PLAN FOR HYDROLOGIC STUDY OF AN AREA TO BE SURFACE MINED FOR COAL IN NORTHWESTERN COLORADO

By Robert S. Williams, Jr., and Nancy E. Driver

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METRIC CONVERSION

Inch-pound units used in this report may be converted to metric SI (International System) units using the following conversion factors:

Multiply inch-pound unit	*By*	*To obtain metric unit*
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

A data-collection network was established in 1980 in northwestern Colorado in a drainage basin which may be surface mined for coal. This report describes the work plan set up to study the premining hydrology of this area near Steamboat Springs, Routt County, Colorado. The bedrock, alluvial, and surface-water systems, as well as the climatic inputs to these systems, are monitored for this study.

INTRODUCTION

Many recent studies of the hydrology of coal-mining areas were started after mining had begun. This sequence makes it difficult to determine man-induced impacts on the natural hydrology. In northwestern Colorado (fig. 1) an opportunity was available to begin a study within a watershed where surface-mining activities are expected to start in approximately 3 years. This time frame should permit evaluation of the hydrology of the natural system. The study was begun in 1980 by the U.S. Geological Survey in cooperation with the U.S. Bureau of Land Management. After mining begins, the disturbance from surface mining can be monitored and evaluated.

Purpose of Study

The purpose of the study is to define the hydrologic characteristics of overburden aquifers, coal aquifers, and underburden aquifers to determine the interaction of these aquifers with each other, the surface water, and alluvial aquifers that border and underlie the principal stream of the area.

Conceptual Model

The structural controls (fig. 2) in the study area show that the surficial bedrock aquifers are not subject to interbasin recharge. Consequently the hydrology of the study area is dependent only upon intrabasin interactions between bedrock aquifers, alluvial aquifers, and streamflow, all of which depend upon precipitation inputs.

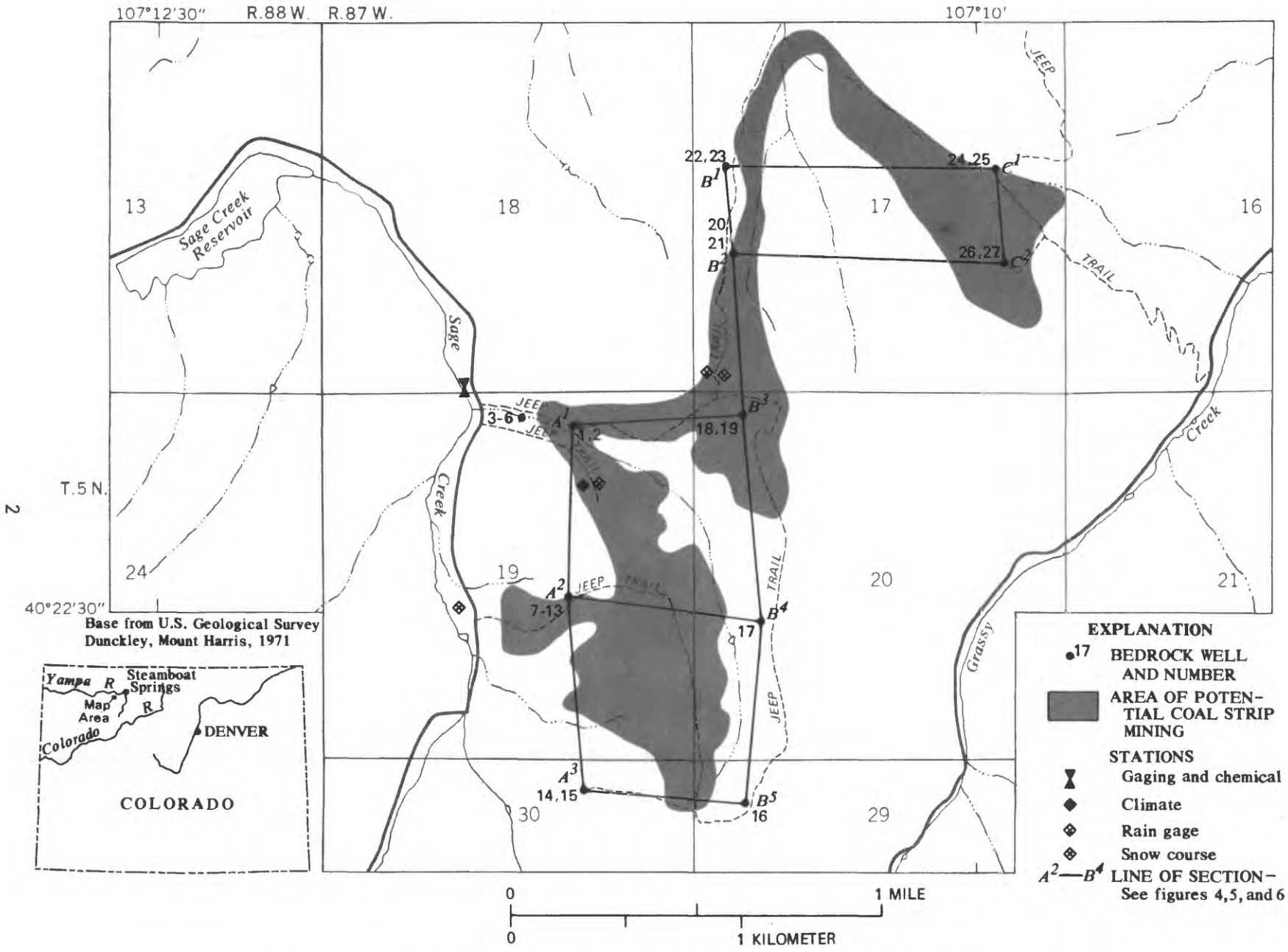

Figure 1.--Location of study area and sites at which hydrologic data are being collected.

