UNDERGROUND COAL MINES AS SOURCES OF WATER FOR PUBLIC SUPPLY IN NORTHERN UPSHUR COUNTY, WEST VIRGINIA

by W. A. Hobba, Jr.

U.S. GEOLOGICAL SURVEY

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DONALD P. HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
603 Morris Street
Charleston, WV 25301
Telephone: (304) 347-5130

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FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

The following factors may be used to convert the inch-pound units published herein to the International System of Units (SI):

Multiply inch-pound units	By	To obtain SI units
	Length	
inches (in.)	25.4	millimeters (mm)
	0.0254	meters (m)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
acres	0.4047	square hectometer (hm^2)
square miles (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre feet	1.233×10^{-3}	cubic hectometers (hm^3)
	1,233.48	cubic meters (m^3)
gallons (gal)	3.785	liters (L)
	3.785	cubic decimeters (dm^3)
	3.785×10^{-3}	cubic meters (m^3)
million gallons (Mgal)	3,785	cubic meters (m^3)
	3.785×10^{-3}	cubic hectometers (hm^3)
cubic feet (ft^3)	28.32	cubic decimeters (dm^3)
	0.02832	cubic meters (m^3)
	Flow	
cubic feet per second (ft^3/s)	28.32	[1]liters per second (L/s)
	28.32	cubic decimeters per second (dm^3/s)
	0.02832	cubic meters per second (m^3/s)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
	0.06309	cubic decimeters per second (dm^3/s)
	6.309×10^{-5}	cubic meters per second (m^3/s)
million gallons per day (Mgal/d)	43.81	cubic decimeters per second (dm^3/s)
	0.04381	cubic meters per second (m^3/s)
micromhos per centimeter at 25°C (µmhos/cm at 25°C)	1.000	microsiemens per centimeter at 25°C (µS/cm at 25°C)

[1]The unit liter is accepted for use with the International System (SI). See National Bureau of Standards Special Bulletin 330, p. 13, 1972 edition.

NOTE REGARDING VERTICAL DATUM

The National Geodetic Vertical Datum of 1929 (NGVD), the reference surface to which relief features and altitude data are related, and formerly called "mean sea level" is referred to as "sea level" throughout this report.

UNDERGROUND COAL MINES AS SOURCES OF WATER FOR PUBLIC SUPPLY IN NORTHERN UPSHUR COUNTY, WEST VIRGINIA

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ABSTRACT

The northern part of Upshur County in central West Virginia primarily uses the Buckhannon River as a source of public water supply. Current (1981) water use of 1.6 million gallons per day exceeded the flow of the river measured during a drought period in 1930 by as much as 1.46 million gallons per day. Three flooded underground mines--the Buckhannon River mine, the Miller-Todd mine, and the Minear mine--located about 6 miles south of Buckhannon at Adrian were considered as a source of municipal water supply during time of drought. They store 1,170 acre-feet of water. This stored water, plus an additional 500 gallons per minute infiltration into the mines, is enough water to supply the 1,500 gallons per minute for 265 days needed by the Buckhannon water system, and projected needs of 2,500 gallons per minute for 135 days for the year 2018.

Most mine water requires some treatment. Water from flooded mines near Buckhannon is moderately hard, slightly acidic, and generally contains excessive amounts of iron, manganese, and hydrogen sulfide. Water from wells in the vicinity of the mines is chemically similar to water from mines. However, after continuous pumping of a flooded mine by the mining company, the dissolved mineral load increased, and specific conductance was reported to have increased from about 400 to 3,000 micromhos at 25°C.

This report also describes how ion exchange, filtration, chemical injection, aeration, and reverse osmosis techniques can be used to remove or reduce chemical and bacterial constituents that could limit use of mine water for public supply.

ACKNOWLEDGMENTS

Many individuals, and officials from mining companies and consulting firms supplied information and assistance during the study. The author appreciates cooperation and information supplied by Denver Tenney, "Dusty" Williams (Upshur Coal Co.), Howard "Red" Gould, and Bill Nesselrotte (Badger Coal Co.) for the flooded mines near Adrian, West Virginia. Lawrence Arch (Bethlehem Mines Corp.) supplied information for their mines near Century, West Virginia. Roger Shingler (Kimball Engineers), David Parks, and Rick Banick supplied information on their public water systems using mine water. Several home owners in Adrian, West Virginia permitted access to their wells for water sampling and aquifer testing.

(p. 3 follows)

1.0 INTRODUCTION

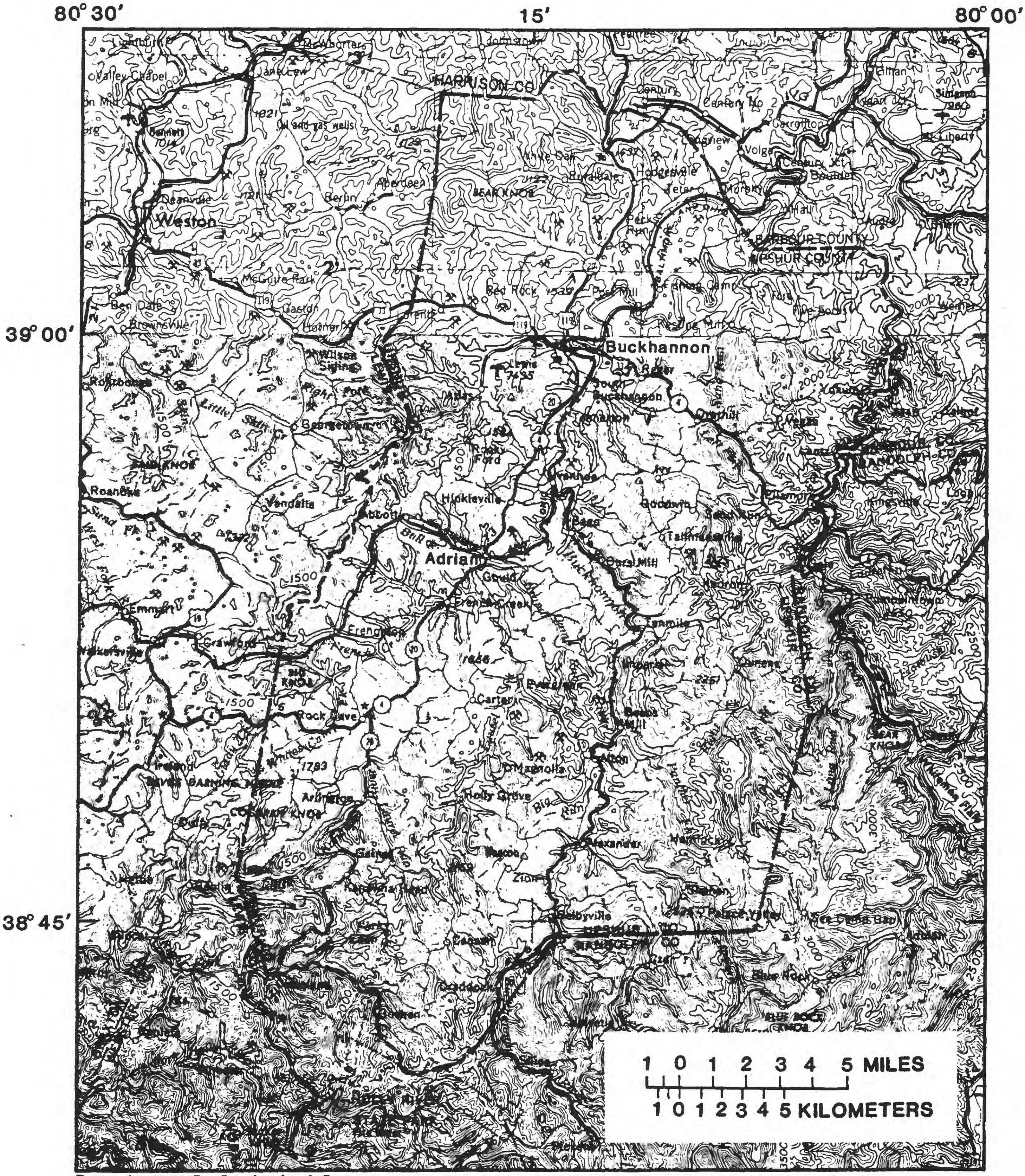
1.0 INTRODUCTION

1.1 Problem

Northern Upshur County Needs an Auxiliary Source of Public-Water Supply in Case of Drought

Water use in northern Upshur County exceeds the drought flow of the current source of freshwater, the Buckhannon River.

Population is increasing in northern Upshur County (fig. 1.1-1), an area served by the Buckhannon public water system. The water system is currently being expanded to serve a larger part of the county. Water for the system is derived from the Buckhannon River. County, city, and regional planners are concerned that, should a drought occur, the available river water would not meet minimum demands. For example, the average daily flow of the river in August through November 1930 and in September through November 1953 was less than the projected use (4.0 Mgal/d) for the year 2018 (Samuel Ludlow, Engineer, Region VII Planning and Development Council, written commun., 1978), and the flow would have been insufficient for five of these months for the 1981 water needs of the area (table 1.1-1 and fig. 1.1-2). The flow of the river for the 4-month period of August through November 1930 is 411 Mgal less than the projected water demand for the year 2018. Thus, a water supply of 2,380 gal/min plus the entire flow of the river would be required to supply the necessary water for the system. The flow of the river for the 3-month period of September through November 1953 is 244 Mgal less than the projected water demand for the year 2018. Thus, 1,860 gal/min plus the entire flow of the river would be required to get the necessary water for the system.



Base from U.S. Geological Survey
Clarksburg 1:250,000, 1956, limited revision 1965, and
Charleston 1:250,000, 1956, limited revision 1965

Figure 1.1-1.—Upshur County and the surrounding area.

Table 1.1-1.--Average flow of Buckhannon River during 1930 and 1953 droughts, and current and projected needs of the Buckhannon water system

Period	Flow of river	Buckhannon water system: Water used in 1981	Buckhannon water system: Projected water needed by 2018
	Average, in million gallons per day		
Drought of 1930			
August------------	1.63	1.6	4.0
September---------	0.26	1.6	4.0
October-----------	.14	1.6	4.0
November----------	.48	1.6	4.0
Drought of 1953			
September---------	2.65	1.6	4.0
October-----------	.67	1.6	4.0
November----------	.65	1.6	4.0

