GROUND-WATER STUDY 1

by

Celso Puente

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1.0 ABSTRACT

Geology and the Occurrence of Coal

The Blue Creek area in Tuscaloosa County lies in the Warrior coal field. The basin is principally underlain by nearly flat-lying sedimentary rocks of the Pottsville Formation of Pennsylvanian age. The Pottsville consists chiefly of alternating beds of sandstone, conglomerate, siltstone, and shale, with interbeds of coal and associated underclays. In the Warrior field, the productive part of the Pottsville Formation contains seven coal groups that may contain from 2 to 10 coal beds each. The Utley Coal Group, which consists of three coal horizons within a vertical interval of 20 to 250 feet, crops out in the basin. Two coal beds within the basal horizon are mined in the study area.

Hydrology and Hydrologic Monitoring

Water percolating downward into the Pottsville Formation, the only source of ground water available to wells in the area, is stored primarily in and transmitted through openings along joints, fractures, and bedding planes. Relatively impermeable clay beds underlying the two coal beds mined in the study area from the base of two perched water zones or aquifers above the regional ground-water system. Because of the occurrence of perched water tables and the irregular lensing character of the aquifers, the configuration of the water table over a large area is generally unpredictable. Areal correlations are possible only within short distances. The aquifers are not a source of large quantities of water. Transmissivity and storage coefficients computed using the slug test method at selected wells ranged from about 1 to 450 ft^2/d and from 1 to 10^{-2} to 1 x 10^{-5}, respectively. Premining quality of ground water is extremely variable but generally suitable for most domestic uses. Surface water draining the mined area is very mineralized. The hydrologic monitoring network consists of inventoried and drilled observation wells with continuous water-level recorders, streamflow-gaging stations with continuous water-quality monitors, and precipitation gages.

Mining Methods and Other Stresses on the Aquifer System

Surface coal mining in the general area started in early 1976 and entailed the stripping of two coal beds within the Utley Coal Group. About 250 acres were surface-mined in the basin. The aquifer systems do not have any significant withdrawal demands other than for domestic purposes.

Probable Hydrologic Impacts and Post-Mining Hydrologic Network

The intersection of the surface mine with water-bearing openings or aquifers resulted in draining of the openings and a corresponding decline in ground-water levels adjacent to the mine. Placement of mine spoils in the mined area has created aquifers of the spoils that store and transmit more water than the original aquifers. The spoils aquifers are a source of recharge to underlying aquifers and a source of base flow to Blue Creek. The low flows of Blue Creek exceed those prior to mining. The quality of water in streams draining the mined area and in wells downdip from the mine has been significantly altered. Mineralization of surface drainage leaving the basin has increased by a factor of 27 since mining started. A post-mining hydrologic surveillance network needed to determine the extent, magnitude, rate, and duration of hydrologic change caused by surface mining could consist of ground-water monitoring wells, streamflow gaging stations, and precipitation gages.

2.0 GEOLOGIC SETTING

AREA UNDERLAIN BY COAL-BEARING ROCKS OF PENNSYLVANIAN AGE

The Blue Creek area is underlain by nearly flat-lying rocks of the Pottsville Formation. The strata generally strike northeastward and dip southeastward about 22 feet per mile.

The basin is underlain by nearly flat-lying rocks of the Pottsville Formation of Pennsylvanian age and the Coker Formation of Cretaceous age (fig. 2.0-1). The two formations are sedimentary in origin but contrast greatly; the Pottsville is consolidated, and the Coker is unconsolidated.

Regionally, the strata in the Pottsville Formation strike northeastward and dip southeastward about 5 to 25 ft/mi except where disrupted by faulting and folding (2)*. The unconformable contact between the Pottsville and the overlying Coker Formation strikes northwestward and dips southwestward from 32 to 37 ft/mi (5). The dip and strike of strata in the Coker Formation parallel those of the contact. In the study area, the Pottsville strata generally strike and dip southeast about 22 ft/mi (fig. 2.0-2). The Coker Formation, which dips southwestward about 32 ft/mi, crops out in less than 5 percent of the area, capping the highest hills and ridges along the basin divides.

The Pottsville Formation consists chiefly of alternating beds of gray sandstone, conglomerate, siltstone, and shale, with interbeds of coal and associated underclays. Shale is the dominant rock type. The thickness of the Pottsville in the area is about 4,000 feet. The Coker Formation consists of fine- to coarse-grained sand and gravelly sand separated in places by lenticular beds of gray, sandy clay.

Several intervals in the Pottsville Formation contain beds of coal and underclay. In the Warrior field, the productive part of the formation contains seven coal units that may contain 2 to 10 beds each (2). These units are, in ascending order, the Black Creek, Mary Lee, Pratt, Cobb, Guin, Utley, and Brookwood. Coal beds cropping out in the basin are in the Utley unit.

The Utley Coal unit in the general area consists principally of three coal horizons (7). This unit consists of two to six coal beds within a vertical interval of 20 to 150 feet (2). Sandstone, generally interbedded with some shale and siltstone and ranging in thickness from 40 to 50 feet, composes the lowermost part of the Utley Coal unit. One or more of the coal beds separated by shale partings may be present in each horizon. The basal coal horizon generally contains the most persistent and thickest coal beds. The second horizon is 10 to 20 feet above the basal horizon and the third horizon 30 to 40 feet above the basal horizon. The two upper horizons are inconsistent in that either or both may be absent in a given area. Two coal beds probably within the basal horizon of the Utley unit, a 24-inch seam and a lower 18-inch seam (fig. 2.0-3), are mined in the general area.

* Numbers in parentheses refer to items in the bibliography.

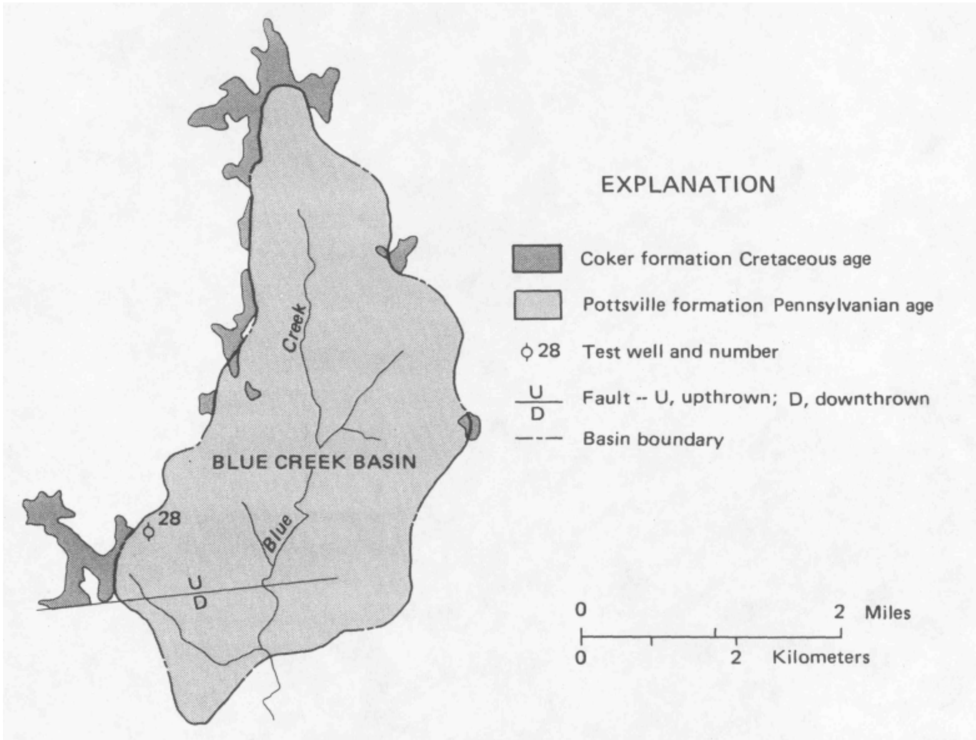


Figure 2.0-1. Geology of general area. (Modified from Puente and others, 1980.)

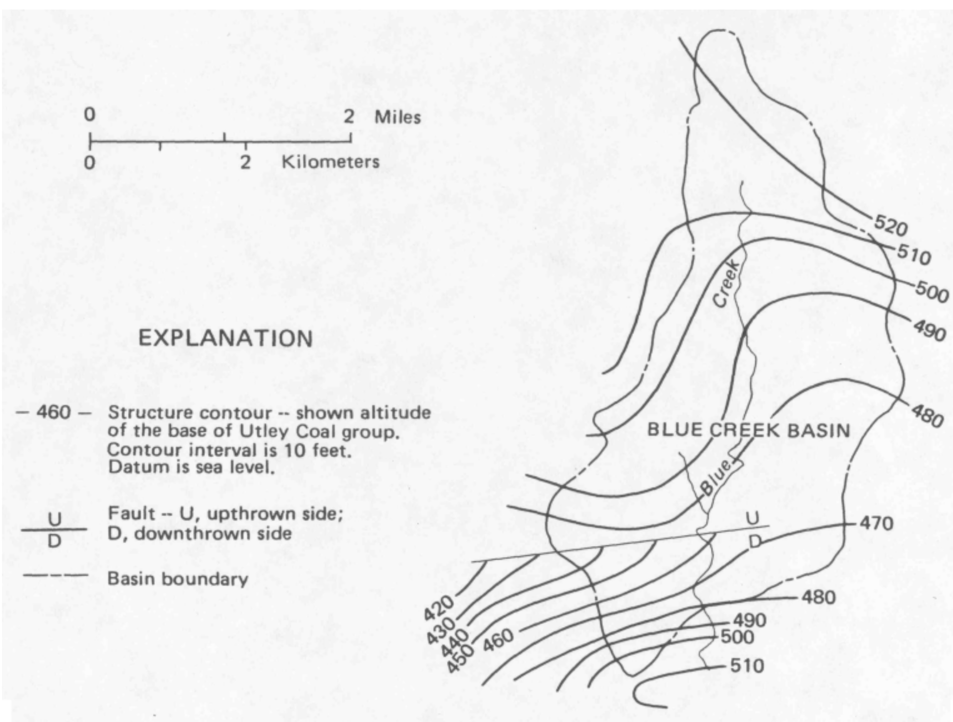


Figure 2.0-2. Contour map showing altitude and configuration of the base of the Utley coal unit. (Structure modified from Semmes, 1929.)