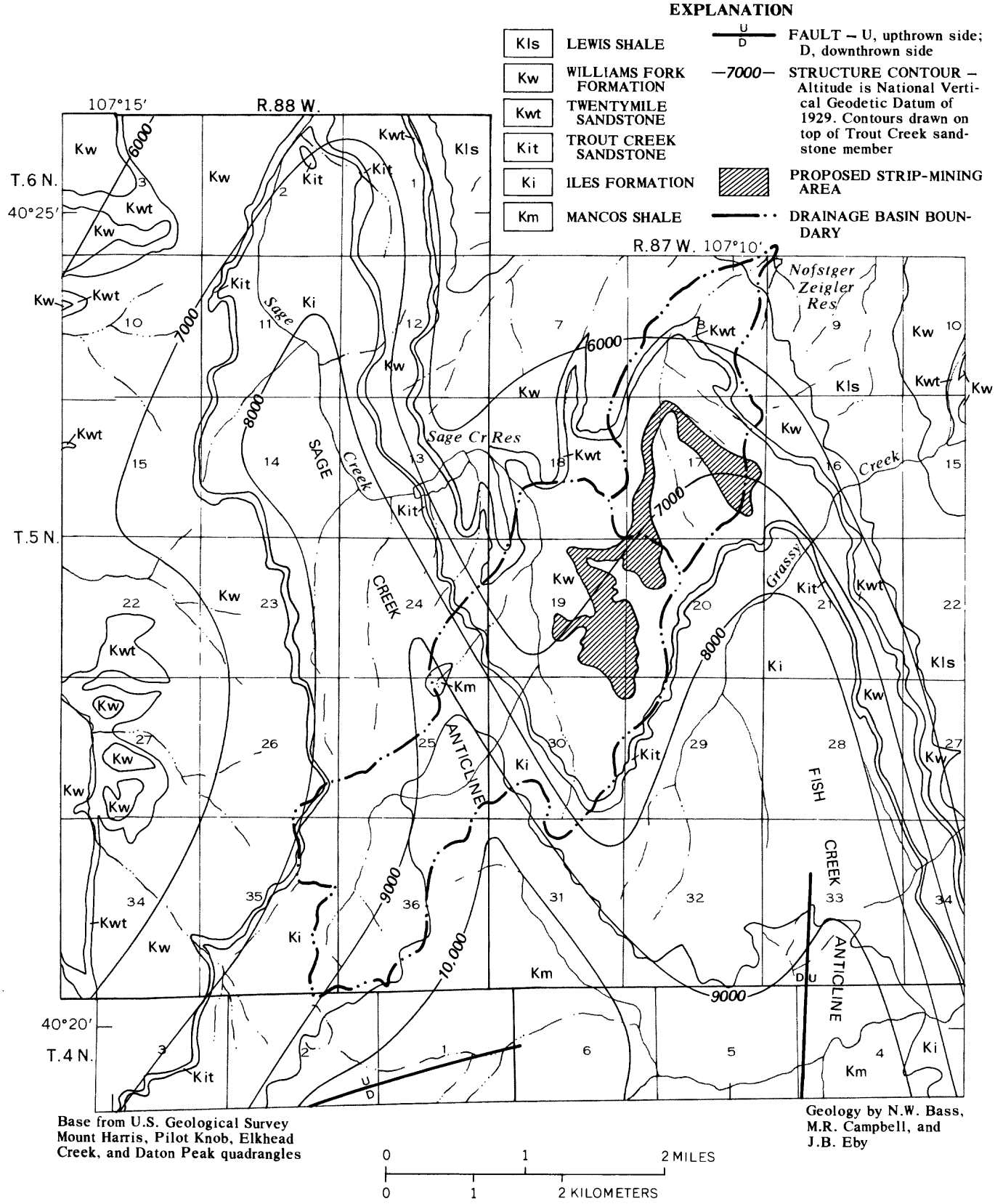

Figure 2.-- Geologic map of Sage Creek study area.

The study area is part of the zone of recharge for the basin. Water infiltrates through the soil and percolates to underlying strata. These strata, or bedrock aquifers, act as conduits to convey water downgradient. In some cases these bedrock aquifers may crop out, releasing the water as springs. The bedrock aquifers also may intersect alluvial fill and recharge the alluvial aquifer, or they may pass below the alluvial material but release water upwards through fractures.

Once the water has entered the alluvial aquifer it may contribute base flow to streams in the area. However, in other locations the stream may contribute to the alluvial aquifer, or there may be no interaction between the stream and aquifer.

Once mining begins the natural stratigraphic sequence is destroyed. The spoil material resulting from the mining eventually is replaced and recontoured. Due to considerable differences between the natural system and the disturbed system, there is a potential for differences in response between the two systems to similar hydrologic inputs. Therefore, the undisturbed hydrologic system must be defined in order to evaluate the effects that mining of coal may have on an area.

Description of Study Area

The study area is located 25 miles west and 8 miles south of Steamboat Springs, Colo., within the Sage Creek drainage, in sections 18, 19, 20, 24, 25, 26, 30, 35, and 36, and within an unnamed drainage in sections 8 and 17, R. 87 W, T. 5 N (fig. 3). The watersheds are shown on the U.S. Geological Survey topographic maps of the Mount Harris and Dunckley quadrangles. The Sage Creek watershed is approximately 5 square miles and ranges in elevation from 7,300 to 8,400 feet. The unnamed watershed joins Scotchman's Gulch in the northwest corner of section 33, R. 87 W, T. 6 N. This watershed is 2 square miles and ranges from 6,700 to 7,600 feet in elevation. The area which may actually be mined for coal (fig. 3) is approximately 2 square miles, has a westerly aspect, and ranges in elevation from 7,300 to 7,900 feet. The vegetation in the area is typified by sage brush, oak brush, and aspen. This semiarid area has an average yearly rainfall of 16 inches, and the average temperatures range from -9°C to 19°C (National Oceanic and Atmospheric Association, 1978). Sage Creek, the main drainage, flows to the north. Intermittent tributaries primarily enter Sage Creek from the east, draining across the area of potential coal mining.

The Sage Creek study area is underlain by the Williams Fork Formation, which is part of the Upper Cretaceous Mesaverde Group (Bass and others, 1955). The general geology of the area is depicted in figure 2. Structurally, the area lies between the Fish Creek anticline to the east and the Sage Creek anticline to the west. The bedding dips predominantly to the northwest. The Twentymile Sandstone bounds the study area on the north, and the Trout Creek Sandstone, a unit in the Iles Formation, forms the east, south, and west boundaries. The two major coal seams lying stratigraphically between the above-mentioned sandstones are the Lennox and Wadge. The Wadge coal seam is the most commonly mined coal in the Williams Fork Formation.

