HYDROLOGY OF THE PRAIRIE DOG CREEK DRAINAGE BASIN, ROSEBUD AND BIG HORN COUNTIES, MONTANA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 81-37

Report prepared on behalf of the

U.S. BUREAU OF LAND MANAGEMENT

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16. Abstract (Limit: 200 words)

The Prairie Dog Creek drainage basin in southeastern Montana was investigated during 1978-79 to establish a basic understanding of the surface-water and ground-water resources and the quality of water in an area having coal-mining potential. The principal mineable coal is the 40- to 60-foot thick Wall and lower Wall coal beds near the middle part of the Tongue River Member of the Fort Union Formation (Paleocene age). Prairie Dog Creek, which originates from springs and seeps from coal and sandstone layers, maintained perennial flow in the upstream and middle reaches then lost flow until the channel near the mouth had only standing water or was dry. The dissolved-solids concentration of streamflow during periods of high flow (1 ft^3/s) ranged from 700 to about 1,000 mg/L and during periods of lesser flow (0.5 ft^3/s) ranged from 1,300 to 1,600 mg/L. Relatively clean sandstone aquifers had transmissivities of about 15 ft^2/d and water of magnesium sulfate or sodium sulfate type, with dissolved-solids concentration ranging from about 2,170 to 3,260 mg/L. The Wall coal aquifer had transmissivities of from 2.5 to 65 feet squared per day; the water was of a sodium sulfate type and ranged from 1,820 to 4,190 mg/L. The Brewster-Arnold coal aquifer had transmissivities similar to the Wall coal but different water type, sodium bicarbonate; the water contains large concentration of fluoride (more than 10 mg/L) and a very high sodium-adsorption ratio (more than 60).

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Front cover: Photograph of trail crossing Prairie Dog Creek, 4 miles upstream from the mouth. View is northwest toward upper end of the basin. Photograph taken in April 1979

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METRIC CONVERSION TABLE

The following factors can be used to convert inch-pound units in this report to the International System (SI) of metric units.

Multiply inch-pound unit	By	To obtain SI unit
	Length	
foot (ft)	0.3048	meter
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer
	Area	
acre	0.4047	square hectometer
square mile (mi^2)	2.590	square kilometer
	Volume	
acre-foot	1233	cubic meter
	Flow	
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	5.454	cubic meter per day
mile per hour (mi/h)	1.609	kilometer per hour
	Gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day
	Specific conductance	
micromho per centimeter at 25° Celsius (µmho/cm)	100	microsiemens per meter at 25° Celsius

temperature in degrees Fahrenheit (°F) can be converted to temperature in degrees Celsius (°C) by the formula:

$$°C = 0.556\ (°F - 32)$$

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

The Prairie Dog Creek drainage basin in southeastern Montana was investigated during 1978-79 to assess the surface-water and ground-water resources and the quality of water in an area having coal-mining potential. The area, a 24.2-square-mile basin, is located 30 miles southwest of Ashland, Montana. The principal mineable coal is the 40-to 60-foot-thick Wall and lower Wall coal beds near the middle part of the Tongue River Member of the Fort Union Formation (Paleocene age). Other possibly mineable intervals are the Canyon coal bed lying 200 to 250 feet above the Wall, and the Brewster-Arnold coal bed lying about 220 feet below the base of the Wall coal beds.

The hydrologic regime in the basin is composed of Prairie Dog Creek and sandstone, coal, clinker, and alluvium aquifers. Prairie Dog Creek, which originates from springs and seeps issuing from coal and sandstone layers, maintained perennial flow in its upstream and middle reaches during 1978 and 1979. In its downstream reach, the flow decreased consistently until the channel near the mouth had only standing water or was dry. The dissolved-solids concentration of streamflow during periods of high flow (1 cubic foot per second or more) in the spring months ranged from 700 to about 1,000 milligrams per liter and during periods of lesser flow (0.5 cubic foot per second or less) in the summer ranged from about 1,300 to 1,600 milligrams per liter.

Forty-two cased observation wells were used to obtain data on aquifer characteristics and quality of water. Relatively clean (free of silt or mud) sandstone beds have transmissivities of about 15 feet squared per day; the water was a magnesium sulfate or sodium sulfate type and dissolved-solids concentrations ranged from about 2,170 to 3,260 milligrams per liter. The Wall coal aquifer has transmissivities ranging from 2.5 to 65 feet squared per day; the water was a sodium sulfate type and dissolved-solids concentrations ranged from 1,820 to 4,190 milligrams per liter. The Brewster-Arnold coal aquifer has transmissivities similar to those of the Wall coal but the water was a sodium bicarbonate type; the water contained an excessive concentration of fluoride (more than 10 milligrams per liter) and had a very high sodium-adsorption ratio (more than 60).

The alluvial aquifer in the Prairie Dog Creek valley has transmissivities ranging from about 1,000 to 5,000 feet squared per day in the middle reaches and as much as 9,200 feet squared per day near the mouth of the creek. The water quality changed from a magnesium sulfate type in the middle reaches to a sodium sulfate type near the mouth. The dissolved-solids concentration decreased from about 1,700 milligrams per liter in the middle reaches to about 1,100 milligrams per liter near the mouth as inflow of water from clinker and alluvial deposits beneath terraces diluted the alluvial water.

INTRODUCTION

Location

The Prairie Dog Creek drainage basin is located in southeastern Montana, on the west side of the Tongue River, 12 miles north of the Tongue River Reservoir and 30 miles southwest of Ashland (fig. 1). The nearest town is Birney, which is 6 1/2 miles northeast of the mouth of Prairie Dog Creek. The downstream and middle parts of the basin are in Rosebud County and the upstream part is in Big Horn County; the headwaters of the north fork of the creek are within the Northern Cheyenne Indian Reservation.

Purpose and scope

This study was conducted by the U.S. Geological Survey at the request of the U.S. Bureau of Land Management. The investigation is part of a series of Energy Mineral Rehabilitation Inventory and Analysis studies in States with Federal lands that have coal-mining potential and that are managed by the Bureau of Land Management.

The project, which was begun in July 1978, included obtaining data on rainfall, surface water, ground water, and quality of water. The work was directed toward assessing the pertinent characteristics and conditions of the hydrology. The purpose of this report is to present the data collected and to define the occurrence, distribution, and chemical quality of the waters in the area.

From August 1978 through July 1979, 34 test holes and observations wells were drilled by the Montana Bureau of Mines and Geology and 12 cored test holes, 5 of which were cased for water-level monitoring, were drilled by the U.S. Bureau of Reclamation. Information from 13 test holes (1 of which was cased), which were previously drilled by the Montana Bureau of Mines and Geology and the Geological Survey, and two existing private wells also was used. A continuous-recording streamflow-gaging station (Prairie Dog Creek near Birney; station 06307528) was constructed during October 1978 and put in operation in April 1979; the station is located 3.3 miles upstream from the mouth of Prairie Dog Creek. A continuous-recording streamflow-gaging station (Prairie Dog Creek above Jack Creek, near Birney; station 06307525) was installed about 9 miles upstream from the mouth. These stations are just outside the probable mining area, at locations upstream and downstream from outcrops of the Wall coal bed, the principal coal unit in the drainage basin.

Beginning in August 1978, or as the surface-water structures or observation wells were completed, data were collected semiweekly or monthly. Aquifer tests were conducted on most of the observation wells. Water samples were collected from the pumped wells and from streams and springs for chemical analyses by the Montana Bureau of Mines and Geology laboratory in Butte or by the Geological Survey's water-quality laboratory in Denver, Colo.

Reconnaissance study and drilling were done in the Spring Creek drainage basin to the south and the Bull Creek drainage basin to the north to gain a more complete understanding of the hydrology in the study area. Local landowners were consulted to obtain data for the few existing stock wells in the study area and to learn the general history of the climate and water-use practices in the area.

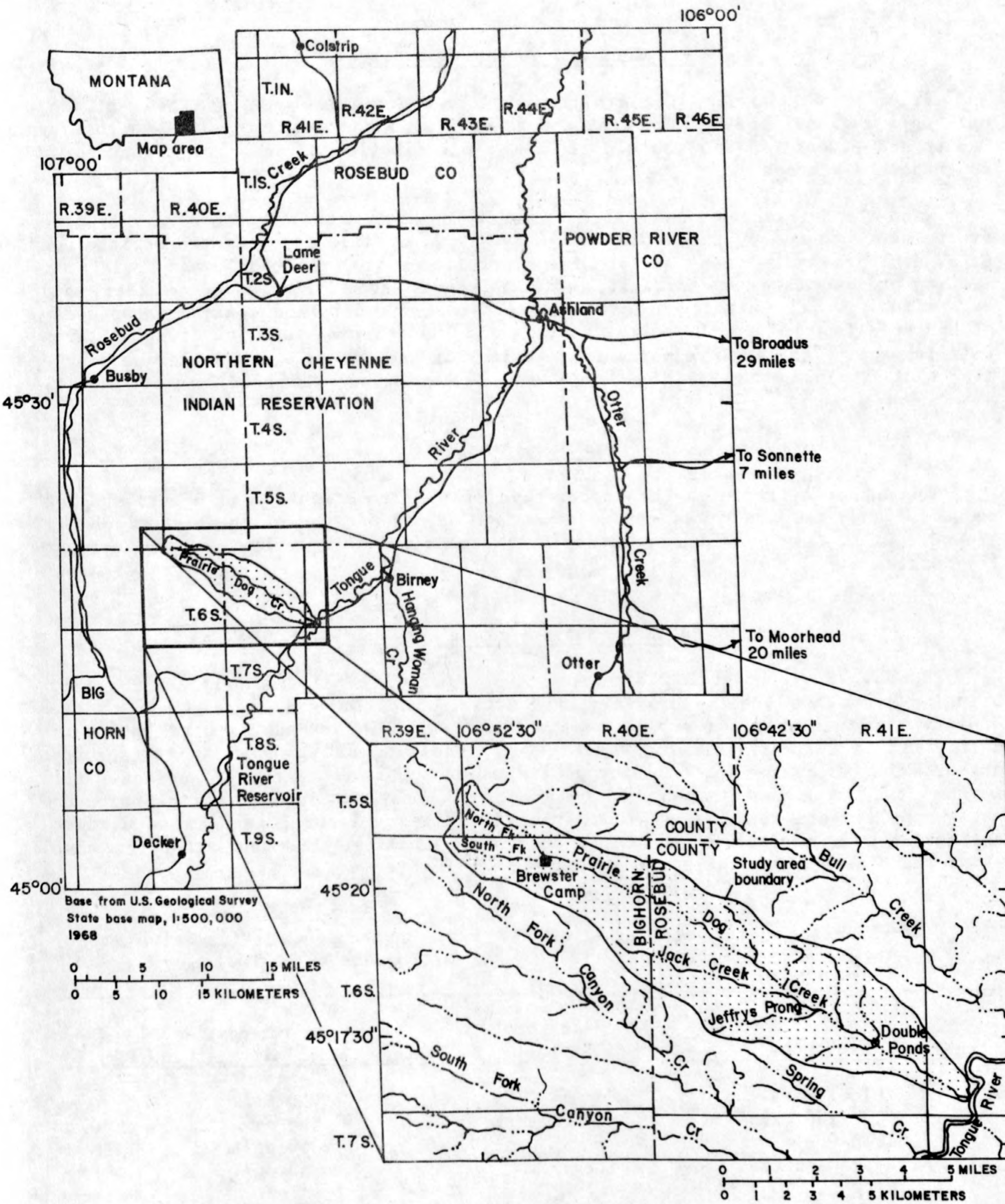


Figure 1.--Location of study area.

Previous and contemporary work

Prior to this study, the Prairie Dog Creek drainage basin had been studied only on a regional basis. The most comprehensive of the regional work was that by Matson and Blumer (1973), who described the distribution of the coal resources in southeastern Montana.

With the increasing interest in coal development, several contemporary studies are being conducted by the Geological Survey. L. E. Cary is using the Prairie Dog Creek drainage basin as an example for a detailed hydrologic model, and he is collecting precise data on rainfall, soil moisture, snow occurrence, weather, and streamflow. W. C. Culbertson is compiling data for a detailed coal-occurrence map of the area from 45° to 46° north latitude and 105° to 107° west longitude. Steven Volz is mapping the coal resources and geology of the two 1:24,000 scale quadrangle maps that include the Prairie Dog Creek basin--Birney SW and Taintor Desert.

Acknowledgments

The author appreciates the cooperation of William McKinney and Robert Ebeling on whose lands the study was conducted and who provided some of the historic background. L. E. Cary provided additional climatological, streamflow, and water-quality data.

Water-quality standards

The U.S. Environmental Protection Agency (1976, 1977), as part of the Safe Drinking Water Act (Public Law 93-523), established standards that apply to the quality of water used for public supply (table 1). The standards give both mandatory limits (primary drinking water regulations) and recommended limits (secondary drinking water regulations) for public water supplies. Although surface water in the study area is not known to be used for domestic purposes, various ground-water supplies are used. Thus, the standards give a measure that can be used to categorize both surface-water and ground-water supplies. Various standards also exist for other uses such as irrigation and stock watering.

Table 1.--Drinking water standards of the U.S. Environmental Protection Agency
[mg/L, milligrams per liter; µg/L, micrograms per liter]

Constituent	Mandatory limit	Recommended limit
Chloride (Cl)	--	250 mg/L
Fluoride (F)	[1]2.2 mg/L	--
Iron (Fe)	--	300 µg/L
Manganese (Mn)	--	50 µg/L
Nitrate (NO_3) as N	10 mg/L	--
pH	--	6.5 to 8.5
Sulfate (SO_4)	--	250 mg/L
Dissolved solids	--	500 mg/L

[1]Based on annual average maximum daily temperature at Birney.

Salinity hazards from dissolved solids pertaining to irrigation waters are dependent to a large extent on physical factors such as soil type, drainage condition, and crop type. The maximum limit for best crop growth is considered to be about 1,000 mg/L (milligrams per liter). The classification given in the following table, as modified from the U.S. Salinity Laboratory Staff (1954), commonly is used with respect to irrigation water:

Salinity hazard	Range in dissolved solids (milligrams per liter)
Low	Less than 170
Medium	170-500
High	500-1,500
Very high	More than 1,500

The ability of livestock to tolerate various concentrations of dissolved solids is dependent upon the type of stock as well as the period of adjustment to increased concentrations. Poultry, pigs, horses, cattle, and sheep in respective order have increasing degrees of tolerance to salinity. Arbitrary stockwater standards for Montana waters (McKee and Wolf, 1971) are shown below:

Category	Range of dissolved solids (milligrams per liter)
Good	Less than 2,500
Fair	2,500-3,500
Poor	3,500-4,500
Unfit	More than 4,500

SETTING

Drainage and topography

Prairie Dog Creek drains an area of 24.2 mi^2 from the drainage divide between Rosebud Creek and the Tongue River on the west to its mouth at the Tongue River. The drainage basin is virtually a straight, narrow valley that is 13 miles long and 1 1/2 to 3 miles wide. In the upper reaches, the stream consists of (herein called) the north fork and the south fork, which join 2 miles east of the divide. Jack Creek, a principal tributary on the south side of the basin, drains an area of 3.5 mi^2 and joins Prairie Dog Creek channel 4 1/2 miles upstream from the mouth. Jeffrys Prong, also on the south side of the basin, drains an area of 1.7 mi^2, and joins the main channel 4 miles upstream from the mouth. The remaining tributaries, from both the north and the south sides, drain areas of less than 1 mi^2.

The altitude of the divide between Rosebud Creek and the Tongue River ranges from 4,470 to 4,674 feet above sea level; the mouth of Prairie Dog Creek is about 3,185 feet above sea level. Generally, the relief between the valley and ridge crests ranges from 350 to 500 feet.

Climate

Wind and temperature

The climate in the Prairie Dog Creek area is typical of the northern Great Plains -- semiarid with warm summers, cold winters, moderate humidity, and generally little but variable rainfall. The winds are predominantly from the northwest, but during the spring, summer, and fall they commonly are from the southwest to west. Occasional and usually short-duration winds from the south and southeast also occur. The winds are slight most of the time; the average wind velocity is about 7 mi/h. The strongest winds, bringing the winter and spring storms, are almost invariably from the northwest.

Air temperatures vary from a monthly average of 21°F for January to 71°F for July at Colstrip, the nearest climatological station having long-term (48 years) temperature records. Average and extreme temperatures are presented in table 2 for the Birney and Colstrip stations. In general, the Colstrip temperatures are 2° to 3°F warmer than for Birney and the Prairie Dog Creek area and, at least at Colstrip, the 1978 average annual temperature was about 2°F cooler than average. The winter of 1977-78 was much colder than average, and this trend was continued during the winter of 1978-79. The monthly maximum and minimum temperatures are included in table 2 to illustrate the extreme variability of temperatures in southeastern Montana. The maximum or minimum values for any particular month did not necessarily occur on the same day at Colstrip and Birney.

Precipitation

The Birney 2 SW station is the nearest climatological station to the study area; it is 2 miles southwest of Birney and 5 miles northeast of the mouth of Prairie Dog Creek. The 23-year average annual precipitation (1955-69 and 1971-78) at the Birney station is 13.46 inches (table 3). The year of least precipitation was 1960 with 5.78 inches; the year of greatest was 1978 with 19.79 inches. At Birney and eight other precipitation stations in southeastern Montana from 1955 to 1978, the wettest years were 1968, 1971, 1975 and 1978; the driest years were 1959, 1960, 1961, and 1965. In general, years from 1956 through 1966 were drier than normal and from 1971 through 1978 were wetter than normal. Thus, this study was conducted after several years of greater than average precipitation and consequently greater than average recharge.

Long-term (more than 35 years) precipitation data are available from four stations near the study area: Broadus, Busby, Colstrip, and Lame Deer (table 3). Only Busby and Colstrip had records through the great drought of the 1930's; both indicate that the drought started in 1929 and ended in 1940 with 1932, 1933, and 1935 having precipitation that was near average or greater than average. The devastating effect the 1930's drought resulted from two 3-year periods (1929-31 and 1936-38) when the rainfall was significantly less than average. During the less severe drought of the 1960's, at most 2 years (1959-60) in succession had significantly less than average rainfall; in some local areas during 1965-66, the precipitation also was less than average. During 1959-61 some stations recorded slightly less than average precipitation.

The monthly average precipitation data from Birney and three nearby stations near the study area--Decker, Lame Deer, and Otter--are presented in table 4. Of the 13.46-inch average precipitation recorded at the Birney station, 6.61 inches fell from April through June--or 49 percent of the total during the 3 months. During the winter months, December through March, 2.00 inches fell--or 15 percent of the total. This relationship does not hold true every year. During 1979, for example, rainfall from April through June was 3.70 inches, which was about 40 percent of the 1979 annual rainfall. During all other years since 1955, precipitation from April through June was about one-half the total, except for 1960 when only 2.48 inches fell during these months; the 2.48 inches was more than 40 percent of the total during that year. During other years when the April to June rainfall was less than average, the amount received in July generally was sufficient to offset the earlier short drought.

Geomorphology

The Prairie Dog Creek valley was eroded by water during at least three major climatic cycles. No attempt was made to date the cycles. The upper terrace, representing the earliest cycle, becomes evident about 5 miles upstream from the mouth of Prairie Dog Creek, where its altitude is about 4,100 feet. Near the Tongue River level, two of the cycles are represented by a second (middle) terrace at an altitude of about 3,500 feet, and the present (lower) stream terrace at an altitude of about 3,350 feet.

The upper terrace slopes southeastward (downstream) toward the Tongue River at about 60 ft/mi. Other, secondary terraces seem to slope at about the same gradient. As viewed from small rises on the upper terrace, the ridgetops appear level for tens of miles to the southwest and northeast. The middle terrace, which also slopes southeastward, joins the stream terrace of Prairie Dog Creek at about the 3,900-foot topographic contour, 8 miles upstream from the mouth.

The lower terrace is a complex of two or three minor terraces formed as a result of the stream adjusting its course in an attempt to reach equilibrium between erosion and deposition. These minor terraces are vaguely defined along some stretches of the valley; elsewhere they are prominent. Under the lower terrace are alluvial-fill deposits that are 15 to 25 feet thick from Brewster Camp (sec. 3, T. 6 S., R. 40 E.) to the double ponds (sec. 26, T. 6 S., R. 41 E.) 2 1/2 miles upstream from the mouth (fig. 1). Based on test drilling, the deposits underlying the terraces thicken downstream to about 60 feet near the mouth; most of the thickening probably occurs within 2 miles of the mouth. The alluvial fill exists under the surface of the lower terrace from side to side of the valley--a width ranging from 900 to 1,500 feet from the mouth to 9 miles upstream (sec. 12, T. 6 S., R. 40 E.). From sec. 12 to Brewster Camp, the terraced valley ranges in width from 600 to 900 feet.

Flood plains along the stream channel are narrow from the upstream reaches to the mouth. Flood-plain widths exceeding 50 feet are rare. Along some reaches of the stream, the lower terrace is at about the level of the flood plain, forming an alluvial flat 300 to 600 feet wide. Many of these areas were cultivated during the time of homesteading (about 1910 to 1935), but are used as pastureland today.

Stratigraphy

All rock and coal outcrops in the Prairie Dog Creek drainage area are a part of the Tongue River Member, the uppermost member of the Fort Union Formation (Paleocene age). Typically in southeastern Montana, the Tongue River Member is a series of lenticular layers of sandstone, siltstone, mudstone, clay, carbonaceous shale, and coal. The coal beds are the most persistent units throughout the area, even though they thin or thicken in short distances. Siltstone and mudstone intervals in one test hole may be uncorrelatable with those in a test hole only 1 mile distant. Some sandstone and clay layers are fairly persistent in the Prairie Dog Creek area, but are unlikely to extend very far outside the area. An idealized section of the part of the Tongue River Member represented in the Prairie Dog Creek area is illustrated in figure 2.

The Tongue River Member was deposited in a continental environment in a slowly subsiding basin during early Tertiary time while the Big Horn Mountains to the southwest were rising. The Fort Union Formation is nearly 3,000 feet thick, and the maximum thickness of the Tongue River Member is at least 1,800 feet.

