Predictions for Aquifer Dewatering over Underground Mines in the Pittsburgh, Sewickley, and Upper Freeport Coals of Northern West Virginia

by

Henry W. Rauch [1]
William N. O'Steen [2]
Gerald Ahnell [3], and
Dino F. Giannatos [4]

ABSTRACT

Masters research, by former geology graduate students at West Virginia University, indicates that subsidence associated with underground coal mining has done extensive damage to overlying aquifers. Subsidence-induced dewatering is responsible for the loss of many well and spring water supplies over the coal seams that are commonly deep mined. In northern Preston County, aquifer dewatering is usually restricted to just the first 40 ft of overburden rock immediately overlying the Upper Freeport coal deep mines, but aquifer dewatering extends upwards to between 120 and 180 ft over such mines where pillars have been extracted. In eastern Monongalia County, aquifer dewatering is usually restricted to between 250 and 300 ft of rock overburden immediately overlying Pittsburgh coal deep mines, where at least partial pillar extraction has occurred. More vertically extensive dewatering occasionally occurs over Pittsburgh coal deep mines, where there is nearby surface-mine blasting, where there is longwall mining, where mining intersects permeable rock fracture zones under valleys, and where there are nearby ungrouted vertical air shafts. Any dewatering usually occurs within one year of mining. Variations in the vertical extent of dewatering are also a function of overburden lithology, with greater percentages of clay and shale being associated with less dewatering for the study area.

INTRODUCTION

General Assessment

The effects of underground coal mining on aquifer dewatering have been summarized by Sgambat, et al (1980), based on their literature survey for the eastern United States. Hobba (1981) 'has also reported on dewatered rock and reduced well yields overlying deep mines in West Virginia, especially in the Farmington area of western Marion County. Peng (1978) reported that loss of ground water commonly occurs along with land subsidence, in close association with fracturing and movement of rock layers over deep mines. Peng reported that the extent of land subsidence is related to several parameters, including coal seam thickness, percentage of coal extracted, width of mine panels, and rock overburden thickness; greater subsidence occurs for thicker coal seams, greater percentages of extracted coal, greater panel widths, and lesser overburden thickness. Tandanand and Powell (1982) have determined that rock overburden lithology also relates to the amount of land subsidence suffered from deep mining, with more subsidence occurring for an increasing percentage of weak overburden rock; weak rock was defined as shale, coal, and clay, versus strong rock, or sandstone and limestone. Land subsidence may occur over deep mines through thick overburden rock near the study area of this paper; measurable

[1]Associate Professor of Geology, West Virginia University, Morgantown, W.V.

[2]Florida Department of Environmental Regulation, Tallahassee, FL.

[3]Skelly and Loy Engineers and Consultants, Harrisburg, PA.

[4]Texaco, New Orleans, LA.

surface subsidence has occurred over a longwall mine in the Pittsburgh coal seam of western Monongalia County, West Virginia, for rock overburden zones at least 800 ft thick, as reported by Powell (1981).

Aquifer dewatering by deep mining is associated with loss of ground-water supplies, as wells or springs, where mining activity has occurred close enough to the surface (Hobba, 1981; Sgambat, et al, 1980). Deep mines also commonly impact streams and ponds, reducing their size or flow rate by inducing infiltration in response to the artificially lowered potentiometric surface for ground water (Sgambat, et al, 1980; Hobba, 1981). The effects of deep mining on stream-flow rate, within the study area of this paper, have been summarized by Bowers (1979) for the Scotts Run watershed and by Giannatos (1980a) for the Christopher No. 5 mine area, in eastern Monongalia County.

Loss of water supplies because of mining often leads to severe hardships for the supply users, with a resultant need to haul in water from outside sources or to replace lost supplies with deeper wells where appropriate. Coal companies will often replace such lost supplies with new wells, to keep good relationships with surface-land owners and to avoid lawsuits. It would be an obvious advantage to coal companies, surface owners, and government regulatory agencies to be able to predict the extent of aquifer dewatering in advance of mining. Such knowledge would aid in avoiding costly lawsuits and in more rapidly securing new water supplies to replace lost ones. Such lawsuits usually result when there is major disagreement about the cause or source for a water loss problem, and efficiently replacing lost supplies is only feasible with good hydrogeologic information about the problem and area. Also, coal companies or regulatory agencies reviewing mine permit applications may wish to modify mining plans and extract less coal under sensitive areas, such as housing developments and major streams.

