POTENTIAL EFFECTS OF SURFACE COAL MINING ON THE HYDROLOGY OF THE LITTLE BEAR CREEK AREA, MOORHEAD COAL FIELD, SOUTHEASTERN MONTANA

By Neal E. McClymonds

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CONVERSION FACTORS

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

Multiply inch-pound unit	By	To obtain SI unit
	Length	
foot	0.3048	meter
inch	25.40	millimeter
mile	1.609	kilometer
	Area	
square foot (ft^2)	0.0929	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
acre-foot	1,233	cubic meter
	Weight	
ton (short)	0.9072	megagram
	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)	0.06309	liter per second
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day

Temperature can be converted to degrees Celsius (°C) or degrees Fahrenheit (°F) by the equations:

$$°C = 5/9\ (°F - 32)$$
$$°F = 9/5\ (°C) + 32$$

POTENTIAL EFFECTS OF SURFACE COAL MINING ON THE HYDROLOGY OF THE LITTLE BEAR CREEK AREA, MOORHEAD COAL FIELD, SOUTHEASTERN MONTANA

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ABSTRACT

The Little Bear Creek study area is located near the west end of the Moorhead coal field, about 27 miles south of Ashland, Montana, and 22 miles east of the Tongue River valley near the West Decker and East Decker Coal Mines. The area contains large reserves of Federally owned coal that have been identified for potential lease sale. A hydrologic study was conducted in the area to describe existing hydrologic systems and to assess potential effects of surface mining on local water resources.

Water is available in the Little Bear Creek basin from wells, springs, and stock ponds, and several reaches of stream channels that have interrupted flow. Many of the streams, stock ponds, and springs are dry at least part of the year.

Ground-water information was collected from existing private wells, test holes, and a network of observation wells. The wells were completed in sandstone and coal-bed aquifers of the Tongue River Member of the Fort Union Formation (Paleocene age) and the shallow alluvial sand and gravel aquifers (Pleistocene and Holocene age.)

The basin, with an area of 29.2 square miles, contains the outcrops of the upper 800 feet of the Tongue River Member exposed throughout the area, except along the southwestern and southern divides where the lower part of the Wasatch Formation (Eocene age) caps the ridges. The Lebo Shale Member of the Fort Union Formation underlies the basin at a depth of about 1,100 feet near the mouth of Little Bear Creek. The strata generally dip toward the southwest across the basin, but are offset by a series of faults in the southeastern and southern parts.

Ground water is supplied from sandstone and coal beds of the Tongue River Member and from alluvial sands and gravels along the main stream valleys. Clinker layers, most of which are burned Anderson coal in the northern and central parts of the basin, also contain water in basal parts. In general, the hydrologic and chemical characteristics of the principal aquifers are: Canyon coal -- hydraulic conductivity of about 1.4 feet per day and dissolved-solids concentration of 1,500 to 1,870 milligrams per liter; Dietz coal -- hydraulic conductivity of about 0.5 foot per day and dissolved-solids concentration of 1,750 to 3,220 milligrams per liter; Anderson coal -- hydraulic conductivity of about 0.2 foot per day and dissolved-solids concentration of 2,360 to 5,550 milligrams per liter; sandstone beds (10 or more feet thick) -- hydraulic conductivity of 0.1 to 1.2 feet per day and dissolved-solids concentration of 1,070 to 4,080 milligrams per liter; and alluvial sand and gravel layers -- mean values of hydraulic conductivity of about 10 to 350 feet per day and dissolved-solids concentration of about 2,000 to 10,000 milligrams per liter.

From an assumed mine outline, with an area of about 6.7 square miles, the probable effects of surface mining on the hydrology were evaluated. Within the boundaries of the potential mine, about 235 million tons of Anderson coal and about 95 million tons of Dietz coal would be removed. One stock well and several stock ponds in the mined area would be destroyed. One spring in Davidson Draw possibly would be affected by mining. All sandstone, coal, and alluvial aquifers above the mine floor would be removed. Behind the highwalls of the western, southwestern, and southern parts of the mine, water levels would decline in the sandstone and coal aquifers to a distance of about 2 miles. The freshly exposed and crushed shale, siltstone, and sandstone of the overburden and interburden spoils would be chemically active when mixed with water derived from precipitation and adjacent aquifers.

To mitigate the effects of mining on the downgradient aquifers and surface water supplies, the alluvial aquifer across the mined area theoretically could be reconstructed to simulate pre-mining conditions and the spoils materials could be structured to allow minimum water from leaving the mined area by concentrating the clayey factions along the base and downstream sides. The destroyed stock well and stock ponds could be replaced after mining.

INTRODUCTION

Development of western coal resources has received increased emphasis to meet national energy needs. A large part of the western coal is under Federal ownership; therefore, considerable demand exists for leasing and development of Federally owned coal lands. To ensure orderly development of the Federal coal, the Federal Coal Management Program was initiated, which requires the U.S. Bureau of Land Management to identify tracts of coal for potential lease, analyze the tracts for potential environmental impacts, and schedule selected tracts for lease sale.

One of the primary considerations in the selection of tracts for lease is potential adverse effects to the water resources of the area during mining and reclamation operations, and after abandonment. To determine potential effects and potential for reclamation at and near the coal tract, the U.S. Geological Survey, in cooperation with the U.S. Bureau of Land Management, is conducting hydrologic studies on several potential coal lease tracts in the Powder River structural basin of southeastern Montana. The Little Bear Creek area of the Moorhead coal field is one of these tracts.

Purpose and scope

The purpose of this study was to describe the existing hydrologic systems, to obtain data on the water quality of the area, and to assess potential effects of surface coal mining on local water resources. Specific objectives of the study were to:

(1) Identify ground-water resources in the area;
(2) determine chemical quality of the ground-water resources;
(3) identify surface-water resources and runoff characteristics;
(4) determine probable effects on existing water resources from mining

operations, including changes in the quantity and quality of water; and (5) evaluate the potential for reclamation of local water resources.

To accomplish these objectives, all pertinent data on local geology and hydrology were compiled. Hydrogeologic data were collected from existing wells, observation wells, and test holes during the study, which was conducted from June 1980 through October 1982. Ten observation wells had been drilled in 1975 and 1977 -- 4 within the Little Bear Creek drainage basin and 6 in adjacent basins. Thirty-two test holes (uncased and filled in) were drilled from 1969 through 1982 to evaluate the coal potential in the area and surrounding vicinity. During the study, 21 wells in alluvium, 12 wells in coal or sandstone beds, and 2 test holes in alluvium were drilled. The observation wells of the final network were monitored for water-level fluctuations, were tested by pumping to determine aquifer characteristics, and were sampled for chemical analysis of the water. Ten springs were inventoried and 9 springs and Little Bear Creek were sampled for chemical analysis of the water. Channel-geometry measurements were made to estimate runoff characteristics in the Little Bear Creek basin.

The information in this report emphasizes the potential effects of mining and the potential for reclamation of the hydrologic systems. Supporting technical information on geology, water resources, and water quality also is given for the interested reader and for providing background and attestation of the conclusions reached.

Location and description of area

The Little Bear Creek study area (fig. 1) includes the entire Little Bear Creek drainage basin, including its major tributary, Davidson Draw. Little Bear Creek joins Bear Creek about 1.8 miles upstream from Otter (Bear Creek store and post office), and Bear Creek joins Otter Creek about 2 miles farther downstream. The Little Bear Creek drainage basin straddles the boundaries of Big Horn, Powder River, and Rosebud Counties, and is about 14 miles southeast of Birney and 27 miles south of Ashland, Montana.

The western divide of the study area, which is also the divide between Hanging Woman Creek and Otter Creek drainages, is about 22 miles east of the Tongue River valley near the West Decker and East Decker Mines. The drainage basin of Little Bear Creek has an area of 29.2 mi^2, is about 8 miles long from the mouth southwestward to the upstream divide, and is about 5 miles wide between South Fork Lee Creek drainage to the northwest and Mud Springs Creek drainage to the southeast. The southwestern divide is opposite East Trail Creek drainage and the western divide is opposite Horse Creek drainage, both tributaries of Hanging Woman Creek. To the north of the Little Bear Creek area is Tooley Creek drainage, a tributary of Bear Creek (pl. 1).

Near the mouth, Little Bear Creek is joined from the south by "Miller" draw (named by local ranchers), which has an area of 3.2 mi^2 (pl. 1). Hoover Draw joins Little Bear Creek from the north, 1.4 miles upstream from the mouth; Hoover Draw has an area of 2.7 mi^2. Davidson Draw with an area of 8.2 mi^2, joins Little Bear Creek from the south at 2.7 miles upstream from the mouth. Upstream from this confluence, Little Bear Creek drainage has an area of 11.8 mi^2. Most other tributaries to Little Bear Creek and Davidson Draw are smaller, with drainage areas of less than 2 mi^2.

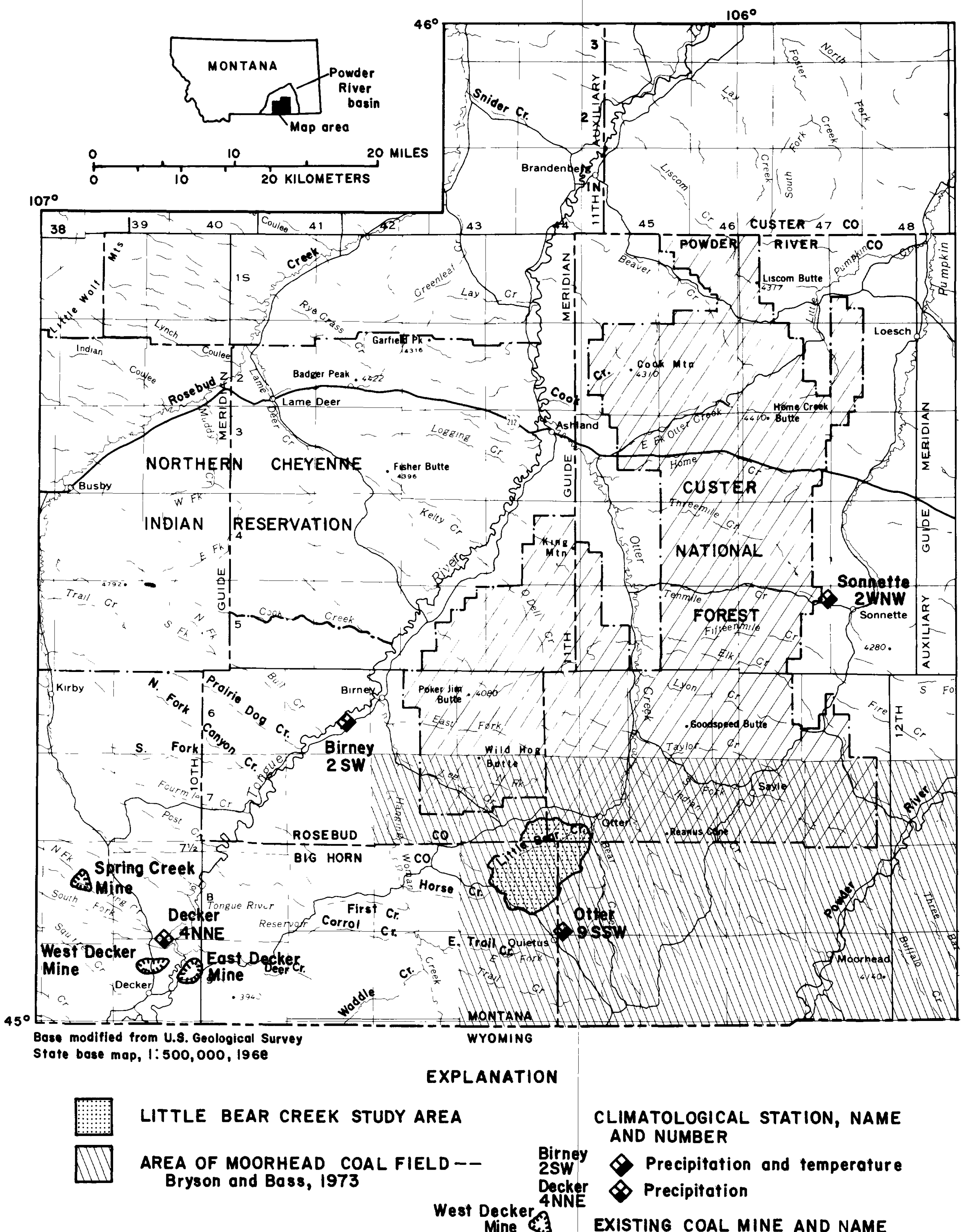

Figure 1.--Location of the Little Bear Creek study area.

The altitude at the mouth of Little Bear Creek, where it flows into Bear Creek, is about 3,510 feet above sea level. The terrain is rugged in the downstream one-third of the basin, with hills rising about 300 feet above the level of the valley in less than one-half mile. The hills and hillsides are covered in this area with clusters of coniferous trees. Farther upstream, in the central part of the Little Bear Creek drainage, the hills become more rolling, with the relief of 100 to 200 feet spread over a mile or more. Few trees of any kind exist in this part of the area, but grassy meadows abound. In the upstream part of the basin, along the western and southern divides, the terrain again steepens. There, mostly flat-topped hills and ridges are deeply incised by narrow valleys; the relief is as much as about 200 feet in a distance of one-half mile. Many clusters of coniferous trees exist on the hillsides of this area. The highest point in the basin is an unnamed hill on the Horse Creek-Little Bear Creek divide; it has an altitude of about 4,190 feet.

Climate

The Little Bear Creek study area has a climate typical of the northern Great Plains. The summers are warm, the winters cold; the humidity is moderate and the precipitation variable and generally light enough to categorize the area as semi-arid.

Air temperatures (fig. 2) vary from a monthly average of about 19°F in January to about 72°F in July at the Otter 9SSW station (about 1.5 mi south of the south divide of Little Bear Creek basin, fig. 1); the annual average temperature is about 46°F during the 21 years of record (1962-82). Only slight differences in temperature occurred between the Birney 2SW station at an altitude of 3,190 feet above sea level and the higher stations (Otter 9SSW at an altitude of 4,060 feet and Sonnette 2WNW at 3,900 feet). The data in figure 2 also show that 1981 was generally warmer than 1982, except in August, and that 1981 had exceptionally mild January temperatures.

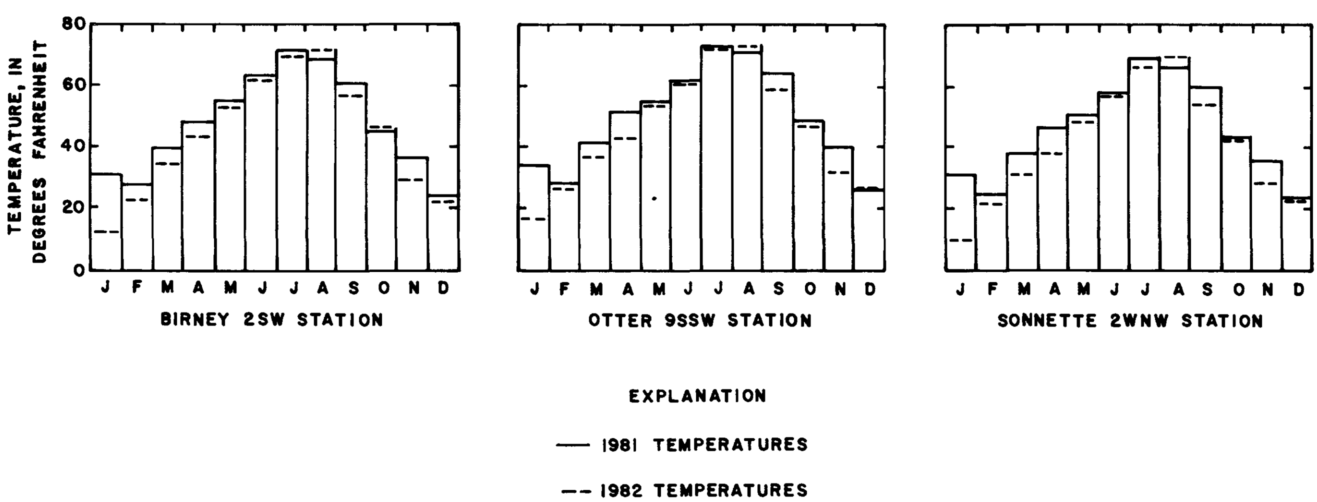

Figure 2.--Monthly average temperatures at three weather stations near the Little Bear Creek area, 1981-82.

The average annual precipitation in the vicinity of the Little Bear Creek area ranges from about 14 inches at the lower altitudes (Birney 2SW station) to about 19 inches at the higher altitudes (Otter 9SSW station, fig. 3). The average annual precipitation in the Little Bear Creek basin probably is between 15 and 20 inches. The graph shows that, during this study, 1980 and 1981 had slightly less than average precipitation and was preceeded by 1 year of less than average precipitation, and 1982 had slightly greater than average precipitation. Monthly precipitation during the study is shown in figure 4. During years of average precipitation, about 40 percent of the snow and rain falls in April, May, and June, and only about 25 percent falls in November through March. During this study, most of the precipitation fell in May through July during 1981, and March through July were fairly wet as well as September and October during 1982.

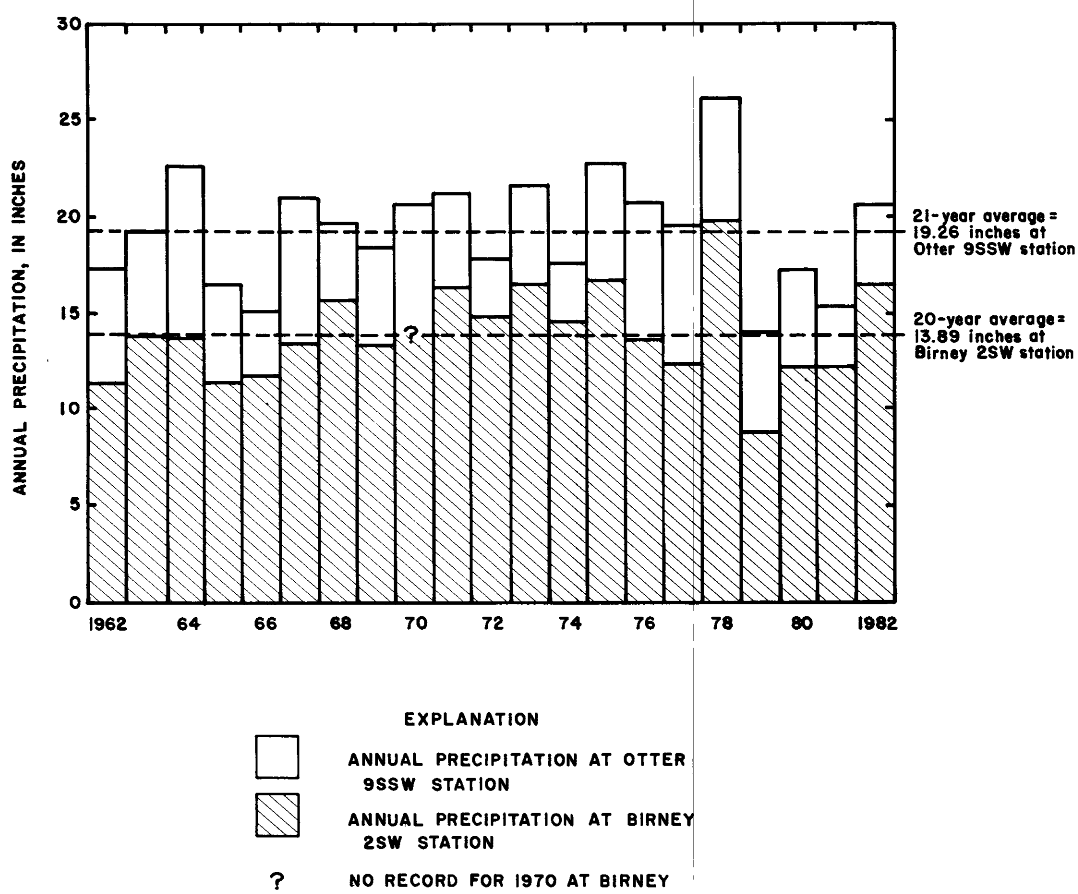

Figure 3.--Effects of altitude on annual precipitation, as evidenced by precipitation at the Otter 9SSW station (altitude 4,060 feet) and the Birney 2SW station (altitude 3,190 feet) near the Little Bear Creek area, 1962-82.

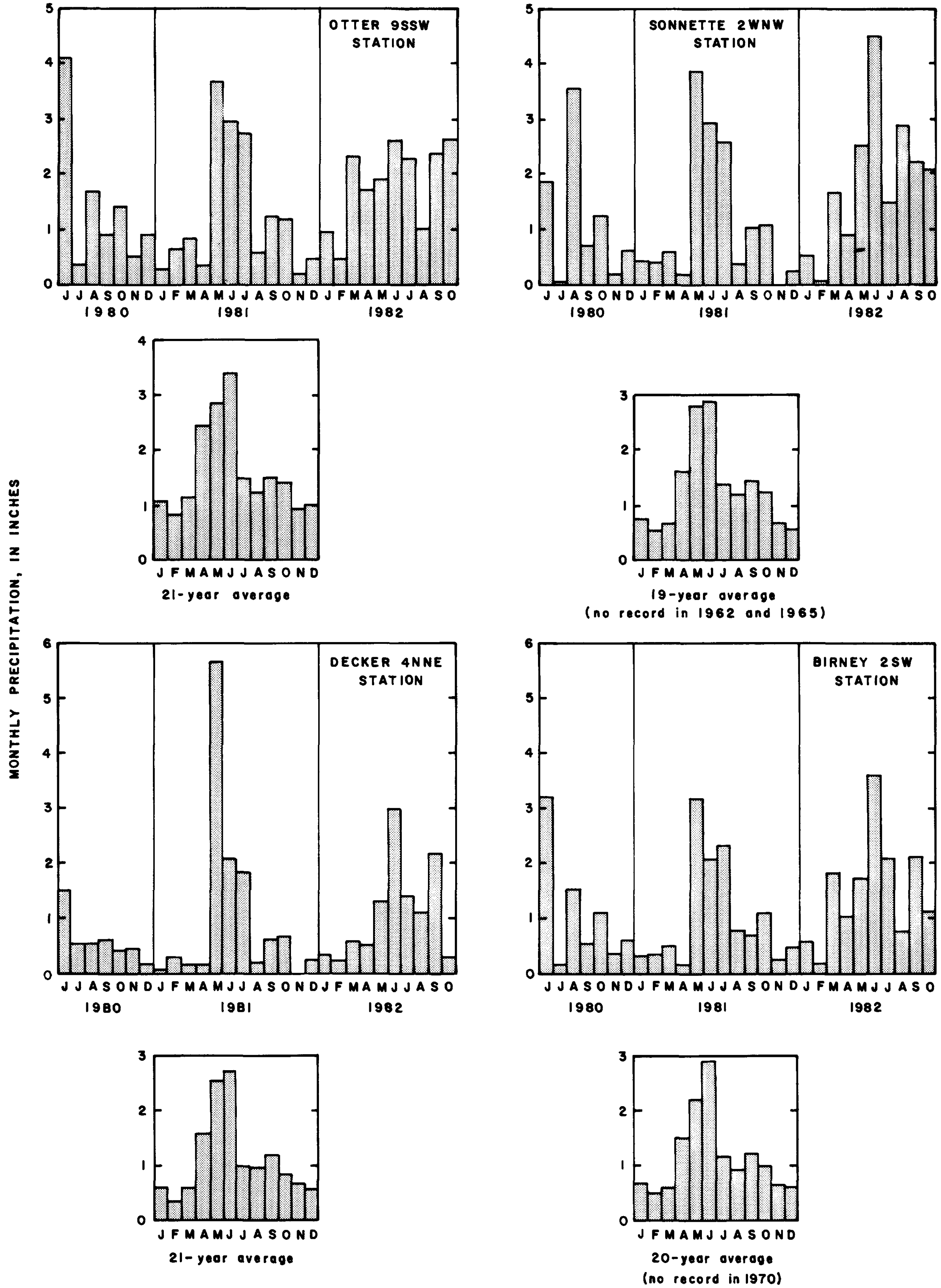

Figure 4.--Monthly precipitation from June 1980 through October 1982 and average monthly precipitation for 1962-82 at four weather stations near the Little Bear Creek area.

Previous investigations

Coal deposits were discovered and used by the earliest pioneers in southeastern Montana, as is evidenced by the numerous small quarries throughout the area. Taff (1909) studied the coal deposits around Sheridan, Wyo., and later Baker (1929) extended the studies northward to the Decker area in Montana. Others studied the multiple coal beds and the stratigraphy of the Tongue River Member of the Fort Union Formation in and around the Little Bear Creek area. Bryson conducted mapping studies in 1940, 1941, and 1946 of the area from Hanging Woman Creek to east of the Powder River valley (Bryson and Bass, 1973); these studies included the Little Bear Creek area. Matson and Blumer (1973) described the quality and quantity of strippable coal in the Tongue River Member in a comprehensive report on coal deposits of southeastern Montana. Culbertson and Klett (1979a) mapped the southern tip of the Little Bear Creek basin in detail. Culbertson and others (1976) and Culbertson and Klett (1979b) mapped the 7 1/2-minute quadrangles east and southeast of the study area. Culbertson and others are currently preparing maps and a report on a broader scale of the 1-degree Birney quadrangle (45°-46° north latitude, 106°-107° west longitude) (W. C. Culbertson, U.S. Geological Survey, oral commun., 1983).

Ground-water resources and hydrologic characteristics of the aquifers in the area have been studied on a regional scale by Perry (1931), Lewis and Roberts (1978), Slagle and Stimson (1979), and Lewis and Hotchkiss (1981). The hydrology has been studied in greater detail in the Bear Creek area (U.S. Department of the Interior, 1977a), just southeast of the Little Bear Creek basin, and in the East Trail Creek area (U.S. Department of the Interior, 1977b), adjoining the study area on the south.

Chemical quality of ground water and the chemical processes that control the quality of water in the Fort Union Formation have been investigated by Lee (1979, 1980) and Dockins and others (1980). The quality of surface water in the region was studied by Knapton and Ferreira (1980).

Potential effects of coal mining on water resources in the Tongue River drainage basin have been the focus of several studies. Effects of coal mining on water resources in the Decker area were studied by Van Voast (1974) and Van Voast and Hedges (1975). Woessner and others (1979) investigated the potential effects of coal mining on the quality of ground water and surface water on the Northern Cheyenne Indian Reservation. Woods (1981) developed a computer model for assessing potential increases in dissolved solids of streams as a result of leaching of mine spoils. McClymonds (1985) reported on the hydrology and potential effects of surface mining in the Horse Creek area, just southwest of the Little Bear Creek area.

WATER USE AND SUPPLY

Ground-water and surface-water supplies are used mostly for livestock watering within the Little Bear Creek basin. One domestic well (P-1) is in use at the Hoover ranch house, and one domestic drilled well (P-6) with a pump and a dug well (P-5) are available but not in use at the present time (1983) at the Stevens ranch house (table 1). A third domestic well (P-7) was dug for the homestead in the upstream end of the basin; the homestead and well were abandoned in the 1930s.

Four wells supply water used for livestock, mostly in the southern one-half of the basin. Three of these wells are equipped with windmills and one has a gasoline engine; the wells are capable of discharging from 5 to 12 gal/min.

Surface water from springs or streams supplies most of the livestock water in the northern one-half of the Little Bear Creek drainage basin. Little Bear Creek has interrupted flow in the channel from spring S-6 to about 1 mile upstream from the mouth. Davidson Draw has interrupted flow from spring S-8 to about 1 mile upstream from its mouth. Hoover Draw has interrupted flow in its middle reaches from spring and seep discharges. Seven springs are developed, with pipe discharges into watering troughs, within the drainage basin; one (S-7) is merely a small flow in Little Bear Creek channel near the upstream reaches of the basin. Other springs and seeps exist in the basin where water emerges onto the surface in broad marshy areas; many of these springs and seeps supply stock ponds with water during all but the driest years.

POTENTIAL EFFECTS OF MINING ON AREA HYDROLOGY

Assumptions

The effects of mining on local hydrologic systems can be predicted most accurately if a mine plan is available that details the location of mine cuts, direction and rate of mine expansion, and duration of mining. The timing and location of mine cuts are particularly important for calculating transient ground-water flow into the mine pit and for evaluating the temporal and spatial changes on the potentiometric surface created by excavation of the pit.