In the Prairie Dog Creek area, the coal-bed sequence in descending order is the Anderson, Dietz (?), Canyon, Cook, Wall, Pawnee, a local coal bed, and Brewster-Arnold (fig. 2). The Anderson coal bed occurs near the top of the Tongue River Member in the highest parts of the drainage. The Brewster-Arnold coal bed is just beneath the surface at the downstream end of the valley. According to correlation of oil-test logs in and near the area, the Brewster-Arnold is about 600 feet above the top of the Lebo Shale Member, which is the middle member of the Fort Union Formation. The principal mineable coal beds in the Prairie Dog Creek area are the Canyon, Wall, and Brewster-Arnold.

In the Prairie Dog Creek area the Tongue River Member dips slightly to the southeast. A broad, almost obscure, anticlinal nose approximately parallels the ridge between Prairie Dog and Canyon Creek valleys. Minor flexures and small faults exist, but most have little affect on ground-water movement through the area. The general dip of the beds is about 50 ft/mi (less than 1°) to the southeast, about the same as the slope and direction of the terraces in the area.

General hydrology

Aquifers in the Prairie Dog Creek area include: Variably permeable coal beds and sandstones of the Tongue River Member of the Fort Union Formation; burned coal beds and clinker on hilltops, hillsides, and under the alluvium of the valleys; alluvial sands and gravels along the larger stream channels. The Tongue River coal beds and sandstones are of Paleocene age. The clinker beds and alluvium are probably no older than Pleistocene and Holocene age. Older formations that may be water-bearing, such as the Cretaceous Hell Creek Formation, Fox Hills Sandstone, and deeper aquifers, are too far below land surface to be considered in this report. Any surface mining in the area will not reach the lower part of the Tongue River Member; thus, mining will not affect aquifers below the relatively impermeable Lebo Shale Member.

Of the variable lithologies in the Tongue River Member, only coal beds and clean permeable sandstone are considered to be aquifers, and only the coal-bed aquifers are laterally extensive throughout the study area. The sandstones, some

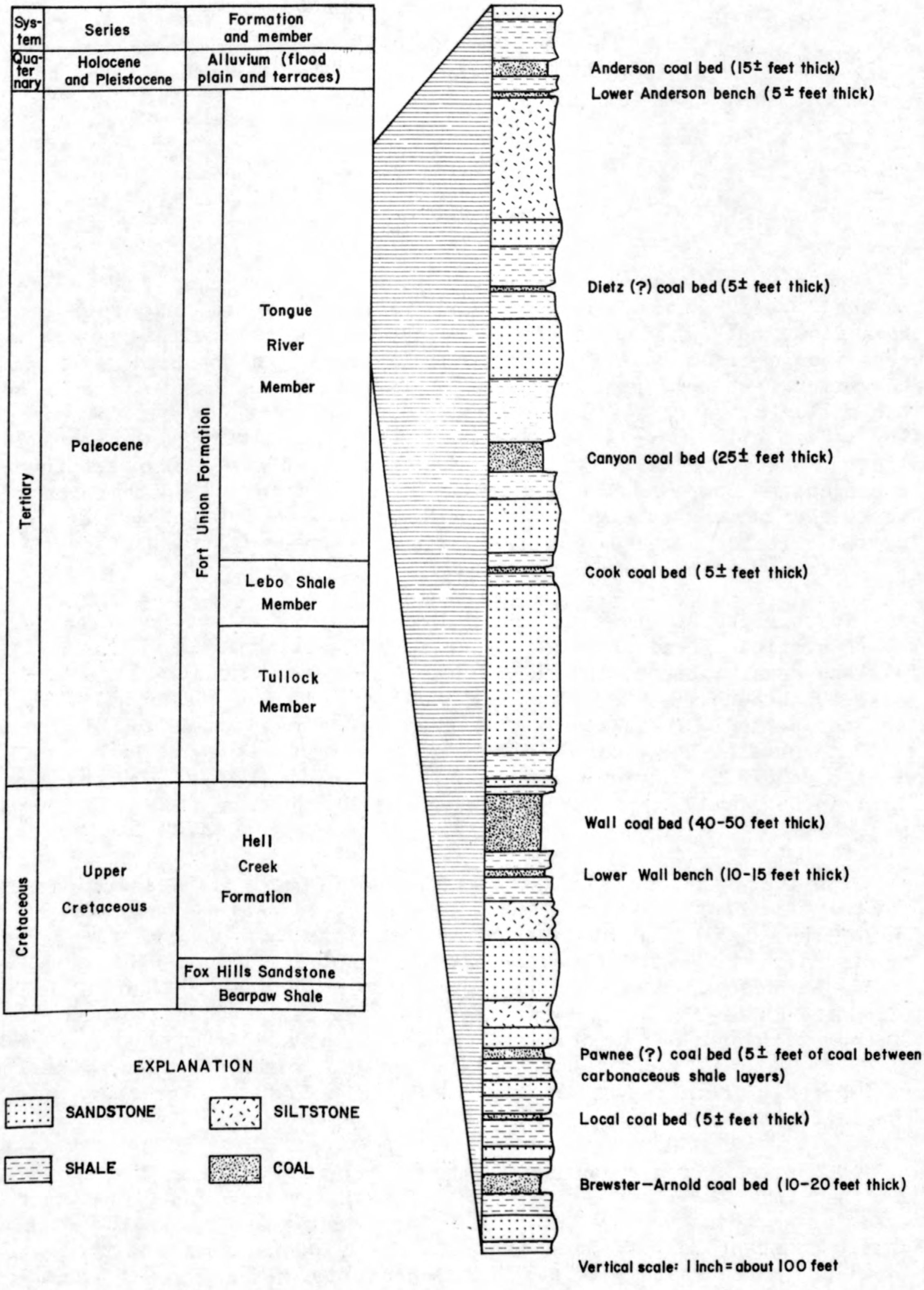


Figure 2.--Idealized section of the Tongue River Member of the Fort Union Formation in the Prairie Dog Creek area.

of which may be traced in outcrops the full length of the valley, are alternately relatively impermeable at one site and permeable at another site; therefore, sandstone is a reasonably fair aquifer only locally.

SURFACE-WATER RESOURCES

Stream discharge

Prairie Dog Creek, in the upstream and middle reaches, had perennial flow during the 1978-79 study period. Local ranchers report that during dry years the creek flows only in the upstream reaches. Base flow originates from springs and seeps issuing from coal and sandstone layers in the upstream and middle parts of the valley. At most places the spring discharge is decreased by seepage directly into colluvial materials or into the alluvium under the stream channels. Streamflow is probably affected somewhat by evapotranspiration, principally in the upstream reaches, but the extent of the effect has not been determined. Downstream from Brewster Camp, at the confluence of the north and south forks of Prairie Dog Creek, the base discharge in Prairie Dog Creek nearly doubles within 1 mile. The few tributaries have only small flows at the surface; most of the gain in flow is by seepage from alluvial materials.

Hydrographs of the daily mean discharge of Prairie Dog Creek at continuous-record stations 5 and 11 (fig. 3) during 1979 are shown in figure 4. In 1979, rainfall was never intense, but the spring thaws of an unusally large snowpack occurred April 10 through 20. This snowmelt, which recharged the upvalley aquifers, caused continuous flow in Prairie Dog Creek until early June. During the study period the discharge at the upstream site (Prairie Dog Creek above Jack Creek, near Birney; station 06307525) varied from 0.06 to 6.81 ft^3/s, and at the downstream site (Prairie Dog Creek near Birney; station 06307528) the flow ranged from no flow on many days to 78 ft^3/s on June 18, 1979, after a period of intense rainfall.

The instantaneous flow of Prairie Dog Creek was measured monthly at sites about 1 mile apart (fig. 3) from August to November 1978 and March through November 1979. The middle and downstream reaches were frozen dry from mid-November 1978 to mid-March 1979, and the upstream reaches were inaccessible and thus not measured. An approximation of the flow at selected periods during 1978 and 1979 is indicated in figure 5. Between measurement site 13 (downstream from the confluence of the north and south forks at Brewster Camp) and site 12 (1 mile downstream from site 13), the flow was increased by inflow from a series of small springs and spring-fed tributaries. Between sites 12 and 8, the creek maintained a nearly constant flow.

Downstream from measurement site 8, alluvium overlies the eroded Wall coal bed or its clinker. During spring runoff, from March into June, Prairie Dog Creek loses water along this reach. During the late summer and fall, the stream maintains a nearly constant flow between sites 8 and 7. Downstream from the Wall clinker zone (downstream from site 7 to the double ponds dam between sites 5 and 4; fig. 3), the stream gradually loses flow to the alluvial aquifer.

The double ponds between sites 5 and 4 are used for water storage. Where the lines between sites 5 and 4 are shown as discontinuous on figure 5, the water is not overtopping the dam but rather is seeping under it.

Downstream from the double ponds, the stream loses flow consistently until the channel has only standing water or is dry at sites 3, 2, and 1. In 1978, there was flow downstream from site 3 until mid-August. In 1979, the channel at site 3 contained no water after the snowpack thawed in March; by the end of April the stream was flowing at this site but it ceased by mid-July. No flow, except after intense rainstorms, was noticed at site 2 nor site 1; however, throughout the year seeps occur from the alluvial gravels for about 100 feet upstream from the mouth of Prairie Dog Creek. The seeps are solely the result of water discharged from the alluvium.

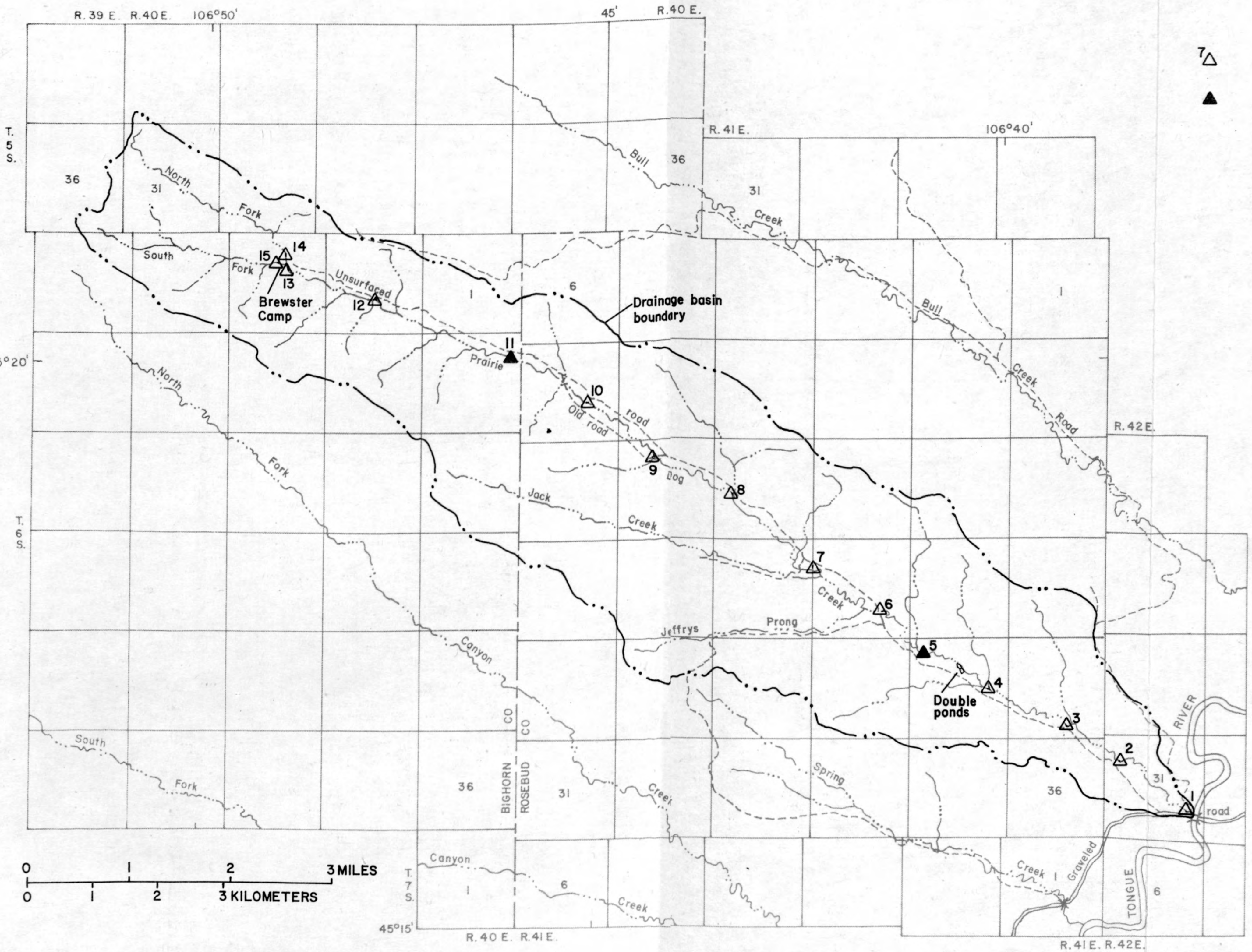
Springs

Most springs in the Prairie Dog Creek basin exist in the upstream reaches. The springs issue principally from the Anderson and some local coal beds down to the Canyon coal bed and from the more permeable sandstone beds. A few springs and seeps issue from the Canyon coal bed in the small tributary valleys on the north side of the valley downstream to within 2 miles of the mouth. Only small seeps were noted in Jack Creek and Jeffrys Prong valleys, although higher in the main valley some small springs occurred in smaller valleys on the south side. During periods of base flow, all flow past Brewster Camp is derived from seeps and springs along the north and south forks of Prairie Dog Creek.

Quality of surface water

Specific conductance and temperature of the water flowing in Prairie Dog Creek were monitored at each of the surface-water-discharge measurement sites (fig. 3) on a 2- to 4-week interval from August through early November 1978 and from March through October 1979 (fig. 6). During the summer and fall of 1978, the specific conductance of low flow was about 1,200 μmho/cm near Brewster Camp at the confluence of the north and south forks (site 13). Downstream, the specific conductance increased as more mineralized water from springs issuing from coal and sandstone aquifers flowed into the main channel; the largest increase occurred between sites 12 and 11. Apparently during periods of low flow, no more mineralized water reached the stream downstream from site 9; the specific conductance remained at about 1,800 μmho/cm or less downstream to beyond the double ponds. Downstream from the double ponds, the water in Prairie Dog Creek, which apparently represents water discharged from alluvium, had a specific conductance of slightly more than 1,700 μmho/cm at site 4. Downstream, this water seeps back into the alluvium. At the mouth, where the water emerges from gravels of the alluvium, the specific conductance was about the same--between 1,700 and 1,750 μmho/cm.

In 1979, during the spring runoff in April and May, the specific conductance of the water in Prairie Dog Creek at site 13 was about 1,100 μmho/cm. Again, as in 1978, the water became more mineralized between sites 13 and 11. Between measuring sites 11 and 9, apparently little water was contributed by springs or seeps; the specific conductance of the water was consistently about 1,400 μmho/cm. Between sites 9 and 8, where the influence of water from the Wall coal aquifer underlying the alluvium begins, the specific conductance rose to about 1,500 μmho/cm in May 1979. Later in the summer of 1979, the specific conductance increased each month as the discharge in the stream declined. By late October, the specific conductance of the stream water at Brewster Camp (site 13) was 1,200 μmho/cm, between sites 11 and 9 it had increased to about 1,800 μmho/cm, and downstream from site 8 the



EXPLANATION

7 △ STREAMFLOW-MEASUREMENT SITE AND NUMBER

▲ CONTINUOUS-RECORD STREAMFLOW-GAGING STATION

5 Prairie Dog Creek near Birney (station 06307528)

11 Prairie Dog Creek above Jack Creek, near Birney (station 06307525)

Figure 3.--Location of surface-water-discharge measurement sites.

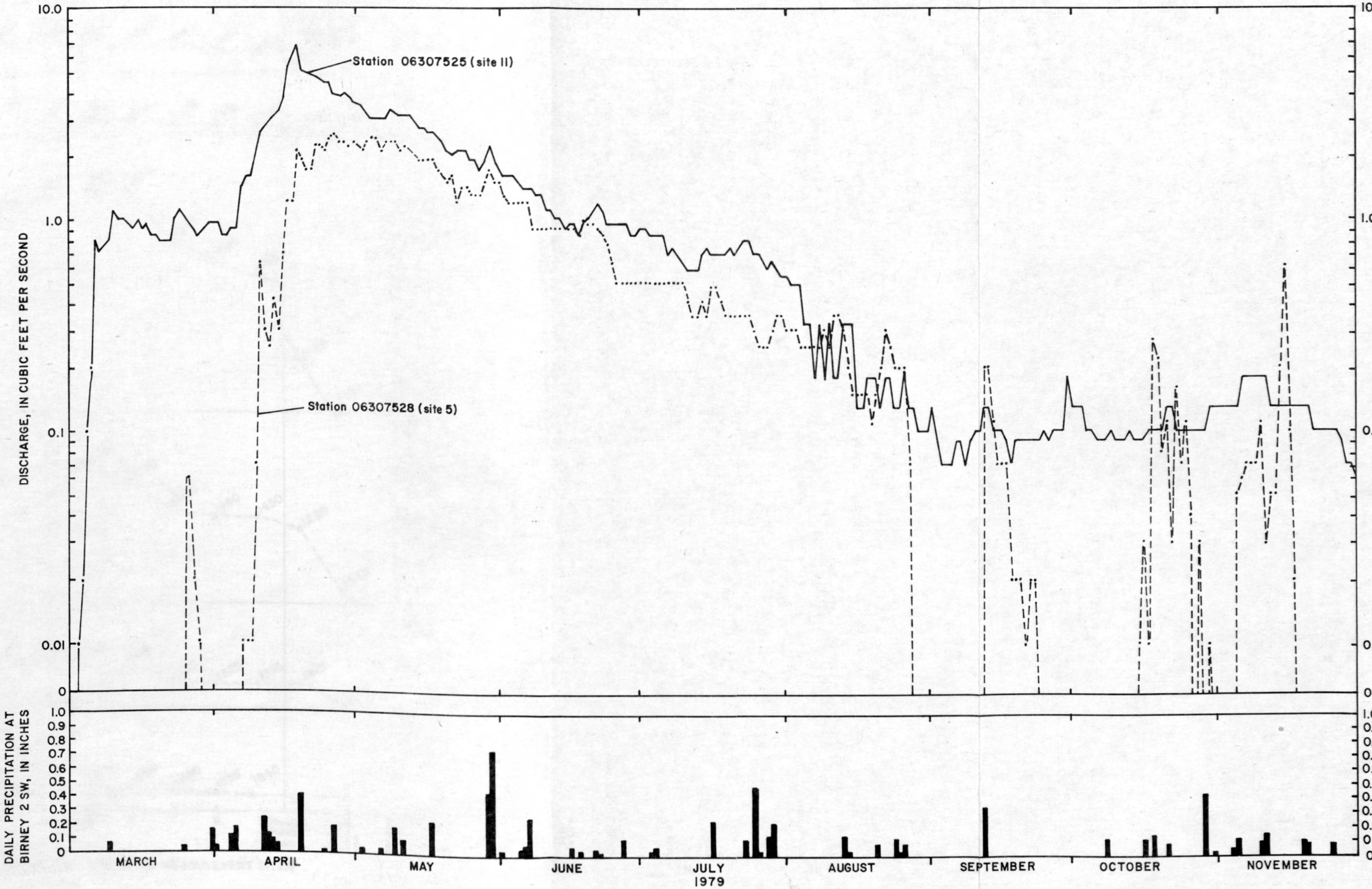


Figure 4.--Daily mean discharge of Prairie Dog Creek at continuous-record stations 5 and 11 during 1979. Daily precipitation data at the Birney 2SW station are shown for comparison.

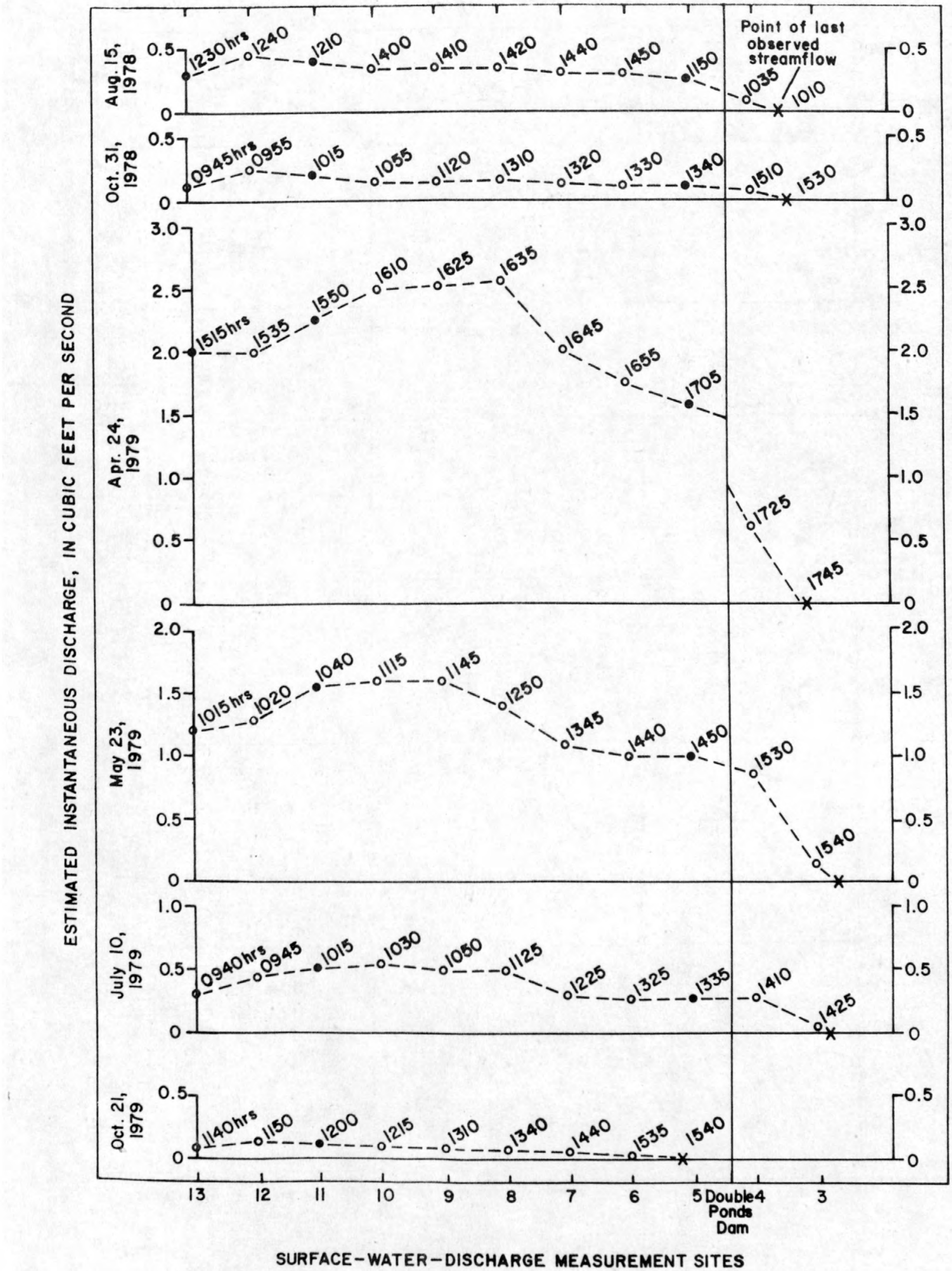


Figure 5.--Estimated flow of Prairie Dog Creek at various periods during 1978 and 1979, as determined at measurement sites. Open circle indicates estimated discharge and solid circle indicates measured discharge. The time of day of each measurement, in hours, is shown above the curves. Site 5 is streamflow-gaging station 06307528 and site 11 is station 06307525.