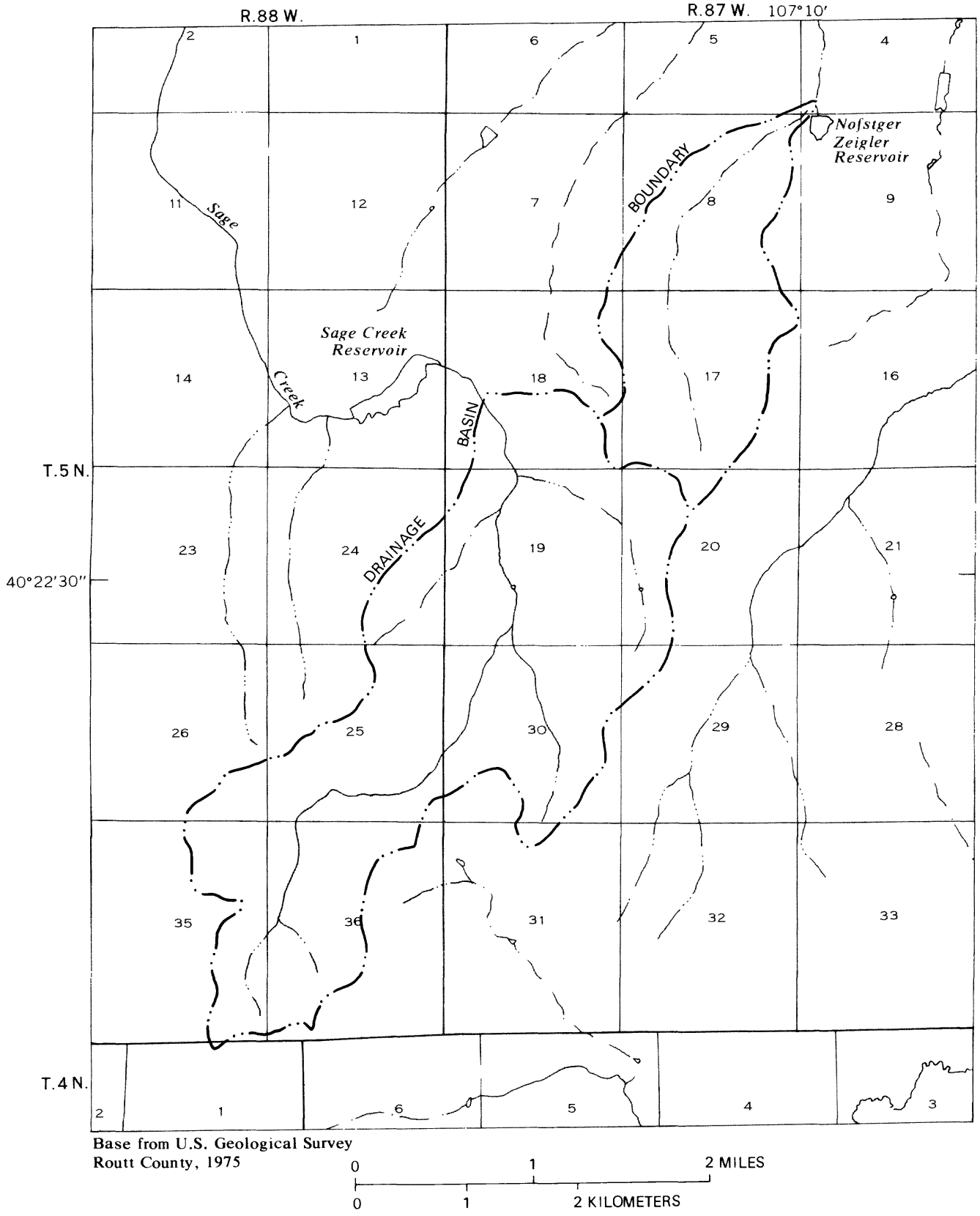

Figure 3.-- Drainage basins of Sage Creek study area.

DATA-COLLECTION NETWORK

Climate

A climate station was established at about 7,400 feet (fig. 1). Temperature, relative humidity, wind speed, and solar radiation are being recorded hourly at the site with a micrologger. A 30-day hygrothermograph, a maximum thermometer, and a minimum thermometer are also at the site. Precipitation is monitored throughout the year with a weighing bucket rain gage. A float-type rain gage with a digital recorder is operated from May through October. At about 7,700 feet a second weighing bucket rain gage and float-type rain gage are installed. These gages are in operation during the same time periods as the gages at the climate station. The data collected are compiled and reported as daily values. Snow courses also are run at each rain-gage site and along the alluvial valley floor (fig. 1).

Surface Water

A streamflow-gaging station with a flume has been established along Sage Creek near the outlet of the study watershed. Streamflow, specific conductance, and temperature are being monitored continuously at the site. Water chemistry is sampled on a regular basis at the flume for major cations, anions, and trace metals.

Ground Water

Twenty-seven bedrock wells were drilled at the Sage Creek study site. A Mayhew[1] 1000 rotary drill rig was used to drill the wells. Eleven of the wells were cored with a 3-3/4-inch diamond drill bit. Sixteen wells were rotary drilled with a 4-3/4-inch triple-cone rock bit.

Well-water quality is monitored quarterly for the first year of the study at 10 of the wells. The water samples are analyzed for major cations, major anions, and trace metals. Two wells in the study area also are equipped with continuous water-level recorders. Water-level measurements are made monthly on most of the wells in the area.

The wells were located in and near the area of potential mining activity (fig. 1). The stratigraphy of the area is depicted by means of fence diagrams (fig. 4) and geologic sections (figs. 5 and 6). Thirteen wells also were drilled in the Sage Creek alluvial valley floor in conjunction with a study of alluvial valley aquifers in northwestern Colorado (fig. 7).

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[1]The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

