HYDROLOGY OF THE ABANDONED COAL MINES IN THE WYOMING VALLEY, PENNSYLVANIA

By

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ABSTRACT

Mine-water discharge into the Susquehanna River degrades the river's quality during periods of low flow to a point critical for subsistence of aquatic life. To determine what measures are required to provide a better quality mine-water discharge in the Wyoming Valley, mine hydrology and mine-water quality are related to mine-pool management. The addition of mine-pool outlets at several locations would increase the rate of discharge and reduce interpool flow, which would reduce the total mineral load discharged to the river. Additional outlets would act as relief overflows to reduce the maximum fluctuation of mine-pool levels, decrease related mine-surface instability, and eliminate surface flooding.

INTRODUCTION

Purpose and Scope

Mine-water discharge into the Susquehanna River from anthracite mines throughout the Northern field has degraded the river quality during low-flow conditions to a point critical to aquatic life. The purpose of this study was to determine what modifications of the underground flow system would provide a better quality of mine-water discharge from the mine-pools in the Wyoming Valley (fig. 1) without causing ground-water flooding or

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Figure 1.--(Caption on next page) belongs near here.

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mine subsidence. This was to be accomplished by (1) determining the underground, interpool flow routes of water from the recharge area to the discharge points, (2) determining the best locations at which the mine pools may be tapped for gravity overflow, and (3) determing the pool levels above which subsidence may occur if pumping from the Delaware-Pine Ridge mine pool ceased. The latter determination was discontinued because the mines were flooded by tropical storm Agnes, in June 1972.

Figure 1.--Location of study area in Wyoming Valley

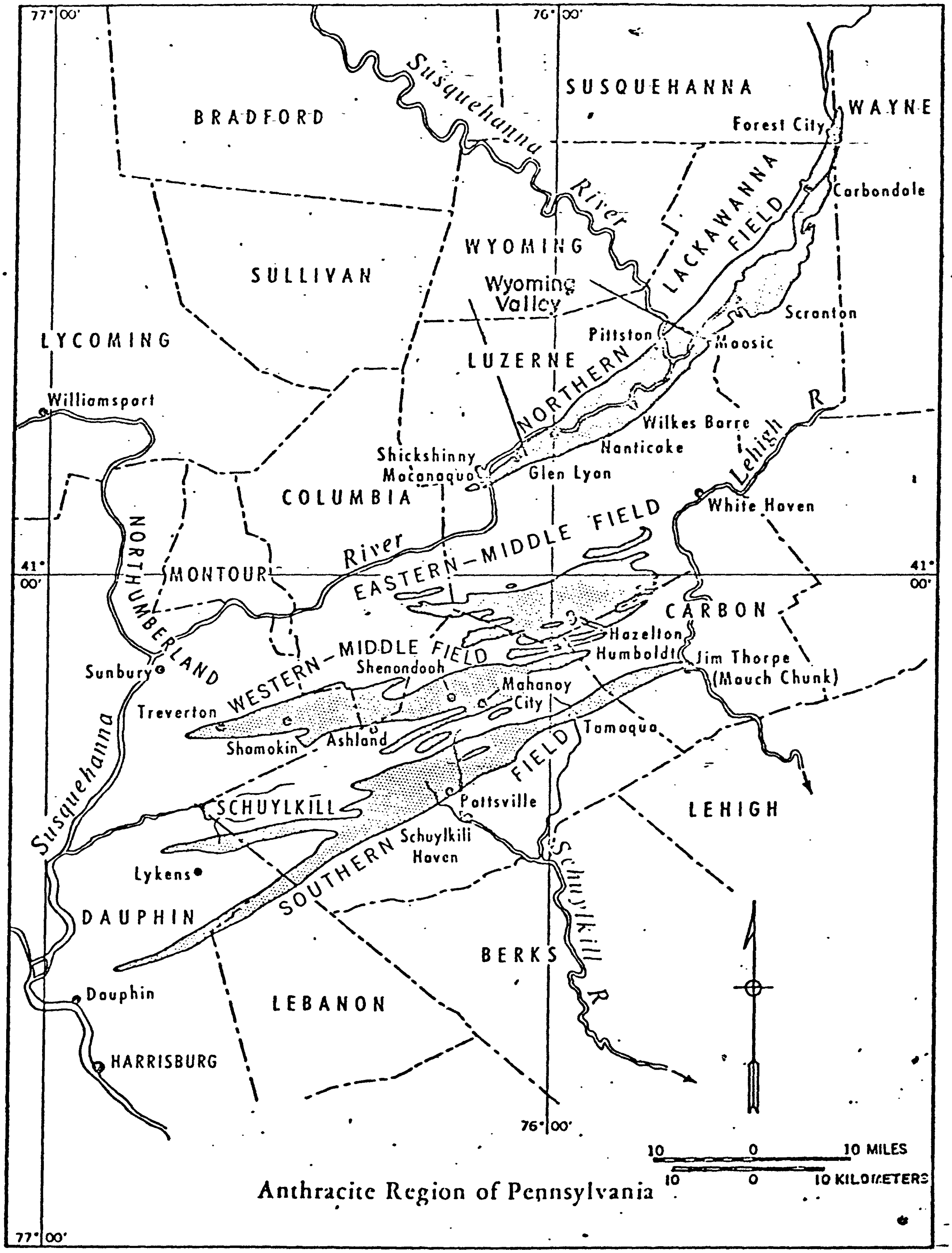

Figure 1. -- Map showing location of study area.