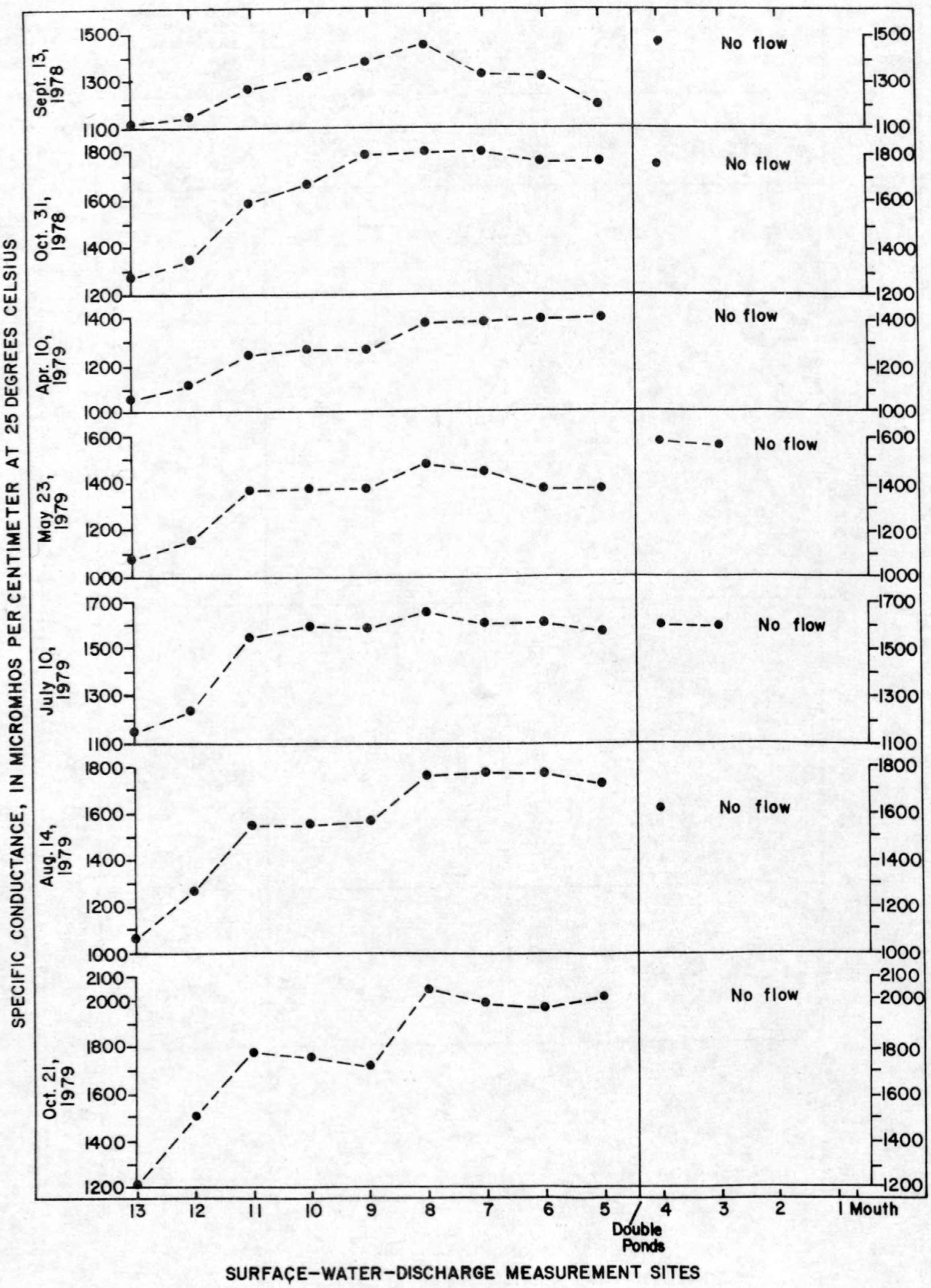


Figure 6.--Specific conductance of water flowing in Prairie Dog Creek at various periods during 1978 and 1979, as determined at measurement sites. Flow of stream at mouth not checked prior to May 1979. Site 5 is streamflow-gaging station 06307528 and site 11 is station 06307525.

conductance was about 2,000 μmho/cm. No flow occurred between the double ponds and measuring site 1 in late summer and fall of 1979, but the specific conductance of the water issuing at the mouth remained about 1,750 μmho/cm.

On August 3, 1978, water samples were collected 0.25 mile upstream from site 15 on the south fork of Prairie Dog Creek, 0.35 mile upstream from site 14 on the north fork, and at site 13 on the main stem downstream from the confluence. The stream was flowing at near base-flow conditions. According to the analyses (table 5), the water in the main stem (site 13) contained 810 mg/L of dissolved solids, and the main constituents were cations of magnesium (110 mg/L) and calcium (92 mg/L) and anions of bicarbonate (510 mg/L) and sulfate (300 mg/L). Water from the south fork (site 15) contained greater concentration of sulfate and less concentration of bicarbonate than water from the north fork (site 14). During periods of high flow in the spring when discharge is greater than 1 ft^3/s, the water contains principally the cations of calcium and magnesium and the anions of bicarbonate and sulfate. Magnesium generally occurs in slightly greater concentrations than calcium. During this time the hardness ranges from about 600 to 800 mg/L, the sodium-adsorption ratio ranges from about 0.5 to 1, and the dissolved-solids concentration ranges from about 700 to 1,000 mg/L -- generally increasing downstream. Later in the summer, when the flow in the stream is less than 0.5 ft^3/s, magnesium becomes the dominant cation and sulfate becomes the dominant anion. The hardness ranges from about 900 to 1,100 mg/L, the sodium-adsorption ratio is 1.0 or slightly greater, and the dissolved-solids concentration ranges from about 1,300 to 1,600 mg/L.

Between June 4 and 6, 1979, water samples were collected from Brewster Camp (site 13) downstream to the mouth of Prairie Dog Creek (site 1). Results of chemical analysis indicate a general downstream increase in most major constituents. The bicarbonate increased slightly from site 13 to site 11, then decreased from site 9 to site 5. The water contained principally magnesium and bicarbonate at Brewster Camp (site 13) but downstream the bicarbonate was replaced by sulfate as the dominant ion.

The water sampled (21 analyses) during 1978-79 from Prairie Dog Creek met the U.S. Environmental Protection Agency drinking water standards for all constituents except sulfate and dissolved solids. At measuring site 11, the sulfate concentration increased from 280 mg/L on April 19, 1979, to 670 mg/L on September 26, significantly greater than the recommended 250 mg/L. Downstream, at site 5, sulfate increased slightly--from 340 mg/L on April 19, 1979, to 750 mg/L on August 24. The dissolved-solids concentration all along the stream consistently exceeds the recommended 500 mg/L, becoming more than 1,000 mg/L along most of the stream during the late summer months. All trace constituents (three samples--two from site 11, one from site 5) were significantly less than the standard maximum contaminant levels of the U.S. Environmental Protection Agency (1977). Analysis was made for the following trace constituents: Arsenic, beryllium, cadmium, chromium, copper, fluoride, iron, lead, lithium, manganese, mercury, molybdenum, nickel, phosphorus, selenium, vanadium, and zinc.

The analyses show that the water generally becomes more concentrated with dissolved solids from spring, through summer, to fall. Water quality during the spring reflects the inflow of snowmelt and spring runoff. Water quality during the fall is dominated by ground-water discharge of springs and seeps to streamflow.

GROUND-WATER RESOURCES

Aquifers

The principal aquifers in the Prairie Dog Creek and adjacent areas are sandstone, coal, clinker, and alluvium. The locations of test holes and observation wells drilled into these aquifers are shown in figures 7 and 8. The relative vertical positions of the sandstone and coal beds are shown in figure 2.

Sandstone

Sandstone aquifers exist throughout the Tongue River Member of the Fort Union Formation, but they are not everywhere sufficiently coarse grained or clean (free of silt or mud) to be considered good aquifers. An interval that may be fairly coarse grained and clean in one locality can change laterally to become finer grained or contain increased silt, thereby decreasing its permeability.

One laterally extensive sandstone, from 20 to 50 feet thick, exists above the Canyon coal bed. This sandstone crops out in the low hills near Brewster Camp and near the ridges in the middle and downstream parts of the Prairie Dog Creek drainage basin. No test holes were drilled into this aquifer, but some seeps and springs issue from the sandstone in the upstream part of the basin.

The principal sandstone aquifer in the Prairie Dog Creek area exists about 30 feet above the Wall coal bed. This aquifer was penetrated by observation well 36-Ss on the drainage divide between Prairie Dog Creek and Spring Creek, where it consists of 73 feet of water-bearing sandstone. Other test holes and observation wells that were drilled through this sandstone penetrated more silt than in well 36-Ss; no other wells were screened in this interval.

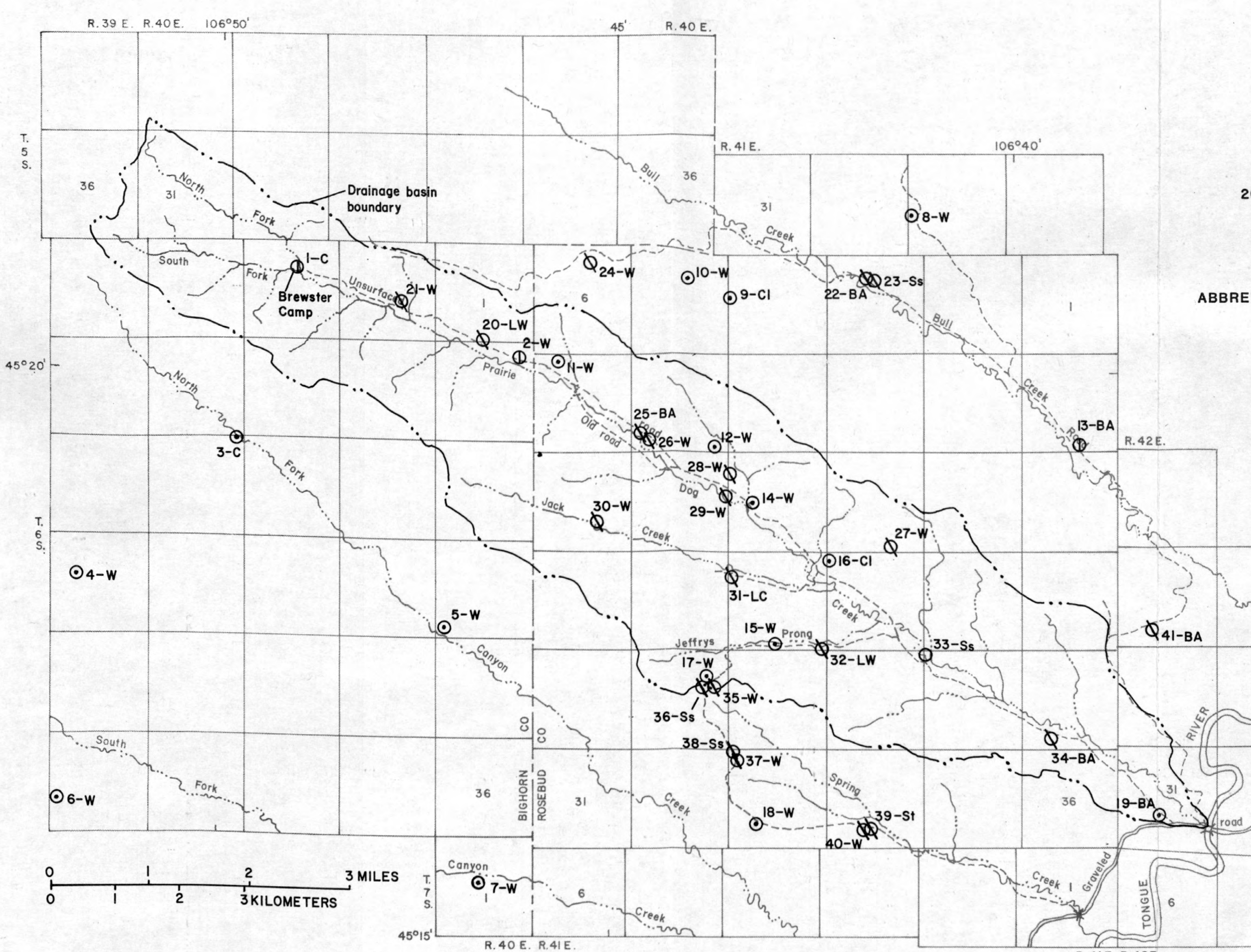
A clean fine-grained sandstone, 46 feet thick, was penetrated in observation well 23-Ss in the Bull Creek drainage basin. The sandstone occurs below the Wall coal bed, about 100 feet above the Brewster-Arnold coal bed. This sandstone interval was not recognized in the Prairie Dog Creek drainage basin in such a clean coarse-grained condition.

The only other observation well to be completed in a sandstone aquifer, well 39-St, is in the Spring Creek drainage basin. The perforations in this well are opposite siltstones and silty sandstones about 50 feet above the Brewster-Arnold bed.

Coal

The coal aquifers, in descending order, include:

1. The <u>Anderson coal bed</u> in the uppermost part of the drainage basin, at altitudes of about 4,300 feet, consists of two or more coal beds from 15 to 30 feet thick. The Anderson, as a unit, becomes thinner and less distinctive to the north; it is hardly recognizable as the massive, thick coal that is mined at Decker, 18 miles to the south.



EXPLANATION

INSTALLATION AND NUMBER

- 8-W ⊙ Test hole
- 1-C ⦶ Test hole; exact location undetermined
- 20-LW ⊘ Observation well; cased
- 33-Ss ○ Windmill

ABBREVIATED PRINCIPAL AQUIFER IN WELL NUMBER

BA	Brewster-Arnold coal bed
C	Canyon coal bed
Cl	Clinker material; burned coal and overburden
LC	Local coal bed
LW	Lower Wall coal bed
Ss	Sandstone
St	Siltstone
W	Wall coal bed

Figure 7.--Location of test holes, core holes, and observation wells completed in the Tongue River Member of the Fort Union Formation in the Prairie Dog Creek drainage basin and adjacent areas.

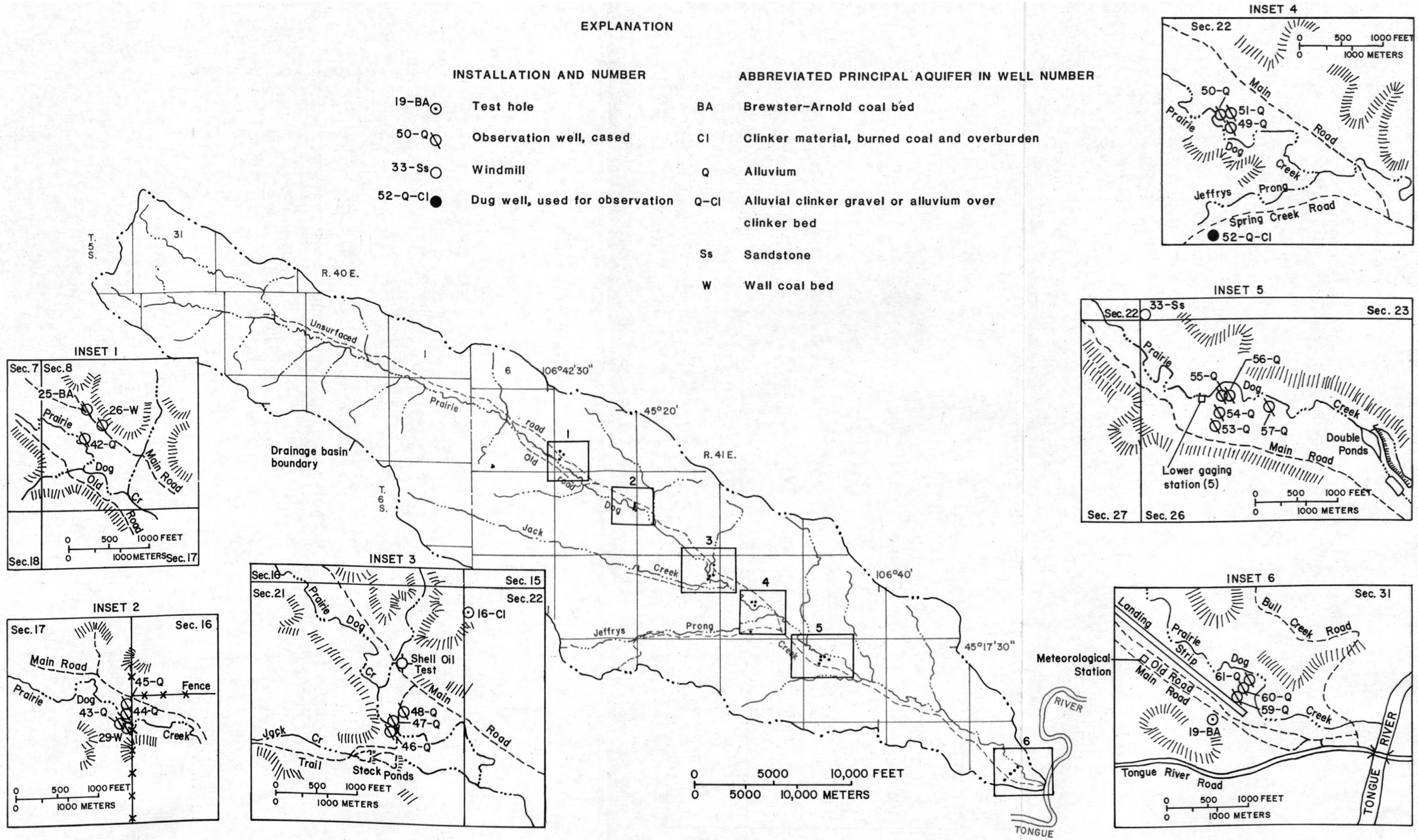


Figure 8.--Location of test holes and observation wells completed in alluvium. Locations of test holes and wells penetrating bedrock aquifers are shown for reference.

No test holes were drilled to the Anderson coal bed, and no definitive hydrologic information was collected. However, springs that contribute to flow of the north and south forks of Prairie Dog Creek upstream from Brewster Camp are known to issue from the interval.

2. A local coal, which may be the disseminated remnants of the Dietz coal bed that is prominent farther south, lies about 150 feet beneath the Anderson coal bed and 100 feet above the Canyon coal bed. In the Prairie Dog Creek area, this local bed is composed of about equal amounts of carbonaceous shale and coal. No test holes penetrated this interval.

3. The Canyon coal bed occurs at an altitude of about 4,050 feet in the upstream part of the basin, is from 20 to 30 feet thick near Brewster Camp, and is fairly massive and water bearing. Northward and eastward, the Canyon coal bed thins to less than 10 feet thick; southward, in the upstream reaches of Canyon Creek valley, the coal is consistently about 30 feet thick. The Canyon coal bed is just beneath the surface at Brewster Camp, occurs about halfway up the hillsides in the central part of the Prairie Dog Creek drainage basin, and forms clinker caps of the higher hills near the downstream end of the basin.

Test holes and observation wells 1-C, 3-C, 4-W, 6-W, 17-W, 24-W, 27-W, 35-W, and 36-Ss penetrated the Canyon coal bed, but none were screened in this interval (see tables 6 and 7). Springs and seeps issue from the Canyon coal bed in the upstream reaches of Prairie Dog Creek drainage basin; the coal is probably a major contributor to the increased streamflow immediately downstream from Brewster Camp (between measurement sites 13 and 12).

4. Two local coal beds, one 50 feet below the Canyon coal and the other 100 feet below (Cook), apparently tongue in and out of the sequence across Prairie Dog Creek valley. No observation wells were completed in those intervals.

5. The Wall coal bed, the principal mineable coal bed in the study area, is 40 to 63 feet thick, generally thinning northward, eastward, and westward. The thickest coal (63 feet) was found in cored test hole 17-W on the drainage divide between Spring Creek and Jeffrys Prong. In other wells east to northwest of the study area the Wall consists of a main bed from 40 to 50 feet thick and a lower bed from 10 to 15 feet thick. The two coals are separated by a 5- to 15-foot layer of carbonaceous shale interbedded with thin sandstone lenses. The Wall coal bed generally is separated from the Canyon coal bed by mudstone, shale, and sandstone 260 feet thick to the south and less than 200 feet thick to the northwest. A fairly persistent sandstone, as much as 100 feet thick, is present above the Wall coal bed in most of the Prairie Dog Creek basin.