No mine plan for the Little Bear Creek area is available. Therefore, predicted effects of mining on the local hydrologic systems are based on the assumptions that: (1) All mining of the Anderson and Dietz coal beds would take place within the presumed mine boundaries shown on plate 2; (2) mining would begin with the excavation along Little Bear Creek valley and expand northward and southeastward from the flood plain and a second mine would expand westward and eastward from the Davidson Draw flood plain (it is assumed that the coal under the flood plains also will be mined eventually); (3) the entire Anderson and Dietz coal beds would be removed from the mined area to a place where the overburden of the Anderson bed is about 200 feet thick; and (4) all mining regulations established by the U.S. Office of Surface Mining and the Montana Department of State Lands would be followed during mining and reclamation.

Effects during mining

Multiple aquifers transmit water through the site of the potential mine pit (see pls. 2 and 3). Several sandstone beds and lenses above the Anderson coal bed and between the Anderson and Dietz beds, as well as the coal beds themselves, would yield water to the potential mine pit. In addition, the alluvial sands and gravels along Little Bear Creek and Davidson Draw, and, to a lesser extent, "Miller" draw and the larger tributaries, would contribute water to the pit.

Mining would begin along the flood plain of Little Bear Creek from 5.2 to 6.7 miles upstream from the mouth, and along Davidson Draw from 1.8 to 3.4 miles upstream from its mouth (pl. 2). The mechanics of diverting flood flow from the potential mined area are not detailed in this report, but the destruction and reconstruction of the alluvial aquifer under the stream flood plains are considered here.

The alluvial aquifers along Little Bear Creek in the area of the potential mine pit have characteristics about like those determined for sections F-F' and G-G' (geologic sections shown on pl. 3; traces of sections shown on pl. 2). As discerned from calculations, using values determined from aquifer tests, about 800 ft^3/d passed section F-F' at October 1980 water levels. As the water levels declined in 1981 and 1982, less water passed this section; the quantity decreased to about 550 ft^3/d by October 1982. Using the same methods of calculations, only 250 ft^3/d passed the downstream section G-G'. One-half mile farther downstream, at section H-H', about 9,000 ft^3/d of water was calculated to pass. Although the downstream section (H-H') would have a larger volume of water because of the larger flow from the clinker terrace in this part of the valley, the excessive difference between sections G-G' and H-H' probably indicates that the calculated quantity of water passing section G-G' is too small. At least as much water is postulated to pass section G-G' as passes section F-F'; that is, at least 800 ft^3/d and probably more. The difference in subsurface flow calculated for section G-G' may be caused by a buried channel which was not found when the four observation wells were drilled across this section. Another reason for the small calculated flow is the thinness of the aquifer at this location. The aquifer probably became significantly dewatered during testing. Additional test holes or a shallow seismic survey across the valley would resolve this question.

Along Davidson Draw valley, just downstream from the potential mine pit, the alluvial aquifer is represented by a line of wells at section J-J' (pl. 3; traces of sections shown on pl. 2). There, the daily flow of water was calculated to be about 1,500 ft^3/d at June 1982 water levels. By mid-September 1982, the water level had declined nearly 1 foot; the water passing at that time would be about 1,000 ft^3/d.

To determine the quantity of water that will discharge into the mine pit from aquifers in the Tongue River Member of the Fort Union Formation after the initial box cut is excavated, a modified version of a formula by R. W. Stallman was used. Stallman's formula (in Ferris and others, 1962) for constant drawdown in a channel was halved to apply to one side of the channel (one mine pit wall). In the version used below, the equation is:

$$Q = \frac{s_o}{\sqrt{\pi t}} \sqrt{ST}; \qquad (1)$$

where

- Q = volume of water inflow, in cubic feet per day per foot of mine-pit length;
- s_o = water-level drawdown along the channel (wall), in feet;
- t = time, in days;
- S = storage coefficient (dimensionless); and
- T = transmissivity of the aquifer, in feet squared per day.

The values used in the calculations were selected from information determined from aquifer tests conducted during the study. To simplify the calculations, the coal and sandstone aquifers were combined and a unified average hydraulic conductivity value was multiplied by the variable thickness of contributing aquifers to determine the transmissivity values. The test results of observation wells 0-3 (Dietz coal), 0-5 (Dietz coal), 0-12 (sandstone), 0-24 (Dietz coal), 0-25 (Anderson coal), 0-32 (sandstone), 0-33 (sandstone), 0-35 (Anderson coal), and 0-37 (Anderson coal) were used to calculate the unified average hydraulic conductivity, which was about 0.5 ft/d. The transmissivity value used in the equation depends on the thickness of the combined aquifers, which varies with the depth of the mine pit and height of the potentiometric surface above the floor of the mine pit. The value for the storage coefficient was not determined for the aquifers in the Little Bear Creek basin, because all the aquifer tests were single well, single aquifer tests. An arbitrary value of 0.005 was used in Stallman's formula, based on an interpretation of the results by W. A. Van Voast in the Colstrip area (Van Voast and others, 1977).

Applying Stallman's formula (modified), about 2,700 ft^3/d of water from a 1,000-foot front of the potential mine wall would enter the pit from sandstones and coal aquifers along the north side of Little Bear Creek, in the vicinity of stratigraphic section A-A', near obervation well 0-24 and test hole T-6 (pl. 3). Because the south side of Little Bear Creek is slightly updip, the south side pit would have slightly less water flowing in. The volume of water is based on a duration of 100 days which is the estimated time required to excavate the first mine cut. The quantity of water entering the mine pit would decrease with time as storage within aquifers is depleted. Water-level declines next to the mine pit, as the mine expands northwestward and northward, would be as much as about 200 feet along the northern extent of the potential mine after 5 to 10 years of mining. Water-level declines along the divide between Little Bear Creek and South Fork Lee Creek drainages probably would occur for 2 to 3 miles northwestward and northward beyond the final mine highwall.

Less water, about 1,600 ft^3/d, would flow from the potential mine along the Davidson Draw initial box cut, because only about one-half of the Anderson coal bed is saturated. As the mining progresses southward, the water-level declines approximately keep up with the mine expansion; at the south extent of the mine, the water-level decline will be about 250 feet at the final highwall. Water-level decline will occur southward across the Little Bear Creek-Mud Springs Creek divide, but probably will not affect any existing wells or springs.

In the potential mine pit between Little Bear Creek and Davidson Draw and eastward from Davidson Draw, the volume of water entering the mine pit along a 1,000-foot front would be about 3,000 ft^3/d in the middle sections (when the mine is about halfway between the north and south edges). Water-level declines, as the mine expands to the southwest, southeast, and east, will cause less flow into the mine pit. Total water-level declines would be about from 130 to 250 feet. The decline probably would extend eastward into the Horse Creek basin and southward into the East Trail Creek basin. Because the water-level decline would be less than 10 feet 2 to 3 miles from the final highwall of the mine, no known wells or springs would be affected. The lowered water levels probably would recover somewhat after mining ends and the spoils are replaced along the highwalls. The lateral extent of the water-level decline west, southwest, and south of the final mine wall is estimated to be about 2 miles. The dip of the strata and the faulting at the east end of the mine probably would create conditions which are not accounted for in the above calculations. All values and calculated volumes are considered to be approximate; therefore, the results are only best estimates of potential conditions.

Long-term effects

Assuming that the size and outline of the potential mine are approximately as shown on plate 2, about 235 million tons of Anderson coal and about 95 million tons of Dietz coal would be removed. Within the area of the potential mine, an area of about 6.7 mi^2, the altitude of the land surface would be lowered about 45 feet. All sandstone, coal, and alluvial aquifers above the mine floor would be removed, and the natural (pre-mining) flow of ground water in and near the mine pit would be disrupted. One stock well (P-8) would be destroyed. Springs, except for the possible exception of spring S-8 in Davidson Draw, would not be affected because most springs are from clinker layers topographically above the valleys where mine-contaminated water would flow. Spring S-8 is just north of the potential mine pit. The origin of the water to the spring is uncertain; it may be from alluvial sources or it may be associated with the fault, which exists very close to the spring site. If the water is from alluvial sources, the spring would become dry when the alluvium upstream is removed. If the water rises along the fault plane, mining would have no effect on the spring. Several ephemeral stock ponds in the area of the potential mine would be destroyed; one pond (SP-4) receives water from ground-water seeps and contains water nearly perennially.

Water from rainfall and snowmelt on the mine spoils would percolate downward, saturating parts of the mine spoils. After flow systems become established in the mine spoils, water would move downvalley, eventually mixing with the water of the alluvial aquifers in Little Bear Creek, Davidson Draw, and "Miller" draw valleys. The water moving through the mine spoils would acquire a chemical quality dependent on the mineralogy of the spoils material.

The mean dissolved-solids concentration of water that would occur in saturated spoils is estimated to be in the range of 3,200 to 7,000 mg/L (milligrams per liter). This range of the mean dissolved-solids concentration is about 140 to 300 percent of the mean dissolved-solids concentration (2,330 mg/L) of 23 water samples collected from shallow wells completed in the Tongue River Member in the Little Bear Creek study area (data in table 7). The magnitude of the increase in dissolved solids, between ground water in the natural environment and water in mine spoils, is based on geochemical studies at mine sites in the Powder River Basin of southeastern Montana (Davis, 1984) and in western North Dakota (Groenewold and others, 1983). Water in the saturated mine spoils would be predominantly a sodium sulfate or sodium bicarbonate type, based on the dominant water types in the undisturbed aquifers.

Along Little Bear Creek, Davidson Draw, and "Miller" draw, the alluvial aquifers would function as a conduit for water flowing from the mine spoils. Unless mitigating measures are taken, the chemically degraded water from the spoils would pass down the alluvial valleys to the Bear Creek and Otter Creek alluvial aquifers.

The potential exists for a long-term change in the quality of water in the aquifers downgradient (to the northeast) from the mined area. After mining, the probable direction of ground-water flow along the southwestern and southern boundaries of the mine would be from the unmined strata toward the mine spoils.

POTENTIAL FOR RECLAMATION OF HYDROLOGIC SYSTEMS

Reclamation of the potential mined area would depend on careful planning during the mining process. The crushing of overburden and interburden between the Anderson and Dietz coal beds would expose soluble minerals that could be leached by surface and ground waters. The planned reclamation could be successfully completed by selective placement of the overburden (mine spoils) to minimize the volume of water passing into and from the chemically active spoils material. In addition, a relatively impermeable wall of clayey material could be compacted along the eastern and northern faces of the potential mine pit, between the pit and the Anderson clinker layers, to restrict the flow of ground water into the greatly permeable clinker.

The alluvial aquifers along Little Bear Creek, Davidson Draw, "Miller" draw, and their main tributaries, theoretically could be reconstructed by placing and compacting a clayey layer as a base, then overlaying the previously collected sand and gravel, and finally replacing the alluvial muds and soils. The alluvium with the largest concentration of minerals is near the line of wells 0-28 to 0-30 in the middle reaches of Davidson Draw, where the alluvial aquifer rests directly on weathered Anderson coal. Removal of the coal from this vicinity may improve the quality of the alluvial water slightly. Elsewhere, the alluvial waters have moderate concentrations of minerals; mining would probably increase the mineral concentrations and degrade the water. With a carefully planned and reconstructed alluvial aquifer through the mined area, degradation of the alluvial waters downstream could be kept to a minimum.

The stock well (P-8), which would be destroyed by the potential mine, could be replaced by another well near this site. The present well obtains most of its water from a sandstone beneath the Dietz coal bed; the post-mining well could be deepened somewhat to extend below any contamination resulting from the mining activities, but would have to be no deeper than the Canyon coal bed (about 320 feet below the present, pre-mining surface). All stock ponds destroyed by the potential mine could be reconstructed near their present localities, but pond SP-4 would have its source for the seeps destroyed.

SUPPORTING TECHNICAL DISCUSSION

Geology

Stratigraphy

The stratigraphic section of exposed rocks (fig. 5) in the Little Bear Creek area includes the upper part of the Tongue River Member of the Fort Union Formation (Paleocene age) and the lower part of the Wasatch Formation (Eocene age). The part of the stratigraphic section most affected by mining in the Little Bear Creek area would be from near the top of the Tongue River Member to the base of the Dietz coal bed.

At depths of about 3,500 feet under the central part of the area is the base of the Fox Hills Sandstone (Late Cretaceous age). The Fox Hills and the overlying lower sandstones of the Hell Creek Formation (Late Cretaceous age) form an aquifer unit about 550 feet thick (Lewis and Hotchkiss, 1981). The upper part of the Hell Creek Formation, consisting mostly of shale, forms a confining layer about 380 feet thick.

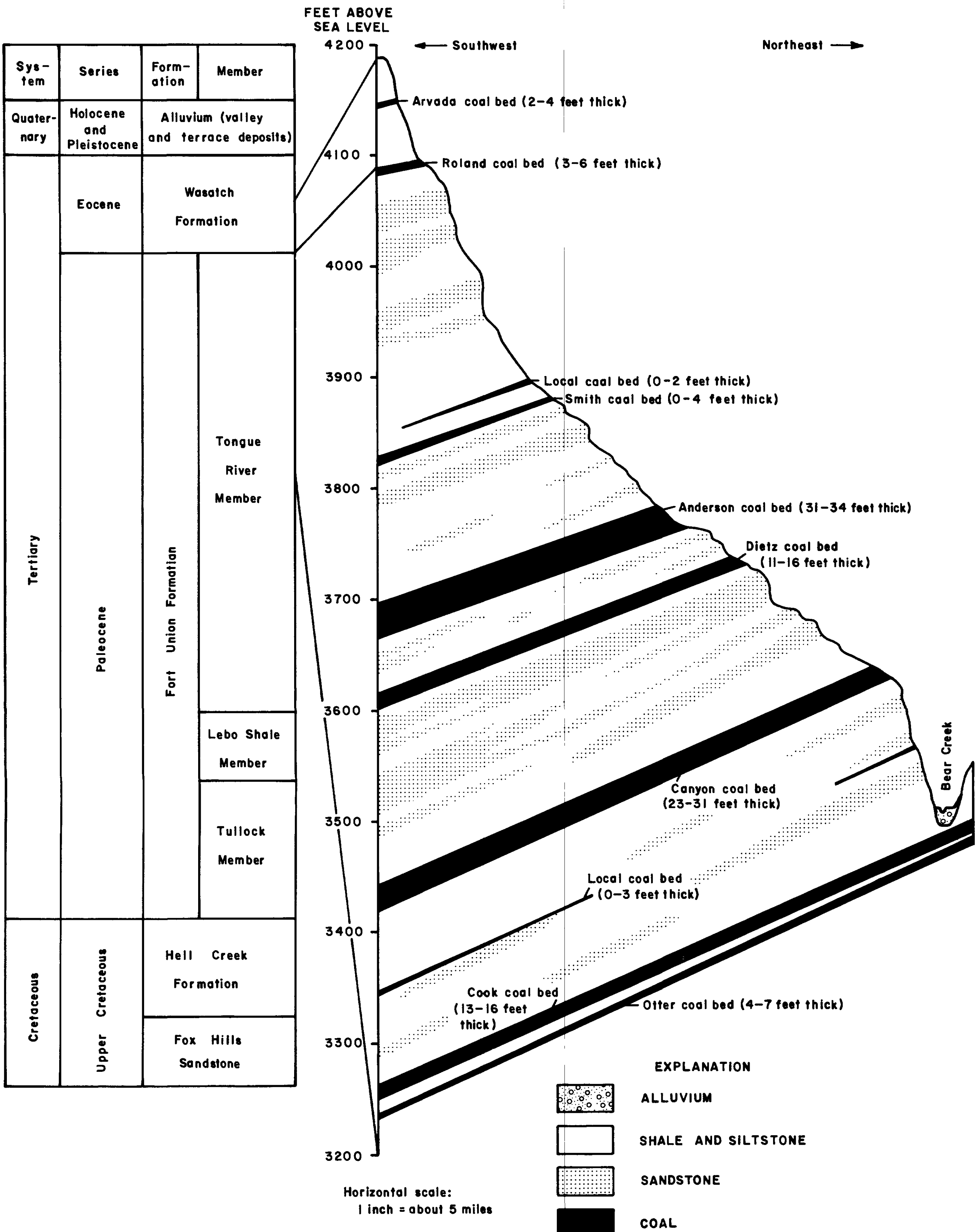

Figure 5.--Idealized section trending northeast across the Little Bear Creek area, showing stratigraphic succession of the upper part of the Tongue River Member of the Fort Union Formation and the capping Wasatch Formation.

The Fort Union Formation consists of three members: the Tullock Member at the base, with an average thickness of about 580 feet under the Little Bear Creek area; the Lebo Shale Member, about 380 feet thick; and the Tongue River Member, about 1,900 feet thick. The Tullock Member is composed of alternating sandstone and shale, with a few thin coal beds; it generally is considered to be an aquifer (Lewis and Hotchkiss, 1981). The Lebo consists of dark shale, with few sandstone beds, and also a few thin coal beds; it is a confining layer at most localities in southeastern Montana.

The Tongue River Member consists of gray and light-gray shale and sandstone beds or lenses, and has several intervals of coal. The sandstone beds thin or thicken laterally; some are permeable enough locally to form adequate aquifers for stock wells. The coal beds, in the Little Bear Creek area, are thickest in the upper part of the Tongue River sequence. The coal beds that were investigated for the study, are, from lower to upper: The combined Cook and Otter coal beds, from 17 to 22 feet thick, split into separate beds to the west and south; the Canyon bed, from 23 to 31 feet thick, usually a massive coal unit; the Dietz bed, from 11 to 16 feet thick; and the Anderson bed, from 31 to 34 feet thick, also usually a massive coal unit. The interval of the Tongue River Member between the Otter and Anderson coal beds is about 450 feet thick in most parts of the Little Bear Creek area. Above the Anderson bed, the Tongue River strata are shale and sandstone, with a few thin coal beds, nearly 400 feet thick. Among the coal beds, two are most persistent: the Smith bed about 120 feet above the Anderson, and the Roland at the top of the Tongue River Member.

After the Tongue River Member had been eroded during late Tertiary time and the coal beds were exposed, broad areas of the thicker coal beds and smaller areas of the thinner beds were ignited, probably by lightning strikes, and were burned. The remnants of the burned coal and scorched overburden create a resistant, but largely permeable, caprock of clinker layers, which form the hilltops in the northern and western parts of Little Bear Creek basin (pl. 2).

The Wasatch Formation, overlying the Roland coal bed, is composed of shale, sandstone, and a few coal beds. Vestiges of the Wasatch commonly are at altitudes above 4,100 feet along the southwestern divide between Little Bear Creek and Horse Creek drainages, and about 4,040 feet along the southern divide with the East Trail Creek drainage. Because of its altitude, the Wasatch Formation is readily drained of water and is not hydrologically significant in the study area.

The latest deposition in the Little Bear Creek area occurred after the valleys were eroded during late Pleistocene time. Alluvial material was deposited, with generally coarse sand and gravel at the base and finer silt and mud above. The age of these deposits is considered to be late Pleistocene and Holocene. These alluvial deposits compose the largest yielding aquifers in the Little Bear Creek area at the present time (1983).

Local structure

A general southwest dip of the Tongue River Member sediments is disrupted by a series of faults in the southeastern and southern parts of the Little Bear Creek basin (fig. 6). Three en echelon faults, with south side downthrown, exist from sec. 11, T. 8 S., R. 44 E., to sec. 10, T. 8 S., R. 45 E. (pl. 2). The northernmost of the three faults seems to have a displacement of about 60 feet where it

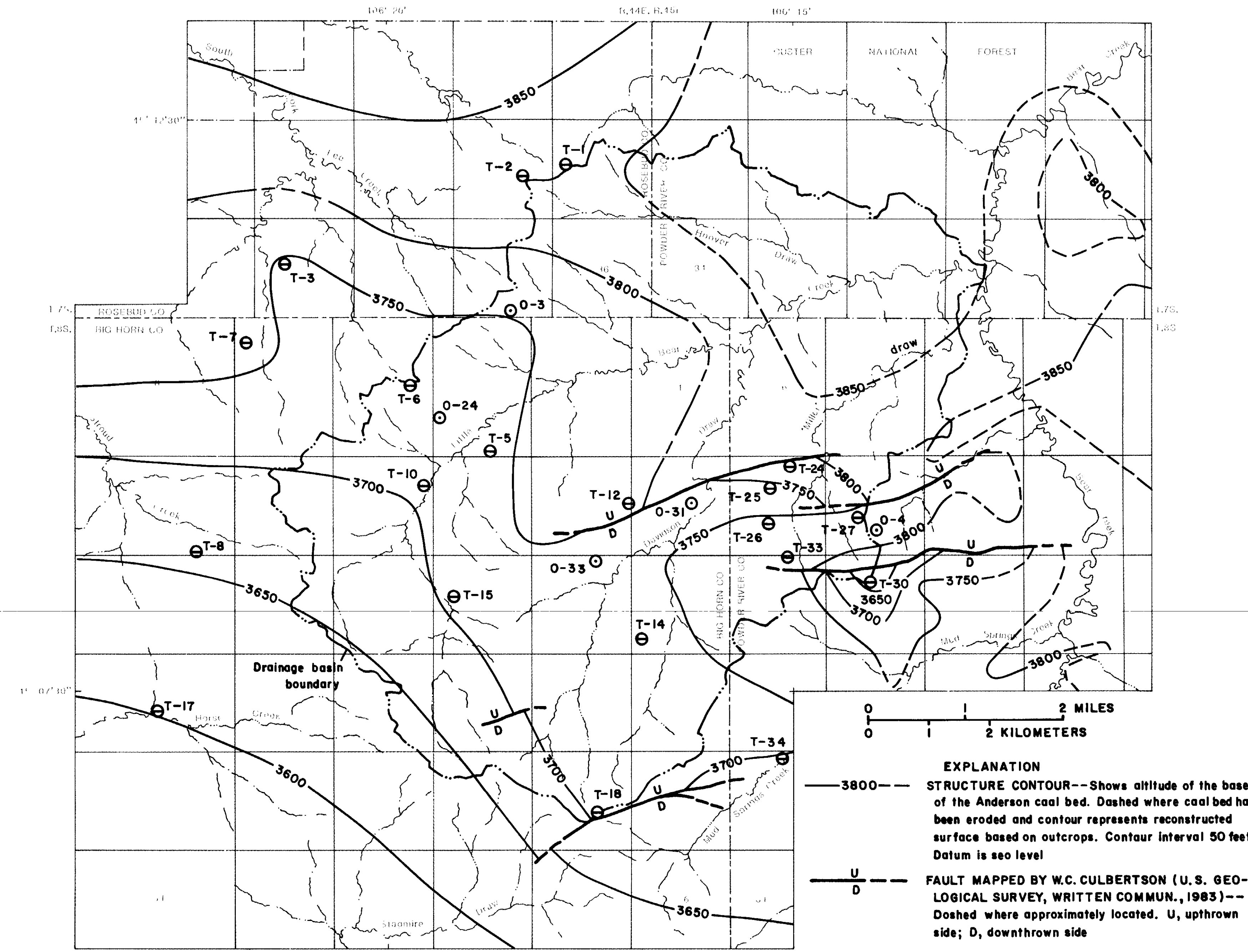

Figure 6.--Structure and configuration of the base of the Anderson coal bed in and near the Little Bear Creek area.

crosses Davidson Draw. The middle fault, through the center of sec. 8, T. 8 S., R. 45 E., displaces the Anderson and Dietz coal beds as much as 30 to 40 feet near the eastern edge of the section. The southern fault has a large displacement in its western part -- about 180 feet between test hole T-30 and well 0-41. This fault creates a structural depression centered near test hole T-30.

The two faults near the southern divide have displacements of 20 to 30 feet, with south side downthrown. They are too high in the basin to have any hydrologic significance on the Tongue River aquifers.

The structure map (fig. 6) shows no regular anticlines or synclines. The contours are drawn on the base of the Anderson coal bed from a fairly good distribution of data sites and from outcrop altitudes. A broad trough occurs north of Little Bear Creek basin, trending generally southwestward to the upstream end of Little Bear Creek. The nose of a broad anticline develops east of the trough, but is broken by the east-trending faults in the eastern part of the basin. The three faults cause intricate but laterally short troughs and ridges, as well as the sink in the northern part of sec. 17, T. 8 S., R. 45 E. Because of the varying thickness of sediments underlying the Anderson and between the Dietz and Canyon coal beds, the general structural features on the base of the Anderson bed are probably distorted or obliterated with depth.

Ground-water resources

The ground-water resources are discussed by aquifer in the following sections of the report. If appropriate data are available, the discussion includes occurrence and thickness of aquifers, aquifer characteristics, water-level fluctuations, potentiometric surface, and quality of the water. Corresponding tabular data are given at the end of the report. The data include construction and hydrologic data from private wells (table 1), test holes (table 2), observation wells completed in the Tongue River Member (table 3), and observation wells completed in alluvium (table 4). Aquifer-test data are given for the Tongue River Member (table 5) and the alluvium (table 6). Ground-water-quality data are listed in table 7 for wells completed in the Tongue River Member and in table 8 for wells completed in alluvium.

Tongue River aquifers

Aquifers of the Tongue River Member include sandstone and coal beds between the Lebo Shale Member of the Fort Union Formation and the Wasatch Formation. The lower 1,100 feet of the Tongue River Member lies below all outcrop exposures in the Little Bear Creek basin. The Cook and Otter coal beds lie under the Bear Creek alluvium at the mouth of Little Bear Creek; these coal beds are exposed along the valley side walls near Otter, Mont., downstream from the mouth. In the following section only the aquifers from the Cook and Otter coal beds and above are described. The deeper aquifers would be unaffected by mining in the Little Bear Creek area. Almost all of the Tongue River aquifers are recharged by local precipitation.

Cook and Otter coal beds

The Cook and Otter coal beds lie about 850 feet below the top of the Tongue River Member in the Little Bear Creek basin. The two coal beds form one massive coal bed, 22 feet thick, near the mouth of Little Bear Creek. To the west and south, the bed splits into two distinctive coal beds. The lower bed, the Otter coal, is between 4 and 7 feet thick under most of the Little Bear Creek basin; it is separated from the Cook coal bed by a 2- to 10-foot thick carbonaceous shale layer. The Cook coal bed is 16 feet thick in the northeastern part of the basin and is 13 to 15 feet thick under most of the central, western, and southern parts. Overlying the Cook and Otter coal beds are from 120 to 160 feet of mostly gray shale, with few light gray sandstone lenses and one or two local coal beds no more than 3 feet thick. The sandstone lenses, some as much as 10 feet thick, probably extend no more than 2 miles laterally before pinching out.

Aquifer characteristics

Only well O-11 was drilled specifically to the Cook-Otter coal-bed aquifer. This well, west of the Hoover Draw-Little Bear Creek confluence, penetrated 16 feet of Cook coal, 1 foot of shale, and 6 feet of Otter coal. The perforated interval slightly missed the full interval of the coal beds, so about 21 feet of the coal aquifer contributes water to the well (table 5). The well was pumped at 2.4 gal/min in July 1982; the aquifer hydraulic conductivity was calculated to be about 1.2 ft/d. During the test, the water-level drawdown was about 9 feet from a static water level of 151.2 feet below land surface. The well probably could be pumped at nearly 5 gal/min, if the water level were drawn down to near the top of the perforated interval--184 feet below surface.

Water-level fluctuations

Water-level measurements were made periodically from March 1981 through October 1982. The water level fluctuated between 150.8 and 151.3 feet below land surface during the measurement period (fig. 7); the fluctuations of the water level are attributed to variations in barometric pressure between measurements rather than to any annual or seasonal water-level changes.

Quality of water

The single chemical analysis of water from the Cook-Otter coal aquifer is hardly appropriate for statistical comparison with other aquifers in the Little Bear Creek area. However, for coal beds of comparable thickness and depth beneath the surface, the water seems to be comparable to an average sample. In well O-11, the water was a sodium bicarbonate type (fig. 8) having a dissolved-solids concentration of about 1,750 mg/L, with small concentrations of calcium, magnesium, potassium, chloride, and sulfate. The reported concentration of sulfate was less than 5 mg/L, which seemed extraordinarily small for a coal aquifer; but the cation-anion balance is correct, so the sulfate value probably is correct. The fluoride concentration was 3.2 mg/L, which is greater than the concentration[1] established for human consumption, but near the average concentration for relatively deeply buried Tongue River aquifers.