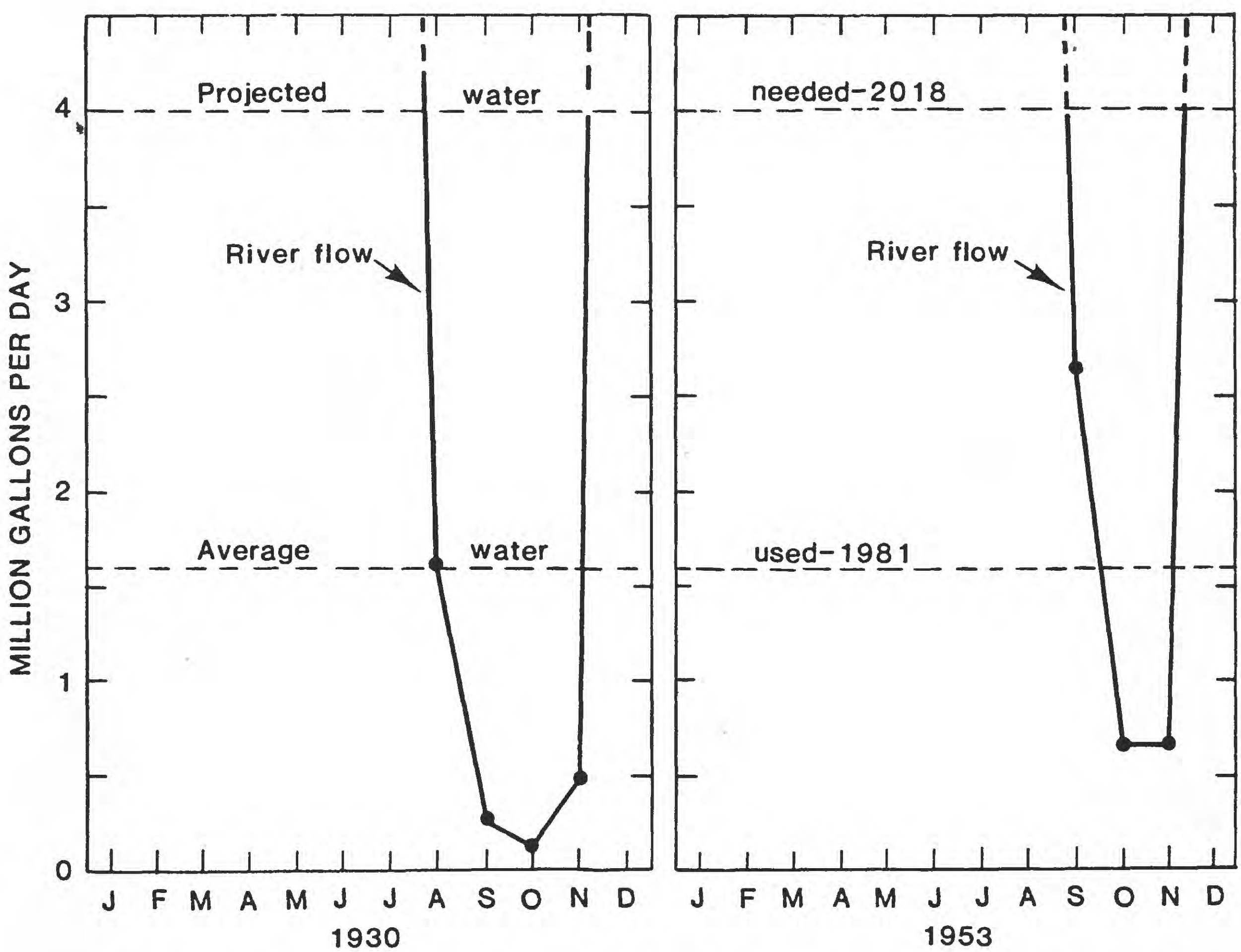


Figure 1.1-2.--Average river flow during 1930 and 1953 droughts, and current and projected needs of the Buckhannon water system.

1.2 Purpose and Scope

Purpose of Study Is To Determine if Active or Abandoned Underground Coal Mines Can Be Used for Public Supply

The purpose of this study was to determine if water of adequate quantity and quality could be obtained from active or abandoned underground coal mines for public-water supply in northern Upshur County during drought.

Numerous active and abandoned underground coal mines (primarily north, south, and west of Buckhannon) were visited. Effort was directed toward obtaining mine maps, mapping flooded areas, collecting flow and pumping data, and sampling wells and flooded mines for water quality. Three flooded and abandoned mines south of Buckhannon were considered to have the most potential for public supply. A description of large coal mines in Upshur County is given in section 4.1 "Location and Description of Mines." A description of the three mines studied in detail is given in section 4.2.1 "Flooded mines."

Information on mine yields, water quality, and water treatment was also collected from several of the 70 communities in West Virginia that use mine water for public supply. Possible treatments for modification of mine water in the study area are discussed as are the possible effects of heavily pumping a mine on water quality and yield.

Photograph 1.2-1 shows the Buckhannon River, which currently supplies much of the public-water supply in northern Upshur County. Part of the water in the River is derived from drainage or pumpage from active and abandoned coal mines.

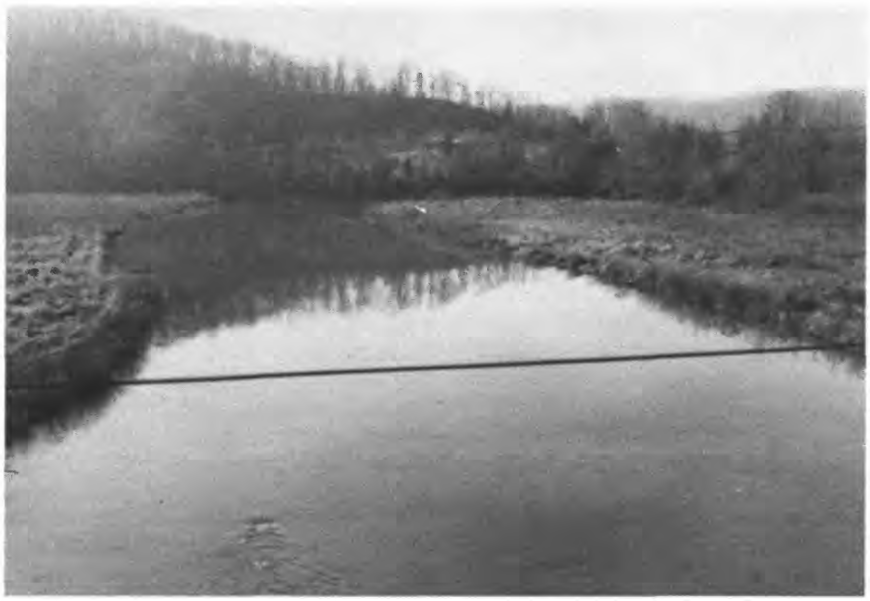


Figure 1.2-1.--The Buckhannon River north of Buckhannon flowing at about 250 cubic feet per second.

1.3 Location and Hydrogeologic Setting

Upshur County Underlain by Aquifers with Low to High Yields

During drought, the aquifers release only small amounts of water. The flow in the Buckhannon River has been as low as 0.2 cubic feet per second.

Upshur County, West Virginia (fig. 1.3-1) is generally underlain by flat-lying beds of sandstone, shale, coal, and some limestone. These rocks generally have poor-to-good water-bearing characteristics.

The underlying strata, from oldest to youngest, include the Pottsville Group, the Allegheny Formation, the Conemaugh, Monongahela, and Dunkard Groups of rocks. (See fig. 1.3-1.) The rocks become progressively poorer aquifers from the older to younger groups: Average yield of wells in these groups and the Allegheny Formation is 45, 26, 16, 13, and 12 gal/min, respectively (Friel and others, 1967, p. 80-81). Maximum well yields range from 75 to 400 gal/min. The Pottsville Group is about 500 ft below land surface at Buckhannon, and the water it contains may be salty. East of Buckhannon, the Pottsville Group is not as deep and the water should be fresh (Friel and others, 1967, p. 92). The best well in the Allegheny Group yields 350 gal/min. Highest yields in the Conemaugh are reported from valley wells tapping massive sandstones near the base of the group. One well yields 400 gal/min. The Redstone and Pittsburgh coals north and west of Buckhannon are near the base of the Monongahela Group. The Upper Freeport coal south of Buckhannon is at the top of the Allegheny Formation.

Ground-water discharge sustains a low base flow in the Buckhannon River during prolonged dry periods. The minimum flow of the river at Hall (about 7 mi downstream from Buckhannon) since April 1915 was 0.2 ft^3/s on October 23 and 27, 1930. According to Friel and others (1967, p. 40), the average low flow of the river that can be expected for 7 consecutive days in 10 years is 2.0 ft^3/s.

The hatched areas in figure 1.3-1 indicate where coal has been mined out. The Redstone, Pittsburgh, and the Upper Freeport coals are the only beds that have been deep mined. The mines in the Redstone coal, west of Buckhannon, contain little water because the water drains freely from them. Similarly, the mines in the Redstone and Pittsburgh coal, north of Buckhannon near Century, contain some flooded parts but are for the most part freely draining. Only the flooded mines, south of Buckhannon near Adrian, store significant quantities of water.

Lineaments were mapped from satellite imagery and aerial photography and are shown in figure 1.3-1 (modified from Reynolds and others, 1979). Lineaments are linear features that appear on photographs or other imagery as tonal alignments in the soil, vegetation, or topography but generally cannot be identified on the ground. Lineaments commonly represent fractures or faults that may be zones of increased permeability and water storage and, therefore, good places to install water wells. These fractured zones also provide avenues for downward migration of freshwater in upland recharge areas, and avenues for upward migration of saline water in valley discharge areas. Where lineaments pass through underground mines, rooffalls and water and gas leakage may occur (J. Jansky, Mining Safety and Health Administration, oral commun., 1978).

Only three wells having high chloride (salt) concentrations were reported by Ward and Wilmoth (1968) near Buckhannon. These wells range from 100 to 211 ft deep and two are located near major lineaments.

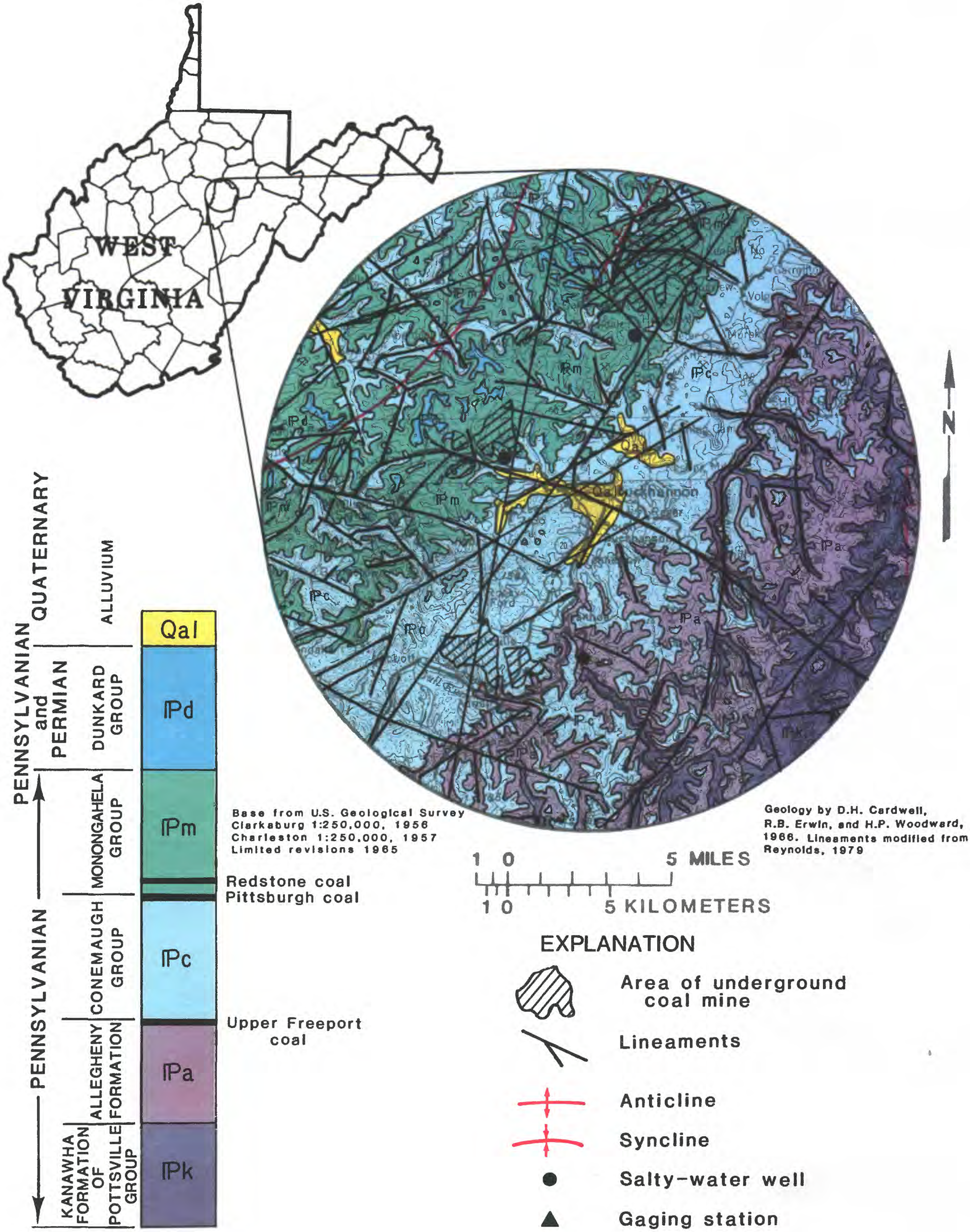


Figure 1.3-1.--Locations of large areas of known undermining, lineaments, salty-water wells, and stream-gaging site.