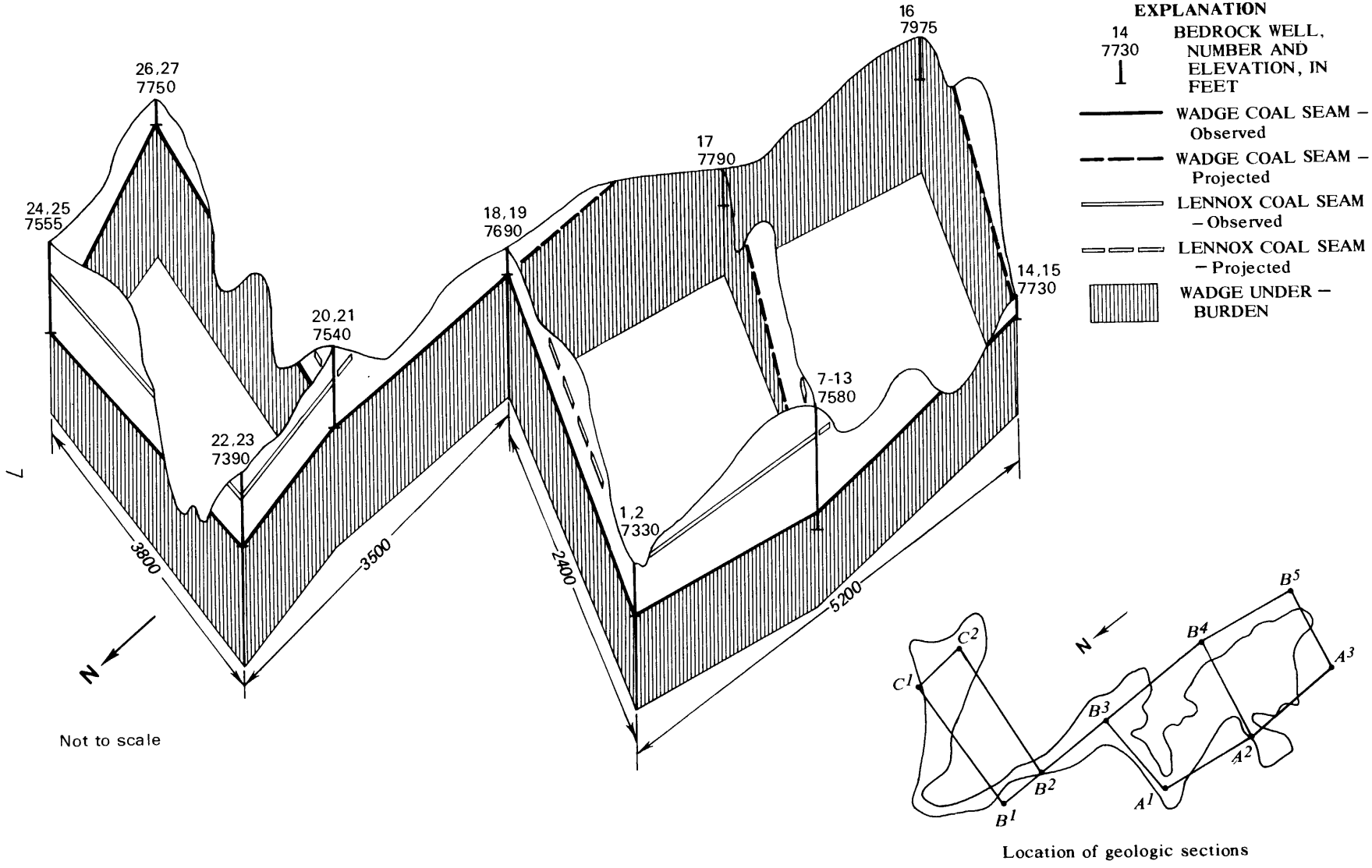

Figure 4.-- Fence diagram of Sage Creek study site. Location of diagram shown in figure 1.

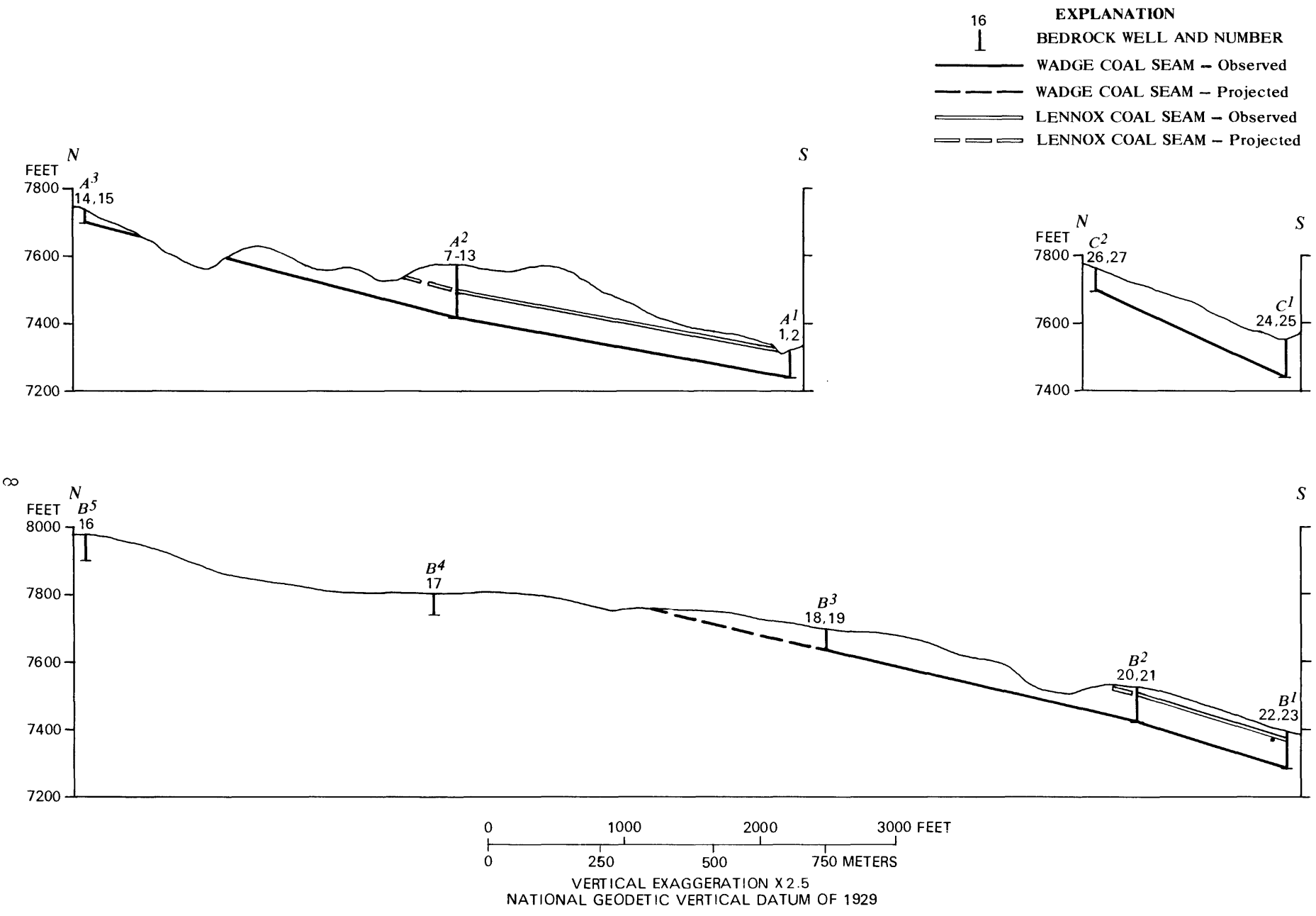

Figure 5.-- South to north geologic sections of Sage Creek study area. Location of sections shown in figure 7.

