HIGH-EXTRACTION MINING, SUBSIDENCE, AND VIRGINIA'S WATER RESOURCES

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Preface and Acknowledgements

The Virginia Center for Coal and Energy Research was established in 1977 as an "interdisciplinary study, research, information and resource facility for the Commonwealth." As a public service research organization, the Center's mission is to research and provide information on coal and energy issues of public interest.

It was with this mission in mind that we initiated this project to explore the technical, regulatory, and legal issues concerning mine subsidence and water resources in Virginia. Because of the sensitive nature of this subject to the coal industry, citizens' and environmental groups, and state agencies and policy makers, we have undertaken a deliberate and lengthy process of research, draft reports, and circulation for review and comment. The research was initiated in May 1988. The original draft was prepared in May 1989 and circulated to state agency representatives and coal companies. Extensive comments were received over the next several months and a second rewritten draft was circulated for wider review in October 1989. Once again, lengthy comments were received, prompting further research which was incorporated into this final report.

It has been our intent in this study to provide the most balanced review possible of a most complex and sensitive subject. We sincerely hope that we have achieved that objective and that this report will contribute to further discussions and research on mine subsidence and water resources in Virginia.

We would like to gratefully acknowledge the individuals who gave of their time in interviews for the project research and those who painstakingly reviewed and commented on previous drafts. Their participation should not be construed as endorsement or concurrence with the interpretations or conclusions of this report. The authors alone are responsible for the views expressed as well as any errors contained herein.

Interviewees (additional information provided in bibliography)

- John A. Arway, Division of Fisheries Environmental Services, Pennsylvania Fish Commission.
- William H. Bledsoe, Virginia Division of Mined Land Reclamation.
- Dennis Boyles, U.S. Office of Surface Mining Reclamation and Enforcement.
- Fletcher Cooke, Attorney, Pittston Coal Group.
- Tom Galloway, Attorney, Galloway and Greenberg.
- Gerald Gray, Attorney.
- Tom Harrell, U.S. Office of Surface Mining Reclamation and Enforcement.
- Lynn Haynes, Technical Services Division, Virginia Division of Mined Land Reclamation.
- William Henika, Virginia Division of Mineral Resources.
- Jack Holbrook, Anthracite Reclamation Programs Branch, U.S. Office of Surface Mining Reclamation and Enforcement.
- Frank Jernejcic, West Virginia Department of Natural Resources.
- John Kernig, Pennsylvania Bureau of Mining and Reclamation.
- Gary LeCain, U.S. Geological Survey.
- Jay Lehr, Executive Director, National Water Well Association.
- Eugene Mathis, Pittston Coal Group, Inc.
- Jim McElfish, Attorney, Environmental Law Institute.
- Judy McKinney, Dickenson County Concerned Citizens.
- Harry Payne, Division of Reclamation, Ohio Department of Natural Resources.

- Anthony Scales, Technical Services Division, Virginia Division of Mined Land Reclamation.
- Mark Scott, West Virginia Department of Energy.
- Conrad T. Spangler, Chief Engineer, Virginia Division of Mined Land Reclamation.
- Don Stump, Office of Surface Mining Reclamation and Enforcement.
- Tim Sullivan, Kentucky Department of Surface Mining Reclamation and Enforcement.
- Richard Swisshelm, U.S. Geological Survey.
- David Whitehurst, Virginia Department of Game and Inland Fisheries.
- Dermot Winters, U.S. Office of Surface Mining Reclamation and Enforcement.

Reviewers

- Steven G. Breeding, Assistant to the General Manager, Community Relations, Island Creek Corporation, Oakwood, Virginia.
- Richard S. DiPretoro, Geologist, Morgantown, West Virginia.
- Eustace Frederick, Vice President, Consolidation Coal Company, Bluefield, Virginia.
- Gary R. Hooper, Vice Provost for Research and Graduate Studies, Virginia Tech.
- Michael E. Karmis, Professor and Head, Mining and Minerals Engineering, Virginia Tech.
- James M. McElfish, Jr., Environmental Law Institute, Washington, D.C.
- Claude D. Morgan, P.E., Regional Manager - Engineering and Environmental Affairs, Consolidation Coal Company, Bluefield, Virginia.
- Ken Price, General Manager, Virginia Division, Island Creek Corporation.
- Henry W. Rauch, Department of Geology and Geography, West Virginia University, Morgantown.
- Gary Slagel, Director, Environmental Regulatory Activities, Consolidation Coal Company, Pittsburgh, Pennsylvania.
- Ernest R. Stout, Associate Provost for Research, Virginia Tech.
- Virginia Department of Mines, Minerals, and Energy.
- Virginia Division of Mined Land Reclamation.

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Chapter 1: Introduction

Underground coal mining is viewed by many as being preferable to surface mining in terms of its disruption of the environment and of coalfield communities. Certainly the impacts of unregulated surface mining can be serious. The effects of surface mining in some Appalachian states were a major impetus to the passage, in 1977, of national environmental legislation to control the effects of coal mining. Virginia, therefore, can be considered fortunate in that most of the state's coal reserves are only minable through underground methods. Nonetheless, underground mining is not without environmental impacts. One of them is subsidence.

Although recent debate in Virginia, summarized in this chapter, has centered on the effects of longwall mining, subsidence results from other underground mining technologies as well. Longwall mining and pillar-extraction mining (sometimes called pillar-retreat mining) together comprise high-extraction mining, in which more than 50 percent of the coal is removed from a seam. The higher the percent of coal removed, the more likely is subsidence to occur. This report considers the effects and regulation of subsidence from all high-extraction mining. Much, but not all, of the research reviewed concerning both subsidence and the hydrologic effects of subsidence focuses on longwall mining, perhaps because of the more rapid, complete, and predictable nature of subsidence over longwall mines. Thus, considerably more is known about longwall subsidence than about subsidence over pillar-extraction mines in which some supporting coal is left. In this report, we have approached subsidence from both technologies for the most part as essentially similar. We note possible and demonstrated differences where appropriate throughout the report.

Controversies over subsidence and its impacts are not limited to Virginia. The title of a recent conference on subsidence reflects the industry's perspective: *An Industry Under Seige: Some Facts About Subsidence.*[1] According to Gerald T. McPhee, Director of Governmental Relations for Island Creek Corporation, legislation or regulatory revisions aimed at longwall mining have been proposed in four of the 11 states in which longwalls are operating, and there are organized anti-longwall groups in 3 of the states.[2]

Environmental impacts of coal mining, including subsidence, are regulated in Virginia by the Department of Mines, Minerals and Energy, Division of Mined Land Reclamation (DMLR), under the provisions of the Virginia Coal Surface Mining Control and Reclamation Act of 1979 (VCSMCRA). VCSMCRA was passed and the Virginia program was implemented in order for the state to take over responsibility for coal mining regulation from the federal government. The U.S. Surface Mining Control and Reclamation Act of 1977 provides for nationally uniform controls over the environmental effects of coal mining, but allows states to take over responsibility for regulation, with federal oversight and review.

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[1] Co-sponsored by the American Mining Congress and the West Virginia Coal Association in Charleston, West Virginia, April 5-6, 1989. That it attracted nearly 200 industry and nonindustry attendees illustrates the level of interest and concern in every state in which high extraction mining is practiced.

[2] Presentation on state legislative initiatives at *An Industry Under Seige: Some Facts About Subsidence*, Charleston, West Virginia, April 5, 1989.

High Extraction Mining and Subsidence Issues

Longwall Mining Employment Effects

Longwall mining has made great strides in Virginia in the midst of a retrenchment of the coal mining industry. Virginia's coal mining industry suffered during the past decade from a decline of the U.S. steel industry and rising world export competition. In order to stay competitive, the coal industry has looked to productivity gains made possible by increased mechanization. Longwall mining technology has been one of the most important sources of improved productivity. Yet its contribution to increased labor productivity in Virginia coal mines has been blamed for job loss.[3] Unemployment in Dickenson County, for example, officially averaged 15 percent during 1986 when unemployment in Virginia as a whole was exceptionally low. Furthermore, researchers familiar with employment in the area contend that the methods used to estimate official unemployment rates grossly underestimate the true numbers of unemployed and underemployed workers.[4]

Industry officials deny that longwall mining costs jobs, pointing out that without the technology many of the largest mines could not operate profitably and would be closed. Furthermore, they contend that although there are fewer workers underground in a longwall mine, the technology requires more support personnel than conventional mining methods. Finally, they say that using longwall technology is the only way to mine very deep coal seams with any degree of safety.

It is true that while Virginia production increased from 41.8 to 46.4 million tons from 1986 to 1988, the number of mine workers decreased from 12,525 to 11,096. And in 1988, the ten highest production mines in the state used longwall equipment. These were also the top ten in mine employment with 2,600 workers, or 24 percent of the total number of miners. These miners produced 13.7 million tons or 30 percent of the state total at a productivity of 2.8 tons per worker-hour, 17 percent better than the state average of 2.4 tons per worker-hour. Other things being equal, one could argue from these figures that mines using longwall equipment have contributed to job loss by improving productivity. However, there are other factors in the overall mining employment picture, such as the necessity of competing in a world coal market and the technological limitations on mining certain seams by conventional mining methods, that make it difficult to attribute job loss to productivity gains realized through longwall mining.

Property Damage from Subsidence

Subsidence can damage buildings, septic drainfields, roads, well casings, and other structures located on affected ground. Most coal companies offer compensation for such damages. An issue of concern is the adequacy of compensation being provided by mining companies to affected residents, and the right of mining companies to cause subsidence without permission from surface owners.

Subsidence from both longwall mining and pillar-extraction mining can cause property damages. However, subsidence from longwall mining is predictable and immediate, and it affects relatively large areas, while that from pillar extraction mining is generally less certain and slower to develop. Individual areas undermined by pillar extraction mines are generally smaller than the areas undermined by longwall mines. Pillar-extraction mines are better able to alter mining plans to avoid causing subsidence under individual surface structures. Perhaps for these reasons, the impacts of longwall mining have attracted substantially more public attention in recent years than pillar-extraction mining.

The complaints of property owners affected by subsiidence from longwall mining recently reached Richmond, where the Virginia General Assembly formed the Joint Sub-

[3] Hibbard, Walter R., Jr. *An Abridged History of the Southwest Virginia Coal Industry*. Blacksburg: VCCER, July 1987, p. 37.

[4] Seltzer, Curtis. *Economic Development in Virginia's Coal Counties: Strategies for the Future*. Blacksburg: VCCER, September 1987, pp. 9-12.

committee Studying the Effects of Longwall Mining. At a series of hearings held in the coal counties, the subcommittee heard from property owners whose property was damaged by subsidence; from people living in fear of methane gas explosions, earthquake-like jolts, and "seismic bumps" allegedly caused by active land subsidence; and from some who said their lives have been affected by anxiety over the anticipated loss of their homes. The subcommittee also heard from mining company management, who described the programs for mitigation and compensation that the companies have voluntarily implemented. Some citizens have been satisfied by these programs, but others say they are inadequate.[5]

Environmental Effects of Subsidence

Land subsidence associated with high extraction mining is of environmental concern primarily because of its actual and potential effects on water resources. Beyond lowering surface elevation, damage to the land surface itself is generally limited to formation of fissures and cracks.[6] However, hydrologic effects resulting from mining subsidence may be more serious. Effects observed in some states where high-extraction mining is practiced include "stream capture" through subsidence cracks in streambeds; disturbance of aquifers and contamination of groundwater; well and spring dewatering and degradation; and far-reaching alteration of the hydrologic regime in some watersheds. It should be noted that hydrologic effects of subsidence are site-specific. Thus it is far from certain that the entire range of effects documented in other states will be found in Virginia.

The subsidence impacts of underground mining are regulated under the federal Surface Mining Control and Reclamation Act and implementing state laws and regulations. In Virginia these are the Virginia Coal Surface Mining Control and Reclamation Act and regulations administered by the Division of Mined Land Reclamation. These rules offer certain mechanisms to protect the "hydrologic balance" and certain public water supplies. However, they do not require companies to relace or compensate property owners for disruptions of individual water supplies from underground mining as they do for disruptions from surface mining.

The environmental effects of subsidence, particularly those involving disruption of water supplies, can have serious social impacts. In a U.S. Bureau of Mines study of the short-term effects of longwall mining on shallow water sources, the authors note:

> In rural areas, such as much of the northern Appalachian coal region, the degree of subsidence damage to frame structures generally is not as devastating as even a temporary loss of water sources, especially in farming. While a certain amount of water can be hauled for household use, the requirements for watering farm animals or washing are substantial and heavily dependent on a local supply.[7]

Purpose of Research

The purpose of this research is to investigate the evidence for hydrologic effects of subsidence caused by high extraction mining and to assess the adequacy of current institutional controls for dealing with these mining technologies. There are several reasons for focusing on the hydrologic effects of high extraction mining.

1. If water resources are permanently damaged, the land's ability to support

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[5] The Subcommittee released its report, *Senate Document No. 26*, in January 1989. Only Senator Buchanan signed the report; a dissenting report was filed by three other Subcommittee members, and one member declined to endorse either report. Senator Buchanan, the Subcommittee's chairman, proposed legislation that called for increased monitoring of subsidence effects of high extraction mining techniques, as well as better premining notice for surface owners. However, its provisions merely emphasized what is already provided for in the current regulations under the Virginia Coal Surface Mining Control and Reclamation Act of 1979. The bill died in committee.

[6] Ingram, D. K. *Surface Fracture Development Over Longwall Panels in South-Central West Virginia*. Washington: U.S. Department of the Interior, 1989. Bureau of Mines Report of Investigation, RI-9242.

[7] Moebs, N. N.; Barton, T. M. "Short-term effects of longwall mining on shallow water sources." In: *Mine Subsidence Control*. Proceedings, Bureau of Mines Technology Transfer Seminar, Pittsburgh, September 19, 1985. Washington, D.C.: U.S. Bureau of Mines, IC-9042, 1985, p.14.

future human uses as well as plant and animal life is diminished.

2. Because of the nature of hydrogeology, these are difficult impacts to assess. Our current understanding of hydrogeology and the hydrologic impacts of high extraction mining is relatively primitive compared to what is needed to assess cause and effect relationships with certainty.

3. No known actions by a mining company can "repair" damaged groundwater systems, and there is considerable uncertainty concerning "natural repair" mechanisms.

Research methods

Research focused on two broad areas. The first concerned the technical question of the documented and potential hydrologic effects of high-extraction mining. The second included the institutional controls over the environmental effects of high-extraction mining in Virginia, at the federal level, and in other states. Research methods employed can be grouped accordingly:

Technical Issues

1. Review and analysis of published and unpublished literature in the areas of mining engineering, geology, geohydrology, hydrology, regulatory analysis, and law.

2. Examination of selected DMLR mining permit files and complaint investigations.

3. Interviews with knowledgeable geologists and hydrologists.

Legal/Regulatory Issues

1. Analysis of the U.S. Surface Mining Control and Reclamation Act and federal regulations under that Act; the Virginia Coal Surface Mining Control and Reclamation Act, and the Virginia Permanent Regulatory Program for Surface Coal Mining and Reclamation Operations; and related materials, such as committee hearing reports.

2. Examination and analysis of memoranda and documents of the Division of Mined Land Reclamation (DMLR).

3. Personal interviews with officials of DMLR, the federal Office of Surface Mining Reclamation and Enforcement (OSMRE), and mining regulatory agencies in other states; with environmental officials in Virginia and other states; and with attorneys representing environmental groups, citizens groups, and coal companies.

4. Review of OSMRE annual oversight reports for Virginia and other states.

5. Analysis of court case decisions and common law.

Research was conducted from March, 1988 through April, 1990. Two earlier versions of this report were circulated for comment and revised accordingly. A list of those from whom comments were received is appended.

Chapter 2: High-Extraction Mining

In Virginia most minable coal reserves can only be accessed by underground mining methods, which account for the majority of coal production (Figure 1).

Continuous mining technology accounts for the greater part of underground coal mine production in Virginia. This technology employs a mobile piece of equipment called a "continuous miner," to break coal from the mine face (the exposed part of the coal seam) and move it to a system of conveyers and/or shuttle cars that then transport the coal from the mine. Depending on mine conditions, the mine face is worked in six- to eight-yard increments, at which point the machine is moved so the mine roof can be secured and ventilation extended. Because of the necessity of roof support, a considerable amount of coal (typically 40 percent or more, depending on mine conditions) must be left intact; the resulting mine design is called "room-and-pillar." In a room-and-pillar mine a series of parallel tunnels, called entries, are developed with continuous miners. The entries are then connected by tunnels called cross-cuts. In plan view the resulting pattern of extraction results in a honeycomb-like mine design.

The vast majority of room-and-pillar mining operations in Virginia practice what is variously called pillar-retreat, pillar-extraction, or pillar-recovery mining. When a section is fully developed in a room-and-pillar plan, the blocks of coal (pillars) supporting the roof are "pulled" starting at the far end of the section and working back (retreating) toward the entry. There are numerous methods for recovering the coal in the pillars, all of which result in a higher extraction ratio than conventional room-and-pillar (typically, at least 70% of the coal is removed). As a rule, some degree of roof support must be left in place, so that subsidence may not be uniform or complete. The methods used for pillar recovery and the amount of coal and roof support remaining vary with local mine conditions. Table 1 shows the variety of methods used and the number of Virginia mines using them.

Longwall mining removes all coal from a panel 350-1000 feet wide and from 1000 to 9000 feet long.[8] In Virginia mines, face width varies from 580 to 730 feet. Coal is cut away from the longwall face, which extends across the width of the panel, either by a shearer with rotating cutters or by a plow-like device that is pulled across the face. The cutting device is moved back and forth across the face, removing up to three feet of coal at a pass. The coal is carried away from the face by an armored face conveyor to the head- or tail-entry, where it is emptied onto a stage loader and thence to an entry belt conveyor that takes the coal toward the mine entrance. A series of self-advancing, hydraulic powered supports, lined up side-by-side across the longwall face, provides roof support. As the cutter advances the supports are hydraulically propelled forward, leaving the mine roof behind to collapse.

There are no "pure" longwall mines. A considerable amount of coal must be removed to prepare for the installation and working of a longwall. Continuous miners create the parallel and other entries necessary for coal removal and ventilation. A single underground mine can extend over a very large area; because of coal seam conditions and other factors, some portions may be better suited to room-and-pillar mining, with or without pillar retreat. than to longwall mining.

Longwall mining has some distinct advantages over other mining methods. First, it allows more complete coal extraction from a seam. Second, it provides miners with

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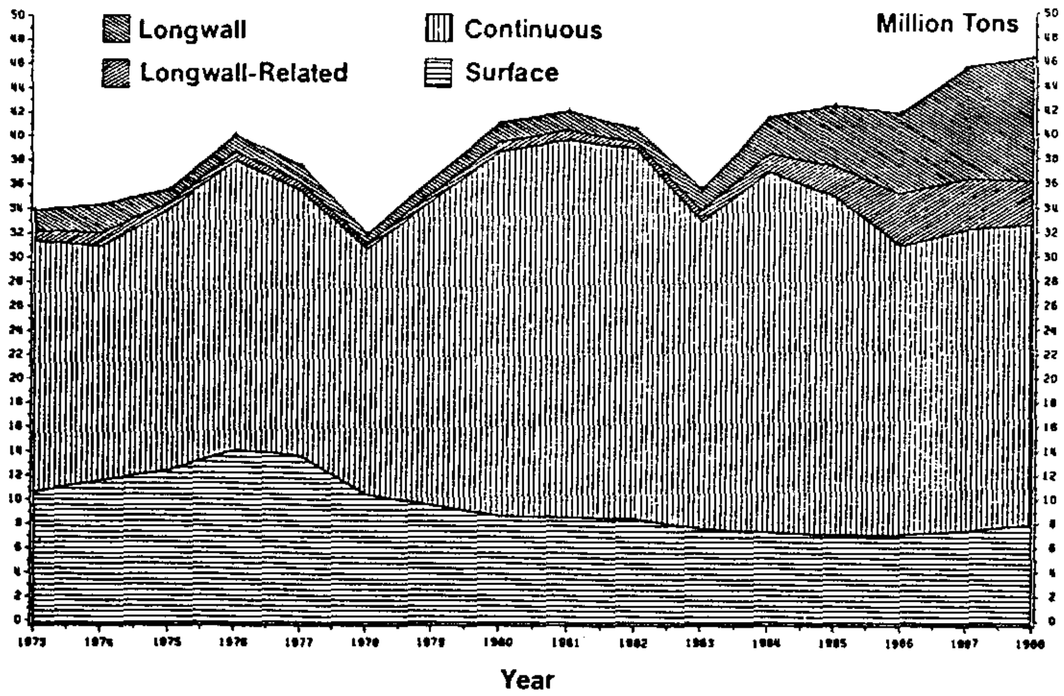
[8] Peng, S. S. *Coal Mine Ground Control*. New York: John Wiley and Sons (Second Edition), 1986, p. 15.

FIGURE 1: VIRGINIA COAL PRODUCTION BY METHOD: 1973 - 1988



Source: Randolph, J.; Clutter, T.; Prelaz, L. J. *1989 Virginia Coal Directory*. Blacksburg: Virginia Center for Coal and Energy Research, 68 pp., August 1989.

greater safety, because cutting is performed beneath a canopy of steel supports, and because fewer miners are necessary. The need for fewer miners may also reduce exposure to coal dust, which causes black lung. Finally, longwall mining is the only feasible way to mine very deep seams with any degree of safety, because compressional forces at great depth can cause both roof collapse and pillar failure.

Longwall mining, because of its systematic removal of roof support, causes rapid and fairly predictable subsidence of overburden. Pillar extraction mining is likely to cause relatively rapid subsidence, but its development is not as predictable as is the case with longwall mining. Depending on local conditions in the mine, some pillars may be nearly completely removed while others are left intact (to facilitate ventilation, for example). "The result is an inconsistent and staggered system of pillar support within a 'pillared area.' This can cause variations in the degree and delays in the timing of subsidence."[9]

While the effects of the subsidence caused by longwall mining vary, its rapidity, predictibility, and completeness have some advantages over the subsidence that may ultimately occur above room-and-pillar mines. For one thing, subsidence above room-and-pillar mines may occur decades after mining is complete, even when pillar recovery methods are used. Residents of urban areas in Illinois and Pennsylvania are now suffering the effects of subsidence from long-abandoned room-and-pillar mines. Remediation or compensation to owners of surface structures damaged in such circumstances may be difficult or impossible, because many companies have long since

[9] Price, K. (General Manager, Virginia Division) and Breeding, S. G. (Assistant to the General Manager, Community Relations). Island Creek Coal Company, Oakwood, Virginia. Personal communication, January 19, 1990.

TABLE 1: 1989 VIRGINIA UNDERGROUND COAL MINE PERMITS MINING METHOD AND EQUIPMENT TYPE

Number of Permits	Method	Type of Equipment
Longwall		
13	Longwall	Longwall
Pillar Recovery		
56	Pocket and Wing	Continuous Mining Machine
1	Pocket and Wing	Scoop Haulage
9	Left and Right	Continuous Mining Machine
7	Split Pillar/Split Wings	Continuous Mining Machine
1	Split Pillar/Split Wings	Scoop Haulage
1	Split Pillar/Split One Wing	Continuous Mining Machine
6	Split Pillar (only)	Scoop Haulage
4	Open End	Continuous Mining Machine
128	Three Cut	Continuous Mining Machine
7	Three Cut	Scoop Haulage
1	Three Cut	Loading Machine
6	Two Cut	Continuous Mining Machine
2	One Cut	Continuous Mining Machine
7	Five Cut (large blocks)	Continuous Mining Machine
1	Four Cut (large blocks)	Continuous Mining Machine
237		
Other Underground		
64	Various	Various
Total Underground		
314		

Source: Data provided on request by Virginia Division of Mines, 1990.

gone out of business.[10] In the interests of economic efficiency and long-term planning, it is advantageous to have complete subsidence while the mining operation is still in progress or shortly thereafter. The degree of predictability allows for measures that prevent or minimize damage to surface structures.

High-Extraction Mining in Virginia

In 1989, 250 of 314 (80 percent) underground mine permits in Virginia specified high extraction methods, 237 with pillar recovery techniques and 13 with longwall equipment. According to industry sources, pillar recovery is what makes it possible to operate

[10] SMCRA calls for "restoration and reclamation of land and water resources adversely affected by past coal mining, including ... prevention, abatement, and control of coal mine subsidence." 91 Stat. 457, 30 U.S.C. 1231. The program is funded through a reclamation fee collected on coal currently being extracted.

underground mines profitably using conventional technology. On average, these pillar recovery mines extract about 70 percent of the coal present, although this may vary considerably from mine to mine and within each mine. These mines amount to about 85 percent of Virginia's non-longwall underground production.

In 1989, Virginia had 13 longwalls in ten mines, second only to West Virginia. They are owned by four companies: Island Creek Coal Co. (5); Pittston Coal Group, Inc. (Clinchfield) (4); Consolidation Coal Co. (2); and Westmoreland Coal Co. (2).[11] As of March 1989, one of the longwall units was idle, so that only 12 are producing coal. This number accounted for more than ten million tons of coal, over a quarter of the state's total underground mine production and more than a fifth of total coal production by all methods. This number represents only actual longwall production; in the mines where longwalls operate, total production is considerably higher: 13.7 million tons, representing over a third of all Virginia underground production and more than 30 percent of all coal mined in 1988.[12]

Although modern longwall mining was introduced into the Commonwealth in 1968, its contribution to total state coal production remained small (less than 7 percent) until 1984.[13] Longwall mining production totals climbed in each year since. According to industry officials, longwall mining makes it possible, both technologically and economically, to mine coal deposits that would not otherwise be mined.[14] This is due to improved safety, greater extraction, and increased productivity (2.8 tons per man per hour *vs.* 2.4 tons per man per hour for all methods in 1988). Given current market conditions, it is safe to say that longwall use is the main reason Virginia coal production has been increasing since 1984.

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[11] Randolph *et al., op cit.*

[12] Randolph *et al., op cit.*

[13] Randolph *et al., op cit.*.

[14] Mathis, E., President, Pittston Coal Group, Inc., Lebanon, Virginia. Interviewed by Ted Clutter, VCCER, May 3, 1988.

Chapter 3: Hydrogeology of the Virginia Coal Fields

Geology

The coal-producing region of Southwest Virginia lies in the Appalachian Plateau physiographic province, and is drained by the Clinch, Powell, and (via Russell Fork and Levisa Fork) Big Sandy rivers. The area is characterized by rugged, mountainous topography consisting of deep, V-shaped valleys with steep slopes and narrow, winding ridges. The landforms were shaped by the erosion of a high plateau of sedimentary origin. These sedimentary rocks, which range from Cambrian through Pennsylvanian ages, were uplifted as a block, and deformation is not nearly so dramatic as in the adjacent Valley and Ridge Province. Accordingly, strata remain nearly level to gently sloping, with only occasional deep fractures. There are several coal-bearing formations, all of Pennsylvanian age, and at least 27 major coal seams.[15] These formations consist of alternating layers of sandstone, shale, thin layers of clay, and coal beds.

Soils in the coalfields are the product of weathering and disintegration of parent materials. The richest soils are found in the floodplains at valley bottoms, which are filled with unconsolidated material washed down from the slopes. On the slopes themselves, soils are generally thin and prone to erosion after vegetative cover is removed. On level-topped ridges that have escaped erosion, soil covers are thick. Soil and slope conditions confine agriculture to the small areas found in valley bottoms and ridge tops.

Surface Water

Streams draining the coalfields are almost universally dendritic, testimony to the erosional morphogenesis of the region. Exceptions occur at major faults, along which several of the larger streams run in relatively straight lines. Although the region on average receives plentiful precipitation, there is a remarkable variation in stream flow. Because of steep slopes and thin soil cover, runoff following precipitation is relatively quick. During dry months, all but the largest streams are reduced to very low flows.

Surface mining has affected the hydrology of streams draining some basins that have been extensively mined. Base flows in these streams have increased since the advent of surface mining, and this increase, together with observed changes in flow duration, indicates enhanced infiltration and storage of precipitation with correspondingly more gradual drainage.[16] In other mined basins, however, such effects have not been observed. Extensive mining activity also may change surface and groundwater quality: water in mined basins tends toward a sulfate type, while that from unmined basins is predominantly of a bicarbonate type.[17]

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[15] National Research Council, Committee on Ground-Water Resources in Relation to Coal Mining. *Coal Mining and Ground-Water Resources in the United States.* Washington, D.C.: National Academy Press, 1981, p.55.

[16] Larson, J. D.; Powell, J. D. *Hydrology and Effects of Mining in the Upper Russell Fork Basin, Buchanan and Dickenson Counties, Virginia.* Richmond: U.S. Geological Survey, Water-Resources Investigations Report 85-4238, 1986.