Casings in 10 of the observation wells were perforated opposite the Wall coal beds and casings in 2 additional wells were perforated opposite the lower Wall beds. Aquifer tests were conducted in all but the cored observation wells and well 21-W, which had little water at the base of the Wall section. The only identifiable springs issuing from the Wall are from the lower Wall. Undoubtedly, the Wall coal beds and clinker layers transmit water into the colluvial and alluvial deposits along every line of outcrop, but the springs or seeps were not observed at the surface.

6. Local coal beds (one of which may be correlatable with the Pawnee coal bed of other areas) at about 120 and 170 feet beneath the base of the Wall coal bed are

fairly persistent in the study area, although at some places they grade to carbonaceous shale. The lower of these coal beds is penetrated by observation well 31-LC. No springs were observed issuing from these two coal layers.

7. The Brewster-Arnold coal bed is 10 to 20 feet thick, generally thicker to the southeast and thinner to the north and west. At the southeast end of Prairie Dog Creek valley, the Brewster-Arnold is about 200 feet beneath the base of the Wall. Upvalley at well 25-BA, about 7 miles to the northwest, the intervening material thickens to more than 250 feet. The intervening material consists of mudstone, siltstone, and shaly sandstone, evidently all with minimal permeability in the Prairie Dog Creek drainage.

Four observation wells are completed in the Brewster-Arnold coal bed. Wells 22-BA, 34-BA, and 41-BA were installed with 4-inch casing and were test pumped; well 25-BA was installed with 2-inch casing and was used for water-level observation only. The Brewster-Arnold coal bed lies beneath the surface throughout the Prairie Dog Creek area; it is exposed at the lower end of the Bull Creek drainage basin and along the Tongue River downstream from the mouth of Prairie Dog Creek.

Clinker

Burned coal and scorched overburden overlie all the principal coal beds on the ridges and hillsides throughout the area. These are significant recharge areas for rainfall and snowmelt. Three wells were drilled in attempts to obtain water at the base of the clinker--all were unsuccessful. Test hole 16-Cl, on the north side of Prairie Dog Creek drainage basin opposite the mouth of Jack Creek, was drilled with thick mud, so if water-bearing material was penetrated it was not evident; drilling was stopped above the base of the clinker because of caving material, and the hole was abandoned. Well 9-Cl on the south side of Bull Creek drainage had a similar problem. In well 32-LW, on the south side of Jeffrys Prong drainage, the potentiometric surface was below the clinker and the well was completed in the unburned lower Wall coal bed.

Observation well 58-Q-Cl was drilled to check colluvial materials on the south side of Prairie Dog Creek valley about 2 miles upstream from the mouth. This well probably penetrated either clinker beds or colluvial material directly connected to clinker beds. No aquifer test was conducted, because the water level in the well was too close to the bottom for pumping to be effective when tests were attempted during October 1978 and 1979. A water sample was obtained, though, for chemical analysis.

Clinker material, because of its open, fractured condition, is very permeable. No springs were located along the base, however, because of the talus and rubble cover. Springs issue from the lower Wall beds, which are overlain by thick clinker beds at several sites; much of this water probably comes directly or indirectly from the overlying clinker beds. In other areas, water from the clinker apparently moves through the talus or colluvial material and down into the alluvial aquifer without reaching the surface.

Alluvium

Only the alluvium under the Prairie Dog Creek valley was investigated. In most of the side valleys, such as Jeffrys Prong and the small unnamed tributary valleys, only a thin alluvial cover overlies the Tongue River Member. Some minor tributary valleys, however, are eroded through thick terraces. Jack Creek valley has alluvial muds and sands in places, but outcrops of the Tongue River Member exist in the stream channel at many places.

An extensive drilling program was conducted in Prairie Dog Creek valley and observation wells were installed. Eighteen wells were completed in the alluvium in six localities -- from 7 miles upstream to within 0.5 mile of the mouth (fig. 8). Aquifer tests were conducted on most of these wells and at all but one of the localities. The locality not tested was in the area of wells 49-Q, 50-Q, and 51-Q, about 4 miles upstream from the mouth.

The alluvial material along the Prairie Dog Creek valley is composed of silt, sand, and gravel from 20 to 25 feet thick for most of the valley length. The gravels are fairly thick in many areas and are very permeable in some localities. At almost all localities, a well yielding 15 to 20 gal/min could be constructed if needed. Near the mouth of Prairie Dog Creek, the alluvium is 50 to 60 feet thick and contains 30 to 40 feet of permeable gravel materials. A well yielding more than 100 gal/min is possible in this vicinity.

Recharge

The coal and sandstone aquifers in the Prairie Dog Creek area are recharged from relatively local sources. The drainage divide between the Tongue River and Rosebud Creek consists of broad areas of fairly level terrain. Some of the rain falling on these areas may percolate through the 500 to 900 feet of overlying material to the principal aquifers, but the amount of water in one year reaching the Wall coal bed or the overlying sandstone is considered to be small. However, considering the time that may be involved (hundreds, or even thousands of years), the total amount would be considerable. Because the percolating water moves so slow, dry and wet years will have little affect on the recharge throughout the long period.

Most of the water recharging the coal and sandstone aquifers probably originates from higher terraces along the ridges to the north and south of Prairie Dog Creek valley and percolates downward to the underlying aquifers. Clinker beds, which commonly form level, terrace-like topography, are excellent collectors of rainfall that transmit the water to underlying beds.

Recharge to the alluvium is from springs and seeps, mostly in the upstream end of Prairie Dog Creek valley. Recharge also occurs during periods of flooding of the stream. Water that has percolated through the clinker beds all along each side of the valley will partly move into adjacent talus and terrace deposits and downward into the alluvium beneath the valley.

Discharge

During this study (1978-79), only two stock wells were in use in the Prairie Dog Creek area. Four other wells existed, but they had not been used for several years. Discharge from the two wells is miniscule compared to the amount of ground water available in the valley. Discharge from the aquifers, therefore, is almost entirely natural.

Springs and seeps account for nearly all discharge from the aquifers in the area. Most discharge from the aquifers occurs beneath colluvial and alluvial deposits, and cannot be measured. Observed springs would account for only a small percentage of the total discharge.

AQUIFER CHARACTERISTICS

The hydrologic properties of most significance in describing the operation of a hydrologic system are the ability of the aquifers to transmit and store water, which are measured by transmissivity, hydraulic conductivity, and storage coefficient. Transmissivity (*T*) is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. Transmissivity is reported in units of feet squared per day; that is, transmissivity is the amount of water in cubic feet passing through an area of aquifer one foot in width and the full thickness of the aquifer during 1 day if the hydraulic gradient was 1:1. Transmissivity is equal to the integration of the hydraulic conductivities across the saturated part of the aquifer.

The hydraulic conductivity (*K*) of an aquifer is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. Hydraulic conductivity is reported in units of feet per day; it is a measure of the amount of water passing through a 1-square-foot area of the aquifer, 1 foot long, during 1 day, where the gradient of the water table or potentiometric surface is known.

Storage coefficient (*S*) is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The storage coefficient is dimensionless.

Aquifer characteristics are commonly determined from data collected while pumping from the aquifer. Transmissivity and hydraulic conductivity values were determined by the Theis method described by Lohman (1972, p. 15-19). Storage values were determined by methods described by Lohman (1972, p. 8-10).

Sandstone aquifers

Aquifer-test results

Three wells were drilled and completed in the overburden and interburden sandstone layers in the Prairie Dog Creek area. Records of these wells are presented in table 7 and aquifer-test data are given in table 8; locations of the wells are shown in figure 7.

Transmissivities range from 0.04 ft^2/d in well 39-St to 530 ft^2/d in well 23-Ss. The aquifer material at these two sites ranges from very fine grained sandstone and siltstone that have minimal permeability to a very fine to fine-grained clean sandstone that has greater permeability. Most of the relatively clean sandstone layers are expected to have transmissivities of about 15 ft^2/d and hydraulic conductivities of 1 to 1.5 ft/d.

Water-level fluctuations

Water levels in three wells (36-Ss, 38-Ss, and 39-St) completed in sandstone aquifers of the Tongue River Member were measured monthly from September 1978 through October 1979; these wells are located on the drainage divide between Prairie Dog and Spring Creeks or are in the Spring Creek drainage basin (fig. 7). The water levels generally fluctuated less than 1 foot. Water levels in wells 36-Ss and 38-Ss showed a slight rise during the spring of 1979, and a decline during the summer (fig. 9). The rise again in September is not explainable from the short-term data available. The study area received little rainfall during the summer of 1979, so the September rise did not result from immediate recharge. Equally inexplicible are the cyclic rise and decline of the water level in well 39-St during the summer and fall of 1979.

Well 23-Ss in Bull Creek valley has too short a record for definitive interpretation (fig. 9). The decline from late June through October 1979 is most likely normal summer decline of water level in the shallow aquifer owing to lack of recharge after the spring rains and decreasing leakage from the overlying Wall clinker beds. The decline was seemingly not affected by the pumping during the test on July 10. The low point of the decline is near the altitude of Bull Creek south of the well site; a hydraulic connection may be present between the sandstone aquifer and the alluvial aquifer in this vicinity.

Quality of water

The sandstones and siltstones in the Prairie Dog Creek area contain very differing types of waters, both from place to place and rock interval to rock interval (see table 9). Well 36-Ss on the Prairie Dog-Spring Creek divide was completed in sandstone above the Wall coal bed; it contained magnesium sulfate water having large secondary concentrations of calcium and bicarbonate, slightly acidic water (pH 6.7), and a dissolved-solids concentration of 2,980 mg/L. In contrast, well 39-St in the Spring Creek valley was completed in siltstones and silty sandstones above the Brewster-Arnold coal bed. Well 39-St contained sodium bicarbonate type water having small concentrations of calcium and magnesium and relatively small concentrations of sulfate. Water in this well was moderately alkaline (pH 8.3), had a very large sodium-adsorption ratio of 75, and a dissolved-solids concentration of 2,170 mg/L. The large fluoride concentration, nearly 9 mg/L, is several times greater than the primary standards of 2.2 mg/L set by the U.S. Environmental Protection Agency (1976) for drinking water.

Well 23-Ss was completed in fairly clean sandstone in Bull Creek valley. Water from the well was a sodium sulfate type having concentrations of all constituents that were about average in comparison with the other sandstone and siltstone waters in the area.

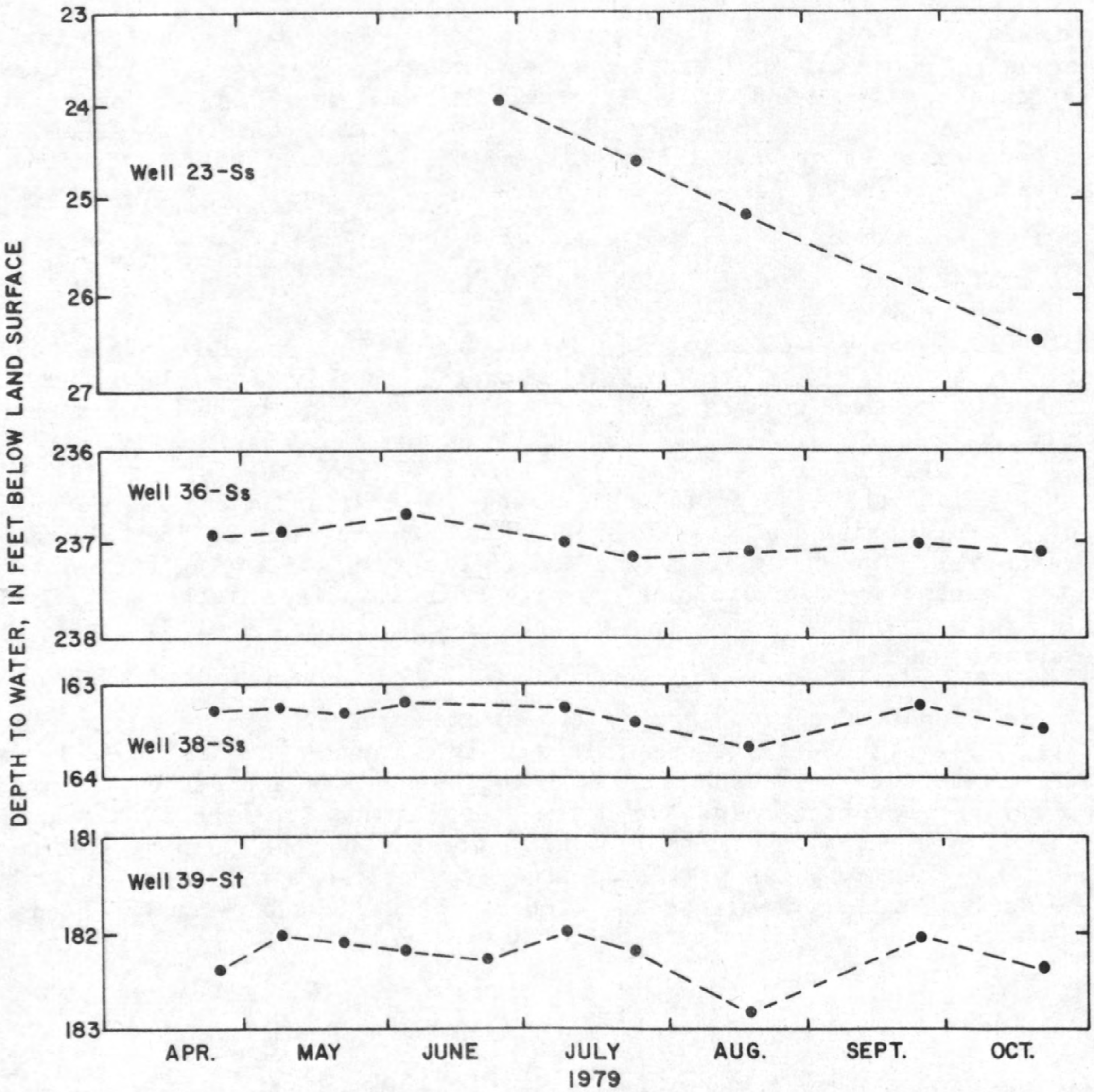


Figure 9.--Water-level fluctuations, April-October 1979, in four wells completed in sandstone aquifers of the Tongue River Member of the Fort Union Formation in the Prairie Dog Creek drainage basin and adjacent areas.

Coal aquifers

Aquifer-test results

Eleven coal-aquifer wells were tested; well records are given in table 7 and the results of aquifer tests are given in table 8. The greatest transmissivities were 80 ft^2/d for well 34-BA, 65 ft^2/d for well 26-W, and 60 ft^2/d for well 29-W--all for areas where the coal lies relatively close to the land surface. The smallest transmissivity values were for wells 37-W, 20-LW, 32-LW, 22-BA, and 41-BA, which can be explained by the fact that the aquifers either are deeply buried or consist of thin beds of coal.

The lower Wall coal bed, which is generally separated from the Wall coal bed by 5 to 15 feet of relatively impermeable clay or carbonaceous shale, is deeply buried in well 20-LW. However, the lower Wall is near the surface and overlain by clinker beds in well 32-LW, which should create large permeabilities. Both lower Wall wells have small transmissivity values -- 0.25 ft^2/d for 20-LW and 0.53 ft^2/d for 32-LW. The aquifer at well 32-LW is completely saturated, and the clinker overburden should contribute substantial recharge, but apparently the coal in this vicinity is highly compacted with few and small fracture openings. In other places in the Prairie Dog and Spring Creek drainage basins, the lower Wall coal bed supplies water to several springs. The spring flow is small but sufficient for stock use.

The remaining wells in table 8 (28-W, 35-W, and 40-W) probably are more typical in terms of average transmissivity values in the Prairie Dog Creek area. These wells have transmissivities of about 15 ft^2/d and hydraulic conductivities of about 0.3 ft/d. In general, wells completed in the Brewster-Arnold coal bed should yield about the same amount of water as wells penetrating the Wall.

Water-level fluctuations

During the period of study, water levels in most wells completed in the coal aquifers showed little fluctuation, generally less than 2 feet (see table 7). Water-level fluctuations in 5 of the 17 observation wells completed in coal aquifers are shown on figure 10; the rest have minimal water-level fluctuations. This stability of water levels, from season to season, indicates that the coal aquifers are less affected by short range variability of annual rainfall.

The water level in well 26-W fluctuated the most. The water level was about 32 feet below land surface in June 1978 and probably was higher earlier in the spring. During the summer and fall of 1978, the level declined to about 36 feet. Thick snow cover during the winter of 1978-79 caused greater than average recharge during the spring of 1979, and the water level rose to about 31 feet below land surface by late April. The level declined again during the drier summer and fall of 1979 to a low of about 40 feet by November. These fluctuations, paralleling so closely the seasonal snowmelt and rainfall, indicate a readily rechargeable aquifer at this locality. The lowest level, about 40 feet in November 1979, is still higher than the water table in the alluvium 200 feet south of this site. The Wall coal bed does not subcrop beneath the alluvium for a mile to the southeast, so the source of recharge to the Wall at well 26-W must be upvalley, possibly through fractures in a fault zone. Whatever the source, the recharging water must have a good hydraulic connection with the Wall aquifer.

Well 28-W, located downvalley near where alluvial gravels have been deposited on an eroded surface of the Wall coal, also showed a rise in water level during the spring of 1979. From a depth of about 104 feet below land surface during the winter of 1978-79, the water level rose to about 101 feet below land surface during April 1979. From interpolation of the altitudes on a topographic map, the water level in

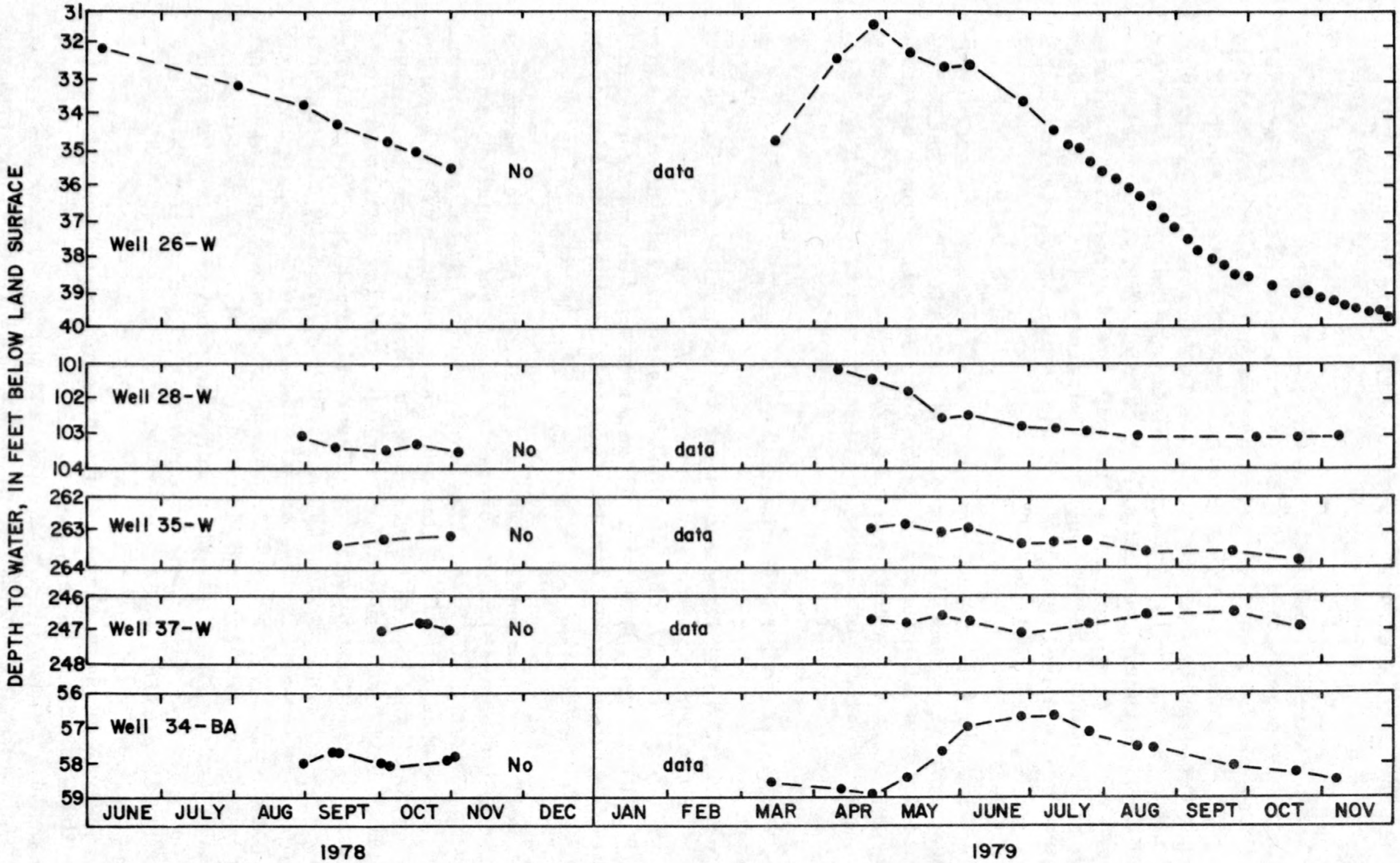


Figure 10.--Water-level fluctuations, June-October 1978 and March-November 1979, in five wells completed in coal aquifers of the Tongue River Member of the Fort Union Formation in the Prairie Dog Creek drainage basin and adjacent area.

well 28-W seems to be 5 to 10 feet higher than the water level in the alluvium 1,000 feet to the southwest.

The hydrographs for wells 35-W and 37-W are included in figure 10 to show the more normal water-level fluctuations in wells completed in coal aquifers. These wells are located on or near the drainage divide between Prairie Dog and Spring Creeks, where the Wall coal bed is deeply buried and distant from direct-recharge areas. Both wells have water-level fluctuations of about 1 foot and show no definite seasonal rises or declines.

Water levels in well 34-BA in the Brewster-Arnold coal rose 2.3 feet during late spring 1979 and declined during the summer. The rise and decline indicate fairly direct and only slightly delayed recharge to this coal bed from sources upvalley.