(p. 11 follows)

2.0 FEASIBILITY OF USING MINES FOR PUBLIC SUPPLY

2.0 FEASIBILITY OF USING MINES FOR PUBLIC SUPPLY

More Than 70 Towns in West Virginia Obtain Water Supply from Coal Mines

More than 70 towns in West Virginia obtain water from coal mines, but they are principally in the southern half of the State where mine water is low in acidity and iron.

Thousands of abandoned surface- and underground-coal mines are located in West Virginia, and ground water from these mines drains into local streams. This water is, in some instances, suitable for public-water supply.

More than 70 towns or villages in West Virginia currently derive all or part of their water from coal mines (Lessing and Hobba, 1981). Systems known to be using mine water as a supply after 1960 are listed in table 2.0-1. Since that time, some systems have been consolidated into larger systems and some have switched to surface-water supplies. Current records (1980) from the West Virginia Department of Health indicate that about 70 systems supply 81,600 people with water from coal mines. Most of these public supplies have been developed in mines in the southern half of the State where the coal beds generally have low sulfur content and acid-mine drainage is usually not a problem.

Coal-mine tunnels act as conduits that drain and store ground water. The efficiency of draining water from the rocks surrounding the mine depends upon the degree of joints and subsidence fractures in the rock that permit the movement of water into mines. The water that enters active mines is drained or pumped from the mine to land surface. When mines are abandoned, the water may flood the mine, except in mines where the coal dips toward a mine opening in a hillside. These mines do not flood, unless the entrance is sealed, and perennial drainage can dewater much of the rock above the mine.

Communities are using water from freely draining mines and from flooded mines. When water from a flooded mine is used, the water is usually pumped from a well that taps a low flooded area in the mine. Flooded mines generally represent a better source of ground water than freely draining mines because:

1. The mine essentially is a reservoir that stores water; thus, pumpage can exceed inflow for a period of time during dry months.

2. The water is somewhat protected from contamination by humans and animals.

3. Flooding prevents aeration and lessens oxidation of minerals (particularly pyrites), thus, reducing the amounts of acid and iron in the water.

When water from freely draining mines is used, it generally is necessary to seal the mine entrance to keep humans and animals out and to provide for water storage when discharge of the mine is less than demand of the water system. The quality of water from a freely draining mine may vary seasonally with the influx of recharge water (namely percolating precipitation). The quality of water in a flooded mine generally does not vary significantly because recharge water mixes with the water already stored in the mine. However, with long-term pumping of a flooded mine, dewatering of the overburden and parts of the coal mine may cause significant changes in water quality.

Table 2.0-1.--Public-water systems using mine water as a supply after 1960

[Data compiled from West Virginia Department of Health (1956, 1977) and from current files of the West Virginia Department of Health. Gal/day, gallons per day]

City or system name	Approximate use (gal/day)	Approximate population served	County name
Affinity	35,000	-----	Raleigh
Algoma	12,000	100	McDowell
Alpoca	---------	550	Wyoming
Allen Junction	32,000	550	Wyoming
Amherstdale	55,000	1,122	Logan
*Amigo	60,000	250	Raleigh
Arbuckle PSD	---------	1,000	Fayette
Ashland	---------	150	McDowell
Bartley[1]	100,000	-----	McDowell
Big Stick	---------	200	Raleigh
Blaine Community	---------	88	Mineral
Braeholm	70,000	-----	Logan
Bottom Creek	---------	88	McDowell
Brooklyn	9,000	-----	Fayette
Brenton	---------	160	Wyoming
Buchanan	3,000	56	McDowell
Cannelton	---------	580	Fayette
Capels	60,000	-----	McDowell
Caretta	75,000	808	McDowell
Chauncey[2]	---------	1,782	Logan
Coal City	40,000	-----	Raleigh
Cinderella	---------	190	Mingo
Coalburgh	8,000	-----	Kanawha
Coalwood[1]	280,000	1,100	McDowell
Crown Hill	---------	250	Kanawha
Crumpler	20,000	600	McDowell
Danese	---------	1,200	Fayette
Davin	---------	175	Logan
Dehue	3,200	600	Logan
Duo Water Works	---------	80	Greenbrier
Eccles	100,000	-----	Raleigh
Elkhorn	250,000	946	McDowell
*Epperly-		100	Raleigh
Winding Gulf.	---------	-----	Nellis
Ethel[2]	3,000	-----	Logan
Fayetteville[3]	102,000	-----	Fayette
Gary	1,300,000	2,828	McDowell
*Georges Creek	---------	32	Logan
Giatto[2]	37,000	200	Mercer
Glen Rodgers[3]	150,000	-----	Wyoming
*Glen White	38,000	-----	Raleigh
Goodwill	3,000	-----	Mercer
Hampton Road	22,000	-----	McDowell
Havaco	40,000	443	McDowell
*Helen[1]	10,000	540	Raleigh
Hemphill	20,000	519	McDowell
Hiawatha	---------	85	Mercer
Holden[2]	30,000	3,200	Logan
Hot Coal	---------	250	Raleigh
Indian Ridge	---------	100	McDowell
Jenkin Jones[2]	---------	508	McDowell
Kayford	30,000	-----	Kanawha
Keystone[2]	180,000	-----	McDowell
Killarney	4,000	-----	Raleigh
Kingston	70,000	52	Fayette
Landgraff and Eckman.	---------	670	McDowell
Laurel Creek	-------	700	Fayette
Lawton	8,000	50	Fayette
Layland	23,000	-----	Fayette
Lilly Brook	8,000	-----	Raleigh
Lorado	-------	700	Logan
Lundale[2]	33,000	-----	Logan
MacBeth	-------	500	Logan
Man	21,000	427	Logan
Manitoba	-------	444	Logan
Marfrance	15,000	350	Greenbrier
Marianna	-------	130	Wyoming
Minden	40,000	800	Fayette
Mount Hope	-------	3,000	Fayette
Mount Storm	14,500	1,700	Grant
Munsen[4]	100,000	500	McDowell
Nellis	-------	280	Boone
Oak Hill	685,000	-----	Fayette
Orville	-------	88	Logan
Otsego[2]	13,000	84	Wyoming
Pine Creek[3]	-------	500	Logan
Premier	-------	400	McDowell
Pinnacle	-------	150	Mercer
Princewick	-------	250	Raleigh
Quinwood Water Department.	-------	1,500	Greenbrier
Ragland	17,000	400	Mingo
Rensford[2]	12,000	-----	Kanawha
Republic	5,000	-----	Kanawha
*Rhodell	50,000	900	Raleigh
Rolfe	-------	437	McDowell
Rock Lick	-------	100	Fayette
Salem-Gatewood.	-------	1,400	Fayette
Scarbro	-------	2,400	Fayette
Sagmore	-------	24	Mercer
Sewell	-------	250	Fayette
Sabine	-------	300	Wyoming
Slab Fork	50,000	300	Raleigh
Smithers Utility Co.	200,000	1,696	Fayette
Stephenson	18,000	230	Wyoming
Stirrat[2,3]	-------	-----	Logan
*Stoco	100,000	2,499	Raleigh
*Stotesbury	10,000	240	Raleigh
Sullivan	20,000	75	Raleigh
Superior	10,000	300	McDowell
Twilight-Robin Hood.	-------	250	Boone
Twin Branch	-------	175	McDowell
Welch	540,000	-----	McDowell
Weyanoke	4,000	-----	Mercer
Welton	-------	550	Wyoming
Wyoming	65,000	-----	Wyoming
Wyco	-------	160	Wyoming
Yolyn	-------	400	Logan
Upland[2]	-------	635	McDowell
Vivian	-------	300	McDowell

[1] Mine shaft supplies water. [2] Well(s) also used as water source. [3] Stream also used as water source.
[4] Active mine supplies water.

* Telephone inquiries were made for details on water-plant operation and water treatment.

(p.15 follows)

3.0 FACTORS AFFECTING USE OF MINES FOR PUBLIC SUPPLY

Numerous Factors May Affect the Suitability of Mine Water for Public Supply

Factors such as subsidence (or rooffalls), active mining, large water withdrawals, locations of withdrawal, gas or oil wells, and rock fractures may affect the suitability of mine water for public supply.

Major factors affecting the quality of water obtained from mines are listed in table 3.0-1. The factors are not necessarily listed in the order of importance, and there may be interaction among factors. Two of the more important factors—location and amount of water withdrawal—are discussed in greater detail below.

The chemical quality of mine water can be affected by the location of the water withdrawal. Analyses of water quality (table 3.0-2) show that water from the flooded part of Minear mine (sump well), for example, has a pH of 6.6, and concentrations of dissolved solids, iron, manganese, and alkalinity of 382 mg/L (milligrams per liter), 3.5 mg/L, 0.33 mg/L, and 215 mg/L, respectively. (See figure 4.2-1 for location.) In contrast, water from the Minear mine drain at the highwall has a pH of 4.5, dissolved solids of 200 mg/L, total iron 19 mg/L, total manganese 0.60 mg/L, and no alkalinity. If the mine were heavily pumped or dewatered (permitting the entrance of air into the mine), the water quality in the sump well probably would change toward that of the water discharging at the Minear mine highwall. Although total dissolved solids and alkalinity decrease, the acidity, total iron, and total manganese increase; thus, treatment methods may change and costs would be increased.

The change in water quality during water withdrawals appears to be related to pooling of recharging "fresh" ground water and perhaps some stratification of mineralized mine water (fig. 3.0-1). The sump well in the Minear mine is cased for only 20 ft, and water can be seen leaking into the well from the rocks below the casing and draining down the well bore. This observation and the chemical data indicate that the water draining from the overburden into the mine forms a pool of "fresh" water in the mine at the bottom of the well. When the well is pumped, the "fresh" pool of water is removed first. After pumping for a period of time, the "fresh" water is depleted; the water that was stored elsewhere in the mine reaches the pump; and the quality of the pumped water changes. Open fractures connecting the overburden to the mine could also act as conduits (similar to the well) and create pools of "fresh" water in the flooded mine.

In addition to water-quality changes, large withdrawals of water from a flooded mine could lower the water level in the mine and remove buoyant support from the roof rock in the mine. This in turn could cause rooffalls or subsidence. Subsidence could, in turn, rupture a gas well casing or coal barriers between mines. In addition, lowering the water level could cause upward migration of salty water along the natural fractures and along lineaments. Should subsidence fracture the rocks to land surface, this would permit greater infiltration of precipitation or water from septic tanks or barnyards and greater leakage downward of water from the overlying rocks.

Table 3.0-1.--Factors and their effect on the quantity and quality of water from mines

Factor	Could possibly cause:
1. Subsidence	Turbidity or change in chemical quality, rupture of coal barriers, lower water levels in the ground and in flooded mines, increase in recharge to flooded mines, rupture of gas well casings and subsequent contamination of water by gas or salty water.
2. Active coal mining	Turbidity or change in chemical quality, subsidence, lower water levels in the ground and in flooded mines.
3. Large water withdrawals	Subsidence, lower water levels in the ground and in flooded mines, turbidity or change in chemical quality.
4. Location of withdrawal pump	Better quality of water to be obtained at a point of overflow from a flooded mine than water obtained from sump well in lowest part of flooded mine.
5. Gas or oil wells	Leakage of gas, oil, or salty water into fresh ground water or flooded mines, contamination of ground water or flooded mines by drilling fluid from new wells, or introduction of waste water from injection wells.
6. Rock fractures	Increased infiltration from precipitation or septic tank effluent in upland areas, increased upward movement of deep salty water in lowland areas which could contaminate fresh ground water or flooded mines, increased likelihood of roof falls or subsidence, increased likelihood of saltwater contamination in area of large water withdrawal.