[17] *Ibid.*; and Rogers, S. M.; Powell, J. D. *Quality of Ground Water in Southern Buchanan County, Virginia.* Richmond: U.S. Geological Survey, Water-Resources Investigations 82-4022, May, 1983.

Groundwater

The most important factor in determining overall groundwater flow in the coalfields is topography. Like surface water, groundwater flows down the ridge slopes toward the valleys, eventually discharging into streams and comprising their base flows. Groundwater availability, as evidenced by well yields, is greatest in valleys and on lower slopes.[18]

Besides topography, rock characteristics exert a great influence on the direction of flow and on the amount of groundwater available. Transmissivity is a measure of the ability of water to move through a rock formation. Transmissivity depends on the permeability of the rock, which can be either primary or secondary (Figure 2).

Primary permeability refers to movement of water through spaces between rock grains, and depends on amount of pore space and the size and shape of the rock grains. In small-grained rocks such as shale or clay, permeability is very low. Layers of such rock act as "aquitards," retarding the movement of water. More porous rocks, such as certain sandstones, store greater quantities of water and permit relatively easy passage. Such rocks are generally referred to as aquifers. Sandstones in the Virginia coalfields, however, tend to be well-cemented and generally poor water sources.[19]

Secondary permeability refers to the movement of water along rock fractures, bedding planes, joints, and faults. Because of the low primary permeability of rock layers in the formations underlying the valleys and ridges of the Appalachian Plateau, secondary permeability is much more important to both groundwater storage and flow than primary permeability.[20]

In a study in Preston County, West Virginia, secondary permeability of sandstone units was found to be one to three orders of magnitude greater than their primary permeability.[21] These findings agree with those of Schubert, who points out that increased hydraulic conductivity produced by fracturing can drastically alter the hydrologic characteristics of rock.[22] Sloan and Warner, similarly, warn against using groundwater models based on primary hydraulic conductivity in areas such as the Appalachian coal region, where aquifer storage and flow characteristics are fracture controlled.[23]

Considerations of topography, lithology, and stratigraphy are all important in understanding the occurrence and movement of groundwater in the Virginia coalfields. There are two hydrologic studies that together provide a good general understanding of groundwater hydrology in the Virginia coalfields. The first is an investigation conducted in 1979/80 by Wyrick and Borchers of the role of stress-relief fractures in the hydrology of an Appalachian valley.[24] Erosion of valleys from sedimentary formations

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[18] Epps, S. R. *Buchanan County Groundwater: Present Conditions and Prospects.* Richmond: Virginia Water Control Board, Planning Bulletin 311, October 1978; and Dovel, M. R. *Wise-Dickenson County Ground Water: Present Conditions and Prospects*. Richmond: Virginia Water Control Board, Planning Bulletin 333, June 1983.

[19] LeCain, G. U.S. Geological Survey, Marion, Virginia. Personal communication, October 14, 1988.

[20] Wyrick, G. G.; Borchers, J. W. *Hydrologic Effects of Stress-Relief Fracturing in an Appalachian Valley*. Washington, D.C.: U.S. Geological Survey, Water Supply Paper 2177, 1981. p.10.

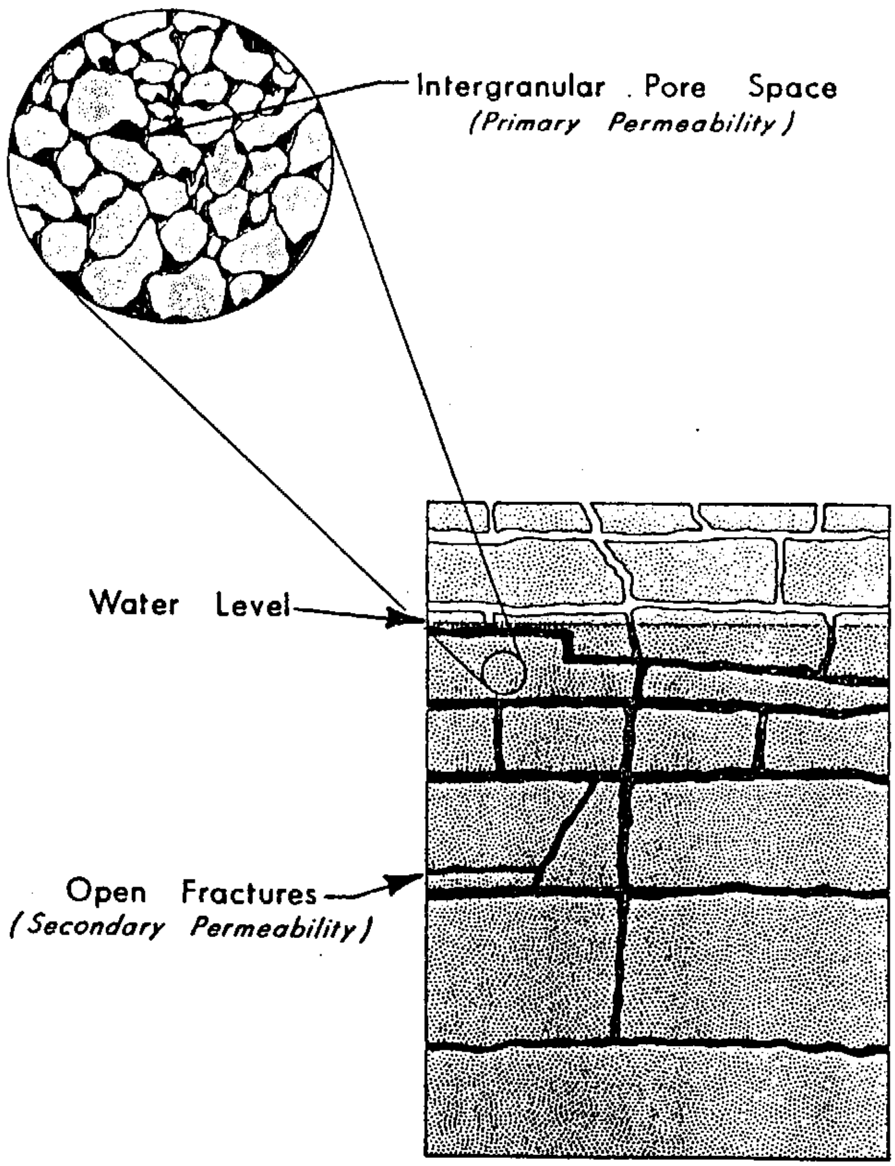
[21] Schmidt, R. D. *Fracture Zone Dewatering to Control Ground Water Inflow to Underground Coal Mines*. Washington, D.C.: U.S. Bureau of Mines, BUMINES RI 8981, 1985.

[22] Schubert, J. P. *Fracture Flow of Groundwater in Coal-Bearing Strata*. Prepared for 1980 Symposium on Surface Mining Hydrology, Sedimentology, and Reclamation, Lexington, Kentucky, December 1-5, 1980.

[23] Sloan, P; Warner, R. C. "A Case Study of Groundwater Impact Caused by Underground Mining." In: Graves, D. H.; DeVore, R. W. (eds.) *Proceedings, 1984 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, Lexington, Kentucky, December 2-7, 1984*. Lexington: University of Kentucky, Office of Engineering Services, December 1984 (Bulletin UKY BU136). pp. 113-120.

[24] Wyrick, G. G.; Borchers, J. W. *Hydrologic Effects of Stress-Relief Fracturing in an Appalachian Valley*. Washington, D.C.: U.S. Geological Survey, Water Supply Paper 2177, 1981. p.10.

FIGURE 2: PRIMARY AND SECONDARY PERMEABILITY



Source: Wyrick, G. G.; Borchers, J. W. *Hydrologic Effects of Stress-Relief Fracturing in an Appalachian Valley*. Washington, D.C.: U.S. Geological Survey, Water Supply Paper 2177, 1981.

characteristic of the Appalachian Plateau removes compressional stress of overlying material, resulting in predictable patterns of fractures in valleys and on ridge walls. On the ridges, stress relief results in vertical fractures that allow the valley walls to slump outward and downward. This slumping causes compression fractures at the base of the ridges. The slumping also opens up horizontal fractures in bedding planes between different strata. Another consequence of the erosional removal of compressing rock is the upward arching of rock strata on valley floors, which causes vertical fractures there as well as opening of bedding planes between the strata underlying the valley floors (Figure 3).

Wyrick and Borchers' analysis of the results of pump tests and slug tests of strategically placed wells, as well as streamflow data, yielded results consistent with the theory that the fracture system described above controlled groundwater movement in the valley. Water falling on ridge tops and slopes enters vertical fractures, moving through them and horizontal fractures on the ridge sides, eventually intercepting horizontal fractures at the valley floor. The water flows through these fractures until it reaches a level at which the streambed intercepts them, and then empties into the stream. In this model there is little movement of water within the ridge mass, except on its fractured outer edges.

The second study[25] was a cooperative effort of the Powell River Project, the Virginia DMLR, several mining companies, and the U.S. Geological Survey. This study used mobile testing equipment to investigate hydraulic properties of various strata encountered in exploratory drilling by mining companies in the Virginia coalfields. Tests were conducted to determine transmissivity, hydraulic heads, and hydraulic connection of water-bearing zones. Although the final report is still in preparation, preliminary results are as follows:

In the Virginia coal region, the uppermost 100-150 feet is a fractured zone, with a weathered mantle of unconsolidated material (alluvium and colluvium). The most accessible groundwater is in the fractured zone. Fracture flow (i.e., secondary permeability) is predominant, and well yields are low, rarely above 5 gallons per minute (gpm). This zone is the source of most domestic water supplies, either through springs or shallow wells. Groundwater recharge in this zone is relatively rapid, and following a rainfall drainage from it feeds streams for one to four days.

Below this upper layer, the only lithologic units with significant transmissivity are coal seams. Siltstones, shales, and sandstones consistently show extremely low transmissivity over a wide range of elevations except where fractured. In contrast, coal seam transmissivities show a consistent correlation with elevation: the deeper the seam, the lower the transmissivity. At greater depths, increasing pressure closes the cleats and microchannels through which water moves. The coal seams comprise the only deep lithologic units with significant groundwater storage. Most perennial springs occur at coal seams, and most stream baseflow in the area is from water slowly released from the coal seams. Recharge to the coal seams is through deep fractures.

This view of coal seams as the only lithologic units capable of storing and transmitting significant quantities of water is corroborated by an earlier study of the hydrology of the Upper Russell Fork Basin in Buchanan and Dickenson counties.[26] Water levels were monitored in five ridgetop wells, each open to a different coal seam. Water levels at the wells were at different altitudes, and unsaturated zones were encountered between the coal beds, "indicating the presence of a series of perched water zones above the coal beds."[27]

Springs are frequently associated with coal seam outcrops, because coal seams are relatively permeable and because they are often underlain by clay. Hence, water flowing downward through vertical fractures is stopped in its movement by the clay, then flows along the slight inclination of the layer until emerging on a hillside. The "perched aquifers" supplying such springs individually may be of little regional significance as water sources, but they are adequate to supply a small number of households where they occur. According to a Virginia Division of Mineral Resources geologist involved in mapping the coalfields, springs are valuable in helping to locate coal seam outcrops.[28]

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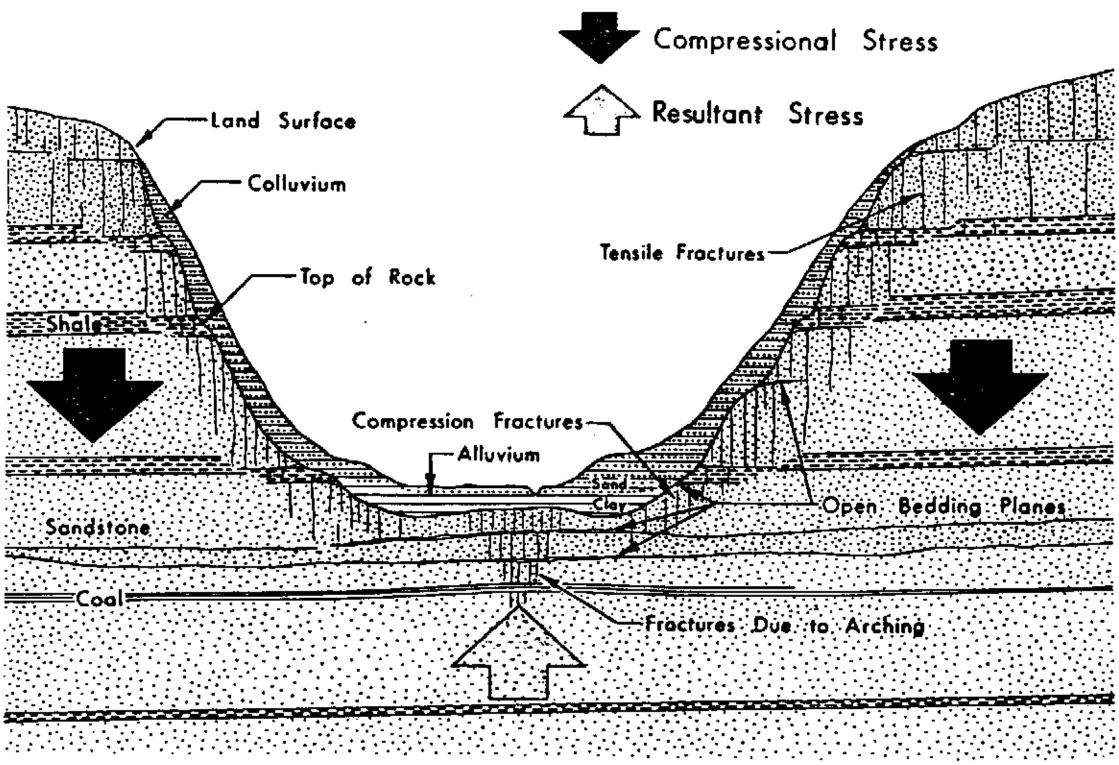
[25] LeCain, G. U.S. Geological Survey, Marion, Virginia. Personal communication, October 14, 1988.

[26] Larson, J. D.; Powell, J. D. *Hydrology and Effects of Mining in the Upper Russell Fork Basin, Buchanan and Dickenson Counties, Virginia*. Richmond: U.S. Geological Survey, Water-Resources Investigations Report 85-4238, 1986.

[27] *Ibid.*, p. 30.

[28] Henika, W. Virginia Division of Mineral Resources, Blacksburg. Personal communication, August 1988.

FIGURE 3: STRESS-RELIEF FRACTURING



Source: Wyrick, G. G.; Borchers, J. W. *Hydrologic Effects of Stress-Relief Fracturing in an Appalachian Valley*. Washington, D.C.: U.S. Geological Survey, Water Supply Paper 2177, 1981.

Groundwater Quality

There are several sources of information on groundwater quality in the coalfields of Virginia. One is the *Planning Bulletin* series for Wise, Dickenson, and Buchanan counties published by the Virginia Water Control Board.[29] Data for these reports are from analyses of spigot samples from wells located, for the most part, in valleys. It is likely that use of existing wells biases overall water quality characterization, because they are usually in areas of good water quality. Buchanan County's groundwater is described by Epps as "characteristically acid to slightly alkaline, irony, somewhat hard, and may have a sulfurous odor."[30] Local problems include higher-than-recommended levels of iron, manganese, chloride, sulfates, and dissolved solids; hardness; acidity; and dissolved gases, including hydrogen sulfide and methane.

Water quality problems seem to stem from the geochemistry of the area rather than from substances introduced by man. Dovel, in his review of groundwater conditions in Wise and Dickenson counties, describes the water from the coalfields in those counties as "irony, moderately hard and acid, and [it] may be discolored and malodorous."[31] Wa-

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[29] Epps, S. R. *Buchanan County Groundwater: Present Conditions and Prospects*. Richmond: Virginia Water Control Board, Planning Bulletin 311, October 1978; and Dovel, M. R. *Wise-Dickenson County Ground Water: Present Conditions and Prospects*. Richmond: Virginia Water Control Board, Planning Bulletin 333, June 1983.

[30] Epps, *op. cit.*, p. 29.

[31] Dovel, *op. cit.*, p. 55.

ter quality problems for these counties are similar to those of Buchanan County, with the exception of the Powell River Valley in Wise County, which comprises a different geologic regime.

The U.S. Geological Survey has conducted several studies of surface and groundwater quality in the region. In a study of groundwater in southern Buchanan County, findings generally support the characterization of groundwater quality found in Epps' study. No area-wide degradation of groundwater quality was found, but some local effects of surface mining were apparent. Stream water is generally rich in bicarbonate in unmined areas, but may take on a sulfate character in some heavily mined areas, depending on the chemical characteristics of the rock units disturbed. Well and spring water from coal seams is sulfate-rich.[32] In a study of Buchanan and Dickenson counties, mining was again found to result in increased sulfate concentrations in ground and surface water.[33]

Groundwater Usage

Groundwater provides most of the water for all uses in the coal fields. In the Big Sandy water supply planning area, which includes all of Dickenson and Buchanan counties and parts of Wise and Tazewell counties, ground water supplied more than two-thirds of all water used within areas designated by the State Water Control Board in 1982 as "demand centers."[34] These include most urbanized areas within the planning district boundaries. Approximately half of the population and nearly all public water supply systems in the area are included within the demand centers. In the more remote parts of the region beyond the demand centers, domestic users, businesses, and industrial and mining operations are all heavily dependent on groundwater.

A study focusing exclusively on domestic water users found that in Buchanan County only 7.9 percent of year-round housing units were supplied by public or private water systems; over 80 percent relied on individually drilled or dug wells, while the remainder used other sources such as springs and cisterns.[35] In Dickenson County, 36.3 percent of housing units were supplied by public or private water systems; the remainder relied on wells, springs, cisterns, and other sources.[36]

The importance of an adequate and dependable water supply to individual landowners cannot be overstated. Some, however, question whether the springs and wells relied upon by rural residents of the coalfields are in fact adequate and dependable. According to Island Creek Coal Company, most such sources "have been historically intermittent and unreliable, with good quantity in wet weather and little or no flow during dry periods."[37] On the other hand, a consulting geologist familiar with conditions in Appalachia comments, "rural people are not stupid. Homesites where adequate supplies could not be developed have long since been abandoned if they were ever occupied."[38] There is, in fact, no

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[32] Rogers, S. M.; Powell, J. D. *Quality of Ground Water in Southern Buchanan County, Virginia*. Richmond: U.S. Geological Survey, Water-Resources Investigations 82-4022, May, 1983.

[33] Larson, J. D.; Powell, J. D. *Ibid*.

[34] *Big Sandy Water Supply Plan*. Richmond: Virginia State Water Control Board, Planning Bulletin 346, March 1988, p. II-11. The two-thirds supplied by groundwater includes water supplied within the demand centers by both individual systems (mostly wells) and public and private water supply systems.

[35] Island Creek Coal Company reports that of the approximately 450 properties that have been or may be affected by that company's current or future mining operations, 199 or 44 percent use public water systems; 214 or 48 percent use individual wells; and the remainder use other water sources. Price, K.; Breeding, S. Virginia Division, Island Creek Coal Company, Oakwood, Virginia. Personal communication, January 19, 1990.

[36] George, C. A.; Gray, J. L. *Water for Tomorrow: A Report on Water and Wastewater Needs in Virginia*. Roanoke: Virginia Water Project, Inc., October 1988.

[37] Price, K. General Manager, Virginia Division, Island Creek Coal Company. Oakwood, Virginia. Personal communication, August 9, 1989.

[38] DiPretoro, R. Geologist, Morgantown, West Virginia. Personal communication, January 18, 1990.

systematic documentation of the adequacy and reliability, or lack thereof, of shallow wells and springs in the coalfield region of Virginia.

Groundwater also serves as the principal source of domestic and industrial water for both individual wells and public systems in the more densely populated areas of the region. The geology and morphology of the area prevent regional movement of groundwater, limiting the supply in each valley. Epps reported in 1978 that some population centers in Buchanan County were in danger of depleting their supplies through overuse.[39]

Groundwater is also an important source of water for wildlife, which depend on springs and seeps. Moreover, it supplies the base flow for area streams.

Summary

This section has described the hydrogeology of the Virginia coalfield region. The area's normally ample precipitation is carried away relatively quickly by steep streams with low base/peak flow ratios. Groundwater occurs primarily in fractured zones near the surface and in alluvial valleys. Both storage and transmissivity are dominated by secondary permeability in the fractured zones, which extend from the surface to a depth of 100-150 feet. Coal seams are the only lithologic units with significant groundwater transmissivity. Groundwater quality is variable over the area; common problems are high levels of iron, hardness, acidity, and odor. The adequacy and reliability of shallow wells and springs serving rural residents and businesses in the area are questionable.

Nevertheless, groundwater supplies most of the domestic and industrial needs of the coal counties. Many of these needs could not be supplied by any other source of water without considerable investment. Springs, seeps, and surface streams fed by groundwater also provide aquatic habitat and water for game and nongame wildlife.

[39] Epps, *op. cit.*, p. 73.

Chapter 4: Subsidence Effects on Water Resources

The hydrologic balance is defined in the *Virginia Coal Surface Mining Reclamation Regulations* as:

> ...the relationship between the quality and quantity of water inflow to, water outflow from, and water storage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake, or reservoir. It encompasses the dynamic relationships among precipitation, runoff, evaporation, and changes in ground and surface water storage.[40]

In this section, a number of studies are reviewed in order to understand the mechanism whereby high-extraction mining might affect the hydrologic balance. None of these studies was conducted in Virginia. Because they were undertaken in nearby Appalachian states with similar geologic conditions, however, their results have implications for the Commonwealth.

General Mechanism and Conceptual Model

The mechanism of action is subsidence. As described in Chapter 2, longwall and most high extraction mining unavoidably cause subsidence of the overlying rock by removing its subjacent support. This is called "planned and controlled subsidence" in the Surface Mining Control and Reclamation Act.

In room-and-pillar mining, blocks of stress-bearing coal are left in place to support the mine roof, commonly leaving the cavity intact when the mine is abandoned. Deformation of overlying strata is limited to layers relatively close to the mine. Depending on mine conditions, pillar collapse can result in eventual surface subsidence. Severe subsidence over mine cavities can develop if these cavities are close to the surface.

As discussed in Chapter 2, in most Virginia room-and-pillar operations, additional coal is removed by mining the pillars. Techniques vary depending on specific mine conditions, but together they comprise pillar-retreat (or pillar recovery) mining. In pillar-retreat mining, blocks of coal supporting the roof are partially or completely removed, beginning at the farthest reaches of the fully-developed mine section. Roof collapse may or may not be immediate, depending on how much of the pillar coal is removed. The development of subsidence above pillar-retreat operations is not as straightforward as with longwall panels, and few predictive studies have been reported in the literature. The timing and extent of subsidence depend on where and how much coal is removed; it is unlikely that a "well-developed subsidence trough" similar to that seen above longwall panels would result. However, with extraction ratios of 80 percent or higher, fairly rapid subsidence would be expected.

Longwall equipment, on the other hand, mines a broad face, typically between 350 and 1000 feet wide, and as high as the coal seam is thick. As the mine face moves through the seam, roof supports are moved forward, allowing the mine roof behind to collapse and causing surface subsidence.

The geomechanics of subsidence above longwalls have been studied extensively and are well-understood. As the mine roof is allowed to collapse, there is an area of caving and severe fracturing which occurs directly above the mined coal seam. This area extends upward 30-60 times the coal seam thickness, depending on the mechanical qualities of overlying rock strata (Figure 4).

Strata sag above the caved area. A "zone of continuous deformation" may extend to approximately 50 feet of the ground surface,

[40] *Virginia Coal Surface Mining Reclamation Regulations*, Sec. 480-03-19.700.5, p. II-10.

depending on the geomechanical properties of overburden layers. This zone is characterized by intermittent fracturing, bedding plane separation, and some sliding of beds across each other. The presence of relatively plastic clay layers or massive rock layers in this zone may prevent the formation of new vertical fractures, so that downward water movement is slowed or stopped. A near-surface zone comprising the upper 50 feet of overburden may show increased fracturing and permeability because of compression and tension. At the surface is a well-defined subsidence trough. The horizontal dimensions of the trough are greater than those of the collapsed mine void.

The subsided surface extends across an area defined by "angle of draw." The Institution of Civil Engineers (ICE) in England defines angle of draw as "the angle between the line from the edge of the excavated area, normal to the seam, and the line joining the edge of the excavated area to the point of zero effect at the surface."[41] The ICE puts the angle of draw at 25 to 35 degrees, but because the subsidence trough tails off gradually the extent of major deformation is generally smaller than this. The angle of draw varies according to the mechanical characteristics of rock strata above the mine void. Considering the size of a longwall panel (up to 1000 feet wide and 9000 feet long) and distance to the surface, the subsidence trough for a single panel may cover a large area. Furthermore, in a typical longwall mine there are multiple panels in close proximity.

A conceptual model of the hydraulic impacts of underground mining was developed by Booth, using mining engineering concepts of strata movement and mine hydrology.[42] In particular, he relates the effects of different types of underground mining (longwall versus "deep headings and uncollapsed room-and-pillar mines") on rock strata in the overburden to their hydraulic impacts. His conclusions, supported by field observations in the Appalachian Plateau of Pennsylvania, are worth quoting at length:

> Much of the ground-water impact of deep underground coal mining is dependent on and explicable by the hydraulic property changes resulting from mine-induced stresses. The impact of a single supported heading is local but intense. It comprises a large pressure drop and rapid dewatering in the increased-permeability zone in the seam and immediate roof within the pressure arch, but a minor effect on main-roof strata above this. An uncollapsed network of such headings [such as that found in a room-and-pillar mine] forms an underdrain which may locally affect lower aquifers considerably but whose effects on the shallow system are slight and diffuse.
>
> In contrast, the strata deformation and hydraulic impact of longwall mining are widespread and considerable. Lower aquifers connected to the working areas through fracturing are intensely affected and provide much of the inflow to the mine. Any hydraulic connections between the mine and shallow aquifers probably lie in tensile zones above the working areas and at the leading edge of the subsidence profile, but such connection is not a prerequisite to mine-related impacts. Whereas the hydrologic impact of supported headings is due to the drainage to the mine, that of longwall mines is also due to independent aquifer response. Subsidence-induced permeability increases in shallow aquifers cause increased throughput and (accentuated by storativity increases) lowered water levels in recharge zones regardless of mine drainage. Later compression and settlement cause partial reductions in permeability and storativity and partial recoveries in water levels.[43]

Booth also points out that the specific effects of a mining operations depend very much on local geologic conditions.

Rauch, summarizing his own and others' work (primarily in West Virginia), relates dewatering to subsidence theory. In the zone of caving and deep fracturing, dewatering is severe. Wells penetrating the zone are "partially to totally dewatered and exhibit no short term recovery."[44] In the surface zone

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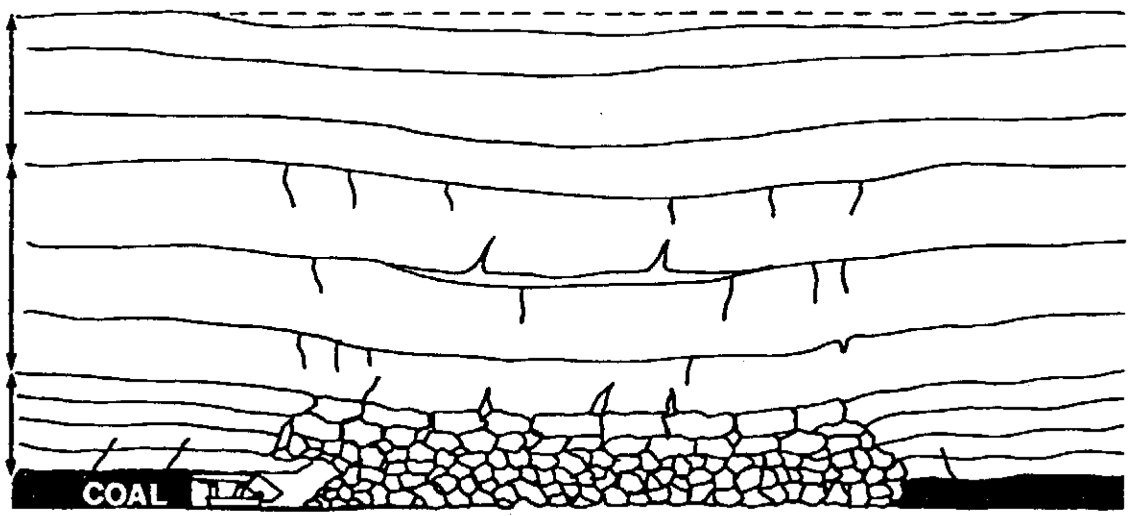
[41] Institution of Civil Engineers. *Ground Subsidence*. London: Institution of Civil Engineers, 1977, p. 13.

[42] Booth, C. J. "Strata movement concepts and the hydrogeological impact of underground coal mining." *Ground Water* 24(4):507-515, July-August 1986.