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[1] The maximum contaminant level established by the U.S. Environmental Protection Agency (1977) for fluoride ranges from 1.4 to 2.4 mg/L, depending on the annual average of the maximum daily air temperatures for the area.

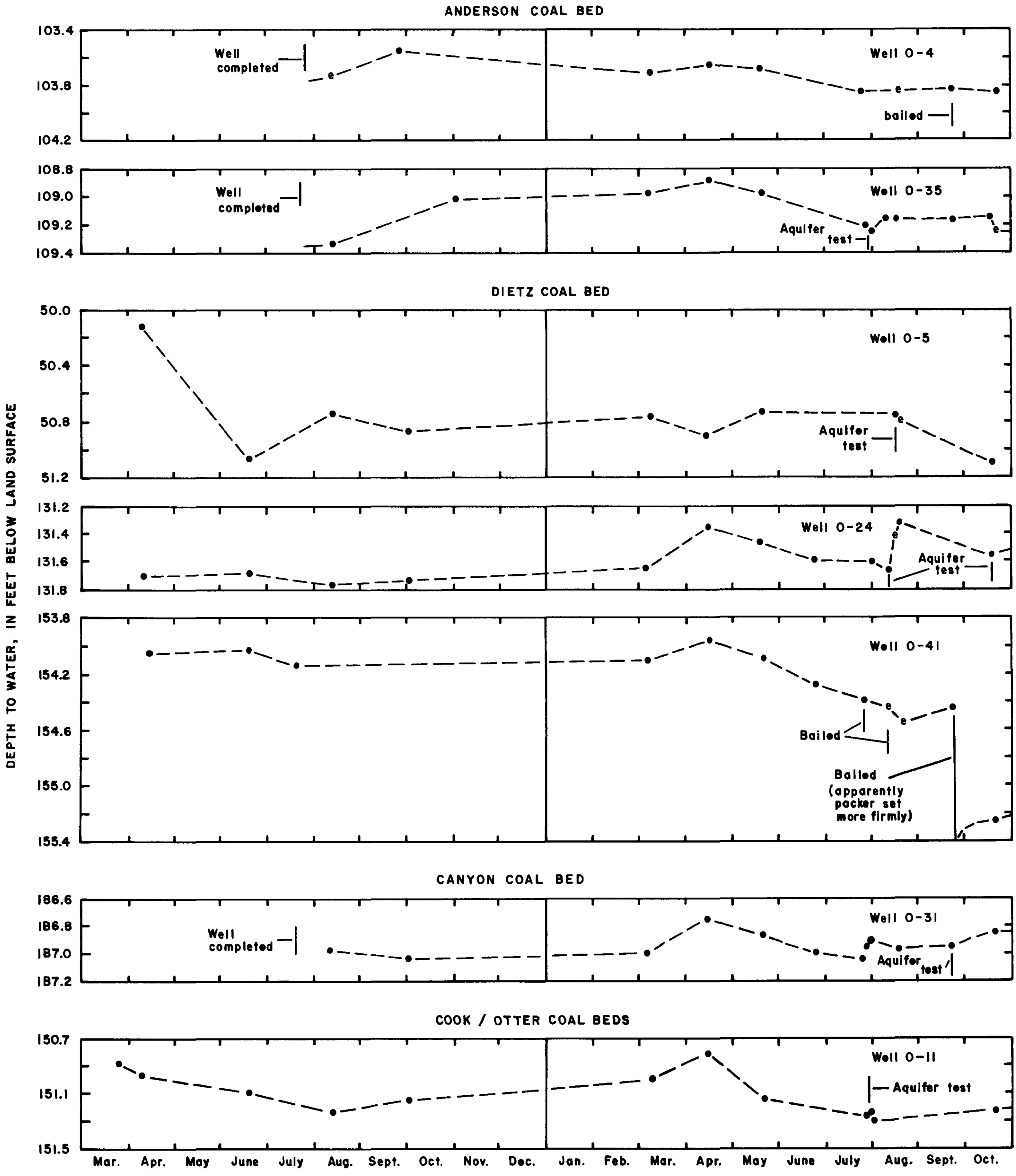

Figure 7.--Water-level fluctuations from March 1981 through October 1982 in observation wells completed in coal-bed aquifers in and near the Little Bear Creek area.

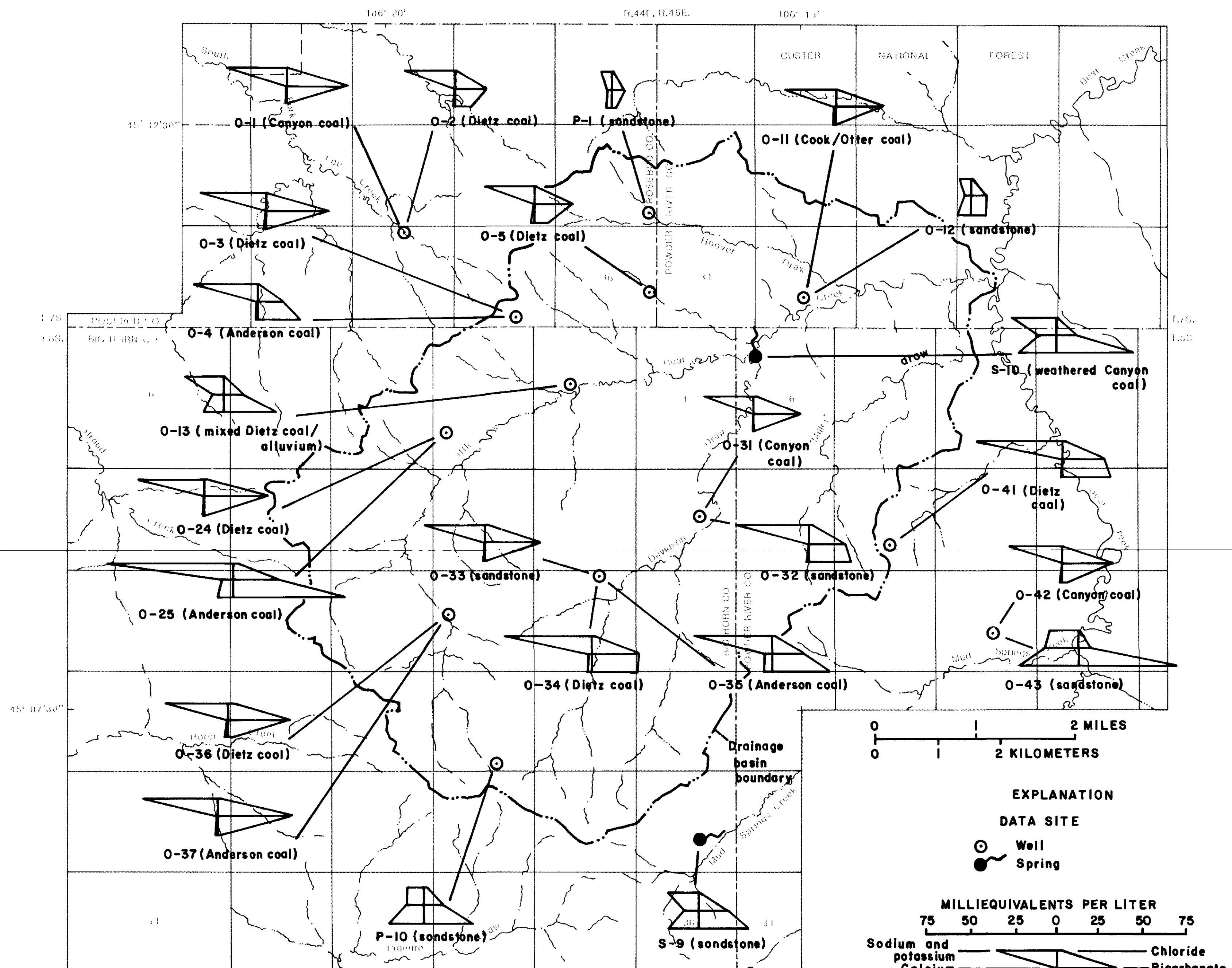

Figure 8.--Chemical-constituent diagrams for water from coal and sandstone aquifers in and near the Little Bear Creek area.

Canyon coal bed

The Canyon coal bed underlies most of the Little Bear Creek basin, except the topographically lower northeastern part, where Little Bear Creek and "Miller" draw valleys have eroded through the Canyon and underlying shale and sandstone. In these areas and a short distance upstream from the mouth of Hoover Draw, the Canyon coal has been burned, forming extensive clinker layers.

The thickness of the Canyon coal bed ranges from 23 feet to the west in the Stroud Creek basin and to the south of the southern tip of the Little Bear Creek basin to 31 feet in the upstream reaches of Lee Creek valley and the northern tip of the Little Bear Creek drainage. Under most of the Little Bear Creek area, the Canyon coal is 27 to 28 feet thick. The coal is massive at most places, but a shale layer exists near the top of the bed to the northwest (test hole T-7) and another shale layer develops near the base to the south (test hole T-14) and southwest (test hole T-15).

Above the Canyon coal bed is 140 to 180 feet of shale and sandstone lenses and beds; some of the sandstone beds seem to be fairly extensive, persisting for 2 or more miles laterally. Most of the sandstone beds are 10 feet thick or less; but in some localities, such as across the central part of the Little Bear Creek basin from test hole T-10 through observation well 0-29 and test holes T-25 and T-18, sandstone beds are as much as 28 feet thick. Local coal beds 1 to 3 feet thick also exist at various horizons between the Canyon and Dietz coal beds.

Aquifer characteristics

Three observation wells are open to the Canyon coal aquifer in and near the Little Bear Creek basin. Well 0-1, located in the upstream reaches of South Fork Lee Creek drainage, penetrated 31 feet of Canyon coal and was pumped at 5.5 gal/min in June 1975. The static water level was 186.6 feet below land surface, and the drawdown was about 25 feet; the calculated aquifer hydraulic conductivity was about 2 ft/d. Well 0-31, located on the west side of Davidson Draw in the southeast-central part of Little Bear Creek basin, penetrated 28 feet of Canyon coal aquifer but is only open to 27 feet of the coal aquifer. Well 0-31 was pumped at 7.8 gal/min in September 1982; the water-level drawdown was 47 feet from a static level of 186.9 feet below land surface. The aquifer hydraulic conductivity here was calculated to be about 1.5 ft/d. Well 0-42, located north of Mud Springs Creek southeast of Little Bear Creek basin, penetrated the Canyon coal aquifer from 152 to 180 feet below land surface. This well was pumped at 6 gal/min in June 1975. The drawdown was 46 feet from a static water level of 81.8 feet below land surface; the aquifer hydraulic conductivity was calculated to be about 0.7 ft/d. Based on the aquifer tests conducted on the three widely separated wells, the Canyon coal aquifer is assumed to be capable of yielding from about 7 to 10 gal/min and have an average hydraulic conductivity of about 1.4 ft/d.

Water-level fluctuations

Of the three Canyon coal-bed wells, only well 0-31 was monitored for water-level fluctuations during the study (fig. 7). The water level varied from 186.7 to 187.0 feet between July 1981 and October 1982. The fluctuations of the water level are attributable to the various barometric pressures at the times of the measurements, rather than to any probable seasonal fluctuations. The very small variation (0.3 foot) indicates that even the barometric pressure has only a slight effect on the water-level fluctuation.

Quality of water

Water from the three wells completed in the Canyon coal aquifer was a sodium bicarbonate type (fig. 8), with small concentrations of calcium, magnesium, potassium, and chloride, and moderate to large concentration (2.8 to 5.1 mg/L) of fluoride (table 7). The dissolved-solids concentration ranged from 1,500 mg/L in well O-31 to 1,870 mg/L in well O-1. The sulfate concentration was small (10 mg/L) in well O-1 northwest of the study area and moderate (66 mg/L) in well O-42 southeast of the area. Generally, the water from the Canyon coal and Cook-Otter coal aquifers is very similar.

Dietz coal bed

The Dietz coal bed probably will be the deepest coal to be mined in the Little Bear Creek basin. The Dietz coal is 11 to 16 feet thick in the study area and is generally massive. The thickest Dietz beds are along the northwestern border of the basin and in the upstream part of Lee Creek drainage. The Dietz thins southeastward, southward, and southwestward. In most of the Little Bear Creek basin, the Dietz coal bed is 12 to 14 feet thick.

The interburden between the Dietz coal bed and the overlying Anderson coal bed consists of gray shale and light-gray sandstone. Few, if any, carbonaceous shale layers exist in this interval, except near the main coal beds. The interval locally contains as much as 50 percent sandstone, but more commonly the sandstone is 20 percent or less of the interval. The sandstone beds generally are not laterally extensive, but could be important aquifers locally.

Aquifer characteristics

In and near the Little Bear Creek basin, eight observation wells were drilled specifically to the Dietz coal bed and casings were perforated opposite the coal interval. The wells (O-2, O-3, O-5, O-13, O-24, O-34, O-36, and O-41) are 40 to 290 feet deep. Seven of these wells were either pumped or bailed to determine the aquifer characteristics. The aquifer characteristics in the wells seem to be separable into two groups. In the first group, wells O-5 and O-24 were pumped at 1.6 and 5 gal/min, respectively; the calculated aquifer hydraulic conductivities were about 1.4 and 0.7 ft/d. These wells are in the northern part of Little Bear Creek basin. A third well (O-13) has alluvial gravels directly overlying the Dietz coal bed in the Little Bear Creek valley near S-6 ("Tanner" spring). During the pumping, at 3.4 gal/min, the water level in the nearby alluvial well (O-19) declined minimally, but over a broader area the alluvial gravels are probably hydraulically connected to the Dietz coal aquifer. The calculated aquifer hydraulic conductivity in well O-13 was 7 ft/d, which probably was affected by leakage from the overlying gravel layer.

The second group of Dietz wells yielded little water. They include well O-3 near the northwestern divide of Little Bear Creek, and wells O-34, O-36, and O-41 from the south-central part of the area to the southeastern divide. Well 0-3 was pumped at 0.9 gal/min, and had a drawdown of 61 feet; the calculated aquifer hydraulic conductivity was about 0.05 ft/d. Wells 0-34, 0-36, and 0-41 were bailed because the yield was too small to pump. The hydraulic conductivities were calculated from recovering water-level measurements--all were about 0.007 ft/d. The Dietz coal bed is 13 to 16 feet thick in these four wells, and the depths (180 to 260 feet) are not much greater than in wells 0-5 and 0-24 (75 to 181 feet). Apparently the coal bed merely is less fractured in the localities of the second group of wells. Considering both the first and second groups, the mean hydraulic conductivity of the Dietz coal aquifer is presumed to be about 0.5 ft/d.

Water-level fluctuations

The water levels in the Dietz coal aquifer generally were affected by the barometric pressure at the time of measurements during 1981-82. At wells 0-3, 0-24, and 0-36, which are deep enough to have no external interference and which have firmly set packers, the water-level variations were 0.5 foot or less. At well 0-5, in the north part of the basin, where the Dietz coal bed is only 75 feet below a surface consisting of Anderson clinker layers, the water level varied from 50.1 to 51.1 feet during the study. The water level in well 0-5 generally rose during the winter and declined during the summer. At wells 0-34 and 0-41, water levels adjusted after the wells were pumped or bailed, probably as a result of the packer setting more securely and sealing off overlying waters. Representative fluctuations in water levels are shown in figure 7.

The water level in well 0-13 was similar to the levels in the overlying alluvial gravels. This condition is additional evidence of a hydrologic connection between the coal and alluvial aquifer at this locality.

Quality of water

Water from most of the Dietz coal aquifer wells was a sodium bicarbonate type, with small to moderate concentration of sulfate (fig. 8). The other major ions, calcium, magnesium, potassium, and chloride usually existed in small concentrations. Fluoride concentrations were variable--from 3.1 to 3.7 mg/L in wells 0-3, 0-24, and 0-36, and from 1.3 to 1.6 mg/L in wells 0-5, 0-13, 0-34, and 0-41. Generally, the smallest concentrations of fluoride existed where the Dietz coal bed is at the shallowest depths.

Two wells completed in the Dietz coal bed yielded sodium sulfate type water. Well 0-13, which contained a mixture of water from coal and alluvial aquifers, was expected to have sodium sulfate type water--the dominant water type of the alluvial aquifers. But water from well 0-41 was not a mixture; this well is just east of the Little Bear Creek basin divide and lies between two faults. The water from well 0-41 could have been slightly mixed with water from the overlying sandstone aquifers. Well 0-34, which contained sodium bicarbonate sulfate type water, is located in the south-central part of Little Bear Creek basin at a site about one-quarter mile south of another fault. The sulfate concentration in most other "normal" wells completed in the Dietz coal aquifer was small to moderate (about 5 to 83 mg/L). Well 0-5, in which the Dietz coal bed is less than 100 feet deep, contained water with a sulfate concentration of 350 mg/L.

Excluding the wells with large sulfate concentrations, the average dissolved-solids concentration in water from the Dietz coal aquifer was about 2,000 mg/L, the average hardness was about 70 mg/L, and the major-ion concentration averages were: calcium--13 mg/L; magnesium--10 mg/L; sodium--750 mg/L; potassium--7 mg/L; bicarbonate--1,790 mg/L; sulfate--180 mg/L; and chloride--26 mg/L. The pH of the water from all wells completed in the Dietz coal aquifer ranged from 7.4 to 8.2; the water generally was moderately alkaline.

Anderson coal bed

The Anderson coal bed underlies the central part of the Little Bear Creek basin from the northwest divide southward, then eastward to the southeast divide. In the northeast part of the basin, the Anderson either is eroded along the main stream valleys or has been burned, forming clinker caprock along the ridges (pl. 2). Where present, the Anderson coal bed is 31 to 34 feet thick and is minable in a mile-wide crescent from near the northwest divide, southward and eastward to the southeast divide; and from the clinker layers to the northeast to the 200-foot overburden line to the southwest and south. Within most of this area, the Anderson is a massive coal bed between 32 and 33 feet thick.

Above the Anderson coal bed is typical Tongue River Member gray shale, light-gray sandstone or siltstone, and a few local coal beds mostly less than 3 feet thick. The sandstone beds and lenses are 0 to 20 feet thick and usually of limited lateral extent. One persistent coal bed, the Smith coal, is 2 to 3 feet thick and lies between 135 and 155 feet above the Anderson bed in the northwest, southwest, and southeastern parts of the basin, but pinches out to the northeast. At the top of the Tongue River Member, the Roland coal bed is 340 to 390 feet above the Anderson. Because of the high altitude of the sediments above the Anderson coal bed, they contain water only for short distances away from the southwestern and southeastern divides of the Little Bear Creek basin.

Aquifer characteristics

Four observation wells were drilled to, and have perforated casing opposite, the Anderson coal bed within the Little Bear Creek basin, and one well (O-38) was completed in the Anderson south of the study area in East Trail Creek basin. All observation wells were pumped or bailed to test the aquifer characteristics of the Anderson coal bed.

Wells O-25, O-35, and O-37 were pumped at 2.2, 1.6, and 1.1 gal/min, respectively. The results of these tests seem to be most representative of the Anderson coal aquifer in the Little Bear Creek area; the calculated hydraulic conductivity was about 0.3 ft/d for two of the wells and about 0.06 ft/d for the third (O-37). An average hydraulic conductivity is presumed to be about 0.2 ft/d.

Well O-4, located near the northwest divide of the Little Bear Creek area, contained Anderson coal that was only partly saturated; the coal bed is from 95 to 129 feet below land surface and the water level, when tested, was 103.8 feet below land surface. This well had a yield too small to pump, so the aquifer characteristics were determined from recovering water-level measurements after bailing to near the bottom of the well. The recovering water level indicated a yield of 0.3 gal/min and the calculated aquifer hydraulic conductivity was about 0.008 ft/d.

Well 0-38 had a very good yield for the Anderson coal aquifer. The well was pumped at 4.4 gal/min with only 13 feet of drawdown; the calculated aquifer hydraulic conductivity was about 4 ft/d. The coal aquifer is apparently more fractured at this site than elsewhere.

Water-level fluctuations

During 1981-82, water levels in observation wells perforated opposite the Anderson coal aquifer fluctuated about 0.5 foot, mostly in response to variations in atmospheric barometric pressure at the times of the measurements (fig. 7). Only at well 0-4 did the water-level measurements indicate a trend of declining water levels. This decline was so small (0.4 foot) and the period of measurements so short (2 years) that little significance can be attributed to it.

Potentiometric surface

Because of the few points of reference of water levels in the Anderson coal aquifer, no attempt was made to contour the potentiometric surface. In the Tongue River aquifers in the upstream part of the Little Bear Creek valley, downgradient is toward the Horse Creek valley along the southwest-dipping strata. Data are not available to determine where a ground-water divide exists between the upstream reach of the Little Bear Creek and the Horse Creek valleys. The existing data indicate that the water level in the Anderson coal aquifer is at an altitude of about 3,754 feet above sea level in observation well 0-37 and at an altitude of about 3,645 feet in the observation well in the Horse Creek valley (number 0-26 in the Horse Creek report by McClymonds, 1985). No wells between are available to indicate where the water-level divide might be. The divide is presumed to be between well 0-37 and the topographic divide between the Horse Creek and the Little Bear Creek basins, which would indicate that downgradient ground-water flow would be toward the potential mine pit in the Little Bear Creek drainage. In the Davidson Draw drainage, the Anderson coal aquifer is nearly horizontal; the topographic divide with East Trail Creek and the ground-water divide probably are nearly along the same line.

In the vicinity of the Little Bear Creek valley where the Anderson coal bed is at land surface, southwest of spring S-6, flow is toward the valley. This diversion of the flow direction is indicated by the water levels in wells 0-4 (water-level altitude of about 3,776 feet), 0-25 (about 3,771 feet), and 0-23 (about 3,745 feet). Well 0-23 penetrates both alluvium and the lower part of the Anderson coal aquifer; the water level in the well reflects the water level of the alluvial and coal aquifers at this location.

In Davidson Draw valley, a fault crossing the valley may be of hydrologic significance. North of the fault, the base of the Anderson coal bed is about 80 feet above the level of the flood plain. South of the fault, the base of the Anderson is about at the level of the flood plain. The upper part of the Anderson coal is burned in this vicinity; the fact that the lower 10 to 20 feet of coal is not burned indicates that it probably was saturated at the time of the burn. No data points for water levels of the Anderson aquifer are available in this vicinity, but it is suspected that, upstream from the fault, the potentiometric surface in the Anderson coal aquifer slopes toward Davidson Draw valley. A developed spring (S-8) in the stream channel may be a result of the fault and the structural position of the Anderson coal bed at this locality.

Quality of water

Water from five sampled observation wells completed in the Anderson coal aquifer in the Little Bear Creek area had a broad range of dissolved-solids concentrations (fig. 8). Well 0-37, in the southwest part of the area and the deepest well (216 feet to bottom of Anderson), had water of a sodium bicarbonate type, with 2,360 mg/L of dissolved solids. Well 0-25, in the western part of the area and a relatively shallow well (126 feet to bottom of Anderson), had water of a sodium sulfate type, with 5,550 mg/L of dissolved solids. Most other shallow wells (0-4 with bottom of Anderson at 129 feet, and 0-35 with bottom of Anderson at 155 feet) also had water of a sodium sulfate type, but relatively less mineralized--2,400 mg/L of dissolved solids for well 0-4 and 3,320 mg/L for well 0-35. The fifth sampled well was 0-38, south of the study area in the East Trail Creek basin. Analysis of the water from this well, in which the bottom of the Anderson coal bed is at 175 feet below land surface, indicated a sodium bicarbonate type water.

Other constituents in water from the Anderson coal aquifer generally were present in small to moderate concentrations. Calcium concentrations ranged from 10 mg/L (well 0-38) to 130 mg/L (well 0-25), magnesium ranged from 6.7 mg/L (well 0-38) to 120 mg/L (well 0-25), potassium concentrations averaged about 9 mg/L, chloride concentrations averaged about 28 mg/L, and silica concentrations averaged about 11 mg/L. The hardness of the water ranged from 53 mg/L (well 0-38) to 820 mg/L (well 0-25), median pH was about 7.5, and the sodium-adsorption ratio averaged about 34. The fluoride concentration ranged from almost 1 mg/L in wells 0-25 and 0-35 to 2.1 mg/L and 1.8 mg/L in wells 0-37 and 0-38, respectively (marginal for human consumption according to standards established by the U.S. Environmental Protection Agency, 1977) to 3.1 mg/L in well 0-4 (unacceptable for human consumption).

Sandstone beds

Sandstone beds and lenses exist in the interburden between each of the major coal beds. Any of these sandstone beds, which are relatively free of silt or clay and are 10 feet or more thick, are potential aquifers. All the deep private wells in the Little Bear Creek basin and vicinity are perforated opposite these sandstone aquifers, although some also are perforated opposite adjacent coal beds.

The sandstone beds between the Canyon and Dietz coal beds are 3 to 30 feet thick. The average ratio of thickness of sandstone to total thickness of interburden in this interval, as determined from available test-hole and observation-well lithologic logs, is about 25 percent; the range is from 10 to 40 percent. Plotting the percentage of sandstone thicknesses on a map produced a scattering of large and small values. The beds were formed from sand deposited during Paleocene time in broad, meandering channels of streams flowing from the general area of the Big Horn Mountains northwestward toward the Williston basin. The positions of these buried channels could not be determined from the broadly scattered data points obtained to date.

The sandstone beds between the Dietz and Anderson coal beds are 2 to 35 feet thick, but most are 10 feet or less thick. Plotting the sandstone-to-interburden percentages on a map shows a cluster of large values (more than 40 percent) in the vicinity of test holes T-6 and T-10 and well 0-24 in the northwest part of the Little Bear Creek basin, and another group of fairly large values (about 30 percent) outside the eastern boundary of the basin (well 0-41 and test hole T-28). An exceptionally small percentage of sandstone (less than 20 percent) exists in the central part of the basin (wells 0-3, 0-31, and 0-33, and test holes T-4, T-14, and T-25).

Aquifer characteristics

Four wells in and near the Little Bear Creek study area were drilled, cased, and perforated opposite of sandstone aquifers. Of those wells (0-12, 0-32, 0-33, and 0-43), only the three within the Little Bear Creek basin were pumped (table 5).

Well 0-12 is located on the north side of the Little Bear Creek valley, about one-half mile upstream from the Hoover Draw confluence. The well penetrated 8 feet of fairly clean sandstone between depths of 28 and 37 feet. The sandstone lies about 10 feet below the base of the Canyon coal bed, which is burned to clinker on the hillside north of this site. The water level in this well is about 20 feet higher than the water level in the Little Bear Creek alluvial aquifer 300 feet to the south. The well was pumped at 3.1 gal/min for 100 minutes, and had about 9 feet of drawdown. The aquifer hydraulic conductivity was calculated to be about 1.2 ft/d, which is the largest hydraulic conductivity for sandstone within the study area. Halfway through the test, the water changed from clear to dark orangish-brown; there was no change in the specific conductance, nor any change in taste or smell. Particulate matter causing the color was filtered out when the water sample was collected for chemical analysis; the filter retained a black residue. Apparently the cone of depression intercepted water from the Canyon coal clinker layer under the hill to the north, and water from clinker was being drawn into the pumped well.

Wells 0-32 and 0-33 are located along Davidson Draw in the south-central part of the Little Bear Creek basin. Both wells have casing perforated in apparently the same sandstone beds between the Canyon and Dietz coal beds. In well 0-32, the sandstone beds were mostly clean, but a few ledges contained quartzitic sandstone. In well 0-33, the quartzitic sandstone thicknesses increased to more than one-half of sandstone interval, greatly decreasing the productivity of this well. Well 0-32 was pumped at 2.4 gal/min with about 37 feet of drawdown. Well 0-33 was pumped at about 0.8 gal/min with 67 feet of drawdown. The calculated aquifer hydraulic conductivity at the two wells were about 0.5 ft/d at well 0-32 and about 0.1 ft/d at well 0-33. As interpreted from gamma logs, 19 feet of sandstone contributed water to well 0-32 and 29 feet of sandstone contributed to well 0-33. The lesser hydraulic conductivity of the sandstones in well 0-33 can be attributed to the greater proportion of quartzitic material in sandstone beds at that site.