Study Area

See Figure 1 for the location of the study area. The total area covers portions of four topographic quadrangle maps in Monongalia County, and portions of six topographic quadrangle maps in Preston County. The Monongalia County area was studied primarily by Ahnell (1977) and Giannatos (1980a, 1980b), and also by Moore (1976), Hilgar (1979), and Bowers (1979), for well and spring dewatering effects. The Preston County area was studied by O'Steen (1982).

Methods of Investigation

The study area was chosen because of some reported problems of insufficient well and spring yields there and because of its close proximity to Morgantown and West Virginia University. Within the Preston County study area five subareas were defined having a total of 23 underground mines in the Upper Freeport coal seam (O'Steen, 1982). The Bakerstown coal was not included in this study since there are few deep mines in this coal and few available wells and springs for monitoring of dewatering effects. The five subareas are the Borgman-Campground area, Kanes Creek area, Lenox area, Masontown area, and Valley Point area. These five subareas were selected because of their concentration of underground mines and used ground-water supplies, as indicated by reported information from Mountain State Surveying Company and from earlier works of the first two authors.

The locations of all deep mines within the study area were drawn on topographic base maps based on mine maps provided by the West Virginia Geological and

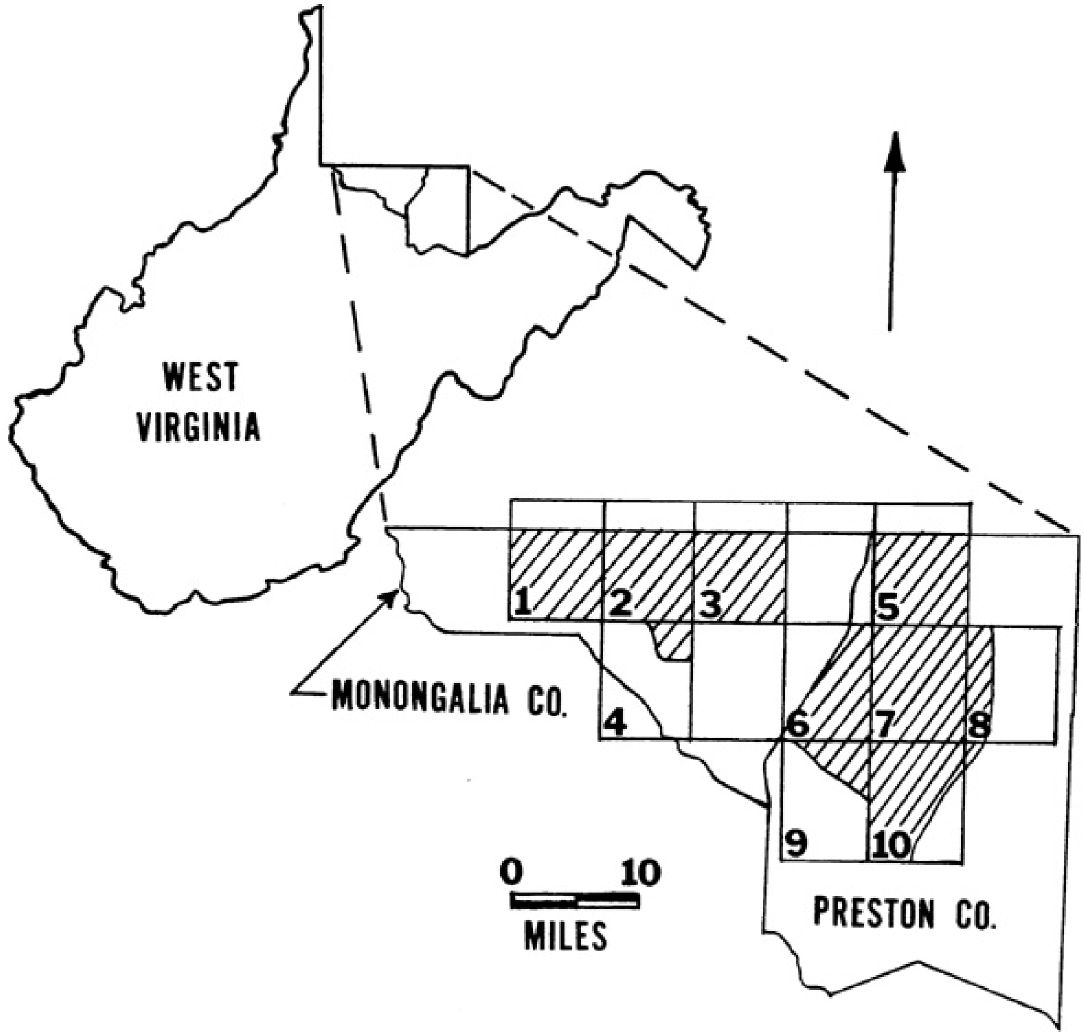

Figure 1. Location of the study area in Monongalia and Preston counties is noted by diagonal lines. Numbers refer to the following U.S. Geological 7½ minute Survey topographic maps: 1 = Blacksville; 2 = Osage; 3 = Morgantown North; 4 = Rivesville; 5 = Bruceton Mills; 6 = Masontown; 7 = Valley Point; 8 = Cuzzart; 9 = Newburg; 10 = Kingwood.

Figure 1. Location of the study area in Monongalia and Preston counties is noted by diagonal lines. Numbers refer to the following U.S. Geological 7-2 minute Survey topographic maps: I = Blacksville; 2 = Osage; 3 = Morgantown North; 4 = Rivesville; 5 = Bruceton Mills; 6 = Masontown; 7 = Valley Point; 8 = Cuzzart; 9 = Newburg; 10 = Kingwood.

Economic Survey and Mountain State Surveying Company. Fifty-seven water wells and 38 domestic springs were chosen for detailed study because of their locations overlying or in close proximity to deep mines. These sampled supplies represent many of the available supplies near tested mines, for representative testing of dewatering effects. Pertinent information on sampled water supplies was obtained by interviewing their owners, as described by O'Steen (1982). Wherever possible, well depth and depth to water were measured in the field, to confirm data reported by the owners. Lithologic logs were obtained for the Preston County study area from the Preston County Report by Hennen and Reger (1914), the West Virginia Geological and Economic Survey, local companies, and other published reports.