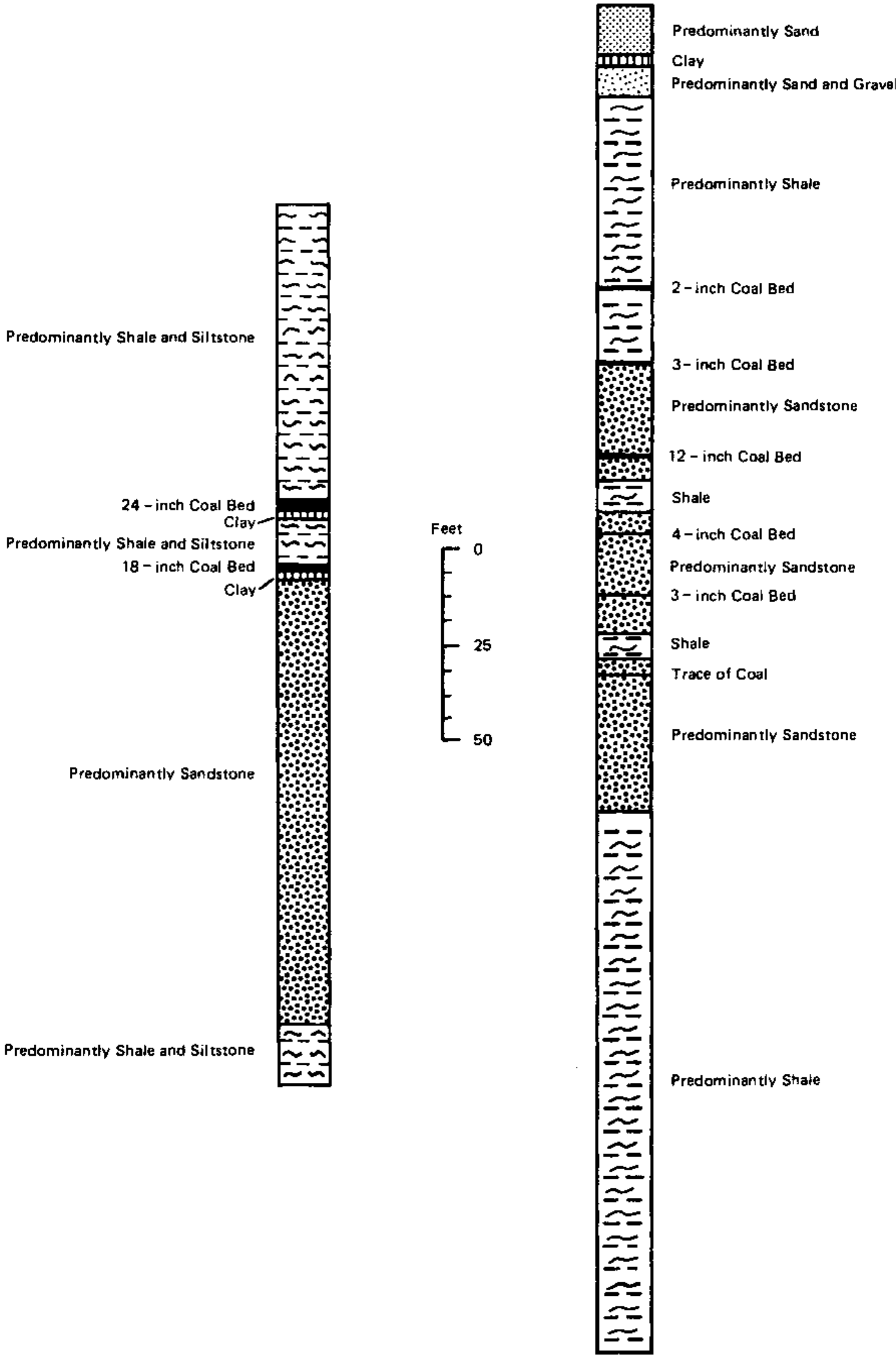


Figure 2.0-3.— Stratigraphic columns for selected test wells in the vicinity of the mine-permit area (see fig. 3.2-1 for test-well locations).

3.0 HYDROLOGIC SETTING

3.1 CLIMATE

AREA CHARACTERIZED BY WARM AND HUMID WEATHER

The average annual temperature is about 63˚F. The average annual precipitation is about 56 inches per year.

The Blue Creek area has a subtropical climate characterized by warm and humid weather. According to National Weather Service records (3), the average annual temperature is about 63˚F. January is generally the coldest month with an average temperature of 44˚F and July, the hottest with an average temperature of 80˚F. The length of the growing season averages 225 days, with the frost-free season occurring from late March through early November.

The average annual precipitation, almost all in the form of rain, is about 56 inches. Snowfall is very light and infrequent. About 55 percent of the average annual precipitation occurs from December through April. The wettest month is March and the driest is October; drought seldom occurs. Monthly precipitation data at sites near the study area are shown in figure 3.1-1. Summer rains, produced by convective storms, are more intense but briefer and smaller in area than rains associated with winter and early spring frontal storm systems.

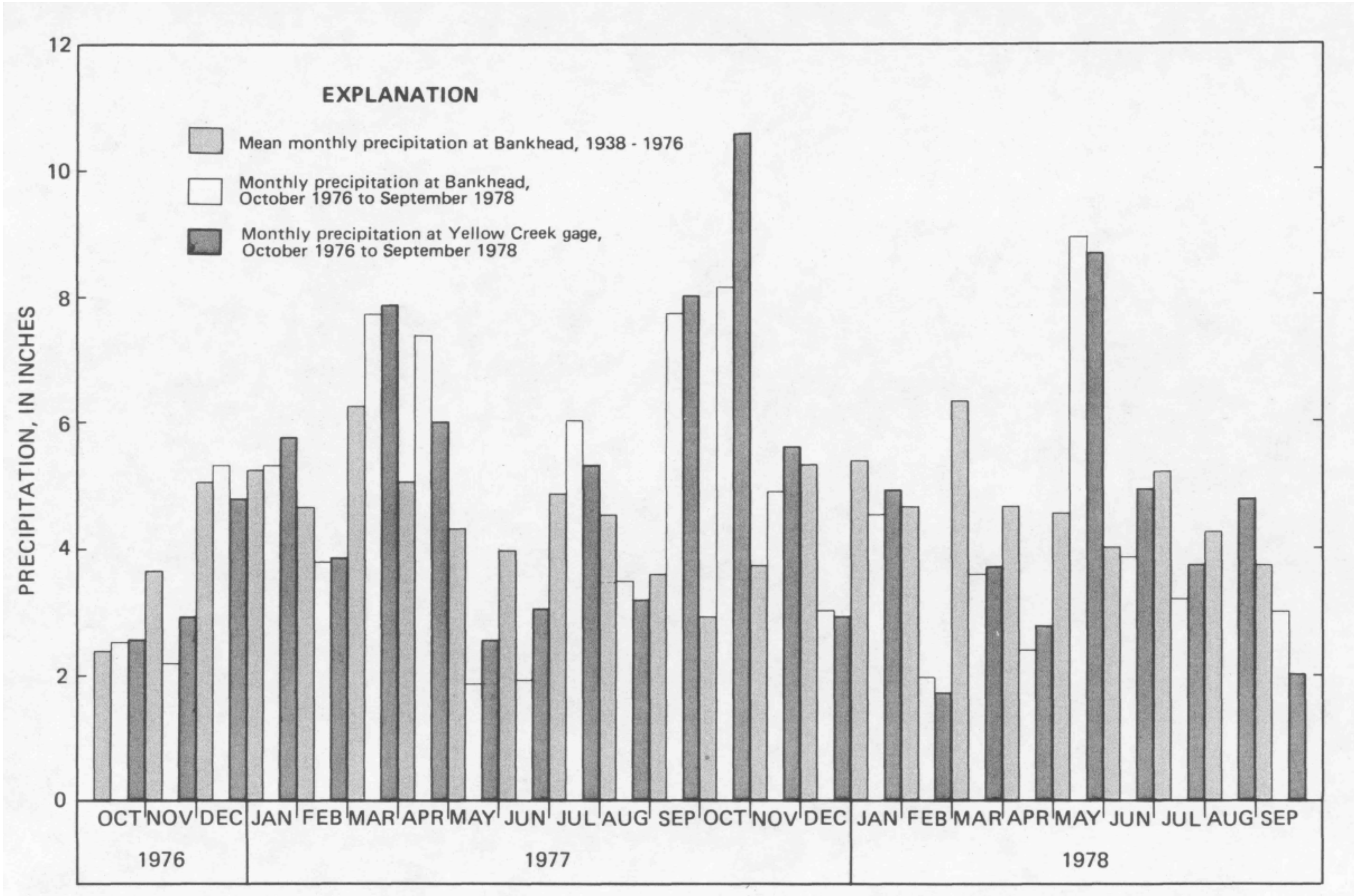


Figure 3.1-1.— Monthly precipitation near the mine permit area. (Modified from Puente and others, 1980.)

3.0 HYDROLOGIC SETTING

3.2 OCCURRENCE AND MOVEMENT OF GROUND WATER

FRACTURED BEDROCK IS THE MAJOR SOURCE OF GROUND WATER

Water is principally stored in and transmitted through openings along joints, fractures, and bedding planes. Well yields are small, reflecting limited ground-water storage and little aquifer permeability.

The principal source of water in the Blue Creek area is from precipitation. Water percolating downward into the Pottsville Formation, the only source of ground water available to wells in the area, is primarily stored in and transmitted through openings along joints, fractures, and bedding planes.

Water in the Pottsville Formation occurs under water-table, artesian, and perched conditions. Aquifers overlain by relatively permeable rocks that permit precipitation to enter directly by percolation are under water-table conditions. Aquifers lying between relatively impermeable rocks, where the water is confined under pressure, are under artesian conditions. Perched water-table conditions occur where rocks of little permeability (unfractured sandstone, soft shale and underclay associated with coal) impede the downward movement of water to the regional water table. Under perched conditions, one or more water tables may exist above the local stream level. All conditions may be present at different levels in the same area.

The occurrence and movement of ground water in the Blue Creek basin is based on geology, well inventory, and information obtained from a test-drilling program in the area. The locations of wells inventoried and test wells drilled are shown in figure 3.2-1. Detailed information for these wells is given in tables 3.2-1 and 3.2-2. Additional data-collection sites to define streamflow (site 3) and rainfall (site A) also are shown in figure 3.2-1. The surface-water site in Blue Creek has been instrumented, since 1976, for continuous monitoring of streamflow, water quality (temperature and specific conductance) and daily suspended sediment.

A schematic diagram illustrating the occurrence and movement of water in the Pottsville underlying the general area is shown in figure 3.2-2. Relatively impermeable clay beds underlying the two coal beds mined in the general area form the base of two perched water zones or aquifers above the regional ground-water system. Recharge to the upper aquifer is from precipitation percolating into the formation. The lower aquifer is recharged by leakage through the overlying clay and precipitation where the clay is absent.

