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GEOLOGICAL SURVEY

RESULTS OF TEST DRILLING AND HYDROGEOLOGY OF CAPPS COAL FIELD, ALASKA

By Gordon L. Nelson

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Multiply	by	to obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
ton, short	0.9072	megagram (Mg)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
degree Fahrenheit (°F)	(°F-32)/1.8	degree Celsius (°C)

Other abbreviations in this report are:

µg/L, microgram per liter

mg/L, milligram per liter

µS/cm, microsiemens per centimeter at 25 °C

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By Gordon L. Nelson

ABSTRACT

Capps coal field, one of the Beluga coal fields located 60 miles west of Anchorage, Alaska, is in a remote roadless area above the treeline. Two major coal seams, the 20-foot thick Capps seam and 40-foot thick Waterfall seam, will be mined to supply an export market. No high-yield aquifers were identified during drilling of seven test wells and two continuously cored drill holes, but several Tertiary units of coal and weakly consolidated sandstone and conglomerate collectively provided as much as 60 gallons per minute to wells. Melting of the winter snowpack continues throughout the summer and precludes measurement of baseflow in Capps Creek until late winter, when stream discharge is less than 10 cubic feet per second. Sedge bogs and thin discontinuous glacial aquifers are probably the source of water for springs that sustain baseflow in the area to be mined. Heads in the deeper bedrock aquifers are commonly below land surface; these aquifers do not contribute to baseflow in the mine area. The concentration of dissolved solids in ground water appears to increase with depth, but dissolved solids did not exceed 161 milligrams per liter in any sample. Both ground water and surface water are potable but ground water may require aeration to remove an odor of hydrogen sulfide.

INTRODUCTION

Alaska, which has about half of the nation's coal reserves, has only one small (about 700,000 tons annually) active mine. However, the potential for development of new mines is great. One of the most likely places for such development within the next 10 years is the Beluga coal fields on the west side of Cook Inlet (fig. 1). In just one 50,000-acre part of this field, industry has identified 750 million tons of economically extractable low-sulfur coal within 30 mi of tidewater (Sanders, 1980).

The Capps Creek coal field (hereafter called the Capps field) is one of the Beluga coal fields. The field is about 24 mi from tidewater and about 60 mi from Anchorage (fig. 1). There are no roads into the field, but tractor trails provide access from the nearest road near Tyonek.

The Capps field is situated in rolling uplands that range in altitude from 1500 ft to 2000 ft above sea level. The east side of the field is deeply incised by Capps Creek and North Capps Creek near where they flow into the glacially excavated Beluga River valley. Sedge bogs occupy about 10 percent of the coal field (Gough and Severson, 1983), and the field is entirely above the treeline.

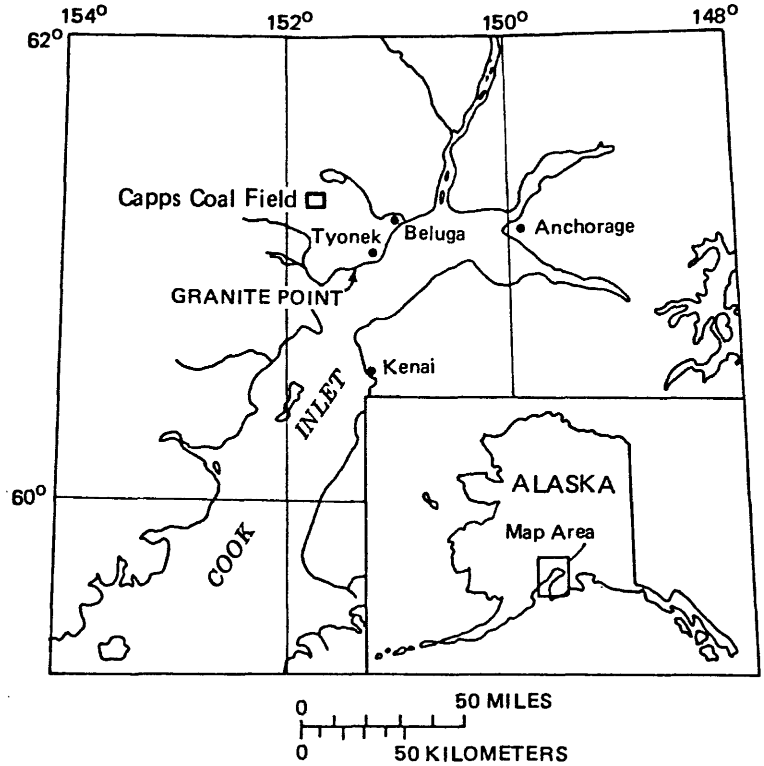


Figure 1.--Location of the Cook Inlet basin and Capps coal field.

The Capps field is owned by Cook Inlet Region, Incorporated, an Alaska Native Regional Corporation, and is leased to Beluga Coal Company, a subsidiary of Placer Amex, Incorporated. Both owner and lessee of the field cooperated by granting the U.S. Geological Survey free access to the property and by providing proprietary data that aided in planning the field work. Funding for the Capps Creek stream-gaging station was provided by the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys.

During the energy shortage of 1978-1980, the economics of developing the Beluga coal fields began to look attractive to investors. Two proposed markets were the Far East export market (primarily Japan and Korea) and a proposed methanol plant to be built near Granite Point. The Far East is still a potential market in spite of the current (1985) abundance of petroleum, because Japanese and Korean utilities wish to diversify their energy sources. The Capps field is attractive for early development because a coal seam that is 40 to 55 ft thick subcrops under generally less than 20 ft of overburden along a linear distance of about 1 mi.

Although many test holes were drilled to obtain coal resource information, no hydrologic data were collected. However, the drilling logs indicated that most of the materials within 200 ft of the surface were fine-grained Tertiary sediments of the Tyonek Formation. Few of the units appeared to have the permeability required to be classified as aquifers. No water wells have been drilled in the Capps field; the nearest water wells are in the Tyonek area. However, the near-surface bedrock penetrated by wells in the Tyonek area is stratigraphically higher (younger) than in the Capps field. Adkison and others (1975) reported that the lower part of the Tyonek Formation contained coarser materials than the younger materials found near Tyonek.

Ground-water information in the Capps area is needed to determine whether adequate quantities of ground water are available for use in mining operations and to determine whether significant drainage problems may occur. Data on ground-water quality are necessary to determine whether naturally occurring pollutants exist in ground water and might be drained to the surface environment during mining.

PURPOSE AND SCOPE

The objectives of this report are to:

1. Define aquifers and confining units in the Capps Creek coal field.
2. Evaluate properties of aquifers and estimate whether significant quantities of ground water may be obtained from wells.
3. Describe chemical qualtity of ground water and surface water.

This project included drilling of water wells and evaluating hydrologic results of other drilling in the field. Packer tests were conducted to determine the vertical distribution of heads and to selectively sample individual aquifers in uncased wells. Ground-water and surface-water samples were collected and analyzed for major ions and three metals.

PREVIOUS WORK

Barnes (1966) summarized previous geological studies of the Beluga coal fields, mapped coal outcrops, and estimated coal reserves. In the Capps field he identified one major coal seam that he called the Capps seam. Subsequently, the Beluga Coal Company drilled the intersections of a land grid having ¼-mile spacing and identified two major coal seams that they named the Capps seam and the Waterfall seam (Placer Amex, Inc., 1977, written commun.) That terminology will be used in this report.

Scully and others (1981) made a hydrologic reconnaissance of the Capps field. The ground-water aspects of their report were limited to studies of baseflow and springs because there were no wells in the Capps field. Baseflow information indicated that about 30 percent of streamflow was derived from ground-water sources. However, there was no information on which geological units were aquifers nor on which aquifers supplied most of the baseflow. Such factors could be evaluated only be test drilling.

This study was made concurrently with studies by the U.S. Geological Survey, Office of Engineering Geology. The Engineering Geology studies focused on geotechnical properties of materials and on mapping of surficial geology (Chleborad and others, 1980; 1982). Hinkley and others (1982) analyzed whole-rock chemical composition of core samples from the two holes drilled by Chleborad. Severson and Gough (1983) and Gough and Severson (1983) analyzed geochemistry of soils and vegetation in the Capps field.

There are no meterological stations in the Capps field. However, the National Weather Service maintains a station at Beluga about 25 mi southeast of the Capps field. Data collected at Beluga indicate that for the very short period of record, precipitation has averaged 27.1 in/yr (fig. 2). However, a significant orographic effect causes precipitation at the Capps field to be greater. Fog and rain commonly occur in the Capps field when Beluga is experiencing fair weather.