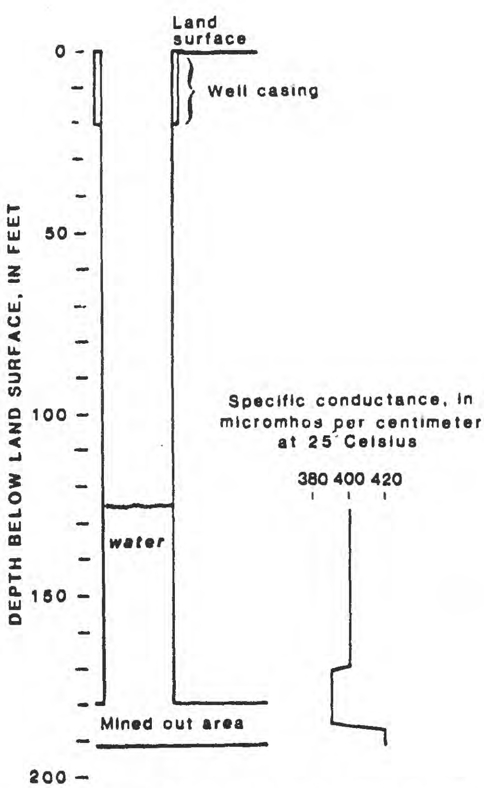


Figure 3.0-1.--Well tapping flooded Buckhannon River mine and specific conductance profile of water in the well.

Table 3.0-2.--Chemical analyses of well and mine water

Date	Time	Specific conductance (μmho/cm at 25°C)	pH (units)	Temperature (°C)	Hardness as $CaCO_3$	Calcium, dissolved	Magnesium, dissolved	Sodium, dissolved	Alkalinity as $CaCO_3$	Sulfate, dissolved	Dissolved chloride	Dissolved silica	Dissolved solids residue at 180°C	Dissolved barium	Dissolved cadmium	Total recoverable iron	Suspended recoverable iron	Dissolved iron	Dissolved lithium	Total recoverable manganese	Suspended recoverable manganese	Dissolved manganese	Dissolved strontium	Dissolved zinc
					Milligrams per liter									Micrograms per liter										
Site no. on figure 4.2-1 / Identification no. / Name / (Latitude, longitude)																								
4 / 385420080162001 / Cunningham Well / (lat 38°54'20", long 80°16'20")																								
9-4-80	1200	600	7.2	16.5	120	37	6.5	67	190	45	23	--	320	--	--	90	70	20	--	30	10	20	--	--
3 / 385428080161801 / Miller Town Well / (lat 38°54'28", long 80°16'18")																								
9-4-80	1130	650	7.1	12.0	34	10	1.9	140	230	18	53	8.6	364	740	1	50	50	0	8	10	0	10	230	0
- / 385443080163101 / Miller-Todd Mine / (lat 38°54'43", long 80°16'31")																								
9-4-80	1400	530	6.6	12.5	120	30	10	57	85	130	10	9.1	316	40	2	120	120	0	16	40	0	40	330	17
5 / 385453080154001 / Minear 72 Ft Well / (lat 38°54'53", long 80°15'40")																								
9-2-80	1715	340	5.8	12.0	82	23	5.8	23	75	71	3.2	12	202	90	3	7,700	1,000	6,700	6	390	0	450	200	47
- / 385454080152801 / Minear Mine at high wall / (lat 38°54'54", long 80°15'28")																								
9-3-80	1430	320	4.5	11.5	81	19	8.0	1.6	0	110	1.0	14	200	40	4	19,000	19,000	18	16	600	0	650	180	74
6 / 385505080155201 / Minear Mine Sump Well / (lat 38°55'05", long 80°15'52")																								
9-3-80	1130	630	6.6	11.4	130	37	8.1	87	215	94	10	10	382	100	2	3,400	0	3,500	13	280	0	330	510	11
7 / 385555080172401 / Buckhannon River Mine Well / (lat 38°55'55", long 80°17'24")																								
2-3-81	1340	390	7.2	13.5	69	20	4.3	67	--	--	--	8.5	--	490	<1	--	--	<3	<4	--	--	<1	580	14
2-3-81	1430	370	7.3	11.8	72	21	4.4	66	130	--	--	8.6	--	500	<1	--	--	<3	<4	--	--	<1	580	18

NOTE: All samples had 0 micrograms per liter of lead, molybdenum, vanadium, beryllium, cobalt, and copper; except the sample from the Buckhannon River Mine well which had less than--10,10,6, 1, 3, and 10 micrograms per liter of these constituents respectively; the sample from Cunningham well was not analyzed for these constituents.

17a (P.19 follows)

4.0 POTENTIAL OF MINES IN NORTHERN UPSHUR COUNTY FOR PUBLIC SUPPLY

4.0 POTENTIAL OF MINES IN NORTHERN UPSHUR COUNTY FOR PUBLIC SUPPLY

4.1 Location and Description of Mines

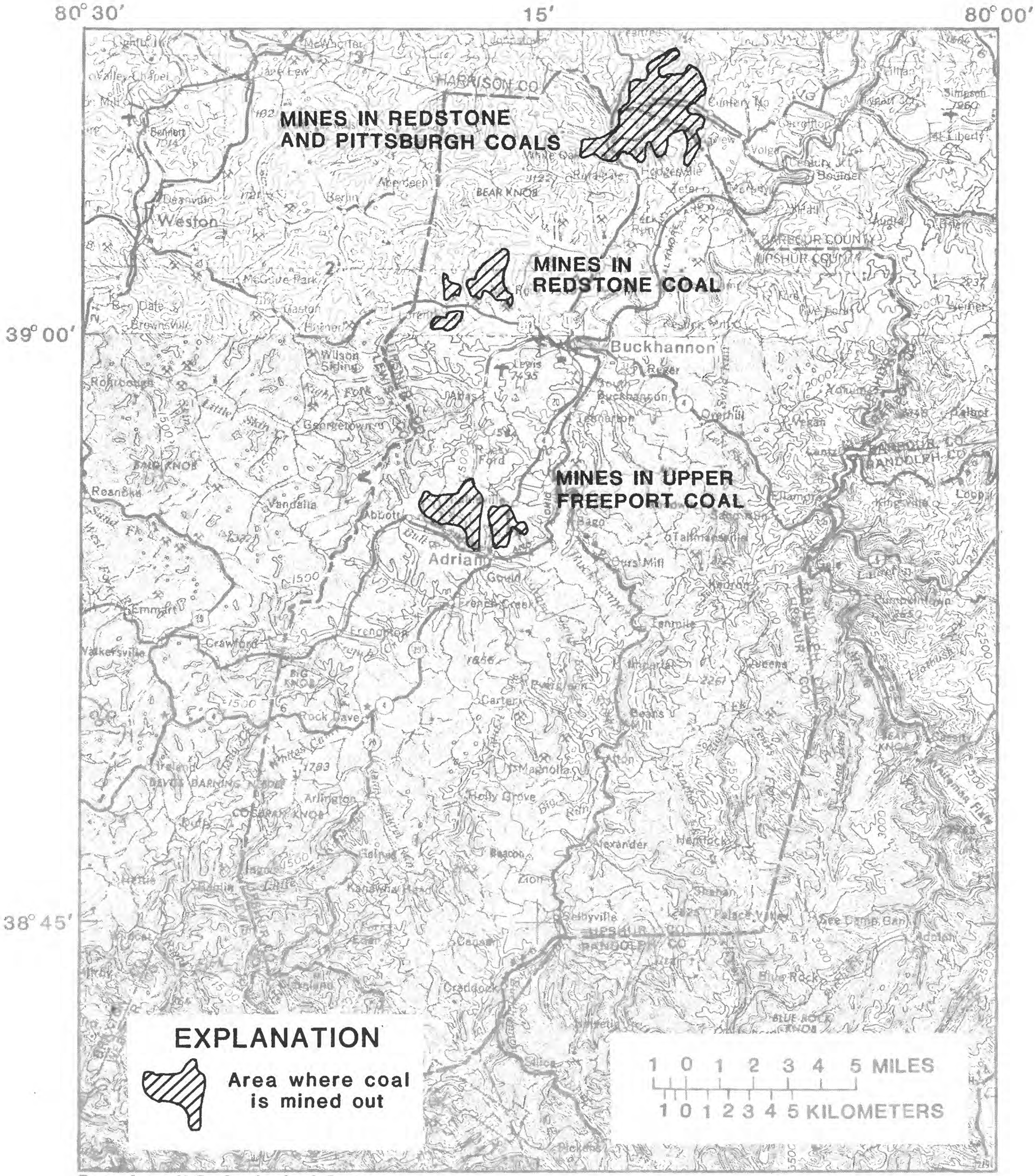
Underground Coal Mines Are Located in Northern Upshur County to the North, West, and South of Buckhannon

The underground coal mines located north and west of Buckhannon are in the Redstone and Pittsburgh beds of coal, whereas those south of Buckhannon are in the Upper Freeport bed of coal.

Underground coal mines are located north, west, and south of Buckhannon in the Redstone, Pittsburgh, and Upper Freeport beds of coal (fig. 4.1-1). The mines in the Redstone coal are stratigraphically the highest in the local area. The Redstone coal is from 4 to 6 ft thick and lies about 40 ft above the Pittsburgh coal (Reger 1918, p. 447, 477) which lies at the base of the Monongahela Group of rocks.

The Pittsburgh coal is 8 ft thick in the northern tip of Upshur County, but it is only 1.5 ft thick about 1.7 mi north of Buckhannon (Reger 1918, p. 477). Thus it is uneconomical to mine except in the northern part of the county. Both the Pittsburgh and Redstone coals have been and are being mined in the area near Century.

The Upper Freeport coal is stratigraphically the lowest in the study area. This coal bed is separated from the overlying Pittsburgh coal by 600 ft (Reger, 1918, p. 201) of the Conemaugh Group of rocks. The Upper Freeport coal is best developed near Adrian where it may be 6 ft thick. To the east of Adrian and east of Buckhannon, it ranges from 2 to 4 ft in thickness (Reger, 1918, p. 523, 527). All of the flooded abandoned-underground mines in the Upper Freeport coal are located about 6 mi south of Buckhannon near Adrian.



Base from U.S. Geological Survey
Clarksburg 1:250,000, 1956, limited revision 1965, and
Charleston 1:250,000, 1956, limited revision 1965

Figure 4.1-1.--Areas of underground coal mines in the northern part of Upshur County.

4.2 Yield of Mines

4.2.1 Flooded mines

Flooded Underground Mines near Adrian Store About 1,170 Acre Feet of Water

Three flooded mines near Adrian store about 1,170 acre-feet of water or enough water to supply 2,400 gallons per minute for 110 days, or for 140 days when an additional 500 gallons per minute infiltration is considered.

Three flooded abandoned-underground mines in the Upper Freeport coal bed near Adrian are shown in figure 4.2-1: The Buckhannon River mine, the Miller-Todd mine, and the Minear mine. These are the only mines in northern Upshur County that store large amounts of water. The map shows the location of all the mines (the flooded portions are shaded). The Buckhannon River mine is the largest, and it was abandoned in 1952. Approximately 368 acres of the Buckhannon River mine are flooded and, because about 50 percent of the 5-foot thick coal bed was removed, about 920 acre-feet of water can be stored in the mine. The mine was flooded at the time a new pump, capable of pumping about 1,750 gal/min, was installed at the sump well (fig. 4.2-1). It took 6 or 7 months of continuous pumping at full capacity to dewater the mine (Howard "Red" Gould, former mine-pump operator, oral commun., 1980). After dewatering, the pump was operated about 16 hours a day, 5 days per week. At a pumping rate of 830 gal/min, the yield for a 7-day week was 1.2 Mgal/d. The total mined area when the mine was abandoned was about 800 acres. Thus, the approximate rate of drainage into the mine was slightly more than 1 gal/min per acre. This is in general agreement with Carpenter and Herndon (1933, p. 6) who report that mines in the Pittsburgh Coal normally discharge 0.7 gal/min/acre, and about half that amount during drought. The Upshur Coal Company's active mine lies west of the Buckhannon River mine. Presently (1981), 800 to 1,000 gal/min is pumped from this mine, but part of this water is overflow from the flooded Buckhannon River mine. Most of the water is pumped into the Buckhannon River drainage basin, but about 150 gal/min is pumped into the West Fork River drainage basin ("Dusty" Williams, Upshur Coal Company, oral commun., 1980).