The water in interconnected openings moves downward from the upper aquifers and (or) laterally to the outcrop of the aquifer on hillsides where the water discharges as seeps or springs and becomes a part of streamflow. The seeps or springs most commonly discharge during periods of greatest rainfall, but in most instances, cease to flow in a relatively short time if precipitation is absent.

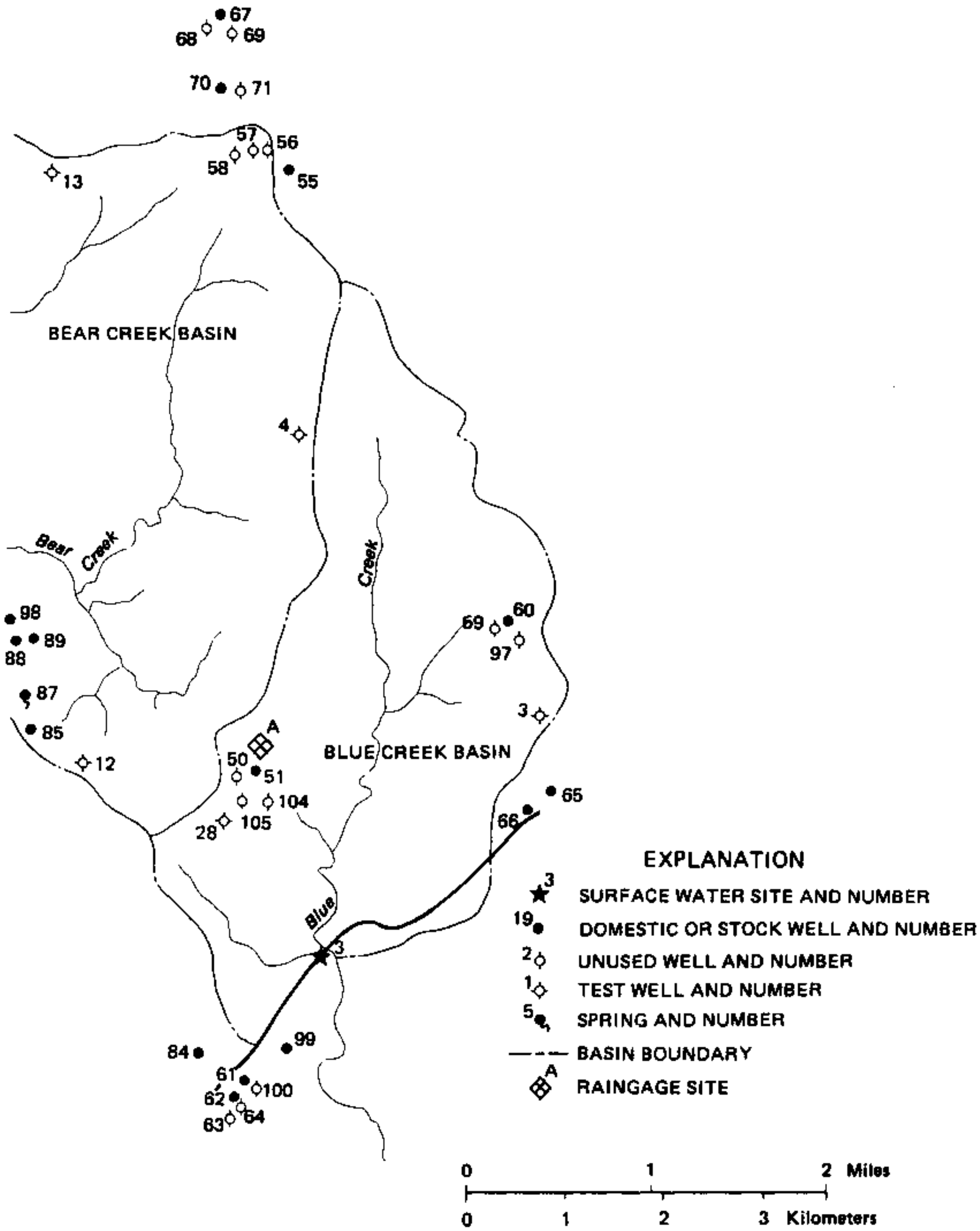


Figure 3.2-1.— Location of wells and springs in the general area. (Modified from Puente and others, 1980.)

Table 3.2-1 — Records of wells and springs in and near Blue Creek basin completed in Pottsville Formation. (Well numbers correspond with those on figure 3.2-1.)

Depth: Reported depths given in feet.

Water-bearing unit: Ppv Pottsville Formation.

Altitude: Altitude determined by aneroid barometer. In feet above sea level.

Water level: Reported levels given in feet; measured levels given in feet and tenths. Use of water: D domestic; N none.

Field determination: ˚C degrees Celsius

						Water level			Field determinations			
Field well number	Owner	Year com-pleted	Depth of well below land surface (feet)	Diame-ter of well (inches)	Altitude of land surface (feet)	Below land surface (feet)	Date of measure ment	Use of water	Date	Specific conduct -ance (micro-mhos at 25 ˚C)	PH	Tem perat ure (˚C)
50	C. Zeanah	—	61	4	551	25.9	4-21-77	N	4-21-77	265	6.9	17.0
51	C. Zeanah	—	118	4	551	49.2	4-21-77	D	4-21-77	225	6.9	17.5
55	D. Bar net	—	52	6	646	41.7	5-31-77	D	5-31-77	350	6.9	21.0
56	Irvin Realty	—	152	6	656	69.2	5-31-77	N	5-31-77	138	—	17.5
57	Irvin Realty	—	152	6	656	82	5-31-77	N	5-31-77	200	6.7	17.0
58	Irvin Realty	1975	32	36	640	15.1	5-31-77	N	5-31-77	33	—	19.5
59	L. Bagwell	1950	62	6	574	26.2	6- 1-77	D	6- 1-77	255	6.8	18.5
60	L. Bagwell	1928	39	6	574	26.2	6- 1-77	N	——	—	—	—
61	E. Long	—	89	6	492	45.9	6- 1-77	D	6- 1-77	340	7.3	19.5
62	J. Bagwell	—	92	6	492	45.9	6- 1-77	D	6- 1-77	315	6.8	18.0
63	J. Bagwell	1970	328	6	466	72.2	6- 1-77	N	——	—	—	—
64	J. Bagwell	—	210	6	492	33.1	6- 1-77	N	——	—	—	—
65	J. Bolton	—	98	6	525	73.7	6- 1-77	D	6- 1-77	415	7.1	18.5
66	J. Bolton	—	56	6	525	35.1	6- 1-77	D	6- 1-77	422	6.9	20.0
67	J. Baker	—	285	6	653	116.8	6- 2-77	D	6- 2-77	340	7.5	17.5
68	J. Baker	1917	98	6	660	86	6- 6-77	N	6- 6-77	270	7.3	17.5
69	J. Baker	1917	98	6	446	85.3	6- 6-77	N	——	—	—	—
70	W. Baker	—	187	4	660	—	6- 6-77	D	——	—	—	—
71	W. Baker	—	112	6	660	66.3	6- 6-77	N	6- 6-77	126	7.0	17.5
84	J. Smith	—	34	6	499	13.1	6- 9-77	D	6- 9-77	125	6.7	16.5
85	W. Griffin	—	102	6	584	60.0	6- 9-77	D	6- 9-77	112	6.6	19.0
87	J. Neal	—	Spring	—	516	—	6- 9-77	D	6- 9-77	42	6.7	17.0
88	T. Davis	1976	103	6	505	246	6- 9-77	D	6- 9-77	65	6.5	17.0
89	T. Davis	1976	96	6	502	37.7	6- 9-77	D	6- 9-77	75	6.4	17.5
97	L. Bagwell	—	98	6	443	23.0	7-19-77	N	7-19-77	215	6.6	24.0
98	T. Davis	—	Spring	—	476	—	7-27-77	D	——	—	—	—
99	E. Long	—	77	6	495	11.8	8- 8-77	N	——	—	—	—
100	E. Long	—	36	6	492	27.2	8- 9-77	N	——	—	—	—
104	C. Zennah	1977	27	6	535	10.5	8-17-77	N	——	—	—	—
105	C. Zennah	1977	38	6	564	21.0	8-l 7-77	M	——	—	—	—

Table 3.2-2 — Records of test wells drilled in and near Blue Creek basin completed in the Pottsville Formation. (Well numbers correspond with those in figure 3.2-1) Altitude: Altitude determined by aneroid barometer.

Well number	Date completed	Depth of well below land surface (feet)	Diameter of well (inches)	Depth of casing below land surface (feet)	Altitude of land surface (feet)	Water level: Below land surface (feet)	Water level: Date of measurement
T -3	6-25-78	290	6	29	633	106.0	6-25-78
T -4	6-20-78	47	6	25	640	89.9	6-25-78
T -12	7-26-78	267	6	49	584	—	—
T -13	7-27-78	166	6	40	581	69.6	10-13-78
T -28	9-15-78	248	6	26	607	181.4	9-20-78

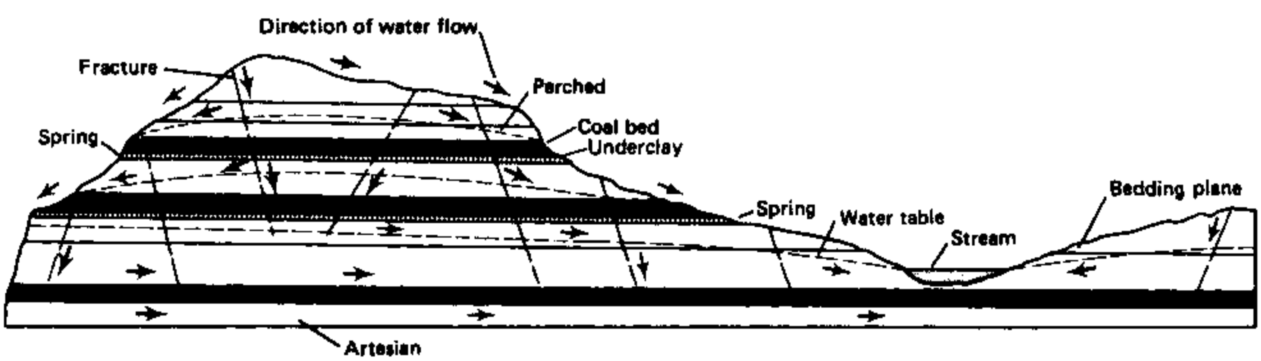


Figure 3.2-2. Schematic diagram showing general occurrence and movement of ground water in the Pottsville Formation underlying the area.