ACKNOWLEDGMENTS

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HISTORY OF MINE PUMPING AND INUNDATION

As the coal was exhausted, or as mining became uneconomical, many mines in the anthracite coal fields were closed and allowed to fill with water. By 1960, pumping of water from mines in the Lackawanna Coal Basin had stopped, and the mine-water levels rose until they overflowed at the surface; discharges were largest near Old Forge and Duryea. Although most of the deep mining in the Wyoming Valley Coal Basin ceased in the 1958-62 periods, a few mines south of Wilkes-Barre remained active. In October 1967, these mines ceased operation because of the high cost of pumping and treating the water. At that time, engineers with the Pennsylvania Department of Mines and Minerals Industries believed that once these mines were filled with water and pool levels in the South Wilkes-Barre, Stanton-Empire-Hollenback, Baltimore, Peach Orchard, and Delaware-Pine Ridge mines reached an altitude of 500 feet mine subsidence would probably occur--affecting the surface and causing broken gas mains and possibly explosions. State officials decided, therefore, that the Commonwealth would maintain the mine-pool levels in these mines between altitudes of 450 to 475 feet. They planned to pump water from boreholes to be drilled in the South Wilkes-Barre and Delaware-Pine Ridge Mines. Until these boreholes were constructed and the pumps put into operation, the mine-pool levels were to be maintained by pumping from the Delaware No. 2 shaft of the Delaware-Pine Ridge mine. Pumping from the shaft began in June 1968. Three 36-inch boreholes were completed in the South Wilkes-Barre mine on September 1, 1971. A 1,000 gal./min. (gallons per minute) pump was installed in one of the boreholes and operated for 3-days in May 1972 to test the quality of water discharged.

In June 1972, torrential rains of Tropical Storm Agnes caused record-high mine-pool levels throughout the Wyoming Valley. Flooding of the Susquehanna River caused a power stoppage in the Wyoming Valley, and the pumps in the Delaware shaft ceased pumping. Mine-water was subsequently discharged through numerous natural and man-made openings into the mines, and high pool levels caused collapse of the land surface into shallow mine chambers at 28 reported sites. The collapse generally occurred in areas where mining left little support for the unconsolidated glacial-drift overburden. During the storm, the glacial drift became saturated with water and locally slumped into the empty chambers below.

The more serious collapse into mine chambers of the Delaware-Pine Ridge mine occurred in the Parsons area, east of Wilkes-Barre. In this area the Kidney and Hillman coal beds dip 30 to 40°, and the tips of the mine chambers have been driven up to the overlying glacial drift. During the storm seven holes developed over the subsurface contact of the coal beds with the glacial drift. The collapse was probably the combined result of saturation of the glacial drift and increased hydraulic head imposed from below, through rock fractures and mine openings, by the rapidly rising Delaware-Pine Ridge pool. This head ultimately reached 45 feet above the base of the glacial drift.

MINE HYDROLOGY

The source of water in the mines is precipitation, which averages 37 inches annually at the Wilkes-Barre-Scranton Airport. For each square mile, this amounts to 1.75 million gallons daily, or about 1,220 gal./min. About 45 percent of the precipitation enters the underground mines, either directly, through downward percolation, or indirectly, from overland run-off that enters the mines through the strip mines at the outcrop and through seepage from streams, as they pass over broken and caved ground. Slightly more than half the total annual precipitation in the valley leaves the area as runoff in streams, of which about 85 percent has been routed through the mines. Most of the recharge occurs in the outcrop area as overland runoff and seepage from surface stream.

Pumping records of the mines and reports from the mining companies indicate that large volumes of water must be discharged from the mines immediately after heavy precipitation. Most of the mining companies provided pump capacity 10 times the annual average rate of pumping to dispose of this water. After a heavy rain, the pumps at many of the mines ran at peak capacity for several days to remove the inflow. When high inflows continued for several days, the monthly average pumping rate was three to four times the annual rate.

When most of the mines in the Wyoming Valley were in operation, an average of 125,000 gal./min. was continually pumped to the surface. Since the mines have been abandoned and filled with water, only about 30,000 gal./min. overflows by gravity. Present overflow is smaller than former pumpage because the mines are now full, or nearly full, of water and water that recharged the mines from the rivers, overlying ground-water bodies and recirculated pumpage is now rejected.

Discharge of mine water was similarly reduced in the Lackawanna Valley (Fig. 1). An average of 100,000 gal./min. was continually pumped to the surface when the mines were operating; now about 50,000 gal./min. overflows by gravity. Reduction, however, was less because of topographic differences in the two valleys. The Wyoming Valley is a broad, flat plain with gentle slopes that rise away from the plain. The Susquehanna River which traverses the plain, has a gradient of about 2 feet per mile and is the base level for all hydrologic systems in the valley. The mine-pools drain to the Susquehanna River and receive water only from upgradient sources.

The Lackawanna Valley, on the other hand, is drained by the Lackawanna River, which has a gradient of about 14 feet per mile, and does not constitute a base level for local hydrologic systems. Northeast of Scranton the mine pools are as much as 120 feet below the river and receive seepage from the river.

Mine-Water Pools

The water pools in the mines are not like water bodies on the land surface. They are enclosed vertically between the floor and roof of openings and horizontally by barrier pillars or unmined sections of coal. Most commonly pools of adjacent mines are connected only where manways have been made through barrier pillars or where pillars have been removed by third mining. In places pools are interconnected where subsidence has fractured barrier pillars and permitted seepage from a higher pool to a lower one. Most of the areas of interconnection are known and are shown on the mine maps. Those interconnections pertinent to mine interflow in the Wyoming Valley are described in the appendix and are shown on figure 2.

Figure 2. --(Caption on next page) belongs near here.