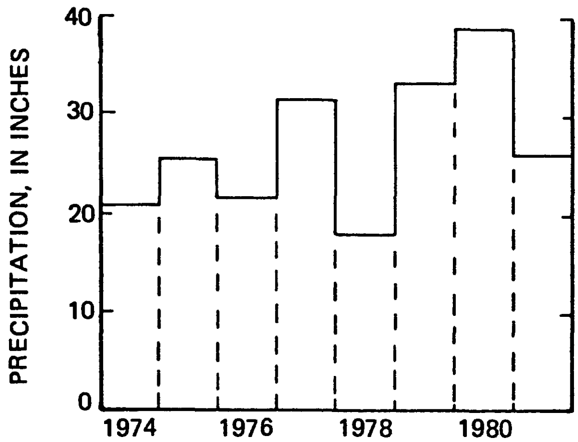


Figure 2.--Water-year (October 1 to September 30) precipitation at Beluga, Alaska, 1974-81.

STREAMFLOW AND SURFACE-WATER QUALITY

Since 1979 a stream-gaging station has been operated on Capps Creek about 3 mi downstream from the proposed mine. Over the period of record, discharge ranged from about 5.0 to 710 ft^3/s and averaged 61.2 ft^3/s.

Melting of winter snowpack continues until nearly the end of the following summer. Frequent rains during August and September keep discharge greater than baseflow until after freezeup in the fall. True baseflow, derived solely from ground water, occurs only during the winter (fig. 3).

Stream water in the Capps field is always dilute, even at baseflow conditions. Scully and others (1981) measured specific conductance over a wide range of discharges in several Beluga-area streams. They empirically determined that specific conductance (SC) is related to dissolved solids (DS) by:

$$DS = 0.7 \ SC + 6$$

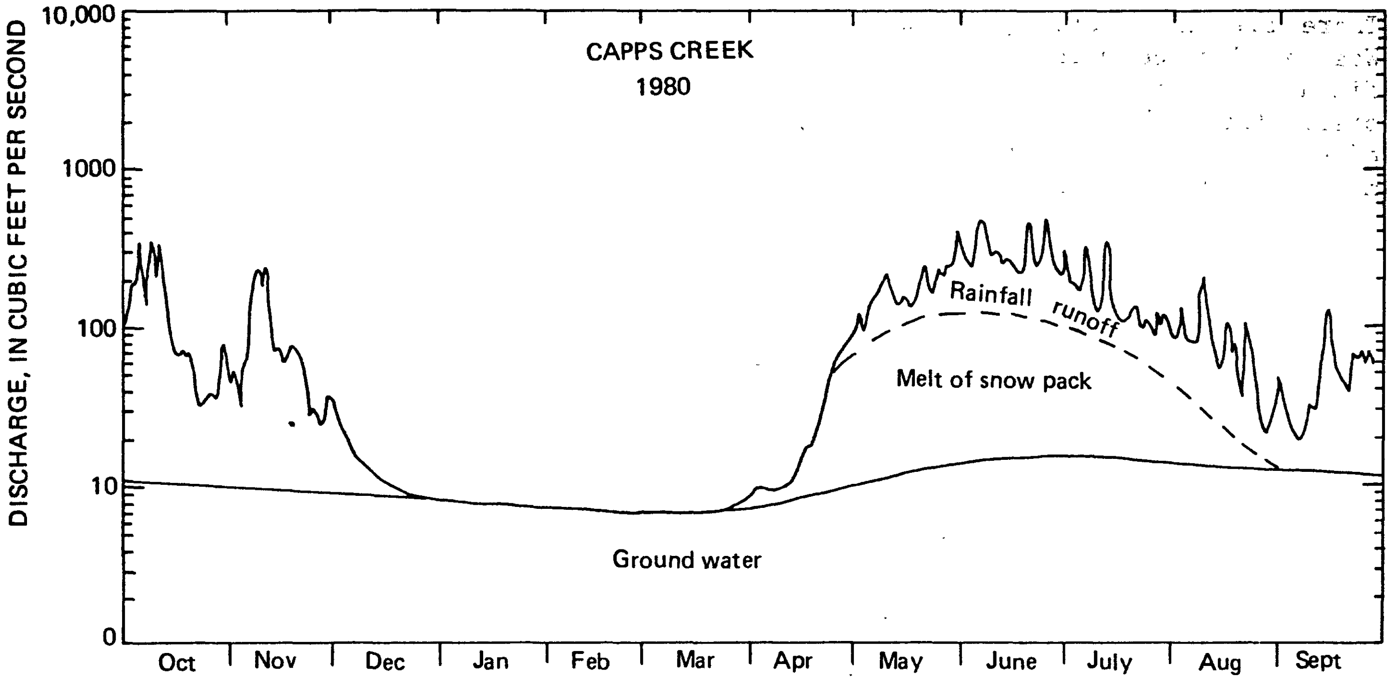


Figure 3.--Hydrograph separated into three components of streamflow. Lines illustrate a conceptual model of runoff but are not precise.

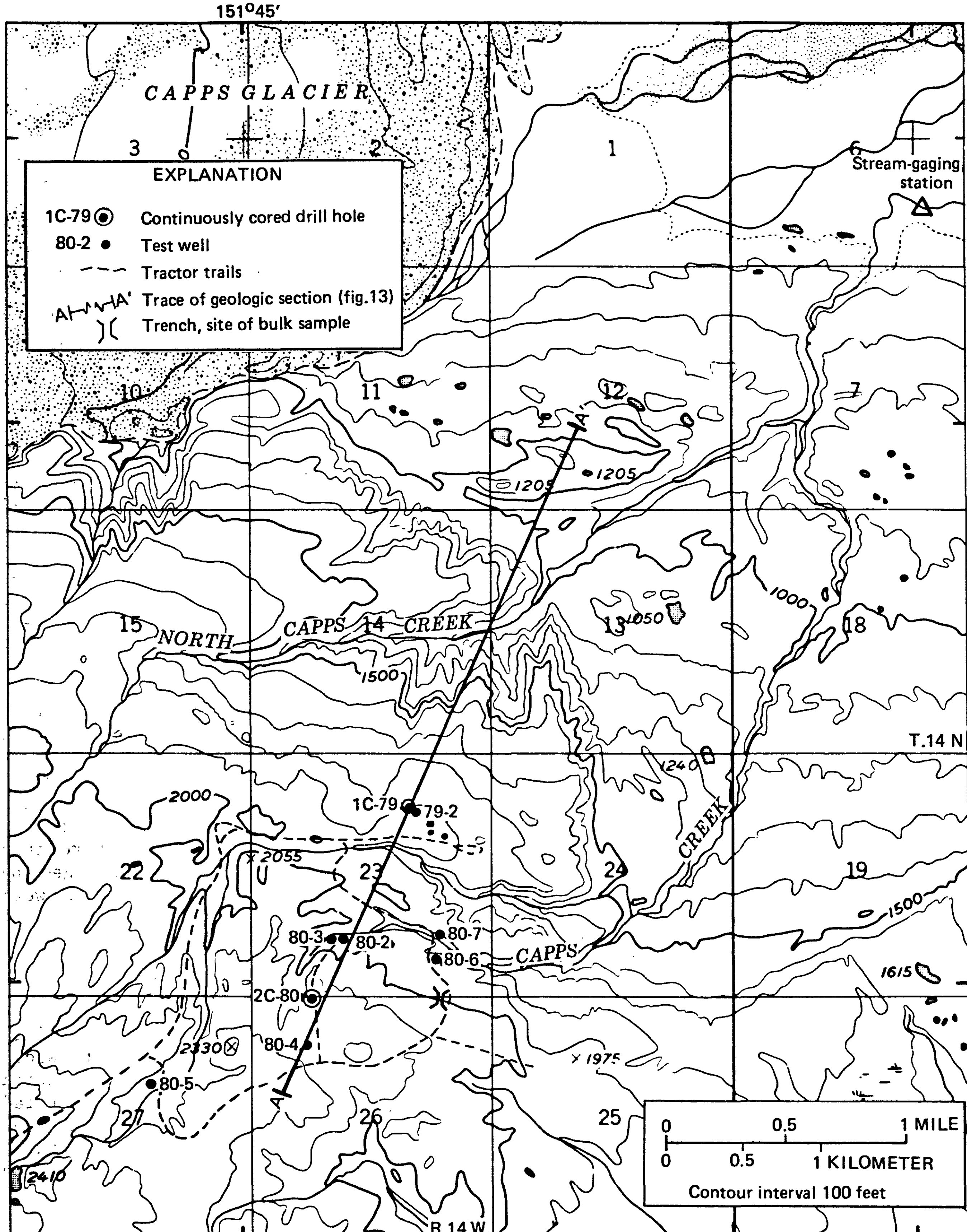
All 13 specific conductances measured earlier for Capps Creek samples were within the range 20 to 70 µS/cm. All the specific conductances measured during this study were within the lower one-third of this range. The 70 µS/cm value measured on April 14, 1976, was for late-winter baseflow conditions (5.5 ft^3/s) when all streamflow was derived from discharge of ground water. From these data and the relationship between dissolved solids and specific conductance, it appears that streamflow is always less than about 60 mg/L dissolved solids.