The configuration of the water table in the area generally conforms to the overlying topography. Water levels generally range from 20 to 150 feet below land surface on hilltops, from 5 to 30 feet in lowland areas, and generally between the two extremes on the hillsides. Ground-water movement in the Blue Creek area is generally to the southeast. Water levels typically fluctuate in response to seasonal variations in precipitation and evapotranspiration (fig. 3.2-3). Water levels are usually highest from November through April and lowest from May through October. The decline in water levels during the latter period is due to lack of precipitation and the increase in evapotranspiration during the growing season. Water levels generally rise during the fall when evapotranspiration decreases and precipitation increases. The water-level fluctuations in test well 4 (fig. 3.2-3) are fairly representative of fluctuations in other wells tapping the Pottsville in the general area. Because of the complex occurrence of perched water tables and the irregular lensing characteristics of the aquifers, water levels in wells completed in the Pottsville over a large area are generally unpredictable. Areal correlations are possible only within short distances (4).

The Pottsville Formation is generally not a source of large quantities of water, but does provide enough for domestic use in the Blue Creek area. The yields of wells completed in the formation average less than 5 gal/min; the greatest yields generally are from wells in lowland areas. Yields seldom exceed 25 gal/min (6). The small yields of wells and springs from the Pottsville reflect limited aquifer storage and little permeability.

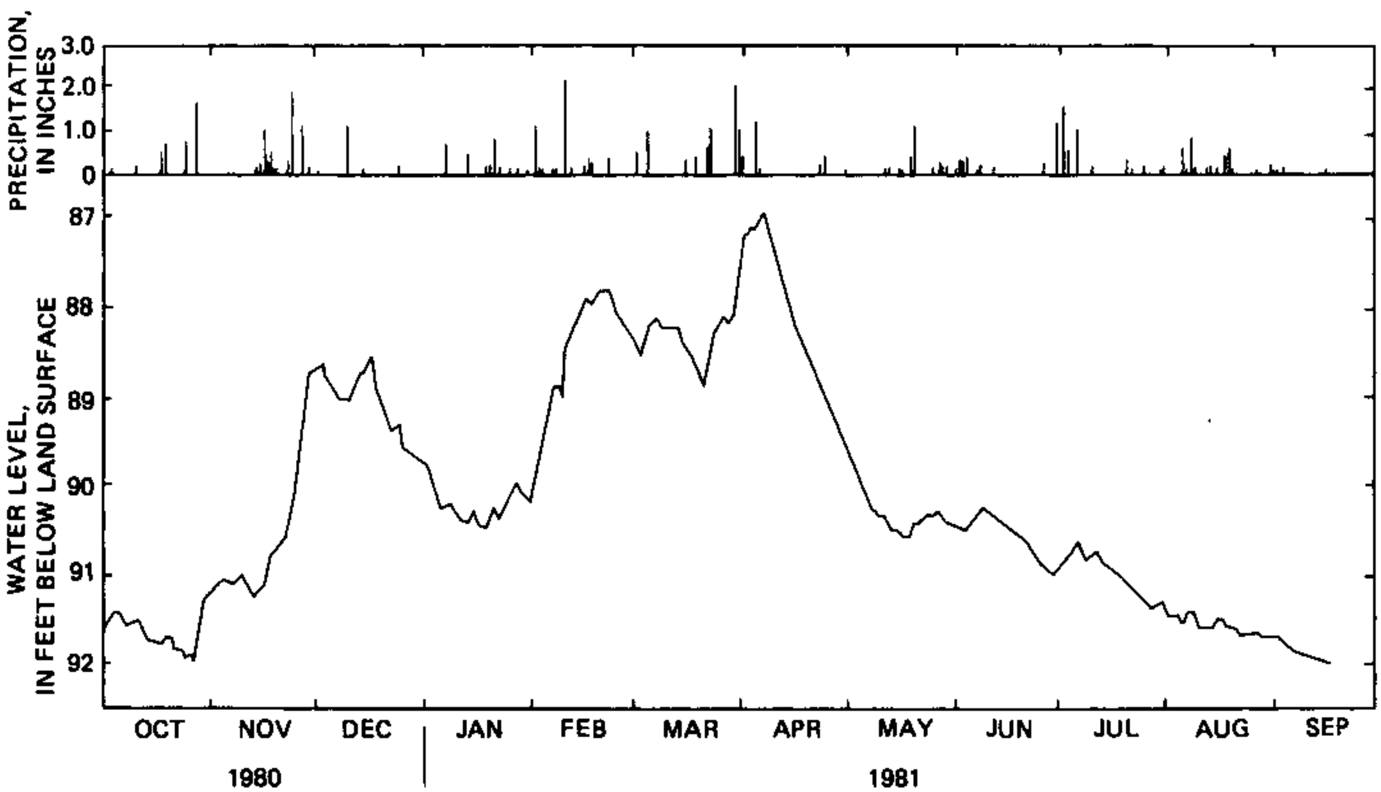


Figure 3.2-3.— Precipitation at site A and daily mean water levels at test well A.

Estimates of the aquifer's ability to store water (storativity) and transmit water (transmissivity) were computed by the "slug test" method (1). This method was used because of the small yields from wells in the area. The more widely used aquifer-test procedures for determining transmissivity and storativity were not practical because of the very small discharge rates required to avoid pumping the wells dry in a very short period of time. Transmissivity (T) and storativity (S) determined for selected wells in the area, ranged from less than one to 450 ft^2/d and from 0.01 to 0.00001, respectively.

The slug test consisted of suddenly dropping a weighted float, having a known volume ($V = 0.195\ ft^3$), into a well and periodically measuring the subsequent water level in the well. Figure 3.2-4 illustrates the initial rise in water level and the well features measured in applying the method. This method makes use of the equations:

$$H/H_o = Tt/r_c^2 \qquad\qquad S = (r_c^2/r_s^2)\ \alpha$$

where H_o = the rise in water level at time of the injection = $V/\ \pi\ r_c^2$
H = the residual rise in the water-table sometime ‘t’ after the weighted float is added,
r = radius of open hole, r = radius of well casing,
$\alpha = (r_s^2/r_c^2)S$.

Assumptions made in the analyses were (1) the wells fully penetrate a confined aquifer of small transmissivity, and (2) $r_c = r_s$.

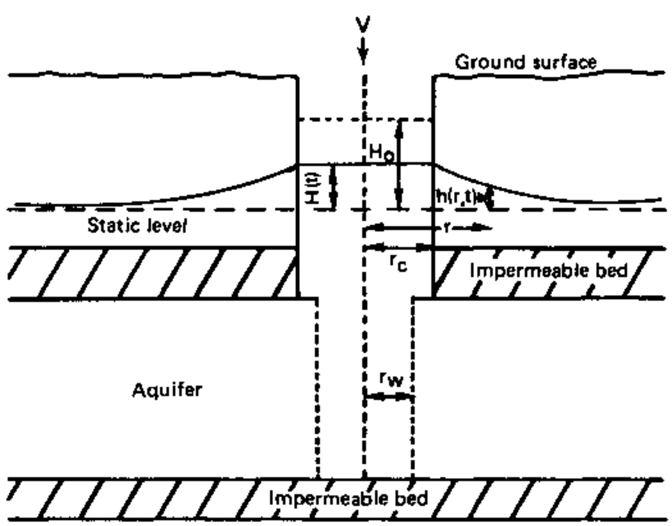


Figure 3.2-4.— Cross section through a well in which a known volume is instantaneously injected.
(Modified from Reed, 1980, fig. 9.1.)

The slug test data for test well 4 are listed in table 3.2-3 and a semi-log plot of H/H_o versus 't' is shown in figure 3.2-5. The field curve (dots representing field-test data) in figure 3.2-4 was superimposed on several type curves (fig. 3.2-6) prepared from data given in table 3.2-4, to achieve a best fit between the field curve and the type curves. Corresponding values of 't' (from the field curve) and Tt/r_c^2 (from the type curve) were read at an arbitrarily selected 'match' point on the horizontal scale. Computations for T and S are shown in figure 3.2-5.

The computed transmissivity and storativity represent only local conditions near the tested well and cannot be extrapolated to other areas in the basin. Because the storativity values depend upon the shapes of the type curves, which differ only slightly when α differs by an order of magnitude, the determinations of storativity are considered to be of limited reliability (1).

Table 3.2-3 – Recovery of water level in test well 4 near Blue Creek basin after instantaneous addition of weighted float.

t (seconds)	Head below land surface datum (feet)	H (feet)	$\frac{H}{H_o}$
-1	91.95	—	—
0	90.96	0.99 (H_o)	1.00
5	91.05	.90	.91
20	91.14	.81	.82
32	91.21	.74	.75
45	91.27	.68	.69
52	91.32	.63	.64
70	91.37	.58	.59
105	91.48	.47	.47
115	91.51	.44	.44
135	91.56	.39	.39
150	91.59	.36	.36
197	91.67	.28	.28
213	91.70	.25	.25
234	91.72	.23	.23
253	91.74	.21	.21
275	91.76	.19	.19
300	91.78	.17	.17
385	91.84	.11	.11
470	91.87	.08	.08
590	91.88	.07	.07
735	91.90	.05	.05