Figure 2.-- Map showing barrier pillars, their breaches, and locations of boreholes, Wyoming Valley, Pennsylvania

Interpool Circulation

The route of the water moving within a mine is usually complex and in many areas unknown. Water generally moves within a mined bed to boreholes, shafts, tunnels, or fractures. Although a mine may have many interconnections, water becomes stagnant if no inflow is received. Isolated pools above and away from a pool also exist, as a result of restricted mining, geologic structure or unusual recharge conditions. A simplified schematic diagram of flow routes from areas of recharge to discharge points is shown in figure 3.

Figure 3. --Belongs near here.

Figure 3.--Schematic maps of water flow through the mines in the Wyoming Valley, Pennsylvania

Most interpool water movement beneath the Wyoming Valley is from the valley perimeter, where recharge enters through crop falls, stippings, and broken roof rock, and flows to the valley center, where it discharges to the surface through constructed openings southwest of Wilkes-Barre. The pools can be grouped into two major complexes, based on the flow system to which each pool is connected (Fig. 3b). For discussion, they are the northwest and southeast complexes. The northwest complex overflows through the Buttonwood shaft and includes the following mine pools shown in Figure 2:

Nottingham-Buttonwood

Avondale-Grand Tunnel

Loree-Gaylord

Lance

Kingston

East Boston

Black Diamond

Harry E - Forty Fort

Maltby-Westmoreland

Henry-Prospect-Miners Mills

No. 14 - No. 6

Laflin

Ewen

Schooley

Exeter

Stevens

The southeast complex discharges from the three boreholes constructed by the Commonwealth in the South Wilkes-Barre mine and includes the following mine pools (Figure 2):

Truesdale-Bliss

Sugar Notch

Huber

Franklin

Stanton-Empire-Hollenback

South Wilkes-Barre

Baltimore

Mineral Spring

Peach Orchard

Delaware-Pine Ridge

Conlon

Movement through the following mines is negligible because the pillars have not been breached or because they are not part of the outcrop area (figure 2):

Loomis

Inman

Woodward

Dorrance-Pettibone

Sullivan Trail

Alden

Mine pools at the extreme ends of the Wyoming Valley have individual overflow points and are excluded from the study. Those shown on figure 2 and 3 are as follows:

Wanamie-Stearns

Number 7.

Butler

Number 9.

Seneca

Mine-pool Fluctuation

Mine-pool fluctuations are caused by changes in the relative rates of recharge to and discharge from the mines. Pools are recharged by percolation from the surface and underground flows from adjacent mines and discharged by flow to the surface or to adjacent mine(s). The amplitude of fluctuation of a pool depends on the rate of recharge to and discharge from a mine pool and the storage capacity of the mine. Examples of mine-pool fluctuation are shown by hydrographs on Figure 4. The Nottingham-Buttonwood pool, through which the northwest mine-pool complex discharges, fluctuates less than 2 feet (excluding the rise due to Tropical Storm Agnes). The Maltby-Westmoreland and the Exeter pools normally fluctuate 9 and 10 feet, respectively (excluding the storm).

Figure 4. --Belongs near here.

Figure 4.-- Fluctuations of three mine pools.