The Miller-Todd mine is located updip and adjacent to the Buckhannon River mine. This mine was abandoned in the 1960's and is now flooded downdip from the portal (fig. 4.2-1), which discharges about 200 gal/min. Approximately 62 acres of this mine are flooded, and about 155 acre-feet of water is stored. There are no sump wells at this mine. During mining, a centrifugal pump with a 4-inch discharge line was operated full time and a pump with a 2-inch discharge line was operated intermittently pumping water out the mine entrance (Denver Tenney, former coal miner, oral commun., 1980).

The mine of the Minear Coal Company is located updip and adjacent to the Miller-Todd mine. At least 91 acres have been mined, and approximately 38 acres are flooded. Thus, about 95 acre-feet of water is stored in the mine.

As indicated above, the Miller-Todd and the Minear mines are east of and updip from the large Buckhannon River mine. Although a coal barrier lies between each of the mines, the barriers probably contain joints and fractures; pumping water from the Buckhannon River mine probably would induce water to move from the other mines toward the pumped mine. The dominant vertical fractures in the coal beds of this area trend almost east-west (N 80°W) as shown on a map by Kulander and others (1980). Because ground water in this area moves primarily through fractures, permeability in the coal bed may be enhanced in the east-west direction parallel to vertical fractures, which would promote hydraulic connection through the coal barriers that separate the three mines. Thus, the amount of water that could be pumped from the Buckhannon River mine depends on: (1) the amount of water stored in the mine, (2) the degree of hydraulic connection with the adjacent flooded mines, (3) the amount of water stored in the other two flooded mines, and (4) the amount of water leaking into the mines from the surrounding rocks as the mines are dewatered.

The three mines store a total of 1,170 acre-feet of water. This potentially could supply the current (1981) needs of Buckhannon for 178 days or about 6 months. Assuming an average infiltration rate of about 1 gal/min per acre into the mine, an additional 500 gal/min or 0.72 Mgal/d is available from the mines. Therefore, there should be enough water to supply the current needs of Buckhannon (1,500 gal/min) for 265 days or nearly 9 months.

The table below summarizes the number of days the water supply in the three flooded mines should last for given rates of withdrawal in 1981 and in 2018 for normal and drought conditions. The supply of water would appear to be adequate for projected needs in the year 2018 during a drought similar to that in 1930 and 1953 (see section 1.1 for details on these droughts).

Water withdrawal rate in gal/min	Date of use of conditions	Day's supply of water stored in mines	Day's supply of water stored in mines plus 500 gal/min infiltration rate
1500	1981 use	178	265
2500	est. 2018 use (normal conditions)	108	135
1/ 1900	2018 (drought similar to that of 1953)	140	190
1/ 2400	2018 (drought similar to that of 1930)	110	140

1/ Withdrawal rate assumes same amount of streamflow is available as in 1930 and 1953 droughts, and that water users are not conserving water.

Note that once the water stored in the mines is depleted, the yield of the mines then will be equal to the infiltration rate estimated to be 500 gal/min.

Quality of water stored in the mines

Mine name	Coal bed	Volume of water stored (acre-feet)	pH (units)	Iron	Manganese	Sulfate	Dissolved solids	Chloride	Hardness, calcium carbonate	Specific conductance (micromhos per centimeter at 25°C)
				Water-quality characteristics, Milligrams per liter						
Buckhannon River 1/	Upper Freeport	920	7.2	0.5	0.99	---	1230	---	---	---
Miller Todd 2/	Upper Freeport	3/ 155	6.7	0.0	.06	130	----	6.4	120	460
Minear 2/	Upper Freeport.	4/ 95	6.0	2.7	.24	83	----	6.0	100	650
			5/ 4.0	21.0	.73	130	----	2.0	85	380

1/ Analysis courtesy Upshur Coal Company.
2/ Analysis by West Virginia Geological and Economic Survey.
3/ Measured and sampled 6-27-80; overflows 200 gallons per minute.
4/ Measured and sampled 7-23-80; overflows 25 gallons per minute.
5/ Measured at highwall.

4.2.2 Freely draining mines

Freely Draining Mines near Century Discharge As Much As 1,400 Gallons Per Minute to Right Branch Gnatty Creek

Freely draining mines near Century discharge as much as 1,400 gallons per minute to Right Branch Gnatty Creek, but during a drought this flow may be reduced by 50 percent.

Mined areas north, west, and south of Buckhannon are shown in figure 4.2.2-1. The mines of Bethlehem Mines Corporation, north of Buckhannon at Century, are in the Redstone and Pittsburgh coal beds. The Redstone coal is mined out, but there is active mining in the underlying Pittsburgh coal. The Redstone coal crops out on the hillside and water freely drains from the mines, but a few low areas in the mines are flooded and store water (Lawrence Arch, Chief Engineer, Bethlehem Mines Corporation, oral commun., 1980).

Water drains from the Bethlehem mines at three sites. The measured and estimated flows and partial chemical analyses at the sites are shown in figure 4.2.2-2. Combined flow from sites 1 and 2 was about 280 gal/min on June 26, 1980. Flow from site 3 is reported by the mining company to range from 200 to 550 gal/min. The water discharging at site 1 comes from mines in the Redstone coal and in the underlying Pittsburgh coal. The water discharging at sites 2 and 3 comes from mines in the Redstone coal. All of this water enters the Right Branch of Gnatty Creek and flows northward away from Buckhannon. The amount of mine water entering the creek during a drought would probably be less than 700 gal/min (about 50 percent of normal flow, Carpenter and Herndon, 1933, p. 6).

The mines west of Buckhannon and in the vicinity of Red Rock are in the Redstone coal. Much of the coal is mined out, but there is still some mining activity. Little water reportedly drains from the mines at Red Rock. A field investigation in the area on June 26, 1980 confirms that small tributary streams that would carry local mine drainage were either dry or flowing less than 25 gal/min. The largest observed flow was 36 gal/min of what appeared to be mine drainage into Wash Run; the water had a pH of 5.5 and specific conductance of 650 mho/cm at 25°C. Mining officials, familiar with the mines in the Red Rock area, reported no significant flooded areas in the mines.

The available data indicate that there is less water available from the freely draining mines north and west of Buckhannon than there is from the flooded mines south of Buckhannon. Also, water from the freely draining mines generally contains more dissolved minerals than water from the flooded mines.

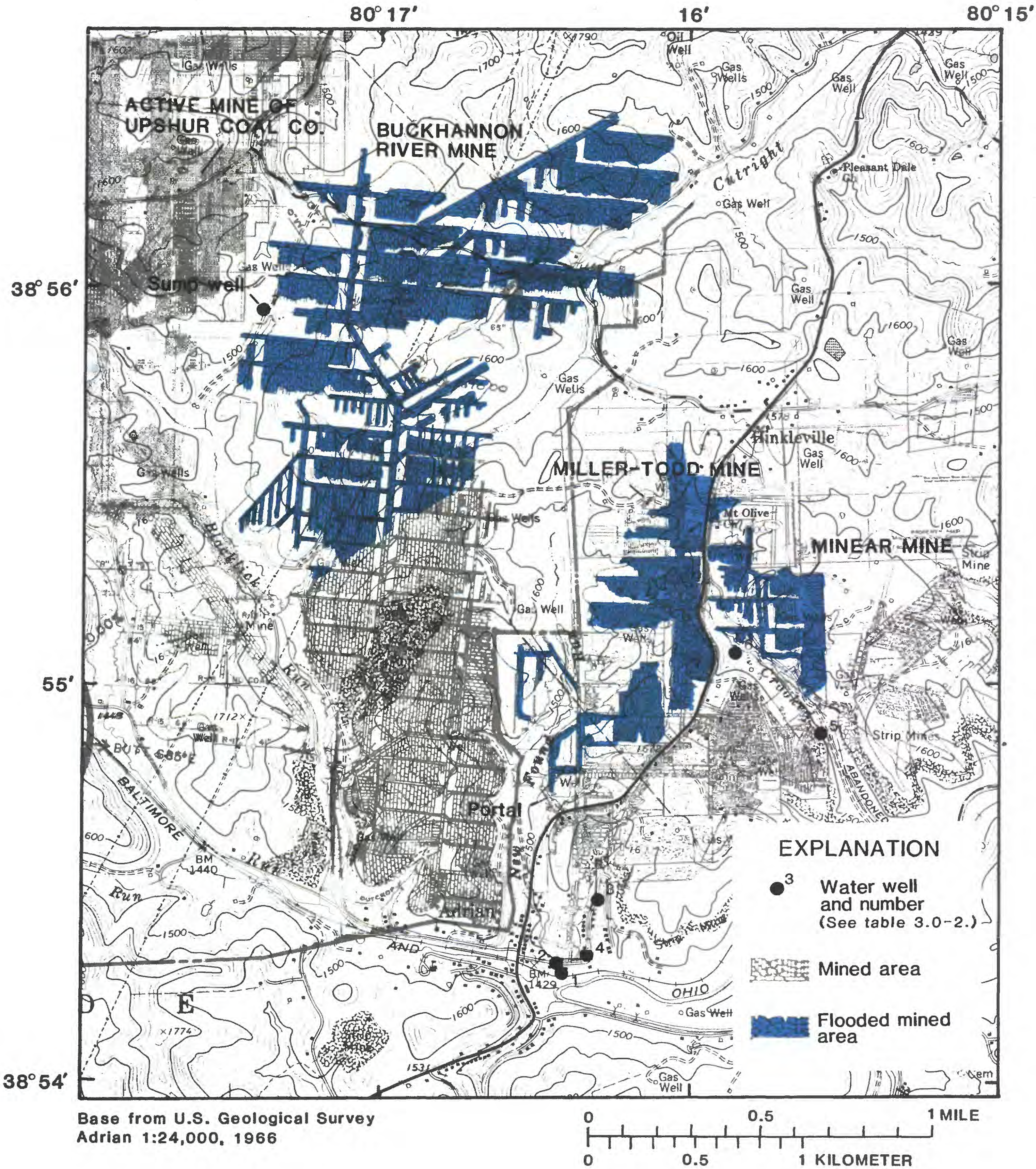


Figure 4.2-1.--Flooded parts of three abandoned coal mines south of Buckhannon, near Adrian and the general quality of the stored water.