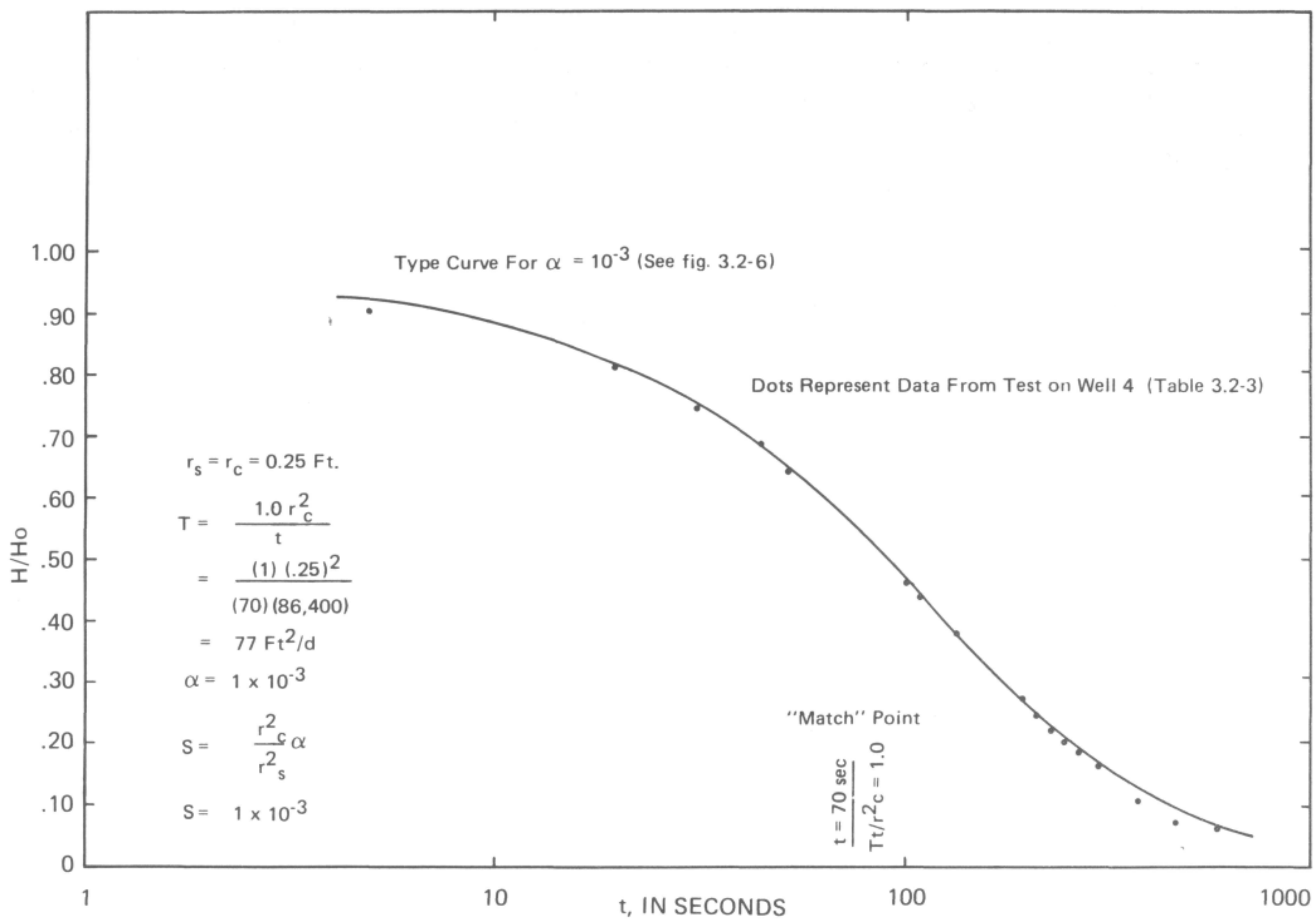


Figure 3.2-5.— Plot of data from slug test at test well 4, September 16, 1980.

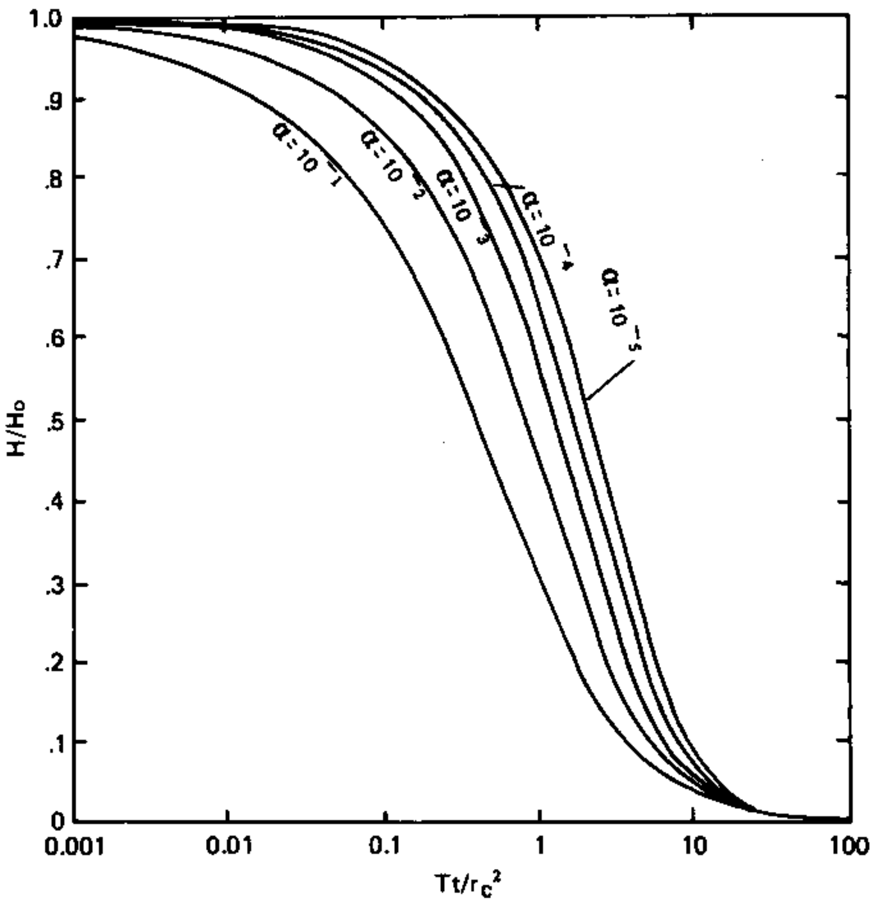


Figure 3.2-6.— Type curves for instantaneous charge in well of finite diameter, for H/HO versus Tt/r_c^2 for five values of α.
(From Lohman, 1972, pi. 2; and Cooper and others,1967, table 1.)

Table 3.2-4. – Values of H/H_O for a well of finite diameter (1)

$\frac{Tt}{r_c^2}$	H/H_O				
	α =0.01	α=0.001	α =0.0001	α=0.00001	α=0.000001
0.0010	0.9771	0.9920	0.9969	0.9985	0.9992
.00215	.9658	.9876	.9949	.9974	.9985
.00464	.9490	.9807	.9914	.9954	.9970
.010	.9238	.9693	.9853	.9915	.9942
.0215	.8860	.9505	.9744	.9841	.9888
.0464	.8293	.9187	.9545	.9701	.9781
.10	.7460	.8655	.9183	.9434	.9572
.215	.6289	.7782	.8538	.8935	.9167
.464	.4782	.6436	.7436	.8031	.8410
1.0	.3117	.4598	.5729	.6520	.7080
2.15	.1665	.2597	.3543	.4364	.5038
4.64	.07415	.1086	.1554	.2082	.2620
7.00	.04625	.06204	.08519	.1161	.1521
10.0	.03065	.03780	.04821	.06355	.08378
14.0	.02092	.02414	.02844	.03492	.04426
21.5	.01297	.01414	.01545	.01723	.01999
30.0	.009070	.009615	.01016	.01083	.01169
46.4	.005711	.005919	.006111	.006319	.006554
70.0	.003722	.003809	.003884	.003962	.004046
100.	.002577	.002618	.002653	.002688	.002725
215.	.001179	.001187	.001194	.001201	.001208

3.3 QUALITY OF GROUND WATER

CHEMICAL QUALITY OF GROUND WATER IS VARIABLE, BUT GENERALLY SUITABLE FOR MOST USES

Water from deep wells tends to be more highly mineralized than water from shallow wells. Water from wells located on hilltops is usually less mineralized than water from wells in valleys.

The quality of ground water in the area is extremely variable, but is generally suitable for most uses. Water-quality data from wells completed in the Pottsville Formation in Blue Creek basin (fig. 3.2-1) and other nearby areas are summarized in table 3.3-1.

Water from deep wells tends to be more mineralized and alkaline than water from shallow wells or springs. Water from wells located on hilltops is usually less mineralized than water from wells in valleys. Important reasons for this variability are (1) the amount of time ground water has been in contact with the rocks and (2) the pattern of ground-water circulation as it moves from points of recharge to areas of discharge. Acidic rain-water in the area remains acidic as it percolates through decaying organic matter on the land surface and through generally acidic soil. This acidic water dissolves and leaches minerals as it moves downward through the rocks towards the discharge areas. The end results are that ground water at shallow depth in recharge areas (hilltops and hillsides) is commonly acidic with little dissolved minerals, and water at greater depth or in the discharge areas (valleys) is commonly alkaline with much dissolved minerals.

Generally, water in the Pottsville Formation is a calcium-magnesium-bicarbonate type. The specific conductance of water in aquifers underlying ridges and at depths less than 50 feet was generally less than 150 umho/cm (micromhos per centimeter at 25˚ Celsius). The specific conductance of water in aquifers in lowland areas or underlying ridges at depths exceeding 50 feet ranged from 150 to about 550 umho/cm. Dissolved-solids concentrations ranged from 50 to 360 mg/L (milligrams per liter), and pH ranged from 5.6 to 8.0 with a median of 6.9. In all but the shallowest wells, the water was moderately hard to very hard and had bicarbonate concentrations ranging from 4 to 280 mg/L.

Locally, dissolved iron and manganese concentrations exceeded 300 and 50 ug/L (micrograms per liter), respectively. Trace-element concentrations, other than those for iron and manganese, were well below maximum concentrations established by the U.S. Environmental Protection Agency (1977).

Table 3.3-1 – Summary of selected chemical and physical properties of water from the Pottsville Formation (6).
[results in milligrams per liter, except as indicated; ug/L, micrograms per liter]

Property	Number of analyses	Mean	Range
Specific conductance (micromhos at 25 ˚C)	37	287	59-555
Temperature (˚C)	34	18.2	16.0-22
pH (units)	38	6.9	5.6-8.0
Color (units) 2/	27	17	5-100
Hardness as $CaCO_3$	34	117	19-220
Noncarbonate hardness	37	5	0-59
Total Acidity as H+	18	0	0
Total Acidity as $CaCO_3$	26	0	0
Calcium (Ca)	37	26.8	2.5-46
Magnesium (Mg)	37	11.6	2.8-26
Sodium (Na)	37	16.5	2.7-63
Percent Sodium (%)	37	25	8-63
Sodium absorption ratio (SAR)	37	.7	.2-2.8
Potassium (K)	37	2.6	.6-7.0
Bicarbonate (HCO_3)	37	159	4-280
Carbon Dioxide (CO_2)	30	54	3.1-217
Carbonate (CO_3)	37	0	0
Sulfate (SO_4)	34	12	.2-59
Chloride (Cl)	33	3.4	.8-14
Fluoride (F)	32	.1	.0-.3
Silica (SiO_2)	31	20	.1-34
Dissolved Solids (calc.)	21	175	50-360
Total Nitrate (N)	23	.25	.01-2.4
Total Nitrate (NO_3)	18	1.7	.00-5.0
Total Nitrite (N)	15	.00	.00
Total Organic Nitrogen (N)	19	.33	.00-1.1
Total Kjeldahl Nitrogen	21	.42	.00-1.3
Phosphate (PO_4)	5	1.2	.09-2.9
Phosphorus (P)	27	.23	.00-. 96
Arsenic (AS) (ug/L)	28	1	0-4
Boron (B) (ug/L)	5	0	0
Cadmium (Cd) (ug/L)	37	1	0-5
Chromium (Cr) (ug/L)	30	3	0-10
Cobalt (Co) (ug/L)	36	1	0-9
Copper (Cu) (ug/L)	32	3	0-17
Iron (Fe) (ug/L)	34	762	0-11 , 000
Lead (Pb) (ug/L)	37	3	0-65
Lithium (Li) (ug/L)	37	16	0-40
Manganese (Mn) (ug/L)	37	139	0-1,100
Mercury (Hg) (ug/L)	35	.4	.0-.6
Selenium (Se) (ug/L)	27	.1	0-2
Strontium (Sr) (ug/L)	35	278	0-1.000
Zinc (Zn) (ug/L)	37	84	0-370

1/ - Median Value
2/ - Platinum - Cobalt

4.0 HYDROLOGIC IMPACTS OF SURFACE MINING

4.1 INTRODUCTION OF IMPACTS

HYDROLOGIC ENVIRONMENT ALTERED BY SURFACE COAL MINING

The effects of surface coal mining on the ground-water hydrology include the decline of ground-water levels, increased ground-water discharge, and degradation of ground-water quality.