Collected and measured data for wells and springs were next entered into tables, and graphical plots were then constructed for each of the five defined subareas of Preston County. Rock overburden thickness, between a well bottom or spring and the underlying mined coal, was plotted versus horizontal distance to the nearest mined area, both unpillared (with pillars left after mining) and pillared (with pillars extracted) mine areas. Based on these plots, dewatered supplies were compared to unaffected supplies to identify data trends relating to aquifer dewatering. Based on this analysis, descriptive geologic models for aquifer dewatering were formulated.

The Monongalia County study area was investigated using similar methods to those described above for Preston County. Only deep mines in the Pittsburgh and Sewickley coal seams were investigated, since little underground mining occurs in other coals. West of the Monongahela River, most of the Pittsburgh coal and much of the overlying Sewickley coal has been deep mined in central Monongalia County by the Consolidation Coal Company and a few smaller companies, covered largely by topographic quadrangles 2 and 4 and the eastern portion of 1 from Figure 1. East of the Monongahela River in eastern Monongalia County, deep mines in the Pittsburgh and Sewickley coals are mostly small and isolated by incised valleys, similar to the deep mines of Preston County. Mining in general progressed from eastern towards western Monongalia County over the past several decades.

Data on deep mine areas, locations, and mining dates were obtained from the West Virginia Geological and Economic Survey and from personnel of the principal mining companies. Reported information for surveyed wells and springs was obtained by interviewing owners, as done by Moore (1976) in eastern Monongalia County (quadrangle area 3 of Figure 1), by Ahnell (1977) in quadrangle areas 1 and 2, by Giannatos (1980a) in quadrangle 4, and by Giannatos in the northern portion of quadrangle 2. Ninety-three wells and two springs were examined altogether. These water supplies were selected to be representative of hydrogeologic conditions in their local areas, and all such supplies overlie or are in the vicinity of known deep mines.