[43] *Ibid.*

[44] Rauch, H. W. "Ground Water Impacts From Surface and Underground Coal Mining." In: *Proceedings*

FIGURE 4: SUBSIDENCE ABOVE A HIGH-EXTRACTION COAL MINE



Source: After Peng, S. S.; Chiang, H. S. *Longwall Mining*. New York: Wiley and Sons, 1984.

and the zone of continuous deformation, water supplies and aquifers "typically suffer only partial and temporary water losses above subsided coal mines and recover within a few days of the initial impacts."[45] Factors influencing water supply impacts, according to Rauch, include vertical proximity of the well or aquifer to the mine, lateral proximity to the mine, overburden lithology and stratigraphy, fracture zones, longwall panel width, type of water supply, topography, and distance to the nearest stream.[46]

Similar conclusions were reached by Hasenfus *et al.* as a result of extensive hydrological and geomechanical monitoring at a longwall mine in West Virginia.[47] Overburden depth at the mine was roughly 700 feet, and directly above the coal bed lay approximately 200 feet of highly competent limestone and sandstone strata. The study included subsidence monitoring, time domain reflectometry, static water level observations and hydraulic conductivity in test wells, premining and postmining coring, and seismic surveys. Four distinct overburden zones were identified and related to impacts on aquifers in those zones. In Zone 1 (the "gob zone"), just above the mined panel and extending 4 to 6 times the mined seam thickness, porosity is greatly increased by caving and rubblization. Zone 2 (the "highly fractured zone"), above Zone 1 and extending to about 30 times the seam thickness, is a transitional, highly-fractured zone with massive block-type caving and vertical fracturing. In Zones 1 and 2 no recovery of water levels was observed. Zone 3, the

of a Conference on West Virginia Ground Water 1987 -- Status and Future Directions. Morgantown, West Virginia: West Virginia University, Water Research Institute, 21 pp., 1989.

[45] *Ibid.*

[46] Rauch, H. W. "A Summary of the Ground Water Impacts From Underground Mine Subsidence in the North Central Appalachians." In: *Proceedings, Coal Mine Subsidence Special Institute, December 8, 1989, Pittsburgh, Pennsylvania*. Eastern Mineral Law Foundation, 1989. 31 pp. (Chapter 2).

[47] Hasenfus, G. J.; Johnson, K. L.; Su, D. W. H. "A Hydrogeomechanical Study of Overburden Aquifer Response to Longwall Mining." In: Peng, Syd S., editor. *Proceedings of the Seventh International Conference on Ground Control in Mining*. Morgantown: West Virginia University, COMER, Department of Mining Engineering, 1988, pp. 149-162.

"composite beam" extending from above the highly fractured zone to within 50 feet of the surface, exhibits little vertical fracturing and occasional horizontal slippages between strata. Water levels in perched aquifers in this zone may decline temporarily but subsequently recover. In this zone, downward movement of water is inhibited because the integrity of low-permeability layers is maintained despite subsidence. Zone 4, the "surface zone," comprises the uppermost 50 feet. Strata in this zone are susceptible to fracturing and movements. The researchers concluded that the use of geomechanical data such as time domain reflectometry, surface subsidence, and rock strength characterization is extremely useful in interpreting hydrologic response to mining.

Field Studies

During the past decade there have been a number of other studies documenting the hydrologic impacts of high-extraction mining, both in the Appalachian region and elsewhere. Although these studies were performed in states other than Virginia, the hydrogeologic characteristics of nearby Appalachian states such as Kentucky, southwestern Pennsylvania, and West Virginia are close enough to those of the Virginia coalfields to indicate potential for similar effects.

One of the earliest was Hobba's study of the effects of mining and mine collapse in three West Virginia watersheds.[48] The sites were chosen to compare the effects of deep mining and subsequent mine collapse in areas where the mined coal seam lay above major drainage with those in which the seam lay below major drainage. Overburden in the above-drainage area was generally less than 150 feet thick; in the below-drainage area thickness ranged from 600 to 700 feet. Subsidence was greatest over shallow mines, but reached the land surface even where the mined seam lay 600-700 feet beneath the surface. In both cases Hobba (like Booth) found that mining and subsidence fractures increased hydraulic conductivity and the hydraulic connection of aquifers. Rock units near the surface showed higher transmissivity in mined basins than in unmined basins, and increased infiltration and circulation of groundwater through these rock units resulted in higher mineral loads in streams. Subsidence fracturing resulted in changes to the hydrologic balance that included increased infiltration of precipitation and surface water, decreased evapotranspiration, and higher base flows in some small streams. In above-drainage areas, pumping of water draining into mines caused diversion of water underground from one watershed to another. Static head in observation wells in mined areas fluctuated 50-100 feet in the course of a year, indicating rapid recharge and draining of water-bearing zones penetrated by the wells. Little drainage from wells and streams was found in areas undisturbed by subsidence in the areas in which mining was below major drainage.

Stoner used well testing methods to determine the hydrologic characteristics of an area in the Appalachian Plateau in Pennsylvania before and after underground coal mining. He found water-bearing zones to be common at the interfaces between sandstones and shales, and in fractured sandstones and coals as well. Static water levels in wells closest (vertically) to the mine were affected most. Both pillar retreat and longwall mining "may cause increased vertical permeability by fracturing which could hydraulically connect shallow aquifers to a deep mine. However, complete overburden collapse may result in water-level recovery of shallow aquifers as indicated at one well site over long-wall mining."[49] Stoner speculates that the rapid recovery of this well "could be explained by the reduction of vertical permeability of the strata overlying the mine coupled with complex interflow between various aquifer horizons tapped by the open-hole well. As the long-wall panel advanced beyond [the well], mine-induced fractures may have reclosed or become plugged with clay gouge to effectively reduce vertical permeability. Subsequent recovery of the shallow aquifer heads would then be

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[48] Hobba, W. A., Jr. *Effects of Underground Mining and Mine Collapse on the Hydrology of Selected Basins in West Virginia*. Morgantown, West Virginia: U.S. Geological Survey, USGS RI-33, 1981, 77 pp.

[49] Stoner, J. D. "Probable hydrologic effects of subsurface mining." *Ground Water Monitoring Review* 3(1):128-137, Winter 1983, p. 136.

possible."[50] In a later study, Stoner and others observed very rapid recovery (7 hours) in one well above an active longwall panel.[51]

The supposition that subsidence fractures reseal relatively quickly, allowing water level recovery, is accepted by engineers at some mining companies. Dr. Jay Lehr, hydrologist and well expert, and Executive Director of the National Water Well Association, also believes that subsidence effects on groundwater levels are temporary.[52] Others, however, including a hydrologist who has studied the geohydrology of the Virginia coalfields, doubt that subsidence fractures will ever seal themselves.[53] This is a controversial and important point, because it bears directly on the question of whether dewatering of shallow aquifers is short-term or a long-term. Like many other impacts of subsidence, it may be entirely dependent upon site-specific conditions.

Wells of different depths, tapping different aquifers, may be unequally affected by subsidence. In one U.S. Bureau of Mines study, subsidence and groundwater levels were monitored above an active longwall panel in western Pennsylvania before, during, and after mining. Coal seam thickness was four to five feet overburden depth 550 feet; panel length was 2900 feet and face width was 585 feet. Zones of fracturing were increased by subsidence, which stopped within four months after passage of the longwall face. Transmissivity was dramatically impacted by this fracturing, and changes in groundwater flow patterns were observed. Although the deep aquifer monitoring wells (drilled to a depth of 250 feet) showed "precipitous" declines in water levels, wells penetrating the shallow aquifer zone (75 foot depth) were protected to some extent by an aquitardal layer that evidently resisted fracturing. This conclusion is consistent with Booth's conceptual model and borne out by observation of flows from a spring near the center line of the longwall panel, which correlated with precipitation but not with passage of the longwall face. Hydrology was still unstable at the end of one year, as indicated by cascading in some monitoring wells; deep well water level declines had recovered only slightly. However, aquifer dewatering was limited mainly to deep wells in the area directly above the longwall operation. Water quality, as indicated by conductivity, was only slightly affected.[54]

Tieman and Rauch observed differential dewatering effects on water supplies at different vertical and horizontal distances from longwall panels at a mine site in Greene County, Pennsylvania.[55] Fifty-eight water wells and springs, as well as streams, were monitored over several longwall panels of different ages and over unsubsided room-and-pillar mine workings. Topographic relief in the area ranged from 300 to 450 feet. The 650- to 1,000-foot thick mine overburden consisted of shale, mudstone, claystone, fire clay, sandstone, limestone, and coal. No negative impacts were reported for water supplies over or near unsubsided mine works. Eight of 11 water supplies above longwall panels appeared to have been partly to completely dewatered. Dewatering occurred at vertical distances of 655 feet and greater above the mined seam (the Pittsburgh Coal Seam), but not closer to the

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[50] Stoner, J. D., *ibid.*, p. 133.

[51] Stoner, J. D.; Williams, D. R.; Buckwalter, T. F.; Felbinger, J. K.; Pattison, K. L. *Water Resources and the Effects of Coal Mining, Greene County, Pennsylvania*. Prepared by the U.S. Geological Survey, Water Resources Division, in cooperation with the Pennsylvania Geological Survey. Harrisburg: Pennsylvania Geological Survey, Water Resource Report 63, 166 pp. plus maps, 1987.

[52] Lehr, J. Executive Director, National Water Well Association, Ames, Iowa. Personal communication, August 22, 1989.

[53] LeCain, G. U.S. Geological Survey, Marion, Virginia. Personal communication, October 1988.

[54] Pennington, D.; Hill, J. G.; Burgdorf, G. F.; Price, D. R. *Effects of Longwall Mine Subsidence on Overlying Aquifers in Western Pennsylvania*. Washington, D.C.: U.S. Bureau of Mines, BUMINES-OFR-142-84, May 1984, 130 pp.

[55] Tieman, G. E.; Rauch, H. W. "Study of Dewatering Effects at an Underground Longwall Mine Site in the Pittsburgh Seam of the Northern Appalachian Coalfield." In: *Eastern Coal Mine Geomechanics. Proceedings, Bureau of Mines Technology Transfer Seminar, Pittsburgh, PA. November 18, 1986*. U.S. Bureau of Mines Information Circular 9137, 1987, pp. 72-89.

seam. The greatest degree of dewatering was observed in water supplies above panel centers.

Eleven of 13 water supplies not directly over longwall panels but within an angle of dewatering influence of 42° were partly to completely dewatered. Dewatering occurred in a zone 720 feet or greater above the mined seam, but not vertically closer.

No dewatering was observed below the regional drainage level defined by the major stream over the mine. Vertical and horizontal proximity to the major stream appeared to shield water supplies from dewatering. Proximity to other perennial streams also influenced the degree of dewatering of water supplies, with water supplies developed above the elevation of the nearest perennial stream at greater risk.

Water lost from groundwater supplies and streams did not drain to the mine. Instead it migrated downward, probably through subsidence fractures, to near regional drainage level, and then horizontally through a sandstone formation, eventually discharging to the largest stream over the mine.

Streams located above regional drainage and undermined by longwall panels less than 30 months old were partly to completely dewatered during baseflow conditions. Normal baseflows were seen in streams above regional drainage and undermined by panels at least 36 months old, indicating progressive recovery over the period in these undermined streams.

All of the accessible, partly dewatered groundwater supplies over longwall panels recovered partially within one to three years. Of the four completely dewatered supplies that were accessible, two showed partial recovery. Extent of recovery was influenced by location, with wells adjacent to panels and near stream level recovering more quickly and to a greater extent than those over longwall panel centers. Several new springs appeared or were developed at lower elevations on slopes following mining.

A U.S. Bureau of Mines study showed a similar result with respect to differential dewatering of aquifers. Subsidence and groundwater effects were monitored over a coal mine in Barbour County, West Virginia during developmental and pillar retreat mining. Overburden thickness was approximately 600 feet, and coal seam thickness 5.5 feet. This study used a clustered piezometer technique, with seven units in two clusters penetrating discrete sandstone formations at 30 feet (570 feet above mine level), 220 feet (380 feet above mine level), 260 feet (340 feet above mine level), and 360 feet (240 feet above mine level). Water levels were measured before, during, and after pillar-retreat mining. There were significant water level declines in deep strata. For example, in the deepest sandstone formations the water level dropped more than 250 feet during retreat mining. In general, "the closer the stratum lay to mine level, the greater the decline in piezometric level."[56] In keeping with this general finding, effects were minor and transient in the shallowest formation, while in the 220-foot and 260-foot formations water levels dropped 50 to 100 feet during active mining and recovered only partially after one year. Water quality changes were observed in all formations monitored, with higher concentrations of dissolved solids and (in one formation) manganese, increased conductivity, and lower pH following mining. Water chemistry changes were noticeable at one site two years after completion of mining, but "were not necessarily so significant as to render the water unfit for drinking purposes."[57]

Another U.S. Bureau of Mines investigation demonstrated dewatering effects that depend on the location of the well in relation to the longwall panel and the angle of draw. Groundwater levels, stream flow, and subsidence were monitored above a longwall panel in southwestern Pennsylvania at a greater depth than the above study. In this case overburden thickness ranged from 750 to 1000 feet. Maximum surface subsidence at trough center was more than three feet. Five 150-foot monitoring wells, designed to simulate typical domestic water wells, were constructed across the longwall panel. Wells 500 feet or more outside the panel rib line were unaf-

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[56] Bruhn, R. W. "Influence of deep mining on the ground water regime at a mine in northern Appalachia." In: Peng, S. S. (ed.) *Proceedings, 2nd Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, June 9-11, 1986*. Morgantown: West Virginia University, Department of Mining Engineering, August 1986, pp. 234-248.

[57] Bruhn, R. W., *ibid*.

fected, while those within the boundary of the longwall showed precipitous declines. One well near the centerline went dry and had not recovered after a year of postmining monitoring. Two wells, 100 and 300 feet outside the longwall panel rib line (the first within the 15° angle of draw indicating the limit of major surface deformation and the other within the 25° angle of draw delimiting detectable surface deformation) declined 15-20 feet but recovered to near premining levels within ten months. Small streams and a spring located within 1200 feet of the panel were unaffected.[58]

In yet another study, groundwater effects of high-extraction mining (longwall and pillar-retreat) in Upshur County, West Virginia were compared with those of abandoned room-and-pillar mining in Barbour County, West Virginia. Groundwater sources (wells and springs) did not evidence impacts from unsubsided room-and-pillar mine workings, but dewatering was apparent over the longwall mines. Dewatering of strata above longwall mines extended to nearly 300 feet above the top of the mined coal seam; less severe but still apparent impacts were seen up to 360 feet above the coal seam. Dewatering of overburden extended within an angle of influence of approximately 20 degrees from the mined panel. Well and spring dewatering were also dependent upon lithology and the location of a groundwater supply's recharge zone: if most of it was within the angle of influence, dewatering was likely. The presence of lineaments[59] also influenced dewatering. Eighty percent of accessible dewatered wells showed no significant recovery one to three years after dewatering. Stream flow was also affected, with a decline in flow proportional to the percent of the recharge area that was dewatered in areas with 100-170 feet of overburden. Complete loss of flow was also seen in some of these streams.[60]

Besides reductions in stream flows resulting from decreased groundwater contributions, streams may be directly affected by the development of subsidence cracks and fissures in the streambed. In West Virginia, subsidence has sometimes resulted in the complete or partial capture of stream flow.[61]

The effects of subsidence on streams were studied by Dixon and Rauch at three underground mine sites in northern West Virginia. Baseflow discharge was studied in selected streams located over and adjacent to longwall panels. Streamflow impacts were noted for streams crossing over longwall panels at all three sites. Flow depletion typically began before the streams crossed over the panels, and became more severe as the panels were approached. As the streams crossed over the panels' upstream edges, streamflow usually increased somewhat and then decreased again as they flowed across the panels. Streams commonly dried up over mine panels located within 500 vertical feet of the surface, but did not go dry over deeper panels. Recovery of streamflow, inferred by comparison with nearby streams over panels of different ages, was observed. Flows regained normal levels within one to two years after initial undermining where overburden exceeded 500 feet. One stream associated with a long lineament in an anticlinal setting had not re-

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[58] Moebs, N. N.; Barton, T. M. "Short-term effects of longwall mining on shallow water sources." In: *Mine Subsidence Control*. Proceedings, Bureau of Mines Technology Transfer Seminar, Pittsburgh, September 19, 1985. Washington, D.C.: U.S. Bureau of Mines, IC-9042, 1985, pp. 13-24.

[59] A lineament can be defined as a linear topographic feature that reveals the presence of a subsurface geologic feature such as a fault. Lineaments are often detected through such surface features as the alignment of stream channels or soil, vegetative, or topographic features detectable by aerial photography.

[60] Cifelli, R. C.; Rauch, H. W. "Dewatering effects from selected underground coal mines in north-central West Virginia." In: Peng, S. S. (ed.) *Proceedings, 2nd Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, June 9-11, 1986*. Morgantown: West Virginia University, Department of Mining Engineering, August 1986, pp. 249-263.

[61] Jernejcic, F. West Virginia Department of Natural Resources. Personal communication, January 6, 1989. Also, Cifelli and Rauch, *ibid.*, p. 252, note that "[s]treams located over longwall panels at [two active longwall mines in West Virginia] exhibited the disappearance or severe reduction of flow along the length of the streams, ponding of water due to subsidence and the local reversal of the natural hydraulic gradient, and lining of the streams by the mining companies in order to limit mine inflow rates of stream water."

turned to normal by the fifth year after undermining.[62]

Subsidence has also been reported to alter surface topography and thus drainage patterns, resulting in ponding in some areas. Sometimes more destructive (at least in the short term) than subsidence cracking and ponding have been the measures taken by coal operators to correct these problems. In the case of subsidence cracks intercepting stream flow, coal operators sometimes grade streambeds, then line them with plastic or rubber to prevent water inflow to the mines. Channelization and rerouting of streams are also undertaken, sometimes at the request of the surface owner, to alleviate ponding.[63]

Hydrologic effects of multiple longwall panels were studied by Walker *et al.*[64] and by Schultz.[65] In the former study, five wells were positioned over the centerline, edge, or chain pillar of three consecutively mined longwall panels in Greene County, Pennsylvania. Overburden thickness was 750-1000 feet, and the wells of a depth similar to domestic water wells, 150 feet. The wells over the panel centerlines showed the greatest water level fluctuations and loss of static head. Fluctuations and head loss also occurred over previously mined panels during active mining of an adjacent panel. Water levels in four wells recovered to near-premining levels within 18 months after mining; the fifth stabilized for several months after being undermined and then went completely "dry" for the remainder of the study.

Schultz's study involved not only well level monitoring but also aquifer tests. Ten observation wells 17 to 150 feet deep over two longwall panels, mined at depths of 670 to 804 feet, were monitored, along with springs and seeps. Eight of the wells were near the panel centerlines. Supporting Booth's conceptual model, subsidence over the panels caused increased permeability. Of the eight wells in which usable results were obtained, there were static water level declines of less than 10 feet in six wells, 25 feet in one well, and 42 feet in another. Water levels were influenced by dry weather as well as mining. Three observation springs located above the panels showed a decline in discharge, while new springs or seeps were observed forming downslope from them.

Thirty-nine wells in areas not undermined during the study period were also monitored. These wells were in areas grouped into three types: 1) areas not undermined; 2) areas previously undermined by room-and-pillar methods; and 3) areas previously undermined by longwall mining methods.[66] The mean seasonal water level in wells in longwall-mined areas ranged from 2.64 to 31.35 feet lower than in wells in the other areas. Twenty-nine percent of the wells in longwall-mined areas were dry at least once during the study period compared to 3 percent of the wells in other areas. The mean annual water level fluctuation was higher in wells in longwall-mined areas than in those in the other areas.

Coe and Stowe evaluated changes in the hydrologic balance above two longwall operations in the Appalachian coal basin in Ohio. The water level in a deep well dropped dramatically when an adjacent panel was mined. Shallow water sources located above or adjacent to active panels were all affected. However, over a second mine, the majority of water sources monitored were not affected by longwall-related

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[62] Dixon, D. Y.; Rauch, H. W. "The Impact of Three Longwall Coal Mines on Streamflow in the Northern Appalachian Coal Field." Paper presented at Geological Society of America Annual Meeting, St. Louis, Missouri, 1989. GSA Meeting Paper Abstracts, 21(6):A231, 1989.

[63] Jernejcic, *ibid.*; and Holbrook, J., Anthracite Reclamation Programs Branch, U.S. Office of Surface Mining, Wilkes Barre, Pennsylvania. Personal communication, January 6, 1989.

[64] Walker, J. S.; Green, J. B.; Trevits, M. A. "A case study of water level fluctuations over a series of longwall panels in the northern Appalachian coal region." In: Peng, S. S. (ed.) *Proceedings, 2nd Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, June 9-11, 1986*. Morgantown: West Virginia University, Department of Mining Engineering, August 1986, pp. 264-269.

[65] Schultz, Robert A. *Ground-Water Hydrology of Marshall County, West Virginia, with Emphasis on the Effects of Longwall Coal Mining*. Charleston, West Virginia: U.S. Geological Survey, Water Resources Investigations Report 88-4006, 1988, 139 pp.

[66] Schultz does not report how long before his study mining took place.

subsidence. Lithology and topography apparently accounted for the difference in mine effects on water sources; although overburden thickness above the second mine was only half that above the first mine, a higher percentage of clays, shales and claystones, together with less-rugged topography, apparently accounted for the difference.[67]

Groundwater impacts were evaluated over three mine sites, two in northern West Virginia and one in southwestern Pennsylvania, by Dixon and Rauch. The study specifically focused on determination of the maximum extent of dewatering; the potential for physical damage from subsidence to well structures; the recovery of water levels after dewatering; and the geologic and mining factors responsible for observed effects. The three mine sites were distinguished primarily by the thickness of overburden above the mine workings. Dewatering of groundwater supplies due to subsidence over longwall panels was measured or reported at all three sites, with the most extensive dewatering occurring at the site where overburden was thinnest (Site A, less than 160 feet) and least extensive dewatering occurring at the site with the thickest overburden (Site C, 320 to 640 feet). Water level recovery was greater at the two sites with thick overburden, and much less extensive at the other site. At Site A, shallow dug wells in valleys and near streams showed full recovery within eight months of dewatering, in contrast to dug wells on hillsides and drilled wells. At Site C, water levels in accessible shallow wells returned to normal within one to 14 days after initial dewatering. At site B, extent of recovery was not determined. Hydraulic conductivity in shallow rock strata with 250 feet of the surface was measured at Site C, and increases of five- to 500-fold were observed. Structural damage to undermined wells, including collapsed well strata, ruptured well partitions, ruptured plastic pipe, and pinched metal pipe, was common at Site A, but less common at Site C.[68]

One of the most comprehensive studies of the effects of coal mining on water resources was undertaken by Stoner *et al.* in Greene County, Pennsylvania.[69] Extensive hydrologic and geologic data were evaluated in order to assess the effects of past and current mining, both surface and underground, on groundwater and surface water quantity and quality. A numerical model was developed to clarify groundwater flow and to predict effects of future mining on groundwater flow and static levels. One component of the study involved the monitoring of groundwater levels over three different active underground mines: one room-and-pillar, one pillar removal, and one longwall mine. In one well, the bottom of which was located 240 feet above the room-and-pillar mine, no decline in static water level was observed. A well 608 feet above a longwall mine showed an eight-foot decline, with nearly immediate recovery. However, the static water level in the well whose bottom was located 90 feet above a pillar-removal operation dropped 200 feet and had not recovered appreciably at the end of a year. Five test wells installed above abandoned underground mines showed water level fluctuations similar to those in wells over unmined areas, suggesting that water-level conditions generally stabilize after completion of underground mining. The extremely rapid recovery observed in the well above the longwall mine was not predicted by the groundwater simulation model.

Summarizing from their investigations, Stoner *et al.* state that "future underground mining of the Pittsburgh coal, where overlying rocks are not fractured to the depth of the mine, will not appreciably affect

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[67] Coe, C. J.; Stowe, S. M. "Evaluating the impact of longwall coal mining on the hydrologic balance." In: Graves, D. H.; De Vore, R. W. (Editors) *Proceedings, 1984 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, University of Kentucky, Lexington, December 2-7, 1984.* Lexington: University of Kentucky, Office of Engineering Services (Bulletin UKY BU136), pp. 395-403, December 1984.

[68] Dixon, D. Y.; Rauch, H. W. "Study of Quantitative Impacts to Ground Water Associated with Longwall Coal Mining at Three Mine Sites in the Northern West Virginia Area." In: *Proceedings, Seventh International Conference on Ground Control in Mining, August 3-5, 1988, Morgantown, West Virginia.* Morgantown: West Virginia University, 1988, pp. 321-335.

[69] Stoner, J. D.; Williams, D. R.; Buckwalter, T. F.; Felbinger, J. K.; Pattison, K. L. *Water Resources and the Effects of Coal Mining, Greene County, Pennsylvania.* Prepared by the U.S. Geological Survey, Water Resources Division, in cooperation with the Pennsylvania Geological Survey. Harrisburg: Pennsylvania Geological Survey, Water Resource Report 63, 166 pp. plus maps, 1987.

groundwater quantity in Greene County."[70] Possible exceptions to this general prediction would occur where overburden depth is less than 300 feet, and in situations where "vertical fracture zones or fractures caused by collapsed mine workings effectively connect shallow aquifers to a deep mine."[71] In general, the authors suggest that the effects of fracturing from deep mines will be isolated and generally less than those reported in cases where the mining has not been as deep. Changes in groundwater quality due to underground mining were not documented, in contrast to observed effects of active and reclaimed surface mines. Surface mining of coal also adversely affected water levels in nearby wells. Acid mine drainage into surface waters was found to be common in eastern Greene County, where past and present mining has been concentrated.

Summary of Field Studies

This chapter has reviewed a number of studies on the hydrologic effects of high-extraction underground coal mining in the Appalachian region. They are listed in Table 2 along with the location and characteristics of the study.

Following is a discussion of the extent to which certain specific effects alleged to result from high-extraction mining are supported by the research reviewed. The application of study results to coal mining conditions in Virginia is discussed in the next section.

1. *Subsidence affects groundwater hydrology.* All studies reviewed support this conclusion.

2. *Wells within the subsidence area may be dewatered to some extent; i.e., they may exhibit at least short-term drops in static water levels.* All relevant studies reviewed support this conclusion.

3. *Shallow aquifers are less likely to exhibit water level declines than deep aquifers.* There is considerable disagreement among the studies with respect to this statement, indicating that site-specific factors, including overburden thickness and character and especially vertical separation between well bottom and mined seam play a major role. Booth's model predicts that shallow wells will be affected regardless of a vertical hydraulic connection to the mine void, while Stoner would expect impact to shallow wells only if such a connection exists. In general, however, the studies reviewed indicate that wells vertically closer to mine works are more likely to be affected. Rauch's explanation of the different zones above a collapsed mine void lends conceptual support to this conclusion.

4. *The likelihood of dewatering depends on a well's horizontal distance from the mined panel, with those within an angle of draw at increased risk and those above the panel centerline at greatest risk.* Booth's conceptual model predicts this conclusion, and his study of well response to a longwall panel indicated that wells within 1400 horizontal feet of the panel showed some dewatering, while those farther away did not. Moebs and Barton found that water levels within the boundary of the longwall panel showed precipitous decline, while those 500 feet or more outside the panel rib line, and outside a 25° angle of draw, were unaffected. Rauch, generalizing from his own and others' studies, describes an "angle of dewatering influence" of about 30° +/- 10° with respect to groundwater loss near longwall panels.[72] In fact, most studies in which monitoring wells were positioned both inside and outside of the subsided area support this conclusion.

5. *Water level declines in affected wells are only short-term.* There is conflicting evidence regarding the duration of effects on groundwater. Most studies suggest that site-specific factors determine the rapidity of recovery. Such factors include vertical distance between the mine workings and the well bottom; well location, coal seam depth, and overburden thickness and character; whether

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[70] *Ibid.*, p. 107.

[71] *Ibid.*

[72] Rauch, H. W. West Virginia University, Morgantown, West Virginia. Personal communication, January 16, 1990.