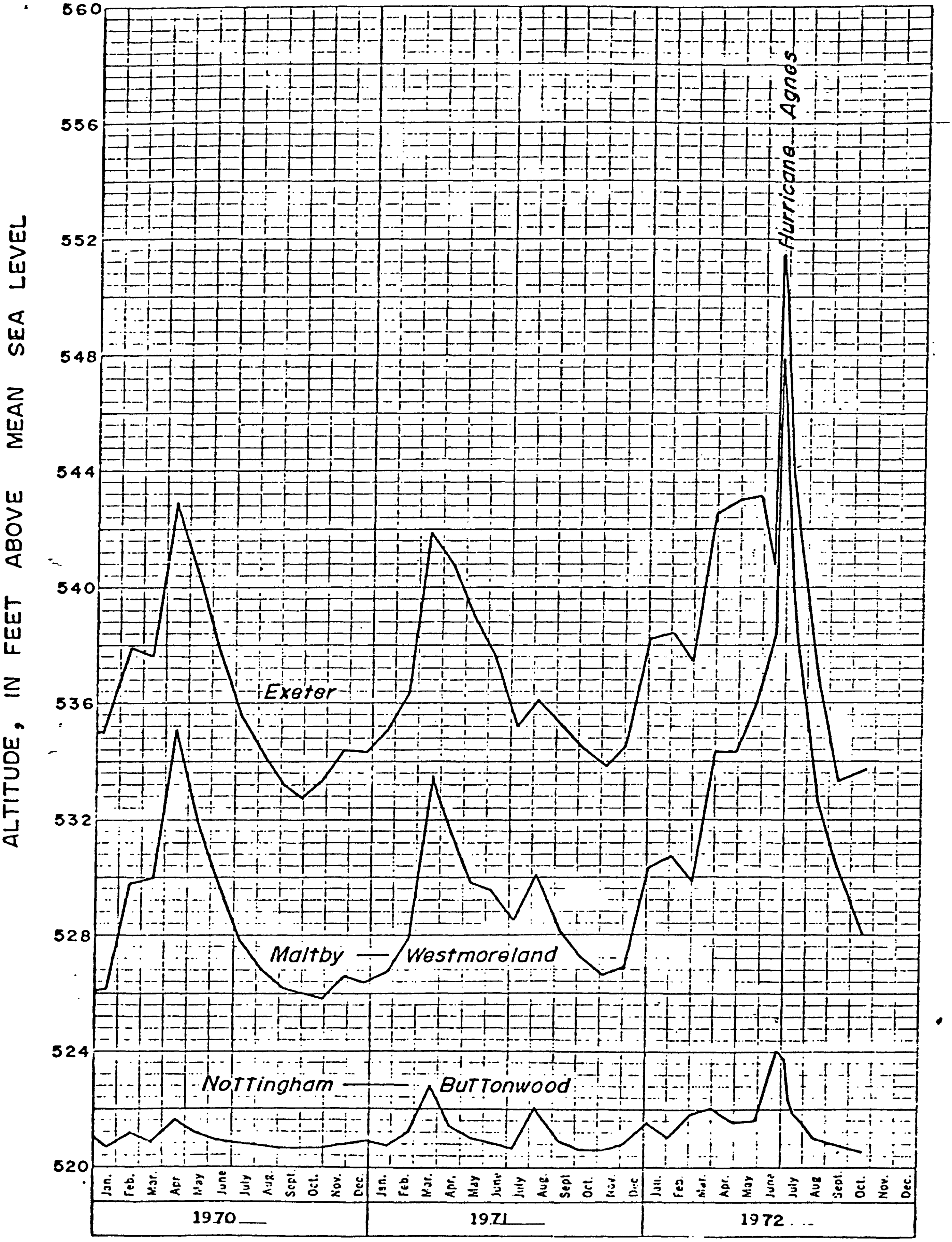

Figure 4. -- Hydrograph showing fluctuations of three mine pools.

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Table 1. --Analyses of water collected from four mine discharges in the W oming Valley on June 16, 1972

(Locations shown on fig. 2)

Reported values, in milligrams per litre

Analyses by U.S. Geological Survey

Element	Delaware-Pine Ridge Mine (Delaware shaft)	Nottingham-Buttonwood Mine (Buttonwood shaft)	South Wilkes-Barre mine (36-inch drainhole)	Truesdale Mine (24-inch drainhole)
Aluminum (Al)	6.3	2.2	0.14	7.4
Antimony (Sb)	.005	.005	.005	.05
Arsenic (As)	.046	.046	.049	.18
Barium (Ba)	.005	.003	.004	.01
Beryllium (Be)	.008	.003	.004	.019
Bismuth (Bi)	.0005	.0005	.0005	.0005
Boron (B)	.06	.04	.05	.13
Cadmium (Cd)	.005	.005	.005	.005
Chromium (Cr)	.004	.003	.003	.012
Cobalt (Co)	.77	.34	.015	1.23
Copper (Cu)	.01	.010	.010	.010
Gallium (Ga)	.026	.018	.024	.06
Germanium (Ge)	.06	.04	.05	.13
Iron (Fe)	320	160	260	910
Lanthanum (La)	.051	.036	.045	.11
Lead (Pb)	.05	.002	.001	.003
Lithium (Li)	.26	.14	.11	.18
Manganese (Mn)	36	22	16	56
Molybdenum (Mo)	.0004	.0004	.0007	.0004
Nickel (Ni)	1.3	.48	.078	2.2
Silver (Ag)	.005	.003	.004	.01
Strontium (Sr)	3.4	1.7	3.4	8.1
Tin (Sn)	.06	.04	.05	.13
Titanium (Ti)	.007	.011	.006	.019
Vanadium (V)	.04	.03	.035	.09
Ytterbium (Yb)	.011	.003	.006	.033
Yttrium (Y)	.10	.031	.050	.30
Zinc (Zn)	3.4	.96	.2	8.8
Zirconium (Zr)	.15	.054	.10	.84
Total solids	4070	2730	3670	9450

QUALITY OF MINE WATER

In order to appraise the quality of mine-water discharge into the Susquehanna River, samples were taken from three major sources: (1) the pumped discharge from the Delaware Shaft of the Delaware Pine-Ridge mine, (2) the Buttonwood shaft outfall from the Nottingham-Buttonwood mine, and (3) one of the three 36-inch boreholes in the South Wilkes-Barre mine--and from a minor source, a 24-inch borehole into the Truesdale-Bliss mine. Spectrographic determination of 29 different metals in the four samples were made by the U.S. Geological Survey, and the results are shown on table 1.

Due to cessation of all pumping from the Delaware-Pine Ridge mine, the interpool flow system changed (Fig. 3a and 3b), greatly affecting the pre-"Agnes" quality of the South Wilkes-Barre mine discharge. Prior to the cessation of pumping at the Delaware Shaft, about 1,000 gal./min. was overflowing through one of the 36-inch boreholes constructed into the South Wilkes-Barre mine. When pumping ceased, mine-pool levels rose, and now all the southeast complex overflows through the 36-inch boreholes in the south Wilkes-Barre mine. Recent sampling of the major overflows by the Pennsylvania Department of Environmental Resources (table 2), showed that the quality of the overflow from the Buttonwood Shaft remained relatively unchanged since Agnes; however, the quality of the discharge from the South Wilkes-Barre mine deteriorated-- dissolved solids increased more than 70 percent.

Table 2.--Partial analyses of samples from two mine discharges in the Wyoming Valley. Courtesy of the Pennsylvania Department of Environmental Resources.

(Analyses in ~~mg~~ milligrams per litre)

(Mine Discharge)

Date Sampled (1972)	Nottingham - Buttonwood			South Wilkes-Barre		
	Dissolved ~~Total~~ Solids	Fe	Mn	Dissolved ~~Total~~ Solids	Fe	Mn
8-8	2834	188	22.5	----	---	----
8-30	3230	192	16.0	5730	---	----
9-20	----	145	20.0	----	400	----
12-7	3620	150	22.0	6420	515	39.0

Table 3.--Analyses of samples from boreholes penetrating the uppermost inundated mine voids ([illegible])

(analyses in milligrams per litre except as noted)