TEST DRILLING

All drilling was done by rigs mounted on tracked vehicles that could traverse the roadless and boggy terrain. Geophysical logs were run in each well except TW 79-2 and TW 80-7. The natural gamma, gamma-gamma (density), and neutron (moisture) logs were used to identify formational contacts that could not be determined accurately during drilling. Lithologic logs of all wells for which geophysical logs were run have been modified to reflect formational contacts indicated by the geophysical logs.

The drilling was done in cooperation with the U.S. Geological Survey, Office of Engineering Geology (OEG). Geologists from OEG supervised the continuous coring of two holes, drill hole 1C-79 in 1979 and 2C-80 in 1980; the results were reported by Chleborad and others (1980). The U.S. Geological Survey, Water Resources Division drilled test well 79-2 in 1979 and six other wells in 1980 (fig. 4).

The 1980 drilling, which could not be started until September, had to be terminated on October 17 because a heavy snowfall forced a rapid evacuation of personnel and equipment from the field. Although all test wells were completed, packer testing and sampling of the wells had to be postponed until 1981.



Base from U.S. Geological Survey, Tyonek B-5, 1:63,360, 1958

Figure 4.–Location of drilling sites in Capps field. Geologic section A-A′ is shown in figure 13.

TW 79-2

The first test well, TW 79-2 drilled in 1979 and designed to penetrate both the Capps and Waterfall seams, is about 100 ft from drill hole 1C-79 that was continuously cored by Chleborad and others (1980). The drill hole was drilled using bentonite mud as a circulating fluid, and it was not possible to determine water yield from the formations. The well was drilled using air rotary methods. Figure 5 compares logs of test well 79-2 and the upper 250 ft of drill hole 1C-79.

The two holes are only 100 ft apart and presumably the logs should show similar lithologies. The geologic contacts can be accurately determined in the continuously cored drill hole, but water-bearing units cannot be identified when drilling with a bentonite slurry. The water-bearing zones can be identified when drilling with air in the test well, but poor return of cuttings precludes accurate identification of the geological contacts. The combined use of lithologies and contacts from the drill hole and the water yields from the test well provides a more accurate assessment of actual conditions at the site.

The diamicton in the upper 30 ft of the hole was generally unsaturated, except near the top of the Capps coal seam where seepage of less than 0.5 gal/min was detected. No other water-bearing zones were detected to the total depth of 250 ft in the test hole.

Below the Capps seam the sediments consist of unsaturated sandstone, siltstone, and small-pebble conglomerate. The conglomerate is apparently quite permeable; drilling-fluid circulation in drill hole 1C-79 could not be maintained in the interval 200 to 397 ft and water was injected by gravity flow into the conglomerate in test well 79-2 at a rate of about 100 gal/min.

The 1979 drilling site is near the northern edge of the Capps coal field and is near the bluff where North Capps Creek has deeply incised the sediments. The conglomerate penetrated in the test well, or its lateral equivalent, crops out downdip within a distance of about 0.5 mi. Drainage of ground water to the surface at the downdip outcrop probably keeps the coarse units unsaturated between the drilling site and the outcrop. A major objective in selecting sites for subsequent wells was to penetrate similar conglomerates farther from the outcrop, where they might be saturated, and nearer land surface, where they might be recharged by streams and by direct infiltration of precipitation. All subsequent sites were more than 1 mi from the outcrop.

Drill Hole 2C-80

Drill hole 2C-80 (fig. 6) was continuously cored, and the cores were analyzed to determine engineering properties of the materials. The lithologic and geophysical logs indicate that the well penetrated about 65 ft of overburden, the 40-foot thick Waterfall seam, and 95 ft of sediments that underlie the Waterfall seam (Chleborad and others , 1980). The water surface in the well is 110 ft below land surface, but is not a static water level. An aquifer above the water surface yields water that can be heard cascading down the well. A temperature log indicates water flows out of the well into a formation near 165 ft.

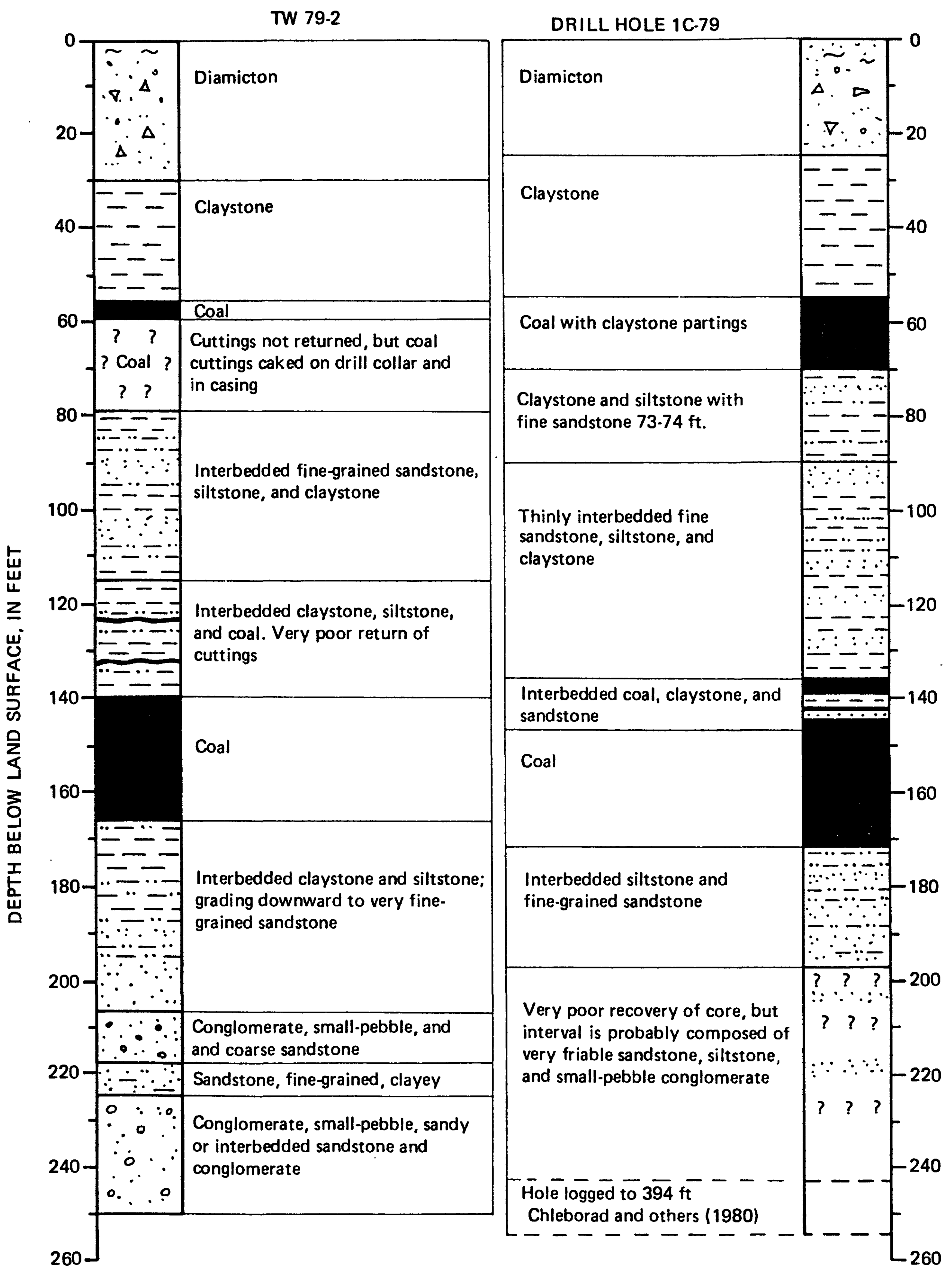


Figure 5.--Well logs, TW 79-2 and drill hole 1C-79.