The sandstone beds between the Dietz and Anderson coal beds have no observation wells open to them. However, private well P-1 is completed in this sandstone at the ranch house in Hoover Draw. There, the sandstone yields about 1.5 gal/min; Mr. Hoover reports that if the well is pumped more than 10 minutes, loose sand enters the well. Properly constructed wells completed in sandstone beds between the Dietz and Anderson coal beds in other parts of the area, particularly the western and eastern edges, probably could yield 5 gal/min or more.

Private well P-10 obtains about 5 gal/min from a sandstone bed above the Anderson coal bed in the southern part of the Little Bear Creek basin. Other wells probably could be successfully completed in sandstone beds at high altitudes in the basin. At lower altitudes near the outcrop lines, these sandstone beds probably would be dewatered by natural discharge.

Water-level fluctuations

The water level in well O-12 generally follows the seasonal water-level fluctuations in the alluvial aquifer of the Little Bear Creek valley (fig. 9). The highest measured water level was 27.8 feet below land surface in March 1981. From there, the level declined during the spring and summer to 28.6 feet below land surface. In 1982, the level declined from a March high of 28.4 feet to 28.9 feet in October.

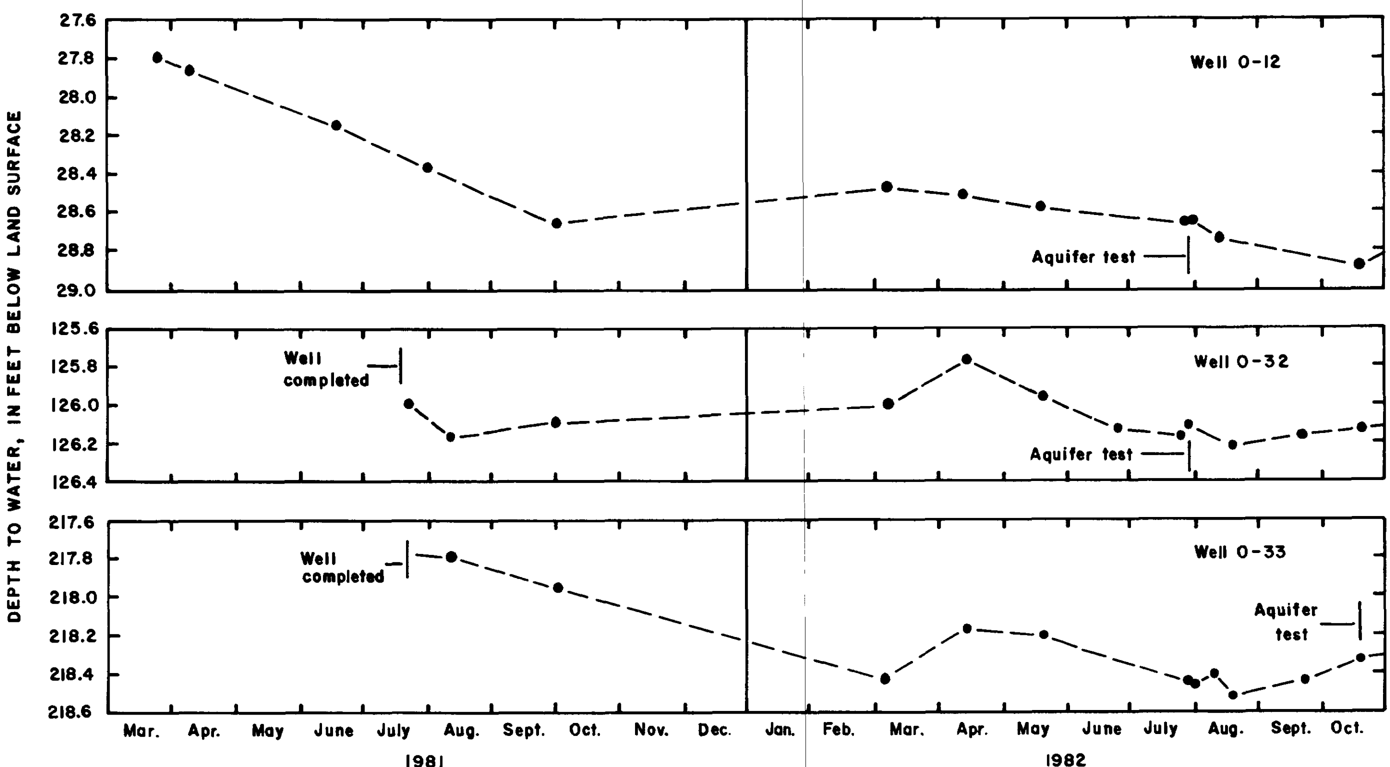

Figure 9.--Water-level fluctuations from March 1981 through October 1982 in observation wells completed in sandstone aquifers.

Wells O-32 and O-33 had water levels that fluctuated with the atmospheric barometric pressure, as do most of the artesian wells in the Little Bear Creek basin. Water levels in well O-32 fluctuated between 125.8 and 126.2 feet below land surface, and water levels in well O-33 were between 217.8 and 218.5 feet below land surface.

Quality of water

The quality of water from sandstone aquifers in the Little Bear Creek basin was variable; dissolved solids ranged from 556 mg/L in well P-1 (base of sandstone 44 feet deep) to 4,080 mg/L in well O-43 (base of sandstone 63 feet deep); the water type varied from magnesium sulfate in wells O-43 and P-10 to sodium bicarbonate in wells P-1 and O-33 (fig. 8). Well O-12 had water containing principally magnesium, sodium, bicarbonate, and sulfate and well 0-32 had water containing principally sodium, sulfate, and bicarbonate.

Concentrations of individual constituents in the water also were variable; in some samples the variability was related to aquifer depth. In the shallow wells (0-12, 0-43, P-1, and P-10) the pH was about 7 units, and in the deep wells (0-32 and 0-33) the pH was about 8 units. Average bicarbonate concentration was about 540 mg/L in water from the shallow wells, and was about 1,570 mg/L in the deep wells. The calcium and magnesium concentrations were about 10 to 30 times larger in the shallow wells than in the deep wells except for wells P-1, for which the calcium and magnesium was only 3 times greater. The sodium concentration was 2 to 4 times larger in the deep wells than the shallow wells. The potassium (5.2 to 16 mg/L) and chloride (4.9 to 26 mg/L) concentrations were relatively small in both shallow and deep wells. The sulfate concentration was variable between shallow and deep wells, but the extremes--55 mg/L in well 0-33 (base of sandstone 325 feet deep) and 2,700 mg/L in well 0-43 (base of sandstone 63 feet deep) may have been related partly to depth. Fluoride also seemed to be related to depth; in shallow wells concentrations ranged from 0.5 to 1.1 mg/L and in deep wells the concentrations were larger--2.9 mg/L in well 0-32 (base of sandstone 246 feet deep) and 4.1 mg/L in well 0-33 (base of sandstone 325 feet deep).

Alluvial aquifer

An alluvial aquifer exists under the flood plain and lower terraces of the valleys in the Little Bear Creek basin, from the confluence of Little Bear Creek with Bear Creek to far up the many tributary valleys near the drainage divides. In the upstream reaches of the stream valleys, the alluvium is thin (probably less than 10 feet thick) and the quantity of water yielded to wells probably would be small. Downvalley, about 2 to 3 miles downstream from the divides, the alluvium thickens and broadens, and the sand and gravel aquifers probably would yield more water. To determine the aquifer characteristics of the alluvium, lines of wells were drilled across the valley at four sites along Little Bear Creek and at two sites along Davidson Draw. Three holes were drilled in the downstream end of Hoover Draw in an attempt to locate the buried channel under the terrace deposits; only one of these (well 0-7) was cased and none penetrated the main channel.

Aquifer characteristics

Well line 0-26 to 0-27

The well line farthest upstream along Little Bear Creek is represented by wells 0-26 and 0-27; this line is about 6.6 miles from the mouth of the creek. A third test hole (T-9) was drilled but was dry, so the casing was pulled and the hole was filled (pl. 3, section F-F'). Test hole T-9 has nearly 4 feet of sand and gravel at the base, but the water level during 1981 and 1982 was deeper than the base of the alluvial materials at that site.

Wells 0-26 and 0-27 were tested (table 6) in June 1982, when the water levels were near the highest during the study for this part of the valley. Well 0-26, which is located closer to the apparent center of Little Bear Creek valley, penetrated shale in the Tongue River Member at a higher level than did well 0-27. Well 0-26 was drilled through 20.5 feet of alluvium; the lower 9.5 feet of the hole has

5.5 feet of sand and gravel in three layers, but only the lowermost 1.5 feet was contributing water in June 1982 (see section F-F', pl. 3). Well 0-26 was pumped at 1.2 gal/min with 0.8 foot of drawdown; the estimated hydraulic conductivity was 6 ft/d at the June 1982 water level. The well also was pumped in October 1982, when the water level was nearly 1 foot deeper -- leaving about 0.5 foot of saturated sand and gravel aquifer. At the deeper water level the well yielded only about 0.2 gal/min.

Well 0-27 apparently was drilled into a deeper part of the valley alluvium. There, the alluvium is 27 feet thick; the lower 11 feet has sand and gravel in four layers totaling 7 feet thick, but only the lower two layers (2.5 and 1.5 feet thick) contributed water in June 1982 when the well was pumped. The well was pumped at 1.9 gal/min with 0.8 foot of drawdown; the calculated hydraulic conductivity was 120 ft/d. Based on the tests of wells 0-26 and 0-27, and assuming that more water flows on the north side of the valley near well 0-27 than on the south side (pl. 3), the estimated hydraulic conductivity of the alluvium is about 100 ft/d.

The volume of water flowing past well line 0-26 to 0-27 would depend on the width of the buried channel penetrated by well 0-27, which is not precisely known. Assuming that geologic section (F-F') illustrated on plate 3 is approximately correct, the calculated volume of water passing the line at October 1980 water levels is about 800 ft^3/d. The volume decreased to about 550 ft^3/d at October 1982 water levels. These results were determined by Darcy's law (Lohman, 1972) and the formula:

$$Q = KIA \tag{2}$$

where

Q = volume of water flowing past the well line, in cubic feet per day;
K = median hydraulic conductivity of the alluvial materials, in feet per day;
I = gradient of the water table, in feet per foot; and
A = saturated cross-sectional area of the contributing sand and gravel at the well line, in square feet.

The value of K was assumed to be about 100 ft/d; I was measured as a 10-foot drop per 900 feet downvalley, or about 0.011; and A was measured from the geologic section as about 750 ft^2 at the October 1980 water levels, and about 500 ft^2 at the October 1982 water levels.

Well line 0-20 to 0-23

The next line of wells downstream along Little Bear Creek includes wells 0-20, 0-21, 0-22 and 0-23; these wells are about 5.0 miles upstream from the mouth of the creek. The north side of the alluvial aquifer channel is fairly well located by well 0-23, where the alluvium is 20 feet thick and has a sand and gravel layer in the lowest 2 feet, with the Anderson coal bed below (pl. 3, section G-G'). In October 1980, the water level was about 3 feet above the base of the alluvium, but only 2 feet of sand and gravel was contributing water to the well. In October 1982, the level was only about 1 foot above the base. Well 0-23 was drilled through the base of the Anderson coal, so water entering the well comes from both the coal and the alluvial sand and gravel layer. The south side of the alluvial aquifer channel is not well defined. Well 0-20, located on a low terrace on the south side of the valley, penetrated 20 feet of alluvium but at a lower altitude than that of well

0-23; at well 0-20 four layers of sand and gravel totaling 6 feet thick exist in the lower 9 feet of alluvium. At October 1980 water levels, the lower three sand and gravel layers were saturated (4 feet of contributing sand and gravel). Below the alluvium is 3.5 feet of basal Anderson coal bed. Saturated alluvium continues south of well 0-20 for an unknown distance. Outcrops of Anderson clinker exist in the hillside about 250 feet to the southeast, so the alluvial channel is presumed to continue for 150 to 200 feet south of well 0-20. Under wells 0-20 through 0-22 the alluvial channel bottom seems to be fairly flat--no incised narrow channels were located by the four wells in this line, but one may exist. Well 0-22 was at a locale of the deepest alluvium of the four wells. At the October 1980 water levels, well 0-22 had 4.5 feet of contributing sand and gravel; the contributing aquifer thickness decreased to about 3.5 feet at the lower water levels in October 1982.

All four wells in line 0-20 to 0-23 were pumped or bailed to determine the aquifer characteristics in this vicinity. The tests were conducted from August through October 1982 when the water level was lower than when the wells were drilled (October 1980). Because of the low water levels when the tests were conducted, the pumping water levels were drawn down into the aquifer, thus negating several assumptions for an ideal aquifer test. The results given below, therefore, are only approximations, but the best values obtainable under the conditions at the the time of the tests.

Well 0-20 was pumped at 1.3 gal/min with about 8 feet of drawdown in August 1982. The perforations in the casing of this well are open only to the lowest 1.5 feet of sand and gravel aquifer and to 3.5 feet of Anderson coal aquifer. The calculated hydraulic conductivity, about 2 ft/d, would represent a combination of the two aquifers.

Well 0-21 was pumped at 2.4 gal/min with 3.0 feet of drawdown in October 1982. About 3 feet of contributing sand and gravel aquifer and 3.5 feet of Anderson coal aquifer are opposite the perforated interval of the well. Most (80 percent, or more) of the water is presumed to be from the alluvial aquifer. The calculated hydraulic conductivity was about 12 ft/d for well 0-21.

Well 0-22 was pumped at 1.2 gal/min with 1.4 feet of drawdown in October 1982. This well had 3.4 feet of contributing sand and gravel aquifer and 3 feet of Anderson coal aquifer opposite the perforated casing interval. Here also, most (80 percent or more) of the water is presumed to be from the alluvial aquifer. The well probably could be pumped at 4 gal/min, with the pumping water level remaining above the bottom of the alluvium. The calculated hydraulic conductivity was about 12 ft/d.

Well 0-23 was bailed in September 1982, when the water level was very low. An estimated 0.5 foot of alluvial sand and gravel and 7 feet of Anderson coal aquifer were contributing water to the well at this time. Probably most of the water and the computations reflect the characteristics of the coal aquifer. The hydraulic conductivity was calculated from the recovering water-level measurements after bailing using the method devised by Jacob (Ferris and others, 1962), which includes residual drawdown; the result was a hydraulic conductivity of about 0.1 ft/d. The well yielded about 0.25 gal/min with a drawdown of 6.0 feet.

In calculating the volume of water passing well line 0-20 to 0-23, all values are small because of the low water levels at the time of the tests; therefore, a large volume of potentially contributing sand and gravel aquifer is not included in the calculations. Using the Darcy equation, $Q = KIA$, with an approximate K of 10 ft/d, a gradient of about 0.007, and an area of 1,500 ft^2 of contributing sand or gravel aquifer at the October 1982 water levels, the volume of water passing well line 0-20 to 0-23 would have been about 100 ft^3/d.

Well line 0-14 to 0-19

This well line, which includes wells 0-14, 0-15, 0-16, 0-18, and 0-19, is 4.5 miles upstream from the mouth of Little Bear Creek and is downstream from the emergence of the Anderson coal bed to above the level of the lower valley (pl. 3, section H-H'). Outcrops of Anderson clinker layers exist halfway up the slopes of the hills north and south of the valley. Well 0-17 is west of the line, 20 feet from well 0-16. Well 0-13 has casing perforated in the underlying Dietz coal bed at the north end of the well line; this well is included with the Dietz coal bed discussion.

On the north side of the valley, the Anderson clinker layer is the source of water for spring S-6 ("Tanner" spring), which supplies water to a perennial pond just north of the Little Bear Creek flood plain. Other seeps and underflow from the clinker layers also reach the Little Bear Creek alluvium a short distance upstream from the well line. On the south side of the valley, no obvious springs exist, but the Anderson clinker layers surround the small tributary valley, which probably contributes additional ground-water flow to the main valley alluvium.

As shown on plate 3, section H-H', the base of the alluvial channel is broad and fairly level in the northern one-half of the section, but deepens to the south (under well 0-14). Under the surface soil and mud layers, at depths ranging from 4.5 feet in well 0-19 to 10 feet in well 0-15, is a very soft layer of fine sand from 2 to 3.5 feet thick. Below this soft layer are alternating layers of mud, sand, and gravel. The saturated thickness of the alluvium is 7 to 8 feet in the middle of the valley and 13 to 14 feet near the southern edge.

All five wells in the line and well 0-17, offline, were pumped to determine the characteristics of the aquifer at this locality. The tests were conducted in July, August, and September 1982. The water level declined about 1 foot between the July and September tests; this decline would affect the comparability of the test results.

Well 0-14, at the south end of the well line, was pumped at 2.4 gal/min with 2.9 feet of drawdown in July 1982. Although the sand and gravel layers in the saturated part of the alluvium are about 8 feet thick, only the lower three beds, which are 1.5, 1, and 0.5 feet thick, are exposed to the perforated interval in the casing. The calculated hydraulic conductivity is about 110 ft/d for well 0-14.

Well 0-15, 200 feet to the north, was pumped at 5.6 gal/min with 1.3 feet of drawdown in August 1982. This well is open to 3.5 feet of saturated sand and gravel. The hydraulic conductivity was calculated to be about 280 ft/d.

Well 0-16 is 200 feet north of 0-15 and was pumped at 21 gal/min with 2.8 feet of drawdown is September 1982. Well 0-17 was pumped at 2.1 gal/min with 1.0 foot of drawdown in July 1982. Although the wells are only 20 feet apart, the calculated hydraulic conductivities vary considerably--about 640 ft/d for well 0-16 and about 200 ft/d for well 0-17. Well 0-16 is open to 2.5 feet of contributing sand

and gravel and well 0-17 is open to 2 feet of sand and gravel. The only probable explanation for the discrepancy in hydraulic conductivities seems to be the depth of the alluvium at these sites--well 0-16 is 1 foot deeper; this lower foot apparently yields more water.

Well 0-18, 50 feet north of well 0-16, was pumped at 5.4 gal/min with 0.9 foot of drawdown in August 1982. This well is open to 3.5 feet of sand and gravel. The calculated hydraulic conductivity was about 570 ft/d, which is comparable to well 0-16.

Well 0-19 is 150 feet north of well 0-18 and was pumped at 9.1 gal/min with 2.2 feet of drawdown in July 1982. The well is open to 3 feet of saturated sand and gravel, but the hydraulic conductivity was calculated at only about 130 ft/d. The proximity of the north edge of the alluvial materials, about 170 feet away, may explain the decreased calculated hydraulic conductivity.

To calculate the volume of water passing well line 0-14 to 0-19 by the Darcy equation, $Q = KIA$, the alluvial aquifer was divided into fifths--the hydraulic conductivity along the north and south edges of the valley were assumed to be about 100 ft/d, the middle was assumed to be about 600 ft/d, and the parts between were assumed to be about 300 ft/d. The gradient of the water table in this stretch of alluvial valley is about a 1 foot drop per 100-foot length, or 0.01. The area of the contributing sand and gravel aquifer at mid-summer 1982 water levels is about 3,600 ft^2. Therefore, about 9,000 ft^3/d of water flows through the alluvial aquifer at this locality.

Well line 0-8 to 0-10

The well line farthest downstream includes wells 0-8, 0-9, and 0-10, which are about 1.9 miles upstream from the mouth of Little Bear Creek and about 0.5 mile upstream from the confluence with Hoover Draw. At this locality, the alluvial valley is about 500 feet wide; the deepest and thickest part of the alluvium is along the north side of the valley apparently near well 0-10, where it is about 22 feet thick (pl. 3, section I-I'). From the north edge, the base of the alluvium slopes gradually upward to the south and the surface slopes downward, so that in well 0-8, which was drilled on the flood plain of Little Bear Creek, the alluvium is only 11 feet thick. The upper 3.5 to 12.5 feet of alluvium is composed of mud, gravelly mud, or clayey mud; below are sand and gravel layers interbedded with thinner mud layers. The saturated interval of the alluvium is about 8 feet thick to the south and 10.5 feet thick to the north.

The three wells in the line were tested in August 1982 to determine the characteristics of the alluvial aquifer. Well 0-8 was pumped at 3.6 gal/min with 3.4 feet of drawdown. This well is open to about 6 feet of saturated sand and gravel aquifer. The hydraulic conductivity was calculated at about 8 ft/d. Well 0-9 was pumped at 4.8 gal/min with 1.3 feet of drawdown. It also has about 6 feet of saturated aquifer and the hydraulic conductivity was about 100 ft/d. Well 0-10 was pumped at 6.0 gal/min with 4.0 feet of drawdown. Well 0-10 has about 6 feet of saturated sand and gravel contributing to the well. The calculated hydraulic conductivity was about 65 ft/d.

Although the valley is narrower at well line 0-8 to 0-10 than at well line 0-14 to 0-19, the saturated aquifer is much thicker. The calculated volume of water passing the downstream locality is about 1,700 ft^3/d. This volume was calculated by the Darcy equation, $Q = KIA$, using an estimated value for K of about 60 ft/d, a gradient of about 0.01, and an area of about 2,850 ft^2 for the contributing saturated aquifer. Adding this volume to the volume of water flowing on the surface--about 0.05 ft^3/s or about 4,300 ft^3/d--then a total of about 6,000 ft^3/d of ground and surface water passes the well line.

Between well line 0-14 to 0-19 and well line 0-8 to 0-10, Little Bear Creek flows interruptedly, is dammed by at least one small stock pond, and has a channel that is alternately marshy or dry. All the evaporation and transpiration that occur along the channel subtract water from the total flow in the aquifer. Also, between the two well lines, Davidson Draw joins the main stem of Little Bear Creek, which would add to the flow in the aquifer. Apparently the subtractions are greater than the additions, if the calculated flows of 6,000 ft^3/d at well line 0-8 to 0-10 and of 9,000 ft^3/d at well line 0-14 to 0-19 are approximately correct.

Well line 0-28 to 0-30

This well line includes wells 0-28, 0-29, and 0-30 in the Davidson Draw valley about 1.7 miles upstream from the confluence of Little Bear Creek and Davidson Draw; the confluence is about 2.7 miles upstream from the mouth of Little Bear Creek at Bear Creek. After the wells were drilled, an east-trending fault was discovered across the Davidson Draw valley about 0.1 mile downstream from the well line. The fault, with the north side upthrown about 80 feet at this locality, probably does not affect the lithology of the alluvium along the valley, but may introduce subsurface flow from the Tongue River Member aquifers to the alluvial aquifer downstream from the well line.

At the well line, the alluvial valley is about 600 feet wide and the alluvium, under the flood plain, is 8 to 11 feet thick (pl. 3, section J-J'). Under the terrace to the east, the alluvium has a probable maximum thickness of about 18 feet. Under the flood plain, the alluvium is composed of 4 to 6 feet of mud and gravelly mud in the upper part, and 4 to 6 feet of sand and gravel with thinner mud layers in the lower part.

The three wells of the line were tested in June 1982 to determine the aquifer characteristics. Well 0-28, on the terrace east of the Davidson Draw channel, was pumped at 0.6 gal/min with 4.0 feet of drawdown. At the time of the test, the well had about 2.4 feet of saturated sand and gravel contributing to the well, plus 2 feet of hard, fractured coal (the basal Anderson coal bed) and 2 feet of soft, weathered coal. Probably most of the water (60 percent or so) came from the alluvial aquifer. The calculated hydraulic conductivity of well 0-28 was about 2 ft/d at the time of the test. In June 1981, at the highest recorded water level, well 0-28 had 3.5 feet of sand and gravel contributing water to the well; in September 1982, only about 2 feet of aquifer was contributing.

Well 0-29, located on the flood plain of Davidson Draw about 80 feet west of the stream channel, was pumped at 0.9 gal/min with 0.6 foot of drawdown. About 3.5 feet of sand and gravel aquifer was contributing to the well in June 1982. The hydraulic conductivity was calculated to be about 20 ft/d. At the highest recorded water level in June 1981, well 0-29 had 3.5 feet of sand and gravel contributing water to the well; by September 1982, at the lowest water level, about 3 feet of aquifer was contributing water.

Well 0-30, located about 120 feet west of well 0-29 on a low terrace about 2 feet above the flood plain of Davidson Draw, penetrated a thicker section of sand and gravel than the wells to the east. This well was pumped at 1.4 gal/min with 0.3 foot of drawdown; it could probably be pumped at 4 gal/min and maintain a pumping water level above the lowest sand and gravel bed. Of the 4.5 feet of sand and gravel layer, only about 2.3 feet was saturated at the time of the test. The hydraulic conductivity was calculated at about 350 ft/d. At the June 1981 water levels, well 0-30 had about 4 feet of sand and gravel contributing water to the well; in September 1982, the contributing thickness was only 1.5 feet.

One reason for the much larger hydraulic conductivity on the west side of the valley than the center or east side is the clinker hill to the west. Eastward, at the locality of the well line, the Anderson coal bed is unburned and partly eroded throughout a broad, relatively flat plain. Westward, hills rise above the valley, and the Anderson coal bed is burned to clinker in all but the lowest part. The clinker gravel supplied a large part of the materials to the alluvial aquifer on this side of the valley, whereas shale and siltstone supplied the materials for the east side.

Because of the large variability of the permeable materials in the alluvial aquifer at the locality of well line 0-28 to 0-30, the calculated volume of water passing through the locality is not certain. In the calculations, 5 ft/d was used as a hydraulic conductivity for the eastern one-third of the valley, 20 ft/d was used for the middle part, and 350 ft/d was used for the western edge. The water table along the valley in this vicinity drops about 10 feet in 800 feet, for a gradient of 0.012. The total area of contributing sand and gravel aquifer at the time of the tests was about 1,300 ft^2. The total volume of water passing the well line is calculated to be about 1,500 ft^3/d at the June 1982 water levels.

Well line 0-39 to 0-40

Davidson Draw valley narrows downstream and the hills to either side rise abruptly from the valley floor. Anderson clinker layers cap hills to the east and west. The well line, which includes wells 0-39 and 0-40, is 0.5 mile upstream from the mouth, where Davidson Draw joins Little Bear Creek. There, the alluvial material of the valley is about 350 feet wide and 20 feet thick under the terrace and 13 feet thick under the flood plain (pl. 3, section K-K'). The upper part of the alluvium is composed of mud, gravelly mud, and clayey mud 8 to 14 feet thick. The lower part has layers of sand and gravel and thinner layers of mud; together, the thickness is 5 to 7 feet.

Wells 0-39 and 0-40 both were tested in June 1982, but the yield of well 0-40 was too small to pump. This well was bailed several times during the summer and tests were conducted in September 1982. Well 0-39 was pumped at 2.2 gal/min with 1.7 feet of drawdown. At the time of the test, 4.5 feet of saturated sand and gravel was contributing to the well. The calculated hydraulic conductivity was about 15 ft/d. From the configuration of the Davidson Draw valley at this locality, most of the alluvium (more than 60 percent) is considered similar to that underlying well 0-39. The contributing thickness of the sand and gravel aquifer in well 0-39 was greatest in March 1982 (5 feet) and least in September 1982 (about 4 feet).

Because of its small yield, well 0-40 was bailed to the bottom and the aquifer characteristics were determined from the recovering water-level measurements using the method devised by Jacob (Ferris and others, 1962). The yield of the well was calculated to be about 0.2 gal/min at 5.4 feet of drawdown, and the hydraulic conductivity was about 0.1 ft/d. At the time of the test the well had about 3.3 feet of sand and gravel aquifer opposite the perforated casing. In retrospect, the aquifer must have more mud or other fine materials than originally deduced. At the highest recorded water level in March 1982, well 0-40 had 3.5 feet of sand and gravel contributing water to the well; in September 1982, at the lowest water level, about 3 feet of aquifer was contributing water.

In the calculation of the volume of water passing well line 0-39 to 0-40, the geologic section is assumed to represent actual conditions, and most water is assumed to flow through the eastern one-half of this section. The volume was calculated using the Darcy equation, $Q = KIA$, where the average hydraulic conductivity for the west one-half is about 15 ft/d and for the east one-half is about 0.1 ft/d, the gradient is about 0.01, and the area is about 800 ft^2 on the west side and 350 ft^2 on the east side. The total flow past the line, therefore, is about 120 ft^3/d. This volume compares unfavorably with the 1,500 ft^3/d passing well line 0-28 to 0-30. The loss of nearly 1,400 ft^3/d of water might be explained as recharge into sandstone beds of the underlying Tongue River Member. The fault, 0.1 mile downstream from well line 0-28 to 0-30, would be a convenient flow path for the excess water, but other evidence, such as spring S-8, indicates that the fault zone yields water rather than absorbs it.