Flow directions

The configuration of the potentiometric surface of water in the Wall coal aquifer in the Prairie Dog Creek area is shown in figure 11. Water in the Wall coal aquifer generally flows southeastward (perpendicular to the contours), more or less in the direction of the dip of the beds. In the central and downstream parts of the valley, the gradient of the potentiometric surface is about 80 ft/mi; projected southeastward at this gradient, the potentiometric surface would intersect the surface of the flood plain of the Tongue River. Northwestward from wells 28-W and 29-W the gradient flattens to less than 20 ft/mi. Well 20-LW has an anomalously high water level, or water in well 21-W is anomalously low. The 3,750-foot contour was drawn at the position shown in figure 11 because well 21-W has casing perforated in the Wall coal bed only and well 20-LW has casing perforated in the lower Wall only. The 80-foot gradient may continue northwestward to the faults west of well 20-LW. However, the faulting was not mapped in detail, and additional observation wells would be required to determine which water level is anomalous.

The configuration of the potentiometric surface of water in the Brewster-Arnold coal aquifer also is shown in figure 11. The locations of the contours are based on four scattered observation wells completed in this aquifer, so the data could be variously interpreted. As shown, the gradient of the potentiometric surface in the Brewster-Arnold coal bed is about 50 ft/mi to the southeast, probably becoming more easterly in Bull Creek valley. Projecting the gradient southeastward to the Tongue River, the potentiometric surface is about level with the flood plain of the river. This interpretation is supported by the fact that: (1) The Brewster-Arnold coal bed crops out in the banks of the river just north of the mouth of Prairie Dog Creek, and (2) this area is a discharge point for the Brewster-Arnold coal aquifer as exemplified by two known springs near the study area.

Quality of water

Analyses from nine observation wells completed in coal aquifers are presented in table 9. A sample was not collected from well 37-W because the pump filled with coal debris before a water sample could be obtained. The water sample collected from well 22-BA was contaminated with drilling mud or cement and the analysis was not considered representative of the aquifer water. The analysis for well 29-W is included in the table, but the sample was probably contaminated with alluvial water and is not considered typical of the Wall coal aquifer. Water from nearby well 28-W is more representative of the Wall aquifer in this vicinity.

The chemical quality of water from the Wall coal aquifer is represented by analyses for wells 26-W, 28-W, 35-W, and 40-W. The water is a sodium sulfate type having large concentrations of bicarbonate. The best quality water is from well 40-W, located in the middle part of Spring Creek valley; the analysis shows a dissolved-solids concentration of 1,820 mg/L. The most mineralized water is from the deeply buried Wall aquifer, which is penetrated by well 35-W on the drainage divide between Prairie Dog and Spring Creeks; the dissolved-solids concentration was 4,190 mg/L. The other wells, 26-W and 28-W, are located near the center of Prairie Dog Creek valley. The main difference between the waters from these wells is the contrasting proportions of the cations. Water from well 26-W, located upvalley and completed in coal more deeply buried, has relatively larger calcium and magnesium concentrations, and relatively smaller sodium concentration, than water from well 28-W. In general, the concentrations of the individual anions and cations are similar in the waters from wells 26-W and 40-W. Except for total concentrations, samples from these two wells probably represent typical water of the Wall coal aquifer.

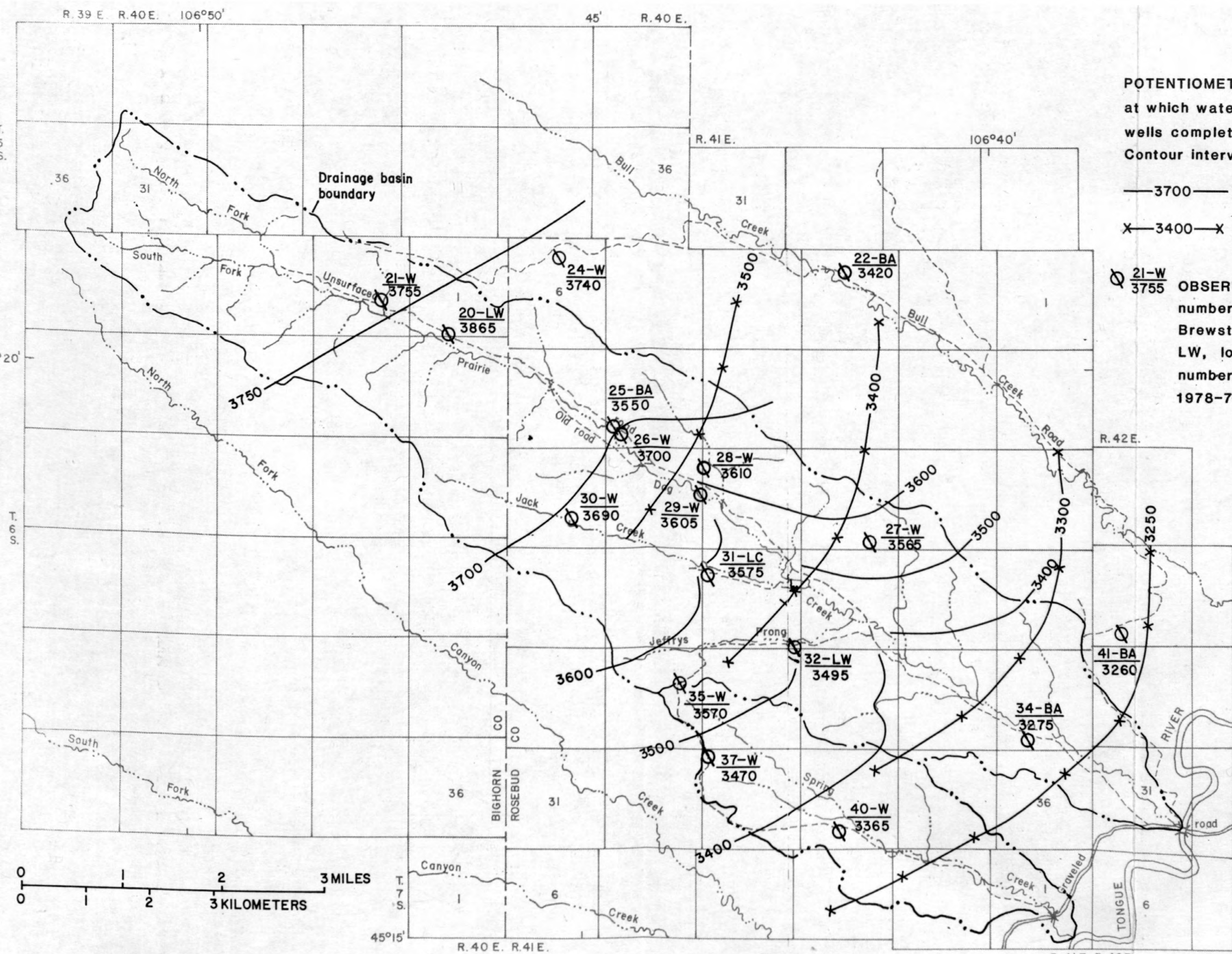
Wells 20-LW and 32-LW derive water from the lower Wall coal bed. Well 20-LW is near the upper end of the Prairie Dog Creek valley and the lower Wall is 238 to 248 feet below land surface. Well 32-LW is in Jeffrys Prong valley and the lower Wall bed lies beneath the main Wall clinker at 35 to 43 feet below land surface. A clay beneath the clinker must be nearly impermeable, because water from well 32-LW is representative of a coal-type water and gives no indication of having received leakage from the better quality water contained in the clinker aquifer. The water from well 32-LW, as might be expected from its shallow occurrence, is of better quality (1,810 mg/L of dissolved solids) than water from deeper well 20-LW (2,290 mg/L of dissolved solids). Both waters from the lower Wall coal aquifer are dominated by sodium and sulfate, as is water from the Wall bed. The calcium and magnesium concentrations in water from well 32-LW are slightly greater and the bicarbonate is less than is typical for water from the Wall coal aquifer.

Two samples were collected from wells completed in the Brewster-Arnold coal aquifer. Water from well 34-BA, which is 145 feet deep, and well 41-BA, which is 208 feet deep and is located in the drainage divide between Prairie Dog and Bull Creeks, is of the sodium bicarbonate type and has a small (for coal) sulfate concentration. Both samples of water from the Brewster-Arnold coal have large fluoride concentrations, much exceeding the mandatory limit of the Environmental Protection Agency for drinking water. The sodium-adsorption ratio was more than 65 in both samples of water from the Brewster-Arnold coal aquifer, which makes this water unsuitable for irrigation.

Alluvial aquifers

Aquifer-test results

Nineteen wells were drilled in the alluvium along the Prairie Dog Creek channel at six general localities (fig. 8). Most of the wells were drilled inline across the valley to determine variations of materials along the flanks and terraces and in the middle of the valley. At almost every locality the well having



EXPLANATION

POTENTIOMETRIC CONTOUR--Shows approximate altitude at which water level would have stood in tightly cased wells completed in the indicated aquifers, 1978-79. Contour intervals 50 and 100 feet. Datum is sea level

——3700—— Wall coal aquifer

×—3400—× Brewster-Arnold coal aquifer

Ø 21-W / 3755 OBSERVATION WELL; CASED--Upper number is well number. Abbreviated principal aquifer is BA, Brewster-Arnold coal aquifer; LC, local coal bed; LW, lower Wall coal bed; W, Wall coal bed. Lower number is altitude of potentiometric surface, 1978-79

Figure 11.--Approximate configuration of the potentiometric surface, 1978-79, for the Wall and Brewster-Arnold coal aquifers in the Prairie Dog Creek drainage basin and adjacent areas

the largest yield was the one near the center of the valley, regardless of the location of the present creek channel. Records of the observation wells completed in alluvium are given in table 10 and the results of aquifer tests at 13 sites are summarized in table 11.

The large transmissivities at some of the wells and the relatively small dissolved-solids concentrations in water from the alluvium emphasize the importance of the alluvial aquifer as a source of drinking water in the Prairie Dog Creek drainage. The amount of flow under the flood plain and the terraces is significant, at least during periods of normal to abundant rainfall.

Well 42-Q is the alluvial well drilled farthest upvalley in the area (inset 1, fig. 8). It is located on the north edge of the valley on the lower terrace, so it probably is not completed in the most productive part of the alluvial materials. The calculated transmissivity of 1,200 ft^2/d probably is less than average for the alluvium in this part of the valley; a well farther to the southwest, nearer the center of the valley, probably would yield more water.

Downvalley, wells 43-Q, 44-Q, and 45-Q are located in a north-south line near the creek (inset 2, fig. 8). These wells penetrated coarse clinker gravels, and although only 2 to 5 feet of the aquifer was saturated, the transmissivity values are nearly the largest of the area--as much as 5,300 ft^2/d. The large transmissivities result from the clean, coarse gravel that comprises the aquifer in this area where the valley narrows to a width of about 300 feet.

Wells 46-Q, 47-Q, and 48-Q were drilled just upstream from the mouth of Jack Creek (inset 3, fig. 8). Here, the transmissivity of the aquifer is calculated to be 930 ft^2/d at well 46-Q, 80 ft^2/d at well 47-Q, and 200 ft^2/d at well 48-Q. Upstream from the area, between insets 2 and 3, the Wall coal bed occurs beneath the alluvium; downstream, the Wall occurs above the alluvium in the valley sides. Because the potentiometric surface slopes southeast and the aquifer is saturated, the Wall might be expected to discharge water to the alluvium in this area. However, calculation of the amount of the alluvial water flowing past the two lines of wells indicates no significant gain; about 6,500 ft^3/d passes each site -- on the basis of late September water levels. The Wall coal aquifer apparently discharges little if any water to the alluvial aquifer in this area at this time of year.

No wells in the area of inset 4 (fig. 8) were tested. Water levels were too near the bottom of the wells during late September 1979 when aquifer testing was done.

Wells 53-Q through 57-Q were drilled just downstream from a streamflow-gaging station (inset 5, fig. 8). Here, the valley is about 700 feet wide. According to the lithologic logs, the alluvial material is fairly homogeneous, particularly in the saturated zone. Wells 54-Q and 55-Q were tested; well 53-Q did not have sufficient water to pump during late September 1979. The transmissivity at well 54-Q, nearer the middle of the valley, is about 4,800 ft^2/d. Data from the aquifer test on well 55-Q, which has confirming data from the observation well 56-Q, 20 ft to the east, indicate a transmissivity of 2,100 ft^2/d for the alluvium along the north side of the valley. Considering the increased volume of saturated aquifer in this area, these calculations seem to compare favorably with those for the area of wells 43-Q, 44-Q, and 45-Q (inset 2, fig. 8).

Wells 59-Q, 60-Q, and 61-Q were drilled about 2,000 feet upstream from the mouth of Prairie Dog Creek (inset 6, fig. 8). Aquifer tests were conducted on all three wells, indicating a transmissivity of 40 ft^2/d on the south edge of the valley (well 59-Q), 9,200 ft^2/d near the center (well 60-Q), and 600 ft^2/d on the north side of the valley (well 61-Q). Assuming an average hydraulic conductivity of about 50 ft/d, the calculated amount of water leaving the Prairie Dog Creek drainage basin is about 13,500 ft^3/d through the alluvial aquifer. Calculating: 13,500 ft^3/d equals 0.3 acre-foot per day, or 110 acre-feet per year; the drainage area of Prairie Dog Creek is 24.2 mi^2, which equals about 15,000 acres; the amount of annual rainfall to recharge the alluvial aquifer and pass downvalley and out of the area would be about 0.007 foot, or 0.09 inch of the 12-inch average annual rainfall -- or about 0.7 percent of the annual rainfall flowing from the area via the alluvial aquifer. The rest of the rainfall, except for the miniscule part that percolates to underlying coal and sandstone aquifers, is evaporated or transpired from vegetation in the area, or flows out as surface water during infrequent floods.

Along the valley, a channel probably exists that would have a transmissivity of 2,500 ft^2/d or more. Therefore, properly located wells across the valley probably would yield at least 20 gal/min anywhere from Brewster Camp to the mouth of the creek.

Water-level fluctuations

The alluvial aquifer reflects directly and almost immediately the rainfall and snowmelt in the Prairie Dog Creek basin. Fluctuating water levels from August 1978 through December 1979 at each line of alluvial wells are shown in figure 12. Only the spring, summer, and fall 1979 water levels are shown for wells in the middle part of the valley because the wells were not drilled until May 1979. Owing to the fact that the winters of 1977-78 and 1978-79 provided about equal amounts of snow, water-level fluctuations in these wells were probably about the same during 1978 and 1979.

The water level in the upvalley well (42-Q) declined from about 9 to about 17 feet below land surface. The shallowest water level may have been 1 to 2 feet higher than shown in figure 12 as a result of March and April thawing of an unusually heavy snowpack. The much more subdued fluctuation in well 44-Q, 1 mile downstream, reflects the greater transmissivity of the alluvial materials in this area. The water level in well 44-Q declined about 2 feet from May through September 1979.

The difference in water-level fluctuations (fig. 12) and transmissivity between wells 46-Q and 47-Q, which are only 86 feet apart on either side of Prairie Dog Creek channel, probably can be attributed to lithology. From May through September, the water level in well 47-Q declined about twice as fast as in well 46-Q -- from about 13 to about 19 feet below land surface in well 47-Q, and from about 13 to about 16.5 feet in well 46-Q. The lithologic logs permit insight to the reason. A gravel and clay layer exists near the base of the alluvium in each well, but in well 46-Q a clinker gravel occurs beneath the clay layer (fig. 13). This clinker might be continuous from the clinker outcrop between Prairie Dog and Jack Creeks, and water in the clinker might reach well 46-Q. The clinker, which would absorb large amounts of recharge from rainfall and from the streamflow in Prairie Dog and Jack Creeks, would reasonably have a higher potentiometric surface than the alluvium. That the clinker readily absorbs and transmits water is exemplified by

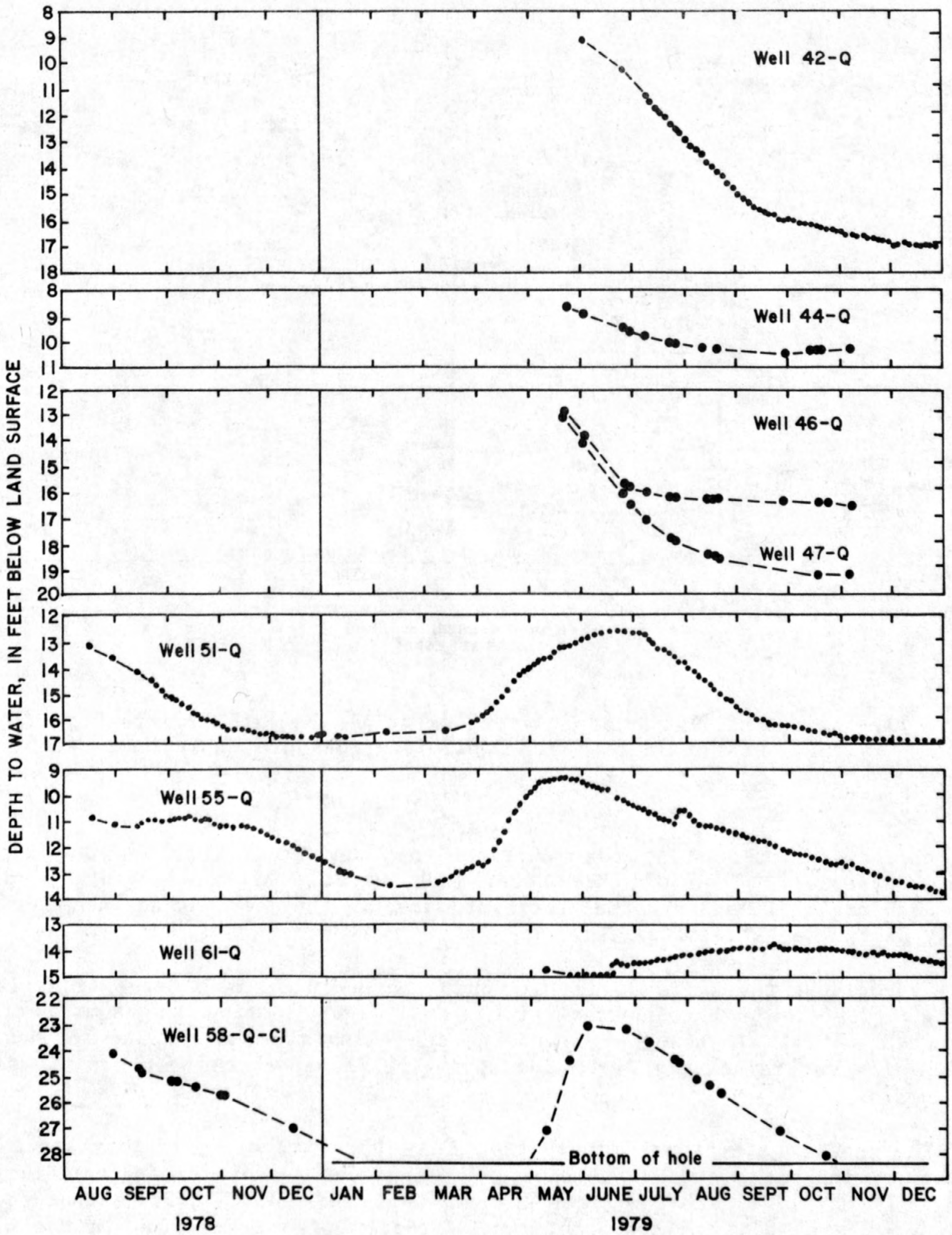


Figure 12.--Water-level fluctuations, August 1978-December 1979, in wells completed in alluvium.

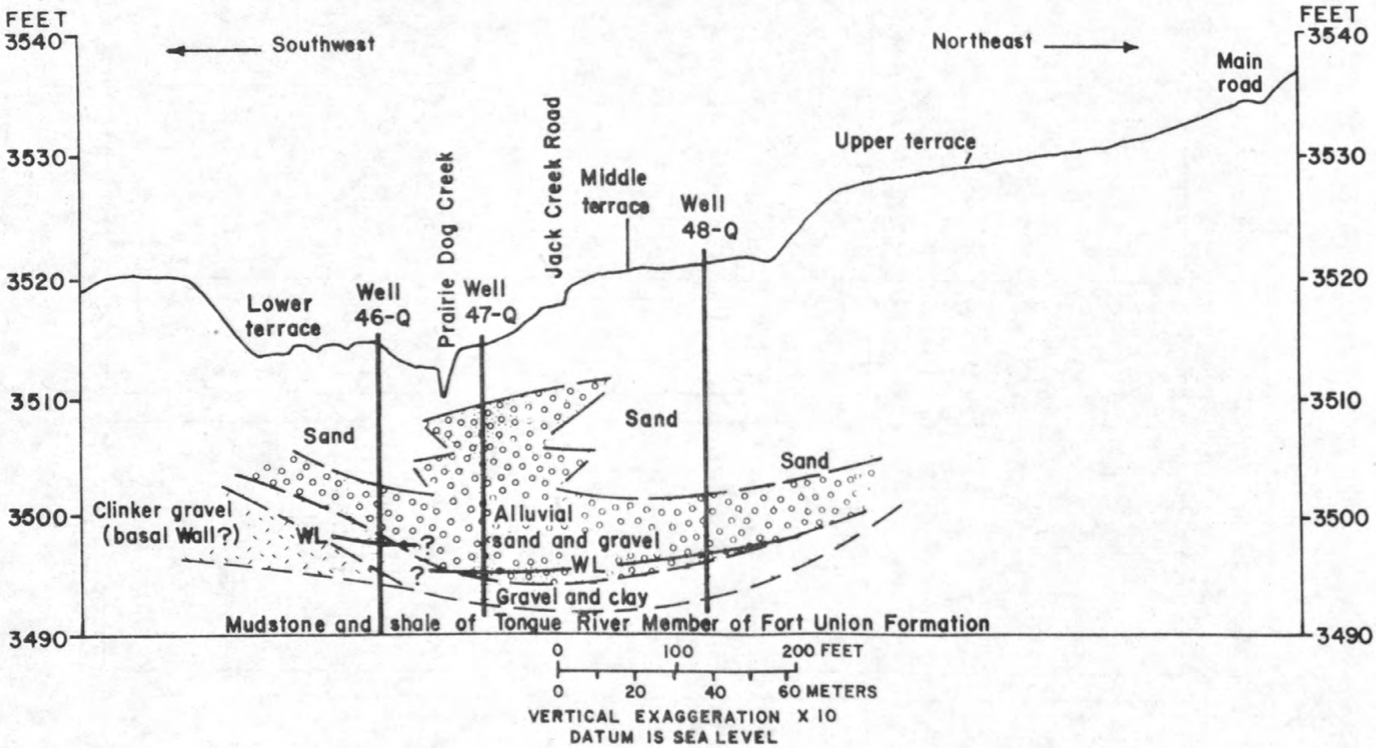


Figure 13.--Idealized sketch of alluvial materials beneath Prairie Dog Creek near the mouth of Jack Creek. Well locations are shown on inset 3, figure 8.

the upstream stock pond at the lower end of Jack Creek that was dug into this clinker material. The pond has never held water. After the spring rains of 1978 Jack Creek flowed into the pond, but water in the pond leaked into the clinker nearly as fast as streamflow entered.