TABLE 2: SUMMARY OF STUDIES

Author	Location	Mine Depth (Ft.)	Mine Type	Focus
Hasenfus *et al.* 1988	WV	700	Longwall	Static water levels, aquifer characteristics; relationship of geomechanics to aquifer recovery
Hobba 1981	WV	< 150 600-700	Abandoned	Hydrologic balance
Stoner 1983	PA	unspecified	Pillar retreat and longwall	Aquifer characteristics, recovery of shallow aquifers
Pennington *et al.* 1984	PA	550	Longwall	Static water levels, aquifer characteristics
Tieman & Rauch 1987	PA	650-1000	Longwall	Dewatering effects on wells, springs, and streams
Bruhn 1986	WV	600	Pillar retreat	Effects on aquifers at different depths
Moebs & Barton 1985	PA	750-1000	Longwall	Static water levels and streamflow; angle of draw
Cifelli & Rauch 1986	WV	unspecified	Longwall and pillar retreat	Groundwater effects of high-extraction mining vs. abandoned room-and-pillar
Dixon & Rauch 1989	WV	< 500 > 500	Longwall	Subsidence impacts on streams
Walker *et al.* 1986	PA	750-1000	Longwall	Impacts on wells over multiple longwall panels
Schultz 1988	WV	670-804	Longwall, room-and-pillar	Effects on wells over two panels; comparison with unmined, previously room-and-pillared, and previously longwalled
Coe & Stowe 1984	OH	unspecified	Longwall	Hydrologic balance; shallow vs. deep wells
Dixon & Rauch 1988	WV, PA	< 160 160-320 320-640	Longwall	Static water levels, dewatering bounderies and factors, damage to well structures
Stoner *et al.* 1989	PA	Various	Various	Regional impacts of mining on water resources; groundwater impacts of longwall, room-and-pillar, pillar retreat, and surface mining; modelling

the mine workings are above or below drainage; topography; the presence of lineaments and vertical fractures; hydraulic connections between streams and wells; and the presence or absence of aquitardal layers. Booth notes that "subsidence-induced permeability increases in shallow aquifers cause increased throughput and (accentuated by storativity increases) lowered water levels in recharge zones," while later compression and settlement "cause partial reductions in permeability and storativity and partial recoveries in water levels."[73] Examples of complete recovery, partial recovery, and no recovery of wells are found throughout these studies. It should be noted that most of the studies did not continue monitoring longer than one year after mining, and thus could not draw conclusions with respect to long-term effects. Three studies (Hobba; Cifelli and Rauch; Stoner *et al.*) examined hydrologic impacts over relatively long-abandoned mines. Stoner's data suggest that groundwater availability over abandoned mines may not be appreciably different from that in unmined areas, although in cases where mine collapse causes fracturing of overburden, this may not hold. Schultz found that wells over abandoned longwall mines showed decreased water levels relative to those over abandoned room-and-pillar mines and those in areas never undermined. It is unclear from his study, however, how long before well monitoring the mining had been done. Moreover, several of these studies coincided with periods of low precipitation, which is likely to have affected recharge and well recovery.

6. *Springs and streams above or close to high-extraction mines may be adversely affected (i.e., partially or completely dewatered).* Of the studies in which springs and streams were monitored, those of Cifelli, Schultz, Dixon and Rauch, and Coe indicated dewatering, while those of Moebs and Pennington did not. Again, site-specific factors of hydrogeology, mined seam elevation in relation to major drainage, and location of the spring or stream probably control.

7. *Water quality of streams, springs, and wells in the vicinity of high-extraction mines is unlikely to be significantly affected.* Most of the studies reviewed focused primarily on mining effects to water movement and availability. Of those that examined water quality changes after active mining, most found that water quality changes were transient and of small magnitude. Whether such changes are significant biologically or for human use was not directly addressed. Potential effects are likely to be highly dependent on site-specific factors, including the mineral composition of overburden.

8. *Subsidence may make more groundwater available for development.* There are several aspects of groundwater availability for development: infiltration, hydraulic conductivity, and storativity. Increased fracturing associated with subsidence would logically be expected to enhance these aspects of groundwater availability owing to decreased runoff, greater infiltration, and increased storage. Increased amounts of groundwater available for development would depend on where increased storage and enhanced secondary permeability occurred. Static water levels might also show increased fluctuation in response to precipitation events. Results from studies in which aquifer testing was conducted are mixed, however, indicating once again that site-specific factors may control. Bruhn found that the effect of pillar retreat mining was either to leave hydraulic conductivity unchanged or to increase it by one or two orders of magnitude. No dominant trend in storativity values was observed in his study. Pennington found that "fracturing from subsidence apparently has little effect on the hydraulic conductivity of the aquifers."[74] Hobba found that high transmissivities were associated with areas affected by mine collapse, and concluded that mining and mine subsidence "increases the total amount of water available for development by

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[73] Booth, C. J., *op cit.*,, p. 514.

[74] Pennington, D., *et al.*, *op. cit.*, p. 93.

permitting increased infiltration and reduced evapotranspiration."[75]

9. *Subsidence may alter stream flow characteristics.* A potential effect of subsidence on surface streams is alteration of base flows. In his investigation of hydrologic effects of subsidence due to underground mining, Hobba found that subsidence increased infiltration, reduced evapotranspiration, and increased base flows in small streams draining the subsided area.[76] Ecological and social impacts stemming from such an effect might be beneficial, because streams in the coalfields are known for quick discharge of precipitation runoff and low base flows. None of the studies examined the effects of mine subsidence on peak flows.

Applications to Virginia

The studies reviewed above were conducted in the northern Appalachian region of Pennsylvania, West Virginia, and Ohio. Therefore, conclusions drawn from them are limited to their specific areas, geological formations, and mining conditions. Nevertheless, because of broad geological similarities between those areas and the Virginia coalfield region, it is possible to draw inferences about the *potential* effects of high-extraction mining in Virginia. Moreover, no published studies have focused on the hydrologic effects of subsidence in the Commonwealth.

Geology and mine depth are two important factors in understanding the implications for Virginia of the out-of-state studies. Concerning geology, some conditions in Virginia are different from northern West Virginia and Pennsylvania; for example, the massive sandstone formations found in some parts of the Virginia coalfields have no counterparts in northern West Virginia or Pennsylvania. On the other hand, there is considerable variation in geomechanical properties of overburden even within Virginia. The studies reviewed include a range of geologic conditions and demonstrate potential impacts in a variety of situations.

Concerning mine depth, there was a great deal of longwall mining done in relatively shallow coal seams in West Virginia during the early 1980s. Several of the studies reviewed included mines at depths less than 500 feet, while about half studied mines at 600 to 1000 feet. In contrast, seven of Virginia's ten operating longwall mines are mining seams with 1000 to 2700 feet of overburden. The minimum overburden of the other three longwall mines operating in Virginia is 420 feet.[77] On the other hand, most of Virginia's pillar extraction operations are above drainage, operating at considerably less depth than the state's longwall operations, at depths similar to those mines documented in reviewed studies. Despite the differences, the apparent similarities between the geology, topography, and mining techniques in the published studies reviewed above and those found in the Virginia coalfields lend credence to the view that the *potential* exists for similar effects in Virginia.

There is some evidence that effects similar to those documented elsewhere are being experienced in Virginia. From 1983 through 1989, DMLR received 52 complaints of well loss, spring loss, well degradation, or pond loss associated with subsidence from underground mining. Twelve were judged valid by the agency; fifteen not valid; twelve inconclusive because of insufficient data; and the remainder (13) are either under investigation or have been settled privately. Of the 52 water-related complaints, 27 were at mines with longwalls. The number of valid, not valid, inconclusive, and other complaints associated with longwall mines were, respectively, five, two, ten, and ten.[78] Another six complaints of spring loss or well loss during the same period were judged by DMLR to be due to subsidence from non-longwall underground mining operations.[79] While these numbers by themselves cannot

[75] Hobba, W. A., Jr., *op. cit.*, p. 74.

[76] *Ibid.*

[77] Randolph *et al.* 1989.

[78] DMLR complaint investigation file, Big Stone Gap, February 1990.

[79] *Ibid.*

support conclusions (primarily because they do not represent the universe of water problems caused or alleged to be caused by high-extraction mining in Virginia, as discussed in Chapter 6), they do suggest that some adverse hydrologic impacts are being experienced in the coal fields.

The potential effects of mining-induced subsidence on groundwater levels and flow in the Virginia coalfields are likely to be localized. According to the findings in available literature, effects such as lowering of groundwater levels and dewatering of aquifers that supply wells, springs, and seeps are not likely to extend much beyond a limit defined by an angle of draw generally between 15 and 35 degrees. This is expected because of the low transmissivities of deep lithologic units, except where lineaments or large fractures are encountered. Moreover, groundwater systems in the coal-producing region of Virginia are generally limited by topography, with no hydrologic connection between groundwater systems from one valley to the next. This fact is recognized by Epps in her report on groundwater prospects for Buchanan County:

> Groundwater shortages in high use areas will become more severe unless new areas with underdeveloped groundwater supplies are tapped. Considering the difficult terrain and the economics involved, it is probable that people in built-up sections will continue to suffer seasonal shortages which will gradually become year-round shortages while the next valley a mile away has groundwater to spare.[80]

To say that the hydrologic effects are localized is not to diminish their importance. The impacts of these effects can be severe to affected individuals and local ecosystems. And while the area of potential effects around a particular high-extraction mine in most cases does not extend far beyond the undermined area, some of these operations are very large, with thousands of acres subject to subsidence over their life. The percentage of land area in Buchanan, Dickenson, and Wise counties that may ultimately be affected by high-extraction mining subsidence is substantial. Nevertheless, it should be possible in most cases to determine the limits beyond which subsidence-related groundwater effects/impacts will not occur. Effects on surface waters could create impacts outside the immediate area of the mining operation. Research suggests that streams draining mined areas show changes in chemical composition, with increased sulfate levels and in some cases increased dissolved solids.[81] These effects, however, are perhaps more closely related to surface mining. Virginia is fortunate that the pyritic geological strata responsible for the worst acid mine drainage problems in other Appalachian states are not present in large quantities.

Summary

There is considerable research evidence of short-term hydrologic impacts of rapid subsidence; the exact nature of the effects depends on site-specific factors of lithology, topography, and stratigraphy, as well as the location, dimensions, and timing of mining operations. The studies reviewed seem generally consistent with Booth's conceptual model, in which fracturing and sagging of strata overlying high-extraction mines and within a specified and limited angle of draw increase transmissivity and storativity both in deep formations and in shallow aquifers. Groundwater levels are likely to decrease in the vicinity of subsided areas, affecting wells and springs, and groundwater flows may be disrupted. Several researchers saw evidence of at least partial aquifer recovery to premining levels after completion of active subsidence. In the few studies that examined water quality impacts, the effects of subsidence on groundwater, if any, were short-term and minor. Water quality impacts could be a concern where there are large deposits of pyritic or other highly reactive mineral materials in the overburden, but this is generally not a problem in Virginia. Surface streams may be directly affected by

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[80] Epps, S. R. *Buchanan County Groundwater: Present Conditions and Prospects*. Richmond: Virginia State Water Control Board, Planning Bulletin 311, October 1978, p. 73.

[81] Larson, J. D.; Powell, J. D. *Hydrology and Effects of Mining in the Upper Russel Fork Basin, Buchanan and Dickenson Counties, Virginia*. Richmond: U.S. Geological Survey, Water-Resources Investigations Report 85-4238, 1986; and Rogers, S. M.; Powell, J. D. *Quality of Ground Water in Southern Buchanan County, Virginia*. Richmond: U.S. Geological Survey, Water-Resources Investigations Report 82-4022, May 1983.

streambed fracturing or indirectly affected by groundwater rerouting. Although the studies reviewed in this chapter were not conducted in Virginia, and there are some differences in geologic structure, basic similarities in mining, geology, and topography between the Virginia coalfields and those of the studied areas lead to a conclusion that similar effects could be occurring here.

Chapter 5: Institutional Mechanisms for Protection of Water Resources

This chapter reviews the institutional controls -- the laws, policies, and implementing government agencies -- that protect Virginia's water resources and users from adverse subsidence effects. Two major water resource protection mechanisms are described:

1. The Surface Mining Control and Reclamation Act (SMCRA), as implemented by VDMLR, which provides a mechanism for protection of water resouces considered apart from human uses.

2. The common law, which provides protection for water resources only when property rights are involved.

Regulatory Framework Under SMCRA

Public policy must determine what level of water resources protection is possible, desirable, and appropriate. Those involved in the policymaking process must weigh the potential social and environmental impacts of high-extraction coal mining against the potential economic impacts of regulation.

In theory, levels of protection range from full protection to none at all. This issue can be viewed as a continuum, associating with each level of protection a level of acceptable damage. In a general sense it is possible to distinguish a few broad categories:

Full protection. No damage would be allowed to groundwater and surface water resources. No diminution in quantity or quality would be allowed, consistent with Virginia's antidegradation policy for groundwater quality.[82] There would be no adverse social or environmental impacts (apart from the opportunity cost of mining), and productive and beneficial uses of both water and land (insofar as its use depended on water availability) would be unimpaired. Given that the technical studies reviewed in the previous chapter show that high-extraction mining may cause adverse effects to water resources, this level of protection is probably inconsistent with further development of coal resources through high-extraction mining.

Partial protection. Partial protection would allow limited deterioration of water quantity or quality in connection with coal extraction. Limits could be set in terms of severity of degradation, areal extent, and duration. Allowable damage would be short-term, localized, and consistent with long-term, cumulative protection of the resource. For example, temporary disruption of wells and streams, with recovery after a year or two, might be permitted under a partial protection standard. Partial protection is consistent with a cost-benefit approach, because it allows for flexibility and compromise. Temporary disruption of streams and wells within a circumscribed area might be considered a reasonable price to pay for extracting coal. (Who pays the price is a distinctly different question). The cumulative effect of numerous short-term, local water resource disruptions must also be considered in permitting decisions.

No protection. If no protection were provided, coal mining operators would not be required to take any measures to prevent erosion, treat mine drainage, or remediate damage to surface owners or the environment. Costs to mining firms would be reduced, allowing coal to be sold at more competitive prices on the world market. Coal mine employment would probably in-

[82] See section in this chapter on Virginia water law and policy.

crease, with attendant regional economic benefits. Disruption of existing water resource use could be widespread, particularly in areas with numerous mining operations. In a worst-case scenario (mining above drainage, severe fracturing to surface), wells, springs, and streams could be damaged or destroyed and surface owners left with no legal recourse. Productive use of land and water resources could be seriously disrupted. The need to protect and replace vital water supplies would subject the region's citizens, industries, and governments to numerous costs.

In terms of the preceding framework, Congress intended to provide for partial protection of water resources in passing the Surface Mining Control and Reclamation Act of 1977.[83] SMCRA has two overall purposes: to encourage exploitation of coal resources, and to minimize environmental damage in doing so. The following review of SMCRA provisions (as implemented in Virginia) shows that Congress was aiming at a level of protection of hydrologic resources that would minimize mining impacts, containing them both spatially and temporally. Throughout the Virginia and federal statutes is the phrase, "minimize the disturbance to the hydrologic balance," the performance standard for allowable hydrologic damage within the mine permit and adjacent areas. Outside the permit area, "material" damage is to be prevented.

Such a standard only implies that the operation will do no more damage than necessary, that the damage will "constitute the least possible." No standard of protection is implied by "minimal damage." In theory, a mining operation could minimize the environmental disturbance to the extent technologically and economically feasible, and still do considerable damage.

Clearly, extraction of coal reserves cannot be accomplished without some localized, short-term effects on water resources. Short-term, localized damage consistent with long-term, cumulative protection is what Congress seems to allow in requiring that (a) damage to the hydrologic balance be minimized within the permit area (localized damage); (b) lasting impacts be considered in the cumulative hydrologic impact assessment (CHIA) process; and (c) impacts outside the permit area (nonlocalized damage) be prevented. This localized, short-term damage constitutes environmental degradation acceptable under SMCRA.

Although SMCRA and its implementing regulations are highly detailed and complex, Congress and OSM recognized that there would be many determinations that could not be made across the board and were better delegated to the judgement and discrimination of those implementing the regulations. Through such terms as "minimize," "aquifer that significantly ensures the hydrologic balance," "material damage," and the like in SMCRA, Congress left considerable latitude to DMLR and similar agencies in other states for determining levels of protection for the hydrologic balance.

Virginia's Coal Surface Mining Reclamation Regulations

The Virginia Coal Surface Mining Control and Reclamation Act (VCSMCRA) was passed to implement a state primacy program under SMCRA. Regulations instituted by DMLR in the Department of Mines, Minerals, and Energy (DMME) are similar to the federal regulations. Following the federal regulatory scheme, Virginia's regulations rely on a system of permitting, bonding, monitoring, and detailed performance standards for all phases of coal mining operations to achieve their purpose: to minimize environmental damage associated with coal mining. The following sections describe relevant permitting, monitoring, and performance requirements for protection of the hydrologic balance.

Permitting Requirements

General. Applicants for underground mine permits are required to submit a general description of premining environmental conditions, including: cultural and historic resources; climate; vegetative cover; fish and wildlife resources; and land use, capability, and productivity. Detailed information regarding the mine itself is required in an operations plan, including maps; schedules of planned operations; mining techniques and equipment; and an explanation of planned

[83] Note, however, that one of Congress' stated purposes in the Act is to "assure that the rights of surface landowners and other persons with a legal interest in the land or appurtenances thereto are *fully protected* from such operations" (emphasis added). SMCRA Sec. 102(b), 30 U.S.C.A. Sec. 1202(b).

construction, maintenance, use, and removal of mining facilities. A reclamation plan describing intended methods and timing of reclamation efforts, and their estimated cost, must also be submitted.

Hydrologic Information. Detailed hydrologic information must also be submitted with the permit application. Required baseline groundwater information includes "the location and ownership for the permit and adjacent areas of existing wells, springs, and other ground-water resources, seasonal quality and quantity of ground water, and usage."[84] Minimum requirements for groundwater quality include measures of total dissolved solids, pH, total iron, and total manganese. For groundwater quantity, minimum requirements are "approximate rates of discharge or usage and elevation of water in the coal seam, and each water-bearing stratum above and potentially impacted stratum below the coal seam."[85] Additional data may be required if a determination of probable hydrologic consequences (PHC; see below) indicates that adverse impacts to the hydrologic balance may occur, on or off the permit area.

There is a difference between the hydrologic information requirements applicable to surface mines and those applicable to underground mines. For surface mines expected to adversely impact water resources used for domestic, agricultural, industrial, or other purposes, applicants are required to identify alternative sources of water. In the case of surface mining, DMLR also has the authority to require the mining company to replace affected water supplies. Identification of alternative sources and replacement of adversely-affected water supplies are not required for underground mines.

PHC. The permit applicant is required to submit a determination of probable consequences of mining on the "quality and quantity of surface and ground water under seasonal flow conditions for the proposed permit and adjacent areas."[86] The PHC (probable hydrologic consequences determination) describes potential adverse impacts, if any, on the hydrologic balance, including sediment yield from the disturbed area; acidity, total dissolved and suspended solids, and other water quality parameters; flooding or streamflow alteration; and ground and surface water availability. The PHC must also determine whether contamination of ground or surface water could occur as a result of contact with toxic or acid-forming materials. Each permit revision for an ongoing mining operation must be reviewed by DMLR with regard to whether or not a new or revised PHC is necessary.

CHIA. Before issuing a permit, DMLR is required to assess of the probable consequences of the applicant's mine, together with all other active, planned, or abandoned mines in the area, on the area's water resources. This "cumulative hydrologic impact assessment" (CHIA) must also be reviewed for each permit revision. The purpose of the CHIA is to determine "whether the proposed operation has been designed to prevent material damage to the hydrologic balance *outside the permit area*"[87] (emphasis added).

Hydrologic Reclamation Plan. A hydrologic reclamation plan must be submitted, explaining how the applicant's mining and reclamation operations will be conducted to "minimize the disturbance to the hydrologic balance" within the permit and adjacent areas, to prevent material damage outside the permit area, and meet applicable water quality laws and regulations, in particular those of the Clean Water Act at 40 CFR Part 434. Specific objectives of the plan are to "avoid acid or toxic drainage; prevent to the extent possible using the best technology currently available additional contributions of suspended solids to streamflow; provide and maintain water treatment facilities when needed; control drainage; and restore approximate premining recharge capacity."[88] The plan must specifically address the potential adverse impacts identified in the PHC.

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[84] Sec. 480-03-19.784.14

[85] *Ibid.*

[86] Sec. 480-03-19.784.14(e)

[87] Sec. 480-03-19.784.14(f). "Material damage" is used in the context of SMCRA to mean functional impairment.

[88] Sec. 480-03-19.784.14(g)

TABLE 3: ELEMENTS OF THE MINE PERMIT APPLICATION PROCESS

Submitted by Applicant

- Premining Environmental Resources Information
- Mine Operation Plan
- Reclamation Plan
  - Geologic Information
  - Groundwater Hydrology
  - Surface Water Hydrology
  - Probable Hydrologic Consequences
  - Hydrologic Reclamation Plan
  - Groundwater Monitoring Plan
  - Surface Water Monitoring Plan
  - Subsidence Survey
  - Subsidence Control Plan

Performed by DMLR

- Cumulative Hydrologic Impact Assessment

Monitoring. The PHC provides the basis for design of monitoring plans, focused on parameters related to the suitability of ground and surface water for current and approved postmining land uses. The design and intensity of monitoring efforts depend on expected hydrologic consequences.

Groundwater monitoring plans should include installation of monitoring wells in significant water-bearing strata; water quality monitoring within the permit area; and individual monitoring of "each significant aquifer" in any adjacent area that has wells, springs, and/or mine discharges. Quarterly submission of data is required. Monitoring must be sufficient to identify the causes of any diminution or contamination of usable groundwater, guard against offsite influences, and provide representative data on the effects of the proposed coal mining operation. Specific DMLR instructions for groundwater monitoring allow for tailoring of the monitoring network according to the specific conditions and expected effects of the mining operation, and for waiving or adding some monitoring requirements at the discretion of the regulatory agency.

Surface water monitoring requirements include measurements of total dissolved solids or specific conductance, total suspended solids, pH, total iron, total manganese, and flow at strategic locations upstream and downstream of potential impact areas. Point source discharges must be monitored in accordance with Clean Water Act requirements.

Subsidence Survey and Control. For underground mines a subsidence control plan is required. The permit must include information on and show the location of structures or renewable resource lands within the permit or adjacent areas. Renewable resource lands are defined as "areas which contribute significantly to the long-range productivity of water supply or of food or fiber products, such lands to include aquifers and aquifer recharge areas."[89] The plan must demonstrate whether or not subsidence will cause material damage or diminution of reasonably foreseeable uses of structures or resource lands, including aquifers.

If so, the plan must contain a description of the size, sequence, and timing of development of underground mine works; the mining method used; a description of the geological conditions likely to affect subsidence development and its effects; and a description of the anticipated effects and measures planned for mitigation of these effects. Po-

[89] Sec. 480-03-19.700.5

tential impact areas are usually calculated using a 28 degree angle of draw.[90]

If the preliminary survey shows, and DMLR agrees, that structures or resource lands do not exist in the permit or adjacent areas, or that subsidence would not cause material damage, no further information is required.

Performance Standards

Hydrologic Balance Protection. The general performance standard for underground mines is that all operations "shall be conducted to minimize disturbance of the hydrologic balance within the permit and adjacent areas, to prevent material damage to the hydrologic balance outside the permit area, and to support approved postmining land uses."[91]

Specific performance standards for groundwater protection relate primarily to effects within the permit area of surface operations associated with underground mining: handling of earth materials, excavations, and drainage control. Besides the requirement that these operations be conducted to minimize acidic or toxic infiltration to groundwater systems and restore the approximate premining recharge capacity, the specific performance standards in this section (480-03-19.817.41) are related entirely to monitoring. Only one section raises the possibility that something other than monitoring may be required: Section 480-03-19.817.41(c)(2)(ii) states, "if degradation, contamination or diminution of water quality or quantity are evident through monitoring, then additional monitoring *and/or remedial action* may be required by the Division." (emphasis added).

Performance standards for both groundwater and surface water protection apply mainly to above-ground operations of an underground mine, apart from monitoring requirements. In both cases, monitoring is required throughout the course of mining and reclamation until bond release, unless DMLR is satisfied the operation has met the general performance standards stated above.

Subsidence Control. The performance standards for subsidence control demonstrate the apparently paradoxical treatment of longwall and other high extraction mining methods evident in SMCRA.[92] Mine operators must either take whatever measures are technologically and economically feasible to prevent subsidence resulting in material damage, or adopt a mining technique (e.g., longwall mining or pillar retreat mining) that provides for planned subsidence "in a predictable and controlled manner."[93] If subsidence results from a mining operation, the operator is required to repair surface damages "by restoring the land to a condition capable of maintaining the value and reasonably foreseeable uses which it was capable of supporting before subsidence";[94] and, *to the extent required by state law*, either correct material damage to any structures or facilities by repair or compensation. The emphasized phrase reflects a significant change in the federal regulations, the consequences of which are discussed below.

Underground mining cannot be conducted under or adjacent to public buildings;

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[90] Brown, D. R., Commissioner, DMLR. Memorandum re: Requirements for Subsidence Control Plans, October 10, 1986.

[91] Sec. 480-03-19.817.41(a)

[92] "Paradoxical" in that subsidence from underground mining causing material damage is not allowed, *except* in "those instances where the mining technology used requires planned subsidence in a predictable and controlled manner." SMCRA Sec. 516(b)(1), 30 U.S.C. 1266. This clause reflects Congress' concern for prevention of unplanned subsidence years after completion of mining, and their conviction that high-extraction mining was preferable in this respect. The Congressional sponsors of SMCRA, according to Congressman Morris Udall (Arizona) (one of the bill's principle proponents) considered longwall mining "ecologically preferable, and it and other methods of controlled subsidence are explicitly endorsed." 123 *Congressional Record* H22731, July 10, 1974; quoted in Gorrell, G. R.; McGuire, K. M. "Major issues in subsidence regulation." In: Peng, S. S. (ed.) *Proceedings, 2nd Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, June 9-11, 1986*. Morgantown: West Virginia University, Dept. of Mining Engineering, August 1986, pp. 19-30.

[93] Sec. 480-03-19.817.121(a)

[94] Sec. 480-03-19.817.121(c)

TABLE 4: PERFORMANCE STANDARDS FOR HYDROLOGIC BALANCE PROTECTION

Inside the Permit and Adjacent Areas

- Minimize disturbance to the hydrologic balance
- Support approved postmining land uses

Outside the Permit and Adjacent Areas

- Prevent material damage

churches, schools, and hospitals; or water impoundments, unless the subsidence control plan demonstrates that subsidence will not cause material damage. DMLR reserves the right to limit the amount of coal extracted in order to prevent subsidence damage to the facilities listed above, and to "any aquifer or body of water that serves as a significant water source for any public water supply system."[95] The agency can also suspend mining operations if such damage is imminent, or if public safety is imperiled. Finally, mining operators are required to give six months notice to owners and occupants of surface structures beneath which mining is planned.[96]

Significant Regulatory Changes

Since Virginia's regulatory program under SMCRA was approved by the U.S. Secretary of the Interior in 1981, there have been significant modifications to regulations defining protection of the rights of surface owners affected by subsidence. These modifications have resulted from litigation over statutory authority for some regulatory requirements.

Replacement of Water Supplies. One significant change for protection of surface owner rights concerns the requirement for replacement of water supplies damaged by mining operations. As mentioned above, Virginia regulations and those of the Office of Surface Mining Reclamation and Enforcement (OSMRE) at the federal level require replacement of water supplies disrupted by surface mining, but not those disrupted by underground mining. In OSMRE's original (1979) regulations under SMCRA the water replacement requirement was considered applicable to both surface and underground mining.[97] However, in *In Re: Permanent Surface Mining Regulation Litigation*,[98] Judge John Flannery, (U.S. District Court for the District of Columbia), ruled that the language in SMCRA, Sec. 717. applied only to surface coal mining, despite the fact that in Sec. 701, "surface coal mining operations" is defined to include "surface impacts incident to an underground coal mine" as well as the areas "where such activities disturb the natural land surface." Following this ruling, federal regulations were modified accordingly (in 1983, under Interior Secretary Watt) and Virginia incorporated this distinction in its permanent regulatory program.

A challenge by the National Wildlife Federation and others to the 1983 regulations pointed to SMCRA reclamation plan requirements as a basis for requiring water replacement by underground coal operators. Sec. 508(a)(13) calls for the reclamation plan to include a description of measures that will assure protection of the quantity of surface and ground water systems, both on- and off-site, *or to provide alternative sources of water where protection of quantity cannot be*

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[95] Sec. 480-03-19.817.121(d)

[96] In Virginia, the notice requirements are generally for surface owners and occupants over the mine works and (for high extraction mines) within a 28 degree angle of draw.

[97] Gorrell, G. R.; McGuire, K. M. "Major issues in subsidence regulation." In: Peng, S. S. (ed.) *Proceedings, 2nd Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, June 9-11, 1986.* Morgantown: West Virginia University, Dept. of Mining Engineering, August 1986, pp. 19-30.

[98] 19 *Environment Reporter*, *Cases*, 1477, 1495, May 16, 1980.