RESULTS

Preston County Study Area

Table I presents the general stratigraphic column for the lower Conemaugh Group in Preston County, after Hennen and Reger (1914). Field investigations by O'Steen (1982) revealed that 17 surveyed wells and springs were totally dewatered while 13 such supplies were partially dewatered in the close vicinity of underground mines in the Upper Freeport coal. These numbers reflect only the sampled supplies; the actual number of dewatered supplies is probably much larger in the study area, especially considering that information for many wells and springs near deep mines was unavailable.

Where substantial pillars were left behind in deep mines, relatively little aquifer dewatering occurred. In such cases dewatering was usually restricted to a 40 ft vertical zone just above the mined Upper Freeport coal seam, including the Uffington shale and the Lower Mahoning sandstone. The thick Thornton fire clay layer just above the Lower Mahoning sandstone acts as a major aquiclude (or confining layer) to retain ground water in perched aquifers above this clay.

However, where pillars have been pulled or mostly removed during retreat mining, substantial aquifer dewatering has occurred. The dewatered zone in these instances extends to at least 120 ft above the Upper Freeport coal, or at least up to the base of the massive Buffalo sandstone. Partial to complete dewatering has also commonly occurred in the zone 120-150 ft above pillared mines, and occasionally occurred in the 150-180 ft zone above these mines, extending up to or slightly above the top of the Buffalo sandstone. In no known case has dewatering extended as high as the Bakerstown coal seam, however.

The amount of rock overburden dewatering between 120 and 180 ft over a mine appears to primarily be a function of two parameters. One is the percentage of fire clay and shale in the stratigraphic column, especially for the first 120 ft of overburden rock above the Upper Freeport coal. As the percentage of shale and especially fire clay decreases, more dewatering becomes evident up to at least 150 ft above this coal. Shale and clay act as confining units to protect perched ground water above.

TABLE 1

Generalized Stratigraphic Column for the Lower Conemaugh Group, after Hennen and Reger (1914)

TABLE 1

Generalized Stratigraphic Column for the Lower Conemaugh Group, after Hennen and Reger (1914)

Lithologic Unit	Thickness (ft)	Total Thickness over Upper Freeport Coal (ft)
Coal, Bakerstown	4	192
Limestone, Albright	2	190
Fire-clay shale	10	188
Limestone, with marine fossils, Pine Creek	1	178
Shale, often red, 5' to	15	177
Sandstone, massive, gray, sometimes pebbly, Buffalo	40	162
Limestone, with marine fossils, Brush Creek, 1' to	5	122
Shale, black, with plant and marine fossils, Brush Creek, 0' to	26	117
Coal, Brush Creek	1	91
Fire-clay shale, with nodules of ferriferous limestone, Brush Creek	4	90
Sandstone, massive, Upper Mahoning	20	86
Coal, not persistent, Mahoning, 0' to	1	66
Fire-clay, good, not persistent, Thornton, 0' to	10	65
Sandstone, gray, Lower Mahoning	45	55
Shale, dark, sandy, with plant fossils, Uffington	10	10
Upper Freeport coal (Alleghany Group)	6	0

Clay appears to be the most effective lithology for confining units, since clay will readily reseal any vertical fractures created by ground subsidence following deep mining. Strata having at least 10 percent clay usually do not suffer dewatering above the 120 ft level, whereas strata containing much less clay are usually dewatered above 120 ft.

The second factor that apparently affects the vertical extent of overburden dewatering is the proximity distance to the boundary between adjacent pillared and unpillared sections of a mine. Only three water supplies (springs) have been dewatered between 150 and 180 ft above deep mines; all three springs are located directly over a deep mine and within 200 ft horizontally of the boundary between pillared and unpillared sections. Differential land subsidence is greatest near the edges of deep mines where the coal has been mostly extracted, according to Peng (1978). Therefore wider subsidence fractures under tension should be located in the vertical zone above the edges of pillared mines, and such fractures could account for the unusually great vertical extent of dewatering near these three springs.