Water-level fluctuations

The fluctuations in the water level at several well lines reflect the variability of the alluvial aquifer throughout the Little Bear Creek and Davidson Draw valleys. At well line 0-26 to 0-27 from October 1980 to October 1982, the fluctuation was 1.4 feet (as represented by well 0-27 in fig. 10). In well 0-27, the water level rose slightly during the winter of 1980-81, from 21.5 feet to 21.2 feet below land surface, then declined during the summer to 22.1 feet in October 1981. The level rose again during the winter of 1981-82 to 21.6 feet in April 1982 and continued to rise until late June, then declined during the summer to 22.6 feet in October 1982. These fluctuations reflect a normal seasonal cycle, except that the level generally was 0.3 to 0.5 foot lower in 1982 than in 1981.

At well line 0-20 to 0-22 the water level did not follow the normal seasonal cycle; rather it declined almost steadily from October 1980 to October 1982. A water-level recorder was installed in well 0-22 in May 1981. The water level was 14.7 feet below land surface in October 1980, but declined to 15.1 feet in May 1981 (fig. 10). Through the summer, the level continued to decline to 16.3 feet at the end of December. In mid-January, the battery on the recorder froze and the clock stopped. Between mid-January and early March, when the recorder was started again, the water level rose from 16.4 to 16.2 feet, then declined through the spring and summer to 17.1 feet below the surface in October 1982. A severe rainstorm in late July caused a temporary rise in the water level of about 0.4 foot. The maximum decline from October 1980 to October 1982 in well 0-22 was 2.4 feet. In well 0-20, at the south end of the well line, the decline during this period was 2.7 feet; in well 0-21 it was 2.6 feet; and in well 0-23, with a combination of alluvial and Anderson coal aquifers, the decline was 1.9 feet.

Along well line 0-14 to 0-19, the water-level fluctuations follow a seasonal trend--high in the spring and early summer, declining during the summer growing

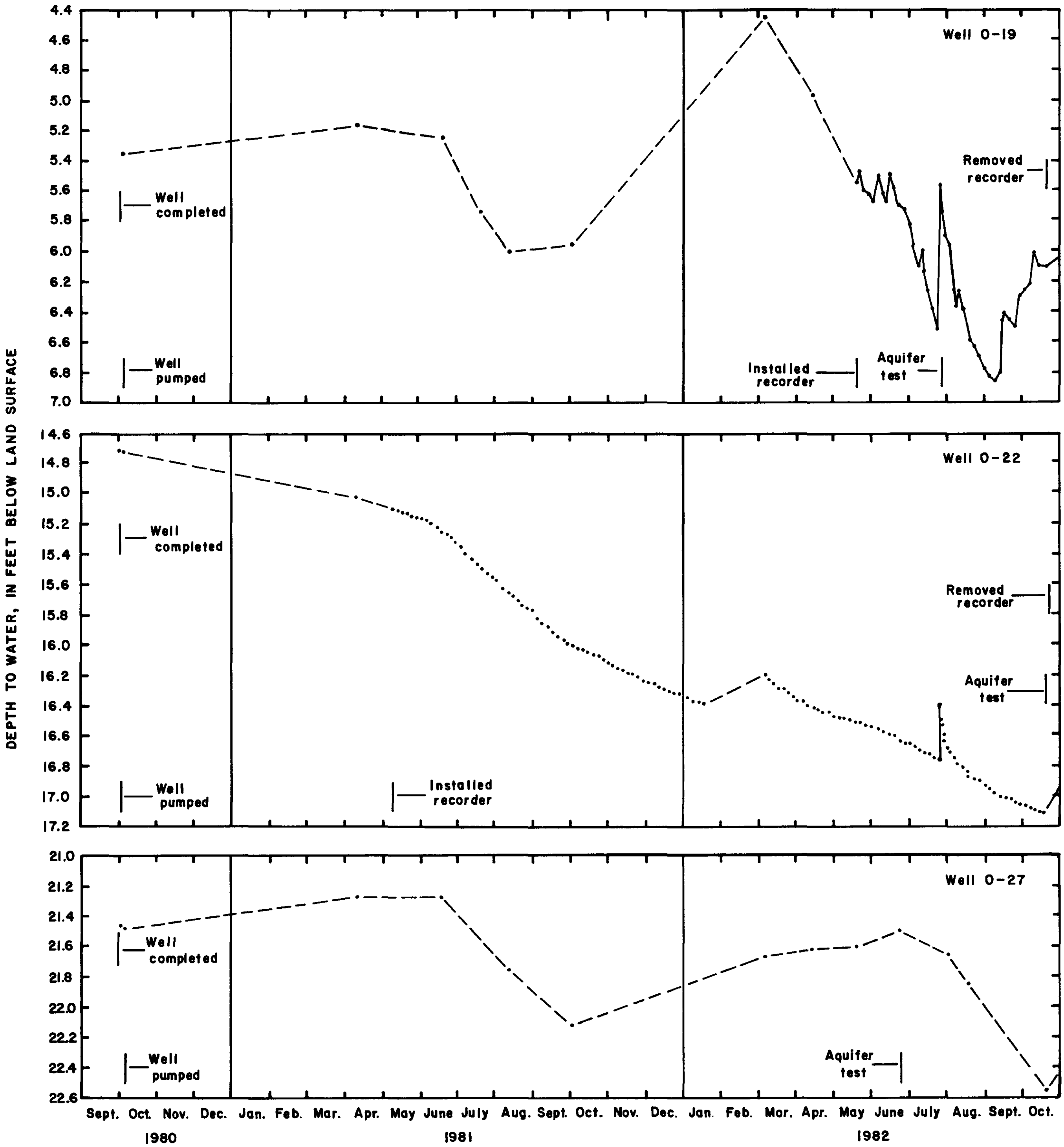

Figure 10.--Water-level fluctuations from September 1980 through October 1982 in observation wells completed in alluvium along the Little Bear Creek valley.

season, and rising again when the growing season ends in September or October. A water-level recorder was operated in well 0-19 from mid-May to mid-October 1982 (fig. 10). The well is situated on the flood plain with a Little Bear Creek channel meander passing west, north, and east of the site. The channel has a lush growth of reeds and sedge grass, and most of the time has standing or very slowly moving water. The water level in well 0-19 fluctuated diurnally as well as seasonally, usually rising at night when evapotranspiration is minimal and declining from about 1000 to 1800 hours when evapotranspiration is at a maximum. These daily fluctuations were as much as 0.2 foot, but usually 0.10 to 0.16 foot. The water level in well 0-19, and probably the other wells in the line, is also sensitive to rainfall and rises in the level of water in Little Bear Creek. In May and June 1982, the level of the water table rose after each rainfall of 0.25 inch or more. Between the rains, the level declined. From mid-June to July 24, 1982, there was little rainfall and the water level in well 0-19 declined from 5.5 to 6.5 feet below land surface. On the evening of July 24, a severe rainstorm swept through the area. The Otter 9SSW weather station reported 1.8 inches of rainfall, but the storm was much more intense north and northeast of the station; probably more than 2 inches of rain fell on the middle and downstream parts of the Little Bear Creek basin. The water level in well 0-19 rose substantially from 6.5 to 5.6 feet during the night. By the afternoon of July 25, the water level was declining again. The decline continued to mid-September when the water level was almost 6.9 feet below land surface.

In mid-September, another rainstorm reversed the decline and the water level rose about 0.5 foot. The water level declined again, much more slowly, to about the first of October, at which time the growing season was ending and the water level began to rise; this rise continued through the winter of 1982-83.

Periodic measurements of the water levels in the other wells of the well line show rises and declines of the water levels nearly identical to those in well 0-19 during 1981 and 1982. At well 0-14, on the south end of the line, the water level fluctuated 1.4 feet from April to October 1981, and 2.0 feet from March to late September 1982. At well 0-16, near the middle of the valley and where the alluvium is most productive, the water level fluctuated 1.0 foot from April to October 1981 and 2.3 feet from March to late September 1982.

At well line 0-8 to 0-10, the water levels fluctuated seasonally, similar to those at well line 0-14 to 0-19, except that the fluctuation was more subdued. A water-level recorder was installed on well 0-8 in early May 1981 (fig. 11). The instrument recorded a high in mid-May of 2.4 feet below land surface after a rainstorm, and a low of 3.2 feet in mid-September 1981. Diurnal fluctuations through the summer were as much as 0.1 foot, but most of the daily fluctuations caused by evapotranspiration were between 0.05 and 0.07 foot. One possible reason for the diurnal fluctuations at well line 0-8 to 0-10 being about one-half of those in well line 0-14 to 0-19, is the existence of a natural pond just upstream from well line 0-8 to 0-10. The pond is at the same altitude as the alluvial water level and maintains a flow in Little Bear Creek during all but the driest seasons. After late September 1981, which is the end of the growing season, the water level in well 0-8 rose abruptly from 3.2 to 2.7 feet by mid-November, then more slowly to 2.6 feet by early January 1982. An early January thaw allowed the water level to rise to 2.2 feet by mid-January, then sub-zero temperatures caused the recorder clock to stop. In March 1982, after a spring rainstorm, the water level rose to 1.8 feet below land surface, and the cycle of fluctuation began again through the spring and summer of 1982. The highest level of the year occurred after the July 24, 1982, rainstorm, when the water level reached 1.75 feet below land surface. After the storm, though,

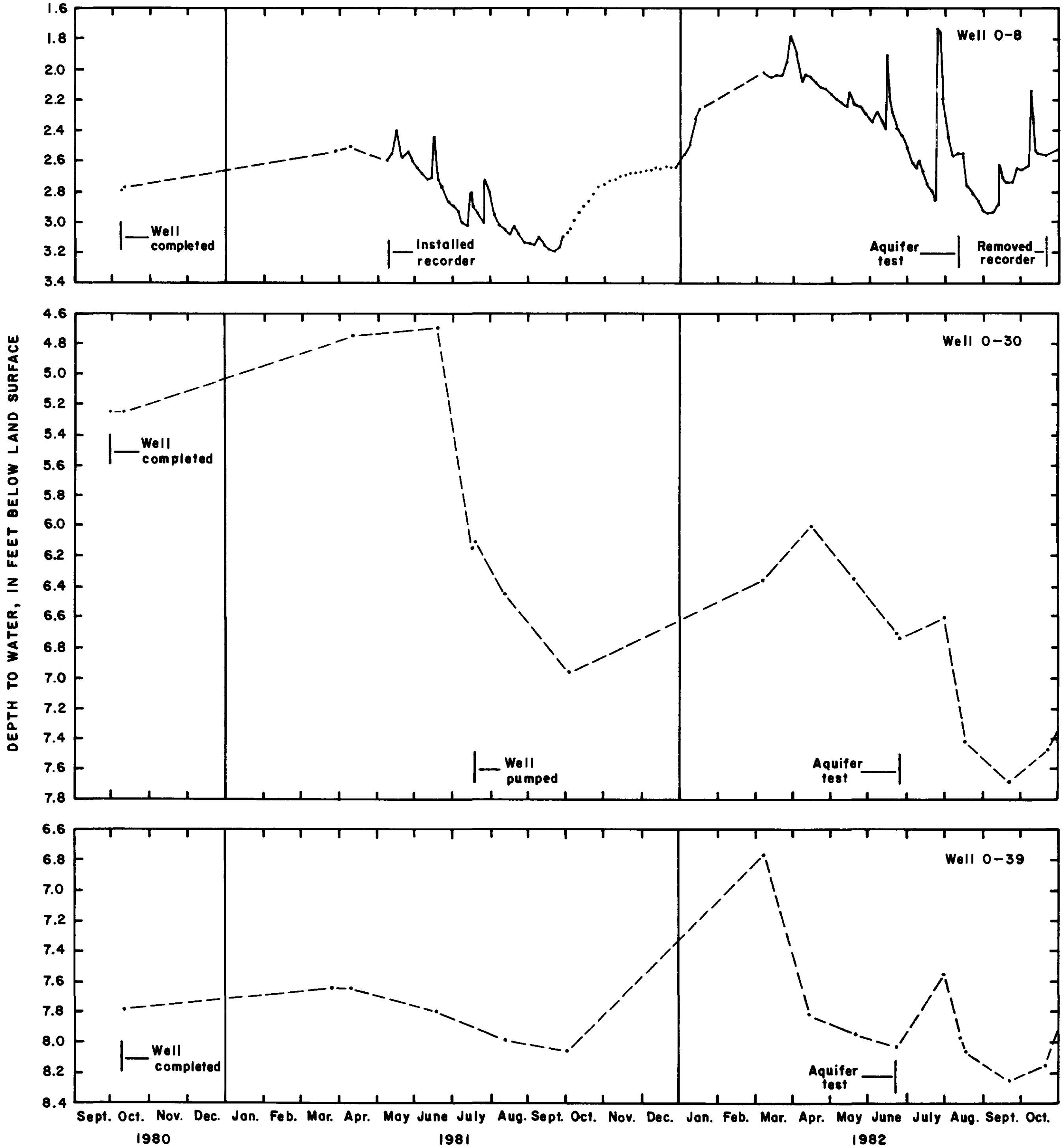

Figure 11.--Water-level fluctuations from September 1980 through October 1982 in observation wells completed in alluvium along the Little Bear Creek and Davidson Draw valleys.

the level declined rapidly to 2.6 feet by early August, and to 2.95 feet, the low for the year, in early September. Several rainstorms in September occurred about the same time as the end of the growing season, and water levels began to rise; the general rising trend continued through October.

The water levels of wells 0-9 and 0-10 were measured periodically. In 1981, the water level in well 0-9 fluctuated about 0.8 foot and in well 0-10 it fluctuated about 0.5 foot. In 1982, the water-level fluctuation was about 1.2 for well 0-9 and 1.0 foot for well 0-10.

Along Davidson Draw water-level measurements at the two well lines were made periodically during the study. From the plots of these measurements, the water level across well line 0-28 to 0-30 rose from October 1980 to mid-June 1981, then declined rapidly in July after the spring rains ended (represented by well 0-30 in fig. 11). The level continued to decline until early October 1981, then rose through the winter until April 1982. From April to late September 1982, the water levels declined, except during and after the severe late-July rainstorm. Well 0-30, on a low terrace above the flood plain near the middle of the valley, had a water-level fluctuation of about 2.3 feet in 1981 and about 1.7 feet in 1982; the level was about 1 foot lower throughout 1982.

Downstream, in the narrower part of the valley, the water levels showed different trends in well line 0-39 to 0-40. From October 1980 through most of 1981, the water level fluctuated about 0.5 foot, and began its decline in late March 1981 (represented by well 0-39 in fig. 11). In contrast to the plot of water levels upstream at well line 0-28 to 0-30, water-level fluctuations across well line 0-39 to 0-40 were more active in 1982. The high in early March declined about 1 foot by mid-April, then declined another 0.5 foot by late September, except for the rise during and after the late July 1982 rainstorm. The total fluctuation at well 0-39 was 1.6 feet in 1982. Across well line 0-39 to 0-40, the lowest water levels were only 0.2 foot lower in 1982 than in 1981, but the highest level, in early March 1982, was nearly 1 foot higher than the 1981 level.

Quality of water

The alluvial water in the Little Bear Creek basin was predominantly a sodium-magnesium sulfate type (fig. 12). Generally, the sulfate concentrations greatly exceeded the 250-mg/L concentration recommended by the U.S. Environmental Protection Agency (1979) for human consumption, but the sodium-adsorption ratio was small enough for the water to be used for irrigation. Except at a few localities, the water was acceptable for stock watering.

Along the Little Bear Creek valley, the chemical composition of the water in the alluvial aquifer changes as the lithology along the sides of the valleys changes. At well line 0-26 to 0-27 in the upstream part of the valley, which drains the upper part of Tongue River Member, the water had a dissolved-solids concentration of about 3,400 mg/L and was a magnesium-sodium sulfate type. There (well 0-27), the concentrations were 2,100 mg/L of sulfate, 280 mg/L of magnesium, and 480 mg/L of sodium. Calcium and bicarbonate concentrations were relatively moderate, and concentrations of potassium, chloride, and silica were small. The fluoride concentration was 1.0 mg/L, which is nearly typical of the alluvial aquifer water throughout the basin. The pH was slightly alkaline at 7.4, the hardness was 1,600 mg/L, and the sodium-adsorption ratio was small at 5.2.

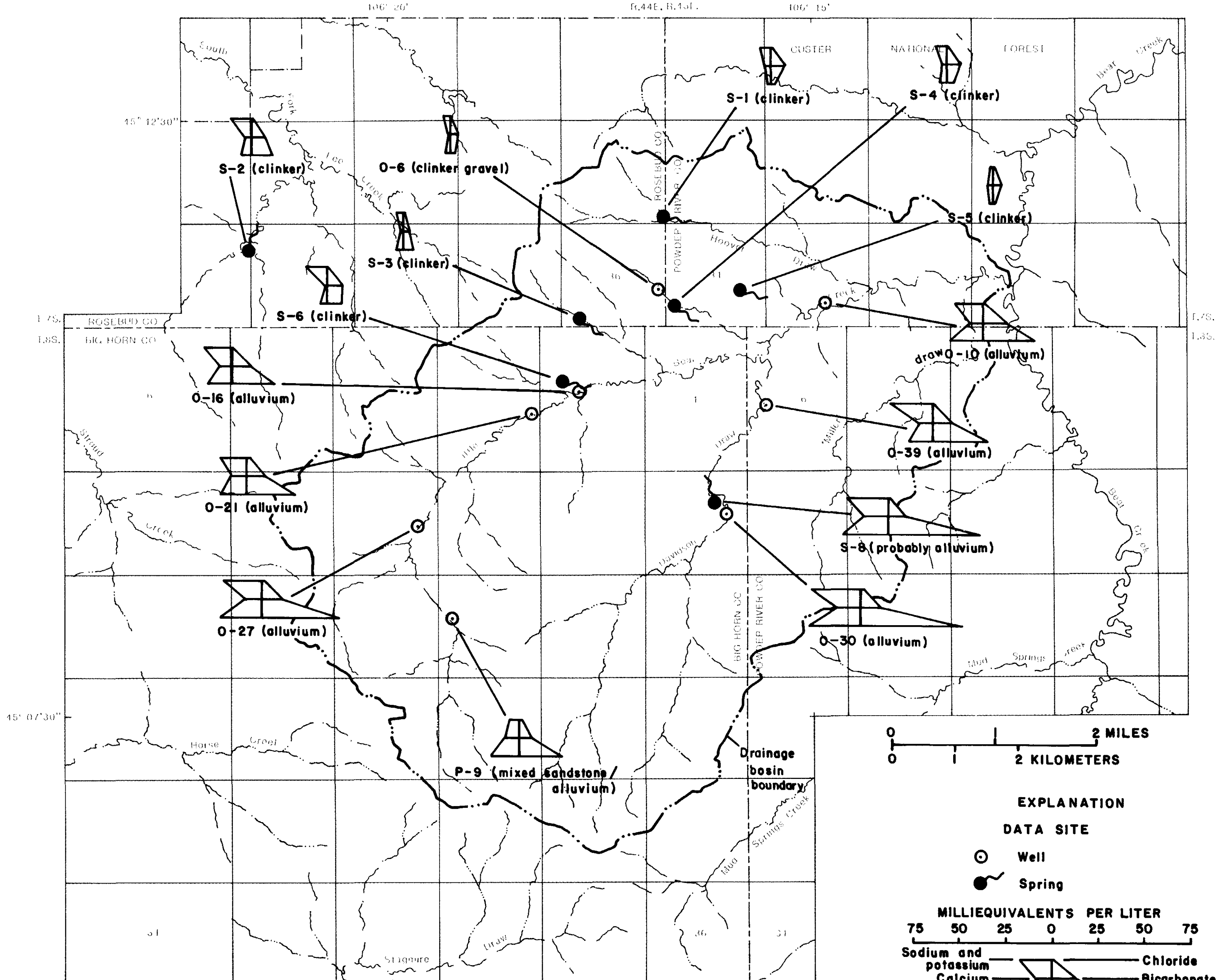

Figure 12.--Chemical-constituent diagrams for water from alluvium and clinker in and near the Little Bear Creek area.

Downstream, at well line 0-20 to 0-23, where the sides of the valleys are near the uppermost extent of the burned Anderson coal clinker layers, the water in the alluvial aquifer improved in quality. There, the dissolved-solids concentration ranged from 2,070 mg/L in well 0-23 on the north side of the valley to 2,310 mg/L in well 0-20 on the south side. In the center of the valley, which transmits most of the water past the well line, the water from wells 0-21 and 0-22 had an average dissolved-solids concentration of about 2,230 mg/L. The water was a sodium-magnesium sulfate type, with an average concentration of 325 mg/L sodium, 170 mg/L magnesium and 1,250 mg/L sulfate. The fluoride concentrations decreased slightly from the upstream well line (0-26 to 0-27) to 0.5 mg/L at wells 0-21 and 0-22. The pH was slightly alkaline at about 7.5; the hardness was about 1,100 mg/L; and the sodium-adsorption ratio was about 4.3.

Well line 0-14 to 0-19 is only 0.5 mile downstream from line 0-20 to 0-23, but it receives water from an expanded area of Anderson clinker, which indirectly and directly supplies the alluvial aquifer with less concentrated water from clinker, springs, and seeps. The average dissolved-solids concentration of six wells (five wells in the line and well 0-18) was about 2,130 mg/L; the concentrations ranged from 2,020 mg/L in well 0-15 in the south-central part of the line to 2,200 mg/L in well 0-19 at the north end. Water from all the wells was a sodium-magnesium sulfate type (fig. 12). Average concentrations were 340 mg/L of sodium, 150 mg/L of magnesium, and about 1,200 mg/L of sulfate. The fluoride concentration was slightly greater than upstream or downstream; it averaged about 1.0 mg/L. The hardness was slightly smaller than upstream or downstream, with an average of about 940 mg/L. As upstream and downstream, the pH remained in the slightly alkaline range--a median of about 7.3--and the sodium-adsorption ratio remained small--an average of about 4.9. Approximate average concentrations of calcium (130 mg/L), potassium (7.0 mg/L), chloride (9.6 mg/L), and silica (19 mg/L) generally were similar to those of most other alluvial water in the Little Bear Creek basin.

Across well line 0-8 to 0-10, the farthest downstream line in the basin, the dissolved-solids concentration decreased from the south side to the north side; also there was a substantial increase in concentrations compared to those from well line 0-14 to 0-19, 2.6 miles upstream. The probable reasons for the greater concentration of minerals downstream are the decreased contribution of clinker water as the Little Bear Creek valley is eroded deeper into shale, siltstone, and sandstone of the middle part of the Tongue River Member, and the contribution of more minerally concentrated water from the Davidson Draw drainage. At well 0-8, which yielded the least water from the alluvial aquifer, the water had the largest concentration of minerals--3,620 mg/L of dissolved solids. At well 0-10, which had the largest yield, the concentration of minerals was smallest--2,600 mg/L of dissolved solids. The water was mostly a sodium-magnesium sulfate type, except along the north edge of the alluvial valley (well 0-10) where the magnesium concentration was larger relative to the other constituents and a magnesium-sodium sulfate type water existed.

The increase in dissolved solids at well line 0-8 to 0-10 was caused by an increase in all constituents except fluoride, which was present in a relatively small concentration of about 0.8 mg/L, and silica, which remained at about 19 mg/L. Because most of the water passed the well line on the north side of the valley, the average concentration of the constituents would be less than the average of the samples from the three wells; considering the total volume of water the average concentrations probably would be more similar to the concentrations in the water from well 0-10.

The most mineralized water from alluvial sources in the Little Bear Creek basin, and from the existing alluvial-well network, was found in well 0-28 (well line 0-28 to 0-30) in the Davidson Draw drainage. Well 0-28 obtained its water from the east side of the valley, partly from alluvial sand and gravel and partly from the Anderson coal aquifer, which at this locality is weathered to very soft coal. Wells drilled at similar sites, where alluvial sand and gravel overlie soft, weathered coal, also probably would yield greatly mineralized water. Water from well 0-28 had a dissolved-solids concentration of 10,100 mg/L, with 6,400 mg/L of sulfate and 2,300 mg/L of sodium; the water was a sodium sulfate type. The other constituents also had relatively large concentrations: 300 mg/L of calcium, 580 mg/L of magnesium, 1,070 mg/L of bicarbonate, and 3,100 mg/L of hardness. Even the fluoride concentration was greater than in the other wells of the line--1.8 mg/L in well 0-28, versus an average of 0.8 mg/L for the two wells to the west.

Well 0-30, the westernmost of the wells in the line, had the largest hydraulic conductivity (300 ft/d) so it probably has water most typical of that passing well line 0-28 to 0-30. There, the water was a sodium-magnesium sulfate type (fig. 12), with 640 mg/L of sodium, 320 mg/L of magnesium, and 2,700 mg/L of sulfate; the dissolved-solids concentration was 4,270 mg/L. The relative concentrations of the other constituents were typical for alluvial waters from the Little Bear Creek basin.

Downstream in Davidson Draw, the water from wells 0-39 to 0-40 was similar, despite the dissimilarity of the hydraulic conductivities of the two wells. The water was a sodium sulfate type, with an average of 2,760 mg/L of dissolved solids. The apparent reason that the water had much smaller concentration of minerals at these two wells compared to wells in line 0-28 to 0-30 upvalley is the broad area of Anderson clinker west of the valley, which supplies water subterraneously to the Davidson Draw valley. There are two main differences between water from well 0-39, which is completed in a fairly permeable alluvial aquifer (hydraulic conductivity of 15 ft/d), and water from well 0-40, which is completed in rather impermeable sand and gravel (hydraulic conductivity of 0.1 ft/d)--the bicarbonate and sulfate concentrations. The bicarbonate concentration was 687 mg/L in well 0-39 and 1,030 mg/L in well 0-40, and the sulfate concentration was 1,500 mg/L in well 0-39 and 1,400 mg/L in well 0-40. The other constituents in the waters from the two wells were very similar, with calcium averaging 120 mg/L, magnesium 145 mg/L, potassium 7.6 mg/L, chloride 18 mg/L, and silica 12 mg/L. The fluoride concentration was 1.4 mg/L in well 0-39 (rather large for alluvial aquifers in southeastern Montana) and 0.9 mg/L in well 0-40.

Surface-water resources

Stock ponds

From 1:24,000-scale topographic maps, 29 stock ponds were counted within the Little Bear Creek basin; not all ponds were visited. Most of the ponds receive water from snowmelt or rainstorms in the spring and summer; many of the ponds are dry by fall. Some ponds receive water from springs or seeps and hold water all year, except during droughts; seven of these ponds are designated on plate 1.

The dam for stock pond SP-1 is located across Little Bear Creek downstream from well line 0-14 to 0-19. The surface of this pond fluctuates with the level of the alluvial water table; thus, it is higher in the mornings than evenings and higher during the spring than during late summer. The pond was observed to have no water in August and September 1982, but water was available about 1 foot below the pond bottom at that time; the pond began to refill in October 1982.

Pond SP-2 receives water from "Tanner" spring (S-6), which derives its water from Anderson clinker on the west side of the pond (pl. 1). Anderson clinker north (upstream) and east of the pond also probably is supplying water to the pond subterraneously. During the study (1980-82), pond SP-2 was full and overflowing directly to the Little Bear Creek channel at well line O-14 to O-19, except in August and early September 1982 when spring S-6 ceased to flow. Even during this dry period, however, the water level in the pond remained high, about 1 foot or less below the overflow channel.

Stock pond SP-3 is located in a small northwest-side tributary to Little Bear Creek. The pond receives water from a spring apparently issuing from a sandstone bed from 50 to 80 feet above the Anderson coal bed. The spring was not flowing when the site was visited in the summer of 1980, but the pond was full, and it maintained water during most of the study.

Pond SP-4 was visited late in 1982 and found to be about one-half full of water; it apparently receives water from a sandstone bed 30 to 50 feet above the Anderson coal bed; no coal bed was apparent upvalley from the pond.