TABLE 5: CHANGES IN REGULATIONS

Federal	
1980	Ruling that water replacement was not required for underground mining operations.
1987	Deference to state law on liability for subsidence damage to structures.
Virginia	
1987	DMLR no longer responsible for enforcing liability for subsidence damage to structures.

assured. However, Judge Flannery ruled that this section's scope is limited to planning and permitting requirements, not performance standards.[99] The U.S. Court of Appeals, D.C. Circuit, later ruled in a consolidated appeal of this decision and other issues that Congress did indeed distinguish between surface and underground mining operations with respect to the duty to replace damaged water supplies.[100] As a result, water replacement is still not required for underground mining operations under federal regulations, although state regulatory agencies have the authority to require mitigation measures as conditions of the mine permit approval. It would appear that such measures include water replacement.[101] In order to provide for more consistent protection for surface landowners, some states have enacted laws requiring water supply replacement or compensation.[102]

Compensation for Subsidence Damage to Structures. In 1987, regulatory control over compensation for subsidence damage was removed. Prior to July 1987, Virginia's performance standards for subsidence control, like those at the federal level, provided for surface owner protection from the effects of subsidence. Mine operators, in the event of subsidence damage to structures and other surface features, were required to either promptly replace or repair each damaged structure to the condition it would have been in had subsidence not occurred; purchase the damaged structure for its pre-subsidence fair market value; or compensate the owner for subsidence damages.[103] In 1987 the federal regulations were revised, however, altering the damage correction provisions of both the subsidence control plan and subsidence control performance standards sections with the phrase, "to the extent required under State law."[104] Virginia changed

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[99] *In Re: Permanent Surface Mining Regulation Litigation*, 22 *Environment Reporter, Cases*, 2153, 2165, July 15, 1985.

[100] *National Wildlife Federation v. Interior Department* (1988), 27 *Environmental Reporter, Cases*, 1153.

[101] 52 *Federal Register* 4866, February 17, 1987.

[102] See Chapter 8.

[103] Sec. V817.124

[104] *Federal Register* 52(137):26972-26973, July 17, 1987. The provision that subsidence damage be addressed in subsidence control plans and that damage be corrected or compensated "only to the extent required under State law" was part of OSMRE's original regulations. However, in the Federal District Court for the District of Columbia, Judge John Flannery remanded this portion of the regulation simply on procedural grounds (*In re: Permanent II*, October 1, 1984). Meanwhile, in response to OSMRE's March 1985 notice that certain changes in Virginia's permanent program, originally approved by OSMRE in 1981, were necessary to ensure that it was "no less effective" than the federal program. In order to meet state needs and objectives, Virginia elected to completely rewrite its permanent program regulations. In November 1986, OSMRE found the clause, "to the extent required by State law" in Virginia's proposed revisions to be "less effective than the corresponding federal

its regulations accordingly, since VCSMCRA requires that the state's program be no more stringent than the federal program, and surface owners whose structures are damaged must now negotiate individually with coal companies individually or go to court. Mining operators are still required to repair or pay for damage to the land itself under both federal and state law.[105]

The remainder of this section discusses the extent to which surface owner property rights are protected by common law.

Common Law: Protection of Property Rights

The body of Virginia law concerning property rights in water makes a sharp distinction between waters flowing in a well-defined channel and "percolating" waters, i.e., what is normally thought of as groundwater. The doctrine of riparian rights applies to waters flowing in a channel, even if the channel is underground. Under this doctrine, riparian property owners (i.e., those owning property on the banks of the channel) have the right to use the water flowing through the channel, so long as this use does not interfere with similar rights of other riparian property owners downstream.

There are two common law doctrines that apply to groundwater rights. One is the so-called *English rule* of absolute ownership. The owner of a piece of land is entitled to the use of any and all groundwater he can recover. This rule has been facetiously referred to as the "law of the biggest suck" -- whoever has the biggest pump gets the water. There are no restrictions or considerations regarding water use, except that it cannot be used maliciously. The *American rule*, or "reasonable use doctrine," also allows the property owner to withdraw as much groundwater as he wishes, except that water use must be reasonable and on the premises; it cannot be exported. Virginia courts have held that mining operations are a reasonable use of property insofar as percolating waters intercepted by mining operations are concerned.[106] Although the Virginia courts have not made a definite choice between these two theories, the reasonable use doctrine seems to be favored.[107] The crucial difference between these doctrines and the riparian doctrine is that in the former, the effect of a property owner's use of groundwater on his neighbor's use is not considered. This is probably due to the archaic origins of common law, when groundwater's extent and movements were not understood.

Although the body of law governing the effects of underground mining on surface owner groundwater rights is still evolving, several important issues were settled early in this century. The distinction between waters flowing in well-defined channels and percolating waters was elaborated in *Clinchfield Coal Corp. v. Compton*,[108] where the court stated that for the riparian doctrine to apply, the water must not only flow through a defined channel, but that the channel must be discoverable by surface indications without excavation for that purpose. The presumption is that underground

rules," since that portion of the federal rules had been suspended. OSMRE subsequently rewrote the rules including the phrase in question, and approved the reinsertion of the phrase into Virginia's regulations on July 17, 1987.

[105] Although it remains true that coal operators are liable for damage to structures only to the extent required by state law as of the date of this publication, it appears that a change in federal regulations may occur as a result of a recent court decision. In *National Wildlife Federation v. Interior Department* (1990), the U.S. District Court of the District of Columbia ruled that the Interior Department acted improperly in making the rule change described above. 31 *Environment Reporter, Cases*, at 1007. The court ordered the regulations at 30 C.F.R. Sec. 827.121(c) remanded to the Secretary of the Interior. It appears that Interior will not appeal this ruling, but the coal industry (represented by the American Mining Congress and the National Coal Association, intervenors in the case under discussion) is considering an appeal, according to *Longwall Forum* 2(1). March 1990.

[106] *Clinchfield Coal Corp. v. Compton*, 148 Va. 437, 139 S.E. 308 (1927)

[107] Virginia Groundwater Protection Steering Committee. *A Groundwater Protection Strategy for Virginia*. Richmond: Virginia State Water Control Board, May 1987.

[108] 139 S.E. 308, 148 Va. 437 (1927)

water is percolating water unless it is proven otherwise.[109]

Several cases involving water supplies damaged by coal mining demonstrate that liability depends on several factors, including whether or not the water was percolating, or flowing in a defined channel; ownership of the surface lands and their relation to the coal operation; terms of the deed severing the mineral and surface estates; and the right of subjacent support.

Subjacent Support

Some explanation of the subjacent support principle is necessary. It is well-established in Virginia law that the owner of the surface lands in a severed estate (i.e., where ownership of an underlying coal deposit has been split from ownership of overlying lands) has an absolute right to support of his land, unless this right has been waived. The coal owner must leave sufficient coal pillars, props, or other means to support the mine roof. The principle precludes use of high extraction mining methods, unless the coal mine owner is prepared to accept liability for surface damages.[110]

If subjacent support is not sufficient, the coal owner may also be liable for damages to groundwater supplying wells and springs, depending on the terms of the deed severing the mineral estate. The seminal case regarding subjacent support in Virginia was *Stonegap Colliery Co. v. Hamilton*, in which it was held:

> Where the surface of land and an underlying mine belong to different owners, if the mine owner, in mining the minerals, fails to leave sufficient pillars, props or other means of support to prevent the strata overlying the minerals from breaking and falling, and as a result the said strata are broken, and thereby a spring on the surface is drained and destroyed, the mine owner is liable for resulting damages.[111]

In the same opinion, the court stated:

> If, in mining in the usual and ordinary way, subterranean streams or percolations of water which feed a spring on the surface are intercepted, thereby causing the spring to sink or become dry, there is no liability therefore upon the owner and operator of the mine.

Thus, liability for damage to water supplies hinges upon the question of subjacent support.

This principle was applied in the case of *Drummond v. White Oak Fuel Co.*[112] In this case, the court ruled that the coal owner is liable to the surface owner for destruction of a spring only if the damage is the result of removal of subjacent support; if adequate support was left and no subsidence resulted, the coal owner is not liable. The principle has been affirmed repeatedly in the Virginia courts.[113]

The case of *Oakwood Smokeless Coal Corp. v. Meadows*[114] provides an interesting variation. The cause of action was a spring, not dewatered but rendered unuseable by polluted water draining from the mine onto the plaintiff's adjacent land as percolating water. Because both the coal owner's land and the plaintiff's land had been part of the same parcel when the coal rights were ceded, the

[109] *C&W Coal Corp. v. Salyer*, 104 S.E.2d 50, 200 Va. 18 (1958)

[110] A case decided on January 12, 1990 by the Virginia Supreme Court tested the right of a coal company to conduct longwall mining operations without the permission of the surface owner to remove subjacent support. The case stemmed from the Clinchfield Coal Company's planned removal of coal with five longwall panels from beneath 81 acres of undeveloped land owned by Gerald and Betty Large of Dickenson County. Although reaffirming the principle of an absolute right of subjacent support, the majority of the court agreed with Clinchfield, that a coal operation cannot be enjoined merely because it will cause subsidence, in the absence of any showing that damage will likely result. Two justices dissented.

[111] 119 Va. 271, 89 S.E. 305 (1916)

[112] 104 W. Va. 368, 140 S.E. 57 (1927)

[113] *Kerr v. Clinchfield Coal Corp.*, 169 Va. 149, 192 S.E. 741 (1937); and *Oakwood Smokeless Coal Corp. v. Meadows*, 184 Va. 168, 34 S.E.2d 392.

[114] 184 Va. 168, 34 S.E.2d 392

plaintiff had acquired the land with this burden, which entailed the coal owner's right operate his coal mine. As the court points out, "the right to mine coal without the right to drain the mine is no right at all." Since that time, the Clean Water Act and its amendments have sharply limited the right to dispose of mine drainage into surface streams.

This review of Virginia common law shows that protection of groundwater rights from the effects of underground mining is limited in scope. The question whether protection of property rights, even if it were comprehensive, could adequately protect water resources raises a difficult question: how can society value water resources (or any environmental resources) apart from the rights of individuals to use whatever portions of it they can? It is in part to correct environmental abuses that fall outside the sphere of property rights and their exchange in the market that environmental laws such as SMCRA are created.

Virginia Water Law and Policy

While common law focuses on damages to property rights, and VCSMCRA establishes a regulatory apparatus focusing on a particular industry, there is an as yet uninvoked public policy relevant to this problem: Virginia's Groundwater Protection Policy. As implemented through the Virginia Water Control Law,[115] the policy reflects the following language from Article XI, Section 1 of the Virginia Constitution:

> Further, it shall be the Commonwealth's policy to protect its atmosphere, lands, and waters from pollution, impairment, or destruction, for the benefit, enjoyment, and general welfare of the people of the Commonwealth.

The report of the Groundwater Protection Steering Committee, *A Groundwater Protection Strategy for Virginia*,[116] notes that DMLR authority to require water supply replacement does not extend to underground mining. The report recommends that the Department of Mines, Minerals, and Energy review the adequacy of DMLR's authority to protect groundwater affected by underground mining. DMLR's current representative on the steering committee, when queried regarding the status of this recommendation, responded that a change in the VCSMCRA regulations since the preparation of the report had made such a review unnecessary.[117] The change referred to allows DMLR to include the surface area above underground mines outside the permit area in their monitoring and PHC determination requirements. The significance of this change is discussed in Chapter 7.

Summary

The effects of coal mining and their social and environmental impacts are subject to both regulatory controls and common law in Virginia. In theory, regulation can provide any level of protection for the hydrologic balance, subject to constitutional constraints. SMCRA provides for partial protection. The complex regulatory scheme implemented under SMCRA and in Virginia under VCSMCRA includes detailed requirements for permitting, bonding, performance standards, monitoring, reclamation, and enforcement. The standards for protection of water resources under this regulatory framework are to minimize mining's hydrologic impacts in the immediate vicinity of the mine; leave the land in a condition that will support approved postmining land uses; and prevent material damage outside the immediate vicinity of the mine. Changes at both the federal and state levels have resulted in diminished regulatory control over the impacts of underground mining subsidence on surface property owners.

The impacts of underground coal mining on water rights of surface landowners are largely controlled by common law in Virginia. The Virginia courts have recognized the principle that coal companies are liable for damage to water supplies caused by mine subsidence where no waivers of subjacent support exist, but not for damage

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115 Virginia Code 62.1 *et seq.*

116 Virginia Groundwater Protection Steering Committee. *A Groundwater Protection Strategy for Virginia*. Richmond: Virginia State Water Control Board, May 1987, 79 pp.

117 Haynes, L. DMLR, Big Stone Gap. Personal communication, June 1989.

where there is no subsidence. Virginia's Groundwater Protection Policy, which contains a nondegradation standard with respect to groundwater *quality*, has not been invoked in the case of mining subsidence effects on groundwater.

Chapter 6: Limitations on Protection of Water Resources

Protection of Virginia's water resources and their uses from the effects of high-extraction mining is limited by technical, legal, and institutional factors. They include technical means for prevention of subsidence damage; the knowledge base essential for predicting and identifying hydrologic effects in a complex geologic environment; statutory authority; economic constraints at the policymaking level; and the nature of the legal process. This chapter considers the contraints imposed by these factors on mine operators and on the institutions responsible for protecting water resources and their users.

Knowledge Base

An adequate knowledge base is essential for prediction of mining effects on both ground and surface water, as well as for assignment of liability and equitable settlement of conflicts over damages arising from these effects. The term, "knowledge base," refers to conceptual understanding or modeling in a broad sense, as well as to availability of data on actual field conditions in specific locations. These two components are considered separately, though it is sometimes difficult to distinguish them in practice.

Conceptual Models

The degree of knowledge of the mechanisms of groundwater flow and of groundwater-surface water interactions limits the prediction of subsidence effects on the hydrologic balance and on developed water sources that depend on it. Though considerable progress has been made, modeling of groundwater systems is still relatively crude.

Mathematical modeling of groundwater transport began with the classic work of Henri Darcy, which described the flow of water through porous media in terms of pressure and head.[118] The equation for the flow of water through saturated porous media has been known in its steady-state form since the late nineteenth century. Early mathematical models for groundwater were characterized by the use of simplifying assumptions that allowed the processes to be modeled, but because they were not usually met in practice, limited the usefulness and validity of results. Such assumptions included those of isotropy (groundwater can flow in any direction with equal ease); homogeneity (the aquifer is homogeneous in terms of water storage and transmission); infinite extent in the horizontal plane; and instantaneous response to pumping. Early models, moreover, were only able to consider the steady state. The history of the development of groundwater hydraulics has been "largely a history of the systematic removal of these assumptions one by one."[119] Despite the steady improvement of groundwater modeling, numerical and finite difference models still have difficulty handling saturated zones characterized by inho-

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[118] Darcy, H. "Determination of the laws of flow of water through sand." Translated from *Les Fontaines Publiques de la Ville de Dijon*, by Victor Dalmont, Paris, 1856. In: Freeze, R. A.; Back, W. (eds.) *Physical Hydrogeology*. *Benchmark Papers in Geology*, Vol. 72. Stroudsburg, Pennsylvania: Hutchinson Ross Publishing Company, 1983, pp. 14-21.

[119] Freeze, R. A.; Back, W. (eds.) *Physical Hydrogeology*. *Benchmark Papers in Geology*, Vol. 72. Stroudsburg, Pennsylvania: Hutchinson Ross Publishing Company, 1983, p. 136.

mogeneity.[120] Moreover, the more complicated the model, the more extensive the data requirements. These same cautions apply to integrated groundwater-surface water models, because they generally consist of a groundwater model linked to a surface water model.

Mathematical modeling techniques for hydrologic systems have limited applicability in the complex hydrogeologic systems of the Appalachian Plateau. The effects of extensive fracturing, complex stratification, and topography on transmissivity, storativity, and recharge are difficult for any mathematical model to handle, and the data requirements for precise modeling of a specific site could be prohibitive. These difficulties are multiplied by the additional complexity and uncertainty of subsidence and its effects on the rock layers that comprise aquifer media. Though the development of the subsidence trough over a high-extraction mine is predictable and, in theory, well-understood, there are many complicating factors that make it difficult to predict with precision the size and shape of the final subsidence basin. These factors include the physical properties of the overlying strata; the size of the gob (the broken rock filling the cavity immediately above the caved seam); mining depth, in combination with the height and width of the mine opening; topography; the presence of adjacent panels or overlying abandoned mine works; and time.[121]

Though some recent modeling advances[122] show promise for providing improved predictive capability to the coal industry and DMLR, the limited applicability and practicality of mathematical models of groundwater and surface water continue to limit precise prediction of hydrologic effects of subsidence in Virginia's coal counties. It could be argued, however, that precision is not always essential for regulatory purposes. Using descriptive models of the hydrologic balance,[123] together with study results that delineate the hydrologic effects of subsidence and experience gained through observation of effects, DMLR now has an adequate knowledge base for understanding potential subsidence impacts. This knowledge and experience have led the agency to increase its hydrologic monitoring requirements.

The knowledge base (which includes both conceptual understanding and specific data) has sometimes been inadequate when DMLR must determine (a) if a specific observed effect, for example the loss of a spring or well, was caused by subsidence from an underground mine; or (b) if observed effects indicate significant damage to the hydrologic balance. An adequate PHC determination should identify any stratum that "serves as an aquifer which significantly ensures the hydrologic balance within the cumulative impact area."[124] However, the inadequacy of hydrologic information submitted by some permit applicants has made it difficult for DMLR to determine whether or not an affected aquifer significantly ensured the hydrologic balance. This difficulty is in part due to the vagueness of the regulatory language – what does it mean, for example, to "significantly ensure the hydrologic balance"?

It appears that DMLR may also have contributed to the problem during the mid-1980s by not requiring sufficient data or adequate modeling during the permitting process that would have allowed a better understanding of a specific area's hydrogeology. In Sec. 480-03-19.784.14(h)2 of the Virginia regulations, there is a provision that waives hydrologic monitoring requirements may be waived if the applicant demonstrates in the PHC that "a particular water-bearing stratum in the proposed permit and adjacent areas is not one which serves as an aquifer which significantly ensures the hydrologic balance within the cumulative impact area." In several of its annual oversight evaluation re-

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[120] It should be noted, however, that the effects of inhomogeneity are scale-dependent. Over a large enough area, variations in aquifer characteristics tend to smooth out.

[121] Peng, S. S. *Coal Mine Ground Control*. 2nd Edition. New York: John Wiley and Sons, 1986, pp. 427-428.

[122] See, for example, Owili-Eger, A.S.C. "Dynamic fractured flow simulation model." *Mining Engineering* 41(2):110-114, February 1989.

[123] One such model is that of Wyrick, G. G., *supra* note xx.

[124] Sec. 480-03-19.784.14(h)

ports on DMLR's implementation of SMCRA, OSMRE identified unjustified waivers of groundwater monitoring for underground mines as a problem.[125] However, OSMRE's criticism applied to DMLR's program before November 1986. Rule changes that came into effect at that time, according to DMLR, significantly strengthened Virginia's hydrologic balance protection standards for underground mines by imposing permit information requirements for aquifers in proposed permit and adjacent areas. These information requirements remain in effect today.

To determine that a particular aquifer is a significant component of the hydrologic system, premining data are necessary regarding aquifer characteristics (storage and transmissivity, as well as areal extent), discharges to surface water, and water quality data. However, as discussed in the following section and elsewhere, such data have seldom been required of applicants.

Data Availability

DMLR gained authority to require premining installation of monitoring wells (except in alluvial valleys), piezometers, aquifer testing, and in some cases, monitoring of existing water wells in a regulatory revision of November 1986. In the DMLR permit applications examined as part of this research, all of which were issued prior to the regulatory revision's effective date of February 15, 1987, both subsidence control plans and PHCs simply asserted that the hydrologic effects of proposed mines are not expected to be significant. No modeling or monitoring evidence was offered to support the permit applicant's position, despite SMCRA's clear assignment to the permit applicant of the burden of affirmatively demonstrating that the mining operation would comply with all requirements of the state program.[126]

The lack of hydrogeological data available to regulatory agencies has been noted in the literature. Chugh, *et al.*, note that hydrogeology is the most neglected area in premining investigations.[127] Pendleton argues that the state of the art of predicting hydrologic consequences of subsidence lags behind that of predicting geomechanical consequences:[128]

> Nineteen of the 37 [Colorado coal mining] permit applications reviewed for compliance ... have delineated ground water aquifers or surface water bodies within their permit and adjacent areas. All 37 ... contain projections of the specific hydrologic consequences anticipated as a result of subsidence. Faced with a mandate to minimize impacts to the hydrologic balance, any permit applicant would prefer to demonstrate that the anticipated

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[125] U.S. Office of Surface Mining. *Annual Report, Virginia Permanent Program, for the Period May 1, 1984 to April 30, 1985*. Big Stone Gap, Virginia: Office of Surface Mining, pp. 18-19, November 1985; *and* U.S. Office of Surface Mining Reclamation and Enforcement. *Fiscal Year 1986 Annual Evaluation Report for the Regulatory and Abandoned Mine Land Reclamation Programs Under the Surface Mining Control and Reclamation Act of 1977 in the State of Virginia for the Period May 1, 1985 to June 30, 1986*. Big Stone Gap, Virginia: Office of Surface Mining Reclamation and Enforcement, February 1987, p.9.

[126] Sec. 510(a) and (b) of SMCRA, under "Permit Approval or Denial," state:

> (a) The applicant for a permit, or a revision of a permit, shall have the burden of establishing that his application is in compliance with all the requirements of the applicable State and Federal program. (b) No permit or revision shall be approved unless the application affirmatively demonstrates and the regulatory authority finds in writing ...that— (1) all the requirements of this chapter and the State of Federal program have been complied with

Cited in McGinley, P. C.; Shostak, R. J. *Subsidence and the Federal Surface Mining Act: The Landowners Perspective*. Paper presented at the Coal Mine Subsidence Special Institute, Pittsburgh, Pennsylvania, December 8, 1989, sponsored by the Eastern Mineral Law Foundation.

[127] Chugh, Y. P.; Caudle, R. D.; Agarwala, V. K. "Premining investigations for longwall coal mining." In: Chugh, Y. P.; Karmis, M. (eds.) *International Conference on state-of-the-art of ground control in longwall mining and mining subsidence*. New York: Society of Mining Engineers of AIME, 1982, pp. 3-12.

[128] Pendleton, J. M. "Coal mine subsidence in Colorado: Practical application in a regulatory setting." In: *SME Fall Meeting, Albuquerque, New Mexico, October 16-18, 1985*. Littleton, Colorado: Society of Mining Engineers of AIME (Preprint 85-328), 8 pp., 1985.

> hydrologic consequences of subsidence are minimal. Virtually every permit application's probable hydrologic consequence description observes that ground subsidence will result in cracking of the ground surface above the proposed underground mine workings, but that weathering processes will rapidly seal and eliminate that cracking. While this observation may seem intuitive, little documented evidence exists within the literature to support it. The physical expression of the cracking will probably be relatively rapidly eliminated, but evidence suggests that the hydrologic consequences may be of very long duration.[129]

The primary reason for the optimistic predictions found in the PHCs examined, and their acceptance by DMLR, is that prior to February 15, 1987, PHCs were required to address anticipated hydrologic effects only within permit areas. A permit area generally encompasses an underground mine's surface works. It is usually not an area that will be affected by subsidence, and is only a fraction of the total surface area to be undermined. Figure 5 shows the permit area superimposed above a few of the many longwall panels in a Dickenson County, Virginia mine. This areal limitation on PHCs meant that DMLR did not have the authority to require monitoring above most subsided areas. The implications of the regulatory change to a broader applicability of PHCs are discussed further in Chapter 7.

Data availability to DMLR could be improved if mining companies were required to report instances of damaged water supplies, as they are, for example, in Ohio. Some impacts to water supplies come to DMLR's attention only when the surface owner and the mining company cannot come to a settlement, and the surface owner files a complaint.[130] To judge the dimensions of the problem of subsidence impacts on water resources, information on the number and location of wells impacted is crucial.

Better information is also necessary to distinguish the hydrologic effects of mining from other causes. Problems in predicting hydrologic effects, for example, are greatly amplified by the longstanding drought that plagued southwestern Virginia during the 1980s. Effects have been widespread and severe. Wise, Virginia, for example, reports a cumulative precipitation shortfall from 1981 to 1986 of almost 50 inches below the 1955-1986 average; 1987 and 1988 were also drought years.[131] In some areas, overpumping of aquifers may have contributed to water supply depletion. The precise effect to the hydrologic balance of drought and possible overpumping of aquifers, however, is as uncertain as determining the possible effects of mining. Did a formerly dependable well go dry because of the drought, because of a new well being installed nearby, or because of high-extraction mining? What portion of the observed unusually low flows in a particular stream can be attributed to mining in the watershed and what portion to drought? These questions plague DMLR's complaint investigations, making it impossible to definitively attribute observed effects.

Prevention of Subsidence Damage Through Mine Engineering

While a discussion of the broad range of surface-protection measures afforded by mine engineering is beyond the scope of this report, there are some that are relevant to the protection of hydrologic features from subsidence damage. A review of mining engineering literature on ground control and subsidence reveals two possibilities for preventing subsidence damage from high-extraction mining methods. First, measures may be taken at the surface to strengthen structures, isolate them from surface deformation, or incorporate flexible elements into their design. Second, measures may be taken in the mine, including strategically planning mine layout and operational procedures that will protect surface structures and land features.

In some cases, surface measures may do more harm than good. An official of the West Virginia Department of Natural Resources stated that mining companies in that state

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[129] *Ibid.*, p.5.

[130] Gray, G., attorney, Clintwood, Virginia. Personal communication, January 4, 1989.

[131] Hydrologic Information Storage and Retrieval System (HISARS), Virginia Water Resources Research Center, Blacksburg, Virginia.

FIGURE 5: PRE-1987 PERMIT AREA IN RELATION TO UNDERGROUND MINE

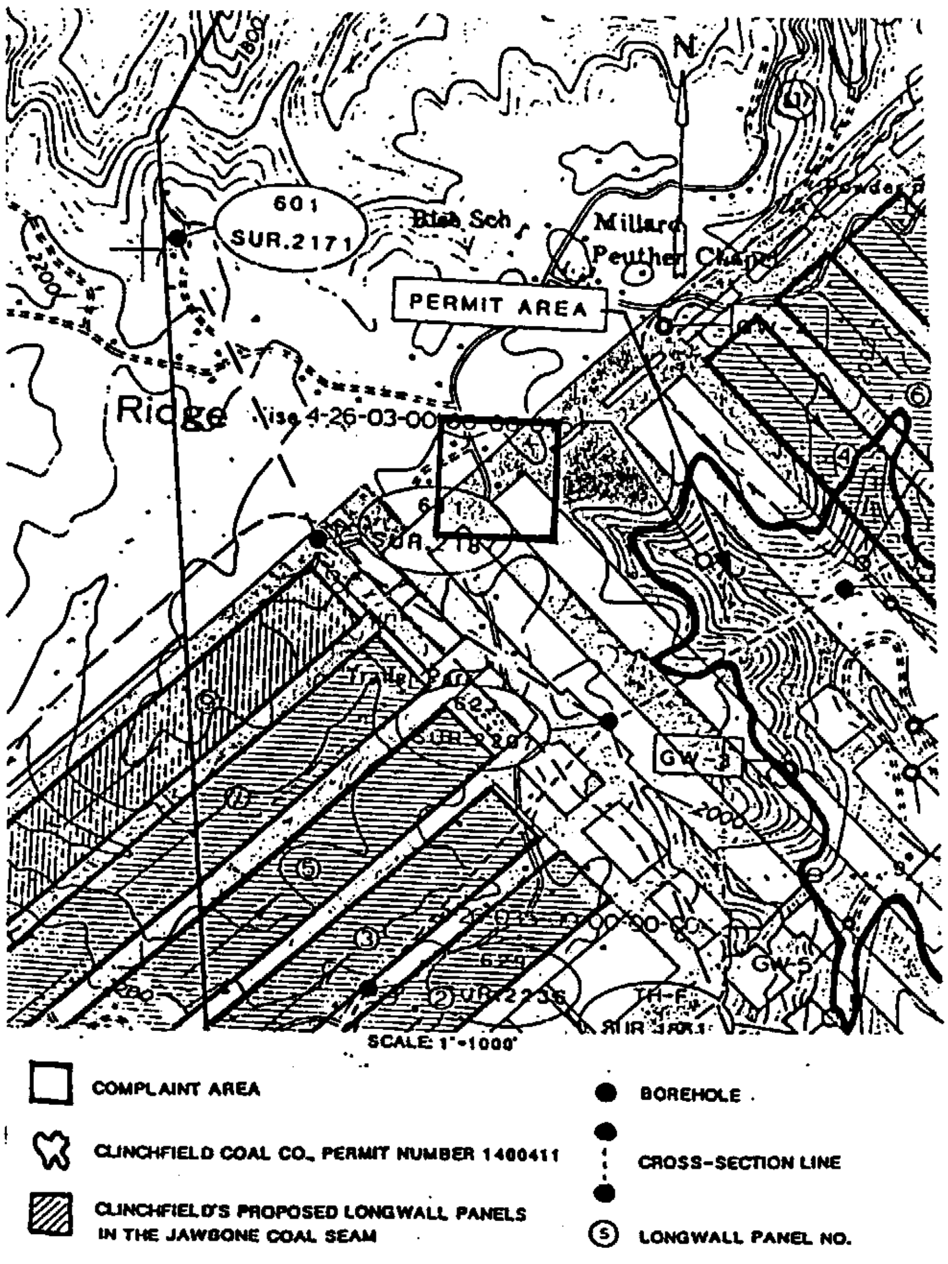

Figure shows the relationship of the permit area to an area potentially subject to subsidence (above panels), prior to regulatory change of February 15, 1987.