Analyses by U.S. Geological Survey

Borehole No. (figure 2)	$Kx10^6$ (micromhos)	Fe	Al	Mn	Zn	Co	Ni	Ca
1	768	2.9	0.0	2.4	0.02	0.01	0.00	73
4	996	3.0	2.8	1.1	.12	.03	.02	390
38	2620	44	2.0	10	.16	.13	.16	80
40	1020	.00	.0	.6	.02	.02	.01	85
42	1120	5.0	.2	.15	.03	.01	.01	13
24*	956	3.1	.8	.10	.02	.01	.01	8.0

* Sample from well tapping unconsolidated deposits

The relatively good quality of mine water sampled in one of South Wilkes-Barre's boreholes before "Agnes" is indicative of the quality of water in the shallow inundated beds throughout the valley. Analyses of samples collected from boreholes penetrating the uppermost inundated mine void in five mines and from one well (locations shown on 2) indicate the quality of the water to be good relative to the major discharges (table 3). The quality of mine water in the anthracite coal mines generally deteriorates with each succeeding deeper mined-out coal bed (Barnes and others, 1964, p. B3: also, Stuart and Simpson, 1961, p. B82). This is related to the amount of internal circulation at depth. The worst quality of water sampled was from borehole 38, tapping the Woodward Mine. The mine is isolated from surface water recharge sources, and the water occurs in beds at altitudes below 300 feet. Many of the water samples from boreholes had a quality similar to that obtained from well 24, which taps deep, unconsolidated glacial deposits. Because the mines have filled with water, the deeper parts of the unconsolidated deposits probably contain some water originating in the mine voids. (Hollowell, 1971, p. 28-29).

The 24-inch borehole, in the Truesdale Mine, was sampled for spectrographic analysis (table 1) to evaluate the quality of discharge that will overflow from a 36-inch borehole being constructed (November, 1972) by the Commonwealth, nearby, at a lower altitude. The borehole is being constructed to discharge water from the Truesdale mine when the pool receives recharge at a rate that exceeds the interpool discharge through Sugar Notch Mine (fig. 3). Subsequent assessment of the mining conditions and potential water-circulation routes indicates that the water that will discharge from the 36-inch borehole. Although the bed that is to be tapped by the 36-inch borehole is the same one tapped by the 24-inch borehole, they will tap it at a different altitude in a small structural basin mapped by Darton (1940) as the Askam Basin. The 24-inch borehole taps the deepest part of the structure, whereas the 36-inch borehole will tap shallow chambers on the northwest flank of the structure. A northwest-southeast trending, nearly horizontal, rock tunnel connects these shallow chambers with all the other mined coal beds along the outcrop on the southeast side of the Valley. This would allow water recharged along the outcrop a direct route to the proposed discharge point, the 36-inch borehole. The fresher water quality flowing through the tunnel will dilute that water circulating through the mined bed and could improve the quality of discharge from the mine.

MANAGEMENT OF MINE POOLS

Additional access boreholes into the mines could improve the quality of mine water discharge from the Wyoming Valley and reduce potential hazards created by high mine-pool levels (resulting from storms of the magnitude of tropical storm Agnes). The boreholes could improve the overall quality of the discharge to the Susquehanna River from the Wyoming Valley by producing a rerouting of the interpool flow, such that flow routes would be shortened (see figures 3b and 3c) and a greater fraction of the recharge would be routed through shallow pools, leaving a smaller fraction to circulate through deep pools. The shorter routing of interpool flow would permit more rapid discharge of recharged water, thereby reducing peak mine-pool levels that, under extremely rapid recharge rates, increase the potential for subsidence and collapse.

By expelling recharged water from the mines more rapidly, high concentrations of acid flushed out by a storm, will ususally occur when the river is high and can assimilate the acid "slugs". This would also reduce the volume of overflow that will possibly have to be treated when the river is at low flow and cannot naturally assimilate the acid mine drainage. The amount of improvement that can be expected as a result of modifications cannot be assessed, because of the complexities inherent in mine pool interflow, the amount and type of sulfide material exposed to the recharged water, and the mixing within the mine pool.

In selecting criteria for outlets the following are considerations: (1) The mine-pool level is at or above land surface and above the mean river stage (taken in section); (2) the mine voids to be tapped have adequate pillar support and open passageways connected to other mined beds below; (3) proximity to the river or a tributary; and (4) proximity to a large undeveloped area where the discharge may be treated. These criteria are discussed in the appendix for the borehole outlet sites that were considered in detail.

Henry-Prospect Mine Pool

An outlet in the flood plain above the Henry-Prospect mines would intercept underground flow from the northern areas of recharge that are now discharging through the Buttonwood shaft (figure 3). Mine conditions seem to be suitable for construction of an outlet to a shallow mined bed in the Henry-Prospect pool (figure 2). An outlet here would reduce individual pool fluctuations in the northwest pool complex and discharge water from the following interconnected mine pools (figure 2):

Stevens

Exeter

Schooley

Ewen

No. 14 - No. 6

Henry-Prospect-Miners Mills.

Also, during the time the mine-pool levels are high, the outlet would drain some water from the following mine pools:

Maltby-Westmoreland

Mount-Lookout

Harry E - Forty Fort.

The outlet would also reduce pool fluctuations in the remaining mine pools that receive interpool flow from the above-listed mine pools. Specifications on the outlet design appear in the appendix.

Delaware-Pine Ridge Mine Pool

An outlet installed in the Delaware-Pine Ridge mine pool would prevent high pool levels and a repeat of the type of collapse discussed previously. Although every effort is being made to fill the mine voids in the area susceptible to collapse, additional protection could be provided by constructing a borehole into the Delaware-Pine Ridge pool. This would provide an added outlet to increase the rate at which recharged water can be expelled from the mine, thereby reducing the amount and time water is in contact with sulfide materials. The outlet would overflow only during a time when the recharge to the pool would raise the pool level above the altitude of the opening of the outlet structure. During nonrecharge periods the pool discharges through the mines to lower outlets.