Pond SP-5 is in the upstream reaches of the Little Bear Creek drainage, about 0.6 mile upvalley from well O-36. The pond derives its water from a sandstone layer, as much as 40 feet thick, about 270 feet above the Anderson coal bed; this may be the same sandstone bed that contributes water to well P-10. The pond was visited in early summer 1981 and found to be nearly full; the level probably declined during the summer. No springs were observed near the upstream tributaries above the pond, but water probably seeps from the sandstone bed to the pond beneath the surface.

Ponds SP-6 and SP-7 are in separate tributaries of Davidson Draw at about the same topographic altitude (about 3,900 feet) and stratigraphic horizon (100 to 130 feet above the Anderson coal bed). The ponds receive water from a 30-foot sandstone bed at this horizon. During the study, pond SP-7, which was most often observed, was about one-half full in the spring and about one-quarter full in the early fall. On the topographic quadrangle map a spring is shown upstream from pond SP-7; no spring was found flowing at the surface during the study, but water probably seeps under the surface to maintain water in ponds SP-6 and SP-7.

Little Bear Creek

In the upstream reaches of Little Bear Creek and its tributaries, the channel has ephemeral flow during most seasons of most years. Flow has been observed for about 0.2 mile downstream from spring S-7 near an old homestead; farther downstream there is no flow except after spring snowmelt or summer rainstorms. From about 0.3 to 0.5 mile upstream from well line O-20 to O-23 and from 0.35 to 0.2 mile upstream from well line O-14 to O-19, the channel of Little Bear Creek has been obliterated by the landowner. The flood plain has been leveled and the stream channel filled in to allow the water from the stream, when it flows, to spread across the flood plain and irrigate crops and to allow easier access of machinery onto the fields.

The channel of Little Bear Creek resumes upstream from well line 0-14 to 0-19 and contains water in a broad (about 20 feet wide), reed-choked channel downstream to pond SP-1. In late summer 1982, the water table in the alluvial aquifer declined below the level of the stream channel, so the channel was dry for a month or two. Interrupted flow continues at places between pond SP-1 and the confluence with Davidson Draw, and on downstream beyond well line 0-8 to 0-10. The farthest downstream mile or so of Little Bear Creek to its confluence with Bear Creek usually is dry, except for periods of runoff from snowmelt or summer rainstorms.

Because there are no streamflow gaging stations on Little Bear Creek, an estimate of the mean annual discharge from the basin was calculated by the regional prediction equations developed by Omang and others (1983). The equations were developed through regression analysis of streamflow and dimensions and gradients of the channels of the streams. For the Little Bear Creek basin, the discharge at the mouth with Bear Creek is estimated at about 2,700 acre-feet during a year of average rainfall. During 1981 and 1982, the rainfall was less than average; the annual volume of water reaching Bear Creek was probably less than 2,500 acre-feet. Using the same regional prediction equations, the estimated annual discharge from the Little Bear Creek basin upstream from the confluence with Davidson Draw is about 1,500 acre-feet.

Regional prediction equations also were used to estimate the probable peak-flow runoff. For runoff, the equations developed by Parrett and Omang (1981) were applied. The equations were developed from multiple-regression analyses of streamflow and basin-characteristic data. In the study area, basin characteristics that were significant are the area of the stream basin, the topography of the basin, and the area of forest cover. The equations indicate that the maximum instantaneous flow in Little Bear Creek at the mouth of Davidson Draw and at the mouth of Little Bear Creek, respectively, would be about 130 and 200 ft^3/s once every 2 years, about 500 and 800 ft^3/s once every 10 years, and about 1,700 and 2,400 ft^3/s once every 100 years. During this study, no floods were observed or measured by indirect methods in the Little Bear Creek channel, but the July 24, 1982, flood probably ranked between the 10- and 100-year flood categories.

Davidson Draw

Davidson Draw contains no water from the upstream reaches to well line 0-28 to 0-30, except during periods of runoff from spring snowmelt and summer rainstorms. From spring S-8, 0.1 mile downstream from well line 0-28 to 0-30, the channel of Davidson Draw has interrupted flow most of the year for about 0.4 mile downstream. The flow is started by spring S-8 and other seeps of the alluvial aquifer coinciding with the surface channel, and is maintained intermittently by other seeps originating in the broad Anderson clinker layer on the west side of the valley. From about 0.2 mile upstream from well line 0-39 to 0-40, the alluvium is thicker and all the flow farther downvalley to the mouth is beneath the surface.

Using the regional prediction equations developed by Omang and others (1983), the mean annual discharge from the Davidson Draw basin, for the ungaged site near the mouth of the draw, is estimated to be about 700 acre-feet during a year of average rainfall. Discharge probably was less than 700 acre-feet during 1981 and 1982. The probable peak-flow runoff, as determined by the equations of Parrett and Omang (1981), is estimated to be about 80 ft^3/s once every 2 years, about 300 ft^3/s once every 10 years, and about 1,100 ft^3/s once every 100 years. Although it was not directly observed, the flood of July 24, 1982, probably had less runoff than estimated for a 10-year flood, because the most severe part of the storm passed north of Davidson Draw drainage.

Hoover and "Miller" Draws

Hoover Draw usually has a dry channel for most of its 3.4-mile length, except for a few seeps existing near the Hoover ranch house and two or three other locations downstream. These seeps are points where the alluvial aquifer water was at the level of the stream channel, and usually extended less than 100 feet downstream. No flow or seeps were observed along "Miller" draw, but the downstream 1 mile was not visited. Both streams would have runoff after a sudden spring thaw from snowmelt or after severe summer rainstorms.

Springs

Springs and seeps exist throughout the Little Bear Creek basin, but most seeps have little or no flow at the surface. Nine of the 10 springs designated on plate 2 are developed and have access for water-quality sampling; two of these springs are outside the Little Bear Creek basin. Most of the springs located within the basin are in the northern one-half of the area, and many are directly or indirectly related to the Anderson clinker layer. Spring names identified by quotes are informal designations as used by local ranchers or as assigned for identification in this report.

Spring S-1 ("Hoover" spring) is located in a small valley tributary to Hoover Creek, just east of the Hoover ranch house. The original spring received water from the clinker and slag rock of burned Anderson coal on the eastern hillside. Later, a small stock pond was constructed upstream from the spring outlet, with the intention of protecting the pipe and tile conduits from flooding. The dam and spillway on the western hillside fulfilled this purpose, but also retained water which increased the later summer flow of the spring. The spring is used for livestock watering.

Spring S-2 ("Wilcox" spring) issues directly from burned Anderson coal slag and clinker east of the Wilcox ranch house on a tributary of South Fork Lee Creek, about 2 miles outside and northwest of the Little Bear Creek basin. This spring has a perennial flow of about 5 gal/min, which is reported by the rancher to vary little from season to season or year to year. The spring was developed by clearing the rubble along the base of the clinker and driving pipes farther into the aquifer. The spring is used for domestic supply at the ranch house.

Spring S-3 (Little Bear Creek Spring) is located on a north-side tributary of Little Bear Creek and also issues from the base of the Anderson coal clinker layer. Seeps from the clinker layer exist on both sides of the valley, and upstream. The spring, located on the southwest side of the valley, was developed by digging a ditch along the base of the clinker northwestward, laying tile in the ditch, and then piping the water by gravity from the tile to a stock trough. This spring was reported by the ranchers to be perennial, but had almost no flow in July 1982. The spring is used for livestock watering.

Spring S-4 ("Dynamite Dugout" spring) is in another north-side tributary of Little Bear Creek near wells O-5 and O-6. At the stock trough in the valley, the base of the Anderson coal clinker is on the hillside about 50 feet above the level of the spring. The spring is actually along a trench dug at the base of the clinker on the southwest side of the valley about 400 feet west of the watering trough. The flow from the spring is reported to be seasonal; the flow, when the spring was sampled in August 1982, was only 0.07 gal/min. The spring is used for livestock watering.

Spring S-5 (Handley Spring) is located in a small tributary valley northwest of Little Bear Creek, and just below the ridge between Little Bear Creek and Hoover Draw; the ridge is capped by the Anderson clinker layer. The outlet pipe of the developed spring is about 50 feet lower than the base of the Anderson clinker, but there is evidence that a ditch extends up the steep valley to the clinker, about 300 feet to the northwest. Spring S-5 is reported to have perennial flow; it was sampled in June 1980, when the flow was 0.6 gal/min. The spring is used for livestock watering.

Spring S-6 ("Tanner" spring) is located at stock pond SP-2, on a small north-side tributary of Little Bear Creek, just northwest of well line O-14 to O-19. An old homestead log cabin stands on the divide to the west, which is underlain by Anderson clinker, and more recent corral, sheds, and animal-dipping apparatus are located on the northwest shore of the pond. The developed spring has an elaborate system of a settling pond and watering troughs, and an overflow directly into the pond. The pipe reaching the troughs was driven or trenched to the base of the clinker layer under the divide to the west. The spring was inventoried in November 1973 when the flow from the outlet pipe was 11 gal/min. A sample was collected in June 1980 to determine the water quality when the flow from the pipe was only 3 gal/min, but the pipe had numerous leaks and water was bypassing the outlet, so a comparison of discharges is not appropriate. In July 1982, the spring was yielding very little water; pond SP-2 was also down to a level of about 1 foot below the overflow channel at that time. The discharge from spring S-6, although usually perennial, is variable between 0 and about 11 gal/min. The spring was used for livestock watering in the 1980's, but was used for domestic supplies in the 1920's and 1930's.

Spring S-7 ("Homestead" spring) is an undeveloped alluvial spring in the upstream reaches of the Little Bear Creek channel. The probable source of the water, in addition to the alluvial aquifer, is a sandstone bed between about 120 and 150 feet above the Anderson coal bed.

Spring S-8 ("Middle Davidson Draw" spring) is located about 1.6 miles upstream from the mouth of Davidson Draw, about 0.1 mile northwest of well line O-28 to O-30. The spring is developed, with an outlet pipe discharging into a stock trough, but the type of construction and source of water are not known. The pipe and trough are situated on the east bank of an oxbow in Davidson Draw channel; the present channel is east and north of the spring site. A fault, trending east-northeast across the valley and upthrown about 80 feet on the north side, is very close to the site of the spring. It is not known if the fault and the spring are interrelated, or just coincident. The spring was inventoried in February 1974 when the flow was 7 gal/ min, and sampled for chemical analysis in June 1980 when the flow was 5.5 gal/min. An additional sample was collected in June 1982 to determine changes in water quality; at that time the flow had decreased to 4 gal/min. The chemical constituents in the water indicate an alluvial source of the water. The spring is used for livestock watering.

Spring S-9 (Mud Springs) is located in Mud Springs Creek, a tributary of Bear Creek southeast of the Little Bear Creek basin. The spring apparently issues from a sandstone bed about 80 feet down-section from the Roland coal bed and near the level of the Waddle coal bed of Culbertson and Klett (1979a). The spring was discharging at a rate of about 1 gal/min when it was inventoried in February 1974. It is used for livestock watering.

Spring S-10 ("Lower Davidson Draw" spring) is located on the south bank of Little Bear Creek where the Davidson Draw valley joins the Little Bear Creek valley. A 4-inch steel pipe emerges from the bank from the direction of the Davidson Draw valley. The source of the water is not known, but from the concentration of the constituents, particularly sodium, magnesium, and sulfate, the source apparently is a weathered Canyon coal bed. The discharge was about 10 gal/min when inventoried in June 1980 and 3.4 gal/min when the spring was sampled in October 1982. The spring water flows directly into the Little Bear Creek channel for use by livestock downstream.

Quality of water

Only sample SW-1 near the well line O-8 to O-10 was collected from Little Bear Creek for chemical analysis (table 10). The sample was collected in August 1982, during low-flow stage of the stream. At this locality the stream has perennial flow, except during the driest years. Upstream and downstream, Little Bear Creek has interrupted flow, so the flow at station SW-1 is water from the alluvial aquifer where the water table has reached the level of the stream channel. The chemical quality of the sample was intermediate between that from well O-9 and well O-10. The dissolved-solids concentration was 2,880 mg/L, and the water was a sodium-magnesium sulfate type. The only significant difference between the surface water and ground water at this locality was that calcium and bicarbonate concentrations were smaller in the surface water; correspondingly, the surface water was less hard--1,200 mg/L compared to the 1,500-mg/L average for the three well waters at O-8, O-9, and O-10.

Water from the springs in the Little Bear Creek area and nearby areas is actually ground water emerging at land surface. Springs S-1, S-2, S-3, S-4, S-5, and S-6 issue from the burned Anderson coal bed clinker layers. This water, generally, has the best quality in the area; that is, the water has the smallest concentration of dissolved solids (table 10). Spring S-5 contained the least mineralized water; the dissolved-solids concentration was 390 mg/L in the sample collected in June 1980. The water was a calcium-magnesium bicarbonate type and was relatively soft (hardness of 230 mg/L). The sulfate concentration was only 92 mg/L and the fluoride was a small 0.6 mg/L. This water is potable for human and livestock consumption.

The dissolved-solids concentrations in water from the other springs issuing from the Anderson clinker layer are about double those from spring S-5. Springs S-1, S-3, and S-4 had dissolved-solids concentrations between 567 and 701 mg/L. Spring S-1 had a sodium bicarbonate type water with relatively small concentration of sulfate--110 mg/L. Spring S-3 had a sodium-magnesium sulfate type water and spring S-4 had a sodium magnesium bicarbonate type, with a moderate concentration of sulfate--210 mg/L. The three springs had water with relatively small hardness, ranging from 240 mg/L in S-3 to 320 mg/L in S-4.

Two springs issuing from the Anderson clinker layers, S-2 and S-6, had concentrations of dissolved solids of more than 1,000 mg/L--1,210 mg/L at S-2 and 1,080 mg/L at S-6. Spring S-2 had water of a sodium sulfate type with large concentrations of bicarbonate--522 mg/L; and spring S-6 had water of a sodium sulfate-bicarbonate type. The two springs had water with relatively small hardness--440 mg/L in S-2 and 270 mg/L in S-6.

In most of the spring water from the Anderson clinker layer, the fluoride concentration was relatively small--1.0 mg/L or less. For a reason not explainable by geographic or stratigraphic setting, fluoride concentration in the waters from springs S-4 and S-6 were much larger--2.3 mg/L at S-4 and 2.8 mg/L at S-6; these values exceeded the standards established by the U.S. Environmental Protection Agency (1977) for human consumption.

The water from spring S-10 probably is from the Canyon coal aquifer, which at this locality is partly weathered. The water was a sodium-magnesium sulfate type, but had much larger concentrations of individual constituents than water from most other springs. The dissolved-solids concentration was 3,380 mg/L, sodium was 550 mg/L, sulfate was 2,000 mg/L, and the hardness was 1,500 mg/L. The fluoride concentration was a relatively small 0.6 mg/L in the sample collected in October 1982.

Water from spring S-9 probably is from a sandstone aquifer near the top of Tongue River Member stratigraphic section. This water also was a sodium-magnesium sulfate type. The concentration of sodium was 410 mg/L, magnesium was 200 mg/L, sulfate was 1,300 mg/L, and the hardness was a relatively small 810 mg/L for sandstone aquifers.

Samples were collected from spring S-8 in February 1974, June 1980, and June 1982. As the discharge from the spring decreased from 7 gal/min in February 1974 to 4 gal/min in June 1982, the dissolved-solids concentration increased from 2,920 to 3,880 mg/L. The water in spring S-8 is assumed to be from alluvial sources, but there also may be another source. The alluvial aquifer across well line O-28 to O-30, about 700 feet to the southeast of the spring (excluding the large dissolved-solids water of well O-28), had an average dissolved-solids concentration of 4,320 mg/L compared with the 3,880 mg/L from the spring in June 1982. The alluvial well water was of the sodium-magnesium sulfate type and the spring water was a magnesium-sodium sulfate type. Most of the constituents were relatively larger in the water from the wells, except the calcium and magnesium concentrations, which were larger in the spring water.

SUMMARY

A study of the Little Bear Creek basin, located about 27 miles south of Ashland, Montana, was conducted from 1980 through 1982 to describe the existing hydrologic systems and to assess the potential effects of surface coal mining on local water resources. At the present time (1983), water in the basin is available from wells, springs, stock ponds, and several reaches of stream channels. The water is used for domestic supply at one ranch house and for livestock consumption throughout the basin. Information for the study was obtained from 34 test holes, 43 observation wells, 12 private domestic and stock wells, 10 springs, 7 stock ponds, and 1 streamflow site.

The Little Bear Creek drainage basin, with an area of 29.2 mi^2, is comprised of the main stem of Little Bear Creek, its main tributary Davidson Draw, and two other tributaries, Hoover Draw joining the main stem from the north side and "Miller" draw joining from the south side near the mouth. Little Bear Creek joins Bear Creek at the northeast end of the basin; Bear Creek is a tributary of Otter Creek, which, in turn, is a major tributary of the Tongue River. Flow in Little Bear Creek is ephemeral during most seasons of most years. Many of the stock ponds are dry by fall, although some maintain water all year. Almost one-half of the springs inventoried had perennial flow.

Little Bear Creek basin is eroded into the upper part of the Tongue River Member of the Fort Union Formation (Paleocene age). The exposed section of the Tongue River Member is 800 feet thick and is composed of alternating layers of shale, sandstone, and coal. Overlying the Tongue River Member, along the southwestern and southern divides of the basin, is the Wasatch Formation. Underlying the basin is about 1,100 feet of Tongue River Member, about 380 feet of the Lebo Shale Member, and 580 feet of the Tullock Member of the Fort Union Formation. The strata generally dip southwestward across Little Bear Creek basin, but are broken by a series of east-trending faults, with southside downthrown, in the southeastern and southern parts of the basin.

Ground water in the area is supplied from sandstone and coal beds of the Tongue River Member throughout the basin and from alluvial sand and gravel aquifers along the main stream valleys. The named coal beds in the Little Bear Creek stratigraphic section, from bottom to top, are: the Cook/Otter beds, Canyon bed, Dietz bed, Anderson bed, Smith bed, and Roland bed. Water-bearing sandstone beds and lenses exist between each of the coal beds. Water also is available in the basal parts of clinker layers. Most of the clinker is burned Anderson coal and its scorched overburden in the northern and central parts of the basin, and burned Dietz and Canyon coals in the northeastern part.

The general hydrologic characteristics of each of the aquifers in the Little Bear Creek area are as described below:

1. Cook/Otter coal beds: 17 to 22 feet thick, one coal bed to the northeast, splitting into separate coal beds to the west and south, with a hydraulic conductivity of about 1.2 ft/d (based on an aquifer test at one well); capable of yielding about 5 gal/min of sodium bicarbonate type water having about 1,750 mg/L of dissolved solids and 3.2 mg/L of fluoride.

2. Canyon coal bed: 23 to 31 feet thick, mostly massive coal, with a hydraulic conductivity of about 1.4 ft/d; capable of yielding about 7 to 10 gal/min of sodium bicarbonate type water having between 1,500 and 1,870 mg/L of dissolved solids and between 2.8 and 5.1 mg/L of fluoride.

3. Dietz coal bed: 11 to 16 feet thick, mostly massive coal, with a hydraulic conductivity of about 0.5 ft/d; capable of yielding 0.2 to 5 gal/min of sodium bicarbonate or sodium sulfate type water having between 1,750 and 3,220 mg/L dissolved solids and between 1.3 and 3.7 mg/L of fluoride.

4. Anderson coal bed: 31 to 34 feet thick, mostly massive coal, with a hydraulic conductivity of about 0.2 ft/d; capable of yielding 0.3 to 4.4 gal/min of sodium bicarbonate or sodium sulfate type water, and having greatly varying dissolved-solids concentrations (between 2,360 and 5,550 mg/L) and between 0.6 and 3.1 mg/L of fluoride.

5. Sandstone beds from above the Canyon coal to above the Anderson coal: About 2 to 35 feet thick, always thickening or thinning laterally, with hydraulic conductivities of between 0.1 and 1.2 ft/d (mean about 0.5 ft/d); capable of yielding between 0.8 and 5 gal/min of variable water types--from sodium bicarbonate to magnesium sulfate--with a considerable range of dissolved-solids concentrations (from 1,070 to 4,080 mg/L) and varying fluoride concentrations (from 0.5 to 4.1 mg/L).

6. Alluvial sand and gravel: Saturated thickness of contributing permeable layers differs along the valleys, and changes seasonally and between wet and dry years. These changes affect the transmissivity, and probably the quality of water during the different seasons.

   a. Well line 0-26 to 0-27: Contributing thickness 2 to 4 feet at high water levels, 0.5 to 3.5 feet at low water levels, having a mean hydraulic conductivity of about 100 ft/d; yields about 2 gal/min of magnesium-sodium sulfate type water having 3,260 to 3,440 mg/L of dissolved solids.

   b. Well line 0-20 to 0-23: Contributing alluvial sand and gravel thickness 2 to 4.5 feet at high water levels, 1 to 3.5 feet at low levels (plus 3 to 7 feet of coal aquifer), having a mean hydraulic conductivity of about 12 ft/d; yields about 4 gal/min of sodium-magnesium sulfate type water having 2,070 to 2,310 mg/L of dissolved solids.

   c. Well line 0-14 to 0-19: Contributing thickness 2 to 3.5 feet at higher and lower water levels, having a mean hydraulic conductivity of about 300 ft/d; yields about 10 to 20 gal/min of sodium-magnesium sulfate type water having 2,020 to 2,200 mg/L of dissolved solids.

   d. Well line 0-8 to 0-10: Contributing thickness about 6 feet at higher and lower water levels, having a mean hydraulic conductivity of about 60 ft/d; yields about 6 gal/min of sodium-magnesium sulfate type water having 2,600 to 3,620 mg/L of dissolved solids.

   e. Well line 0-28 to 0-30: Contributing thickness 3.5 to 4 feet at higher water levels, 1.5 to 3 feet at lower levels, having a hydraulic conductivity of about 5 ft/d on the east side of the valley and 350 ft/d on the west side; yields about 4 gal/min of sodium sulfate or sodium-magnesium sulfate type water having 4,270 to 10,100 mg/L of dissolved solids.

   f. Well line 0-39 to 0-40: Contributing thickness 3.5 to 5 feet at higher water levels, 3 to 4 feet at lower levels, having a hydraulic conductivity of about 0.1 to 15 ft/d; yields about 2 gal/min of sodium sulfate type water having 2,710 to 2,800 mg/L of dissolved solids.

To predict the probable effects of surface coal mining on the hydrologic system in the Little Bear Creek area, a mine outline was assumed. The potential mine, when completed, would have an area of about 6.7 mi^2 and would remove about 235 million tons of Anderson coal and about 95 million tons of Dietz coal. Mining probably would start along Little Bear Creek just west of the Anderson burn area, about 5.2 miles upstream from the mouth, and move northward and southeastward; a second mine could be started at about the same time along Davidson Draw and expand westward and eastward.

The potential mine would destroy one stock well (P-8) and several stock ponds in the mined area. Springs, except for the possible exception of spring S-8 in Davidson Draw, would not be affected by mining. The mining would remove the alluvial aquifer along Little Bear Creek from 5.2 to 6.7 miles upstream from the mouth, and along Davidson Draw from 1.8 to 3.4 miles upstream from the mouth, as well as sandstone and coal aquifers above the mine floor. Along the highwall to the west, southwest, and south, the mine would lower the water levels in the sandstone and coal aquifers. Outside of the mined area, no existing stock wells would be affected by the lowered water table. Water moving through the replaced mine spoils would acquire a chemical quality dependent on the mineralogy of the spoils material.

To mitigate the effects of mining on the aquifers of the Little Bear Creek area, the alluvial aquifer theoretically could be reconstructed by laying a base of clayey, nearly impermeable spoils. The spoils would be overlain by stockpiled sand and gravel below and mud above; this material could then be covered by topsoil. The structuring of the spoils away from the Little Bear Creek and Davidson Draw valley flats could be completed in such a manner to allow a minimum of water to flow through and out of the mined area. The destroyed stock well and stock ponds could be replaced at or near their present sites. The destroyed stock well could be replaced by drilling to the same sandstone it presently obtains water from, or the well could be deepened to near the top of the Canyon coal bed, which is about 320 feet below the present land surface.

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SUPPLEMENTAL INFORMATION

Table 1.--*Construction and hydrologic data for private wells in and near the Little Bear Creek area*

[Abbreviations: microsiemens, microsiemens per centimeter at 25° Celsius, P, PVC plastic; R, reported; RK, rock wall; S, steel; TRM, Tongue River Member of Fort Union Formation]

Well No. (pl. 1)	Owner	Location	Date drilled (month-year)	Altitude of land surface (feet above sea level)	Well depth (feet below land surface)	Aquifer material	Depth to top of aquifer (feet below land surface)	Aquifer thickness (feet)	Casing diameter (inches) and kind	Casing length (feet below land surface)
P-1	D. Hoover	NE¼SE¼SE¼SE¼ sec. 25, T. 7 S., R. 44 E.	7/51	3,810	102	Alluvial sand and gravel. TRM sandstones (above Dietz coal bed).	14 51±	3± 20±	4(S)	102
P-2	D. Hoover	SW¼SE¼SE¼SW¼ sec. 26, T. 7 S., R. 44 E.	9/77	3,895	260	TRM sandstones (below Dietz coal bed).	202	30±	5(P)	260
P-3	U.S. Forest Service Tooley Creek well	NE¼NE¼NE¼SW¼ sec. 19, T. 7 S., R. 45 E.	11/78	3,745	110	TRM sandstones (above Canyon coal bed).	72	18±	5(P)	110
P-4	F. Hagen	NW¼NE¼SE¼NW¼ sec. 34, T. 7 S., R. 45 E.	6/73	3,510	40	Alluvial sand and gravel.	23	10±	4(P)	40
P-5	C. Stevens	NW¼NE¼SE¼NE¼ sec. 2, T. 8 S., R. 44 E.	--/20±	3,735	13	Alluvial sand and gravel.	10±	2±	36(RK)	13
P-6	C. Stevens	SW¼SE¼NE¼NE¼ sec. 2, T. 8 S., R. 44 E.	--/54	3,745	48	Alluvial sand and gravel. Dietz coal bed	20± 25±	2± 12±	4(S)	48
P-7	M. Lloyd	SE¼SE¼NW¼SE¼ sec. 9, T. 8 S., R. 44 E.	--/20±	3,840	14	Alluvial sand and gravel (about 90 feet above Anderson coal bed).	8±	4±	33(RK)	14
P-8	C. Stevens	SW¼SW¼NE¼NE¼ sec. 14, T. 8 S., R. 44 E.	8/66	3,843	226	Dietz coal bed TRM sandstones	185 210	14 10±	4(S)	226
P-9	C. Stevens	NE¼SW¼SW¼NW¼ sec. 15, T. 8 S., R. 44 E.	--/54	3,905	51	Alluvial sand and gravel. TRM sandstone (bottom about 130 feet above Anderson coal bed).	15± 30±	6± 5±	4(S)	51
P-10	M. Lloyd	NW¼SE¼SW¼SE¼ sec. 22, T. 8 S., R. 44 E.	9/67	4,109	190	TRM sandstones (bottom about 200 feet above Anderson coal bed).	178	10±	4(S)	190
P-11	J. Whitham	NE¼NE¼NW¼NE¼ sec. 4, T. 8 S., R. 45 E.	--/20±	3,555	25	Alluvial sand and gravel (Cook coal bed near bottom of well).	--	--	24(RK)	25
P-12	D. Hoover	SW¼NW¼NW¼SW¼ sec. 5, T. 8 S., R. 45 E.	9/81	3,765	42	TRM sandstones (above Canyon coal bed).	42	20±	5(P)	110

[1] Water infiltrates between rocks from water level to bottom.
[2] No record of perforated interval; driller reports "perforated in water veins."