Another geologic factor relating to the extent of dewatering is land topographic slope in the vicinity of a deep mine. The dewatered zone appears to extend farther outward from a pillared mine, both vertically and horizontally, downslope from the mine. Overburden dewatering commonly extends up to about 180 ft above and out to about 200 ft horizontally from pillared deep mines in the downslope direction, especially over adjacent unpillared mine sections. This is in contrast to the upslope sides of deep mines, where dewatering appears to extend only about 150 ft vertically and 20 ft horizontally from the mine. It seems logical that deep mines would disrupt ground-water drainage more in a downslope direction; ground water moving downgradient must pass over a deep mine before discharging to a spring or well downslope of the mine, whereas springs or wells upslope of a mine would be taping ground water that mostly originated upgradient of the mine and did not first flow over the mine.

Monongalia County Study Area

Table 2 presents the general stratigraphic column for the Monongahela Group in Monongalia County, after Hennen and Reger (1913). Field investigations by Ahnell (1977) and Giannatos (1980a, 1980b) showed that 28 sampled wells were completely dewatered and 11 wells were partially dewatered in close proximity to deep mining activities; data inspection indicated that most of these wells were dewatered by mining factors related to underground mining. The actual number of water supplies affected by deep mining is probably substantially greater than those given above, since less than one-half of available water supplies were actually studied. Deep mines are associated with aquifer dewatering in a variety of ways. The most common cause of dewatering is direct ground-water drainage to underground mines through subsidence fractures in rock overburden. This drainage can be indirectly assisted by ground damage from nearby surface mine blasting. The second most common dewatering cause is vertical air shafts that have not been pregrouted to reduce ground-water infiltration. Another cause is nearby boreholes to deep mines that serve as ground-water drains or pumping wells.

Deep mines in the Pittsburgh and Sewickley coal seams directly drain ground water from overlying aquifers in a similar manner to the Upper Freeport coal mines described earlier for Preston County. For most of the Monongalia County study area the room and pillar method of mining with later partial or total pillar extraction has been practiced in the Pittsburgh coal. Only in quadrangle 1 of Figure 1 has longwall mining been recently practiced. The Sewickley coal seam has been deep mined and about 50 percent pillared primarily in the southeastern half of quadrangle 2 and in much of quadrangle 4. This information is based on mine maps and communications with personnel of the Consolidation Coal Company.

TABLE 2

Generalized Stratigraphic Column for the Lower Conemaugh Group, after Hennen and Reger (1913)

TABLE 2

Generalized Stratigraphic Column for the Lower Conemaugh Group, after Hennen and Reger (1913)

Lithologic Unit	Thickness (ft)	Total Thickness over Upper Freeport Coal (ft)
Coal, Waynesburg	5	402
Shale	10	397
Sandstone, Gilboy	35	387
Coal, Little Waynesburg	1	352
Limestone, Waynesburg	4	351
Shale	13	347
Sandstone, Uniontown	35	334
Shale, brown, Annabelle, 0 to 15 feet; absent in many places	0	299
Coal, Uniontown	2	299
Shale	10	297
Limestone, Uniontown	15	287
Shale and with thin sandstone and limestone beds	44	272
Sandstone, Arnoldsburg	30	228
Coal, Lower Uniontown	1	198
Shale	5	197
Limestone, Benwood	65	192
Sandstone, Sewickley	25	127
Coal, Sewickley	5	102
Sandstone, Lower Sewickley	25	97
Limestone, Sewickley	43	72
Coal, Redstone	4	29
Limestone, Redstone	5	25
Sandstone, Upper Pittsburgh	15	20
Shale, limy	5	5
Coal, Pittsburgh	8	0

Data from Ahnell (1977), Giannatos (1980a), and Moore (1976) indicate that under normal circumstances, rock strata have been drained dry in a zone extending upward about 250 ft over the Pittsburgh coal seam, for the whole Monongalia County study area. The one general exception to this rule of thumb is that the dewatered zone appears to extend upward to about 300 ft over the Pittsburgh coal in the northern one-third of quadrangle 2 (Giannatos, 1980b), near the Humphrey No. 7 mine. Most dewatered wells appear to be located over Pittsburgh coal deep mines where pillars were at least partially extracted followed by land subsidence. An inspection of Table 2 reveals that the 250 ft dewatering zone normally extends up to the Arnoldsburg sandstone, with the thick overlying shale unit acting as a confining layer to retain ground water in overlying aquifers. The 300 ft dewatering