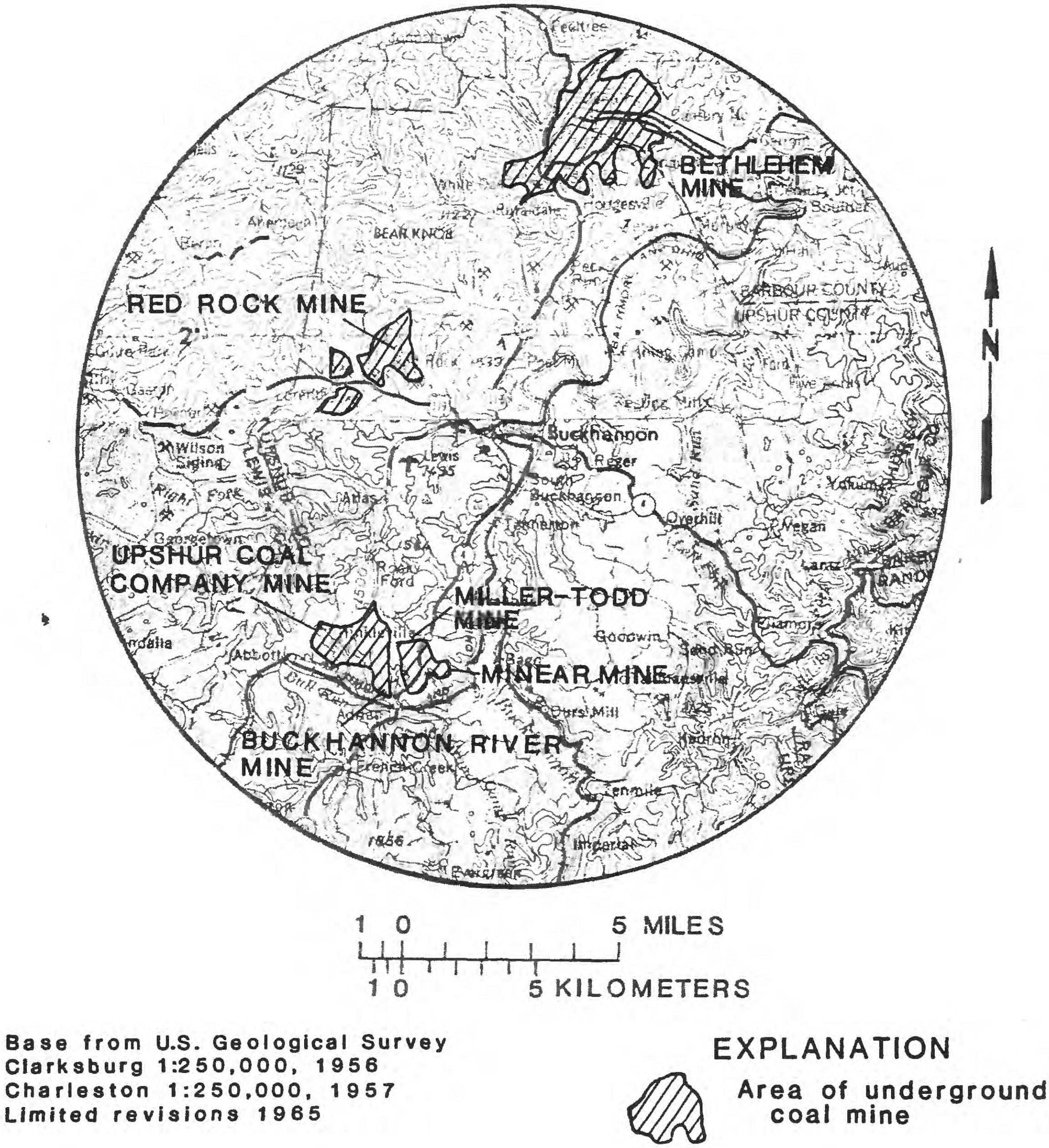
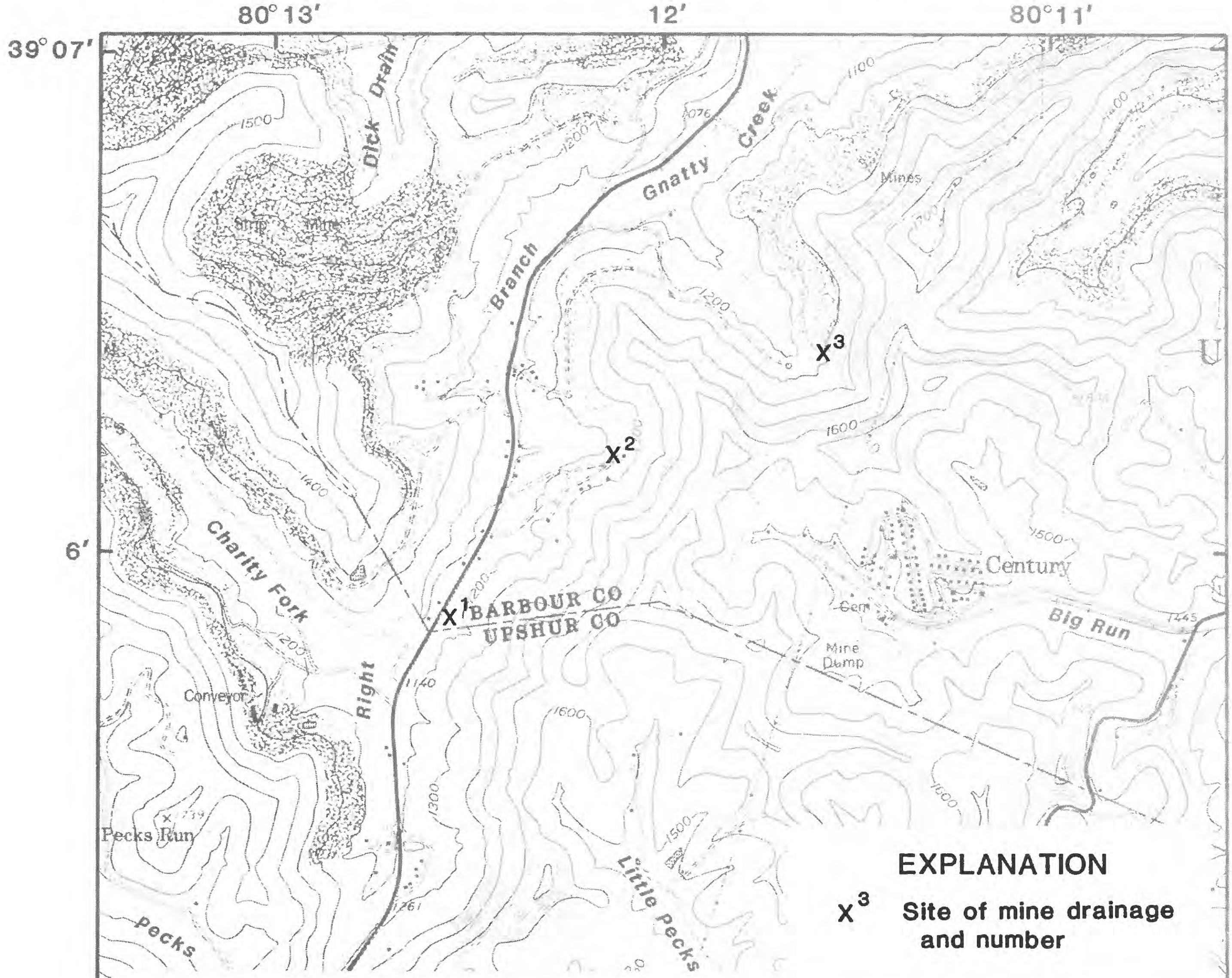


Figure 4.2.2-1.--Major underground coal mines near Buckhannon.



Mine drainage site no.	Coal bed	Flow of mine drainage (gallons per minute)	Specific conductance (micromhos at 25°C)	pH	Iron	Manganese	Sulfate	Chloride	Hardness as calcium carbonate
				Water quality					
					milligrams per liter				
[a]1	Redstone and Pittsburgh.	240	1050	8.5	0.2	0.05	282	6.2	290
[a]1	Redstone-----	40	1300	7.8	4.3	.71	698	8.4	555
[b]3	-----do------	200 to 550	----	6.6 to 8.0	1 to 4	----	425 to 824	---	---

[a] Analysis by West Virginia Geological and Economic Survey.
[b] Data courtesy of Bethlehem Mines Corporation.

Base from U.S. Geological Survey
Century 1:24,000, 1960

0 0.5 1 MILE
0 0.5 1 KILOMETER

Figure 4.2.2-2.--Location, flow, and quality of water draining from coal mines north of Buckhannon, near Century.

4.3 *Quality of Mine Water*

4.3.1 *Chemical and physical characteristics*

Quality of Water from Freely Draining Mines Generally Has Greater Concentrations of Hardness, Sulfate, Iron, and Manganese Than Flooded Mines

Specific conductance of water from freely draining mines in northern Upshur County ranged from 1,050 to 1,300 micromhos; pH ranged from 6.6 to 8.5 units; sulfate concentration ranged from 280 to 820 milligrams per liter; iron concentration ranged from 0.2 to 4.3 milligrams per liter; and manganese concentration ranged from 0.05 to 0.71 milligrams per liter. Specific conductance of water from flooded mines ranged from 320 to 630 micromhos; pH ranged from 4.5 to 7.3 units; sulfate concentration ranged from 71 to 130 milligrams per liter; iron concentration ranged from 0.0 to 6.7 milligrams per liter; and manganese concentration ranged from 0.04 to 0.65 milligrams per liter.

Table 4.3.1-1 allows comparison of the dissolved constituents of water from flooded mines with that of nearby wells and nearby mines that are not flooded but are freely draining.

Water from the freely draining mines north and west of Buckhannon generally have greater concentrations of hardness, sulfate, iron, and manganese than does water from the flooded mines south of Buckhannon. For example, the table shows that, for the freely draining mines, specific conductance ranges from 1,050 to 1,300 micromhos, pH from 6.6 to 8.5, sulfate concentration from 280 to 820 mg/L, iron concentration from 0.2 to 4.3 mg/L, and manganese concentration from 0.05 to 0.71 mg/L. For the flooded mines, specific conductance ranges from 320 to 630 micromhos, pH from 4.5 to 7.3, sulfate concentration from 71 to 130 mg/L, iron concentration from 0 to 6.7 mg/L, and manganese concentration from 0.04 to 0.65 mg/L. The generally greater concentrations of dissolved minerals in water from the freely draining mines may be due to (1) aeration and, thus, rapid oxidation of the minerals in the freely draining mines, or (2) slight differences in the mineralogy of the overburden rock and the coal at the mines north and west of Buckhannon. These mines are in the Redstone and Pittsburgh coals, whereas the flooded mines south of Buckhannon are in the Upper Freeport coal.

The chemical constituents of the raw water of the Miller-Todd and Minear mines at Adrian and the chemical constituents of the raw mine water used by other communities as a public supply in West Virginia and Pennsylvania are shown in table 4.3.1-2.

Table 4.3.1-1.--Complete and partial chemical analyses of water from mines and wells

Date	Time	Specific conductance (µmho/cm at 25°C)	pH (units)	Temperature (°C)	Hardness as $CaCO_3$	Dissolved calcium	Dissolved magnesium	Dissolved sodium	Alkalinity	Dissolved sulfate	Dissolved chloride	Dissolved silica	Dissolved solids residue at 180°C	Dissolved barium	Dissolved cadmium	Total recoverable iron	Suspended recoverable iron	Dissolved iron	Dissolved lithium	Total recoverable manganese	Suspended recoverable manganese	Dissolved manganese	Dissolved strontium	Dissolved zinc
					Milligrams per liter									Micrograms per liter										
					Identification no. — Name — (Latitude, longitude)																			
Water from wells																								
385420080162001 - Cunningham Well (lat 38°54'20", long 80°16'20")																								
9-4-80	1200	600	7.2	16.5	120	37	6.5	67	190	45	23	--	320	--	--	90	70	20	--	30	10	20	--	--
385428080161801 - Miller Town Well (lat 38°54'28", long 80°16'18")																								
9-4-80	1130	650	7.1	12.0	34	10	1.9	140	230	18	53	8.6	364	740	1	50	50	0	8	10	0	10	230	0
Water from flooded mines																								
385443080163101 - Miller-Todd Mine (lat 38°54'43", long 80°16'31")																								
9-4-80	1400	530	6.6	12.5	120	30	10	57	85	130	10	9.1	316	40	2	120	120	0	16	40	0	40	330	17
385453080154001 - Minear 72 Ft Well (lat 38°54'53", long 80°15'40")																								
9-2-80	1715	340	5.8	12.0	82	23	5.8	23	75	71	3.2	12	202	90	3	7,700	1,000	6,700	6	390	0	450	200	47
385454080152801 - Minear Mine at high wall (lat 38°54'54", long 80°15'28")																								
9-3-80	1430	320	4.5	11.5	81	19	8.0	1.6	0	110	1.0	14	200	40	4	19,000	19,000	18	16	600	0	650	180	74
385505080155201 - Minear Mine Sump Well (lat 38°55'05", long 80°15'52")																								
9-3-80	1130	630	6.6	11.4	130	37	8.1	87	220	94	10	10	382	100	2	3,400	0	3,500	13	280	0	330	510	11
385555080172401 - Buckhannon River Mine Well (lat 38°55'55", long 80°17'24")																								
2-3-81	1340	390	7.2	13.5	69	20	4.3	67	--	--	--	8.5	--	490	<1	--	--	<3	<4	--	--	<1	580	14
2-3-81	1430	370	7.3	11.6	72	21	4.4	66	130	--	--	8.6	--	500	<1	--	--	<3	<4	--	--	<1	580	18
Water from freely draining mines																								
Century Mines 101 and 105																								
6-26-80	--	1,050	8.5	--	290	--	--	--	--	282	6.2	--	--	--	--	--	--	200	--	--	--	50	--	--
Century Mine 101 at west portal																								
6-26-80	--	1,300	7.8	--	560	--	--	--	--	698	8.4	--	--	--	--	--	--	4,300	--	--	--	710	--	--
Century Mine 101 north drain																								
1979,1980	--	--	6.6-8.0	--	--	--	--	--	--	425-824	--	--	--	--	--	--		1,000-4,000	--	--	--	--	--	--

NOTE: All samples had 0 micrograms per liter of lead, molybdenum, vanadium, beryllium, cobalt, and copper; except the sample from the Buckhannon River mine well which had less than--10, 10, 6, 1, 3, and 10 micrograms per liter of these constituents, respectively; the sample from Cunningham well was not analyzed for these constituents.