Casing perforations (feet below land surface)	Date of hydrologic data (month-day-year)	Static water level (feet below land surface)	Discharge (gallons per minute)	Onsite water temperature (degrees Celsius)	Onsite specific conductance (microsiemens)	Onsite pH (units)	Quality of water analysis available	Remarks
13-20 65-95	06/30/84	12(R)	1.5	10.0	930	7.4	yes	Top of well sealed to keep sanitary; no access for water-level measurements. Sample collected at water tap at house, about 100 feet north of well.
190-260	09/30/77	105(R)	5(R)	--	--	--	no	--
70-110	11/05/78	45(R)	12(R)	--	--	--	no	Well in pit; not accessible for water-level measurement without removing insulation and pressure tank.
25-40	06/05/73	20(R)	5(R)	--	--	--	no	Unused, 1980-82.
([1])	06/02/80	3.0	--	--	--	--	no	Dug well; unused.
--	11/16/73	36.5	--	9.0	1,830	7.4	yes	Quality of water sample FU-305. Pump installed; unused in 1980-82.
([1])	11/13/73 06/02/80	.5 1.9	-- --	9.0 --	-- --	7.6 --	no no	Dug well; unused.
([2])	08/17/66	145(R)	5(R)	--	--	--	no	Anderson coal bed from 78 to 110 feet depth; probably has water at this site; apparently not open to perforations. Well sealed at top; no access for water-level measurements. Windmill discharge underground to buried settling tank.
([2])	06/04/75 06/26/80	12(R) 10±	4± 5±	9.0 10.0	2,500 2,300	7.6 7.3	yes yes	Quality of water sample FU-607. Windmill pumps water to trough.
([2])	06/19/75 10/17/82	144(R) --	5(R) 5±	11.0 10.0	-- 2,900	7.2 7.3	yes yes	Quality of water sample FU-645. Windmill pumps water to trough.
([1])	02/27/74	--	--	10.0	4,500	7.3	yes	Quality of water sample FU-131. Dug well; in use at ranch house in 1982.
60-110	09/22/81	33(R)	12(R)	--	--	--	no	Piston pump installed, powered by gasoline engine. No easy access for water-level measurement.

Table 2.--*Construction and lithologic data for test holes in and near the Little Bear Creek area*

[Abbreviation: TRM = Tongue River Member of Fort Union Formation]

Test-hole No. (pl. 1)	Identification No.	Location	Date drilled (month-year)	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)
T-1	Birney #09	NW¼SE¼SW¼NW¼ sec. 25, T. 7 S., R. 44 E.	1/79	3,652	720
T-2	SH-04	SE¼NE¼NW¼SE¼ sec. 26, T. 7 S., R. 44 E.	8/69	3,968	230
T-3	SH-09	NE¼SW¼SE¼NW¼ sec. 33, T. 7 S., R. 44 E.	8/69	3,872	132
T-4	SH-118	NE¼SW¼NW¼SE¼ sec. 2, T. 8 S., R. 44 E.	8/69	3,775	66
T-5	SH-03	NE¼SW¼SW¼SE¼ sec. 3, T. 8 S., R. 44 E.	8/69	3,860	130
T-6	U.S. 82-006	NW¼NW¼SE¼NE¼ sec. 4, T. 8 S., R. 44 E.	7/82	3,964	517
T-7	Birney #1A	NE¼NW¼NW¼NW¼ sec. 5, T. 8 S., R. 44 E.	8/78	3,860	578

Material of probable aquifer intervals	Depth to top of probable aquifer (feet below land surface)	Depth to bottom of probable aquifer (feet below land surface)	Probable contributing thickness of aquifer (feet)	Remarks
Anderson coal bed	75	107	32	Massive coal. Water probably only in lower part.
TRM sandstones	123	158	22	With some shale layers.
Dietz coal bed	186	199	13	Massive coal.
TRM sandstones	220	246	13	With some shale layers.
TRM sandstone	278	293	12	Apparently clean sandstone.
Canyon coal bed	328	356	28	Massive coal.
TRM sandstones	405	426	16	With some shale layers.
Cook-Otter coal beds	515	537	20	Split by shale layer at 528-530 feet.
Anderson coal bed	92	125	33	Probably massive coal.
TRM sandstone	174	201	20±	Probably with shale layers.
Dietz coal bed	213	226	13	Probably massive coal.
Anderson coal bed	97	130	33	Probably massive coal.
Dietz coal bed	51	64	13	Probably massive coal.
Anderson coal bed	88	122	34	Probably massive coal.
Smith coal bed	49	52	3	Probably dry.
TRM sandstones	133	188	32	With some shale layers. Water possibly only in lower part.
Anderson coal bed	205	238	33	Massive coal.
TRM sandstones	257	278	15	With some shale layers.
Dietz coal bed	288	302	14	Massive coal.
TRM sandstone	312	322	8	With few shale breaks.
Canyon coal bed	456	484±	28±	Massive coal. Logs end at 484 feet below surface.
Anderson coal bed	65	97	32	Massive coal. Water probably only in lower part.
TRM sandstones	99	137	16	With some shale layers.
Dietz coal bed	146	160	14	Massive coal.
TRM sandstone	211	224	10	With few shale breaks.
TRM sandstone	283	300	14	With few shale breaks.
Canyon coal bed	309	335	23	Split by shale layers at 311-313 and 319-320 feet.
TRM sandstones	420	433	8	With some shale layers.
Cook coal bed	484	499	14	With shale breaks near top.
Otter coal bed	503	507	4	Massive coal.

Table 2.--*Construction and lithologic data for test holes in and near the Little Bear Creek area*--Continued

Test-hole No. (pl. 1)	Identification No.	Location	Date drilled (month-year)	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)
T-8	U.S. 82-008	SE¼SW¼SW¼SE¼ sec. 7, T. 8 S., R. 44 E.	7/82	3,870	515
T-9	LBC#05	SW¼NW¼NE¼SE¼ sec. 9, T. 8 S., R. 44 E.	9/80	3,835	13
T-10	U.S. 82-007	NE¼NE¼SE¼NE¼ sec. 9, T. 8 S., R. 44 E.	7/82	3,830	520
T-11	No. 1 Shamrock -U.S.	NW¼SE¼NW¼NW¼ sec. 10, T. 8 S., R. 44 E.	7/69	3,816	8,096
T-12	SH-02	SW¼SW¼SW¼NW¼ sec. 12, T. 8 S., R. 44 E.	8/69	3,902	130
T-13	LBC#02	SW¼NW¼SE¼NE¼ sec. 12, T. 8 S., R. 44 E.	9/80	3,756	60
T-14	U.S. 82-002	SW¼NE¼SW¼SW¼ sec. 13, T. 8 S., R. 44 E.	6/82	3,930	720

Material of probable aquifer intervals	Depth to top of probable aquifer (feet below land surface)	Depth to bottom of probable aquifer (feet below land surface)	Probable contributing thickness of aquifer (feet)	Remarks
TRM sandstones	107	126	13	With some shale layers. Possibly dry.
Anderson coal bed	181	213	32	Massive coal.
Dietz coal bed	254	268	14	Massive coal.
TRM sandstones	314	341	22	With some shale layers.
Canyon coal bed	429	453	24	Massive coal.
TRM sandstones	474	494	12	With some shale layers.
Alluvial sand and gravel.	7	11	0	Dry. Wells 0-26 and 0-27 to northwest, where alluvial channel is deeper, have water.
Alluvial sand and gravel.	16±	31	9±	Probably with some mud layers.
TRM sandstones	59	82	15	With some shale layers.
Anderson coal bed	91	124	33	Massive coal.
TRM sandstones	154	168	10	With some shale layers.
Dietz coal bed	181	194	13	Massive coal.
TRM sandstones	198	228	18	With some shale layers.
TRM sandstones	244	272	20	With some shale layers.
TRM sandstone	304	320	13	With few shale breaks.
Canyon coal bed	344	372	28	Massive coal.
TRM sandstones	376	417	25	With some shale layers.
TRM sandstones	452	482	20	With some shale layers.
Cook coal bed	496	511	15	Massive coal.
Otter coal bed	--	--	--	Apparently below bottom of hole.
--	--	--	--	No log from 0 to 210 feet, through Anderson and Dietz coal beds.
TRM sandstone	232	252	18±	With few shale breaks.
TRM sandstones	304	318	10±	With some shale layers.
Canyon coal bed	325	353	28	Massive coal.
TRM sandstone	439	460	18±	With few shale breaks.
Cook coal bed	478	492	14	Massive coal.
Otter coal bed	499	504	5	Massive coal.
TRM sandstones	525	558	25±	With some shale layers.
Anderson coal bed	81	112	31	Probably massive coal.
Alluvial sand and gravel.	6	13	5	With some mud layers.
Dietz coal bed	--	--	--	Apparently about 10 feet below bottom of hole.
TRM sandstones	30	76	30	With some shale layers. Probably dry.
Anderson coal bed	160	191	31	Massive coal.
Dietz coal bed	272	284	12	Massive coal.
TRM sandstone	315	326	9	Apparently clean sandstone, with few shale breaks.
TRM sandstones	338	388	24	With some shale layers.
Canyon coal bed	408	435	26	Split by shale layer at 430-431 feet.
TRM sandstones	449	468	14	With some shale layers.
TRM sandstones	496	513	12	With some shale layers.
Cook coal bed	572	586	14	Massive coal.
Otter coal bed	596	603	6	Split by shale layer at 598-599 feet.
TRM sandstones	606	624	15	With some shale layers. Local coal bed at 625-628 feet.

Table 2.--*Construction and lithologic data for test holes in and near the Little Bear Creek area*--Continued

Test-hole No. (pl. 1)	Iden-tifi-cation No.	Location	Date drilled (month-year)	Altitude of land surface (feet above sea level)	Drilled depth (feet below land sur-face)
T-15	Otter #04	NW¼SE¼SW¼NW¼ sec. 15, T. 8 S., R. 44 E.	8/80	3,920	675
T-16	U.S. 81-187	NE¼NW¼NW¼SE¼ sec. 16, T. 8 S., R. 44 E.	6/81	4,083	400
T-17	SH-13	SE¼NE¼NW¼SW¼ sec. 19, T. 8 S., R. 44 E.	8/69	3,720	180
T-18	U.S. 82-001	SE¼NE¼NW¼SE¼ sec. 26, T. 8 S., R. 44 E.	6/82	4,140	680
T-19	U.S. 77-100	NW¼NW¼SE¼SW¼ sec. 4, T. 8 S., R. 45 E.	8/77	3,906	320
T-20	AMAX #117	NW¼NE¼NE¼NE¼ sec. 5, T. 8 S., R. 45 E.	12/74	3,650	300
T-21	AMAX #118	NE¼NW¼NW¼SW¼ sec. 5, T. 8 S., R. 45 E.	12/74	3,760	266

Material of probable aquifer intervals	Depth to top of probable aquifer (feet below land surface)	Depth to bottom of probable aquifer (feet below land surface)	Probable contributing thickness of aquifer (feet)	Remarks
TRM sandstones	22	39	11	With some shale layers. Probably fully saturated.
Smith coal bed	42	45	3	Probably massive coal.
TRM sandstones	157	169	8	With some shale layers.
Anderson coal bed	185	217	32	Mostly massive coal.
TRM sandstone	234	247	7	Two apparently clean sandstone beds, with shale layer between.
Dietz coal bed	262	274	12	Massive coal.
TRM sandstones	340	373	20	With some shale layers.
Canyon coal bed	438	466	26	Split by shale layer at 461-463 feet.
TRM sandstone	470	494	11	Two apparently clean sandstone beds, with shale layer between.
Cook coal bed	613	628	14	Split by shale layer from 616-617 feet.
Otter coal bed	632	639	7	Massive coal.
Smith coal bed	261	264	3	Massive coal. Sandstones above Smith probably dry.
TRM sandstones	297	315	12	With some shale layers.
TRM sandstones	337	375	25	With some shale layers.
Anderson coal bed	387	400+	14+	Incomplete section; drilling stopped in mid-Anderson.
Anderson coal bed	82	115	33	Coal soft at 82-85 feet.
Dietz coal bed	167	180	13	Probably massive coal.
Roland coal bed	60	63	3	Probably dry.
TRM sandstone	165	176	10	Apparently clean sandstone, with few shale breaks.
Smith coal bed	261	263	2	Massive coal.
TRM sandstones	264	281	12	With some shale layers.
TRM sandstones	294	323	14	Sandstone and shale, interbedded.
Anderson coal bed	398	431	33	Massive coal.
TRM sandstone	436	468	18	With some shale layers.
Dietz coal bed	498	509	11	Massive coal.
TRM sandstones	513	528	9	With some shale layers.
TRM sandstones	545	600	28	Sandstone and shale, interbedded.
Canyon coal bed	629	652	23	Massive coal.
Anderson clinker	0	40±	--	Dry.
Dietz coal bed	112	128	14	Probably dry. Split by shale layer at 124-126 feet.
TRM sandstone	158	179	16	With few shale breaks.
TRM sandstone	256	264	7	Apparently clean sandstone, with few shale breaks.
Canyon coal bed	273	300	27	Massive coal.
TRM sandstone	315	bottom	4+	Drilling stopped in sandstone; aquifer is probably thicker.
TRM sandstones	109	148	24	With some shale layers. Probably fully saturated.
Cook coal bed	177	190	13	Massive coal.
Otter coal bed	193	199	6	Massive coal.
TRM sandstones	269	296	20	With some shale layers.
TRM sandstones	71	118	27	Sandstone and shale, interbedded.
Canyon coal bed	142	169	27	Massive coal.
TRM sandstones	213	238	15	Sandstone and shale, interbedded.

Table 2.--*Construction and lithologic data for test holes in and near the Little Bear Creek area*--Continued

Test-hole No. (pl. 1)	Identification No.	Location	Date drilled (month-year)	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)
T-22	AMAX #119	SW¼SW¼SE¼SE¼ sec. 6, T. 8 S., R. 45 E.	12/74	3,830	260
T-23	AMAX #120	NW¼SE¼SW¼NW¼ sec. 6, T. 8 S., R. 45 E.	12/74	3,880	300
T-24	M75-02B	SE¼NW¼NW¼NE¼ sec. 7, T. 8 S., R. 45 E.	9/75	3,862	120
T-25	U.S. 82-003	SE¼NE¼SE¼NW¼ sec. 7, T. 8 S., R. 45 E.	7/82	3,885	420
T-26	SH-01	SE¼SE¼NE¼SW¼ sec. 7, T. 8 S., R. 45 E.	8/69	3,888	130
T-27	M75-07	SW¼NE¼SW¼NE¼ sec. 8, T. 8 S., R. 45 E.	9/75	3,920	170
T-28	U.S. 77-99	SE¼NE¼NW¼SW¼ sec. 9, T. 8 S., R. 45 E.	8/77	3,842	362
T-29	M75-11	NE¼SW¼SW¼SW¼ sec. 10, T. 8 S., R. 45 E.	9/75	3,740	160
T-30	M75-09	NE¼NE¼SE¼NW¼ sec. 17, T. 8 S., R. 45 E.	9/75	3,920	315
T-31	Chandler Finn Creek Govt. 1	SW¼NE¼SE¼SE¼ sec. 17, T. 8 S., R. 45 E.	--	3,760	850+

Material of probable aquifer intervals	Depth to top of probable aquifer (feet below land surface)	Depth to bottom of probable aquifer (feet below land surface)	Probable contributing thickness of aquifer (feet)	Remarks
Dietz coal bed	53	65	12	Massive coal.
TRM sandstones	118	132	11	With some shale layers.
TRM sandstones	152	194	26	Sandstones and shale, interbedded.
Canyon coal bed	225	250	25	Massive coal.
Canyon coal bed	60±	88±	28±	Probably massive coal.
TRM sandstones	120±	150±	20±	Sandstone and shale, interbedded.
TRM sandstones	180±	230±	30±	Sandstone and shale, interbedded.
Cook coal bed	250±	264±	14±	(data from driller's log; depths and
Otter coal bed	266±	272±	6±	thicknesses are approximate.)
Anderson coal bed	58	90	32	Probably massive coal.
TRM sandstone	94	106	9	With few shale breaks.
TRM sandstone	112	bottom	6+	Drilling stopped in sandstone; aquifer is probably thicker.
Anderson coal bed	110	142	32	Massive coal.
TRM sandstones	146	176	17	Two apparently clean sandstone beds, with shale layer between.
Dietz coal bed	194	206	12	Massive coal.
TRM sandstones	216	260	25	Sandstone and shale, interbedded.
TRM sandstones	297	337	28	With some shale layers.
Canyon coal bed	358	385	27	Massive coal.
TRM sandstone	393	401	7	Apparently clean sandstone.
Anderson coal bed	89	121	32	Probably massive coal.
TRM sandstones	105	112	5	Two apparently clean sandstone beds, with shale layer between.
Anderson coal bed	127	159	32	Probably massive coal.
Anderson clinker	0	16±	--	Dry.
TRM sandstones	50	73	14	With some shale layers.
Dietz coal bed	94	106	12	Massive coal.
TRM sandstones	138	162	13	With some shale layers.
TRM sandstones	180	200	14	With some shale layers.
TRM sandstones	223	261	19	Sandstone and shale, interbedded.
Canyon coal bed	280	308	28	Mostly massive coal, shaly in upper 6 feet.
TRM sandstones	315	344	19	Two apparently clean sandstone beds, with shale layer between.
TRM sandstones	64	94	15	Sandstone and shale, interbedded. Upper part may be dry.
Canyon coal bed	112	138	26	Probably massive coal.
Smith coal bed	119	122	3	Probably dry.
TRM sandstones	221	251	17	Sandstone and shale, interbedded.
Anderson coal bed	266	300	34	Probably massive coal.
Anderson clinker	0	10±	--	Dry.
Dietz coal bed	78	90	12	Massive coal.
TRM sandstone	130	146	14	With few shale breaks.
TRM sandstones	175	213	20±	Sandstone and shale, interbedded.
Canyon coal bed	223	248	25	Massive coal.
TRM sandstones	254	288	20±	With some shale layers.
TRM sandstones	338	370	20±	With some shale layers.
Cook-Otter coal beds	378	396	18	Massive coal.
TRM sandstones	422	450	20±	With some shale layers.

Table 2.--*Construction and lithologic data for test holes in and near the Little Bear Creek area*--Continued

Test-hole No. (pl. 1)	Identification No.	Location	Date drilled (month-year)	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)
T-32	M75-10	SE¼SE¼SE¼SW¼ sec. 17, T. 8 S., R. 45 E.	9/75	3,810	140
T-33	M75-03	NW¼NE¼NW¼NE¼ sec. 18, T. 8 S., R. 45 E.	9/75	3,943	190
T-34	M75-18	SE¼NW¼NW¼NE¼ sec. 30, T. 8 S., R. 45 E.	9/75	3,818	130

Material of probable aquifer intervals	Depth to top of probable aquifer (feet below land surface)	Depth to bottom of probable aquifer (feet below land surface)	Probable contributing thickness of aquifer (feet)	Remarks
Anderson coal bed	74	107	33	Probably massive coal.
TRM sandstones	122	132	7	Two apparently clean sandstone beds, with shale layer between.
TRM sandstones	89	117	16	Probably dry in upper part. Sandstone and shale interbedded.
Anderson coal bed	129	161	32	Probably massive coal.
TRM sandstones	170	185	8	Two apparently clean sandstone beds, with shale layer between.
TRM sandstone	44	54	8	With few shale breaks.
Anderson coal bed	87	119	32	Probably massive coal.

Table 3.--*Construction and hydrologic data for observation wells open to the Tongue River Member, of the Fort Union Formation in and near the Little Bear Creek area*

[microsiemens, microsiemens per centimeter per 25° Celsius]

Well No. (pl. 1)	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Aquifer material	Top of aquifer (feet below land surface)	Bottom of aquifer (feet below land surface)	Thickness of aquifer contributing water (feet)	Casing length (feet below land surface)	Casing perforations (feet below land surface)	Packer setting (feet below land surface)
0-1	BC#04	SW¼NW¼NW¼NE¼ sec. 34, T. 7 S., R. 44 E.	01/15/75	3,805	272	Canyon coal bed.	231	262	31	272	232-264	231
0-2	BC#03	SW¼NW¼NW¼NE¼ sec. 34, T. 7 S., R. 44 E.	01/14/75	3,805	86	Dietz coal bed.	66	80	14	86	66-81	--
0-3	LBC#36	NE¼SW¼SW¼SE¼ sec. 35, T. 7 S., R. 44 E.	07/24/81	3,880	213	Dietz coal bed.	180	196	16	212	180-198	141 and 179
0-4	LBC#37	NE¼SW¼SW¼SE¼ sec. 35, T. 7 S., R. 44 E.	07/25/81	3,880	132	Anderson coal bed.	104	129	25	132	93-131	93
0-5	BC#01	NW¼SE¼NE¼SE¼ sec. 36, T. 7 S., R. 44 E.	01/12/75	3,810	95	Dietz coal bed.	75	89	14	95	75-90	--
0-11	LBC#27	SE¼SE¼NE¼SW¼ sec. 32, T. 7 S., R. 45 E.	12/05/80	3,650	210	Cook-Otter coal beds.	182	205	21	210	184-205	181
0-12	LBC#28	SE¼SE¼NE¼SW¼ sec. 32, T. 7 S., R. 45 E.	12/06/80	3,650	44.5	Sandstone	28	37	8	44.5	23-41	21
0-13	LBC#12	NE¼SW¼NE¼NW¼ sec. 2, T. 8 S., R. 44 E.	10/03/80	3,735	40	Dietz coal bed.	15	28	13	40	14.8-29.7	14
0-24	BC#08	SE¼NW¼NW¼SW¼ sec. 3, T. 8 S., R. 44 E.	06/28/75	3,845	201	Dietz coal bed.	181	195	14	200	181-195	180
0-25	BC#09	SE¼NW¼NW¼SW¼ sec. 3, T. 8 S., R. 44 E.	06/29/75	3,845	129	Anderson coal bed.	93	126	33	129	92-127	--
0-31	LBC#29	SW¼SE¼SW¼NE¼ sec. 12, T. 8 S., R. 44 E.	07/17/81	3,810	351	Canyon coal bed.	314	342	27	351	315-341	298 and 312
0-32	LBC#30	SW¼SE¼SW¼NE¼ sec. 12, T. 8 S., R. 44 E.	07/18/81	3,810	252	Sandstone	202	246	19	252	214-251	212
0-33	LBC#31	NW¼NE¼NW¼NE¼ sec. 14, T. 8 S., R. 44 E.	07/20/81	3,890	337	Sandstone	275	325	29	337	279-336	278

Date of hydro-logic data	Static water level (feet below land sur-face)	Pump-ing water level (feet below land sur-face)	Dis-charge (gal-lons per min-ute)	Specific capacity (gallons per minute per foot of draw-down)	Water tem-pera-ture (degrees Celsius)	Onsite speci-fic con-duc-tance micro-siemens)	On-site pH	1981-82 water-level fluctu-ations (feet below land surface)	Remarks
06/17/75	186.6	211	5.5	0.2	13.0	3,150	7.8	186±	Well has submersible pump installed; is used for stock water.
06/17/75	54.3	--	--	--	10.0	2,710	8.0	54±	Well is 19 feet south of well 0-1.
07/23/82	149.5	210	.9	.01	13.5	3,100	7.9	149.0-150.1	--
09/23/82	103.8	129	.3	.01	12.2	3,400	7.7	103.3-103.9	Well is 15 feet northeast of well 0-3. Anderson coal bed from 95 to 129 feet depth; upper 9 feet is dry.
08/16/82	50.8	64	1.6	.1	11.0	2,680	8.2	50.1-51.1	Well has jet pump installed; is used for stock water.
07/30/82	151.2	160	2.4	.2	13.0	2,500	7.9	150.8-151.3	Shale layer from 198 to 199 feet depth; separates Cook coal bed, above, from Otter coal bed, below.
07/28/82	28.6	37	3.1	.3	10.5	1,600	7.3	27.8-28.9	Well is 10 feet east of well 0-11. Apparently clean sandstone, with few shale breaks.
07/24/82	7.5	19.5	3.4	.3	10.0	3,300	7.4	5.8-8.2	Well is 12 feet northwest of alluvial well 0-19.
10/19/82	131.5	178	5	.1	13.0	3,200	7.7	131.3-132.1	--
08/15/82	74.0	110	2.2	.06	12.5	7,250	7.2	72.8-74.0	Well is 10 feet south of well 0-24.
09/21/82	186.9	234	7.8	.1	12.3	2,550	8.1	186.7-187.0	--
07/27/82	126.1	163	2.4	.06	11.5	3,800	8.2	125.7-126.2	Well is 15 feet east of well 0-31. Apparently clean sandstone beds, with some shale layers between. Perforated interval about 80 feet below Dietz coal bed.
10/17/82	218.3	285	.8	.01	13.8	2,850	8.1	218.1-218.5	Well is 15 feet east of well 0-34. Apparently clean sandstone beds, but partly quartzitic and with some shale layers between. Perforated interval about 34 feet below Dietz coal bed.

Table 3.--*Construction and hydrologic data for observation wells open to the Tongue River Member of the Fort Union Formation in and near the Little Bear Creek area*--Continued

Well No. (pl. 1)	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Aquifer material	Top of aquifer (feet below land surface)	Bottom of aquifer (feet below land surface)	Thickness of aquifer contributing water (feet)	Casing length (feet below land surface)	Casing perforations (feet below land surface)	Packer setting (feet below land surface)
0-34	LBC#32	NW¼NE¼NW¼NE¼ sec. 14, T. 8 S., R. 44 E.	07/20/81	3,890	251	Dietz coal bed.	231	245	14	250	231-249	230
0-35	LBC#33	NW¼NE¼NW¼NE¼ sec. 14, T. 8 S., R. 44 E.	07/22/81	3,890	161	Anderson coal bed.	124	155	31	161	123-160	122
0-36	LBC#34	SW¼SE¼SW¼NW¼ sec. 15, T. 8 S., R. 44 E.	07/23/81	3,920	290	Dietz coal bed.	260	273	13	289	258-276	257
0-37	LBC#35	SW¼SE¼SW¼NW¼ sec. 15, T. 8 S., R. 44 E.	07/24/81	3,920	220	Anderson coal bed.	184	216	32	220	182-219	181
0-38	HWC#28	NW¼NE¼SE¼SE¼ sec. 32, T. 8 S., R. 44 E.	05/10/77	3,740	183	Anderson coal bed.	144	175	29	183	147-178	144
0-41	BC#05	NW¼NW¼SW¼SE¼ sec. 8, T. 8 S., R. 45 E.	06/25/75	3,890	216	Dietz coal bed.	190	204	14	212	186-208	184
0-42	BC#06	NW¼SW¼NW¼SE¼ sec. 16, T. 8 S., R. 45 E.	06/27/75	3,715	188	Canyon coal bed.	152	180	28	188	153-183	--
0-43	BC#07	NW¼SW¼NW¼SE¼ sec. 16, T. 8 S., R. 45 E.	06/27/75	3,715	66	Sandstone	49	63	10	66	35-64	--

Date of hydro-logic data	Static water level (feet below land sur-face)	Pump-ing water level (feet below land sur-face)	Dis-charge (gal-lons per min-ute)	Specific capacity (gallons per minute per foot of draw-down)	Water tem-pera-ture (degrees Celsius)	Onsite speci-fic con-duc-tance (micro-siemens)	On-site pH	1981-82 water-level fluctu-ations (feet below land surface)	Remarks
10/17/82	209	246	.2	.005	13.5	4,600	7.6	209±	Packer not set in 1981; water level about 107 feet below surface. After bailing well in August, September, and October 1982, packer seems to have sealed higher waters from well.
07/29/82	109.2	134	1.6	.06	11.8	4,500	7.2	108.9-109.3	Well is 15 feet west of well 0-34.
09/24/82	255	285	.2	.006	14.6	3,220	7.7	248.1-255.2	Possibly packer not firmly set before bailing well in August and September 1982. Dietz bed water level probably about 255 feet below surface.
07/26/82	165.7	204	1.1	.03	13.3	3,700	7.5	165.4-165.9	Well is 10 feet east of well 0-36.
07/07/77	105.1	118	4.4	.3	12.0	2,900	7.6	105±	Well is on north side tributary of East Trail Creek basin, southwest of Little Bear Creek area.
09/24/82	154.4	209	.3	.005	12.0	4,650	7.7	154.0-154.6	Well is just over divide of Little Bear Creek basin, in Bear Creek drainage. Anderson coal bed, from 74 to 107 feet in depth, is probably dry.
06/28/75	81.8	128	6	.1	11.5	2,990	8.0	84±	Well is on north side tributary of Mud Springs Creek basin, southeast of Little Bear Creek area.
06/30/75	33	--	--	--	11.0	5,340	--	34±	Well is 10 feet south of well 0-42. Apparently clean sandstone beds with some shale layers between. Perforated interval about 30 feet below Dietz coal bed level.