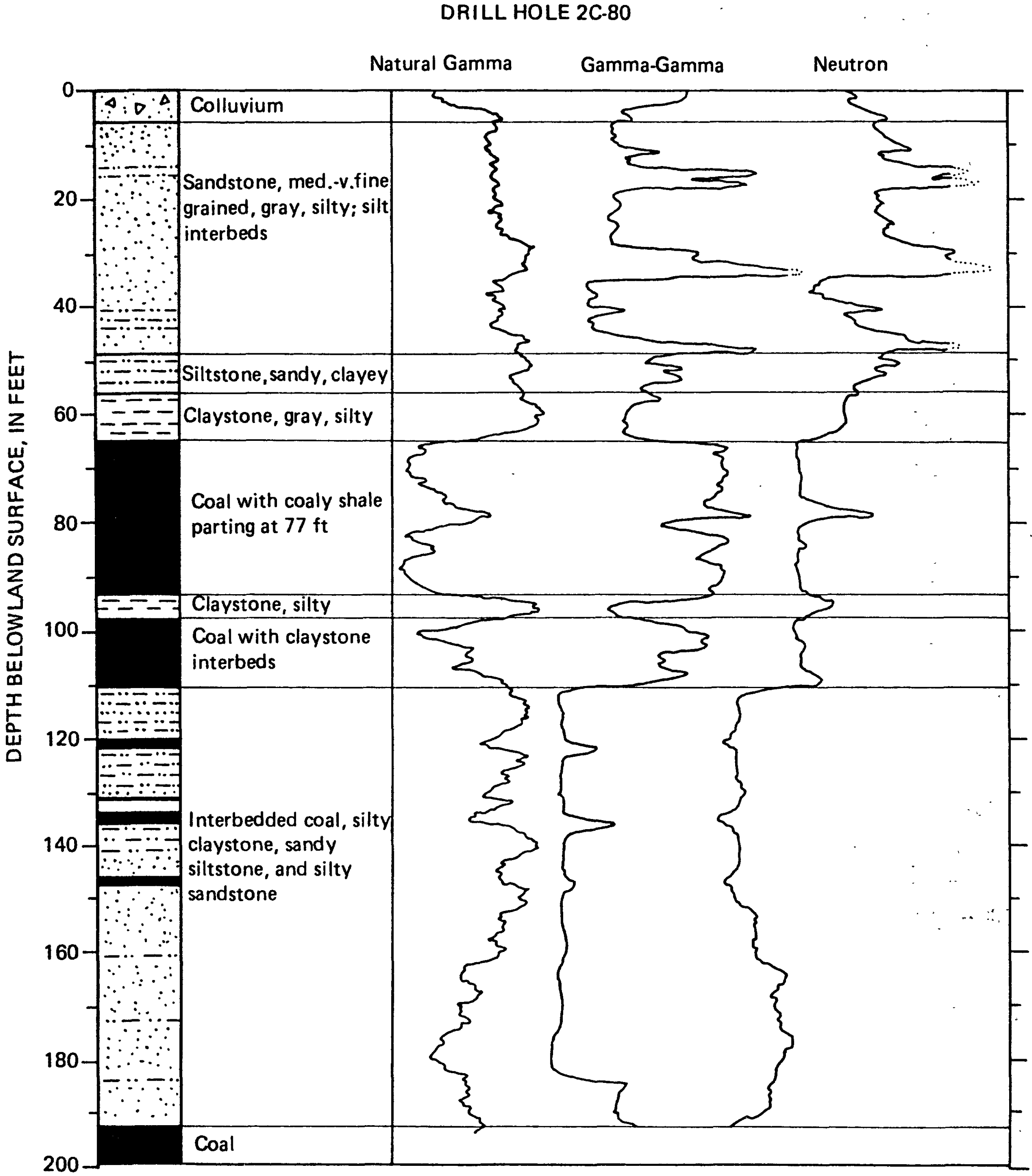


Figure 6.--Well and geophysical logs, drill hole 2C-80.

TW 80-2

In TW 80-2 (fig. 7), the units stratigraphically equivalent to the relatively coarse sand and gravel in TW 79-2 were fine grained and yielded no water. The well produced about 20 gal/min from the Waterfall seam and the underlying conglomerate. During drilling, it appeared that most of the water came from the coal, and a relatively small additional yield was added when the bit penetrated the conglomerate.

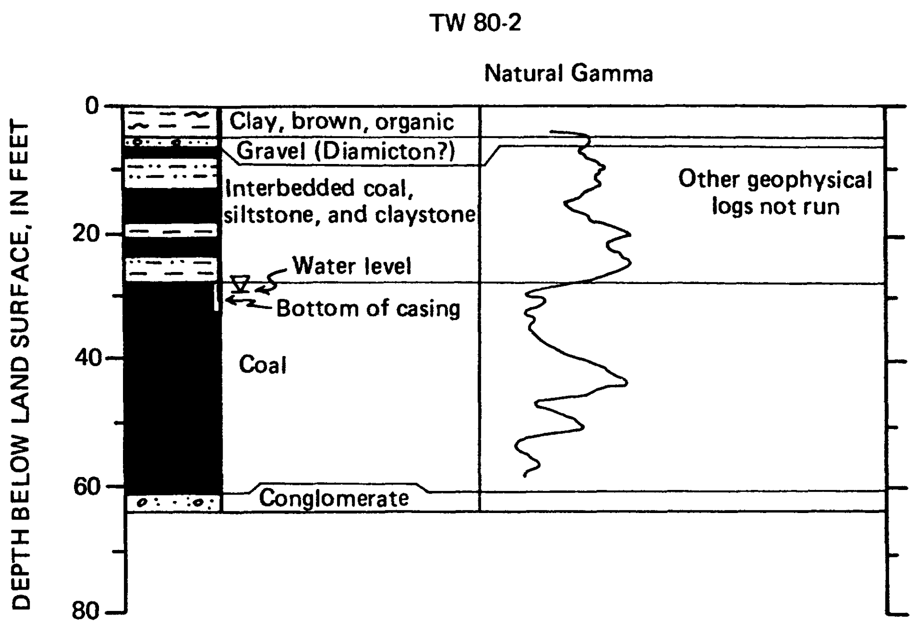


Figure 7.--Well and geophysical log, TW 80-2.

TW 80-3

Test well 80-3, drilled about 40 ft west of TW 80-2, was intended to test materials underlying the Waterfall seam by casing off the materials above 60 ft (fig. 8). However, the casing could not be driven past 49 ft, and the Waterfall seam was not entirely cased off. The completed well produced about 40 gal/min, about a quarter of which was from the Waterfall seam. The remainder of the water that could be detected during drilling was from a 10-foot thick coal bed 61 to 71 ft below land surface. Below 71 ft no increase in well yield was apparent during drilling. However, when a packer was set and the well pumped in 1981, the interval below 98 ft produced about 20 gal/min and the upper interval produced about 40 gal/min.