Conclusions

Reducing water circulation in the mines could improve the quality of the mine-water discharge from the two major outlets in the Wyoming Valley (Buttonwood Shaft and South Wilkes-Barre boreholes). The pools can be made to overflow if the mine pools can be maintained at a high enough level without causing flooding or instability of pillar support in the flood mine workings. Additional outlets would reduce the distance that water from some mine pools presently travels, and increase the rate of discharge from the mine workings. Additional outlets in the following areas would aid discharge:

- Hollenback Park, near Mill Creek, and the Susquehanna River flats near the town of Plains.

The additional outlets would have the added benefit of reducing mine-pool levels and fluctuation, particularly in heavily populated areas.

A study to assess the total mineral load discharging from the mine workings in the Northern Field (Wyoming-Lackawanna Valleys) could follow completion of a mine-pool management program. Determination of minerals loads and assimilative capacities of the Susquehanna River are needed to determine proper treatment for mine drainage. At extreme low flow some or all discharge may have to be treated.

The quality of mine-water discharge to the Susquehanna River could be improved by reducing water circulation through mine workings. This may be achieved to a great degree by diversion of the overland runoff that presently flows into mines. The volume of inflow discussed under the heading of Mine Hydrology indicates a need to backfill strippings and rehabilitate stream channels to decrease inflow to the mines.

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Figure 5. — Chart showing nomenclature and general correlation of anthracite beds in selected mines in the Wyoming Valley.

Note: For the purposes of this report mines were listed together where they shared similar nomenclature. Because of splits in coal beds, discontinuous beds (particularly in the numbered), and unmined beds, the correlation is only valid for mined beds. Locations shown on figures 2 and 3.

Nottingham-Buttonwood, South Wilkes-Barre, Stanton, Empire, Hollenback, Baltimore, Huber, Sugar Notch*	Avondale, Grand Tunnel*, Truesdale	Lance, Loree, Gaylord	Kingston*, E. Boston, Black Diamond	Maltby-Westmoreland*, Henry-Prospect, Franklin, Mineral Spring, Delaware-Pine Ridge	No. 14, No. 6, Ewen, Exeter, Conlon, Miners Mills Peach Orchard
No. 7					
No. 6	No. 6				
No. 5	No. 5				
No. 4	No. 4				
No. 3	No. 3				
No. 2*					
No. 1	George	Snake Island	Snake Island	Snake Island	
Abbott	Abbott	Abbott	Abbott	Abbott	
Kidney	Mills	Kidney	Bowkley	Bowkley	
Hillman	Hillman	Hillman	Hillman	Hillman	Hillman
Top Stanton	Top Stanton		Top Five Foot(Top Orchard*)	Top Five Foot	
Bottom Stanton	Bottom Stanton	Stanton	Bottom Five Foot(Bottom Orchard*)	Bottom Five Foot	Five Foot
Five Foot	Forge	Five Foot	Lance		
Top Baltimore	Cooper(Top Twin*)	Cooper	Cooper	Top Pittston(Top Baltimore*)	Top Pittston
Bottom Baltimore	Bennett(Bottom Twin*)	Bennett	Bennett	Bottom Pittston(Bottom Baltimore*)	Bottom Pittston
			Top Eleven(Checker*)	Marcy	Marcy
Checker		Checker	Eleven Foot	Skidmore	Checker
Top Ross	Top Ross	Top Ross			Top Clark
Bottom Ross	Bottom Ross	Bottom Ross	Ross	Ross	Bottom Clark
Top Red Ash	Top Red Ash	Top Red Ash			Babylon
Bottom Red Ash	Bottom Red Ash	Bottom Red Ash	Red Ash	Red Ash	Red Ash

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APPENDIX

Description of Barrier Pillar Breaches

Breaches in the barrier pillars separating the mine-pools are described below (Ash, 1954). The altitude and location of each breach are shown on figure 2. For general purposes, those mines that are well connected form a common pool and are shown as such on figure 2. The sequence of described breaches follows the order given in the text for the northwest and southeast pool complexes. A generalized nomenclature and correlation chart of anthracite beds for the Wyoming Valley, as used in this report, is shown on figure 5.

Figure 5. —(Belongs near here).

Northwest Pool Complex

Owing to the method of mining the successived beds, the Buttonwood mine overlies the Nottingham mine. Part of the Baltimore bed, the Ross bed, and the Red Ash bed were mined from the Nottingham shaft. The remainder of the Baltimore bed and the beds above the Ross were mined from the Buttonwood shaft. The mines are separated by rock strata, but numerous interconnections were made during mining, so that water has free passage between them.

The barrier pillar along the boundary with the Avondale mine to the west is partly removed in the bottom Red Ash bed at altitude 95 feet.

The barrier pillar between the Loree and Gaylord mines has been removed in the Top and Bottom Red Ash coal beds above altitude 294 feet, in the Bennett coal bed above 361 feet, in the Ross coal bed above 384 feet, and in the Cooper coal bed above 442 feet: therefore, the mines are shown as one common pool.

Figure 5.--Chart showing nomenclature and general correlation of anthracite beds in selected mines in the Wyoming Valley

The barrier pillar between the Lance and Gaylord mine is removed in both the Cooper and Bennett coal beds above altitude 272 feet.

The barrier pillar between the Loree and Lance mines has been punctured by a rock tunnel at altitude 300 feet in the Hillman coal bed, and above altitude 338 feet the pillar has been removed in several places. An entry interconnects both mines in the Bennett coal bed at altitude 367 feet. Two chambers through the barrier pillar interconnect both mines at altitude 389 feet in the Lance coal bed.