Data from Ahnell (1977), Giannatos (1980a), and Moore (1976) indicate that under normal circumstances, rock strata have been drained dry in a zone extending upward about 250 ft over the Pittsburgh coal seam, for the whole Monongalia County study area. The one general exception to this rule of thumb is that the dewatered zone appears to extend upward to about 300 ft over the Pittsburgh coal in the northern one-third of quadrangle 2 (Giannatos, 1980b), near the Humphrey No. 7 mine. Most dewatered wells appear to be located over Pittsburgh coal deep mines where pillars were at least partially extracted followed by land subsidence. An inspection of Table 2 reveals that the 250 ft dewatering zone normally extends up to the Arnoldsburg sandstone, with the thick overlying shale unit acting as a confining layer to retain ground water in overlying aquifers. The 300 ft dewatering zone in northern quadrangle 2 probably extends through the Uniontown limestone. Reasons for the apparent thickening of the dewatered zone near the West Virginia-Pennsylvania state line probably relates to the percentage of fire clay in the lower Monongahela Group. This percentage generally decreases in going north from the Marion-Monongalia county line to the state line, offering less dewatering protection to perched aquifers toward the north (Hennen and Reger, 1913). In fact this trend extends northward into Pennsylvania, where virtually no clay is evident in northern Greene and Washington counties; there aquifer dewatering extends up to about 400 ft above the pillared Pittsburgh coal mines (O'Steen, 1982).

Insufficient data do not allow the estimation of the dewatering extent to be expected over unpillared Pittsburgh coal mines for the study area, although it should be less than 250 ft above these mines. Also, insufficient data is available to us at this time to estimate the dewatering zone thickness over longwall panel mines, where virtually all coal is extracted; however, this dewatering zone normally is probably not much greater in thickness than that over pillared mines, assuming that the height of this zone (in analogy to the subsidence zone) is proportional to the coal seam thickness and percentage of coal extracted (Peng, 1978).

The dewatered zone above Sewickley coal deep mines appears to normally extend to about 150 ft over this coal, even where pillared mines exist. This in turn suggests that Sewickley coal mining causes no more extensive dewatering than do deep mines in the Pittsburgh coal.

Three known exceptions exist to the general rule of thumb stated above, with respect to the 250 to 300 ft dewatering zone above the mined Pittsburgh coal seam. Stream help to prevent some aquifer dewatering in their vicinity over deep mines, and both nearby surface mine blasting and vertical air shafts can cause more extensive aquifer dewatering than normal.

Shallow wells located within about 100 ft of a stream in the study area have retained most of their original yield despite penetrating to within about 175 ft vertically of a deep Pittsburgh coal mine. This same general fact was also noted by O'Steen (1982) for Greene and Washington counties in Pennsylvania. Apparently influent stream conditions are created over deep mines with thin overburden cover, allowing concentrated stream recharge of nearby shallow aquifers to replace aquifer water leaking to the mine and to keep wells from going dry. Stream dewatering or reduction in streamflow rate is another major impact of shallow underground mines that is not addressed in this paper.

Evidence exists in quadrangle 4 of Figure 1 for enhanced aquifer dewatering to deep mines associated with surface mine blasting. Three original water wells were partially to wholly dewatered within 1000 ft of a surface mine in the Waynesburg coal seam and overlying deep mines in both the Pittsburgh and overlying Sewickley coals. These wells penetrated to about 287 to 379 ft above the Pittsburgh coal, and reportedly had adequate yields until the nearby surface mining occurred. These wells then mostly failed, despite being a "safe" vertical distance above the Pittsburgh coal deep mine (at least 250 ft) and above the Sewickley coal deep mine (at least about 150 ft). The most probable explanation for their water loss is that the surface mine blasting caused an increased permeability for vertical fractures in the shale confining units that support the perched aquifers containing these wells, allowing drainage of these aquifers. Three slightly deeper wells were drilled after one of the original wells went dry, but no dependable water supplies were secured. The combined effects of both deep and surface coal mining in the same area apparently lead to dewatered overburden zones being expanded by 100-150 ft above normal levels over a deep mine.