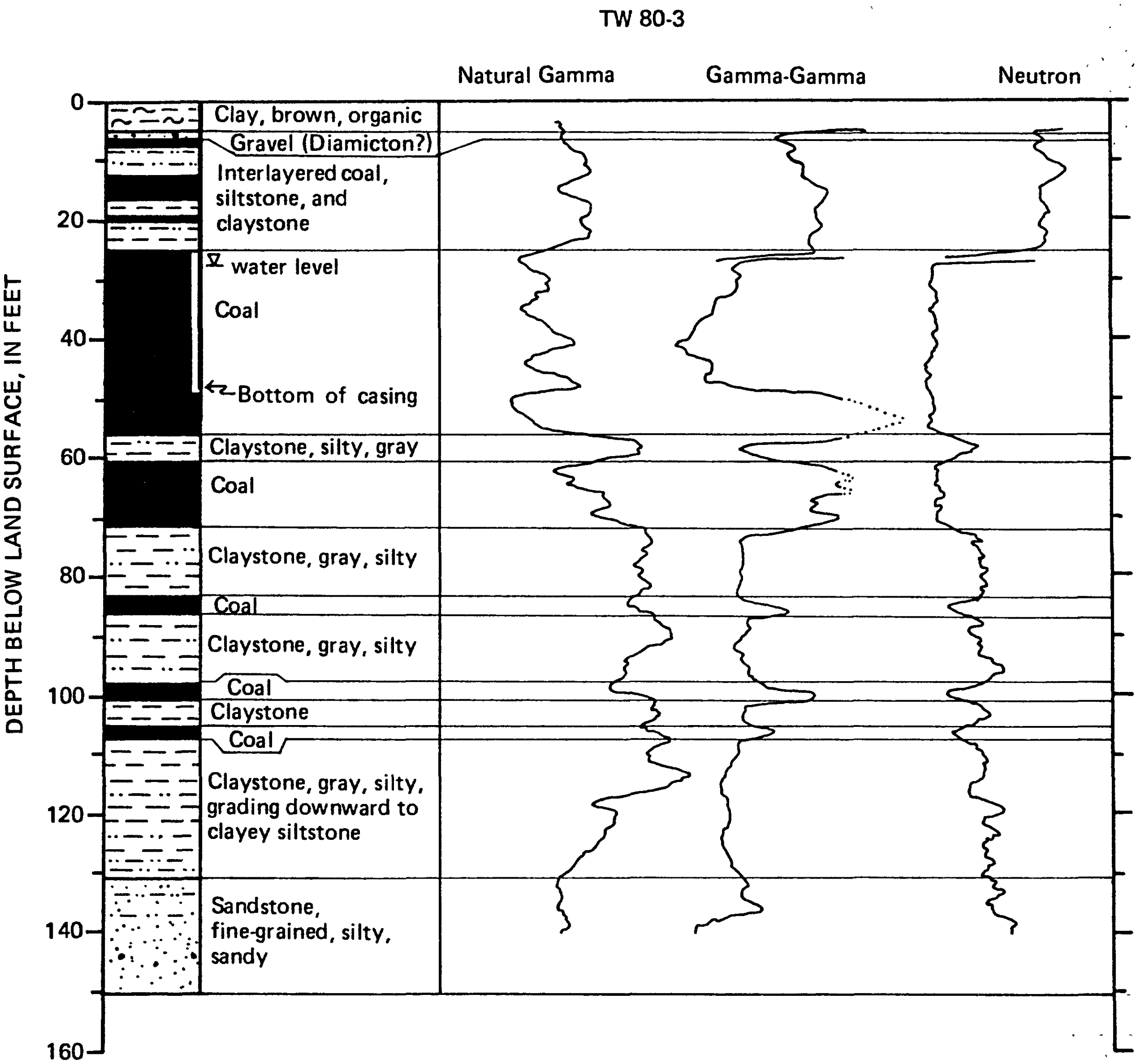


Figure 8.--Well and geophysical logs, TW 80-3.

The two most likely explanations of why the interval below 98 ft yielded no water during drilling but about one-third of the water in July 1981 are: (1) The yield of the upper zones, which had been producing water for several hours by the time the drilling reached 98 ft, was declining at the same time yield was increasing below 98 ft. This resulted in no apparent increase in yield. (2) The permeable materials below 98 ft were unsaturated during drilling but, by July 1981, had become saturated near the well after 9 months of downhole flow from the aquifers above 98 ft.

If the latter explanation is true, then the sample collected from below 98 ft may be water from the overlying aquifers that has been slightly changed by contact with formerly unsaturated rocks. The similarity of the two samples (see table 1 later in the text) does not preclude such an explanation.

Water could be heard cascading into the well, apparently from the Waterfall seam near the bottom of the casing, when the well was sampled in July 1981. An attempt to set a packer below the Waterfall seam at 59 ft failed, possibly because of erosion of the claystone by the cascading water.

TW 80-4

Test well 80-4 was drilled about 1300 ft southwest of drill hole 2C-80 in an area in which the Waterfall seam has been removed by erosion. The materials penetrated are stratigraphically below the Waterfall seam (fig. 9). No aquifers were penetrated during drilling. However, on October 10, 1980, 15 days after the well was completed, water had filled it to 75 ft below land surface. Because of the very low yield, the well was not pumped and sampled.

TW 80-5

Test well 80-5 (fig. 10) was drilled about 0.9 mi southwest of drill hole 2C-80. The site is upgradient and presumably isolated from proposed mining-related activities. The well penetrates materials that are stratigraphically the lowest of any penetrated during this drilling program. The well was drilled in a landslide deposit, and subrounded cobbles of coal from as deep as 60 ft indicate overriding or entrainment of Holocene stream deposits by the landslide. The saturated unconsolidated sand 8 to 22 ft below ft below land surface heaved into the well during drilling.

Most of the water was obtained from the thinly interbedded claystone and coal between 107 and 114 ft. However, an additional small amount, probably less than 5 gal/min, was obtained from the sandstone below 114 ft. After completion, the well flowed naturally at a rate of about 3 gal/min. The water flowed from a 20-foot extension temporarily welded onto the casing, indicating that the head was more than 20 ft above land surface. Packer sets at 95 ft and 114 ft indicated heads were above land surface in both the coal and the sandstone below 114 ft.

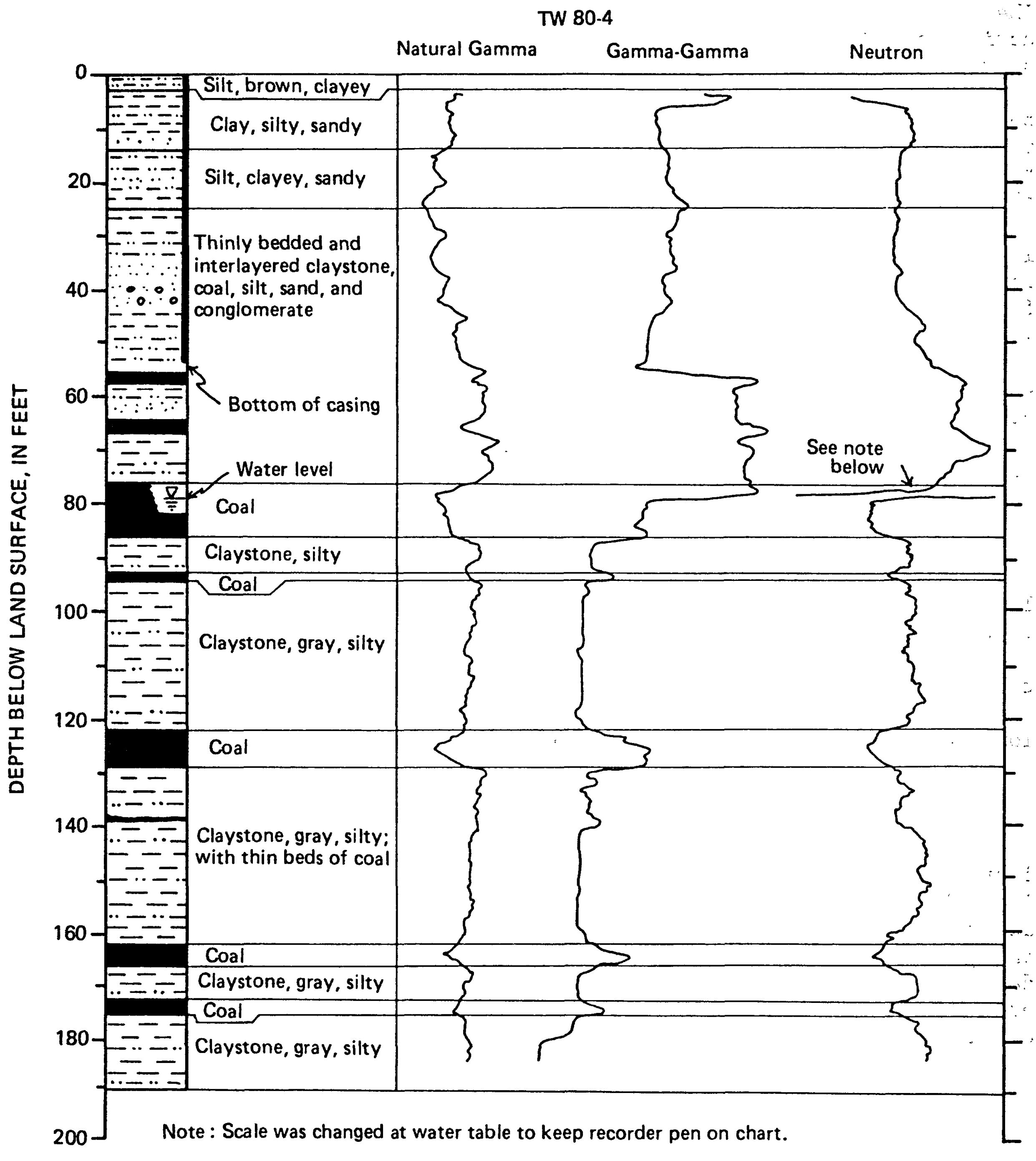


Figure 9.--Well and geophysical logs, TW 80-4.