Table 4.3.1-2.--Chemical analyses of raw and treated mine water used for public supply and raw water from Minear and Miller-Todd mines, near Buckhannon, West Virginia

Town or name	Water source/ coal seam	Date of collection	Sample	Specific conductance (μmho/cm at 25°C)	pH (units)	Temperature (°C)	Hydrogen sulfide present	Hardness as $CaCO_3$	Dissolved calcium	Dissolved magnesium	Dissolved sodium	Alkalinity as $CaCO_3$	Dissolved sulfate	Dissolved chloride	Dissolved fluoride	Dissolved solids (calculated)	Nitrate as NO_3	Dissolved iron	Dissolved manganese
								Milligrams per liter											
Stoco-------	Flooded mine/ Beckley	4-29-76	raw	540	6.5	12.0	Yes	230	57	21	7.6	150	72	5.2	----	268	----	1.70	0.16
Stoco[1]------	Flooded mine/ Beckley	10-15-79	treated	---	7.5	----	---	210	---	----	----	150	---	9.0	0.11	392	0.06	.14	.10
Amigo[1]------	Mine drain/ Pocahontas #3	10-15-79	raw	---	7.4	----	---	130	---	----	----	55	---	<1.0	.09	261	.06	.56	.11
Stotesbury[1] -	Mine drain/ Beckley	10-15-79	raw	---	7.5	----	---	150	---	----	----	350	---	5.0	.26	609	.04	.45	.29
Helen[1]------	Mine drain/ Pocahontas #3	10-15-79	raw	---	7.8	----	---	150	---	----	----	170	---	<1.0	.18	435	.42	.00	.02
Glen White--	Flooded mine/ ?	4- 2-74	raw	540	6.1	16.0	---	170	---	----	----	---	160	3.0	----	---	----	20	----
Hastings,[2] Pa.	Flooded mine/ ?	8-10-77	raw	---	6.6	----	No	480	---	----	----	250	---	----	----	600	----	.02	----
Hastings,[2] Pa.	Flooded mine/ ?	3-20-80	raw	---	---	----	No	410	110	----	----	---	---	----	----	583	----	----	----
Hastings,[2] Pa.	Flooded mine/ ?	9- 5-78	treated	---	7.0	----	No	170	110	----	35	170	---	----	----	306	----	----	----
Minear Mine-	Flooded mine/ Upper Freeport	9- 3-80	raw	630	6.6	11.4	Yes	130	37	8.1	87	210	94	10	----	382	----	3.4	.33
Miller-Todd-	Flooded mine/ Upper Freeport	9- 3-80	raw	530	6.6	12.5	No	120	30	10	57	84	130	10	----	316	----	.12	.04

[1] Analysis by Environmental Health Services Laboratory, South Charleston, West Virginia.
[2] Analysis by Cardan Laboratories, Inc., Spangler, Pennsylvania.

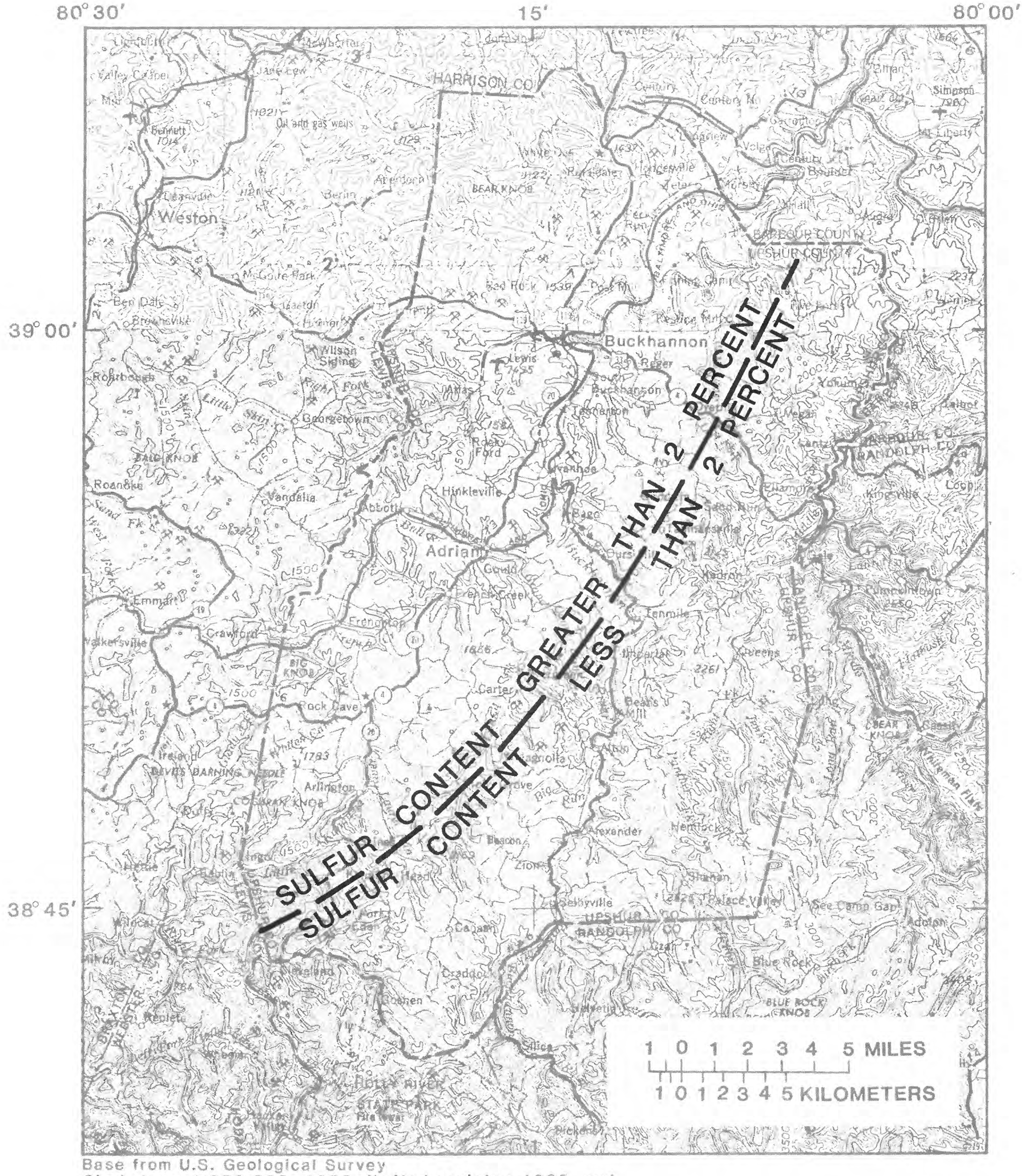
4.3.2 Relation of water quality to chemical composition of coal

Water Quality in Mines May Be Related to Composition of Coal

Water from mines in northern Upshur County generally is higher in dissolved solids, hardness, sulfate, and pH than water from mines in central Upshur County.

Water from mines and wells in the vicinity of Buckhannon generally contains troublesome amounts of manganese (Mn), iron (Fe), sulfate (SO_4), hydrogen sulfide (H_2S), and sometimes excessive hardness (as $CaCO_3$) and chloride (Cl). The analyses indicate that ground-water quality in the area generally improves in a southerly direction. This change in water quality also is reflected in maps of surface-water quality (Friel and others, 1967, pp. 66, 68, 71). Some changes in water quality may be related to the southerly decrease in sulfur content in the coal beds (fig. 4.3.2-1).

The mines north and west of Buckhannon store little water and would be of limited value as a public supply during a drought. Therefore, limited chemical analyses were made on those waters. The flooded mines south of Buckhannon store large amounts of water that could be used for public-water supply during a drought. Although total dissolved minerals, hardness, and sulfate are generally lower in water from the flooded mines than in water from nearby freely draining mines, manganese, iron, and sulfate may be high enough to be troublesome. Also, dewatering the flooded mines may cause water quality to change toward that of the water discharging from the freely draining mines; thus, acidity, iron, and manganese may increase.



Base from U.S. Geological Survey
Clarksburg 1:250,000, 1956, limited revision 1965, and
Charleston 1:250,000, 1956, limited revision 1965

Figure 4.3.2-1.--Parts of Upshur County where total sulfur in coals is less than or greater than 2 percent. (Modified from Headlee and McClelland, 1955.)

4.3.3 Treatment of mine water

Methods Are Available for Removing Problem Chemical Constituents in Mine Water

Numerous treatment methods are available for removing high concentrations of iron, manganese, hydrogen sulfide, and sulfate that are common in mine water.

Iron, manganese, hydrogen sulfide, and sulfate are commonly present in high concentrations in water from mines and wells in this area. Table 4.3.3-1 is a list of ways to reduce or remove these dissolved constituents to the desired level. Also shown are some methods of treating acidity, water, hardness, and high concentrations of total dissolved minerals. Although these constituents were not excessively high in the water samples from the flooded mines, the concentrations may change as pumping continues and the water levels are lowered.

Depending on the quality of the raw water and the desired quality of the finished water, one or more treatment processes may be used separately or simultaneously. Most of the processes mentioned in the table produce a sludge of chemical precipitate or mineralized reject water that must be disposed of in compliance with State and Federal water-pollution laws. Sediment sludge also could be a problem if water is pumped from the Buckhannon River mine. Sediment from a coal-washing operation has been pumped into parts of this mine. The sludge, if disturbed by subsidence or rapid flow of water, could cause turbid water. Turbidity can be removed from the water by flocculation (commonly with aluminum or ferrous sulfate), followed by clarification in a settling basin, and filtration through a sand bed or other filter medium.

Several water companies that use mine water as a source of public supply were contacted for information regarding their source of water and treatment system. Chlorination was the only treatment used for the systems at Elkhorn, Gary, Glen White, Man, and Rhodell, all in southern West Virginia. The water at Stoco (Raleigh County) is chemically similar to the water in the Miller-Todd mine near Adrian: specific conductance, chloride, and pH are similar; the water is hard; and the iron and manganese concentrations are high (table 4.3.1-2). However, the sulfate concentration is nearly twice as high in the water from the Miller-Todd mine. The Stoco Water Company obtains its water from wells drilled into a flooded mine in the Beckley coal bed in Raleigh County (David Parks, Director, Raleigh County Public Service District, oral commun., 1980). Treatment for the water from the flooded mine consists of chlorination and aeration before filtration through a granular anthracite coal filter that removes 2 to 3 milligrams per liter of iron. Soda ash is added to increase the pH to about 7, and the water is chlorinated for disinfection as it enters the distribution system.