Vertical air shafts extending to deep mines have caused extensive dewatering of shallow aquifers in the western portion of the study area, especially in quadrangle 1. In particular, the Pursglove air shaft near Dolls Run and the Mooresville and Wells air shafts near Jakes Run caused dewatering both during and after construction, because they were not pregrouted in surrounding outside rock; most other air shafts of the study area have been pregrouted and have not affected local water supplies, according to officials of the Consolidation Coal Company. According to Ahnell (1977), shallow wells less than about 75 ft deep were dewatered and deeper water wells were often reduced in yield, within 0.5 to 1.0 miles of these three air shafts and within three years of their construction. This dewatering resulted from free gravity drainage of shallow ground water into the shafts that caused large cones of depression in the water table. The cone of depression for the Mooresville shaft can be roughly mapped over time. This depression is approximately five times longer along the valley than it is wide perpendicular to the valley, indicating that shallow aquifer permeability is much greater parallel to the valley trend; a vertical rock fracture zone is the most probable explanation for this fact, and indeed this valley defines a major topographic lineament that is at least 2 miles long.

Another problem in the Jakes Run area besides loss of water supplies involved natural gas. Many water wells in this affected area suffered an influx of natural gas coincident with lowering of the water table, forcing the abandonment of wells not totally dewatered (Ahnell, 1977; Hilgar, 1979). The gas is natural to this area, and could have originated within shallow coal seams like the Waynesburg coal, or within deeper strata that were allowed to drain through improperly cased and abandoned gas wells; many old gas wells are situated in this valley. Wherever the water table was lowered to below the bottoms of the water well casings, the gas was allowed to migrate along the top of the water table through a shallow sandstone aquifer and into the wells. The problem of shallow aquifer dewatering and natural gas contamination was solved by Consolidation Coal Company by first drilling and casing deeper water wells for affected residents, and then reducing ground-water loss into the air shafts by partially sealing them from the inside (as noted by local residents and personnel of Consolidation Coal Company).

Subsidence in the Monongalia County study area has probably been more vertically extensive than aquifer dewatering relative to the deep mines. There is numerous evidence for surface subsidence effects throughout this area where overburden exceeds the 250-300 ft thickness usually ascribed to the dewatered zone. Visual evidence of surface subsidence, as discussed by Hobba (1981) for nearby areas, is primarily subsidence cracks and cracked building foundations; such evidence is apparent throughout the study area. For example, the Jakes Run school house suffered subsidence damage during the spring of 1983, following nearby longwall mining in the Pittsburgh coal seam about 480 ft below the surface. Then nearby Jakes Run drained into subsidence fractures and temporarily dried up during late summer of 1983 (personal communication, W.V. Department of Natural Resources and Consolidation Coal Company). Also, Powell (1981) noted that maximum land subsidence was measured to be about *1-2* to 2 ft over longwall mines in the Pittsburgh coal seam averaging 740-800 ft in depth below the surface in western Monongalia County (west of quadrangle 1).

After overburden strata have stopped subsidening into a deep mine, the softer lithologic units, composed of shale and clay, should resettle and partially reseal vertical joints to once again act as confining units for ground water. This theory would account for perched aquifers retaining water in the upper sequence of subsided strata. It is ironic that while soft strata relates to more land subsidence, they also relate to less aquifer dewatering over deep mines. The fact remains that much aquifer dewatering in strata close to a deep mine is permanent, as noted in this paper. Only on occasions when abandoned deep mines have been flooded has water been reported to have returned to previously dewatered wells, as happened for example over the Christopher No. I mine in quadrangle 2 of Figure 1. These instances are probably restricted to either downdip mines or mines with shaft entrances that would not allow any significant gravity drainage of mine waters after abandonment, in contrast to updip drift mines.