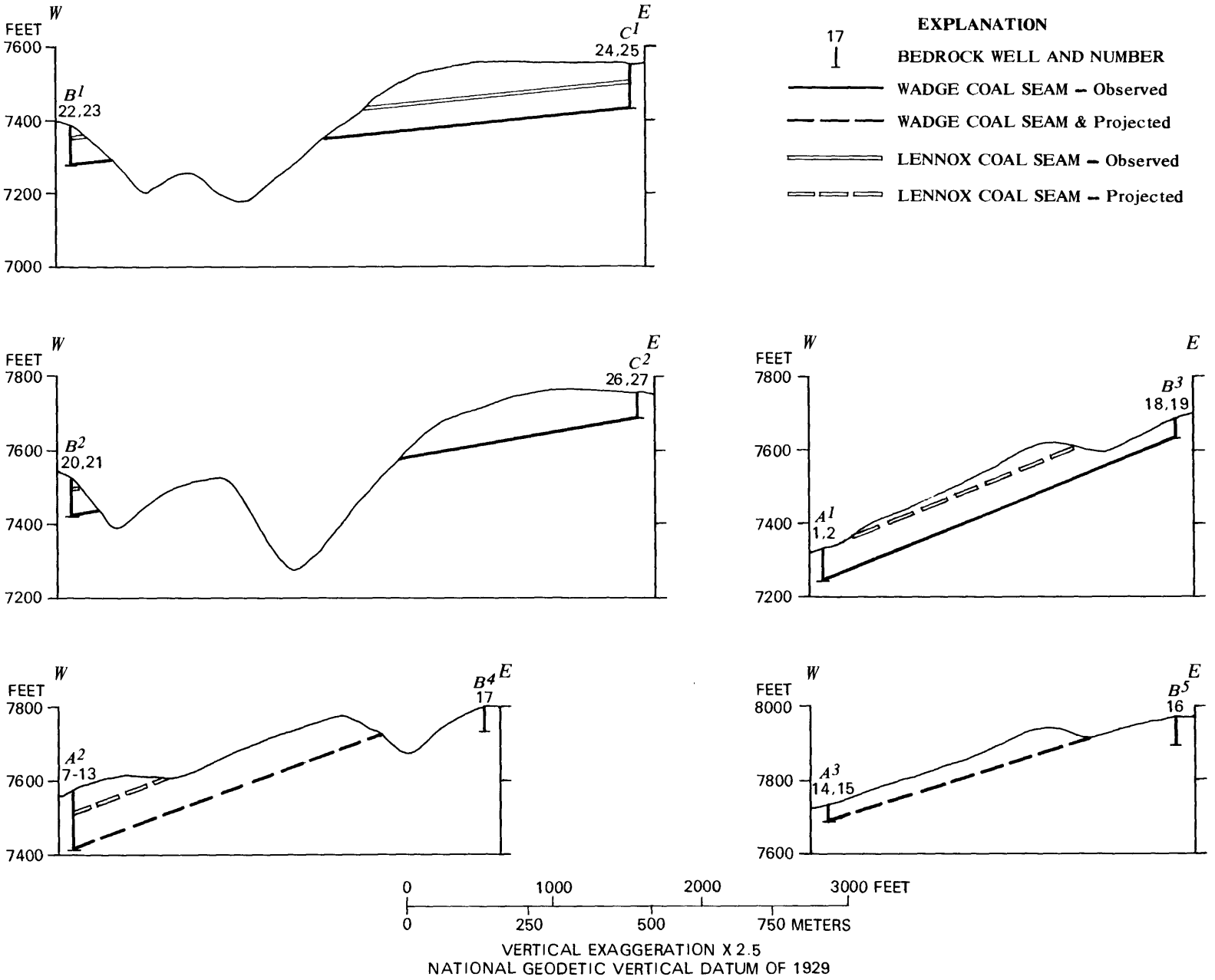

Figure 6.--West to east geologic sections of Sage Creek study area. Location of sections shown in figure 1.

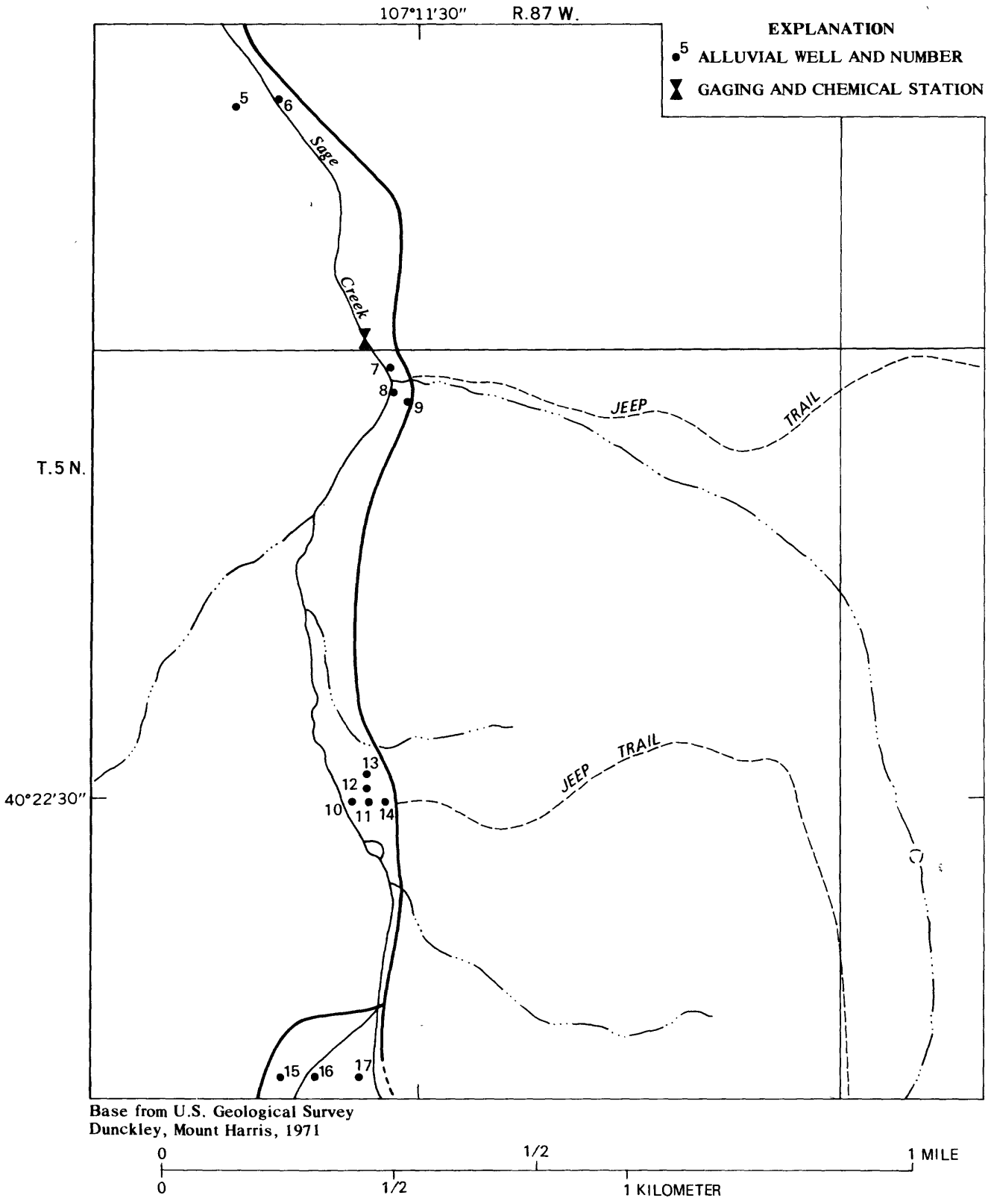

Figure 7.--Location of alluvial wells.