The barrier pillar between the Loree and Kingston mines has been removed above altitude 475 feet in the Cooper coal bed. There are two openings in the Bottom Red Ash coal bed at altitude 513 feet and two openings in the Bennett coal bed at altitude 522 feet. Caving has apparently blocked all the lowest openings, restricting flow to some degree.

The barrier pillar between the Kingston and East Boston mines is breached by two chambers at altitude 357 feet and by a waterway at altitude 160 feet in the Bennett coal bed.

The barrier pillar between the East Boston and Black Diamond mines is perforated by a 12-inch borehole at altitude 100 feet in the Red Ash coal bed, and the pillar is removed above altitude 210 feet in the Ross coal bed.

The barrier pillar between the Black Diamond and the Harry E - Forty Fort mines is breached by an entry at altitude 369 feet in the Red Ash coal bed.

The barrier pillar between the Harry E - Forty Fort and Maltby-Westmoreland mines is, according to the mine maps, unbreached below altitude 540 feet. However, based on the altitude at which the Maltby-Westmoreland pool overflowed after filling, the Forty Fort mine has probably been robbed, resulting in extensive fracturing and access for water interflow.

The barrier pillar between the Harry E - Forty Fort and Henry-Prospect mines was known by mining engineers (John Lacek, oral or written communication, 1966) to be badly cracked by the above-mentioned robbing. Large quantities of water came through the pillar from the Forty Fort to the Henry-Prospect mine even when the mines were in operation.

The barrier pillar between the Maltby-Westmoreland and Mount Lookout mines is removed in the Marcy bed above altitude 365 feet.

A 12-inch borehole was drilled from the No. 72 tunnel in the Bottom Baltimore coal bed of the Henry-Prospect mine to the Maltby-Westmoreland mine at altitude 135 feet.

The barrier pillar between the Henry-Prospect and the No. 14 mines is breached in the Pittston bed at altitude 430 feet by an opening 12 feet wide.

Workings in the Delaware-Pine Ridge mine and Miners Mills mine are isolated from one another, except where an opening 12 feet wide at altitude 300 feet was driven through the barrier pillar in the Hillman coal bed. Water passing through this opening must cross over the crest of an anticline at altitude 447 feet for interpool circulation.

The barrier pillar between the Henry-Prospect and the Conlon mines is offset. An opening at altitude 280 feet in the Top Clark bed connects workings from the Conlon mine only. Two other breaches in the Pittston bed, at altitude 377 and 546 feet, connect Henry and Conlon workings. The opening at altitude 377 feet connects with workings in Conlon mine at 425 feet. The openings at altitude 546 feet have been dammed.

The barrier pillar between the No. 14 and Conlon mines is removed in the Babylon coal bed above altitude 354 feet; however, due to structural and mining conditions, water cannot pass through the opening below 375 feet. After water passes through this opening, it is diverted by the Mill Creek slope anticline into the Henry-Prospect mine through the previously described opening at altitude 425 feet.

The barrier pillar separating the Number 14 - Number 6 and the Butler mines is partly removed in the Pittston and Marcy beds. It is unmined below altitude 625 feet in the Marcy bed.

The Number 14 and Number 6 mines adjoin the Laflin mine along their southern property lines. According to engineers of the Hudson Coal Co., the barrier pillars along these property lines are intact in beds below the Marcy bed. The barrier is removed in the Marcy at altitude 605 feet.

Mining has removed the barrier pillar between the Ewen and Butler mines above an altitdde of 296 feet in the Bottom Red Ash bed.

The barrier pillar has been removed between the Ewen and Number 14 and Number 6 mines at altitude 270 feet in the Top Clark bed and in the Pittston bed at altitude 252 feet.

The barrier pillar between the Ewen and Schooley mines is breached in the Bottom Clark Bed at altitude 120 feet.

The barrier pillar between the Schooley and Exeter is breached in the Checker bed between altitudes 380 and 456 feet.

The barrier pillar between the Exeter and Stevens is removed in the Top Clark bed at altitude 430 feet.

Southeast Pool Complex

The barrier pillar between the Truesdale and Sugar Notch mines is breached at altitude 191 feet, where the Top Ross coal bed is removed.

The barrier pillar between the Sugar Notch and Huber mines is removed in the Kidney coal bed above altitude 215 feet. Robbing in the Sugar Notch mine has caved the workings restricting the flow of water to the Huber mine.

The barrier pillar between the Franklin and Huber mines is offset in some coal beds. Workings from the Franklin mine in the Bottom Pittston coal bed cross the barrier pillar at altitude 356 feet and extend to the offset barrier pillar at approximate altitude 27 feet. The offset barrier pillar is removed in the Bottom Pittston coal bed above altitude 370 feet.

The barrier pillar between the Stanton-Empire-Hollenback and Franklin mines has been removed in the Bottom Pittston coal bed from altitude 334 feet to the outcrop at altitude 640 feet.

The curved main barrier pillar between the South Wilkes-Barre and Stanton-Empire-Hollenback mines is breached by three entries at altitude 520 feet in the Bottom Red Ash coal bed and by a chamber and three entries between altitudes 275 and 249 feet in the Bottom Baltimore coal bed.

The barrier pillar between the Baltimore and Stanton, Empire, and Hollenback mines is partly offset in the Stanton coal bed. The pillar in the Stanton coal bed is breached at altitude 43 feet by four 14-inch horizontal boreholes. Water from the Baltimore mine drains through these boreholes, down through two vertical boreholes from the Stanton to the Baltimore coal beds in the Hollenback mine pool, and through a man-made underground watercourse to the South Wilkes-Barre mine pool.

The barrier pillar between the Peach Orchard and Baltimore mines is intact in all beds below the Pittston coal bed, where a horizontal borehole, with valves at altitude 90 feet, controls the flow of water through the pillar from the Peach Orchard mine.