Rock overburden dewatering has been roughly twice as extensive for pillared deep mines in the Pittsburgh coal compared to those for the Upper Freeport coal, as noted above. Part of this difference is related to thickness of the mined coal seam. The Upper Freeport coal averages about 6 ft thick in northern Preston County while the Pittsburgh coal averages about 8 ft thick in central Monongalia County (O'Steen, 1982). Assuming that the vertical extent of the dewatered zone is directly related to the height of the mined coal seam, then the difference in coal seam thickness would account for only about one-third of the difference in dewatered zone thickness between the Upper Freeport and Pittsburgh coals. The remainder of this dewatered zone difference must be related to geology of the overburden, and the most probable critical factor is clay content; the percentage of clay appears to be significantly greater for rock strata of the lower Conemaugh Group above the Upper Freeport coal than for strata of the lower Monongahela Group above the Pittsburgh coal (Hennen and Reger; 1913, 1914).

CONCLUSION

In conclusion, site specific studies like those described above should aid significantly in enhancing our knowledge of aquifer dewatering related to deep mining, making possible predictions of additional dewatering in advance of mining. With additional research support, more research work will be possible on mine dewatering effects. Eventually we should be able to compose at least descriptive geologic models for predicting average extents of rock strata dewatering at any location, as a function of type of mining method, coal seam thickness, and rock overburden lithology and stratigraphy.

REFERENCES

Ahnell, G., 1977, The Effect of Pittsburgh Coal Mining on Ground-Water Levels in Monongalia County, West Virginia; M.S. Problem Report; Department of Geology and Geography, West Virginia University, Morgantown, WV, 43p.

Ahnell, G., and Rauch, H.W., 1978, The Effect of Underground Coal Mining on Water Wells in Monongalia County, West Virginia; Ground Water, Vol. 16, No. 5, p. 358.

Bowers, J.L., 1979, The Effects of Coal Mining on the Surface and Ground Waters of the Scotts Run Drainage Basin; M.S. Thesis, Department of Geology and Geography, West Virginia University, Morgantown, WV, 90p.

Giannatos, D.F., 1980a, Interrelations of Ground Water and Subsurface Mining in the Christopher No. 5 Mine; M.S. Problem Report, Department of Geology and Geography, West Virginia University, Morgantown, WV 37p.

Giannatos, D.F., 1980b, Effect of Underground Coal Mining on Ground-Water Drainage in the Humphrey No. 7 Mine Area; M.S. Problem Report, Department of Geology and Geography, West Virginia University, Morgantown, WV, 33p.

Hennen, R.V., and Reger, D.B., 1913, Marion, Monongalia, and Taylor Counties Report; West Virginia Geological and Economic Survey, 843p.

Hennen, R.V., and Reger, D.B., 1914, Preston County Report; West Virginia Geological and Economic Survey, 566p.

Hilgar, G.M., 1979, Effects of Coal Mining on Ground-Water Quality in Monongalia County, West Virginia; M.S. Thesis, Department of Geology and Geography, West Virginia University, Morgantown, WV, 108p.

Hobba, W.A., Jr., 1981, Effects of Underground Mining and Mine Collapse on the Hydrology of Selected Basins in West Virginia; Report of Investigation RI-33, West Virginia Geological and Economic Survey, 77p.

Moore, F.S., 1976, A Study of Ground-Water Quality in Eastern Monongalia County, West Virginia; M.S. Thesis, Department of Geology and Geography, West Virginia University, Morgantown, WV, 96p.

O'Steen, W.N., 1982, Evaluation of Aquifer Dewatering by Underground Coal Mines; M.S. Problem Report, Department of Geology and Geography, West Virginia University, Morgantown, WV, 107p.

Peng, S.S., 1978, Coal Mine Ground Control; John Wiley and Sons, 450p.

Powell, L.R., 1981, Longwall Subsidence Case History Number 2, Northern Appalachian Coal Region; Open File Report OFR 124(2)-81, U.S. Department of Interior, Bureau of Mines, Twin Cities Research Center, 12p.

Sgambat, J.P., LaBella, E.A., and Roebuck, S., 1980, Effects of Coal Mining on Ground-Water in the Eastern United States; EPA 60017-80-120, U.S. Environmental Protection Agency, 183p.

Tandanand, S., and Powell, L., 1982, Consideration of Overburden Lithology for Subsidence Prediction; in Proceedings of Workshop on Surface Subsidence Due to Underground Mining, edited by S.S. Peng and M. Harthill, West Virginia University, pp. 17-29.