WELL INFORMATION

Geologic Logs

Geologic cores were used to describe the lithology of the well sites. The "Manual of Field Geology," by Compton (1962) was used to assist in verifying rock types. The strata found were classified by the following criteria:

1. Grain size and grain shape
2. Color
3. Hardness
4. Structure
5. Mineralogy

A general geologic log of the Sage Creek study area is shown in figure 8. Not every borehole penetrated all of these zones. Many boreholes penetrated no Lennox overburden or Lennox coal seam. A few boreholes penetrated only the Wadge underburden.

Geophysical Logs

Geophysical logs were run on each well. The type of log run was dependent upon the physical characteristics of the hole and the information desired for proper well completion. Geophysical logs were run in open holes to determine the location of aquifers and geologic units. After packers were placed and cemented in the hole, nuclear geophysical logs were run to verify the location of the packers and cement. The following seven geophysical logs were run: Neutron, spontaneous potential, single-point resistance, natural gamma, gamma-gamma, temperature, and caliper. Some applications of each log are summarized in table 1. Table 2 is a summary of the geologic and geophysical logs taken at various wells. Keys and MacCary (1976) and David and DeWiest (1966) discuss these types of logs.

Table 1.--*Some applications of geophysical logs*

Application	Type of Log						
	Nuclear			Electrical			
	Natural gamma	Gamma-gamma	Neutron	Resistivity	Spontaneous potential	Caliper	Temperature
Water content----	-	-	x	-	-	-	x
Porosity---------	-	x	x	x	-	-	-
Stratigraphy-----	-	-	-	-	x	x	-
Bed thickness----	-	-	-	-	x	-	-
Fractures--------	-	-	-	x	-	x	-
Temperature of fluid----------	-	-	-	x	-	-	x
Lithology--------	x	x	-	-	-	x	-
Bulk density-----	-	x	-	-	-	-	-
Cement location--	-	x	-	-	-	-	x

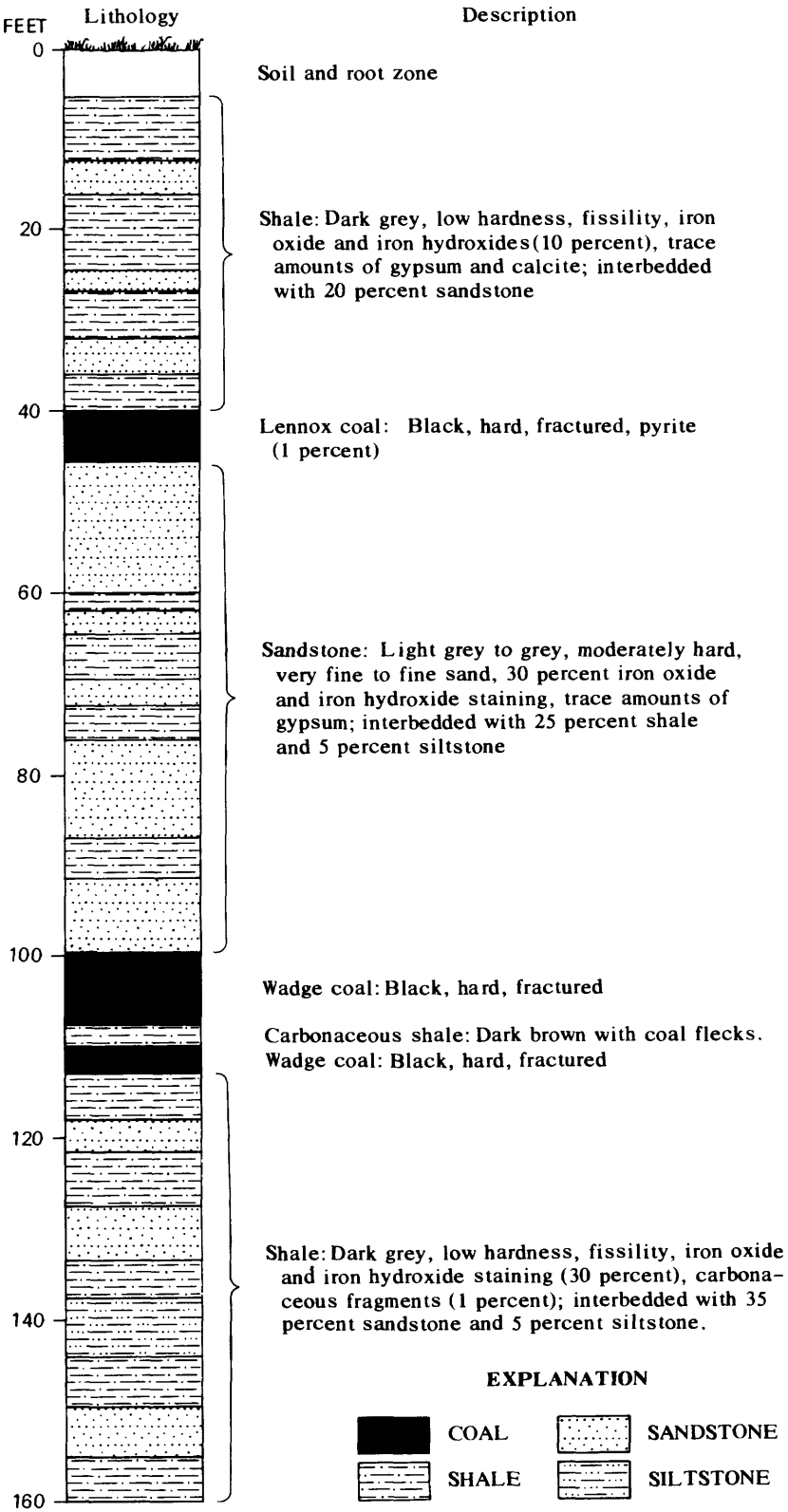

Figure 8.-- General geologic log of the Sage Creek study area.