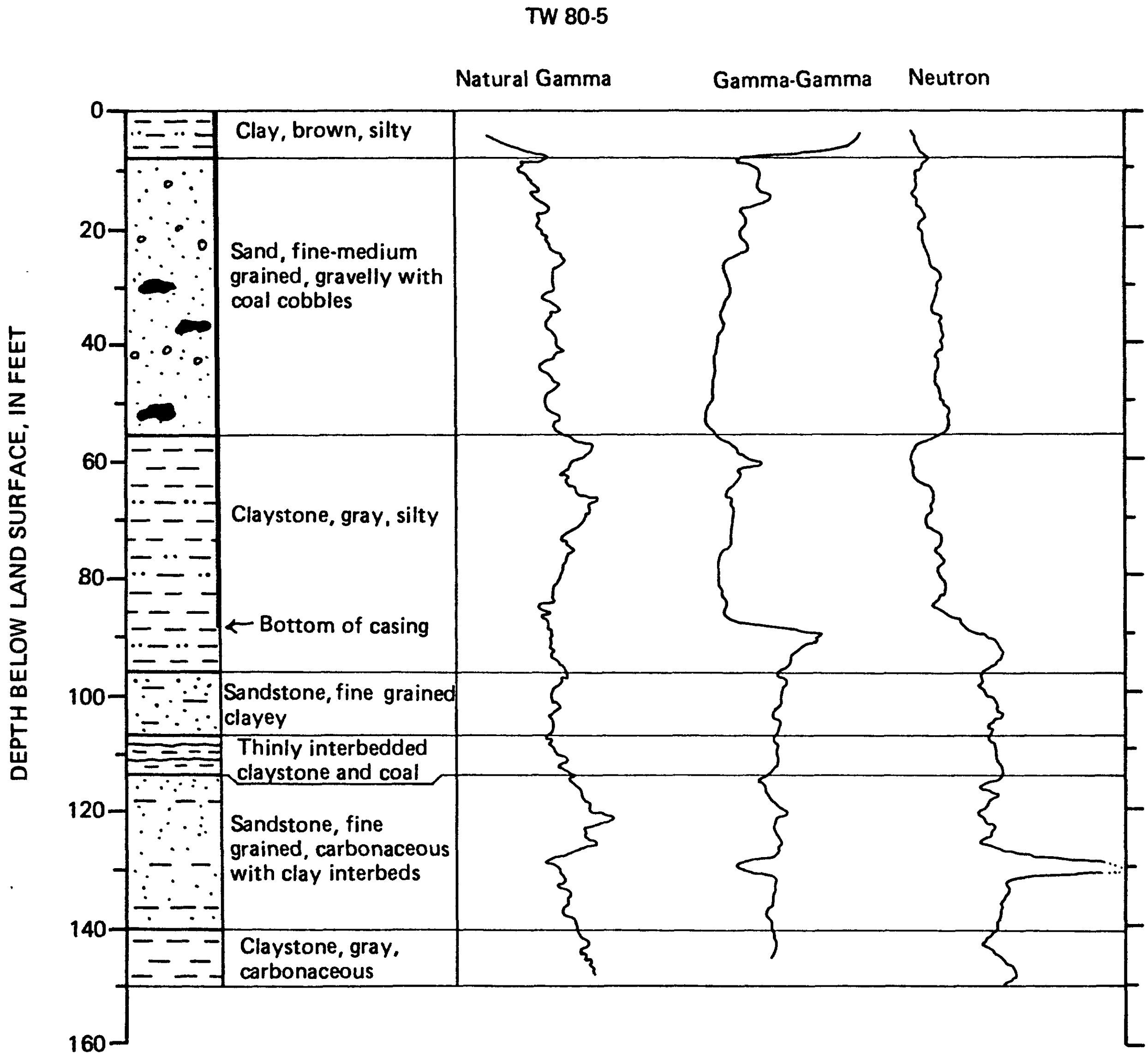


Figure 10.--Well and geophysical logs, TW 80-5.

TW 80-6

Test well 80-6 was drilled in an area in which the Waterfall seam is within 15 ft of land surface. The area is proposed for the earliest mining activity, and the drilling site is near a trench from which a 100-ton bulk sample of coal was mined in 1979.

The well penetrated 11 ft of clay and diamicton overburden on top of the Waterfall seam (fig. 11). Casing was driven to 35 ft and did not case off any aquifers. Most of the water was obtained from a medium-grained sandstone 118 to 120 ft and a coal bed 135 to 142 ft below land surface. Sandstone units below 100 ft also may have contributed a small amount of water. The total yield of the well was about 10 gal/min.

On July 8, 1981, a packer was set at 95 ft below land surface, and, with the pump set above the packer, the well was pumped at a rate of 5 gal/min to test the yield of the Waterfall seam. The water level, which was at 25 ft below land surface after the packer was set and just prior to the pumping test, fell below the base of the Waterfall seam at 45 ft in 19 minutes. (The water level indicated at 22 ft in figure 11 was a composite of all water-bearing zones.) During these 19 minutes of pumping, about 30 gal of water were obtained from casing storage and about 65 gal from the formations. Thus, it is unlikely that the units above the 95 ft depth can provide more than 3 gal/min on a sustained basis.

TW 80-7

Test well 80-7 was drilled downslope and across a stream from TW 80-6. The well penetrated materials (fig. 12) that are stratigraphically equivalent to those in TW 80-3 (fig. 8). The coarse-grained sandstone and small-pebble conglomerate overlying the Waterfall seam appear similar to materials overlying the Waterfall seam in drill hole 1C-79, but in TW 80-7 the materials were saturated and yielded water to the well. Casing was driven to 27 ft, but a break in the casing at 15 ft allowed shallow water to enter the hole. The lithologies and contacts have not been verified by correlation with geophysical logs.

HYDROGEOLOGY

In all four wells that penetrated the Waterfall seam (TW 80-2, 80-3, 80-6, and 80-7), a significant fraction of the well yield was derived from the coal seam. No other unit could be both identified as an aquifer and correlated between two or more wells. The potentiometric surface of the Waterfall seam is about 30 ft below land surface in TW 80-2 and 80-3, 22 ft below land surface in well 80-6, and could not be defined in other wells. However, it is presumably no higher than land surface at the outcrop, which along North Capps Creek is 700 ft below the altitude of the potentiometric surface at TW 80-3. Thus, it appears that a large hydraulic gradient will cause ground water to flow toward the north (fig. 13).

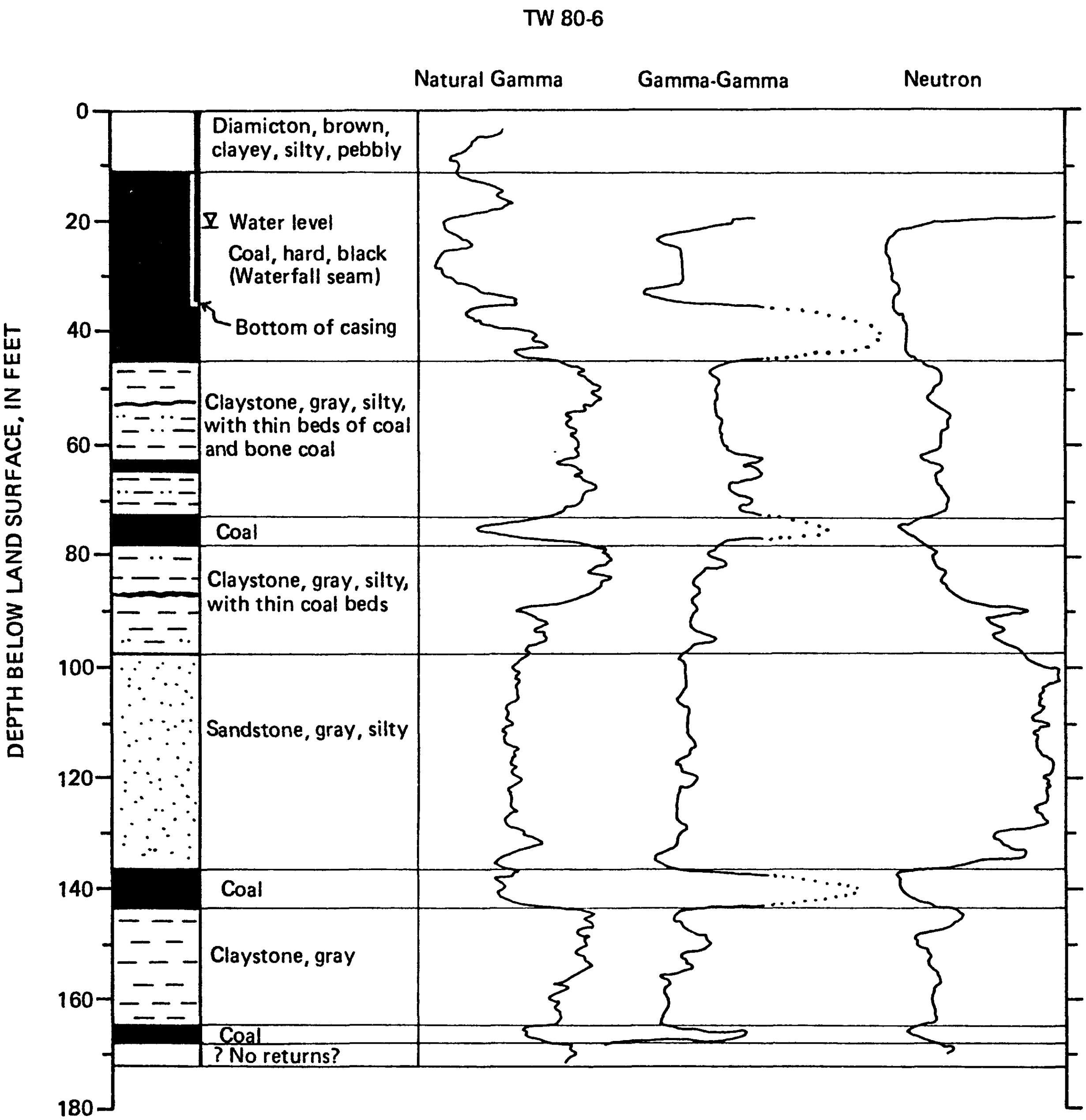


Figure 11.–Well and geophysical logs, TW 80-6.