Source: DMLR subsidence complaint investigation.

grade and channelize streams, sometimes at the request of surface owners, to alleviate drainage problems caused by subsidence or to prevent infiltration of water into mines.[132] In this official's view, these practices have in some cases resulted in severe, though lo-

[132] Jernejcic, F. West Virginia Department of Natural Resources. Personal communication, January 10, 1989.

calized, environmental damage. Mining company officials, however, assert that stream grading is no longer commonly practiced in West Virginia, due to more stringent regulation.[133]

Grouting subsidence fissures in streambeds has been attempted in some cases. The effects of such efforts on George's Creek in western Maryland are currently under study by the U.S. Bureau of Mines, but results have not yet been reported.[134] The various measures reported here to protect or repair surface water features are not applicable to groundwater, and there are no reported techniques that can be applied at or near the surface for protection or remediation of subsidence damage to groundwater recharge or flow.

Mining measures to prevent surface subsidence damage generally attempt to prevent subsidence in a particular location, or to alter the development or progress of the subsidence "wave" that travels with the advancing longwall face. Backfilling of a longwall "gob" (the mined-out area behind the advancing face) to alleviate subsidence is precluded by cost and technical feasiblity.[135] As a general rule the development of a subsidence trough above a longwall panel cannot be prevented. There are, however, mining methods for reducing the damage produced by subsidence ground motion.

The most straightforward method for preventing subsidence damage is to remove only a limited percentage of the coal beneath the surface feature to be protected. Unfortunately, leaving a higher percentage of coal for support would make many mining operations in Virginia economically infeasible. Partial extraction can be achieved through room-and-pillar, board-and-pillar, or panel-and-pillar methods, but not by longwall mining. The extent of the mine in which partial extraction must be practiced in order to protect a surface feature can easily be calculated. As a general rule, about half of the coal seam must be left unmined in order to prevent noticeable subsidence. This percentage may be higher for very deep seams, as greater vertical stress may cause pillar deformation.[136]

Rapid mining and harmonic extraction are two techniques that have the potential to reduce subsidence-induced structural damage. Rapid mining capitalizes on the fact that the faster mining proceeds, the smaller is the tensile strain at the surface.[137] Harmonic extraction relies on a coordinated advance of two adjacent faces, with one to some extent cancelling the surface strains generated by the other. This method requires very close coordination between two longwall systems. Rock stresses and rate of face advance must be closely monitored, and if one operation is stopped by equipment failure, the other must also be stopped. These requirements translate into higher costs and lower productivity. Furthermore, according to one industry official, harmonic mining is infeasible because of inherent mine ventilation problems.[138] These methods are best adapted to protect a small surface area, such as the area beneath a structure, or a stream.

Prevention of Damage Through Regulation

This section considers possibilities for DMLR to prevent potential damage to the hydrologic balance from high-extraction mining.

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[133] Morgan, Claude D., Regional Manager - Engineering and Environmental Affairs, Consolidation Coal Company, Bluefield, Virginia. Personal communication, December 20, 1989.

[134] Holbrook, J., Chief, Anthracite Reclamation Programs Branch, U.S. Office of Surface Mining Reclamation and Enforcement, Wilkes Barre, Pennsylvania. Personal communication, January 9, 1989.

[135] Whittaker, B. N. "A review of progress with longwall mine design and layout." In: Chugh, Y. P.; Karmis, M. (eds.) *State-of-the-Art of Ground Control in Longwall Mining and Mining Subsidence*. New York: Society of Mining Engineers (AIME), 1982, pp. 77-84.

[136] Peng, S. S. *Coal Mine Ground Control*. New York: John Wiley and Sons, 1986, p.458.

[137] Peng, *ibid.*, p.460.

[138] Price, K. General Manager, Virginia Division, Island Creek Coal Company, Oakwood, Virginia. Personal communication, August 9, 1989.

DMLR's requirement that mining operations minimize disturbance to the hydrologic balance within the permit and adjacent areas, prevent material damage outside these areas, and support approved postmining land uses, is subject to interpretation. "Permit and adjacent areas" includes subsidence-impact areas (and occasionally more if DMLR deems it necessary). The clause stating that the hydrologic balance must be able to support approved postmining land uses does limit allowable damage: even if damage is major, it must at least be temporary. Furthermore, "material damage" must be confined to the permit and adjacent areas.

Thus, DMLR has both statutory authority and obligation to circumscribe potential damage to the hydrologic balance in space and time, but not to *prevent* it. Only if the aquifer in question is "a significant source of water supply to any public water system" or is judged to be significant to the hydrologic balance outside the permit area, does it receive special protection, and then only if DMLR determines that subsidence will probably cause material damage. DMLR cannot otherwise prohibit mining that may damage an aquifer not used for a public water supply, even though it may supply a number of domestic wells.

Limited Range of Regulatory Responses

Subsidence damage to the hydrologic balance usually comes to DMLR's attention by way of complaints from surface land owners.[139] When a complaint is received, it is investigated. The investigation may include permit file review, field investigations, and interviews with complainants. If significant adverse hydrologic impacts of subsidence are found that were not predicted by the PHC determination, or if damage is found outside the permit and adjacent areas, DMLR may issue a Revision Order Notice (RON), requiring the mining company to revise either its PHC, its subsidence control plan, or both. In most cases, increased monitoring is required. If the damage is judged serious enough, DMLR can require the mining company to modify its operations. Actions might include designating a "buffer zone" where undermining would not take place, or leaving enough coal to prevent subsidence, but any measure would be ordered only to detect or prevent further damage. For damage already done, there may be no remedy.

Under VCSMCRA, DMLR has several options for action against mining companies whose operations violate permit conditions. Upon finding that a coal company is violating the terms of its permit (either performance standards or reclamation plan) DMLR can issue a notice of violation, giving the company reasonable time to bring its operations into compliance. The agency may also assess a civil penalty with the violation, the amount depending on the severity of the violation's impacts, company culpability, good faith efforts to comply, past violations, and time taken to comply. Civil penalties are unlikely to exceed $5,000, and may be considerably less. If the company fails to abate a violation after the issuance of violation notices and assessment of civil penalties, the agency issues a cessation order for failure to abate the violation. This action requires a minimum civil penalty of $750 per day for up to 30 days. If the company still does not comply, it may forfeit part or all of its permit bond. If more damage than predicted is occurring DMLR may require a bond increase. DMLR also can order a cessation of coal mining if it determines that the operation creates imminent danger to the public health or safety; or is causing or can reasonably be expected to cause significant, imminent harm to land, air, or water resources.[140]

A mining operation or company that has established a pattern of violations must be served with a "show cause order," which essentially requires the company to explain why its permit should not be suspended or revoked. If the company fails to do so to DMLR's satisfaction, the agency may take the threatened action.

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[139] It is worth repeating that an unknown number of water loss cases never come to DMLR's attention. Larger mining companies follow a policy of replacing water supplies that they believe their operations have damaged. As a rule, only those cases that cannot be resolved between the surface owner and the mining company result in complaints.

[140] Sec. 480-03-19.843.11

DMLR has no authority under VCSMCRA to require that mining operators replace water supplies (wells and springs) destroyed or damaged by subsidence. Under Judge Flannery's rulings, water replacement is only required in the case of surface mining.[141]

Limitations on Protection of Water Rights Under Common Law

The scope of protection of property rights in groundwater afforded by Virginia common law is limited with respect to potential damages caused by underground coal mining. When mining does not cause subsidence, the coal company is not liable for damage to groundwater. However, with respect to the high-extraction mining methods that are the focus of this research, the legal principle is well-established that mining companies are liable for damages to groundwater supplies when subsidence is the cause, *unless the right to subjacent support was waived when the mineral estate was severed.*[142]

There are several important points regarding the protection afforded by this established legal principle. First, even when liability is clear, it is difficult under common law to *prevent* the damage for which a party is liable. Except in those extreme circumstances in which a court is willing to grant an injunction to prevent damage from occuring, to pursue a case in torts injury must already exist. Typically, this means that whatever damage to the hydrologic balance results from subsidence must already have occurred.[143]

Second, there is nothing automatic about assignment of liability, even when there is an established legal principle. The coal company is liable for damages if it can be shown that the coal mining operation *caused* the injury. For the same reasons discussed in the section on "Knowledge Base" at the beginning of this chapter, demonstrating causality is not a simple matter. In each case there are similar constraints: lack of monitoring data; lack of a rigorous understanding of highly localized hydrogeologic conditions; and the confounding effects of drought.

Voluntary Water Replacement Policies

Large mining company policies of water replacement reflect a recognition of the established common law principle of liability for subsidence-caused water supply damages, as well as the "good neighbor" policy that these companies espouse. Westmoreland Coal Co., for example, uses the term "good neighbor" in its 1987 draft subsidence policy statement for its Virginia operations. The policy says that if a surface owner's water supplies are affected by the company's operations, Westmoreland will "take appropriate action which could include providing a temporary water supply until the water returns or until repairs can be made, or developing an alternate water supply."[144] Island Creek Coal Co. has applied a similar policy to settle water supply damage claims. The company donated funds for the purchase of a water truck by the Buchanan County Public Service Authority to serve surface owners who had lost water supplies;

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[141] *In re: Permanent Surface Mining Regulation Litigation.* 19 *Environment Reporter, Cases*, 1477, 1495, May 16, 1980; *National Wildlife Federation v. Interior Department* (1988), 27 *Environment Reporter, Cases*, at 1153. However, DMLR would appear to have some ability during the permitting process to encourage mitigatory measures. See 52 *Federal Register* 4866, February 17, 1987.

[142] To uphold waiver claims, Virginia courts normally require that the contract severing the surface and mineral estates contain either explicit language or clear implication of intent to waive subjacent support.

[143] *Gerald and Betty Large v. Clinchfield Coal Co.* is a case in point. Here, the surface owners won a lower court injunction against longwall operations planned under their undeveloped land. The injunction was overturned by the Virginia Supreme Court on the grounds that probable damage was not established. Although the decision does not seem to affect Virginia subsidence liability law, and may not even rule out injunctive relief where probable damage is demonstrated, it seems to establish that mere subsidence in and of itself is not damage, and further limits landowners' ability to prevent subsidence damage through common law.

[144] Westmoreland Coal Company, Big Stone Gap, Virginia.

some properties were hooked up to public water supplies. Island Creek, however, does not pay the water bill after hookup.[145] Consolidation Coal Co. and Pittston Coal Group, Inc. (Clinchfield Coal Co.) follow similar policies.[146]

As stated earlier, the number of settlements and sums involved for water replacement or compensation as a result of high-extraction mining are fully known only to the individual mining companies. Gerald Gray, a Clintwood, Virginia, attorney who has represented a number of surface owners in subsidence damage cases, stated that in the eight water loss cases in which he has been involved (all were alleged to result from subsidence caused by pillar retreat mining), settlements ranged from $5,000 to $45,000. He stated that he knew of another 15-20 cases represented by other attorneys in the area.[147]

Water replacement measures accepted by some surface owners have included installation and maintenance of cistern systems; drilling new wells and installing filters; and connection to a public water supply system. There are four important points with respect to water replacements offered by coal companies: First, spokespeople for surface owners question whether the measures described above constitute adequate replacement for dependable water supplies that were essentially free.[148] Second, these water replacement measures are made voluntarily by the coal companies and at their discretion. Third, voluntary water replacement by the coal companies, especially if it involves trucking in water for a few months, may turn out to be a short-term fix for a long-term problem. Finally, voluntary water replacement policies may not be legally enforceable, although signed agreements resulting from such policies are.

Industry officials argue that there are costs associated with operating private wells, so that the water was never "free." Second, they argue that connecting a resident to a public water supply often constitutes replacement of an undependable and inadequate supply with a reliable one.[149] Finally, they say, far from being a short-term fix for a long-term problem, permanent water supply replacement may be a long-term fix to a short-term problem.

Regarding subsidence-related damages, coal company executives believe that they are not only doing more than they have to, but that they are sometimes victimized by spurious claims. This sentiment has been expressed by others as well. Commenting on coal companies' liability in Kentucky, Smith and Smith argue that legal requirements for proof of causation in cases of hydrologic damage, which formerly favored the coal operators, now favor the surface owner. In their view, the situation is such that "property owners can claim practically anything and have a reasonable chance of collecting a handsome amount of money."[150] On the other hand, Richard DiPretoro, a West Virginia geologist who has served as an expert witness in numerous subsidence damage suits, argues that "spurious claims

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[145] General Assembly of Virginia. *Report of the Joint Subcommittee Studying the Effects of Longwall Mining*. Richmond, Virginia, January 1989, p. 10. Of 465 subsidence damage claims received through the end of calendar year 1989, Island Creek has settled 256 (55 percent) and denied 160 (34 percent). About 6 percent of these claims resulted in lawsuits. The proportion of claims involving water loss is not available. Breeding, S. G., Assistant to the General Manager for Community Relations, Island Creek Coal Company, Oakwood, Virginia. Personal communication, February 2, 1990.

[146] *Ibid.*

[147] Gray, G. Attorney, Clintwood, Virginia. Personal communication, January 4, 1989.

[148] Gray, G., *ibid.;* and McKinney, J., President, Dickenson County Concerned Citizens, Clinchco, Virginia. Interviewed by Ted Clutter, VCCER, May 21, 1988.

[149] Price, K., *op. cit.*

[150] Smith, S. R.; Smith, S. G. "Legal and technical ramifications of environmental data collection." In: Graves, D. H.; De Vore, R. W. (eds.) *Proceedings, 1984 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation*. Lexington: University of Kentucky, Office of Engineering Services (Bulletin UKY BU136), December 1984, pp. 109-111.

are only a tiny fraction of the complaints that are, or should be, made."[151]

Limitations of Voluntary Water Replacement

In cases where there is disagreement between the surface owner and the coal operator as to whether the mining operation caused damage to water supplies, the surface owner may file a complaint with DMLR. Following an investigation, however, DMLR's ability to attribute damages to mining operations are limited, in particular where adequate premining hydrologic monitoring was not conducted. The effects of the longstanding drought in the region make it particularly difficult to determine the cause of well and spring failure.

If DMLR does make a positive determination, it does not have statutory authority to order the mining company to remediate or replace the water supply or compensate the surface owner, though a DMLR finding would undoubtedly strengthen the surface owner's bargaining position with the company. In cases where the operator does not believe that mining caused the damage, the surface owner has only two options: accept the damage and do nothing, or file a court claim against the mining company.

There are a number of reasons why surface owners might accept damage rather than take a mining company to court. The most obvious is cost. Pursuing a court claim against a mining company for water supply damage costs $1,500 to $10,000, according to Gerald Gray.[152] Expenses include attorney's fees as well as fees for consulting geologists or hydrologists, if necessary. This might seem to be a reasonable investment if the outcome were certain, but it is not.

The economic situation in the coal counties has been described earlier in this report. There are so many unemployed, disabled, and retired individuals living in the area on pensions, social security, and unemployment benefits that a significant component of its economy has been called a "mailbox economy." The rural areas under which mining is frequently conducted are not populated, on average, by people of means.

The ability and willingness of a surface owner to challenge a mining company in court depend not only on on financial means, but on information and attitude. Speaking of the problems of seeking restitution for subsidence damages in Dickenson County, Judy McKinney, President of Dickenson County Concerned Citizens (a citizens' group organized in opposition to longwall mining), offered the following characterization:

> A lot of people don't know what to do. I mean it gets to the point that a lot of people get really depressed. They don't know what to do. A lot of people don't understand the steps that they have to go through. [Many] are old people, and they don't know what to do. The only thing they've ever done is just worked real hard all their life and minded their own business. They don't know who to turn to. They don't know all these different agencies. They don't even know [the agencies] exist.[153]

Economic Constraints at the Policymaking Level

In passing SMCRA, Congress aimed not only to control the adverse environmental impacts of mining, particularly surface mining, but also to ensure the continued vigor of the coal mining industry as a hedge against dependence on unreliable foreign energy sources. More specifically, Congress intended to encourage the expansion of underground coal mining, and said so explicitly:[154]

> ... the overwhelming percentage of the Nation's coal reserves can only be extracted by underground mining methods, and it is, therefore, essential to the national interest to ensure the existence of an expanding and economically healthy underground coal mining industry.

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151 DiPretoro, R. S., Geologist, Morgantown, West Virginia. Personal communication, January 18, 1990.

152 Gray, G. Attorney, Clintwood, Virginia. Personal communication, January 4, 1989.

153 McKinney, J.. Clinchco, Virginia. Interviewed by Ted Clutter, VCCER, May 21, 1988.

154 30 U.S.C. 1201(b)

SMCRA aims at balancing environmental protection and coal production expansion, especially from underground coal mining. There is no justification in Congressional intent or statutory language for regulatory requirements so stringent that they would make underground coal mining impossible.

The only certain way to prevent subsidence effects on water resources, particularly groundwater, is to prevent subsidence. This would require prohibiting all high-extraction mining, and perhaps all underground coal mining. As noted above, there is nothing in SMCRA that suggests Congress envisioned or intended such an outcome. Indeed, there is ample evidence that the framers of SMCRA considered longwall mining, with its immediate and final subsidence, an environmentally superior method of underground mining.[155] It should be noted, however, that nearly all of the literature on hydrologic effects of longwall mine subsidence appeared well after SMCRA became law; one can only speculate about what effect the research would have had on Congress' view of longwall mining.

The economic importance of longwall mining to the nation's coal-producing areas, particularly those of Appalachia, is undeniable. According to Gene Mathis, former President of Pittston Coal Group, Inc., which operates several longwall mines in Dickenson and Buchanan counties, longwalls make mines profitable that would be unprofitable with conventional mining methods. According to Mathis, Pittston mines would shut down if longwall mining were no longer possible.[156] This is not only due to the productivity of longwall mining, but because deep coal seams are difficult to mine safely with continuous mining methods. It is clear that much of Virginia's remaining coal reserves cannot be mined economically any other way.

Conflicting goals of environmental protection and economic growth in the coal industry and in coal-dependent regions essentially defined the policy debate that shaped SMCRA. This debate continues as states grapple with various issues that arise in designing and implementing programs to regulate, but not hamstring the industry. Federal policy continues as a battleground for the competing interests of environmentalists, surface owners, and the coal industry. In December, 1988, OSMRE proposed a sweeping reexamination of the closely related questions of "valid existing rights" (VER) to mine in areas subsequently placed off-limits by the passage of SMCRA in 1977, together with the applicability of these prohibitions to subsidence from underground mining. Although the issues are complex, deciding them could result in a significant contraction of the area under which mining that causes subsidence would be allowed. In its announcement of the proposed re-examination of regulations under SMCRA Section 522(e), OSMRE said, "the issue is one of great concern for the coal industry and various environmental and citizen groups because the final rule may have substantial economic or significant environmental consequences."[157] At the time of the announcement, OSMRE prepared a draft environmental impact statement covering the two issues. OSMRE withdrew its proposal for further study on July 21, 1989 after receiving "a large number of comments" on it.[158]

The work of the Joint Subcommittee Studying the Costs and Benefits of Longwall Mining in Virginia (Senate Document 26) illustrates the difficulties involved in reaching consensus on an issue with possibly very significant economic and environmental consequences.[159] The subcommittee report (signed only by Chairman John C. Buchanan) concluded that longwall mining

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[155] Congressman Udall, debating one of SMCRA's predecessors, stated, "In fact the bill's sponsors consider longwall mining ecologically preferable, and it and other methods of controlled subsidence are explicitly endorsed." 123 *Congressional Record* H22731 (July 10, 1974); quoted in Gorell, G. R.; McGuire, K. M., *ibid.*, p. 21.

[156] Mathis, G. Pittston Coal Group, Inc., Lebanon, Virginia. Interviewed by Ted Clutter of VCCER, May 3, 1988.

[157] *Federal Register* 53(248):52374, December 27, 1988.

[158] *Federal Register* 54(139):30557, July 21, 1989.

[159] The complete Subcommittee report was reprinted in the Summer 1989 issue of *Virginia Coal and Energy Quarterly*, Virginia Center for Coal and Energy Research, Blacksburg, Virginia.

is "a significant element" of the Southwest Virginia economy; that it involves "serious costs" resulting from subsidence; and that the question of property rights is a subject of controversy between companies and residents and is at issue in pending litigation. The report recommended clarification of procedural requirements for permitting of longwall mining and deferral of any legislation on property rights issues pending the outcome of ongoing litigation.

A lengthy dissenting opinion to the report (signed by Subcommittee members Alson H. Smith, Jack Kennedy, and Robert Russell) found that Virginia's existing program provides adequate controls on underground mining to ensure proper protection of land and hydrologic balance, that no additional environmental protection is necessary, and that unresolved property rights questions await clarification by pending litigation and federal proposed rulemaking. The dissenting report recommended no new state legislation. While the dissent did not cite economic factors as influencing its findings on the adequacy of current environmental protection, its finding (as do all policy findings concerning environmental protection) constituted a balancing of economic and environmental values. In the 1989 Virginia General Assembly Session, Senator Buchanan introduced a bill reflecting the recommendations of the subcommittee report he signed. Lacking co-sponsorship, the bill died in committee.

Longwall mining's importance to underground coal production and coal production's critical importance to the near-term economic health, indeed survival, of some of Appalachia's coal-producing regions, make it unlikely that policymakers in Washington or in Richmond will move toward more stringent measures for protection of water resources from its potential adverse effects.

Summary

This chapter examines a number of factors that limit protection of water resources in Virginia, with the following conclusions:

The ability to understand, track, and predict hydrologic impacts is constrained by the state of the art of hydrologic modeling.

The lack of mining engineering methods to prevent hydrologic damage may force DMLR into "all or nothing" choices: either high-extraction mining in a particular area is allowed, or it is not.

Subsidence damage to a structure or even a stream can be avoided by limiting the amount of coal extracted from an area beneath it, but an aquifer or "the hydrologic balance" cannot be protected in this way without serious economic consequences of large-scale limitations on mining.

Although DMLR has the authority to order coal operators to repair or mitigate damage to surface water bodies in some circumstances, the technology for doing so may be lacking.

Lack of statutory authority limits DMLR's ability to implement a full-protection strategy. The agency's authority in general does not extend to protection of property rights, but is limited to environmental protection. The agency cannot require replacement of water supplies damaged by subsidence from underground mining. And, although a range of sanctions is available to DMLR, their imposition would likely be triggered by damage rather than preventing damage before it happens.

The sometimes inadequate knowledge not only hampers DMLR but also makes the resolution of property damage disputes difficult. Some of the difficulties the agency's technical personnel have had in determining the significance of observed effects, and in ascertaining their cause (as mining-related or not), appear to have their roots in lack of monitoring and modeling requirements of years past. The following chapter shows how DMLR has responded to the problems of inadequate and insufficient data.

Finally, the economic importance of longwall mining to the Appalachian region and the health of the coal mining industry acts as a constraint on implementation of a full-protection policy. In the absence of information documenting the need for it, the pursuit of a full-protection policy that could seriously damage a vital industry could not be justified by policymakers. Damage to water resources would have to be severe, widespread, and obvious before anything so drastic could be contemplated.

Currently, most of the larger mining companies operating in Virginia have policies for repair, replacement, or compensation for water supplies damaged by subsidence. Many surface owners have taken advantage of these policies through voluntary agreements. Mining companies believe that their policies are more than fair, but some surface owners disagree. When the mining company and the surface owner cannot come to an agreement, recourse is through the courts.

The protection of water resources under common law is limited. Its remedies are primarily after the fact and reached through costly litigation with inherently uncertain outcome. Thus, the surface owner who cannot come to an agreement with a coal operator is forced to make a substantial investment for an uncertain return. If a previous owner of the property sold the right to subjacent support along with the mineral estate, there may be no protection of the water rights.

Chapter 7: Regulatory Response

It is only during the past five years that longwall mining has operated on a large scale in Virginia, and DMLR has followed suit with increased attention to potential subsidence damage to water resources. DMLR has made substantial changes to address deficiencies in state regulations applying to high-extraction underground mines, and in their implementation. As described in Chapter 5, a change in regulations at the federal and state levels has removed DMLR authority to require that adversely affected water supplies be replaced or that their users be compensated.[160] Changes have also occurred in other important areas.

Increased Hydrologic Information. As noted earlier, before February 15, 1987 the PHC determination submitted to DMLR as part of a mine permit application only covered the permit area. The permit area for underground mines was that containing the direct surface impacts of the mine operation, including staging areas, the mine entrance, roads, and coal processing buildings. In most cases, however, the surface area subject to subsidence impacts was beyond the permit area.

February 15, 1987, DMLR modified its permitting requirements to make Virginia's regulations as effective as those of OSMRE. Sec. 480-03-19.784.22, which lists the requirements for geologic information to be included in permit applications, was changed as follows:

> Each application shall include geologic information in sufficient detail to assist in (1) determining the probable hydrologic consequences of the operation upon the quality and quantity of surface and ground water in the permit *and adjacent areas*, including the extent to which surface- and ground-water monitoring is necessary... [emphasis added]

Sec. 480-03-19.784.14, which specifies the hydrologic information required as part of the permit application, was modified to include both the permit and "adjacent areas." Adjacent areas include, at a minimum, all possible subsidence impact areas, calculated by using a 28° angle of draw.

Because the lack of monitoring data has been an important constraint on protecting the hydrologic balance, these changes are significant and should enhance DMLR's ability to predict and respond to subsidence impacts on water resources.

In accordance with increased regulatory authority to require monitoring outside the permit area, DMLR's hydrologic monitoring requirements for high-extraction mines have become more intensive. DMLR not only requires hydrologic monitoring in subsidence impact areas for new permit applications but for significant revisions of existing permits as well. Since most existing permits are for five years and were approved under VCSMCRA during the early- to mid-1980s, post-1987 monitoring requirements will soon be applied to most underground operations.

A hydrologic study being conducted by Island Creek Coal Co. demonstrates DMLR's willingness to use its enhanced authority to require more complete and adequate data on hydrologic impacts of longwall mining. As part of a permit revision agreement, DMLR and Island Creek cooperatively designed the study, and the company has been implementing it. Island Creek operates several longwall mining operations in the Pocahontas No. 3 coal seam in Buchanan County. The seam is deep: 1200 to 1500 feet below drainage in some places, with up to 2400 feet of overburden. The study involves monitoring of static water levels in three strategically located test wells above a

[160] This change resulted from a U.S. District Court decision in *In Re: Permanent Surface Mining Regulation Litigation*. 19 *BNA Environment Reporter, Cases*, 1477, 1495, May 16, 1980.

longwall panel in the VP-6 mine. Water quality samples are also being taken, and water levels in nearby domestic wells monitored. Subsidence and seismic monitoring are providing data for correlation with hydrologic data. Mining was completed in August 1988, and hydrologic monitoring that began before mining operations continues. A final report at the end of 1989 should provide much-needed information on the specific hydrologic effects of longwall mining in Virginia.

Instream Monitoring. Changes to DMLR regulations allowed the agency to begin an instream monitoring program. Mining companies are now required to monitor continuously both streamflow and water quality upstream and downstream of the permit and adjacent areas, including (in some cases) subsidence impact areas. Monitoring prior to the regulatory changes was required for 6 months prior to mining for baseline establishment but is now required both before and during active mining.

Data Management System. Recognizing the need for a more complete regulatory program information base, DMLR has undertaken a comprehensive research and information management effort. It is hoped that a cooperative project involving DMME (DMLR and the Division of Mineral Resources - DMR), the Powell River Project, selected coal companies, OSMRE, and the U.S. Geological Survey (USGS) will better characterize and evaluate the groundwater system of the Southwest Virginia coalfields by establishing geologic and hydrologic databases and producing geologic maps of the area. The hydrologic study was described in Chapter 3 of this report. This new data management system will contain information on static water levels, stratigraphy, rock types (including acidification potential), and water quality parameters at hundreds of geologic data points throughout the coalfields. Based in a minicomputer at DMME's Big Stone Gap offices, the system will comprise a geologic database compatible with the USGS National Coal Resources Data System, and a custom-designed water resources database. Outputs include reports, maps, fence diagrams, and three-dimensional perspective maps.[161] The system, which should provide DMLR, DMR, and coal companies with a much improved information base for planning and permitting of mining operations, reclamation, and mitigation, has no component at this time that pertains directly to possible hydrologic impacts from subsidence.