Table 2.--*Geologic and geophysical logs summary*

Well No.	Geologic logs		Geophysical logs										
			Open hole							Cased well			
			Nuclear			Electrical		Caliper	Temperature	Nuclear			Temperature
	Cored	Cutting	NG[1]	GG[2]	N[3]	R[4]	SP[5]			NG[1]	GG[2]	N[3]	
1	x	-	x	x	-	-	-	x	x	x	x	x	-
2	-	x	x	x	-	-	-	x	x	x	x	x	-
3	-	x	-	-	-	-	-	-	-	x	x	-	-
4	-	x	-	-	-	-	-	-	-	x	x	-	-
5	x	-	-	-	-	-	-	-	-	x	x	-	-
6	-	x	-	-	-	-	-	-	-	x	x	-	-
7	x	-	x	x	x	x	x	x	-	-	x	-	-
8	-	x	x	x	x	-	-	x	-	x	x	-	x
9	-	x	-	-	-	-	-	-	-	x	x	-	-
10	-	x	-	-	-	-	-	-	-	x	x	-	-
11	-	x	x	x	-	-	-	-	-	x	x	-	-
12	-	x	-	-	-	-	-	-	-	x	x	-	-
13	-	x	-	-	-	-	-	-	-	x	x	-	-
14	x	-	x	x	x	-	-	x	-	-	x	-	-
15	-	x	-	-	-	-	-	-	-	-	-	-	-
16	x	-	x	x	x	-	-	x	-	x	x	x	-
17	x	-	x	x	-	-	-	x	-	x	x	x	-
18	x	-	x	x	x	-	-	x	-	x	x	-	-
19	-	x	x	x	x	-	-	x	-	x	x	-	-
20	x	-	x	x	x	-	-	x	-	x	x	x	-
21	-	x	x	x	x	-	-	-	-	x	x	-	-
22	x	-	x	x	x	-	-	x	-	x	x	x	-
23	-	x	x	x	-	x	x	-	-	x	x	x	-
24	x	-	x	x	x	x	x	x	-	x	x	x	-
25	-	x	x	x	x	x	x	x	-	-	-	-	-
26	x	-	x	x	x	-	-	x	-	-	-	-	-
27	-	x	-	-	-	-	-	-	-	-	-	-	-

[1]NG=natural gamma log.
[2]GG=gamma-gamma log.
[3] N=neutron log.
[4] R=resistivity log.
[5]SP=spontaneous potential log.

Well-Completion Information

Specific stratigraphic zones were selected for analysis. Well screen or slotted PVC was placed within the zones and then isolated from the rest of the borehole with packers and cement. The zones of completion and the type of casing opening are shown in table 3. A typical well completion in the Wadge coal seam is depicted in figure 9. The same technique was used to complete wells in the other zones. As can be seen, the Wadge coal seam and the Wadge overburden are the primary zones of interest. These particular zones were chosen, because they are disturbed frequently by mining in this area. Because the wells are completed separately in these zones, the hydraulic and chemical properties of the zone can be determined. This information then will serve as a basis for comparison with the regional hydrogeology.

Well Data Collected

During the first 10 months of the study, all of the essential instrumentation was installed and data collection begun. The water-level data which have been compiled to date are at the end of this report. Well-water samples have been collected; however, chemical analysis of the samples is not complete at this time.

FUTURE NEEDS FOR DATA COLLECTION, ANALYSIS, AND INTERPRETATION

Data collection needs to be continued and the data analyzed and interpreted. About 3 years of data are needed to provide a sufficiently sound base for an interpretive report describing the hydrologic system of the study area.

Statistical analyses based on physically logical relations found in the data are needed to evaluate the numerical uniformity of differences among the data collected at different sites. Statistics also could be used to define the natural hydrologic variability.

Graphical interpretations are needed to show the homogeneity or differences in geologic sections, chemical constituent distributions, statistical relations, quantitative and qualitative comparisons, and time trends. When mining in the study area begins, a determination needs to be made of the feasibility of continuing the monitoring.

SUMMARY

Wells have been established in bedrock aquifers at a site which may be mined for coal in northwestern Colorado. Water chemistry is being monitored at 10 of the wells and water levels are being monitored in all of the wells. The information from the bedrock wells is being interpreted in conjunction with climatological information, surface-flow information, and alluvial aquifers.

Table 3.--*Well depth, land-surface elevation, zone of completion, and type of casing opening*

Well No.	Well depth, in feet	Land-surface elevation, in feet	Zone of completion					Casing opening	
			Lennox overburden	Lennox	Wadge overburden	Wadge	Wadge underburden	Slots	Screen
1	62	7,340	-	-	x	-	-	x	-
2	58.5	7,320	-	-	-	x	-	x	-
3	47	7,300	x	-	-	-	-	-	x
4	47	7,300	x	-	-	-	-	x	-
5	54	7,300	-	x	-	-	-	-	x
6	54	7,300	-	x	-	-	-	x	-
7	146.3	7,580	-	-	-	x	-	x	-
8	133	7,580	-	-	x	-	-	x	-
9	135	7,580	-	-	x	-	-	-	x
10	135	7,580	-	-	x	-	-	x	-
11	151	7,580	-	-	-	x	-	-	x
12	151	7,580	-	-	-	x	-	x	-
13	170	7,580	-	-	-	-	x	-	x
14	26.3	7,730	-	-	-	x	-	x	-
15	9.5	7,730	-	-	x	-	-	x	-
16	65	7,975	-	-	-	-	x	x	-
17	48	7,790	-	-	-	-	x	x	-
18	37.4	7,690	-	-	-	x	-	x	-
19	27	7,690	-	-	x	-	-	x	-
20	85.7	7,540	-	-	x	-	-	x	-
21	100.5	7,540	-	-	-	x	-	x	-
22	79.3	7,390	-	-	x	-	-	x	-
23	106.7	7,390	-	-	-	x	-	x	-
24	108.8	7,555	-	-	-	x	-	x	-
25	90	7,555	-	-	x	-	-	x	-
26	43	7,750	-	-	-	x	-	x	-
27	25	7,750	-	-	x	-	-	x	-