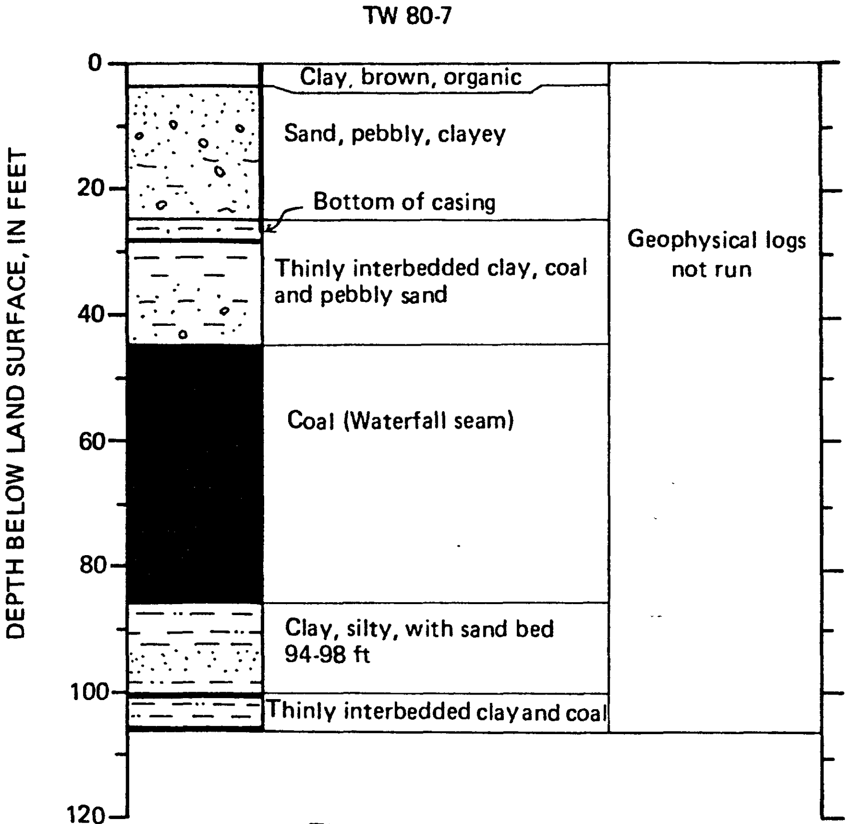


Figure 12.--Well log, TW 80-7.

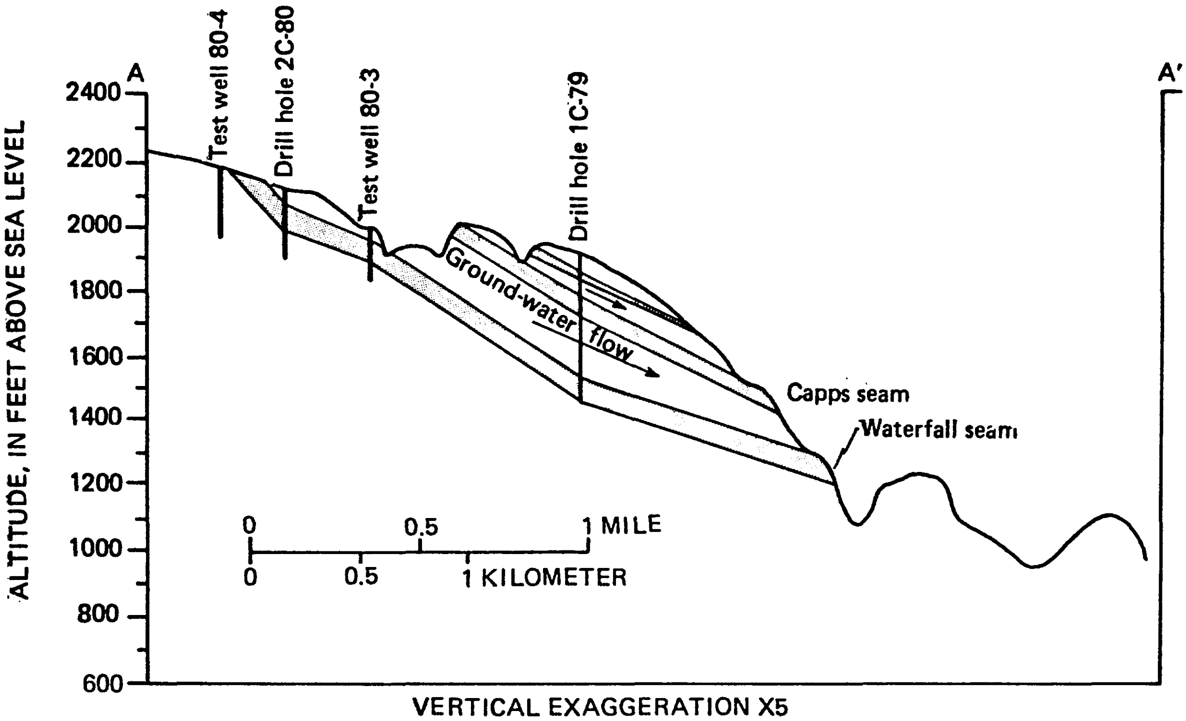


Figure 13.--Geologic section through Capps field. Section is along A-A' in figure 4.

No formal aquifer tests were made. However, the drawdown in TW 80-6 was measured as the well was being pumped (fig. 14) to collect a sample for analysis of water composition. The pumping rate was 5 gal/min and the pumped aquifer(s) were between the bottom of the casing (35 ft) and a packer inflated 92 ft below land surface. Water derived from storage in the casing was a significant part of pumpage during the test. Analysis of the data by the method of Papadopulos and Cooper (1967) accounts for casing storage. The method cannot be used to analyze the storage coefficient of the aquifer, but a small range of values for transmissivity can be calculated for all reasonable values of the storage coefficient (or a , which is the storage coefficient times a factor that is approximately unity). The "F(u,B)=1" match for the greatest and least possible a curves can be used to calculate a range of possible values for transmissivity (fig. 14). It appears that the transmissivity of the 57-foot interval of sediments is within the range of 15 to 46 ft^2/d.

No other aquifer tests were made, either because the yields were too low to sustain a useful pumping rate or because the packer could not be set. However, because TW 80-6 had a good yield compared to the other wells, it is unlikely that other aquifers had transmissivities greater than the upper limit of that in TW 80-6, about 50 ft^2/d.

In most wells, heads decreased with depth. In TW 80-3 and drill hole 2C-80, water could be heard cascading down the well from a shallow aquifer to a lower aquifer. In wells TW 80-2 and TW 80-7 the water levels were 10 ft and 12 ft, respectively, below both the level of the nearby stream and the saturated materials near the stream. At TW 79-2, the low-yield aquifers within 100 ft of land surface were perched over deeper, unsaturated materials.

In TW 80-4, yield of the well was insufficient to determine the heads in any specific units, and in TW 80-6, no change in head with increasing depth could be verified. Only in TW 80-5 was the head increasing with depth. TW 80-5 is outside the area to be mined and is located near the base of a steep slope bordering an upland plateau that is 500 ft above the altitude of the well.

All wells were cased through the first unit that yielded water, thus precluding measurements of the water table. However, saturated materials commonly occur at shallow depths. In sedge bogs, which are widely scattered throughout the area, the water table is at land surface except during prolonged periods of dry weather. During drilling, small amounts of seepage that commonly entered the wells at the base of the unconsolidated materials also indicate saturated materials at depths less than 10 ft.

Numerous springs that feed Capps Creek and its tributaries at altitudes above 1,800 ft cannot obtain water from Tertiary aquifers, in which heads are 10 ft or more below land surface. The most probable sources of water to the springs are sedge bogs and colluvial or glacial aquifers overlying Tertiary sediments.