OSMRE Oversight Reports. Another perspective on DMLR's increased attention to subsidence issues can be found in the annual oversight reports on Virginia's regulatory program compiled by the U.S. Office of Surface Mining Reclamation and Enforcement (OSM). In its fiscal year 1985 report, OSMRE notes that in the previous review period (FY 1984), deficiencies were found in DMLR-approved subsidence control plans. According to OSMRE, "subsidence survey summaries and proposed monitoring plans for surface structures and features did not specify how the degree of damage was to be determined."[162] By 1985, DMLR responded by requiring more complete information on subsidence surveys, and to include the surveys in the permit. OSMRE in its FY 1985 report noted "significant improvement" in subsidence control plans compared to FY 1984.

The FY 1985 report also noted that during 1984 the data used to prepare cumulative hydrologic impact assessments (CHIAs) were inadequate, and that DMLR's groundwater monitoring requirements were deficient.[163] The groundwater monitoring deficiency was a result of DMLR's narrow interpretation of "permit area" in connection with hydrologic monitoring. According to OSMRE, DMLR considered only the impacts of surface disturbances of underground mines on ground water quality and quantity, resulting in permitting "in a manner which does not insure protection of the hydrologic

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[161] Spangler, C. T., III, Chief Engineer, DMLR, Big Stone Gap, Virginia. Personal communication, February 16, 1989; and *Technical Data Management System for Mining and Mineral Resource Information*. Big Stone Gap: Virginia DMME, 1988 (brochure).

[162] *Annual Report, Virginia Permanent Program, for the Period May 1, 1984 to April 30, 1985*. Big Stone Gap: Office of Surface Mining, November 1985, p. 16.

[163] DMLR disagreed with this assessment.

balance outside the permit area."[164] OSM notes that:

> Federal regulations require that ground water monitoring be performed to protect those waters within the permit and adjacent areas which may be adversely impacted. The definition of "adjacent area" at 30 CFR 701.5 includes the "area outside the permit area where a resource of resources are or reasonably could be expected to be adversely impacted by proposed mining operations, including probable impacts from underground workings," a definition which the preamble states was designed to specifically include the probable impacts from underground workings.[165]

DMLR addressed these questions in 1985, making its regulation on hydrology as effective as the federal rule, including changes in response to OSMRE concerns about waivers of groundwater monitoring.

In its FY 1986 evaluation, however, OSMRE again expressed concern over DMLR's permitting of underground mines, specifically regarding subsidence and hydrology information. While subsidence surveys in the permits had improved with respect to surface structures,

> ...renewable resource lands were not fully addressed in any of the permits to the extent that this term includes aquifers and aquifer recharge zones in areas overlying underground workings. Detailed information on geology and hydrology was absent in six permits. The remaining four permits contained technically inadequate information or presented unsubstantiated statements that mining would not appreciably impact the hydrologic regimes.[166]

The report notes that DMLR had developed official policy and procedural modifications to address these concerns during the evaluation period, and that these were undergoing OSMRE review.

OSMRE's FY 1987 evaluation report states that DMLR had resolved the deficiencies in its subsidence control plan requirements with respect to technically adequate information and consideration of aquifers and aquifer recharge areas as renewable resource lands. The FY 1988 evaluation report, examining permit applications approved after the effective date (November 25, 1986) of the regulatory amendment addressing this problem, concluded that "aquifers and aquifer recharge areas are discussed in sufficient detail to justify the absence of, or need for, a subsidence control plan."[167] Through a program amendment, the problem noted in the FY 1985 report with respect to inappropriate or unjustified waivers of groundwater monitoring was also resolved.

During the last four fiscal years, OSMRE has found DMLR's inspection and enforcement program to be satisfactory in most areas. In the FY 1988 report, for example, OSMRE says: "DMLR made 100 percent of all mandated inspections. Inspections were adequately documented and complete inspections appeared to cover all applicable performance standards. Enforcement actions and follow-up actions were appropriate, effective, and timely."[168] OSMRE found that DMLR's record for citing violations had improved in FY 1988.

Summary

A knowledge of what is actually happening in the field is an absolute precondition to any attempts to control the environmental effects of coal mining. DMLR has recognized the

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[164] *Annual Report, Virginia Permanent Program, for the Period May 1, 1984 to April 30, 1985.* Big Stone Gap: Office of Surface Mining, November 1985, p. 18.

[165] *Ibid.*

[166] *Fiscal Year 1986 Annual Evaluation Report for the Regulatory and Abandoned Mine Land Reclamation Program Under the Surface Mining Control and Reclamation Act of 1977 in the State of Virginia for the Period May 1, 1985 to June 30, 1986.* Big Stone Gap: U.S. Office of Surface Mining Reclamation and Enforcement, February 1987, p. 10.

[167] *Regulatory and Abandoned Mine Land Reclamation Programs Under the Surface Mining Control and Reclamation Act of 1977 in the State of Virginia. Fiscal Year 1988 Annual Evaluation Report for the Period July 1, 1987 to June 30, 1988.* Big Stone Gap: U.S. Office of Surface Mining Reclamation and Enforcement, December 1988, p. 19.

[168] *Ibid.*, p. 3.

inadequacy of its knowledge base and has made efforts to remedy the situation.

DMLR has addressed inadequacies in its program with respect to protection of water resources potentially affected by coal mining. One of them, identified earlier in this report, was lack of data, which stemmed in part from DMLR's lack of authority to require adequate data from permit applicants. DMLR has recognized the need for more complete data, and has learned to scrutinize PHC determinations more carefully. It has changed its regulations in order to require monitoring in subsidence areas. Furthermore, the agency has been building what one attorney in the Environmental Law Institute has called an "enviable" information base for regulatory decision making.[169]

[169] McElfish, J. Attorney, Environmental Law Institute, Washington, D.C. Personal communication, March 31, 1989.

Chapter 8: Subsidence Regulation in Five States

One goal of the 1977 Surface Mine Control and Reclamation Act (SMCRA) and OSMRE's implementing program is uniform state regulation of the effects of coal mining, so that individual states cannot gain a competitive coal industry advantage through lax environmental standards. In order to receive authority from OSMRE to implement regulatory programs under SMCRA, states were required to enact laws and promulgate regulations at least as effective as OSMRE's. While various state programs are now more alike than before SMCRA, differences result from individual laws, regulations, court decisions, interpretations of property rights, and implementation by the regulating state agency. Moreover, in none of the states surveyed for this report has the body of laws and regulations stabilized; regulation of surface and underground coal mining continues to evolve in each.[170]

In the following sections, various state regulations under SMCRA are described as they apply to subsidence and the protection of the hydrologic balance. This is not intended to be an exhaustive survey of all coal-mining states. The states included were chosen because either the geology of their coal-mining regions is similar to that of Virginia's (Kentucky and West Virginia); or their regulatory schemes are noteworthy. An indepth examination of each state is not possible within the scope of this research. This section merely highlights some of the salient features of each of the five states' coal mining regulatory programs and related activities.

Pennsylvania

Pennsylvania has a long history of both coal mining and coal mine subsidence problems. In 1913, Pennsylvania passed a law limiting coal mining beneath streets and highways, and later expanded it to provide subsidence protection to public facilities and dwellings. The law was declared unconstitutional in *Pennsylvania Coal Co. v. Mahon*, a landmark U.S. Supreme Court decision on the taking issue.[171] However, the constitutionality of Pennsylvania's current coal mining subsidence control program was recently upheld by the U.S. Supreme Court in *Keystone Bituminous Coal Association, et al., v. Nicholas DeBenedictis, et al.*[172] Pennsylvania's program reflects the state's long acquaintance with subsidence damage to both structures and the land. It goes farther than federal primacy requirements for protection of both surface owners and water resources.

Pennsylvania's regulatory program for the environmental effects of coal mining are authorized under the State' Coal Refuse Disposal Control Act,[173] the Surface Mining Conservation and Reclamation Act,[174] the Bituminous Mine Subsidence and Land Conservation Act,[175] and the Clean Streams

[170] This is not surprising, considering that the federal regulations under SMCRA are still in a state of flux more than a decade after the law was signed.

[171] 260 U.S. 393 (1922)

[172] 107 S.Ct. 1232 (1987)

[173] 52 P.S. Sec. 30.51-30.66

[174] 52 P.S. Sec. 1396.1-1396.25

[175] 52 P.S. Sec. 1406.1-1406.21

Law.[176] Under the revised federal primacy subsidence control program that came into effect July 1, 1983, surface structures are no longer included in the definition of surface lands, revoking federal protection under the requirement that operators protect surface lands from subsidence damage. Pennsylvania's Bituminous Mine Subsidence and Land Conservation Act, however, establishes the operator's duty to "remedy damage to structures." Performance standard regulations under the law (effective March 30, 1985) state that mining shall be conducted to prevent subsidence damage to, among other things, dwellings "in place on April 27, 1966"[177] The prohibition of subsidence damage to structures may be waived by the current owner. Coal operators must, within 10 days of being advised of a claim of subsidence damage to a structure or surface feature, provide the State Department of Environmental Resources (DER) with pertinent information. Claim settlements must be made within 6 months, or an amount (determined by the DER) equal to the reasonable cost of remedying the damage must be deposited with DER, to be held in escrow until the operator submits evidence that the claim has been settled.

For the purposes of subsidence control, Pennsylvania defines streams and springs that flow continuously during the entire calendar year as a result of groundwater discharge or surface runoff as perennial. Section 89.143(b.1.iv.) of Title 25, Pennsylvania Code, states that underground mining activities "shall be planned and conducted in a manner which prevents subsidence damage to ...[a]quifers, perennial streams, and bodies of water which serve as a significant source for a public water supply system." Pennsylvania regulations implementing the federal primacy program (quoted) do not require protection of perennial streams that do not serve as a public water supply. However, protection of such streams was adopted under a separate state law. Under the performance standard an operator is required to maintain the premining uses of the stream, including aquatic life support, water supply, and recreational uses. The operator determines the necessity for and the appropriate measures to be taken to prevent subisdence damage to the stream. If the stream is damaged by subsidence, the operator must restore the stream to its premining condition. If measures taken to protect the stream are ineffective, the operator must submit revised plans or other data to demonstrate that future mining activities will meet the performance standard.[178]

The U.S. Office of Surface Mining Reclamation and Enforcement (OSMRE) made the following statement in its annual report for fiscal year 1986:

> Combined efforts of DER and OSMRE during 1986 have resulted in the modification of the bituminous surface mine permit application to solicit an adequate Probable Hydrologic Consequence (PHC) determination. In turn, the PHC provides supportive information for the proper implementation of an administratively complete and technically proficient Cumulative Hydrologic Impact Assessment (CHIA) process. Based upon the CHIA process, DER will be able to conduct an evaluation of a proposed mining operation in concert with existing and anticipated mining operations to assure the hydrologic balance of the entire area is properly protected.[179]

Pennsylvania has experienced instances of hydrologic damage resulting from longwall mine subsidence. Pumping and treating water flowing into a longwall mine once resulted in an interbasin diversion and consequent periodic dewatering of a trout stream. High-extraction mining subsidence has resulted in dewatering or suspected dewatering of streams in Cambria, Indiana, Washington, and Greene counties, and individual water wells have also been affected.[180]

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[176] 35 P.S. Sec. 691.1 *et seq.*

[177] Sect. 89.143 b.1.ii

[178] *Pennsylvania Bulletin*, 15(13):1172, March 30, 1985

[179] U.S. Office of Surface Mining Reclamation and Enforcement. *OSMRE Annual Report, 1986*. Washington, D.C.: U.S. Department of the Interior, 1986, p. 66.

[180] Arway, J. A. Division of Fisheries Environmental Services, Pennsylvania Fish Commission, State College, Pennsylvania. Personal communication, January 9, 1989.

The Pennsylvania Division of Fisheries Environmental Services identified some problems in the state's regulatory program.[181] Regulations concerning permit application requirements with respect to subsidence control contain a definition of perennial stream that differs from that contained in the general definitions section. The definition in the latter section (Sec. 89.5) identifies a perennial stream as "a body of water flowing in a channel or bed composed primarily of substrates associated with flowing waters and ...capable ...of supporting a benthic macroinvertebrate community..." In the subsidence control application section, by contrast, the definition is more restrictive: "a stream or part of a stream that flows continuously throughout the calendar year as a result of ground-water discharge or surface runoff."[182] According to the agency, this definition change results in a lower degree of protection for some streams that support aquatic life but do not necessarily flow every day of the year.

Moreover, although mining must protect from perennial streams which are not significant sources of public water supply from subsidence damage, "the prediction of subsidence damage [for such streams] may be more of an art than a science. Usually damage must occur prior to DER intervention and then it is a long drawn out process to definitively prove damage."[183] Even with regulations protecting them, it is still possible that perennial streams not undermined may be dewatered into intermittent streams because of subsidence-induced water table reductions or diversions from nonperennial streams in headwater zones.

As in Virginia, Pennsylvania's regulatory agency cannot require replacement of subsidence-damaged water supplies to individual surface property owners. Most water damage cases are resolved outside the regulatory system, and larger coal companies maintain voluntary water replacement policies. As in Virginia, lack of data available to the regulatory agency makes it difficult to determine the cause of well dewatering. Because of a restrictive regulatory interpretation similar to the one recently abandoned by Virginia, groundwater monitoring has been largely limited to determining the effects of underground mine surface facilities.[184]

Kentucky

In 1985, Kentucky's coal production accounted for more than 17 percent of all coal produced in the United States. Underground mines alone produced 81.2 million tons. Despite the size of Kentucky's coal mining industry, however, it maintained only 5 operating longwalls in 1989.

In 1986, the National Wildlife Federation filed suit against the Kentucky Department for Surface Mining Reclamation and Enforcement, part of the Natural Resources and Environmental Protection Cabinet. The suit alleged failure to cite all violations, take alternative enforcement action, and provide information on pre-mining rate of groundwater recharge.[185] A settlement agreement was reached on September 18, 1987.[186] In 1988, through a cooperative agreement, OSMRE provided funding for improved mine inspection and enforcement as called for in the settlement agreement.[187]

The 1987 OSMRE report on Kentucky's mining regulatory program states, "there are several complex issues dealing with hydrology relating to underground mining

[181] Arway, J. A. *Summary, Presentation to the Deep Mine Mediation Committee*. July 1, 1987. State College: Pennsylvnia Fish Commission.

[182] Sec. 89.141(b)2

[183] *Ibid.*, p. 2.

[184] Kernig, J. Pennsylvania Bureau of Mining and Reclamation. Personal communication, August 1988.

[185] U.S. Office of Surface Mining Reclamation and Enforcement. *Fifth Annual Report: Kentucky Permanent Program*. Lexington: U.S. Department of the Interior, August 1987, p. 8.

[186] U.S. Office of Surface Mining Reclamation and Enforcement. *Seventh Annual Report: Kentucky Permanent Program*. Lexington: U.S. Department of the Interior, July 1989, p. 3.

[187] *Ibid.*

which have not been addressed sufficiently by Kentucky."[188] The following statement from the OSMRE report reveals the state of Kentucky's regulation of subsidence-induced environmental impacts:

> Subsidence above underground works is another complex technical issue which needs to be addressed. Large crevices, some as broad as eight feet, have been noted, and on occasion made public roads impassable and dangerous. Kentucky needs to recognize this as a serious problem and begin to deal with it as a mining impact which must be addressed through proper planning and correction by the operator.[189]

The 1989 OSMRE oversight report notes that while Kentucky's inspection program has improved, the state needs increased attention to the areas of blasting and hydrologic impacts of underground mining, "as isolated cases are creating significant environmental concerns to affected citizens."[190]

While the preceding suggests that Kentucky's implementation of subsidence regulations may have been inadequate, at least in recent years, the regulations themselves are similar to those of other states. Kentucky's subsidence controls essentially parallel federal regulations, except that mine operators are liable for subsidence damage to structures. Subsidence control must be addressed in the mining and reclamation plan submitted as part of an underground mining permit application. Existing structures and anticipated subsidence effects must be addressed. The operator has several options to "mitigate the effects of any material damage or diminution of value or foreseeable use of lands" that may occur as a result of subsidence:[191] 1) "Restoration or rehabilitation of structures and features ...to premining condition"; 2) replacement of structures destroyed by subsidence; 3) purchase of structures prior to mining and restoration of land after subsidence; or 4) purchase of noncancellable insurance policies payable to the surface owner in the full amount of the possible material damage or other comparable measures.

The section on performance standards for subsidence control within Kentucky's subsidence regulations (KAR 18:210, Sect. 3) states that each permittee "who conducts underground mining which results in subsidence that causes material damage or reduces the value or reasonably foreseeable use of the surface lands shall, with respect to each surface area affected by subsidence," either restore each damaged "structure, feature, or value," purchase it, or compensate the owner as described above.

Kentucky's regulations, like their federal counterparts, require a prediction of the probable hydrologic consequences (PHC) of mining operations. For groundwater systems, the PHC must include impacts on water quality and quantity, "emphasizing water levels and the potential for water supply diminution for existing users, and dewatering of aquifers which are not currently being used for water supply but have the potential to be developed as a water supply source.";[192] Submission of baseline data to support the Cabinet's determination of cumulative hydrologic impacts is required.

Kentucky regulations regarding hydrology in the performance standards for underground mining is couched in relatively general terms similar to those found in the federal regulations. Underground mining must "minimize disturbance of the hydrologic balance in both the permit area and adjacent areas," in order to prevent "material damage" to the hydrologic balance outside the permit area, and support the approved postmining land uses.[193] Changes in water quality and quantity "shall be minimized." Most of the language on hydrologic effects of mining is geared toward surface operations.

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[188] *Ibid.*, p. 6.

[189] *Ibid.*, p. 7.

[190] U.S. Office of Surface Mining and Enforcement, *id.*, July 1989, p. 1.

[191] 405 KAR 8:040, Sect. 26

[192] 405 KAR 8:040, Sect. 32

[193] 405 KAR 18:060, Sect. 1

Performance standards for subsidence control in Kentucky (405 KAR 18:210), prohibit mining beneath or adjacent to perennial streams unless the Cabinet finds that subsidence will not cause "material damage." If it does, "measures will be taken" to the extent technologically and economically feasible to correct the damage and prevent additional subsidence from occurring. Underground mining is also prohibited beneath any aquifer that serves as a significant source of supply to any public water system. According to DSMRE geologist Tim Sullivan, coal operators are required to identify an alternate water supply if they anticipate damage to an existing one.[194] As with the federal regulations, however, Kentucky's regulations do not require replacement of private water supplies.

Ohio

Although Ohio has relatively few longwalls (three in 1989), there has been considerable activity relating to the regulation of their effects. A noteworthy aspect of the state's regulatory system, from the point of view of this report, is that Ohio requires underground mining operators to replace adversely affected water supplies. Liability for structural damage (described below) is also treated differently than by federal regulations.

Ohio's high level of attention to the effects of longwall mining is attributable, at least in part, to two factors. One is that the economic contribution of coal mining, statewide and even in the coal mining regions of the state, does not loom as large as it does in the coalfields of Virginia. The land being undermined includes productive agricultural land, some used for dairy farm operations. Surface subsidence, and especially hydrologic impacts, can have serious economic consequences on such operations. Second, while Ohio was in the rulemaking process under their primacy program, a number of unexpected and well-publicized adverse impacts of subsidence over longwall mines created a resilient negative image of longwall mining in the state. Ohio's caution in dealing with these impacts, attributable in part to a lack of clear authority under the state's regulations, helped galvanize local opposition. A group called Citizens Organized Against Longwalling (COAL) has significantly influenced the development of regulations dealing with subsidence in Ohio. The organization's success has encouraged formation of local groups in other parts of the state affected by longwall subsidence; there is now "essentially a group for each longwall mine in the state."[195]

Underground coal mining is regulated in Ohio under Chapter 1513 of the Ohio Revised Code (O.R.C. 1513), predating SMCRA and amended in 1978 to extend regulation to the surface effects of underground operations. The state's regulatory program is administered by the Department of Natural Resources (DNR), Division of Reclamation. Though SMCRA, per the Flannery rulings, does not require replacement of water supplies affected by underground mining, Ohio law (O.R.C. 1513) does. Repair of perennial streams damaged by mine subsidence must be included in subsidence control plans; however, Rothwell and Payne note that "the actual feasibility of such repairs remains to be tested."[196]

The state has recently put new policies into effect with respect to structural damage resulting from subsidence. In January, 1989 the Governor of Ohio, by executive order, gave the regulatory agency the power to require repair of such damage.[197] This policy was made part of the state's permanent regulatory program as of August 1989. Mining companies must perform detailed presubsidence surveys, including photo-

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[194] Sullivan, T. Kentucky Department of Surface Mining Reclamation and Enforcement, Frankfort. Personal communication, August 18, 1988.

[195] Payne, H., Ohio Division of Reclamation. Athens, Ohio. Personal communication, October 6, 1988.

[196] Rothwell, R. J.; Payne, H. J. "Longwall coal mining under SMCRA 1977. The Ohio experience." In: Peng, S. S. (ed.) *Proceedings, 2nd Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, June 9-11, 1986*. Morgantown: West Virginia University, Dept. of Mining Engineering, August 1986, pp. 9-12.

[197] Dieringer, T. Chief, Ohio Division of Reclamation. Presentation at *An Industry Under Seige: Some Facts About Subsidence*. Charleston, West Virginia, April 5-6, 1989, sponsored by the American Mining Congress and the West Virginia Coal Association.

graphic evidence, to establish a baseline against which DNR can judge the extent and cause of structural damage.[198] In order to receive, revise, or renew a permit, coal operators must commit themselves to repair or compensate surface owners for subsidence damage unless the surface owner and the operator have a private agreement that addresses repair or compensation. When subsidence damage occurs, DNR notifies the operator, who must then (absent a private agreement) submit and implement a plan for repair or mitigation.

Insufficient data for assessing the potential hydrologic impacts of longwall mining has been a continuing problem for Ohio's regulatory agency. The problem has been addressed through regulation changes and sponsored research. DNR now requires, for new mines or significant extensions in existing mines, a year of premining well monitoring (static water levels and water quality) and correlation data between wells and progress of the longwall face.[199] DNR is considering requiring pump tests (though there is some disagreement among the agency's hydrologists about the value of such tests, given their expense) and aquifer modeling from mining companies using longwalls. The companies' position has been that the aquifers in question cannot be adequately modeled.[200]

Two studies of the hydrologic effects of longwall mining in Ohio have been conducted. In 1984, Coe and Stowe examined effects of longwall mining on well levels and spring and stream flow rates in eastern Ohio.[201] In this study, dug and drilled wells, ponds, developed springs, and a stream were monitored above two different longwall mines. In one case, "nearly all water sources were affected as the result of surface fracturing of a shallow sandstone aquifer, which effectively drained the aquifer."[202] In the second case, several wells were partially or completely dewatered, one of three ponds showed water level decline, and a stream fractured so that its flow was sporadic after mining. Hydrologic disturbance in the second case was described as less severe than in the first because of a higher proportion of plastic shales and claystones in the overburden. More recently, the USGS studied the cumulative impacts of longwall mine subsidence on streamflow, water quality, and benthic populations; however, a severe drought in Ohio during 1988 rendered the study inconclusive so far.[203]

West Virginia

West Virginia, which accounted for nearly a third of the nation's underground coal production in 1985, has more active longwall mines in operation (about 30) than any other state. Following the passage of the West Virginia Surface Coal Mining and Reclamation Act in 1981, the state was granted primacy in implementing SMCRA. The West Virginia Department of Natural Resources (DNR) originally was given authority for implementing the regulations, but in 1985 the West Virginia Energy Act created the West Virginia Department of Energy (WVDOE), which took over regulation of the coal industry, including subsidence regulation.

Implementation of subsidence control regulations in West Virginia did not proceed smoothly. DNR attempted to apply the first set of subsidence control regulations only prospectively, with existing underground mining operations (as of July 15, 1983) "grandfathered." A subsequent court deci-

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[198] Payne, H., Ohio Division of Reclamation, Athens, Ohio. Personal communication, October 6, 1988; and *Coal Outlook* 13(5):4, February 6, 1989.

[199] Payne, H., *ibid*.

[200] Payne, H., *ibid*. Payne notes that coal companies seem to share a concern that the more data they supply, the more likely it is that it will be used against them.

[201] Coe, C. J.; Stowe, S. M. "Evaluating the impact of longwall coal mining on the hydrologic balance." In: Graves, D. H.; DeVore, R. W. (eds.) *Proceedings, 1984 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation, Lexington, Kentucky*. Lexington: University of Kentucky, Office of Engineering Services (Bulletin UKY BU136), December 1984, pp. 395–403.

[202] *Ibid.*, p.402.

[203] Swisshelm, R., USGS, Columbus, Ohio. Personal communication, January 6, 1989.

sion found this action invalid, and in 1985 DNR ordered all underground mining operations to submit subsidence control plans. If a preliminary survey indicates that no material damage or diminution in value or foreseeable use of the land will result from subsidence, the control plan requirement may be waived. This is common in West Virginia, as many mines are located in sparsely populated, mountainous areas.[204]

During the West Virginia permit application review process, the subsidence control plan undergoes a two-level review. High-extraction mine operators (greater than 80 percent coal removal) must submit more data than required for lower extraction mines, including maps of subsidence areas; predicted subsidence profile; measures to prevent material damage to land and structures (unless operator has the right to subside); and a description of planned subsidence effects.

When a coal operator can demonstrate in the subsidence control plan that a legal "right to subside" exists, he does not have to detail measures taken to prevent or remedy damage to structures caused by mining operations. This absolute "right to subside" has recently litigated, but according to Mark Scott, head of WVDOE Administration and Enforcement, leases that give an operator the right to subside offer no legal recourse for damaged property owners. A mine subsidence insurance program makes protection for structures available in West Virginia.

In cases where an operator has no right to subside, WVDOE provides the following guidance to its regulatory personnel:

> Dwellings without the right to subside become extremely sensitive issues to handle. The only acceptable mitigative measure appears to be leaving coal to prevent material damage, unless the company and the resident have worked out some mutually acceptable remedial measure.[205]

Although aquifer mapping was once required for subsidence control plans, currently only narrative descriptions of "significant" aquifers are required.[206] Subsidence control plans must identify alternative water supplies for individual landowners whose wells and springs are likely to be damaged by underground mining. Provision of alternate water supplies is also required in West Virginia.[207] Cases of disagreement between the surface owner and the coal operator over water loss are decided by the regulatory agency.[208] As in most states (following the federal regulations), the terms "significant aquifer" and "hydrologic balance" are not clearly defined for purposes of regulation.

In its subsidence control plan guidelines, West Virginia appears to grant coal operators a presumption of no damage. First, WVDOE says that "if the overburden is more than 250-300 feet and is at least 60 times the seam thickness, material damage to streams is unlikely."[209] The agency takes a similar position with respect to aquifers:

> The effects of subsidence on aquifers are very much site specific based on stratigraphy or lithology. When the ground subsides due to mining, depending on the nature of the overburden, there is a fracture zone, extending above the mined seam, about 35-60 times the seam

[204] Meador, S. "Regulation of surface subsidence in West Virginia." In: Peng, S. S. (ed.) *Proceedings, 2nd Workshop on Surface Subsidence Due to Underground Mining, Morgantown, West Virginia, June 9-11, 1986*. Morgantown: West Virginia University, Dept. of Mining Engineering, August 1986, pp. 6-8.

[205] West Virginia Department of Energy. *Permitting Handbook. Subsidence Control Plan, Guidelines for Interpretive Rules*. Charleston: West Virginia Department of Energy, 1987, p.2.

[206] Federal regulations (30 CFR 701.5) do not modify the word aquifer with "significant" here. DiPretoro argues that this results in a less effective program in West Virginia. DiPretoro, R. S. Geologist, Morgantown, West Virginia. Personal communication, January 18, 1990.

[207] Scott, M., Deputy Director for Administration and Enforcement, Department of Energy, Charleston, West Virginia. Personal communication, August 26, 1988.

[208] Boyles, D. U.S. Office of Surface Mining Reclamation and Enforcement, Charleston, West Virginia. Personal communication, February 24, 1989.

[209] West Virginia Department of Energy. *Permitting Handbook. Subsidence Control Plan, Guidelines for Interpretive Rules*. Charleston: West Virginia Department of Energy, 1987, p.2.

> thickness. If the aquifer and the well bottom are above this zone, and there is a well developed shale bed below the aquifer, the chances of material damage are minimal. Even if there is a temporary loss during mining, the shale bed tries to seal itself after mining, forming an aquiclude, and the aquifer returned more or less to the original level.[210]

West Virginia is requiring increasingly detailed premining hydrologic data.[211] Mining companies have shown a willingness to implement monitoring, because good monitoring data can provide them with protection against spurious water claims. WVDOE has had problems managing data, however, and there are concerns over data quality. The agency has contracted with West Virginia University for data validation and management assistance.[212]

The summary of West Virginia's mining regulatory program in OSMRE's 1986 *Annual Report* noted that "the State has made only minimal progress in implementing the hydrologic protection provisions of SMCRA. Cumulative Hydrologic Impact Assessments (CHIAs) are not being prepared by WVDOE and problems continue to exist in the adequacy of statements of probable hydrologic consequences (PHCs) and in the use of inadequate baseline hydrologic data."[213] A CHIA process has since been implemented in West Virginia, according to Dennis Boyles of the OSMRE field office in Charleston.[214] Each of the WVDOE's seven field offices now has a CHIA leader, and all permits have undergone the process. West Virginia CHIAs are not based on hydrologic modeling, but rather professional judgement of the regulatory personnel. OSMRE still has some concerns about the quality of CHIAs being produced by the agency, however.