Hydrographs for wells downvalley from the mouth of Jack Creek (fig. 12) show a slight difference between declining water levels during the summer of 1978, which had a few rainshowers to recharge the alluvial aquifer, and the summer of 1979, which was relatively dry. The spring peaks appear to be about the same for both years.

The annual water-level fluctuation in wells 51-Q and 55-Q was about 4 feet between spring peaks and winter lows. The apparent reason for the earlier peak in well 55-Q (May 1979) and the later peak in well 51-Q (June 1979) is that the water table near well 55-Q is connected more directly with streamflow in the channel. The good hydraulic continuity between well 55-Q and streamflow is emphasized by hydrographs during the rainstorm of late July 1979. Wells 51-Q and 55-Q, located near the perennial Prairie Dog Creek, were equipped with recorders. The increased flow in the stream was not registered in well 51-Q, but shows sharply in well 55-Q. None of the hydrographs for wells upvalley from 51-Q registered this increase in flow.

The water levels measured during this study in wells completed in alluvium were affected by the average to greater than average precipitation of the preceding

8 years. Where the alluvium thickness is 25 feet or less, such as from near well 53-Q upvalley to beyond well 42-Q, the water levels could lower to near the base of the alluvium after several years of drought. This fact makes the alluvial aquifer an undependable source of water supply.

Near the mouth of Prairie Dog Creek, where the alluvium is deepest and the transmissivity of the alluvial aquifer is large, the water-level fluctuations for well 61-Q are subdued. The water-level altitude at this well was about 30 feet higher than the water table in alluvium of the Tongue River, so there was no effect from the river. During the highest water levels, September and October 1979, the water level was only 1 to 2 feet beneath the stream channel in this vicinity. The interrelation of the stream and alluvial aquifer is indicated by the sharp rise during mid-June 1979 during a flash flood. Minor fluctuations during September also indicate this relation. Otherwise, the annual fluctuation was little more than 1 foot during the period of this study.

Well 58-Q-C1 is included with the alluvial hydrographs to show the occurrence of water near the sides of the valley. The well is located on the high terrace south of the main valley, about 2 miles upstream from the mouth of Prairie Dog Creek. Based on its position with respect to the terrace and the clinker hill to the south, the well is evidently hydraulically connected with water in the basal clinker material. The well contained water during rainy periods of the summer of 1978, but became dry during the following winter. During the spring of 1979, snowmelt provided water that caused the June peak. During the summer of 1979 the rains were not sufficient to keep the clinker aquifer recharged, so the well became dry at the end of October, which was much earlier than for 1978.

Flow directions

Water in the alluvium flows at nearly the same slope as the Prairie Dog Creek channel (fig. 14) downvalley to the southeast (fig. 15). The gradient of the water table in the middle part of the basin is about 80 ft/mi, and in the downvalley part about 55 ft/mi. Near the mouth of the creek, downstream from well 61-Q, the gradient increases to about 100 ft/mi. Some of the water discharges from the gravels at seeps about 100 feet from the Tongue River.

Quality of water

The dissolved-solids concentration of water in the alluvium decreases from the middle parts of the Prairie Dog Creek valley to the downstream parts (table 12). This improvement is probably the result of recharge from the clinker aquifer, through the talus slopes and colluvium that dominate the hilltops and hillsides, downvalley from the mouth of Jack Creek. In the upvalley and middle parts of the basin, the alluvium is recharged by waters from coal and sandstone aquifers.

Water from alluvium in the middle parts of Prairie Dog Creek basin is represented by samples 42-Q, 43-Q, 44-Q, and 45-Q (table 12). These waters are of the magnesium sulfate type and have large concentrations of calcium, sodium, and bicarbonate. The dissolved-solids concentration of water from well 42-Q, the most upvalley alluvial well, was 1,500 mg/L, and from well 44-Q it was 1,700 mg/L. Downvalley, the water became less concentrated in calcium (from 120 to 69 mg/L), magnesium (from 200 to 100 mg/L), bicarbonate (from 710 to 340 mg/L), and sulfate

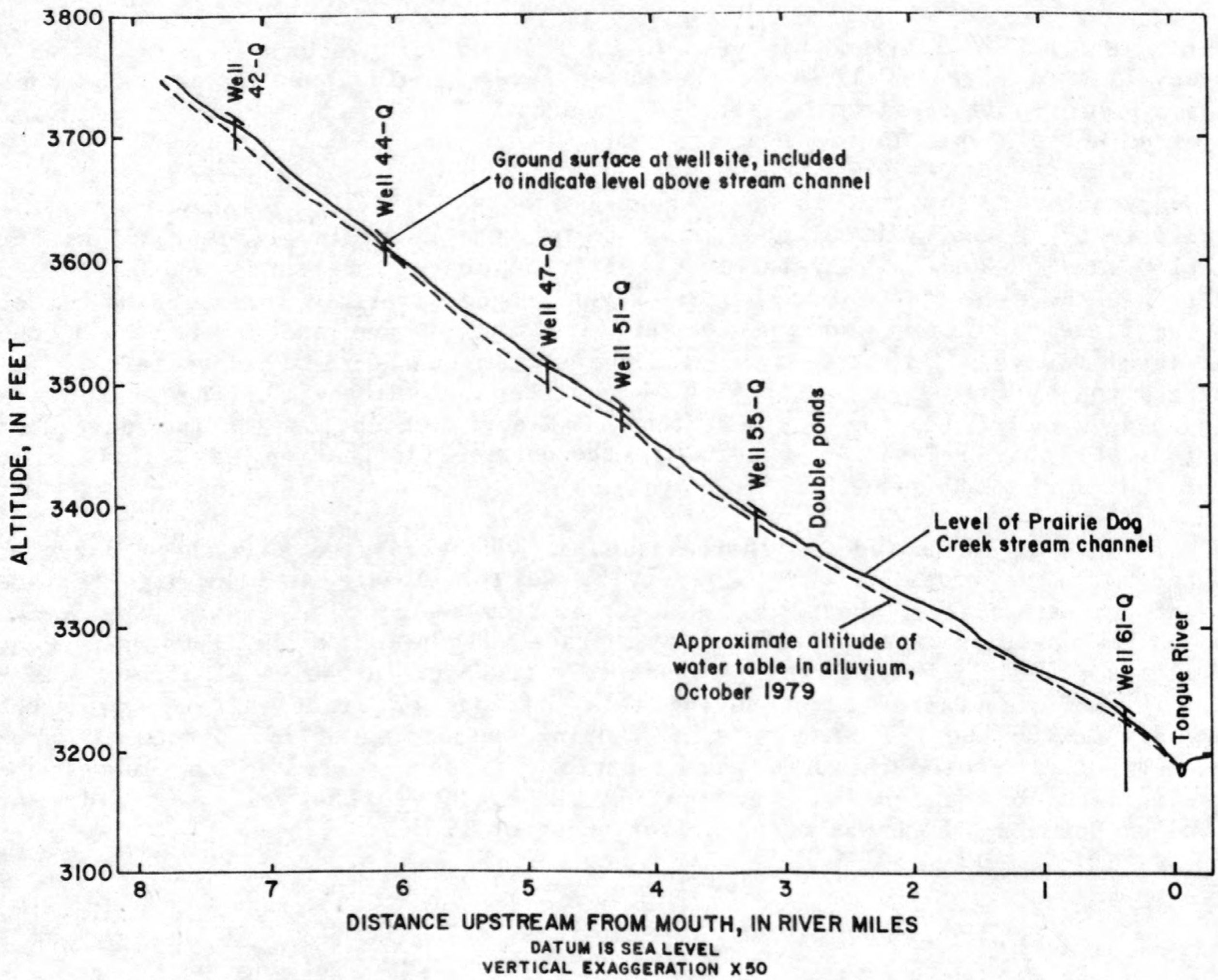
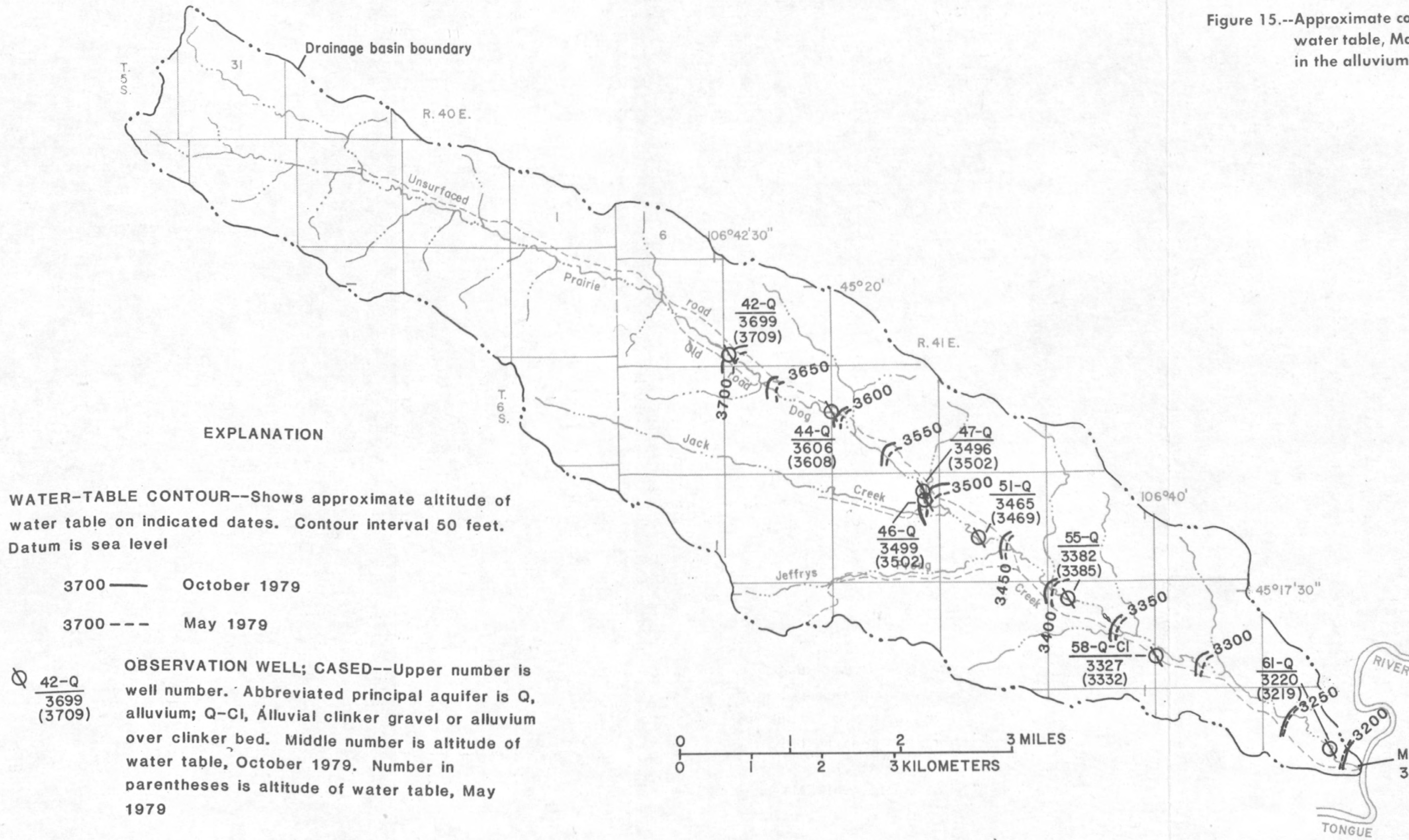


Figure 14.--Longitudinal section of the Prairie Dog Creek channel and the altitude of the water table, October 1979, in the alluvium. Location of wells shown on figure 15.

(from 760 to 600 mg/L) and more concentrated in sodium (from 110 to 150 mg/L), fluoride (from 0.5 to 0.9 mg/L), and silica (from 18 to 25 mg/L). The water near the mouth of the creek is modified -- probably as a result of the influx of water from clinker and alluvial deposits beneath terraces. Dissolved solids decreased slightly and sodium replaced magnesium as the dominant cation.

The sample collected from the alluvial-clinker aquifer (well 58-Q-C1) apparently is not typical of water from clinker in the lower part of the Prairie Dog Creek area. This sample had a dissolved-solids concentration of 1,570 mg/L, which was greater than for water from the alluvial valley to the north. The water was dominated by sodium and sulfate -- probably as much a result of unburned coal as clinker beds.

Figure 15.--Approximate configuration of the water table, May and October 1979, in the alluvium.



SUMMARY

Ground water in the Prairie Dog Creek drainage basin is virtually untapped at the present time. The existing stock wells, only two of which were operable during the study, discharged a small amount of water compared with the total potential supply.

The study was conducted in 1978-79 during a period of increased precipitation and after an 8-year period of greater than average precipitation and consequently greater than average recharge. These circumstances increased the water available in ponds, the creek, and alluvial aquifers, but probably had much less affect on the sandstone and coal aquifers.

Prairie Dog Creek, which originates from springs and seeps issuing from coal and sandstone layers, maintained perennial flow in the upstream and middle reaches during 1978 and 1979. Stream discharge increased from Brewster Camp (measurement site 13) to near the upstream streamflow-gaging station (measurement site 11), and then gradually decreased downstream to the double ponds (near site 4). Discharge was about 2.5 ft^3/s during April 1979 in the middle reaches, but decreased to 0.1 ft^3/s by the late summer of 1979. Surface-water quality also varied with the season; concentrations of dissolved solids were about 700 mg/L during the spring of 1979 and about 1,600 mg/L during the late summer of 1979.

The ground-water regime in the Prairie Dog Creek area includes sandstone, coal, clinker, and alluvial aquifers. The sandstone aquifers are the most unpredictable for water supply because of the lateral variation in permeability. Three aquifer tests were conducted on wells open to sandstone aquifers; transmissivities ranged from 0.04 ft^2/d in well 39-St to 530 ft^2/d in well 23-Ss. Average transmissivity for sandstone aquifers is about 15 ft^2/d. The water from the sandstone should be expected to have dissolved-solids concentrations ranging from about 2,200 to 3,000 mg/L, with large concentrations of magnesium, sodium, bicarbonate, and sulfate.

The coal aquifers are the most dependable water supply. Aquifer tests conducted in wells completed in the main Wall coal bed had well yields ranging from 1.0 to 6.6 gal/min; calculated transmissivities ranged from 2.5 to 65 ft^2/d, generally with the lesser transmissivities in the deeper coal beds. At most places a transmissivity of about 15 ft^2/d could reasonably be expected in wells completed in the Wall coal bed. In general, wells completed in the Brewster-Arnold coal bed should yield about the same amount of water as those completed in the Wall coal.

Water from the coal aquifers varies widely in quality, but is generally of better quality than from the sandstone aquifers. Dissolved-solids concentrations in water from the Wall coal bed ranged from 1,130 to 4,190 mg/L, and two samples of water from the Brewster-Arnold coal contained from about 900 and 1,000 mg/L. The more mineralized waters seem to come from the more deeply buried coal, although more mineralized water (about 2,400 mg/L of dissolved solids) was pumped from wells 26-W and 28-W, where the coal is less than 150 feet deep. In some localities, water from the Brewster-Arnold coal bed has fluoride concentrations that greatly exceeded the primary limit of the U.S. Environmental Protection Agency for drinking water.

Water in the alluvial aquifer should be dependable and fairly abundant, except after several years of drought. Although the aquifer tests conducted on the wells completed in the alluvium indicated transmissivities ranging from 15 to 9,200 ft^2/d, properly located wells across the valley probably would yield at least 20 gal/min anywhere from Brewster Camp to the mouth of the creek--somewhere across the valley a channel exists that would have a transmissivity of 2,500 ft^2/d or more. Alluvial water is most consistent in quality of all ground-water sources, with dissolved-solids concentrations generally ranging from 1,100 and 1,700 mg/L. The water contains principally magnesium, sodium, sulfate, and bicarbonate ions.

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Table 2.--*Average and extreme air temperatures for 1978 at Birney and Colstrip stations*

Station and period		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
		Temperature, in degrees Fahrenheit												
Birney 2SW														
1978 average		9.0	17.2	34.0	48.8	55.6	64.6	69.2	66.0	60.0	46.5	24.3	12.0	42.3
1978 average	Maximum	21.5	29.9	49.4	62.1	69.0	81.2	85.1	84.0	77.3	64.6	37.6	25.1	57.2
	Minimum	- 3.6	4.5	18.6	35.4	42.2	47.9	53.3	48.0	42.7	28.4	11.0	- 1.2	27.3
1978 extremes	Maximum	40	46	80	79	93	92	96	96	99	80	73	44	--
	Minimum	-27	-17	-27	23	31	35	41	40	28	11	-11	-35	--
Colstrip														
48-year average		21.0	26.6	32.2	44.8	54.4	62.7	71.5	70.1	59.0	48.6	34.4	25.7	45.9
1978 average		12.1	19.2	35.4	47.1	55.0	63.8	69.2	67.5	62.0	49.9	26.8	18.7	43.9
1978 average	Maximum	24.7	31.6	48.1	61.1	67.9	79.9	84.7	85.5	79.0	66.6	39.9	27.9	58.1
	Minimum	- .6	6.7	22.6	33.1	42.1	47.6	53.6	49.4	44.9	33.1	13.6	9.5	29.6
1978 extremes	Maximum	45	50	80	77	91	92	96	97	101	77	71	47	--
	Minimum	-22	-18	-10	24	33	36	44	41	32	20	-13	-30±	--

Table 3.--*Monthly and annual precipitation for 1955-78 at Birney and eight nearby stations*

Station and period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual average for period of record	Years of record
	Precipitation, in inches														
Birney 2SW[1]															
1955-78 average	0.55	0.46	0.46	1.56	2.19	2.86	1.05	0.94	1.12	1.01	0.73	0.53	13.46	13.46	23 years 1955-69 1971-78 (missing 1 wet year)
1962-78 average	.74	.48	.55	1.69	2.22	3.04	1.06	.95	1.29	.98	.71	.57	14.28		
Broadus															
1955-78 average	.52	.52	.65	1.60	2.57	2.84	1.35	.95	1.22	1.03	.68	.55	14.48	14.42	48 years 1920-25 1937-78
1962-78 average	.59	.44	.69	1.72	2.74	2.80	1.34	.99	1.38	1.12	.61	.58	15.00		
Busby															
1955-78 average	.75	.63	.61	1.68	2.63	2.69	1.21	1.17	1.34	1.14	.76	.73	15.34	13.55	73 years 1904-13 1914-71 1974-78 (missing 2 average years)
1962-78 average	1.02	.71	.69	1.67	2.76	2.90	1.27	1.25	1.50	1.24	.70	.79	16.50		
Colstrip															
1955-78 average	.66	.64	.64	2.07	2.74	2.84	1.18	1.32	1.44	1.28	.72	.71	16.24	15.61	51 years 1927-74 1976-78 (missing 1 wet year)
1962-78 average	.80	.64	.68	2.11	2.81	3.06	1.25	1.34	1.56	1.33	.61	.77	16.97		
Decker															
1962-78 average	.69	.37	.58	1.80	2.34	2.91	.92	.97	1.27	.90	.73	.61	14.09	13.66	21 years 1961-78
Lame Deer															
1955-78 average	.61	.72	.75	1.92	2.99	2.87	1.23	1.10	1.31	1.10	.98	.74	16.23	16.50	39 years 1938-56 1958-70 1972-78 (missing 1 average, 1 wet year)
1962-78 average	.71	.67	.82	2.13	3.33	3.11	1.21	1.21	1.45	1.07	.93	.74	17.38		
Moorhead															
1955-78 average	.46	.42	.46	1.60	2.33	2.87	1.23	.92	1.17	1.08	.59	.46	13.58	13.09	31 years 1948-78
1962-78 average	.58	.34	.54	1.64	2.50	2.92	1.33	1.00	1.34	1.10	.55	.51	14.35		
Otter 9SSW															
1962-78 average	1.14	.80	1.15	2.74	2.91	3.42	1.41	1.28	1.60	1.33	1.05	1.04	19.87	19.87	17 years 1962-78
Sonnette 2WNW															
1958-78 average	.64	.52	.55	1.69	2.79	2.71	1.18	.91	1.37	1.14	.78	.49	14.77	14.07	26 years 1951-61 1963-64 1966-78 (missing 2 dry years)
1962-78 average	.85	.55	.65	1.91	2.92	2.92	1.26	1.05	1.57	1.23	.80	.58	16.29		

[1]The Birney station has been moved several times from 1955 to 1978, but has always been within 2 miles of Birney and in similar climatological settings.