The barrier pillar between the Mineral Spring and Baltimore mines is intact in all beds below the Marcy coal bed, where a horizontal 8-inch borehole, with valves at altitude 194 feet, controls the flow of water through the pillar from the Mineral Spring mine.

The barrier pillar between the Delaware-Pine Ridge and Mineral Spring mines is unmined below altitude 400 feet. From this point to the outcrop, the Pittston coal bed is removed.

Proposed Mine-Pool Outlets

The location of the proposed drainholes are shown on figure 2. The locations were selected with the aid of mine maps to ensure underground circulation to the proposed drilling site. The specific drilling sites will need to be determined by mining engineers, because mine surveys will be needed for each mined bed to be penetrated and these are to be correlated with surface surveys in order to penetrate the desired mine chamber.

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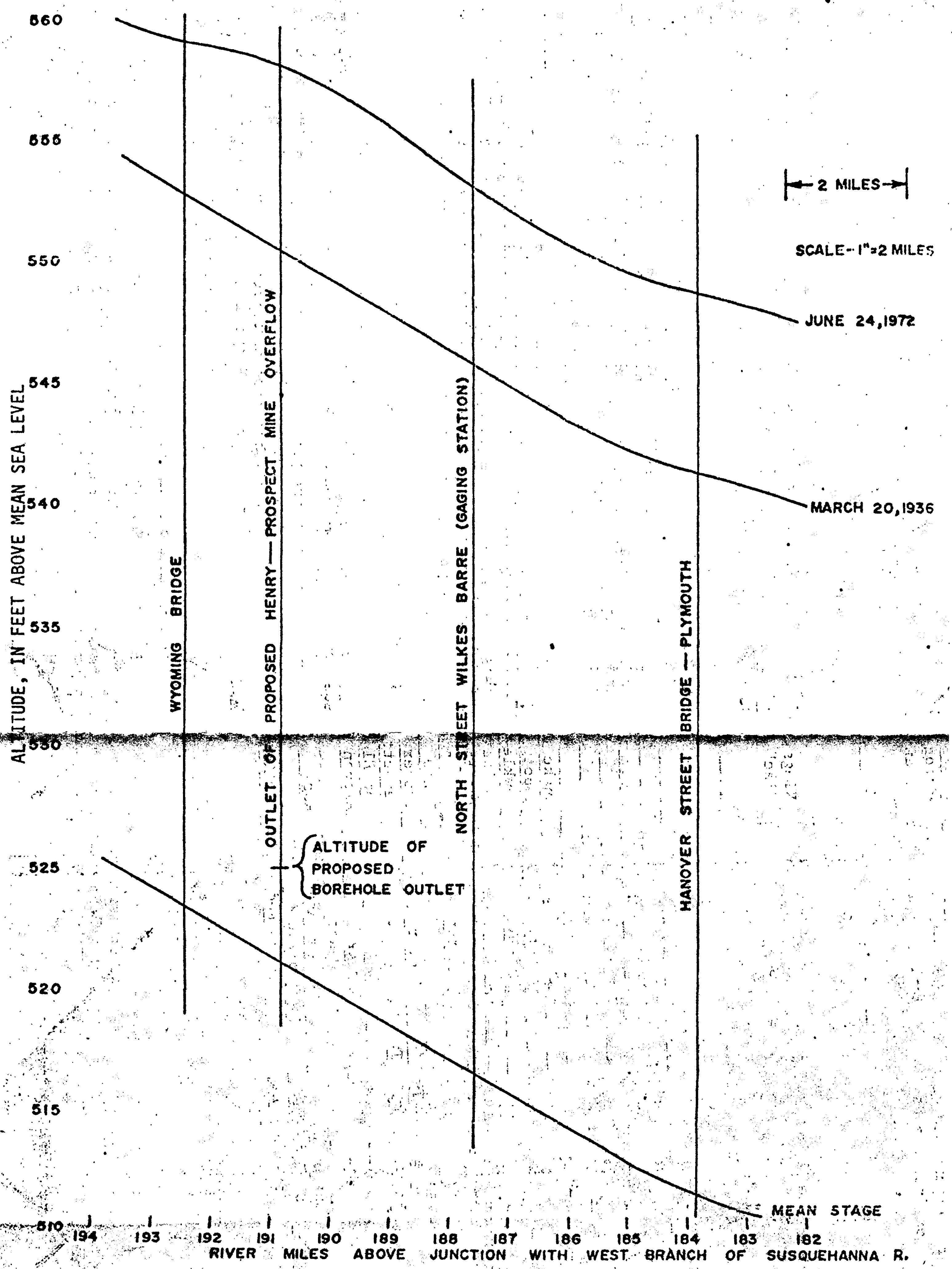

Figure 6. -- Profiles of Susquehanna River at mean and flood stages, in Wyoming Valley

Figure ~~5~~ 6.--Profiles of Susquehanna River at mean and flood stages, in Wyoming Valley.

Delaware-Pine Ridge Mine

An outlet on the old Municipal Golf Course, Hollenback Park, would discharge mine-water at an altitude of about 540 feet. A borehole 36-inches in diameter would allow maximum discharge during periods of sustained recharge. A drainage ditch would be needed from the borehole to Mill Creek. Presently, the Delaware-Pine Ridge pool overflows underground to the Mineral Spring and Henry-Prospect mines. The pool level has declined from the high altitude attained during the June 1972 hurricane of 555 feet to about 533 feet (October 1972). The most stable condition for minimizing collapse in the future would be to provide additional overflow capacity at the surface through the proposed large-diamter boreholes. This relief overflow would reduce the maximum level to which the pool could rise, depending on the recharge rate, to 1 or 2 feet above the overflow outlet.