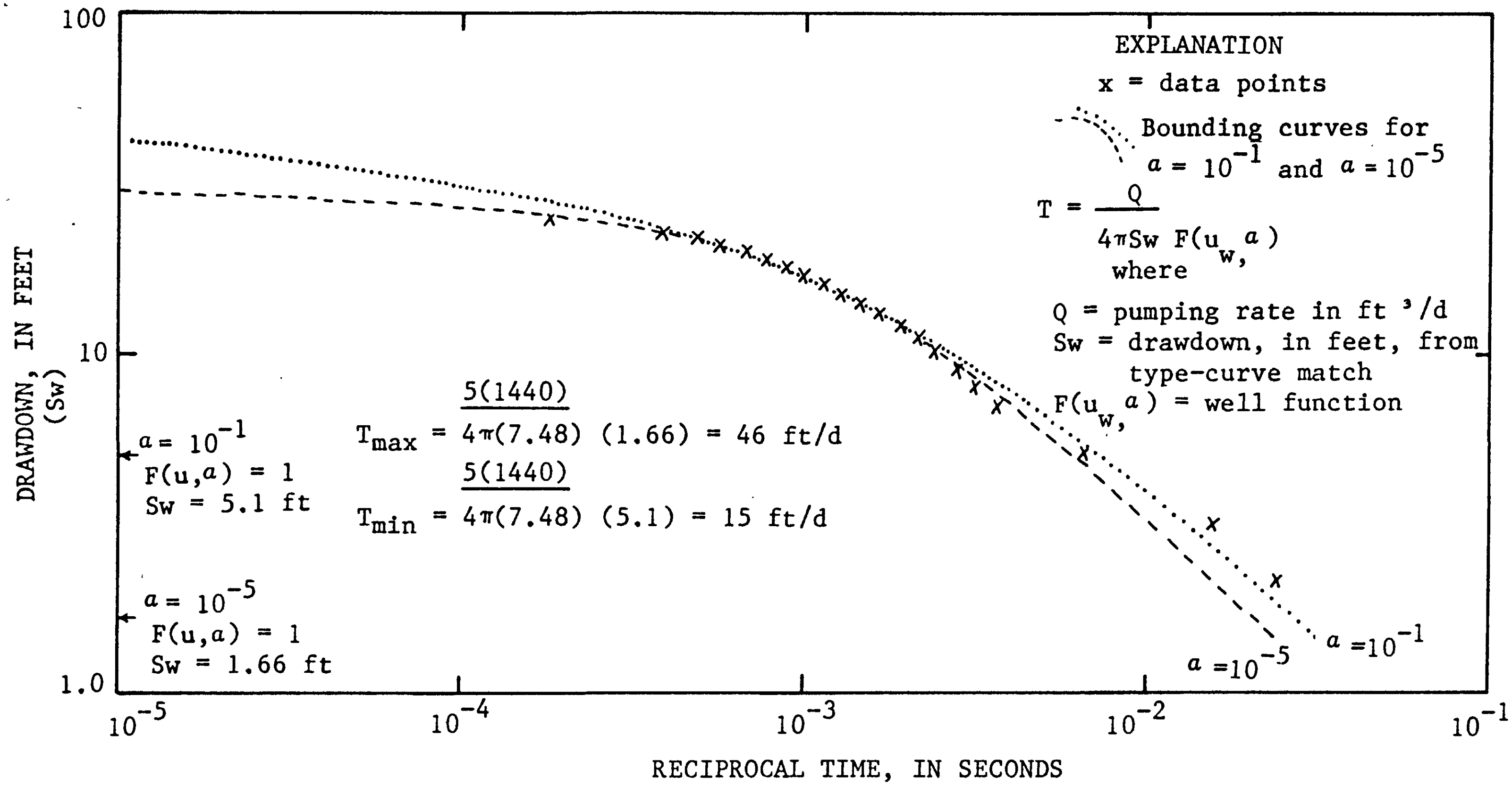


Figure 14.--Drawdown data for TW 80-6 superposed on type curves of Papadopulos and Cooper (1967). Pumping rate is 5 gal/min.

GROUND-WATER QUALITY

Test wells 79-2 and 80-4 and drill hole 1C-79 did not yield enough water to sample. All other wells were sampled in July 1981. Air-inflatable packers were used to isolate zones in each well. The wells were pumped using a 3-inch submersible electric pump. Temperature, specific conductance, and pH were monitored during pumping, and no samples were collected until all three properties were no longer changing with time. In some wells, differences in pH values and specific conductances indicated compositionally different water in shallow and deep water-producing zones. Where this occurred, both zones were sampled. If deep and shallow zones indicated similar values of pH and specific conductance, the packer was deflated and the well was sampled as a composite of all water-producing zones. All samples had a hydrogen-sulfide smell; however, after aeration none were objectionable for drinking. Table 1 lists results of analyses of the samples.

All trace metal concentrations are less than the maximum concentrations recommended for drinking water (U.S. Environmental Protection Agency, 1977). Zinc is the only trace metal present in concentrations greater than 10 μg/L. However, it was not ascertained whether the zinc occurred naturally or if it was derived from galvanized pipe in the wells.

The sample from TW 80-5, the only well drilled outside the area of the proposed mine, appears to differ significantly from the other samples. It has a much higher pH than the others (8.4) and the second highest concentration of dissolved solids (154 mg/L). The sodium concentration is anomalously high and the calcium anomalously low compared to the other samples.

Specific conductance, a general indicator of concentration of dissolved solids, was greater than 53 μS/cm in all samples from Tertiary aquifers. Springs that discharge ground water from the Tertiary aquifers should also yield water of specific conductance greater than 50 μS/cm. The author made a traverse up the streambed of Capps Creek from about 100 ft stratigraphically below the base of the Waterfall seam to a point stratigraphically near the top of the Waterfall seam about 400 ft northwest of TW 80-3. Many springs were sampled during this traverse, but none yielded water having specific conductance greater than 24 μS/cm. This evidence indicates that the relatively high conductance ground water is not discharging in significant quantities in the area of the proposed mine and that the springs appear to be fed by aquifers containing water more dilute than the Tertiary bedrock. These different aquifers are probably sedge bogs and thin unconsolidated deposits overlying the Tertiary sediments. Bog deposits were not penetrated during drilling because they occur in areas where foundation conditions are not good for setting up a drill rig without causing significant environmental damage.

CONCLUSIONS

Coal, sandstone, and conglomerate units of generally low hydraulic conductivity commonly yield water to wells but may be unsaturated near their outcrops. Based on the small amounts of subsurface information, only the Waterfall seam could be identified as an area-wide aquifer. An aquifer test of sediments that included the Waterfall seam indicated a transmissivity of less than 50 ft^2/d. Sedge bogs and thin discontinuous glacial aquifers probably yield ground water to springs that sustain baseflow in the mine area. Heads in the deeper bedrock aquifers are commonly below land surface, and deep aquifers do not contribute to baseflow of streams in the mine area.

Table 1.—Analyses of ground-water samples from Capps coal field

Well	TW 80-2	TW 80-3	TW 80-3	TW 80-5	TW 80-6	TW 80-6	TW 80-7
Depth of sample (ft)	32-64	47-98	98-151	88-155	37-95	95-168	26-90
Date (1981)	7-14	7-14	7-14	7-12	7-8	7-8	7-15
Specific conductance (µS/cm at 25°C)	104	97	107	218	163	247	53
Temperature (°C)	4	4	4	4	4	4.5	4
pH (units)	5.7	5.6	5.6	8.4	6.5	6.8	5.3
Dissolved solids (resid. at 180°C)	76	71	80	154	110	161	53
Silica (mg/L)	14	14	14	23	24	20	13
Alkalinity (mg/L as $CaCO_3$)	55	54	61	126	88	108	34
Dissolved major ions (mg/L)							
Calcium	13	12	12	1.8	14	11	9.0
Magnesium	2.0	1.9	1.8	.3	1.7	1.3	1.1
Sodium	11	7.4	11	55	20	35	3.4
Potassium	.6	.5	.6	.3	.6	.7	.4
Sulfate	2.3	2.1	1.6	3.0	1.5	1.4	3.3
Chloride	10	.3	1.1	.8	.2	.3	.4
Fluoride	.0	.0	.0	.1	.0	.0	.0
Nitrate + nitrite	.05	.01	.02	.02	.02	.28	.01
Dissolved trace metals (µg/L)							
Arsenic	3	2	2	0	1	2	3
Cadmium	0	0	0	0	0	0	0
Chromium	10	0	0	10	10	0	0
Copper	0	0	0	0	0	0	0
Lead	1	0	2	1	0	1	0
Mercury	.1	.1	.1	.1	.1	.1	.1
Selenium	0	0	0	0	0	0	0
Zinc	50	20	40	10	30	10	20

Both ground water and surface water are of drinking-water quality. However, aeration of ground water to remove a hydrogen sulfide odor is usually desirable. The concentration of dissolved solids in ground water appears to increase with the depth of wells, but did not exceed 161 mg/L in any of the samples. Surface water is much more dilute; concentration of dissolved solids probably does not exceed 60 mg/L at lowest baseflow during late winter.

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