The hydrologic environment of Blue Creek basin has been significantly altered by surface coal mining. The impacts of mining on the ground-water system are identified as decline of ground-water levels, augmentation of base flow, and degradation of water quality. The impacts resulted from (1) the removal of parts of aquifers during mining, (2) modification of ground-water movement and storage by removal of overburden and replacement of overburden with spoils, and (3) changes in ground-water quality caused by leachate from mine spoils areas and water impoundments (6).

Surface coal mining in the general area started in early 1976 and entailed the surface mining of two coal beds within the Utley Coal Group. The progression of mining, based on aerial photography flown in 1977-79 and the location of selected wells, springs, and streamflow-gaging sites in Blue Creek and Bear Creek basins are shown in figure 4.1-1. About 250 acres were surface mined in the basin during this period.

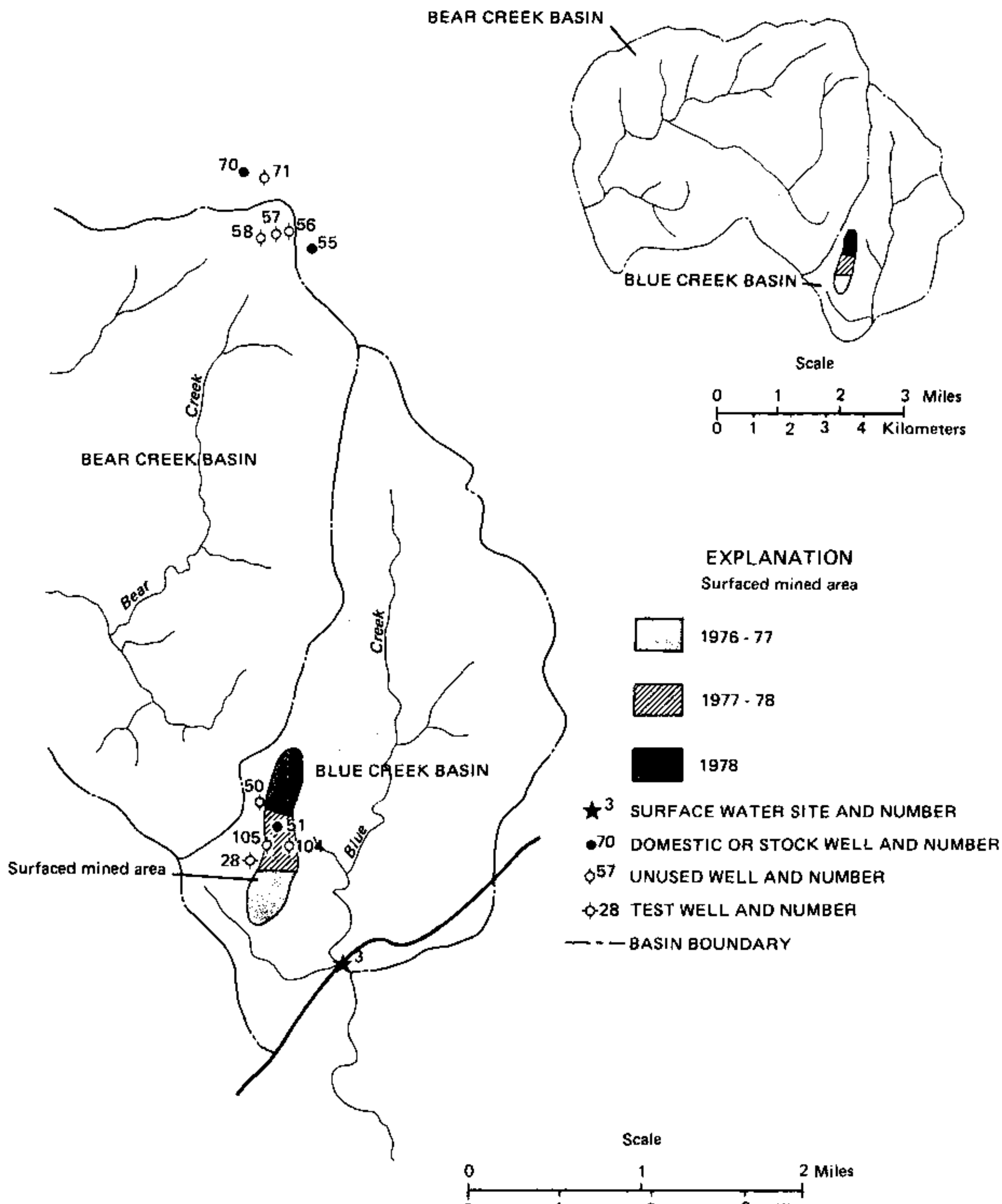


Figure 4.1-1.— Location of selected wells, springs, surface-water sites, and surface-mined areas. (Modified from Puente and others, 1980.)

4.0 HYDROLOGIC IMPACTS OF SURFACE MINING

4.2 DECLINE OF GROUND-WATER LEVELS

DEWATERING OF SURFACE MINES RESULTS IN WATER-LEVEL DECLINES

Penetration of the surface mining operation into aquifers causes the draining of aquifers.

The intersection of the surface mine with water-bearing openings of aquifers resulted in draining of the openings and a corresponding decline in water levels in aquifers adjacent to the mine area. A schematic diagram illustrating the effect of surface mining on the local hydrology is shown in figure 4.2-1. Springs issuing from exposed coal beds in the high walls of the mine indicated that water-bearing zones (fractures) adjacent to and updip from the mine excavations were being dewatered. The resulting decline in water levels is illustrated by the hydrograph for well 50 (fig. 4.2-2). The hydrograph shows a downward trend in 1978. In March 1978, mining progressed northward to within 0.1 mile of the observation well. Since then, the water level in the well has declined periodically to the approximate altitude of the lowest adjacent coal bed mined.

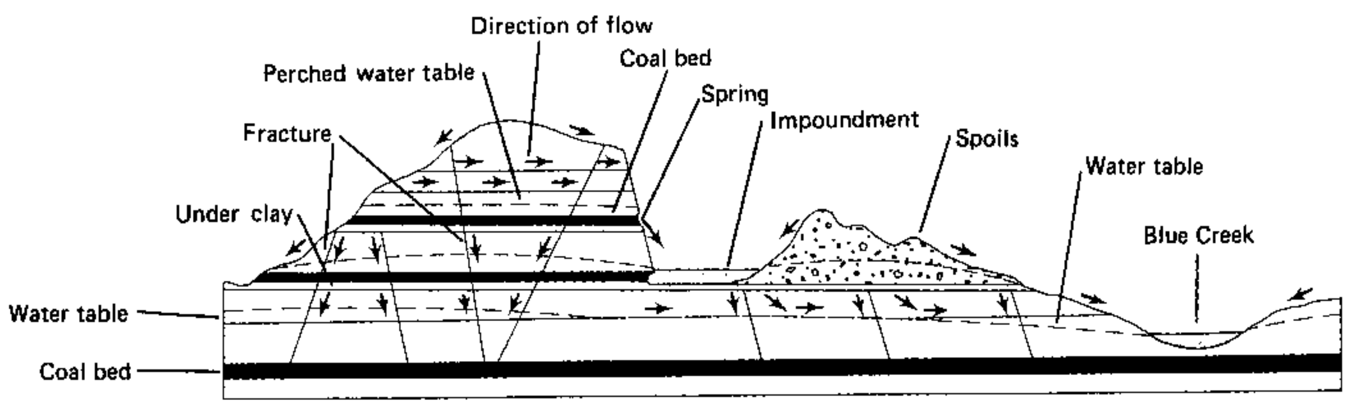
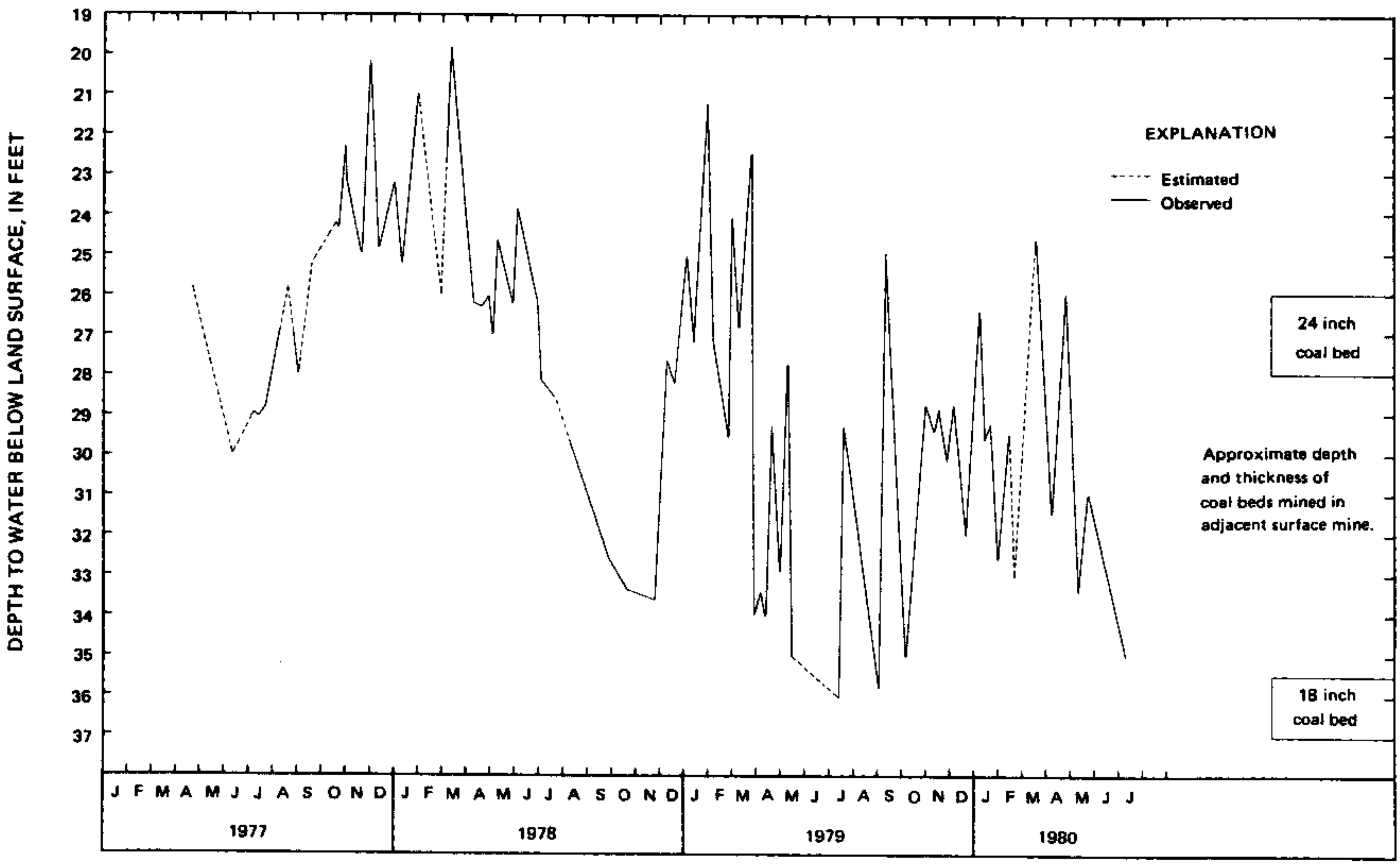