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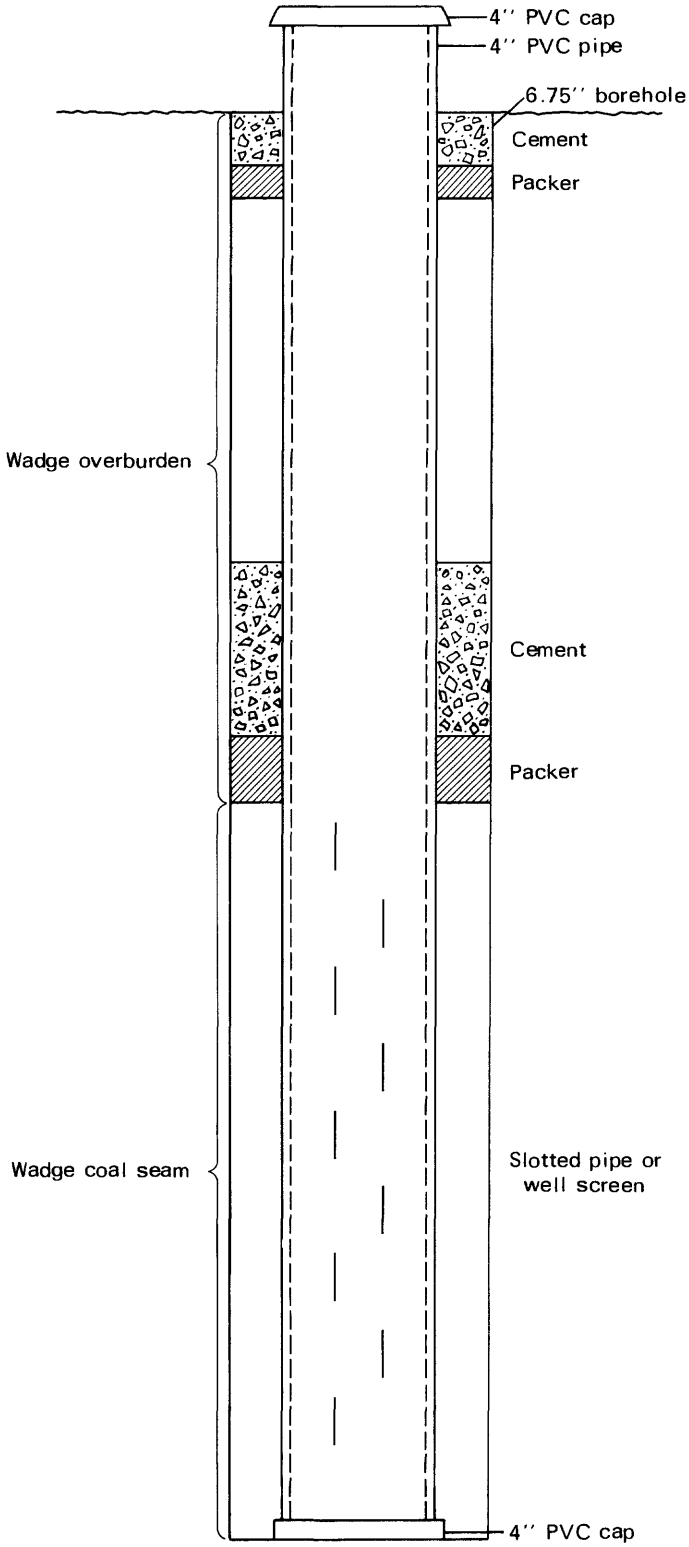

Figure 9.-- Typical well completion (example is for Wadge coal seam).

WATER LEVELS

Depth to water (feet) for wells at one location

[Elevation: 7,580 feet]

Date	Well 7 Wadge coal	Well 8 Wadge coal overburden	Well 9 Wadge coal overburden	Well 10 Wadge coal overburden	Well 11 Wadge coal	Well 12 Wadge coal	Well 13 Wadge coal underburden
8-21-80	109.29	118.78	------	------	------	------	------
10-15-80	119.31	121.35	121.70	129.36	126.47	127.06	160.03
12-04-80	124.13	122.39	121.65	129.17	126.79	127.38	muddy
1-09-81	124.86	122.55	121.52	125.59	130.33	131.24	muddy
2-03-81	124.27	122.06	121.64	126.42	126.91	127.54	dry
3-05-81	124.91	122.73	121.70	125.56	126.96	127.64	161.09

Depth to water (feet) for wells completed in the Lennox overburden

[Elevation: 7,300 feet]

Date	Well 3	Well 4
10-15-80	flowing	flowing
12-04-80	flowing	flowing
1-09-81	flowing	flowing

Depth to water (feet) for wells completed in the Lennox coal seam

[Elevation: 7,300 feet]

Date	Well 5	Well 6
10-15-80	flowing	flowing
12-04-80	flowing	flowing
1-09-81	flowing	flowing

Depth to water (feet) for wells completed in the Wadge overburden below the Lennox coal seam

Date	Well 1	Well 15	Well 19	Well 20	Well 22	Well 25	Well 27
	Elevation, in feet						
	7,340	7,730	7,690	7,540	7,390	7,555	7,750
8-21-80	3.44	Dry	26.23	84.36	-----	-----	-----
9-18-80	-----	-----	-----	-----	73.69	29.43	21.61
10-20-80	-----	Dry	25.45	Dry	Dry	29.15	19.33
11-11-80	29.77	-----	27.65	Dry	Dry	29.35	22.49
12-04-80	20.27	Dry	Dry	Dry	Dry	28.18	22.64
1-09-81	12.26	Dry	Dry	Dry	Dry	-----	-----
2-03-81	9.79	-----	Dry	Dry	Dry	-----	-----
3-05-81	9.41	-----	Dry	Dry	Dry	30.25	23.35

Depth to water (feet) for wells completed in the Wadge coal seam

Date	Well 2	Well 14	Well 18	Well 21	Well 23	Well 24	Well 26
	Elevation, in feet						
	7,320	7,730	7,690	7,540	7,390	7,555	7,750
8-21-80	Flowing	Dry	23.08	88.25	-----	-----	-----
9-18-80	-------	-----	-----	-----	80.16	23.93	38.15
10-20-80	23.52	Dry	-----	93.30	80.64	16.70	38.85
11-11-80	-------	-----	-----	94.50	80.64	15.55	38.67
12-04-80	Flowing	Dry	25.34	95.08	82.82	14.37	40.39
1-09-81	Flowing	Dry	26.32	95.60	61.90	-----	-----
2-03-81	Flowing	-----	27.16	99.11	82.02	-----	-----
3-05-81	Flowing	-----	28.07	97.48	81.88	13.62	40.73

Depth to water (feet) for wells completed in the Wadge underburden

Date	Well 16 Elevation, 7,975 feet	Well 17 Elevation, 7,790 feet
8-21-80	63.94	Dry
10-20-80	Dry	Dry
12-04-80	Dry	Dry
1-09-81	Dry	Dry

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