020	7,020	7,020	7,020	
installation costs	283	5,478	5,478	5,478	
salvage value	0	0	0	0	
NPV	124,981	969,590	1,190,488	22,175,851	
Annualized cost	\$ 10,896	\$ 84,533	\$103,792	\$1,933,389	
Hydrated Lime					
reagent costs	\$ 526	\$ 10,527	\$ 13,158	\$ 263,169	
repair costs	1,000	3,100	3,500	10,500	
annual labor	6,500	11,232	11,232	11,232	
electricity	3,500	11,000	11,000	11,000	
installation costs	38,400	102,000	106,000	204,000	
salvage value	0	0	0	0	
NPV	170,606	513,297	552,070	3,597,957	
Annualized cost	\$ 14,874	\$ 44,752	\$ 48,132	\$ 313,686	

Table 3. Chemicals for acid neutralization and chemicals used for coagulation, flocculation, and oxidation.

NAME	CHEMICAL FORMULA	COMMENTS
Acid Neutralization		
Limestone	CaCO ₃	Used in anaerobic situations (anoxic limestone drains).
Hydrated Lime	Ca(OH) ₂	Requires extensive mixing.
Pebble Quick Lime	CaO	Very reactive, needs metering equipment.
Soda Ash Briquettes	Na ₂ CO ₃	System for remote locations.
Caustic Soda	NaOH	Very soluble, comes as a solid in drums or briquettes, or as a 20% or 50% liquid.
Potassium Hydroxide	KOH	Similar to caustic.
Magnesium Hydroxide	Mg(OH) ₂	Similar to hydrated lime.
Magna Lime	MgO	Similar to Pebble lime.
Ammonia	NH ₃ or NH ₄ OH	Very reactive and soluble. Can be also purchased as aqua ammonia.
Trapzene	CaO ₂	Used as a neutralizer and oxidant. Available as a powder or as briquettes.
Kiln Dust	CaO, Ca(OH) ₂	Waste product of limestone industry. Active ingredient is CaO with various amounts of other constituents.
Fly Ash	CaCO ₃ , Ca(OH) ₂	Neutralization value varies with each product.
Coagulants		
Alum (aluminum sulfate)	Al ₂ (SO ₄) ₃	Acidic, forms Al(OH) ₃ .
Copperas (ferrous sulfate)	FeSO ₄	Acidic, usually slower reacting than alum.
Ferric Sulfate	Fe ₂ (SO ₄) ₃	Ferric products react faster than ferrous.
Ferric Chloride*	FeCl ₃	Also used as an oxidant.
Sodium Aluminate	NaAlO ₂	Alkaline coagulant.
*Other coagulants are magnesium chloride, aluminum chloride, calcium chloride. These chloride compounds are also oxidants.		
Flocculants		
Mineral Flocculants		
- Activated Silica	Na ₄ SiO ₄	A negative charge on surface. Attracts cations and metal hydroxides.
- Clays	bentonite	Negatively-charged surface.
- Metal Hydroxides	Al(OH) _x , Fe(OH) _x	Usually a positively-charged surface.
Natural Flocculants		
- Starch Derivatives	corn starches	Gelatinous materials.
- Polysaccharides	Guar gums	Sticky substances.
- Sodium Alginates	C ₆ H ₇ O ₆ Na	Food thickeners.
Synthetic Flocculants		
- Anionic		Negatively-charged surface.
- Cationic		Positively-charged surface.
- Polyampholytes		Have both positive and negative charges on surface based on pH.
Oxidants		
Oxygen	O ₂	The ultimate oxidant.
Chlorine Compounds	Cl ₂	
- Calcium Hypochlorite	Ca(ClO) ₂	Strong oxidant.
- Sodium Hypochlorite	NaClO	Strong oxidant.
- Calcium Chloride	CaCl ₂	Also a coagulant.
- Sodium Chloride	NaCl	Rock salt.
- Ferric Chloride	FeCl ₂	Also a coagulant.
Peroxide Materials		
- Calcium Peroxide	CaO ₂	Trapzene, an acid neutralizer.
- Hydrogen Peroxide	H ₂ O ₂	Strong oxidant.
Potassium permanganate	KMnO ₄	Very effective, commonly used.

Table 4. Some brand name chemical products with their classification used in AMD treatment.