Figure 4.2-1.— Schematic diagram illustrating the effect of surface mining on the hydrology of a mined area in Blue Creek Basin.



4.2-2. — Water levels in observation well 50 in Blue Creek basin.

4.0 HYDROLOGIC IMPACTS OF SURFACE MINING

4.3 AUGMENTATION OF BASE FLOW

FORMATION OF MINE SPOILS CREATES A NEW AQUIFER

The water in the mine spoils within the mined area is a source of base flow to Blue Creek increasing low flow.

Placement of spoils material in the mined area has created spoils aquifers that generally rest on underclay and shale (fig. 4.2-1). The perched water in the spoil is a source of base flow to Blue Creek. In Blue Creek basin, the spoil aquifers store and transmit more water than the original aquifers. Streamflow records for sites 1 (Bear Creek, draining an undisturbed basin) and 3 (Blue Creek, draining a disturbed basin) (fig. 4.1-1) during the water years 1979-80 indicate a substantial increase in base flow at site 3. The increase is reflected by the shape of the annual flow-duration curves for sites 1 and 3 shown in figure 4.3-1. A steep flow-duration curve denotes variable streamflow derived mainly from direct surface runoff, whereas a flatter curve, particularly in the low-flow part, indicates streamflow derived from surface and(or) ground-water storage. The gradual divergence in low-flow parts of the annual flow-duration curves (fig. 4.3-1) indicates an increase in the basin storage that provides larger and more prolonged base flow at site 3. The increase in low flow results from seeps and springs that issue from the spoil areas and impoundments in the mined areas. The storage of water in the mined areas in Blue Creek basin is expected to increase as mining progresses and may result in low flows significantly exceeding those prior to mining.

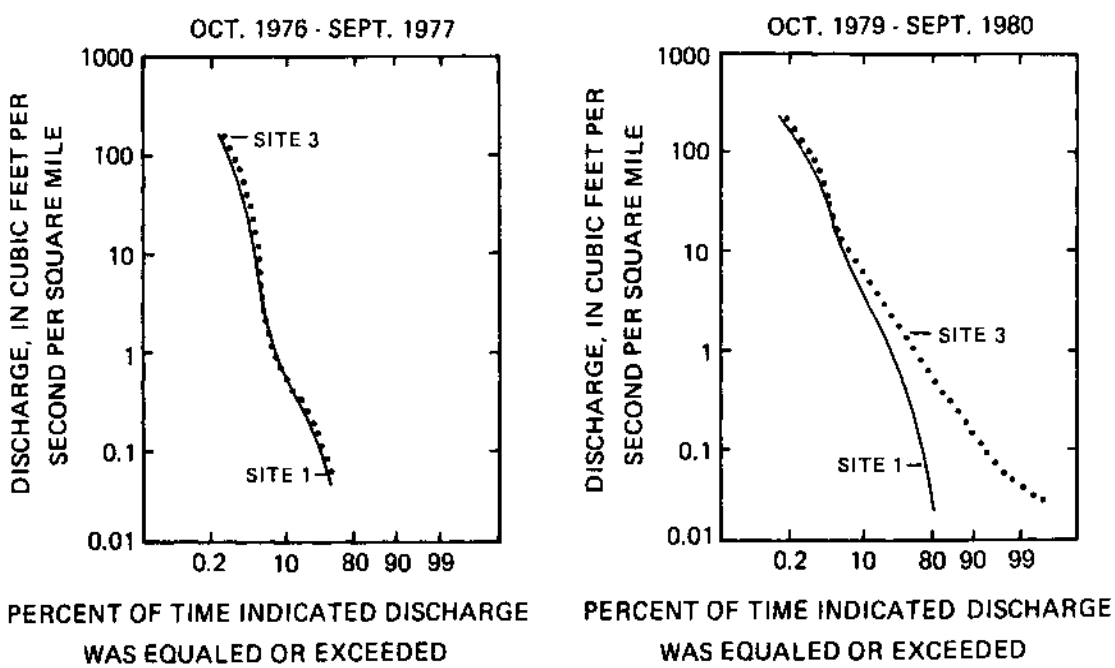


Figure 4.3-1. — Annual flow-duration curves for sites 1 and 3. (Modified from Puente and Newton, 1982.)

4.4 DEGRADATION OF GROUND-WATER QUALITY

GROUND WATER NEAR AND DOWNDIP OF MINE INCREASED IN MINERALIZATION COMPARED TO UNMINED AREAS

Ground-water quality in mined areas has greater dissolved solids, hardness, and concentrations of sulfate, iron, manganese, strontium, and zinc than in unmined areas.

Ground-water-quality degradation was detected in a well near the mined area. Water in well 104 (fig. 4.1-1) near and downdip from the mine, has a specific conductance of 1,180 umho/cm, a sulfate concentration of 338 mg/L, calcium and magnesium concentrations of 110 and 66 mg/L respectively, and a dissolved solids concentration of 864 mg/L. The quality of water in well 104 differed significantly from that in well 28 located updip from the mine (table 4.4-1) and from that in other Pottsville Formation wells in nearby unmined areas (table 3.3-1). As indicated in table 4.4-1, the water in well 104 and site 3 is characterized by much greater hardness, noncarbonate hardness, dissolved solids, and concentrations of sulfate, iron, manganese, strontium, and zinc than water in well 28. The pH of water in wells 28 and 104, and at site 3 was similar. Acid production in the mined area was probably neutralized by calcareous minerals such as siderite, calcite, and ankerite that are commonly present in spoil in the area.

The rate and magnitude of water mineralization in well 104 are probably similar to those of mine drainage sustaining base flow (less than 1.0 ft^3/s) at site 3 on Blue Creek (fig. 4.1-1). As shown in figure 4.4-1, the specific conductance at site 3 increased from 58 umho/cm in November 1976 to 1,550 umho/cm in July 1980. The 1980 value represents a 27-fold increase in mineralization of drainage leaving Blue Creek basin.

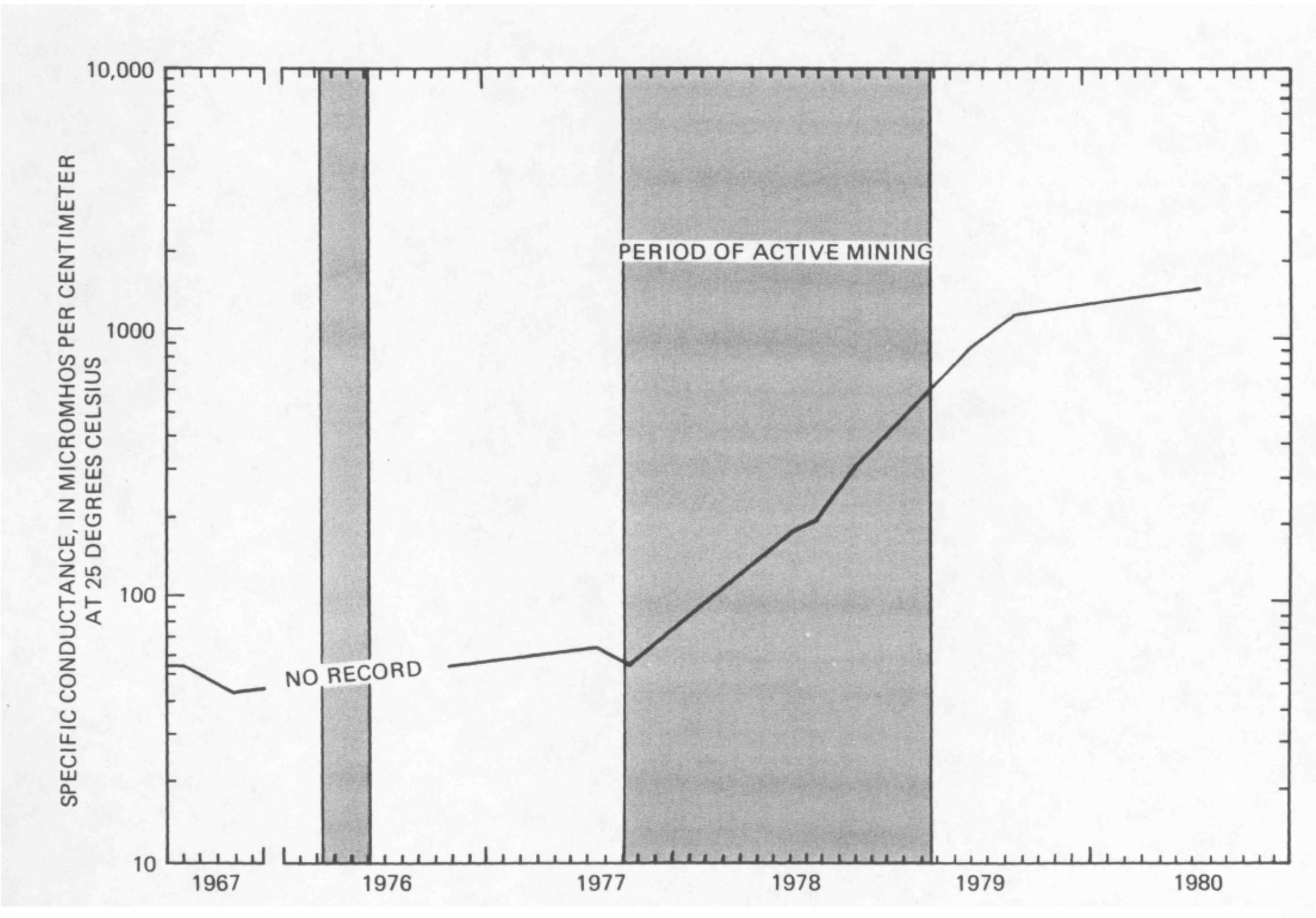


Figure 4.4-1.— Specific conductance in Blue Creek (site 3) during low flow. (Shaded areas indicate time periods of active mining.) (Modified from Harkins and others, 1980.)