Table 4.--*Monthly precipitation at Birney and three nearby stations*

Station and period	Precipitation, in inches												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Birney 2SW													
23-year average	0.55	0.46	0.46	1.56	2.19	2.86	1.05	0.94	1.12	1.01	0.73	0.53	13.46
1978 total	.63	1.04	.30	1.55	7.71	1.83	1.46	.79	1.44	.20	1.86	.98	19.79
1979 total	.26	.90	.24	1.39	1.71	.60	1.26	.40	.33	.83	.61	.29	8.82
Decker 4NNE													
21-year average	.60	.36	.58	1.60	2.23	2.75	1.04	1.07	1.28	.92	.66	.57	13.66
1978 total	.6	.85	.35	2.08	7.12	.34	.81	.88	1.39	.25	1.53	.40	16.6
1979 total	.51	.24	.25	1.28	1.56	.81	1.32	.81	.50	1.12	1.26	.09	9.75
Lame Deer													
39-year average	.67	.62	.87	1.70	2.82	3.24	1.33	1.16	1.33	1.17	.86	.73	16.50
1978 total	.88	.74	.2	1.0	12.44	1.58	2.7	.47	2.71	.12	2.28	.87	26.0
1979 total	.39	1.14	.26	.93	2.11	.84	--	--	--	--	--	--	?
Otter 9SSW													
17-year average	1.14	.80	1.15	2.74	2.91	3.42	1.41	1.28	1.60	1.33	1.05	1.04	19.87
1978 total	.97	1.62	.21	2.48	9.85	1.62	1.50	.95	2.76	.18	2.44	1.55	26.13
1979 total	.66	1.82	.33	1.94	1.39	2.13	2.10	.77	.61	1.18	.68	.34	13.95

Table 5.--*Chemical analyses of surface water*

[Except as indicated otherwise, constituents are dissolved and constituent values are reported in milligrams per liter. Analyses by: BM, Montana Bureau of Mines and Geology; GS, U.S. Geological Survey. Abbreviations: ft^3/s, cubic feet per second; °C, degrees Celsius; micromhos, micromhos per centimeter at 25° Celsius; µg/L, micrograms per liter; mi, mile]

Measurement site (fig. 3)	Location	Date sample collected	Hour	Stream discharge (ft^3/s)	Specific conductance (micromhos)	Onsite pH (units)	Water temperature (°C)	Hardness as $CaCO_3$ (Ca, Mg)	Calcium (Ca)
15	NW1/4 SE1/4 SE1/4 NW1/4 sec. 3, T. 6 S., R. 40 E.	8-03-78	1430	0.5±	1,240	7.9	17.5	660	92
15	SE1/4 NW1/4 SW1/4 NE1/4 sec. 3, T. 6 S., R. 40 E.	6-06-79	0950	.33	1,140	7.9	14.0	630	91
14	NE1/4 NE1/4 NE1/4 NW1/4 sec. 3, T. 6 S., R. 40 E.	8-03-78	1300	.3±	1,100	7.9	15.0	560	71
14	SW1/4 NE1/4 SW1/4 NE1/4 sec. 3, T. 6 S., R. 40 E.	6-06-79	0910	.45	1,020	7.9	12.0	520	69
13	NW1/4 SE1/4 SW1/4 NE1/4 sec. 3, T. 6 S., R. 40 E.	8-03-78	1130	.8±	1,240	8.1	14.0	670	92
		6-06-79	1030	.80	1,100	7.9	13.0	590	83
11	SE1/4 SE1/4 NW1/4 NE1/4 sec. 12, T. 6 S., R. 40 E.	5-15-78	1720	1.7	1,120	8.3	19.5	610	81
		9-13-78	1300	.96	1,260	8.1	8.5	690	95
11	NW1/4 NW1/4 SE1/4 NE1/4 sec. 12, T. 6 S., R. 40 E.	4-19-79	1420	6.8	1,080	8.5	6.0	300	91
		6-04-79	1500	1.6	1,360	8.3	17.0	--	94
		9-26-79	1030	.11	1,700	8.1	14.0	940	95
9	SW1/4 SE1/4 NE1/4 NW1/4 sec. 17, T. 6 S., R. 41 E.	6-06-79	1210	1.1	1,400	8.0	16.0	750	73
8	NE1/4 NE1/4 NE1/4 SE1/4 sec. 17, T. 6 S., R. 41 E.	10-02-79	1330	.10	2,100	8.1	11.5	1,100	110
7	NE1/4 SE1/4 SE1/4 NE1/4 sec. 21, T. 6 S., R. 41 E.	6-06-79	1330	1.3	1,440	8.1	17.5	760	63
5	NW1/4 SE1/4 NW1/4 NW1/4 sec. 26, T. 6 S., R. 41 E.	9-13-78	1530	.53	1,120	8.3	13.5	550	69
		12-15-78	1030	.04	1,860	8.0	.0	940	78
		4-19-79	1700	2.6	1,120	8.6	9.0	620	91
		6-04-79	1530	1.1	1,440	8.6	26.0	730	62
		8-24-79	1000	.10	1,850	8.6	16.0	820	50
4	NW1/4 NW1/4 NE1/4 SE1/4 sec. 26, T. 6 S., R. 41 E.	6-06-79	1430	.89	1,540	8.2	17.0	740	79
1	NW1/4 SE1/4 NE1/4 SE1/4 sec. 31, T. 6 S., R. 42 E.	6-06-79	1540	.03	1,640	7.8	15.0	640	77

Table 5.--*Chemical analyses of surface water--Continued*

Measurement site (fig. 3)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)	Potassium (K)	Bicarbonate (HCO_3)	Alkalinity, total as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)
15	100	31	0.5	5	440	360	360	5.0	0.3	15
15	97	30	.5	4	440	360	310	3.0	.3	9.0
14	92	32	.6	4	530	430	180	4.0	.2	16
14	85	28	.5	4	500	410	180	2.1	.2	12
13	110	33	.6	5	510	420	300	5.0	.3	15
	92	29	.5	4	470	380	250	2.5	.3	11
11	100	41	.7	5	520	430	240	4.8	.4	10
	110	45	.7	9	490	400	350	7.6	.3	12
11	17	35	.9	5	140	110	280	4.0	.3	8.8
	--	51	--	5	490	400	420	5.1	.4	6.9
	170	84	--	7	570	470	670	6.5	.4	13
9	140	61	1	6	490	400	450	1.4	.3	8.9
8	200	110	1	10	520	430	870	8.1	.4	13
7	150	72	1	6	440	360	500	5.5	.3	7.6
5	92	59	1	10	360	300	370	6.4	.3	8.9
5	180	110	2	9	460	380	750	8.4	.3	14
5	95	45	.8	6	410	340	340	5.0	.3	8.3
5	140	74	1	7	430	350	510	6.3	.4	5.2
5	170	120	2	9	500	410	750	9.0	.5	4.5
4	130	100	2	10	480	400	560	5.1	.5	15
1	110	160	3	10	500	410	520	5.0	.8	25

Table 5.--*Chemical analyses of surface water--Continued*

Measurement site (fig. 3)	Dissolved solids, calculated sum of constituents	Nitrite + nitrate, as N	Iron (Fe) (μg/L)	Trace-element analysis available	Analysis by:	Remarks
15	830	0.07	80	No	BM	Sampled 0.25 mi upstream from site 15. Summer base flow.
15	770	.14	110	No	BM	Spring base flow.
14	660	.14	100	No	BM	Sampled 0.35 mi upstream from site 14. Summer base flow.
14	620	.11	20	No	BM	Spring base flow.
13	810	.07	80	No	BM	Sampled at bridge behind Brewster Camp. Summer base flow.
	710	.10	110	No	BM	Spring base flow.
11	740	.05	10	Yes	GS	Sampled 0.10 mi upstream from upper gaging station (site 11.) Spring runoff.
	870	.06	30	Yes	GS	Light rains September 11 and 12. Late summer base flow.
11	510	.44	40	No	GS	Mostly snowmelt.
	--	.18	20	No	GS	Spring runoff.
	1,330	.14	30	No	GS	Late summer base flow.
9	980	.25	0	No	BM	Spring base flow.
8	1,580	.02	70	No	GS	Sampled 0.3 mi upstream from site 8. Base flow.
7	1,020	.11	30	No	BM	Spring base flow.
5	790	.01	30	Yes	GS	Sampled at lower gaging station (site 5). Late summer base flow.
5	1,380	.27	10	No	GS	Base flow.
5	800	.26	--	No	GS	Mostly snowmelt.
5	1,020	.05	10	No	GS	Spring runoff.
5	1,360	.00	10	No	GS	Summer base flow.
4	1,140	.08	20	No	BM	Spring base flow.
1	1,150	.80	60	No	BM	Ground-water discharge at mouth.

Table 6.--*Records of test holes penetrating coal and other aquifers in the Prairie Dog Creek drainage basin and adjacent areas*

[Test-hole number: Abbreviated principal aquifers are BA, Brewster-Arnold coal bed; C, Canyon coal bed; Cl, clinker; W, Wall coal bed. Other aquifers: A, Anderson coal bed; C, Canyon coal bed; Ss, sandstone. Logs available G, gamma-ray; GG, gamma-gamma; L, lithologic; R, resistivity; S, spontaneous potential. Remarks: BM, Montana Bureau of Mines and Geology; SH, State hole; GS, U.S. Geological Survey; U.S, Federal hole; BR, U.S. Bureau of Reclamation]

Test-hole number (fig. 6)	Location	Comple-tion date	Altitude of land surface (feet above sea level)	Hole depth (feet below land sur-face)	Aquifer interval (feet below land surface)	Other aquifers	Other aquifer interval (feet below land surface)
1-C	SE1/4 NW1/4 SW1/4 NE1/4 sec. 3, T. 6 S., R. 40 E.	9-69	4,126	90	52-81	None	--
2-W	NE1/4 NE1/4 sec. 12 T, 6 S., R. 40 E.	9-69	3,865	193	126-173	None	--
3-C	NE1/4 NE1/4 NE1/4 sec. 16, T. 6 S., R. 40 E.	10-69	4,050	210	45-73	Ss	75-98
4-W	SW1/4 SE1/4 NW1/4 sec. 20, T 6 S., R. 40 E.	1977	4,392	663	600-663	A, C	116-130 408-437
5-W	SW1/4 SW1/4 SW1/4 sec. 24, T. 6 S., R. 40 E.	9-69	3,721	102	37-97	None	--
6-W	SW1/4 NW1/4 SW1/4 sec. 32, T. 6 S., R. 40 E.	1977	4,258	640	574-630	A, C	86-113 370-386
7-W	SE1/4 SE1/4 NW1/4 sec. 1, T. 7 S., R. 40 E.	9-69	3,624	260	199-259	Ss	167-199
8-W	SW1/4 NW1/4 NW1/4 SW1/4 sec. 33, T. 5 S., R. 41 E.	9-69	3,783	180	145-177	None	--
9-Cl	SW1/4 SW1/4 SW1/4 NW1/4 sec. 4, T. 6 S., R. 41 E.	6-19-79	3,740	106.5	94-106	None	--
10-W	SE1/4 SW1/4 NW1/4 NE1/4 sec. 5, T. 6 S., R. 41 E.	6-25-79	3,770	174	111-155	None	--
11-W	SE1/4 NE1/4 NW1/4 NW1/4 sec. 7, R. 6 S., R. 41 E.	10-17-78	3,910	302	226-277	Ss	191-220
12-W	SW1/4 SE1/4 SE1/4 SE1/4 sec. 8, T. 6 S., R. 41 E.	5-07-79	3,790	220	146-196	None	--
13-BA	SE1/4 SW1/4 SE1/4 sec. 12, T. 6 S., R. 41 E.	1969	3,425	160	134-144	None	--
14-W	NW1/4 SW1/4 NE1/4 SW1/4 sec. 16, T. 6 S., R. 41 E.	9-69	3,601	165	35-84	None	--
15-W	NE1/4 SE1/4 SE1/4 SW1/4 sec. 21, T. 6 S., R. 41 E.	9-69	3,586	113	54-110	None	--
16-Cl	NW1/4 NW1/4 NW1/4 NW1/4 sec. 22, T. 6 S., R. 41 E.	11-29-78	3,640	113.5	100-113	None	--
17-W	SW1/4 NW1/4 SE1/4 NE1/4 sec. 29, T. 6 S., R. 41 E.	7-24-78	3,825	399	323-386	C, Ss	52-63 205-314
18-W	NW1/4 NE1/4 SE1/4 SW1/4 sec. 33, T. 6 S., R. 41 E.	7-16-79	3,690	383	245-277	Ss (dry?)	76-116
19-BA	SW1/4 NW1/4 NW1/4 SE1/4 sec. 31, T. 6 S., R. 42 E.	9-69	3,243	100	67-83	None	--

Table 6.--*Records of test holes penetrating coal and other aquifers in the Prairie Dog Creek drainage basin and adjacent areas*--Continued

Test-hole number (fig. 6)	Static water level Date	Static water level Feet below land surface	Logs available	Remarks
1-C	--	--	L	Hole cored 55-90 feet. BM SH-47. Site not exactly located.
2-W	--	--	L	Hole cored 130-175 feet. BM SH-121. Site not exactly located.
3-C	--	--	L	No core samples. BM SH-48. In Canyon Creek drainage basin.
4-W	--	--	G,GG	Apparently no core samples. GS U.S. 77-37. In Canyon Creek drainage basin.
5-W	--	--	L	Hole cored 40-79 feet. BM SH-49. In Canyon Creek drainage basin.
6-W	--	--	G,GG S,R	Cored in coal? GS U.S. 77-36. In Canyon Creek drainage basin.
7-W	--	--	L	Hole cored 200-260 feet. BM SH-50. In Canyon Creek drainage basin.
8-W	--	--	L	Hole cored 36-37 feet and 150-163 feet. Lower Wall bed not reached. BM SH-110. In Bull Creek drainage basin.
9-Cl	--	--	L	Reported no water. BR hole cored top to bottom, poor recovery. In Bull Creek drainage basin.
10-W	6-25-79	97±	L	BR hole cored top to bottom. In Bull Creek drainage basin.
11-W	10-17-79	140±	L,G	BR hole cored top to bottom. Gamma log only from 5-60 feet; hole collapsed below.
12-W	5-07-79	96±	L	BR hole cored top to bottom.
13-BA	--	--	L	Hole cored 72-76 feet and 137-144 feet. BM SH-33. In Bull Creek drainage basin.
14-W	--	--	L	Hole cored 40-89 feet. BM SH-46. Lower Wall bed apparently carbonaceous shale here.
15-W	--	--	L	Hole cored 57-113 feet. BM SH-45. In Jeffrys Prong valley.
16-CL	--	--	L	Reported no water. BR hole cored top to bottom, poor recovery.
17-W	7-24-78	280±	L	Hole cored top to bottom. On divide between Prairie Dog and Spring Creek drainage basins.
18-W	7-16-79	161±	L	Hole cored top to bottom. Wall coal bed faulted, partly missing. On Spring-Canyon Creek drainage divide.
19-BA	--	--	L	Hole cored 70-83 feet. BM SH-44.

Table 7.--*Records of observation wells completed in sandstone and coal aquifers in the Prairie Dog Creek drainage basin and adjacent areas*

[Well number: Abbreviated principal aquifers are BA, Brewster-Arnold coal bed; LC, local coal bed; LW, lower Wall coal bed; Ss, sandstone; St, siltstone; W, Wall coal bed. Water-level availability: M, monthly; S, semiweekly. Logs available: D, drillers', G, gamma-ray; L, lithologic; N, neutron. Drilled by: BM, Montana Bureau of Mines and Geology; GS, U.S. Geological Survey; P, private; BR, U.S. Bureau of Reclamation; Remarks: BM, Montana Bureau of Mines and Geology]

Well number (fig. 6)	Location	Completion date	Altitude of land surface (feet above sea level)	Well depth (feet below land surface)	Aquifer interval (feet below land surface)	Casing diameter (inches)	Cased interval (feet above (+) to below land surface)
20-LW	SW1/4 SE1/4 SE1/4 SW1/4 sec. 1, T. 6 S., R. 40 E.	6-11-79	3,940	253	238-248	4	+1.1-253
21-W	NE1/4 SE1/4 NW1/4 SE1/4 sec. 2, T. 6 S., R. 40 E.	8-24-78	4,030	278	227-273	4	+0.9-278
22-BA	SE1/4 SE1/4 NE1/4 NW1/4 sec. 3, T. 6 S., R. 41 E.	6-01-79	3,530	262	182-195	4	+1.6-210
23-Ss	SE1/4 SE1/4 NE1/4 NW1/4 sec. 3, T. 6 S., R. 41 E.	6-05-79	3,530	80	27-73	4	+0.7-79
24-W	SW1/4 NW1/4 NW1/4 NE1/4 sec. 6, T. 6 S., R. 41 E.	6-13-79	4,020	373	339-373+	2	+1.5-368
25-BA	NE1/4 NW1/4 SW1/4 SW1/4 sec. 8, T. 6 S., R. 41 E.	4-25-79	3,745	386.5	366-376	2	+2.4-386
26-W	SW1/4 NE1/4 SW1/4 SW1/4 sec. 8, T. 6 S., R. 41 E.	9-08-76	3,740	140	66-110	4	+1.8-130
27-W	NE1/4 SE1/4 SW1/4 SE1/4 sec. 15, T. 6 S., R. 41 E.	5-22-79	3,860	333	267-312	2	+0.9-329
28-W	SW1/4 SW1/4 NW1/4 NW1/4 sec. 16, T. 6 S., R. 41 E.	8-15-78	3,715	144	98-138	4	+2.1-143
29-W	NE1/4 NE1/4 NE1/4 SE1/4 sec. 17, T. 6 S., R. 41 E.	5-12-79	3,616	54	20-48	4	+0.9-53
30-W	NE1/4 NW1/4 SW1/4 SE1/4 sec. 18, T. 6 S., R. 41 E.	7-23-79	3,805	214.5	136-199	2	+1.8-214
31-LC	SE1/4 SW1/4 NW1/4 NW1/4 sec. 21, T. 6 S., R. 41 E.	11-17-78	3,600	274	170-190	2	+2.7-273
32-LW	SW1/4 SE1/4 SE1/4 SE1/4 sec. 21, T, 6 S., R. 41 E.	6-14-79	3,530	51	35-43	4	+1.0-51
33-Ss	SW1/4 SW1/4 SW1/4 SW1/4 sec. 23, T. 6 S., R. 41 E.	6-55	3,425	300	160-300+	4	--
34-BA	SW1/4 NE1/4 SE1/4 SW1/4 sec. 25, T. 6 S., R. 41 E.	8-30-78	3,335	145	122-141	4	+1.1-145
35-W	NE1/4 SW1/4 SE1/4 NE1/4 sec. 29, T. 6 S., R. 41 E.	9-01-78	3,835	394	328-389	4	+1.1-394
36-Ss	NE1/4 SW1/4 SE1/4 NE1/4 sec. 29, T. 6 S., R. 41 E.	9-13-78	3,834	323	240-313	4	+1.0-323
37-W	SE1/4 NW1/4 NW1/4 NW1/4 sec. 33, T. 6 S., R. 41 E.	9-15-78	3,715	298	242-293	4	+1.0-298
38-Ss	SE1/4 NW1/4 NW1/4 NW1/4 sec. 33, T. 6 S., R. 41 E.	9-26-78	3,715	166	163-165	4	+0.9-166
39-St	NE1/4 NE1/4 SE1/4 SW1/4 sec. 34, T. 6 S., R. 41 E.	9-29-78	3,460	364	341-360	4	+1.6-363
40-W	NE1/4 NE1/4 SE1/4 SW1/4 sec. 34, T. 6 S., R. 41 E.	6-06-79	3,460	155	99-150	4	+0.7-154
41-BA	SW1/4 NW1/4 SE1/4 SW1/4 sec. 19, T. 6 S., R. 42 E.	5-24-79	3,435	208	186-205	4	+0.9-208

Table 7.--*Records of observation wells completed in sandstone and coal aquifers in the Prairie Dog Creek drainage basin and adjacent areas*--Continued

Well number (fig. 6)	Perforated interval (feet below land surface)	Packer setting (feet below land surface)	Other aquifers	Other aquifer interval (feet below land surface)	Static water level: Date	Static water level: Feet below land surface	Discharge (gallons per minute)
20-LW	238-248	236	Wall coal bed	184-231	7-07-79	105.0	0.17
21-W	227-273	218 and 225	Sandstone, fine-grained (probably dry)	105-169	--	--	--
22-BA	180-195	178	Sandstone, very fine to fine-grained	112-139 210-237	7-10-79	108.3	.40
23-Ss	38-73	25	None	--	7-10-79	24.6	4.2
24-W	331-367	--	Sandstone, fine-grained	306-325	10-21-79	281.4	--
25-BA	356-376	--	Sandstone, fine-grained	157-259	10-21-79	186.4	--
26-W	70-110	65	Sandstone, fine-grained. Lower Wall coal	46-66 116-124	10-19-78	35.6	7.6
27-W	269-309	--	Canyon coal (probably dry). Sandstone (maybe dry).	47-58 211-258	10-21-79	305.6	--
28-W	98-138	95	None	--	10-18-78	104.3	1.3
29-W	23-48	21	Alluvium	11-16	10-17-79	11.8	6.6
30-W	154-194	--	None	--	10-21-79	119.8	--
31-LC	169-199	--	Wall coal bed. Sandstone, fine-grained.	28-74 109-153	10-21-79	23.5	--
32-LW	26-51	20	Overlying clinker is dry	--	10-18-79	35.7	.20
33-Ss	--	--	Brewster-Arnold coal	135-160±	7-10-75	--	2±
34-BA	122-141	120	Sandstone and coal seams	74-89	10-16-78	58.0	8.6
35-W	328-389	319 and 325	Sandstone, fine-grained	240-313	10-20-78	263.1	3.5
36-Ss	258-318	206 and 213	Canyon coal bed (probably dry)	64-74	10-20-78	237.4	4.0
37-W	242-293	233 and 241	Sandstone dirty, very fine-grained (mostly dry)	139-163	10-19-78	246.8	2
38-Ss	146-166	140	None (all dry)	--	10-22-79	163.5	--
39-St	341-360	339	Wall coal bed	100-149	10-18-78	183.6	.1
40-W	103-153	97	Sandstone fine-to very fine-grained (WL=63 feet?)	58-75	7-08-79	92.6	1.0
41-BA	186-205	185	Coal seams and sandstone (probably dry)	110-132	10-20-79	180.5	1.2

Table 7.--*Records of observation wells completed in sandstone and coal aquifers in the Prairie Dog Creek drainage basin and adjacent areas*--Continued

Well number (fig. 6)	Chemical analysis available	1978-79 interpolated water-level fluctuation (feet)	Water-level availability	Logs available	Drilled by	Remarks
20-LW	Yes	--	M	L,G,N	BM	Aquifer test by BM.
21-W	No	272-278+	M	L,G,N	BM	Well with and without water at different times. Lower Wall not reached.
22-BA	Yes	107-109	M	L,G,N	BM	Aquifer test by BM. In Bull Creek drainage basin.
23-Ss	Yes	23-27	M	L,G,N	BM	Aquifer test by BM. In Bull Creek drainage basin.
24-W	No	--	M	L,G,N	BR	Hole gravel-packed outside casing, 204-368 feet. Core samples taken. In Bull Creek drainage basin.
25-BA	No	--	S	L,G,N	BR	Hole gravel-packed 350-386 feet. Core samples taken.
26-W	Yes	31-40	S	L,G,N	GS	Aquifer test by BM.
27-W	No	--	M	L,G,N	BR	Hole gravel-packed from 260-328 feet. Core samples taken.
28-W	Yes	101-104	S	L,G,N	BM	Aquifer test by BM. Lower Wall not penetrated.
29-W	Yes	9-11.5	S	L,G,N	BM	During aquifer test, well broke seal to alluvium; Water level rose to water level in alluvium. Lower Wall not penetrated.
30-W	No	--	M	L,G,N	BR	Hole gravel-packed 130-214 feet. Core samples taken. In Jack Creek drainage basin.
31-LC	No	23-25	S	L,G,N	BR	Hole gravel-packed 160-265 feet. Core samples taken. In Jack Creek drainage. basin.
32-LW	Yes	35.5-35.8	S	L,G,N	BM	Clinker dry so well completed in lower Wall coal bed.
33-Ss	Yes	--	--	D	P	Well has operating windmill. Driller's log very general.
34-BA	Yes	56-59	S	L,G,N	BM	Aquifer test by BM.
35-W	Yes	263-264	M	L,G,N	BM	On drainage divide between Prairie Dog and Spring Creeks.
36-Ss	Yes	237-238	M	L,G,N	BM	On drainage divide between Prairie Dog and Spring Creeks.
37-W	No	246.5-247	M	L,G,N	BM	In Spring Creek drainage basin. Lower Wall not penetrated.
38-Ss	No	163-163.5	M	L,G,N	BM	Not enough water in hole to test. In Spring Creek drainage basin.
39-St	Yes	182-184	M	L,G,N	BM	In Spring Creek drainage basin.
40-W	Yes	--	M	L,G,N	BM	Aquifer test by BM. In Spring Creek drainage basin.
41-BA	Yes	179-181	M	L,G,N	BM	Between Prairie Dog and Bull Creeks.