Water from freely draining mines supplies water for Amigo, Stotesbury, and Helen in Raleigh County. Presently, the only treatment used is chlorination. However, treatment systems are currently being installed at Amigo and Stotesbury to filter the water through zeolite filters after the addition of soda ash and potassium permanganate. This treatment will remove iron and manganese before the water is chlorinated and piped into the distribution system.

The Town of Hastings, in western Pennsylvania, obtains water from a well tapping a flooded mine. This system is discussed here because (1) its water comes from a northern bed of coal which often has a high sulfur concentration, and (2) it employs the reverse osmosis (RO) process which is often used for desalinizing sea water but is seldom used for treating mine water. A brief description of the RO process is shown in table 4.3.3-1.

At Hastings, Pa., the mine water is pumped into a holding tank and, then, filtered through inexpensive cartridge-type replaceable filters to remove sediment and organic debris (Rick Banick, Borough of Hastings, Pa., oral commun., 1980). After filtration, the water is treated with sulfuric acid and sodium hexametaphosphate and, then, is pumped through the RO membrane. The water is treated with sodium hydroxide and chlorine and, then, pumped into the distribution pipeline. A drain constantly flushes highly mineralized water that cannot pass through the membrane away from the high-pressure side of the membrane. Flow into the RO system is about 105 gal/min and output is about 80 gal/min. The life of the membrane(s) (about 5 years) is reduced by sediment and chemical precipitates; thus, proper filtration and chemical treatment is necessary for most water before it passes through the membrane.

Table 4.3.3-1.--Selected ways of removing or reducing chemical and bacteriological constituents that exceed recommended concentrations

[After Lessing and Hobba, 1981]

Problem chemical constituent	Symptoms	Treatment
Hardness Calcium (Ca) and Magnesium (Mg)	Forms white scale in tea kettles, plumbing, and as rings in bath tubs. Also, consumes soap.	1. Lime-soda treatment--chemical reactions convert most of Ca and Mg in solution to insoluble calcium carbonate and magnesium hydroxide. The resulting sludge can be removed by sedimentation and filtration.
		2. Ion exchange--zeolite minerals or synthetic resin beads exchange sodium (Na) ions in their structure for Ca and Mg in the water. When the exchange capacity is exhausted, regeneration is accomplished by back flushing with a strong salt (sodium-chloride) solution. The resin beads have a greater exchange capacity than the zeolite minerals.
Iron (Fe)	Forms hard, reddish-brown stains on sinks, commodes, and tubs. May stain laundry brown and impart objectionable taste to food and beverages such as coffee and tea. A slimy deposit indicates the presence of iron bacteria.	1. Oxidation and filtration--aeration followed by sedimentation will usually remove Fe and Mn when organic matter is not present. Chloride or potassium permanganate is also used to oxidize Fe and Mn which is then filtered from the water. These agents are commonly used when the water is high in organic matter as it may be in surface water or ground water containing iron bacteria. The water should be made alkaline before any Fe or Mn removal is attempted.
		2. Oxidation and filtration through manganese green sand--the green sand gives up oxygen to produce insoluble iron hydroxide and manganese oxide. When the available oxygen is exhausted, regeneration is accomplished by back flushing the green sand with potassium permanganate.
Manganese (Mn)	Some objectionable features as iron, but forms brown or black stains.	3. Chemical stabilizer--sodium hexametaphosphate (polyphosphate) stabilizes Fe and Mn and delays precipitation. Delay time varies with the amount of polyphosphate added. The polyphosphate must be added before the water is exposed to air.

Table 4.3.3-1.--**Selected ways of removing or reducing chemical and bacteriological constituents that exceed recommended concentrations**--Continued

Problem chemical constituent	Symptoms	Treatment
Hydrogen Sulfide (H_2S)	Has foul rotten-egg smell and is usually corrosive to plumbing.	Aeration--permits H_2S to escape to atmosphere. Aeration can be accomplished by spraying water into the air, trickling it through beds of coarse coke or stone, permitting it to cascade over steps, or by bubbling air into it (either in an open tank or in a closed system). After aeration, water may still be corrosive because of dissolved oxygen.
Chloride (Cl)	Has salty taste and is usually corrosive.	1. Demineralization by ion exchange--two types of resin beads remove nearly all dissolved mineral matter by cation and anion exchange. When the exchange capacity is exhausted, regeneration is accomplished byback flushing one type resin with acid (usually sulfuric acid) and the other type with alkali (usually sodium hydroxide). Cost is quite high for water containing more than 2,500 mg/L dissolved solids. Cost can be reduced if mixing demineralized water with raw water will produce an acceptable water. 2. Demineralization by reverse osmosis--The raw water is forced through aspecial semi-permeable membrane contained in cannister units through which the water can pass but most of the dissolved minerals cannot. As much as 90 percent of the dissolved minerals may be removed. cannisters can be added in parallel to increase output of the system. Output water can be mixed with raw water or output water from another system to produce water of a desired quality. Cost per gallon generally decreases as output volume increases. Variation in quality of input water has little affect on quality of output water. Mineralized water continuously drains from high pressure side of membrane.
Sulfate (SO_4)	Has bitter taste and may have laxative is effect and is usually corrosive.	
Nitrate (NO_3)	May or may not have unusual odors associated with it. More than 45 mg/L may cause methemoglobinemia in infants but not adults.	
Most dissolved minerals		
Pathogenic Bacteria	Usually no symptoms. High concentrations may cause unusual odor or color.	1. Chemical--chlorine is automatically fed into the water system at a concentration sufficient to kill the bacteria after a contact time of about 30 minutes. Other chemicals that may be used in a similar fashion are iodine and potassium permanganate. Chemical disinfecting may impart a taste to the water, but the taste can be removed by passing the water through an activated charcoal filter if desired. 2. Ultra-violet light--the water passes within 1 to inches of a quartz mercury-vapor lamp, which emits ultraviolet light. Depending on light intensity, the time of exposure required for disinfection may be as little as 1 second. This method produces no disagreeable odors or tastes. 3. Filtration--many bacteria can be removed by filtration through a bed of fine sand.
Acid (low pH)	May taste sour, corrodes iron and copper pipes and metal plumbing fixtures.	1. Limestone treatment--water percolates through a tank of limestone chips which dissolve and neutralize acid. Tanks require slow flow rate and must be back-flushed periodically to clean and loosen chips. Fe and Mn in water can form coating on chips and render them ineffective. 2. Chemical injection--concentrated soda ash of caustic soda (household lye) is automatically injected by chemical feeder. The alkaline solution neutralizes the acid.

5.0 SUMMARY AND CONCLUSIONS

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Flooded Underground Coal Mines Are Potential Sources of Water for Public Supply

Flooded underground coal mines in northern Upshur County near Buckhannon store enough water to supply the current water needs of the Buckhannon water system for about 9 months; the water is slightly acidic, moderately hard, and will require removal of hydrogen sulfide, iron, and manganese. Dewatering the flooded mines may cause further deterioration of water quality.

Northern Upshur County is growing in population with a corresponding increase in the demand for water. For example, current water use in Buckhannon exceeds the 1930 drought flow of its water source, the Buckhannon River, by as much as 1.46 Mgal/d. Thus, the city may need an auxiliary water supply during a severe drought.

Currently, more than 70 communities in West Virginia use mine water as a source of supply, and mine water is a potential source of water for Buckhannon. There are three underground flooded coal mines at Adrian, near Buckhannon, that store about 1,170 acre-feet of water. This stored water, plus an additional recharge of 500 gal/min of ground water into the mine, is enough water to supply current needs of Buckhannon (1,500 gal/min) for 265 days, and projected needs (2,500 gal/min) of the city, for the year 2018, for about 135 days. If droughts comparable to those in 1953 and 1930 occurred in the year 2018, the water in the mines would last for 190 and 140 days when pumped at 1,900 gal/min and 2,400 gal/min, respectively, to augment the surface-water source. Table 5.0-1 summarizes the quantity and quality of water generally available from flooded and freely draining mines in northern Upshur County.

Most communities treat mine water before using it for a public supply. Some communities only chlorinate the water; however, there commonly are problems associated with excessive concentrations of iron, manganese, sulfate, hydrogen sulfide, and acidity. These excessive concentrations are generally removed or reduced by some treatment process in order to make the water entirely satisfactory for household use. Therefore, some communities use aeration, chlorination, and (or) soda ash to oxidize and precipitate common problem constituents such as iron and manganese before filtration through zeolite filters. One community in Pennsylvania uses a reverse-osmosis unit that removes 90 percent or more of all dissolved minerals. Water from the flooded mines near Buckhannon is moderately hard, slightly acidic, and generally contains excessive amounts of iron, manganese, and hydrogen sulfide. The water from the flooded mines is chemically similar to the water from nearby wells, and chemically similar to the water from mines used by some other communities.

Several factors may affect the quantity and quality of water available from flooded mines. For example, active coal mining or subsidence may rupture coal barriers (acting as bulkheads to retain water) and cause turbidity or leakage from flooded mines. Subsidence fractures could rupture old gas or oil well casings and allow gas, oil, or salty water to enter flooded mines, and allow contaminants from the surface to percolate into the flooded mines more easily. Pumpage from the mine may cause rooffalls or subsidence, turbidity, or changes in water quality due to the introduction of air or water into the mines as water levels are lowered in the mine.

Table 5.0-1.--Summary of quantity and quality of water available from coal mines in northern Upshur County

	Mine name	Coal bed name	Volume of water stored	General water quantity	General water quality
Flooded underground mines	Buckhannon River mine	Upper Freeport	920 acre-ft	1. Adequate water stored to supply current needs of 1500 gal/min for 265 days. 2. Adequate water stored to supply projected needs of 2500 gal/min of the year 2018 for 135 days. 3. Once the mine has been dewatered the expected infiltration rate is about 500 gal/min. (About 0.7 gal/min/acre.) 4. Well(s) have to tap the lowest parts of the mine in order to dewater the mine and obtain the 500 gal/min that would infiltrate into the dewatered mine.	Specific conductance range 320-630 µmhos/cm at 25°C pH range 4.5-7.3 units Sulfate range 71-130 mg/L Iron range 0-6.7 mg/L Manganese range 0.04-0.65 mg/L Water flowing out of flooded mine entrance is generally less mineralized than water from wells tapping low areas in the mine. Water from flooded mines generally contains fewer dissolved minerals than water from freely-draining unflooded mines. The range in concentration of minerals in water from flooded underground mines is less than that from the freely-draining unflooded mines. However, heavy pumping from flooded mines may cause a fluctuation in dissolved-mineral content similar to that in water from freely draining unflooded mines.
	Miller-Todd mine	Upper Freeport	155 acre-ft (overflow is 200 gal/min)		
	Minear mine	Upper Freeport	95 acre-ft (overflow is 25 gal/min)		
Freely-draining unflooded underground mines	Mine 101 and 105	Redstone and Pittsburgh	little storage (flow is 240 gal/min)	1. Only a few low areas in mines are flooded and store water. 2. Total flow from three of the larger mines near Century ranged from about 480 to 830 gal/min.	Specific conductance range 1050-1300 µmhos/cm at 25°C pH range 6.6-8.5 units Sulfate range 282-824 mg/L Iron range 0.2-4.3 mg/L Manganese range 0.05-0.71 mg/L
	Mine 101 (west portal)	Redstone	little storage (flow is 40 gal/min)		
	Mine 101 (north drain)	Redstone	little storage (flows from 250-500 gal/min)		
	All mines west of Buckhannon near Red Rock	Redstone	little storage (each flows less than 36 gal/min)		

6.0 SELECTED REFERENCES

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