Table 4.4-1.– Quality of ground water from observation wells 28 and 104, and Blue Creek (site 3).
[results in milligrams per liter, except as indicated; ug/L, micrograms per liter]

SITE ——————	WELL 28	WELL 104	SITE 3
DATE SAMPLED ——————	12/2/79	5/13/80	7/24/80
Specific conductance micromhos at 25˚ C)	415	1180	1550
Temperature (˚C)	17.0	16.0	30
pH (units)	6.6	6.9	7.9
Color (units):[2]/	35	0	2
Hardness as $CaCO_3$	210	550	830
Noncarbonate Hardness	0	260	730
Total Acidity as H^+	0	—	—
Total Acidity as $CaCO_3$	0	—	—
Calcium (Ca)	46	110	150
Magnesium (Mg)	22	66	110
Sodium (Na)	14	57	15
Percent Sodium (%)	20	18	4
Sodium adsorption ratio (SAR)	0.4	1.1	—
Potassium (K)	4.4	3.8	5.6
Bicarbonate (HCO_3)	260	360	130
Carbon Dioxide (CO_2)	105	71	2.5
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	8.3	338	860
Chloride (Cl)	3.6	11	2.2
Fluoride (F)	.1	0.2	0.2
Silica (SiO_2)	—	27	6.8
Dissolved solids (calc.)	227	864	1210
Total Nitrate (N)	1.1	.70	.05
Total Nitrate (NO_3)	4.7	3.1	.22
Total Nitrite (N)	—	—	0
Total Organic Nitrogen (N)	.78	.38	.01
Total Kjeldahl Nitrogen	.88	.53	—
Phosphate (PO_4)	2.0	0	.03
Phosphorus (P)	.66	0	.01
Arsenic (AS) (ug/L)	1	1	0
Boron (B) (ug/L)	0	40	7
Cadmium (Cd) (ug/L)	4	0	5
Chromium (Cr) (ug/L)	10	10	10
Cobalt (Co) (ug/L)	1	0	0
Copper (Cu) (ug/L)	4	5	0
Iron (Fe) (ug/L)	0	60	10
Lead (Pb) (ug/L)	0	1	0
Lithiim (Li) (ug/L)	20	80	9
Manganese (Mn) (ug/L)	100	460	140
Mercury (Hg) (ug/L)	.1	.2	.1
Selenium (Se) (ug/L)	0	0	0
Strontium (Sr) (ug/L)	280	1200	520
Zinc (Zn) (ug/L)	270	620	3

[1]/ - Median Value
[2]/ - Platinum - Cobalt

5.0 POST-MINING HYDROLOGIC MONITORING

MONITORING PLAN COULD DETERMINE HYDROLOGIC CHANGES CAUSED BY SURFACE MINING

A monitoring plan consisting of ground-water monitoring wells, streamflow-gaging stations, and precipitation gages could be used to determine the extent, magnitude, rate, and duration of hydrologic impacts caused by surface mining.

Hydrologic impacts of surface mining previously identified in Blue Creek basin were decline of ground-water levels, augmentation of base flow, and degradation of water quality. Additional ground-water-monitoring wells and surface-water-sampling sites could be used to:

(1) Better define the local geology, and the location, depth and extent of aquifer systems in the area,

(2) Determine the basin ground-water budget (recharge - discharge + change in ground-water storage),

(3) Delineate the lateral and vertical areal extent of water-quality degradation and the gradation in concentration away from the mined area, and

(4) Determine the rate and direction of movement of ground water.

The proposed observation wells, which would supplement the existing surveillance network, would be sited along the perimeter of the mined area and would be constructed so that only water from a selected aquifer can enter each well (fig. 5.0-1). This arrangement would enable observation of water-level fluctuations and water quality in specific aquifers that may be affected by mining. Land-surface altitudes at all observation-well sites and points from which water levels are measured would be referenced to a stable benchmark reference datum in a nearby offsite location.

Aquifer tests would be performed at all wells to determine the transmissivity and storage characteristics, and the hydrologic boundaries of the specific aquifer systems. The data are useful to determine flow velocities, which help in assessing the spread and dilution of degraded ground water from the mined area. Monthly water-level measurements at all observation wells in addition to the continuous water-level records at well 50 would better define the extent of water-level declines and modification of the direction of ground-water movement.

Water samples collected from wells upgradient from the mine (wells W1-W4) would define baseline ground-water quality, whereas samples from wells down-gradient from the mine (wells W6-W10) would measure changes in ground-water chemistry resulting from the mining operation. Additional wells could be added around the perimeter and at greater distance from the mine if ground-water-quality degradation is found to be extensive.

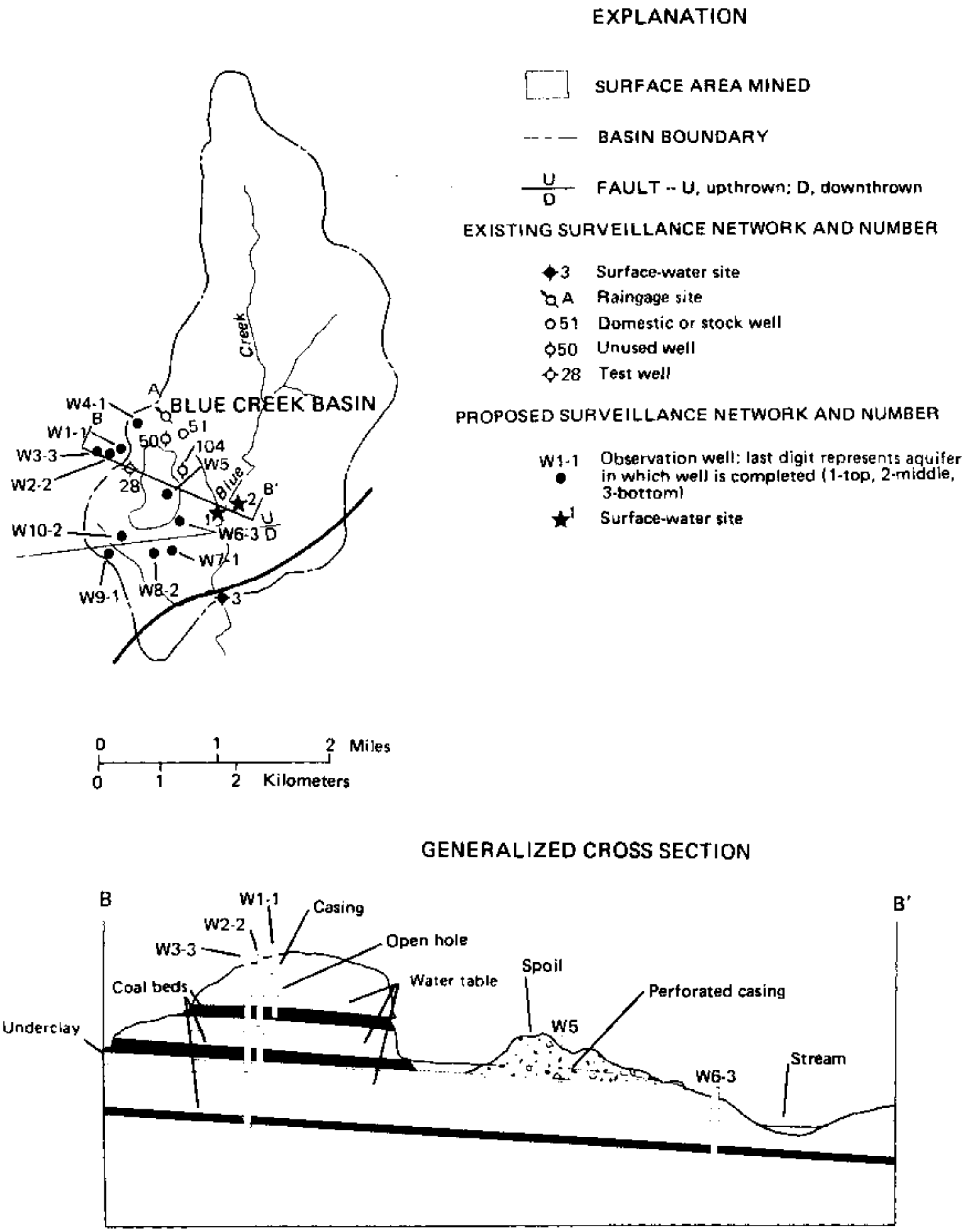


Figure 5.0-1.—Hypothetical hydrologic surveillance network for Blue Creek basin.

Samples would be collected quarterly to describe seasonal changes in ground-water quality in response to changes in seasonal recharge rates to the specific aquifers in the area. More frequent sampling may be needed if significant changes in water quality (sulfate, iron, manganese, pH, acidity, and dissolved solids) are detected. Water-quality constituents analyzed could be the same as those given in table 3.3-1.

Aquifer tests and continuous-recorder measurements of water levels would help define the ability of mine spoils to store and transmit water. Monthly water-quality sampling at observation well W5, completed in the spoils would help define the quality of its stored water, which is a source of recharge to underlying aquifers and a source of base flow to nearby streams.

Measurements of the quantity and quality of water at sites 1 and 3 would determine changes in streamflow regime and changes in chemistry of water leaving Blue Creek basin. Surface-water site 2 would define baseline water-quality conditions upstream from the mined area.

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