Table 8.--*Aquifer-test results at observation wells completed in sandstone and coal aquifers*

[Well number: Abbreviated principal aquifers are BA, Bewster-Arnold coal bed; LW, lower Wall coal bed; Ss, sandstone; St, siltstone; W, Wall coal bed. Specific capacity: gallons per minute per foot of drawdown at end of 2-to 4-hour test]

Well number (fig. 6)	Date of aquifer test	Aquifer interval perforated (feet below land surface)	Static water level (feet below land surface)	Discharge (gallons per minute)	Total drawdown (feet below static water level)	Specific capacity	Transmissivity (feet squared per day)	Hydraulic conductivity (feet per day)
				Sandstone wells				
23-Ss[1]	7-10-79	38-73	24.6	4.2	1.9	2.2	530	15
36-Ss	10-20-78	258-313	237.4	4.0	37	.11	13	.24
39-St	10-18-78	341-346 and 350-360	183.6	.10	150	.0007	.04	.002
				Wall coal-bed wells				
26-W[1]	10-19-78	70-110	35.6	7.6	12	.63	65	1.6
28-W[1]	10-18-78	98-138	104.3	1.3	14	.09	12	.35
29-W[2]	10-17-79	23-48	11.8	6.6	12	.55	60	2.4
35-W	10-20-78	328-389	263.1	3.5	26	.13	14	.24
37-W	10-19-78	242-293	246.8	2.0	36	.06	2.5	.05
40-W[1]	7-08-79	103-153	92.6	1.0	6.9	.14	22	.45
				Lower Wall coal-bed wells				
20-LW[1]	7-07-79	238-248	105.0	.17	70	.002	.25	.02
32-LW	10-18-79	36-43	35.7	.20	14	.01	.53	.07
				Brewster-Arnold coal-bed wells				
22-BA[1]	7-10-79	182-195	108.3	.40	50	.008	.25	.02
34-BA[1]	10-16-78	122-141	58.0	8.6	12	.72	80	4.2
41-BA	10-20-79	186-205	180.5	1.2	20	.06	3.3	.17

[1]Test conducted by Montana Bureau of Mines and Geology.

[2]Well seal broke during aquifer test. Water may be partly from alluvium.

Table 9.--*Chemical analyses of water from sandstone and coal aquifers in the Prairie Dog Creek drainage basin and adjacent areas*

[Except as indicated otherwise, constituents are dissolved and constituent values are reported in milligrams per liter. Well number: Abbreviated principal aquifers are BA, Brewster-Arnold coal bed; LW, lower Wall coal bed; Ss, sandstone; St, siltstone; W, Wall coal bed. Analysis by: BM, Montana Bureau of Mines and Geology; GS, U.S. Geological Survey. Abbreviations: gal/min, gallons per minute; micromhos, micromhos per centimeter at 25° Celsius; °C, degrees Celsius; mg/L, micrograms per liter]

Well number (fig. 6)	Date sample collected	Hour	Well discharge (gal/min)	Specific conductance (micromhos)	Onsite pH (units)	Water temperature (°C)	Hardness as $CaCO_3$ (Ca,Mg)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)
					Sandstone water						
23-Ss	7-10-79	1730	4.2	3,800	7.7	12.0	1,100	130	180	570	8
36-Ss	10-20-78	1400	4.0	3,700	6.7	13.0	1,900	220	320	290	3
39-St	10-18-78	1400	.10	3,100	8.3	17.0	24	5.4	2.5	840	75
					Wall coal-bed water						
26-W	10-19-78	1500	7.6	3,100	7.4	11.0	480	38	94	590	12
28-W	10-18-78	1100	1.3	3,600	7.8	13.5	33	8.4	2.7	910	70
29-W[1]	10-17-79	1330	6.6	1,700	7.2	11.0	500	79	74	190	4
35-W	10-20-78	1100	3.5	5,000	7.0	14.0	1,800	220	300	770	8
40-W	7-08-79	1330	1.0	2,400	7.6	15.0	570	60	100	380	7
					Lower Wall coal-bed water						
20-LW	7-07-79	1500	.17	2,700	8.0	26.0	530	50	99	480	9
32-LW	10-18-79	1240	.20	2,200	7.2	14.0	960	120	160	210	3
					Brewster-Arnold coal-bed water						
34-BA	10-16-78	1400	8.6	1,450	8.1	11.0	2	.7	.1	380	113
41-BA	10-20-79	1400	1.2	2,100	8.3	14.5	12	2.6	1.3	520	66

Well number (fig. 6)	Potassium (K)	Bicarbonate (HCO_3)	Alkalinity total, as $CaCO_3$	Sulfate (SO_4)	Chloride (CL)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, calculated sum of constituents	Nitrite + nitrate, as nitrogen	Iron (Fe) (μg/L)	Trace-element analysis available	Analysis by
23-Ss	14	570	470	1,800	7.5	1.4	14	3,260	0.04	600	Yes	BM
36-Ss	9	1,000	830	1,600	14	.6	20	2,980	.01	920	Yes	GS
39-St	6	1,200	1,500	400	19	8.7	8.0	2,170	.03	20	Yes	GS
26-W	12	890	730	1,100	7.6	2.0	11	2,300	.02	270	Yes	GS
28-W	6	890	740	1,100	11	3.0	8.0	2,490	.02	50	Yes	GS
29-W[1]	8	570	470	480	4.9	.6	12	1,130	.23	580	Yes	GS
35-W	15	1,300	1,200	2,200	13	.8	14	4,190	.01	200	Yes	GS
40-W	13	430	360	1,000	12	1.4	22	1,820	.02	130	Yes	BM
20-LW	8	680	580	940	5.7	5.2	16	2,290	.24	20	No	BM
32-LW	14	340	280	1,100	12	1.1	21	1,810	.00	70	Yes	GS
34-BA	2	830	680	160	8.4	13	8.8	983	.04	10	Yes	GS
41-BA	4	--	290	160	12	12	8.5	--	.01	130	Yes	GS

[1]Well seal broke during aquifer test. Wall water probably mixed with alluvial water.

Table 10.--*Records of observation wells completed in alluvium*

[Well number: Abbreviated principal aquifers are Q, alluvium; Q-Cl, alluvium and clinker. Logs available: G, gamma-ray; L, lithologic; N, neutron. Remarks: BM, Montana Bureau of Mines and Geology]

Well number (fig. 7)	Location	Completion date	Altitude of land surface (feet above sea level)	Well depth (feet below land surface)	Aquifer material	Depth to bottom of aquifer (feet below land surface)	Casing diameter (inches)	Cased interval (feet above (+) to below land surface)	Perforated interval (feet below land surface)
42-Q	SE1/4 NW1/4 SW1/4 SW1/4 sec. 8, T. 6 S., R. 41 E.	5-16-79	3,715	20	sand, gravel	16	4	+1.0-20	6-18
43-Q	NE1/4 NE1/4 NE1/4 SE1/4 sec. 17, T. 6 S., R. 41 E.	5-14-79	3,616	14	sand, gravel	13	4	+1.1-14	6-13
44-Q	SE1/4 SE1/4 SE1/4 NE1/4 sec. 17, T. 6 S., R. 41 E.	5-15-79	3,616	20	gravel, sand	16	4	+1.2-19.5	9-19
45-Q	SE1/4 SE1/4 SE1/4 NE1/4 sec. 17, T. 6 S., R. 41 E.	5-16-79	3,618	19.5	gravel, sand	16	4	+1.1-19	6-18
46-Q	SE1/4 NW1/4 SE1/4 NE1/4 sec. 21, T. 6 S., R. 41 E.	5-17-79	3,515	25	gravel, sand	20	4	+1.1-20.5	7-19
47-Q	SE1/4 NW1/4 SE1/4 NE1/4 sec. 21, T. 6 S., R. 41 E.	5-19-79	3,515	23	gravel, sand	22	4	+0.9-23	7-22
48-Q	NE1/4 NW1/4 SE1/4 NE1/4 sec. 21, T. 6 S., R. 41 E.	5-21-79	3,522	30	gravel, sand; partly clayey	28	4	+1.1-30	19-29
49-Q	NW1/4 SW1/4 NE1/4 SW1/4 sec. 22, T. 6 S., R. 41 E.	5-08-79	3,480	21.5	gravel, sand	18	4	+1.1-20	8-18
50-Q	SW1/4 NW1/4 NE1/4 SW1/4 sec. 22, T. 6 S., R. 41 E.	5-08-79	3,483	22	sand, gravel	19	4	+1.1-21	9-19
51-Q	SE1/4 NW1/4 NE1/4 SW1/4 sec. 22, T. 6 S., R. 41 E.	8-15-78	3,482	21.5	gravel, sand	21	4	+2.0-20	15-20
52-Q-Cl	NW1/4 SW1/4 SE1/4 SW1/4 sec. 22, T. 6 S., R. 41 E.	1910±	3,495	27.5	clinker gravel	26±	26	--	--
53-Q	SW1/4 SE1/4 NW1/4 NW1/4 sec. 26, T. 6 S., R. 41 E.	8-14-78	3,400	27	sand, gravel	24	4	+2.1-23.5	9.5-22.5
54-Q	NW1/4 SE1/4 NW1/4 NW1/4 sec. 26, T. 6 S., R. 41 E.	8-10-78	3,395	23	sand, gravel	22	4	+1.2-23	7-22
55-Q	NE1/4 SE1/4 NW1/4 NW1/4 sec. 26, T. 6 S., R. 41 E.	8-10-78	3,394	25	gravel, sand	20	4	+2.0-22	6-20
56-Q	NE1/4 SE1/4 NW1/4 NW1/4 sec. 26, T. 6 S., R. 41 E.	5-04-79	3,394	22	gravel, sand	20	4	+1.1-22	5-22
57-Q	SW1/4 SW1/4 NE1/4 NW1/4 sec. 26, T. 6 S., R. 41 E.	5-04-79	3,385	24	sand, gravel	17	4	+1.1-24	10-17
58-Q-Cl	NW1/4 NW1/4 SW1/4 SW1/4 sec. 25, T. 6 S., R. 41 E.	8-28-78	3,355	30	clinker gravel	28	4	+1.1-28	21-28
59-Q	SE1/4 NW1/4 NW1/4 SE1/4 sec. 31, T. 6 S., R. 42 E.	5-03-79	3,236	47	sand, gravel	45	4	+1.3-47	17-45
60-Q	NE1/4 NW1/4 NW1/4 SE1/4 sec. 31, T. 6 S., R. 42 E.	5-02-79	3,235	56	gravel, sand	52	4	+0.9-56	33-53
61-Q	NE1/4 NW1/4 NW1/4 SE1/4 sec. 31, T. 6 S., R. 42 E.	5-01-79	3,234	69	gravel, sand	61	4	+1.2-69	21-61

Well number (fig. 7)	Packer setting (feet below land surface)	Date of hydrologic data	Static water level (feet below land surface)	Discharge (gallons per minute)	Chemical analysis available	1978-79 interpolated water-level fluctuation (feet)	Water-level measurement data available	Logs available	Remarks[1]
42-Q	4	7-09-79	11.3	12	Yes	9-17	H	L,G,N	Aquifer test by BM. Recorder installed 7-11-79.
43-Q	4	7-06-79	9.8	11	Yes	8-10.5	S	L,G,N	Aquifer test by BM.
44-Q	6	10-16-79	10.8	31	Yes	8-10.5	S	L,G,N	Initial pumping test 10-02-79.
45-Q	4	10-01-79	12.3	21	Yes	9.5-12	S	L,G,N	
46-Q	5	7-05-79	16.1	5.9	Yes	12-17	S	L,G,N	Aquifer test by BM.
47-Q	4	7-04-79	16.8	.90	Yes	12-19.5	S	L,G,N	Aquifer test by BM.
48-Q	8	9-30-79	25.3	3.0	Yes	18-25	S	L,G,N	
49-Q	8	5-08-79	13.0	1>	No	11.5-16	S	L,G,N	Developed only; data from BM
50-Q	5	5-08-79	13.6	2>	No	12-17	S	L,G,N	Developed only; data from BM
51-Q	9	8-15-78	13.2	1>	No	12-17	H	L,G,N	Developed only; data from BM Recorder installed 9-20-78.
52-Q-C1		8-02-78	23.6	--	No	21.5-24.5	S	G	Old homestead dug well used for observation.
53-Q	7.5	8-14-78	16.9	1>	No	15.5-20.5	S	L,G,N	Developed only; data from BM
54-Q	5	9-28-79	13.8	15	Yes	10.5-15.5	S	L,G,N	
55-Q	4	9-27-79	12.5	6.1	Yes	9-13.5	H	L,G,N	Recorder installed 9-15-78.
56-Q	5	9-27-79	12.4	--	No	9-13.5	S	L,G,N	Observation well, 20 feet southeast of 06S41E26BBDA01.
57-Q	4	9-29-79	15.8	1.8	Yes	11-17	S	L,G,N	
58-Q-C1	16	10-13-78	25.4	3>	Yes	22-28	S	L,G,N	Pumped by BM for water-quality sample.
59-Q	14	9-26-79	16.1	10	Yes	16-17.5	S	L,G,N	
60-Q	16	7-11-79	16.0	30	Yes	15-16.5	S	L,G,N	Aquifer test by BM.
61-Q	18	9-25-79	13.9	30	Yes	13.5-15	H	L,G,N	Recorder installed 7-23-79.

[1]All wells were drilled by Montana Bureau of Mines and Geology except well 52-Q-C1, which is a private well.

Table 11.--*Aquifer-test results at observation wells completed in alluvium*

[Well number: Abbreviated principal aquifer is Q, alluvium. Specific capacity: gallons per minute per foot of drawdown at end of 2- to 4-hour test]

Well number (fig. 7)	Aquifer material	Date of aquifer test	Water intake interval (feet below land surface)	Static water level (feet below land surface)	Discharge (gallons per minute)	Total draw-down (feet below static water level)	Spe-cific capac-ity	Trans-missivity (feet squared per day)	Hydrau-lic conduc-tivity (feet per day)	Storage coefficient
42-Q[1]	sand, gravel	7-09-79	11.3-16.0	11.3	12	3.7	3.2	1,200	260	--
43-Q[1]	sand, gravel	7-06-79	9.8-12.3	9.8	11	1.2	9.2	1,300	530	0.09
44-Q	gravel, some sand	10-16-79	10.8-16.3	10.5	31	1.0	31	5,300	970	.05
45-Q	gravel, some sand	10-01-79	12.3-16.1	12.0	21	1.6	13	3,600	950	.07
46-Q[1]	gravel, some sand	7-05-79	16.1-19.1	16.1	5.9	1.7	3.5	930	300	--
47-Q[1]	gravel, some sand	7-04-79	16.8-20.3	16.8	.90	2.7	.33	80	22	--
48-Q	gravel, some sand	9-30-79	24.3-28.0	24.2	3.0	4.1	.73	200	50	--
54-Q	sand, gravel	9-28-79	13.8-21.8	13.8	15	1.6	9.4	4,800	600	--
55-Q	gravel, some sand	9-27-79	12.5-20.0	12.5	6.1	5.5	1.1	2,100	280	.02
57-Q	sand, gravel	9-29-79	15.8-17.3	15.5	1.8	6.0	.30	15	10	--
59-Q	sand, gravel	9-26-79	17-45	16.1	10	17	.59	40	1.4	--
60-Q[1]	gravel, sand	7-11-79	33-53	16.0	30	1.9	16	9,200	460	.03
61-Q	gravel, sand	9-25-79	21-28 and 36-61	13.9	30	9.3	3.2	600	18	--

[1]Test conducted by Montana Bureau of Mines and Geology.

Table 12.--*Chemical analyses of water from alluvium*

[Except as indicated otherwise, constituents are dissolved and constituent values are reported in milligrams per liter. Well number: Abbreviated principal aquifers are Q, alluvium; Q-Cl, alluvium and clinker. Analysis by: BM, Montana Bureau of Mines and Geology; GS, U.S. Geological Survey. Abbreviations: gal/min, gallons per minute; micromhos, micromhos per centimeter at 25° Celsius, °C, degrees Celsius, µg/L micrograms per liter]

Well number (fig. 7)	Date sample collected	Hour	Well discharge (gal/min)	Specific conductance (micromhos)	Onsite pH (units)	Water temperature (°C)	Hardness as $CaCO_3$ (Ca,Mg)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium-adsorption ratio (SAR)	Potassium (K)
42-Q	7-09-79	1600	12	2,100	7.9	10.0	1,100	120	190	110	2	8
43-Q	7-06-79	1700	11	2,200	8.0	11.5	1,200	130	210	120	2	8
44-Q	10-02-79	1320	28	2,150	7.7	12.5	1,200	130	210	120	2	9
44-Q	10-16-79	1730	31	2,150	7.3	12.0	1,100	120	200	130	2	9
45-Q	10-01-79	1330	21	2,050	7.7	13.0	1,100	120	200	110	1	9
47-Q	7-04-79	1500	.90	1,600	8.1	18.0	750	60	150	120	2	9
48-Q	9-30-79	1330	3.0	1,550	7.8	12.0	690	78	120	90	2	9
54-Q	10-20-78	0900	--	2,000	7.8	11.0	770	81	140	150	2	10
54-Q	9-28-79	1440	15	1,780	7.8	12.0	720	72	130	140	2	11
55-Q	9-27-79	1700	6.1	1,800	7.4	11.5	710	68	130	140	2	11
57-Q	9-29-79	1330	1.8	1,850	7.8	13.0	720	73	130	150	2	11
58-Q-Cl	10-13-78	1500	3.0	2,000	8.0	15.0	830	88	150	220	3	10
59-Q	9-26-79	1430	10	1,600	7.9	13.0	570	64	100	140	2	11
60-Q	7-11-79	1220	30	1,600	8.1	10.0	620	71	110	150	3	10
61-Q	9-25-79	1130	30	1,620	7.6	12.0	580	69	100	150	3	12

Well number (fig. 7)	Bicarbonate (HCO_3)	Alkalinity, total as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Silica (SiO_2)	Dissolved solids, sum of calculated constituents	Nitrite + nitrate, as nitrogen	Iron (Fe) (µg/L)	Trace element analysis	Analysis by
42-Q	670	550	720	7.5	0.4	16	1,500	0.64	20	No	BM
43-Q	630	510	880	9.0	.4	17	1,680	.27	70	Yes	BM
44-Q	720	590	850	7.9	.5	18	1,700	.29	10	No	GS
44-Q	710	580	820	9.0	.5	17	1,660	.22	10	Yes	GS
45-Q	710	580	760	7.3	.5	18	1,580	.34	10	No	GS
47-Q	510	420	540	6.9	.5	20	1,150	.26	70	Yes	BM
48-Q	310	250	570	5.3	.5	19	1,040	.28	10	No	GS
54-Q	580	480	590	7.8	.7	30	1,290	.38	10	No	BM
54-Q	360	290	670	6.8	.7	21	1,230	.37	20	No	GS
55-Q	360	300	670	6.9	.8	21	1,230	.41	--	No	GS
57-Q	360	290	700	7.2	.8	21	1,270	.50	100	No	GS
58-Q-Cl	600	490	780	10.3	.9	23	1,570	--	150	Yes	BM
59-Q	330	270	570	6.2	.9	23	1,080	.24	80	No	GS
60-Q	480	400	540	5.7	.8	27	1,140	2.2	30	Yes	BM
61-Q	340	280	600	6.6	.9	25	1,140	1.0	--	No	GS