Maryland

The environmental effects of underground coal mining in Maryland are regulated through both a primacy program under SMCRA and state statutes, including a law enacted prior to SMCRA that regulates underground coal mines through a permitting system. Maryland's coal mining regulatory program is implemented by the state's Department of Natural Resources, Water Resources Administration, Bureau of Mines.

Maryland is probably unique among the states in having enacted legislation for resolving water replacement conflicts arising from underground mining operations in anticipation of such conflicts, rather than as the result of them. The state currently claims only one active large-scale underground coal mining operation, in Garrett County. The mine has recently added a longwall unit, and while there have been a few instances of water supply damage associated with the operation, all but one have been resolved privately. The case that came to the attention of the Maryland Bureau of Mines as a complaint was related to blasting, not subsidence. Surface mines account for the vast majority of water supply damage complaints handled by the Bureau.

Despite the relative absence of water supply impacts by high-extraction underground mining, Maryland maintains in its primacy program under SMCRA that operators are required to replace damaged water supplies.[215] This regulatory interpretation gained statutory support in 1989, when the obligation to replace damaged water sup-

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210 West Virginia Department of Energy. *Permitting Handbook. Subsidence Control Plan, Guidelines for Interpretive Rules*. Charleston: West Virginia Department of Energy, 1987, p.3.

211 Scott, M., *op. cit.*

212 Boyles, D., *op. cit.*

213 Office of Surface Mining Reclamation and Enforcement. *OSMRE Annual Report 1986*. Washington, D.C.: U.S. Department of the Interior, p. 79.

214 Personal communication, February 23, 1989.

215 Environmental Law Institute. *The Environmental Regulation of Coal Miing: SMCRA's Second Decade*. (Draft) Washington, D.C.: Environmental Law Institute, 1989.

plies was extended to underground mining operations.[216] The new law states that

> The operator of a deep mine shall replace the water supply of an owner of interest in real property who obtains all or part of the owner's supply of water for domestic, agricultural, industrial, or other legitimate use from an underground or surface source where the supply has been affected by contamination, diminution, or interruption proximately resulting from deep mining operations.[217]

Prior to passage of the 1989 law, Maryland maintained a fund to assist in expediting water replacement in surface mining cases. The new law authorizes use of monies from a Deep Mining Fund for remediation of water supplies damaged by underground mining. Before this source of funds was available, landowners with damaged water supplies might face the prospect of waiting for relief while the cause of damage was investigated and remediation negotiated, litigated, and appealed. Alternatively, mine operators might be faced with the choice of paying for immediate water replacement while they appealed the agency's finding, or paying daily fines for noncompliance. The Deep Mining Fund may be tapped, at the request of either the coal operator or the landowner, to pay for immediate water supply replacement. If the operation is found to have caused the damage, the coal company reimburses the fund; if not, the landowner does. The fund may also be used to pay for water supply replacement when problems develop after mining cessation and bond release, or in the event of bond forfeiture. The existence of this fund and the flexibility it allows accounts in part for the lack of coal industry opposition to the 1989 law.[218]

Maryland's regulatory system does not provide for an absolute prohibition of mining beneath perennial streams. The state Department of Natural Resources has the authority to require at least 50 percent of the coal in a seam be left to prevent subsidence that could affect perennial streams. High-extraction mining is prohibited beneath such streams unless a variance is granted. The agency handles undermining perennial streams on a case-by-case basis.

Summary

In a recent presentation on activities related to longwall mining subsidence in different states, especially activities perceived by the mining industry as threats to longwall mining, Gerald McPhee of Island Creek Coal Co. identified two recurring themes: concern over subsidence damage to structures, and concern over effects on water resources.[219] In all but a few of the states where longwall mining is practiced, subsidence has received political recognition as a problem. In several states, citizens' groups opposing the practice have attempted to influence government policy. And on the national level, a battle is taking shape over the application of certain provisions of SMCRA to subsidence effects of underground mining.[220]

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216 Under the federal regulations implementing SMCRA, water supply replacement is required only of surface mining operations.

217 *Ann. Code of Md., Nat Res Art.* SS7-5A-05.2(B) (1989).

218 Abar, T. Maryland Department of Natural Resources. Personal communication, June 6, 1989.

219 McPhee, G. "State Legislative Initiatives." Presented at *An Industry Under Seige: Some Facts About Subsidence.* American Mining Congress and West Virginia Coal Association, Charleston, West Virginia, April 5-6, 1989.

220 On December 27, 1988, OSMRE proposed re-examining the applicability of the prohibitions on mining in Section 522(e) of the Act to subsidence resulting from underground mining. The existing rules had been subject to legal challenge on the basis that they were unclear as to the surface impacts of underground mining. "Beyond clarifying existing rules, OSMRE is interested in examining policy, economic, environmental and legal considerations concerning application of the mining prohibitions in section 522(e) to subsidence resulting from underground mining. This rulemaking proposal, therefore, addresses the broader issue of whether and to what degree subsidence is covered by the mining prohibitions set forth in section 522(e) of the Act. The issue is one of great concern for the coal industry and various environmental and citizen groups because the final rule may have substantial economic or significant environmental consequences." *Federal Register* 53(248):52374, December 27, 1988. The consequences of the application of 522(e) prohibitions on mining to subsidence from underground mining are related to the question of valid existing rights (VER) to mine and the

The five states reviewed in this section have responded in different ways to the problems posed by longwall mining (see Table 6, following page). The problems, however, are substantially the same: damage to surface structures, surface water bodies, and water supplies making use of groundwater. An attempt to account for the varying responses among the states would constitute a major research project in itself. But other states provide experience and lessons that may be useful to both the coal industry and the regulatory agency in Virginia. The clearest lesson is that if longwall mining is practiced on a large scale, there is strong potential for subsidence damage and conflicts between coal companies and landowners.

The next chapter draws upon this review to develop policy/action options for dealing with the conflicts arising from the hydrologic impacts of subsidence.

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interpretation placed upon VER. Section 522(e) prohibits mining within national parks, wildlife refuges, wild and scenic rivers, and other federal and federally-protected lands; as well as occupied dwellings, cemeteries, public roads, and other public buildings and places.

TABLE 6: FEATURES OF SUBSIDENCE REGULATION IN SIX STATES AND THE FEDERAL GOVERNMENT

	OSM	KENTUCKY	MARYLAND	OHIO	PENNSYLVANIA	VIRGINIA	WEST VIRGINIA
No. of longwalls (1989)	n.a.	5	1	3	12	13	29
Standards for protection of perennial streams	No adverse effect on water quantity on quality or envir. resources	No material damage	Discretion of regulatory authority	Repair any damage	Maintain or restore premining condition	Discretion of DMLR	Unknown
Individual water supplies	★	Identify alternative supply	Replace, repair, or compensate	Replace, repair, or compensate	★	★	Provide alternative water source
Coal operator liability for damage to surface structures	★	Yes	Yes	Yes	★	★	Yes
Subsidence damage waivers recognized	Yes	No	Yes	No	Yes, if waived by current owner	Yes	Yes

★To the extent required under state law (common law)
Information sources: OSMRE regulations; for various states, see text.

Chapter 9: Conclusions

This research has considered the evidence for hydrologic effects of subsidence caused by high-extraction mining; the potential impacts of those effects on water resources; and the adequacy of present controls over those effects and impacts. Specifically, we have addressed the following question: Are Virginia's available control mechanisms (technical, regulatory, and legal) adequate to protect water resources from the potential adverse effects of subsidence resulting from high-extraction underground coal mining?

Summary

There is considerable uncertainty over the adequacy of current controls to protect water resources from the potential adverse effects of high-extraction mining. Research evidence from other states suggests that water resources are likely to be adversely affected whenever subsidence occurs. The nature of those effects appears to vary with site-specific factors in ways not yet fully understood. Some states (including Virginia) have chosen to regulate these effects under the provisions of SMCRA; others have considered the effects sufficiently serious to adopt special statutory and regulatory remedies.

Technical research to analyze water resource impacts of subsidence has not been conducted in Virginia. In addition, there is little documented information on the extent of such impacts in Virginia. Because of these data deficiencies, complete assessment of the adequacy of existing controls is impossible at this time. Resolution of water resource problems caused by subsidence is further complicated by the fact that opposing parties hold entrenched opinions unsubstantiated by detailed investigations.

Regarding data deficiencies, two particular concerns are:

1. Lack of detailed technical information on hydrologic effects of subsidence caused by high extraction mining in Virginia.
2. Lack of documented information regarding number of surface owners affected, adequacy of compensation, number of lawsuits brought by affected surface owners, and the distribution of costs associated with subsidence damages to water resources.

The potential for widespread impacts exists: Minable seams underlie a significant portion of the coalfield region; groundwater resources serve a substantial portion of the population.

Detailed Conclusions

1. Mining and its effects on water resources are subjects of vital importance to the coal industry and to citizens of Southwest Virginia.

Many residents, businesses, and public water systems in the Southwest Virginia coalfields rely on groundwater. Irrespective of subsidence impacts, water availability in the coalfield counties is a problem. Surface flows are highly variable, and groundwater availability and quality are poor in some areas. The coalfield region's water resources are vital to its economic development potential and ability to establish a more diverse industrial base.

After decades of mining, many of Southwest Virginia's thickest and most accessible coal seams have been depleted. According to industry sources, it is not economically feasible to retain pillars of sufficient size to prevent long-term subsidence in the majority of the region's as-yet unmined coal seams.

High-extraction mining is essential to the economic well-being of the Virginia coalfields. Longwall mining in particular is vital to the Virginia coal industry's ability to compete in world markets. The coal industry is the major employer in southwest Virginia's coal-producing counties and will likely remain so for many years.

Industry officials show a strong interest in this issue. Some fear that future underground mining will be threatened by increased government regulation. All sides of the debate appear to want problems associated with subsidence resolved equitably and fairly. Our investigations have found little interest among residents of the Virginia coal region in "shutting down" high-extraction mining. They realize the importance of the industry to the region's employment base and economy.

2. To some degree, subsidence may be an inevitable result of all underground coal mining.

The matter of "degree" depends on the mining method (see Table 7), mine depth, geologic conditions, and other site factors. Longwall mines extract 80 percent or more of the coal in place and cause subsidence that develops rapidly and is usually complete within a matter of months. This subsidence is predictable in terms of where, to what extent, and when it will occur.

Pillar retreat or pillar removal methods extract 60-80 percent of the coal in place. They cause subsidence that is usually less predictable in terms of location, extent, and timing than subsidence resulting from longwalls.

Conventional room-and-pillar mining extracts less than 60 percent of the coal, leaving coal pillars to support the overburden. As a result, subsidence is far less than with high extraction methods. While the rule that 50 percent of the coal must be left in order to prevent subsidence has gained some currency, even with only 50 percent extraction some subsidence may occur over the long term. It may take decades for pillars to compact and crumble. While the resulting subsidence will leave shallower depressions than that from high extraction methods, it is impossible to predict where and when that subsidence will occur.

In Virginia, nearly 85 percent of coal production comes from underground operations. Of this underground production, about 35 percent comes from 10 mines using longwalls, about 52 percent comes from 237 mines using pillar removal methods, and about 13 percent comes from 64 room-and-pillar mines. Given this information, the focus of attention given to subsidence from longwall mining by the Joint Subcommittee and others in Virginia appears to be unwarranted. Subsidence impacts are not simply a longwall mining issue, but an overall underground mining concern.

3. Subsidence affects water resources, but the nature of these effects is not well understood.

This proposition is supported by both technical literature and by interviews with federal and state officials, representatives of citizens' groups, and representatives of environmental organizations. All technical studies reviewed showed that subsidence has some effect on water resources (especially groundwater), but the nature of those effects vary widely. Documented effects include declining ground and surface water levels above high extraction mines and depletion of developed water sources. None of the studies provided information on existing or potential technologies capable of preventing hydrologic impacts of subsidence. No scientific studies have been conducted in Virginia that assess the hydrologic impacts of subsidence. Reviewed technical studies were primarily conducted in the northern Appalachian area of northern West Virginia, western Pennsylvania, and southeastern Ohio.

Geology and mine depth are two factors that may prevent the direct application of the results of these technical studies to Virginia. Although general geologic conditions are similar, there are differences in the types of rock found in the study areas relative to those commonly found in Virginnia. These differences may or may not affect the transferability of study results. Concerning mine depths, seven of Virginia's ten longwall mines operate at depths below the surface considerably in excess of depths characteristic of operations treated by the reviewed studies. Many of the state's pillar extraction operations, however, operate at shallower depths, similar to the mining operations studied in northern Appalachia.

In Virginia, DMLR complaint files indicate that mine subsidence impacts on residential wells and springs have occurred. While these complaints offer some evidence, the numbers are not large (12 complaints shown to be mine-related from 1983 through 1989); however, not all water problems are reported to DMLR.

TABLE 7: GENERAL DIFFERENCES IN MINING METHODS

	Longwall	Pillar Retreat	Room & Pillar
Use in Virginia	approx. 35 percent of underground production	approx. 52 percent of underground production	approx. 13 percent of underground production
Percent Extraction	80 +	60-80	< 60%
Depth:	Generally deep (deeper the mine the less potential impact)	Generally less deep (shallower the mine the more potential impact)	Generally less deep (shallower the mine the more potential impact)
Spatial Extent:	Wide (500-1000 ft) subsidence trough.	Less well defined subsidence area, variable both in extent and timing.	Less well defined subsidence area, variable both in extent and timing.
Timing:	Relatively immediate and predictable. Most subsidence complete in 6-12 months.	Variable; some immediate, some after years' delay.	Delayed; may develop decades later, if at all.
Predictability:	Predictable	Not predictable	Not predictable

Hydrologic effects of subsidence may include benefits as well as damages. In the technical reports reviewed for this study, however, disturbances and adverse effects to the prevailing hydrologic balance are well documented, but none of the reviewed studies demonstrated benefits, although this was not their basic focus.

There is considerable uncertainty over the the exact nature of the hydrologic effects of high-extraction mining. These unresolved technical issues could form the basis for further research:

- *Are the groundwater effects of subsidence temporary or permanent?* Do aquifers, particularly confined aquifers, "naturally" repair themselves over time?
- *Can groundwater impacts occur outside the area of surface deformation?* If so, under what circumstances and why?
- *Are significant changes in water chemistry likely to occur as a result of subsidence?* If so, for how long are they likely to persist?
- *What is the impact of hydrologic effects of subsidence on wildlife resources?* Both the literature and experiences of regulatory agencies in other states show that subsidence can damage streams, springs, and seeps that provide water and habitat for plants and animals, but no scientific literature that addresses the issue of subsidence effects on biological productivity has been identified.
- *Does subsidence cause long-term water resource benefits by increasing the affected area's groundwater recharge and storage capacity?* Potential beneficial effects include a more dependable groundwater resource, more consistent stream baseflows, and possible decreased flood potential of streams draining subsided areas.

It is unlikely that any of these issues can be resolved with a simple answer that can be universally applied. Site-specific factors determine the nature of the hydrologic impacts that will result from subsidence. The current state of knowledge prevents accurate prediction of exact hydrologic effects that result from a specific high extraction mining operation.

Industry representatives cite lack of water inflow to mines as evidence that subsidence caused by high extraction mining does not affect groundwater resources in Virginia. Technical studies reviewed indicate that in other states, subsidence can affect groundwater without causing water inflow to mines.

According to the technical studies reviewed, hydrologic impacts are limited in most cases to the surface area subject to subsidence. State officials indicate that minable seams underlie the vast majority of Buchanan, Dickenson, and Wise Counties. If so, the area potentially subject to mine subsidence over the long term may be quite large.

4. The common law provides limited protection for water resources from the effects of subsidence.

Some matters of vital public interest are difficult for the U.S. system of private ownership, free market, and common law to address. In passing statutes to protect the environment, Congress has recognized that protection of private property rights through the common law fails in some instances to protect the public interest. In the case of surface coal mining, this recognition led to the passage and implementation of SMCRA.

Common law affords only limited protection of private water rights. Damage must occur before there is cause for suit, and in some cases the surface owner's predecessors in interest may have ceded the right to subjacent support -- leaving the surface owner no legal recourse. For rural residents of the coalfields, litigation is inherently risky and requires substantial investment.

5. SMCRA offers limited protection of water resources from the subsidence impacts of underground mining.

SMCRA has been effectively implemented in Virginia. OSMRE has approved regulations written by DMLR to implement the federal law. This means that the federal agency considers Virginia's regulations to be "at least as effective" as the federal regulations. According to OSMRE in its annual oversight review of Virginia's program, DMLR has been diligent in enforcing its regulations.

However, SMCRA contains significant ambiguities and limitations with respect to the surface impacts of underground mining. Not surprisingly, the regulatory framework constructed by OSMRE to implement SMCRA's underground mining provisions has been a battleground for industry groups on the one hand, and citizen and environmental groups on the other.[221] The regulations concerning subsidence damage have been under more or less constant legal attack, and have undergone numerous changes. Of special interest to this disicussion is the absence in the federal regulations of a requirement for replacement of water supplies damaged by underground mining, analogous to the requirement applicable to surface mining. Operators of surface coal mines are required to repair, replace, or compensate surface owners for damaged water supplies; underground coal mine operators are not. This inconsistency has been challenged by environmental and citizen groups, but it was found to be consistent with Congressional intent and upheld.[222] Thus, while SMCRA does contain many protections for water resources and (during the permitting process) for surface landowners' water supplies, it does not specifically require replacement, repair, or compensation for water supplies in the event of damage. As discussed in Chapter 8, some states have elected to provide this further protection through other means. Virginia has not done so.

6. Available information is insufficient to determine whether or not the coal industry's voluntary water replacement programs are adequate.

Coal mining companies with high extraction operations say that in many cases they exceed minimum compensation requirements for damage to water supplies, and that corporate responsibility and good citizenship are served. The industry is also aware of the potential political consequences of widespread citizen discontent. Nevertheless, there remains dissatisfaction with industry efforts in some circles.

Currently, only subjective evidence is available to determine the "fairness" of the Virginia coal industry's compensation policies. No independent, objective data source exists that is capable of lending support --

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[221] See, for example, the brief history of litigation over SMCRA's subsidence provisions in *National Wildlife Federation v. Interior Department* (1990), 31 *Environmental Reporter, Cases* at 1010.

[222] *National Wildlife Federation v. Interior Department* (1988), 27 *Environment Reporter, Cases*, at 1153.

or failing to lend support -- to industry claims that the vast majority of affected parties are satisfied with compensation received.

Before public policy changes are considered for compensation of surface owners deprived of water supplies, additional research should determine the adequacy of existing remedies. Potential areas of investigation are:

- *Number of affected surface owners in Virginia and settlements reached (or not reached) in specific cases.* At present, only the mining companies have access to this data, because negotiations between specific firms and affected individuals are a private matter. Aggregation of this information would require cooperation by mining companies or changes in public policy to place this information in the public domain.

- *Degree to which affected property owners are, or are not, satisfied with mining company compensation.* Industry sources claim that the vast majority of affected property owners are satisfied with compensation received under current controls; that citizen outcry results from a small, but vocal, minority. An independent survey could clarify claims to "degree of satisfaction."

- *Amount and distribution of transaction costs (e.g., who pays for settlement of compensation cases and how much) under present compensation mechanisms.*[223] Establishment of an alternative conflict resolution mechanism will also impose costs. Major questions associated with establishing an alternative might include: Will the total of all transaction costs be increased or decreased by the alternative conflict resolution mechanism? Is it appropriate to shift the current burden of transaction costs from affected property owners and the mining industry to the taxpayer?

- *Constitutional issues raised by additional regulation or statutory change that affects established property rights.* Any exercise of the state's police power is potentially vulnerable to constitutional challenge. Legal research into the nature of these issues would be a key ingredient in the deliberation of public policy changes.

Available Options

As discussed above, available data on subsidence effects and the effectiveness of voluntary compensation in Virginia are insufficient to fully determine the adequacy of existing mechanisms for protecting water supplies and resources from the impacts of mine subsidence. However, it is still useful to explore a range of options available to state officials and the industry designed to improve information, foster communication, and remove uncertainty. The following discussion describes several options and their possible implications in Virginia.

1. For DMLR. DMLR has already made several regulatory changes in response to increased high extraction mining activity, as discussed in Chapter 7. The agency has also undertaken a major expansion of its geologic/hydrologic data base, although not focused specifically on subsidence effects. The following action options aim to reduce the uncertainty that now surrounds questions related to the water resource effects of high-extraction coal mining.

- **Require additional premining and monitoring information from mining permit holders and applicants.** If DMLR is to determine whether mining operations have affected individual water supplies, the agency needs a solid information base. Necessary data could be provided by monitoring water levels and flow rates of all developed water sources likely to be affected by subsidence. Data could be correlated with proximity and passage of a longwall face or pillar extraction.

  In some cases, monitoring existing wells may be an adequate substitute for installing new monitoring wells. No new

[223] Transaction costs are costs incurred in specifying, transferring, and policing property rights. According to economist Alan Randall, the transactions industry in a modern economy "is quite massive. It includes sales personnel and their support staffs back at the office, agents of all kinds, attorneys, the police and judicial systems, and the large and growing private-sector enforcement system..." He goes on to state that "transactions costs are clearly no trivial expense." Randall, A. *Resource Economics: An Economic Approach to Natural Resource and Environmental Policy.* New York: John Wiley and Son, 1987, 434 pp.; p. 158.

statutory authority would be necessary for DMLR to implement this requirement.

DMLR needs more than one year of postmining monitoring to support conclusions about long-term hydrologic effects. Long-term monitoring of ground and surface water in strategic locations above representative high-extraction operations would be done at a lower level (i.e., fewer locations, less frequent reporting) after active mining. This monitoring would support DMLR's CHIA process and help to assure that future land uses above such mining operations will not be impaired.

Monitoring could be designed to detect changes in water chemistry as well as changes in quantity. Aquifer testing could be part of such a long-term monitoring program to determine if high-extraction mining may indeed improve groundwater development potential over the long term.

At the same time, better data provided by increased pre- and postmining monitoring might benefit mine operators by protecting them from spurious damage claims. However, the major drawback to increased monitoring is cost, most of which would fall on the mining industry. These additional operations costs could reduce profits and/or Virginia coal production.

DMLR would also experience increased cost for data tracking and analyses. DMLR's geologic/hydrologic data system, however, may be capable of handling this increased data stream without imposing a substantial financial burden on the agency.

- **Conduct or sponsor research.** Another option for increasing understanding of the hydrologic effects of subsidence is additional research conducted or sponsored by DMME/DMLR, such as the recently concluded study of Virginia's groundwater resources jointly sponsored with the U.S. Geological Survey and the Powell River Project. Important technical research topics include: actual water-related effects of mine subsidence experienced in Virginia; land area in the coalfields subject to present and future undermining by high extraction methods; long-term beneficial and adverse effects of subsidence on ground and surface water quantity and quality.

2. **For DMLR, the Mining Industry, and/or Other Organizations.** Citizens groups speaking for surface owners cite lack of information and associated anxiety as a significant problem. Success of current compensation programs varies widely between companies, which industry representatives say is due in large part to differences in communication and outreach. Better communication with surface owners well in advance of mining under or near their properties would help reduce conflicts.

DMLR could institute, and invite industry cooperation in, a public information program for surface owners. Taking the lead, DMLR could provide experts to explain subsidence, its likely impact on surface properties, legal rights of those whose water supplies are affected, and existing mining company subsidence policies. The agency could also produce and distribute informational materials informing surface owner rights, including implications of waivers of "subjacent support," and the willingness (or lack thereof) of insurers/mortgage lenders to underwrite property subject to subsidence. As an objective third party, DMLR would lend credibility to information that, if provided by mining companies, might be viewed with skepticism by some property owners. Free and open communication between mining companies and DMLR would be vital to the success of any information/outreach effort.

Third parties could also provide mechanisms for better communication between the industry and affected property owners. Efforts in this regard are already underway. Through the efforts of the Environmental Law Institute's Center on Surface Coal Mining and the Virginia Coal Association, a Virginia Water and Coal Mining Mediation Group has been formed to bring together coal companies, state agencies, and citizen and environmental groups to identify issues, articulate concerns, and resolve conflicts relating to water impacts of underground mining. This group first met in April, 1990, and a continuing process is planned.

3. **For Legislators/Policymakers.** Current regulations under SMCRA do not address the issue of damages to water users. Both the report of the 1989 Joint Subcommittee and the dissenting report declined to address the issues of property rights and compensation. Based on the research reported here, adverse subsidence impacts to indi-

vidual water supplies are possible in areas where high-extraction coal mining is practiced. Some instances have been reported to DMLR; some have been settled privately; and others have been the subject of court action. Additional cases can be expected in Virginia.

In the current debate between the coal industry and surface property owners over the effects of mining on water, central questions are: (1) whether or not the common law provides adequate protection to those who depend on water supplies potentially impacted by mine subsidence; and (2) if not, what government actions, if any, are possible, desirable, and effective to remedy the situation. The information provided by this study is not sufficient to answer these questions. However, certain policy options have been suggested by others or adopted by other states, and it is useful to draw on the results of this study to explore the possible implications of these options. They include:

1. **No Action.** This is the position recently endorsed by the 1989 Virginia General Assembly after considering subsidence issues surrounding longwall mining. Under this option, property rights would be unaltered, and there would be no additional regulatory involvement in settling disputes over subsidence-induced disruption of water supplies. Mining companies would most likely continue their programs of voluntary water replacement, and affected surface owners would need to negotiate with the mine operators or take them to court. Current mediation efforts would continue.

2. **Increase funding to DMLR to support research and outreach efforts.** Further research is needed to define the magnitude of subsidence impacts on water resources in Virginia. While DMLR has sufficient authority to require mining companies to undertake additional monitoring and environmental investigations, independent data gathering and analyses are also needed. Additional state funding for DMLR-sponsored research would contribute to increased understanding of the issue. DMME proposed an initiative in its 1990-1992 budget request to sponsor additional research into hydrologic effects of high extraction mining.

3. **Amend the Virginia Code to require water replacement or compensation for surface owners.** Currently, surface water owners are entitled to water replacement or compensation if their water source is damaged as a result of mining-induced subsidence, if they haven't waived their right of subjacent support, and if they can convince the mining company and/or the courts of their rights, their damage, and its cause.

In part, replacement/compensation for water supply damage now depends on the continuing good will of the mining companies, as well as their financial ability to continue to bearing the financial burden. Coal company representatives claim that the industry has so far given more than demanded by legal compensation requirements. In some cases, they say, companies have even replaced water supplies not proven damaged by mining, or where deeds have waived subjacent support rights.

If, however, a surface owner experiences loss of a premining water source, such as a well or spring, and the coal company that undermined the property refuses to restore the water, to provide alternative water sources, or to compensate the surface owner, then the surface owner has no alternative but acceptance of the situation or prosecution of a claim against the coal company. The latter alternative can be costly and should be undertaken only if the surface owner can prove that mining caused the water loss and that the coal company did not own the right to cause the water loss. The owner must weigh the costs of litigation against the uncertainty of proving and winning the case.

Before considering any policy that demands water replacement or compensation, additional research on the adequacy of existing compensation is needed. The recent experiences of regulatory agencies, surface owners, and coal companies in Ohio and Maryland would provide a source of useful information on the benefits and pitfalls of such legislation. The possible consequences of establishing a policy requiring replacement or compensation for mining-damaged water supplies:

- For surface owners whose deeds include a waiver of subjacent support, such a policy would transfer certain property rights held by the coal companies to the surface owner.

- For surface owners who have not waived subjacent support rights, such a policy would probably reduce uncertainty and the transaction costs faced in claiming their rights. However, it is unclear whether the policy would provide better or faster compensation than existing voluntary programs.

- For mining companies, such a policy would reduce their flexibility and probably increase costs. However, incremental costs might not be large since they currently provide water replacement/compensation voluntarily.

- Such a policy would place additional costs on DMLR for implementation and enforcement.

Concluding Comments

These options have been presented in an attempt to present in one place the possibilities tried elsewhere or voiced by those engaged in the ongoing debate over high-extraction mining and its effects on water in Virginia.

In this report, our intent has been to provide, in a single work, a view of the many aspects of this debate that is balanced and comprehensive. To this end, we have conducted a thorough review of the technical literature, attempted to draw some conclusions from it, and analyzed the regulatory and legal framework for coal mine subsidence. We hope that we have contributed to a better understanding of the issues involved.

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