	Name	Classification	Comments
NALCO	Ultrion (7883)	Oxidizer/Coagulant	Settles clays/solids.
	7884, 7885, 8887	Flocculants	Settles metal flocs.
	7886	Neutralizer/Coagulant	Applied to alkaline water with Fe
Stockhausen	CM-190, CM-191	Oxidizer/Coagulant	Settles metal flocs.
	CM-196	Flocculant	Settles flocs and clays.
MineTek	Gelfloc	Flocculant	Log-type, settles floc and solids.
DuBois	Mine Guard 200	Neutralizer	NaOH and KOH, freezeproof.
	Coagulite 200, 222, 300	Coagulants	Settles solids.
	Floculite 551, 552	Flocculants	Anionic, settles flocs.
American Cyamamid	1203, 1206	Flocculants	Anionic, settles flocs.
FMC	Calcium peroxide	Oxidant/Neutralizer	Removes metals.
FMC and DuPont	Hydrogen peroxide	Oxidant	
	Calcium/Sodium Hypochlorite	Oxidant	
	Calcium/Ferric/Sodium Chloride	Oxidant/Coagulant	
	Potassium Permanganate	Oxidant	

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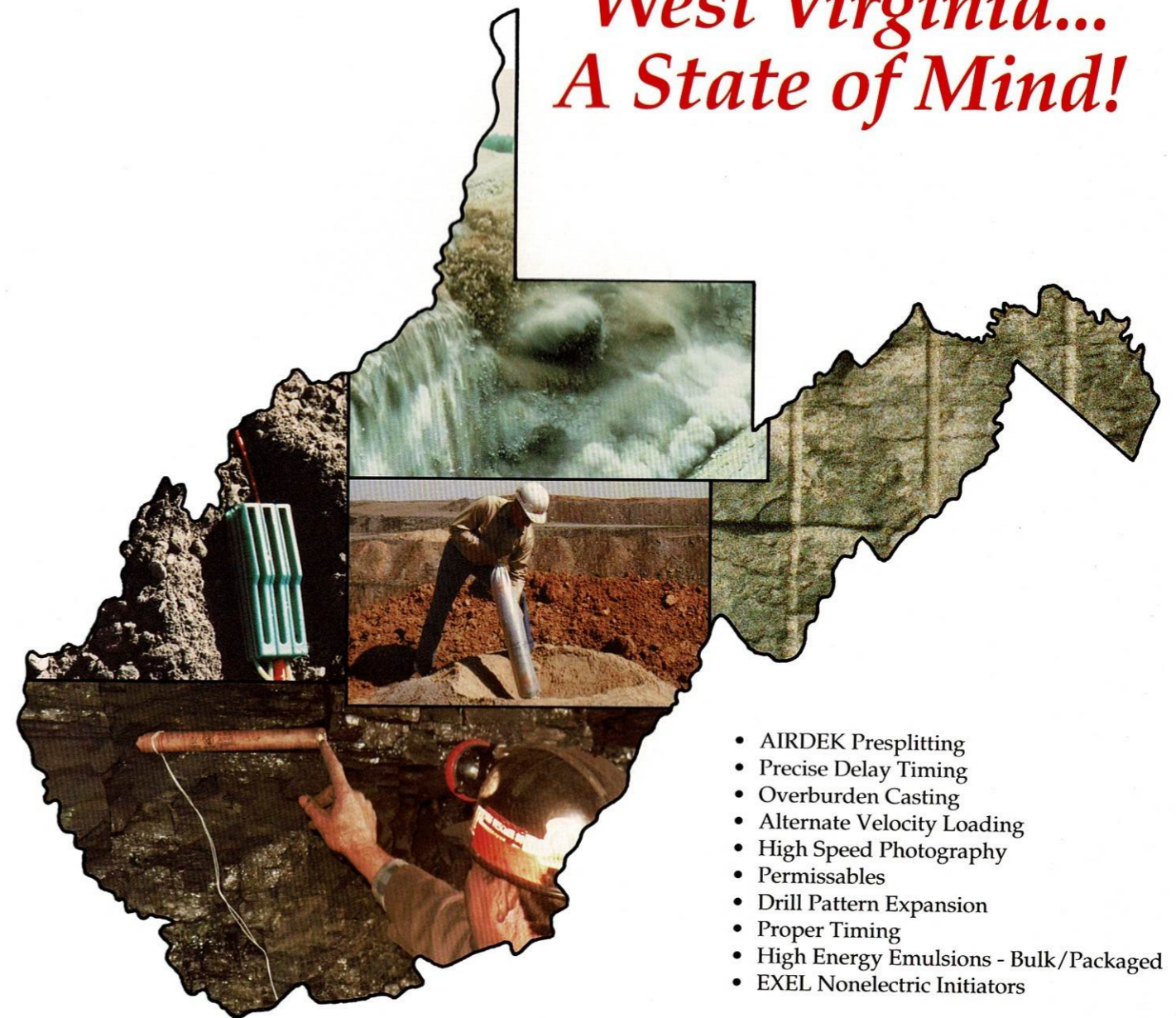
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