Table 4.--*Construction and hydrologic data for observation wells open to alluvium*

[microsiemens, microsiemens per centimeter at 25° Celsius]

Well No. (pl. 1)	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Aquifer material	Top of aquifer (feet below land surface)	Bottom of aquifer (feet below land surface)	Thickness of aquifer contributing water (feet)	Casing length (feet below land surface)	Casing-perforations (feet below land surface)	Packer setting (feet below land surface)
0-6	BC#02	NW¼SE¼NE¼SE¼ sec. 36, T. 7 S., R. 44 E.	01/13/75	3,810	19.5	Clinker gravel	7	15	6	19.5	7-15.5	--
0-7	LBC#21	NW¼NE¼SE¼NW¼ sec. 32, T. 7 S., R. 45 E.	10/07/80	3,660	31.1	Sand and clinker gravel.	15	19	0	31.1	19.1-30.1	17
						Local coal bed	23	30	0			
0-8	LBC#22	NE¼NW¼SW¼SE¼ sec. 32, T. 7 S., R. 45 E.	10/07/80	3,603	14.2	Sand and gravel layers, with mud layers between.	3.5	11	6	14.2	3.7-11.7	3
0-9	LBC#23	NE¼NW¼SW¼SE¼ sec. 32, T. 7 S., R. 45 E.	10/07/80	3,609	18.5	Sand and gravel layers, with mud layers between.	9.5	18	6	17.8	8.8-17.8	8
0-10	LBC#24	NE¼NW¼SW¼SE¼ sec. 32, T. 7 S., R. 45 E.	10/08/80	3,612	24	Sand and gravel layers, with mud layers between.	12.5	22	6	23.8	14.8-21.8	13
0-14	LBC#16	NW¼NE¼SE¼NW¼ sec. 2, T. 8 S., R. 44 E.	10/04/80	3,747	40.1	Sand and gravel layers, with mud layers between.	18	32.5	3	40.1	28.1-32.6	27
0-15	LBC#15	SE¼SW¼NE¼NW¼ sec. 2, T. 8 S., R. 44 E.	10/04/80	3,737	19.5	Sand and gravel layers, with mud layers between.	13.5	18.5	3.5	19.3	13.8-19.3	13
0-16	LBC#14	SE¼SW¼NE¼NW¼ sec. 2, T. 8 S., R. 44 E.	10/03/80	3,735	15	Sand and gravel	11.5	14	2.5	14.7	11.2-14.2	10
0-17	LBC#18	SE¼SW¼NE¼NW¼ sec. 2, T. 8 S., R. 44 E.	10/06/80	3,735	14	Sand and gravel	11	13	2	13.6	11.1-13.6	10
0-18	LBC#17	SE¼SW¼NE¼NW¼ sec. 2, T. 8 S., R. 44 E.	10/06/80	3,735	16	Sand and gravel layers, with mud layers between.	10.5	15	3.5	15.7	10.2-15.7	9
0-19	LBC#13	NE¼SW¼NE¼NW¼ sec. 2, T. 8 S., R. 44 E.	10/03/80	3,734	15	Sand and gravel layers, with mud layers between.	9.5	14	3	14.8	8.3-14.3	8

Date of hydrologic data	Static water level (feet below land surface)	Pumping water level (feet below land surface)	Discharge (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Water temperature (degrees Celsius)	Onsite specific conductance (microsiemens)	Onsite pH	1981-82 water-level fluctuations (feet below land surface)	Remarks
08/17/82	6.2	11	5.2	1.0	11.0	725	7.6	5.5-6.3	Well is 20 feet south of Dietz coal well 0-5.
08/17/82	--	--	--	--	--	--	--	--	Alluvial water in Hoover Creek valley below bottom of well. Casing was retained in well in anticipation of alluvial water rising enough to reach well -- it did not during study period.
08/10/82	2.6	6.0	3.6	1.0	9.5	4,210	7.3	2.0-3.1	Southernmost of three wells inline across Little Bear Creek valley.
08/13/82	8.5	9.8	4.8	3.7	9.5	4,280	7.1	7.6-9.1	Middle of three wells inline; is 127 feet north of well 0-8.
08/16/82	11.8	15.8	6.0	1.5	9.5	3,300	7.2	10.9-12.0	Northernmost of three wells inline; is 133 feet north of well 0-9.
07/25/82	18.0	20.9	2.4	.82	10.0	2,800	7.3	17.4-19.4	Southernmost of five wells inline across Little Bear Creek valley; is 100 feet northwest of tributary channel.
08/14/82	9.2	10.5	5.6	4.3	9.0	2,700	7.2	7.4-9.5	One of five wells inline; is 215 feet north of well 0-14.
09/23/82	7.4	10.2	21	7.5	9.0	2,750	7.2	5.3-7.5	One of five wells inline; is 207 feet north of well 0-15.
07/30/82	6.7	7.7	2.1	2.1	9.0	2,800	--	5.3-7.4	Well is off north-south line; is 20 feet west of well 0-16 and about 20 feet east of Little Bear Creek channel.
08/11/82	7.2	8.1	5.4	6.0	9.0	2,800	7.2	5.4-7.6	One of five wells inline; is 50 feet north of well 0-16.
07/27/82	5.8	8.0	9.1	4.1	9.0	2,900	7.4	4.4-6.7	Northernmost of five alluvial wells inline; is 150 feet north of well 0-18, and about 40 feet west of Little Bear Creek channel. Well is 12 feet southeast of Dietz coal bed well 0-13.

Table 4.--*Construction and hydrologic data for observation wells open to alluvium*--Continued

Well No. (pl. 1)	Identification No.	Location	Date drilled	Altitude of land surface (feet above sea level)	Drilled depth (feet below land surface)	Aquifer material	Top of aquifer (feet below land surface)	Bottom of aquifer (feet below land surface)	Thickness of aquifer contributing water (feet)	Casing length (feet below land surface)	Casing-perforations (feet below land surface)	Packer setting (feet below land surface)
0-20	LBC#09	SW¼SE¼SE¼NE¼ sec. 3, T. 8 S., R. 44 E.	10/01/80	3,758	26	Sand and gravel Anderson coal bed.	16.5 20	20 23.5	1.5 3.5	25.9	18.4-24.4	17
0-21	LBC#08	SW¼SE¼SE¼NE¼ sec. 3, T. 8 S., R. 44 E.	10/01/80	3,755	32	Sand and gravel Anderson coal bed.	11.5 16.5	16 20	4 3.5	20.9	11.9-19.9	10
0-22	LBC#10	NW¼SE¼SE¼NE¼ sec. 3, T. 8 S., R. 44 E.	10/02/80	3,760	27.4	Sand and gravel Anderson coal bed.	15 22.5	22 25.5	4.5 3	27.4	16.4-27.4	15
0-23	LBC#11	NW¼SE¼SE¼NE¼ sec. 3, T. 8 S., R. 44 E.	10/02/80	3,763	30	Sand and gravel Anderson coal bed.	18 22	20 29	1 7	29.9	19.9-28.9	19
0-26	LBC#06	SW¼NW¼NE¼SE¼ sec. 9, T. 8 S., R. 44 E.	09/30/80	3,842	26	Sand and gravel layer.	18	20.5	2	25.9	16.5-20.7	15
0-27	LBC#07	NW¼NW¼NE¼SE¼ sec. 9, T. 8 S., R. 44 E.	09/30/80	3,845	28	Sand and gravel layers, with mud layers between.	22	27	4	27.9	17.9-26.6	17
0-28	LBC#04	NE¼SW¼SE¼NE¼ sec. 12, T. 8 S., R. 44 E.	09/29/80	3,765	24.5	Sand and gravel Anderson coal bed.	14.5 20	18 22	3.5 2	24.2	12.3-17.4	11
0-29	LBC#01	SE¼NW¼SE¼NE¼ sec. 12, T. 8 S., R. 44 E.	09/23/80	3,755	20	Sand and gravel layers, with mud layers between.	6	10	3.5	10.9	5.1-10.9	4
0-30	LBC#03	SW¼NW¼SE¼NE¼ sec. 12, T. 8 S., R. 44 E.	09/29/80	3,756	14	Sand and gravel layers, with mud layers between.	4.5	10.5	4	13.9	4.3-13.9	3
0-39	LBC#25	NE¼SE¼SW¼NW¼ sec. 6, T. 8 S., R. 45 E.	10/08/80	3,668	20	Sand and gravel layers, with mud layers between.	7.5	13	4.5	19.8	8.6-14.3	7
0-40	LBC#26	NW¼SE¼SW¼NW¼ sec. 6, T. 8 S., R. 45 E.	10/08/80	3,675	21.1	Sand and gravel layers, with mud layers between.	15	19.5	3.5	21.1	13.1-21.1	9

Date of hydrologic data	Static water level (feet below land surface)	Pumping water level (feet below land surface)	Discharge (gallons per minute)	Specific capacity (gallons per minute per foot of drawdown)	Water temperature (degrees Celsius)	Onsite specific conductance (microsiemens)	Onsite pH	1981-82 water-level fluctuations (feet below land surface)	Remarks
08/12/82	15.3	23	1.3	.16	10.5	3,050	7.3	13.0-15.7	Southernmost of four wells inline; is about 200 feet north of Tongue River Member outcrop in hillside.
10/20/82	12.6	15.6	2.4	.80	10.6	2,900	7.4	9.9-12.6	One of four wells inline; is 140 feet north of well 0-20, and about 20 feet south of dry channel of Little Bear Creek.
10/19/82	17.1	18.5	1.2	.85	10.6	2,800	7.6	14.7-17.1	One of four wells inline; is 138 feet north of well 0-21, and about 120 feet north of dry channel of Little Bear Creek.
09/23/82	19.0	25	.25	.04	9.9	2,700	7.5	16.8-19.0	Northernmost of four wells inline; is 130 feet north of well 0-22.
06/23/82	18.9	19.7	1.2	1.5	10.0	4,000	7.5	18.6-19.9	Southeasternmost of two wells; is about 100 feet northwest of dry channel of Little Bear Creek.
06/24/82	21.5	22.3	1.9	2.3	10.0	4,200	7.4	21.2-22.6	Northwesternmost of two wells; is about 80 feet northwest of well 0-26.
06/23/82	15.6	19.6	.6	.15	10.0	11,000	7.1	13.9-16.1	Easternmost of three wells inline; is about 100 feet southeast of Davidson Draw channel (usually dry).
06/22/82	5.4	6.0	.9	1.5	10.0	5,800	7.4	3.3-6.3	Middle of three wells inline; is 196 feet west of well 0-28, and about 50 feet west of Davidson Draw channel (usually dry).
06/24/82	6.7	7.0	1.4	4.6	9.0	5,100	7.2	4.7-7.7	Westernmost of three wells inline; is 122 feet west of well 0-29.
06/22/82	8.0	9.7	2.2	1.3	9.1	3,600	7.3	6.8-8.2	Easternmost of two wells; is about 20 feet north and 90 feet west of dry channel of Davidson Draw.
09/24/82	15.2	20.6	.2	.03	9.5	3,550	7.2	14.0-15.2	Westernmost of two wells; is 174 feet west of well 0-39, and about 60 feet north of dry channel of Davidson Draw.

Table 5.--*Aquifer characteristics of the Tongue River Member of the Fort Union Formation in and near the Little Bear Creek area*

[gal/min, gallons per minute; BM, Montana Bureau of Mines and Geology]

Well No. (pl. 1)	Altitude of land surface (feet above sea level)	Aquifer material open to perforated casing	Water intake interval (feet below land surface)	Thickness of aquifer contributing water at time of test (feet)	Date of test	Static water level (feet below land surface)
0-1	3,805	Canyon coal bed	231-262	31	06/17/75	186.6
0-3	3,880	Dietz coal bed	180-196	16	07/23/82	149.5
0-4	3,880	Anderson coal bed	104-129	25	09/23/82	103.8
0-5	3,810	Dietz coal bed	75-89	14	08/16/82	50.8
0-11	3,650	Cook/Otter coal beds	184-205	21	07/30/82	151.2
0-12	3,650	Sandstone bed, just beneath Canyon coal bed -- partly scorched.	28-37	8	07/28/82	28.6
0-13	3,735	Dietz coal bed	15-28	13	07/24/82	7.5
0-24	3,845	Dietz coal bed	181-195	14	10/19/82	131.5
0-25	3,845	Anderson coal bed	93-126	33	08/15/82	74.0
0-31	3,810	Canyon coal bed	314-342	27	09/21/82	186.9
0-32	3,810	Sandstone beds, between Dietz and Canyon coal beds; sandstone with shale layers in lower half.	214-246	19	07/27/82	126.1

Draw-down (feet below static water level)	Discharge (cubic feet per day)	Transmis-sivity (feet squared per day)	Hydraulic conduc-tivity (feet per day)	Remarks
25	1,050	70	2	Test conducted by M. R. Garverich (BM).
61	170	.8	.05	
25	58	.2	.008	Yield too small to pump. Well bailed on September 21 and 23, 1982. Aquifer characteristics calculated from recovery measurements.
13	310	20	1.4	Discharge steady at 1.6 gal/min for last 100 minutes of 120-minute test.
9	460	25	1.2	Discharge fairly steady at 2.4 gal/min for last 60 minutes of 100-minute test.
9	600	10	1.2	Discharge fairly steady at 3.1 gal/min for last 80 minutes of 100-minute test. At the 60-minute point, the water changed from clear to a dark-orangish-brown color -- no taste, no smell, no change of specific conductance.
12	650	100	8	Discharge fairly steady at 3.4 gal/min for last 80 minutes of 100-minute test. Water level in alluvial well 0-19, 12 feet to southeast, had small decline during pumping of well 0-13, indicating Dietz and alluvial aquifers are mostly sealed from each other.
47	960	10	.7	Discharge fairly steady at 5 gal/min for most of 60-minute test.
36	420	10	.3	Discharge steady at 2.2 gal/min for last 70 minutes of 100-minute test.
47	1,500	40	1.5	Discharge fairly steady at 7.8 gal/min for last 80 minutes of 90-minute test.
37	460	10	.5	Discharge fairly steady at 2.4 gal/min for last 180 minutes of 190-minute test.

Table 5.--*Aquifer characteristics of the Tongue River Member of the Fort Union Formation in and near the Little Bear Creek area*--Continued

Well No. (pl. 1)	Altitude of land surface (feet above sea level)	Aquifer material open to perforated casing	Water intake interval (feet below land surface)	Thickness of aquifer contributing water at time of test (feet)	Date of test	Static water level (feet below land surface)
0-33	3,890	Sandstone beds, below Dietz coal bed; sandstone layers interbedded with shale layers.	275-325	29	10/17/82	218.3
0-34	3,890	Dietz coal bed	231-245	14	10/17/82	209
0-35	3,890	Anderson coal bed	124-155	31	07/29/82	109.2
0-36	3,920	Dietz coal bed	260-273	13	09/24/82	255
0-37	3,920	Anderson coal bed	184-216	32	07/26/82	165.7
0-38	3,740	Anderson coal bed	144-175	29	07/07/77	105.1
0-41	3,890	Dietz coal bed	190-204	14	09/24/82	154.4
0-42	3,715	Canyon coal bed	152-180	28	06/28/75	81.8

Draw-down (feet below static water level)	Discharge (cubic feet per day)	Transmis-sivity (feet squared per day)	Hydraulic conduc-tivity (feet per day)	Remarks
67	150	3	.1	Discharge fairly steady at 0.8 gal/min for last 60 minutes of 80-minute test.
37	40	.1	.007	Yield too small to pump. Well bailed in August, September, and October 1982. Aquifer characteristic calculated from recovery measurements.
25	310	10	.3	Discharge fairly steady at 1.6 gal/min for last 60 minutes of 80-minute test.
30	40	.1	.008	Yield too small to pump. Well bailed in August and September 1982. Aquifer characteristics calculated from recovery measurements.
39	210	2	.06	Discharge fairly steady at 1.1 gal/min for last 80 minutes of 100-minute test.
13	850	120	4	Test conducted by J. J. McDermott, (BM). Discharge steady at 4.4 gal/min for last 170 minutes of 200-minute test.
55	55	.1	.007	Yield too small to pump. Well bailed in July, August, and September 1982. Aquifer characteristics calculated from recovery measurements.
46	1,100	20	.7	Test conducted by M. R. Garverich (BM). Discharge steady at 6 gal/min for most of 200-minute test.

Table 6.--*Aquifer characteristics of alluvium*

[gal/min, gallons per minute]

Well No. (pl. 1)	Altitude of land surface (feet above sea level)	Aquifer material open to perforated casing	Water intake intervals (feet below land surface)	Thickness of aquifer contributing water at time of test (feet)	Date of test	Static water level (feet below land surface)
0-6	3,810	Clinker gravel and sand	8-15	6	08/17/82	6.2
0-8	3,603	Sand and gravel layers; shale below 11 feet.	3.5-5 6-8.5 9-11	6	08/10/82	2.6
0-9	3,609	Sand and gravel layers; shale below 18 feet.	9.5-12.5 13-15 17-18	6	08/13/82	8.5
0-10	3,612	Sand and gravel layers; shale below 22 feet.	12.5-15 16-21 21.5-22	6	08/16/82	11.8
0-14	3,747	Sand and gravel layers; shale below 32.5 feet.	26.5-28 29-30 32-32.5	3	07/25/82	18.0
0-15	3,737	Sand and gravel layers; coal below 18.5 feet.	13.5-14.5 15-16 17-18.5	3.5	08/14/82	9.2
0-16	3,735	Sand and gravel layer; coal below 14 feet.	11.5-14	2.5	09/23/82	7.4
0-17	3,735	Sand and gravel layer; coal below 13 feet.	11-13	2	07/30/82	6.7
0-18	3,735	Sand and gravel layers; coal below 15 feet.	10.5-11.5 12.5-15	3.5	08/11/82	7.2
0-19	3,734	Sand and gravel layers; coal below 14 feet.	9.5-10.5 12-14	3	07/27/82	5.8
0-20	3,758	Sand and gravel layer Anderson coal bed	18.5-20 20-23.5	1.5 3.5	08/12/82	15.3

Drawdown (feet below static water level)	Discharge (cubic feet per day)	Trans-missivity (feet squared per day)	Hydraulic conductivity (feet per day)	Remarks
5	1,000	40	7	Discharge fairly steady at 5.2 gal/min for last 60 minutes of 130-minute test.
3.4	700	50	8	Discharge fairly steady at 3.6 gal/min for last 50 minutes of 120-minute test.
1.3	920	600	100	Discharge fairly steady at 4.8 gal/min for last 90 minutes of 130-minute test. Pumping this well had no significant effect on water levels in well 0-8 or 0-10.
4.0	1,150	400	67	Discharge fairly steady at 6.0 gal/min for last 70 minutes of 100-minute test.
2.9	460	340	110	Discharge steady at 2.4 gal/min for last 80 minutes of 100-minute test.
1.3	1,080	1,000	280	Discharge fairly steady at 5.6 gal/min for last 100 minutes of 120-minute test. Pumping this well had no significant effect on water levels in wells 0-14 or 0-16.
2.8	4,000	1,600	640	Discharge steady at 21 gal/min for last 120 minutes of 200-minute test. Calculated storage coefficient = 0.02, based on water-level drawdown in wells 0-17 and 0-18.
1.0	400	400	200	Discharge fairly steady at 2.1 gal/min for last 80 minutes of 100-minute test. Pumping this well caused water level in well 0-16, 20 feet to west, to decline 0.12 foot.
.9	1,040	2,000	570	Discharge fairly steady at 5.4 gal/min for last 80 minutes of 100-minute test. Pumping this well caused water level in well 0-16, 50 feet to south, to decline 0.24 foot.
2.2	1,750	400	130	Discharge fairly steady at 9.1 gal/min for last 90 minutes of 120-minute test. Pumping this well had no significant effect on water level in well 0-18, 150 feet to the south.
8	250	10	2	Discharge fairly steady at 1.3 gal/min for last 50 minutes of 130-minute test. Apparently, most of the water was coming from the Anderson coal bed.

Table 6.--*Aquifer characteristics of alluvium*--Continued

Well No. (pl. 1)	Altitude of land surface (feet above sea level)	Aquifer material open to perforated casing	Water intake intervals (feet below land surface)	Thickness of aquifer contributing water at time of test (feet)	Date of test	Static water level (feet below land surface)
0-21	3,755	Sand and gravel layers	12.6-14.5 15-16	2.9	10/20/82	12.6
		Anderson coal bed	16.5-20	3.5		
0-22	3,760	Sand and gravel layers	17.1-18.5 20-22	3.4	10/19/82	17.1
		Anderson coal bed	22.5-25.5	3		
0-23	3,763	Sand and gravel layer	19-20	1	09/23/82	19.0
		Anderson coal bed	22-29	7		
0-26	3,842	Sand and gravel layer; shale below 20.5 feet.	19-20.5	1.5	06/23/82	18.9
0-27	3,845	Sand and gravel layers; shale below 27 feet.	22-24.5 25.5-27	4	06/24/82	21.5
0-28	3,765	Sand and gravel layer	15.6-18	2.4	06/23/82	15.6
		Anderson coal bed	20-22	0		
0-29	3,755	Sand and gravel layers; shale below 10 feet.	6-8.5 9-10	3.5	06/22/82	5.4
0-30	3,756	Sand and gravel layers; shale below 10.5 feet.	6.7-8 9.5-10.5	2.3	06/24/82	6.7
0-39	3,668	Sand and gravel layers; siltstone below 13 feet.	8-11.5 12-13	4.5	06/22/82	8.0
0-40	3,675	Sand and gravel layers; clayey siltstone below 19.5 feet.	15.2-16 17-19.5	3.3	09/24/82	15.2

Drawdown (feet below static water level)	Discharge (cubic feet per day)	Trans-missivity (feet squared per day)	Hydraulic conductivity (feet per day)	Remarks
3.0	460	80	12	Discharge fairly steady at 2.4 gal/min for last 50 minutes of 110-minute test. Apparently the water was coming mostly from the alluvium. Pumping this well had no significant effect on water levels in wells 0-20 or 0-22.
1.4	230	80	12	Discharge fairly steady at 1.2 gal/min for last 60 minutes of 80-minute test. Possibly the underlying Anderson coal bed is contributing water to this well, but the amount is probably small.
6	50	1	.1	Well bailed in August and September 1982. Aquifer characteristic calculations made from recovery water-level measurements. Probably, at the September 1982 water levels, the alluvium is contributing very little water; most water is probably coming from the Anderson coal bed.
.8	230	10	7	Discharge fairly steady at 1.2 gal/min for last 80 minutes of 100-minute test.
.8	360	500	120	Discharge steady at 1.9 gal/min for last 80 minutes of 90-minute test. Pumping this well had no significant effect on water levels in well 0-26, 94 feet to the southeast.
4.0	110	5	2	Discharge fairly steady at 0.6 gal/min for last 60 minutes of 70-minute test.
.6	170	70	20	Discharge fairly steady at 0.9 gal/min for last 40 minutes of 100-minute test. Pumping this well had no significant effect on water level in wells 0-28 or 0-30.
.3	270	800	350	Discharge fairly steady at 1.4 gal/min for last 50 minutes of 100-minute test.
1.7	420	70	15	Discharge fairly steady at 2.2 gal/min for last 90 minutes of 100-minute test. Pumping this well had no significant effect on water level in well 0-40, 174 feet to west.
5.4	40	.4	.1	Yield too small to pump; well bailed in August and September 1982. Aquifer characteristic calculations made from recovering water-level measurements.

Table 7.--*Chemical quality of water from private and observation wells open to the Tongue River Member of the Fort Union Formation in and near the Little Bear Creek area*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviations: microsiemens, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter. Symbol <, less than]

Well No. (pl. 1)	Date sample collected	Depth of contributing aquifer (feet below land surface)	Onsite specific conductance (microsiemens)	Onsite pH	Water temperature (degrees Celsius)	Hardness (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)
					Cook-Otter coal beds					
0-11	07/30/82	184-205	2,500	7.9	13.0	29	6.3	3.1	630	51
					Canyon coal bed					
0-1	06/17/75	231-262	3,150	7.8	13.0	29	5.6	3.5	780	64
0-31	07/20/83	314-342	2,550	8.1	12.3	30	6.0	3.6	630	50
0-42	06/30/75	152-180	2,990	8.0	11.5	55	10	7.4	660	39
					Dietz coal bed					
0-2	06/17/75	66-80	2,710	8.0	10.0	36	8.2	3.6	610	45
0-3	07/20/83	180-196	3,100	7.9	13.5	48	8.8	6.4	840	52
0-5	08/16/82	75-89	2,680	8.2	11.0	80	14	11	660	32
0-13	07/24/82	15-28	3,300	7.4	10.0	880	120	140	480	7.1
0-24	08/12/82	181-195	3,200	7.7	13.0	55	10	7.3	850	50
0-34	10/17/82	231-245	4,600	7.6	13.5	210	42	26	1,100	33
0-36	09/24/82	260-273	3,220	7.7	14.6	140	22	21	800	29
0-41	09/24/82	190-204	4,650	7.7	12.0	130	25	17	1,100	42
					Anderson coal bed					
0-4	09/23/82	104-129	3,400	7.7	12.2	83	15	11	800	38
0-25	08/15/82	93-126	7,250	7.2	12.5	820	130	120	1,600	24
0-35	07/29/82	124-155	4,500	7.2	11.8	370	66	49	990	23
0-37	07/26/82	184-216	3,700	7.5	13.3	85	16	11	960	45
0-38	07/07/77	146-175	2,900	7.6	12.0	53	10	6.7	690	42
					Sandstone beds					
0-12	07/28/82	28-37	1,600	7.3	10.5	610	82	98	140	2.9
0-32	07/27/82	214-246	3,800	8.2	11.5	79	15	10	930	46
0-33	10/17/82	279-325	2,850	8.1	13.8	47	8.5	6.3	780	49
0-43	06/30/75	49-63	5,340	6.7	11.0	2,400	360	370	340	3.0
P-1	06/30/84	14-94	930	7.4	10.0	228	40	31	120	3.6
P-10	10/17/82	178-189	2,900	7.3	10.5	1,400	190	230	220	2.5

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CaCO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, sum of constituents	Remarks
				Cook-Otter coal beds					
4.2	1,740	--	1,430	<5	28	3.2	7.2	1,750±	
				Canyon coal bed					
6.3	2,080	0	1,710	10	30	5.1	7.9	1,870	
4.3	1,600	0	1,310	24	31	2.8	8.9	1,500	
5.6	1,750	0	1,440	66	23	2.8	7.4	1,650	
				Dietz coal bed					
5.1	1,100	0	902	430	15	5.1	9.1	2,000	
5.6	2,160	0	1,770	41	24	3.7	8.7	2,000	
8.5	1,380	--	1,130	350	20	1.3	9.5	1,750	
12	652	--	535	1,400	12	1.6	16	2,500	Water probably a mixture of alluvial and Dietz coal waters.
6.9	2,220	--	1,820	<5	35	3.4	7.5	2,200±	
9.1	1,600	--	1,310	1,200	31	1.3	9.0	3,220	
7.4	2,080	--	1,710	83	38	3.1	8.8	2,010	
7.9	1,440	--	1,180	1,300	35	1.5	7.5	3,220	
				Anderson coal bed					
5.6	860	--	705	1,100	18	3.1	18	2,400	
13	1,500	--	1,230	2,900	36	.9	9.8	5,550	
13	1,150	--	945	1,600	25	.6	12	3,320	
7.5	2,630	--	2,160	6	45	2.1	8.1	2,360	
5.4	1,880	--	1,540	<5	18	1.8	8.6	1,670±	
				Sandstone beds					
11	585	--	480	410	9.0	1.1	16	1,070	Water color turned dark-orangish-brown after pumping for 60 minutes; color filtered out. Apparently water partly from overlying clinker layer.
7.0	1,210	--	990	1,100	20	2.9	8.1	2,690	
5.9	1,930	--	1,580	55	26	4.1	8.6	1,860	
16	486	--	399	2,700	8.8	.5	22	4,080	Water probably a mixture of alluvial and sandstone waters.
5.2	470	--	385	110	4.9	.6	14	556	Log indicates water a mixture of alluvial and sandstone waters; analysis indicates water mostly from sandstone.
6.3	634	--	520	1,300	13	.5	12	2,290	

Table 8.--*Chemical quality of water from private and observation wells open to alluvium*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviations: microsiemens, microsiemens per centimeter at 25° Celsius; TRM, Tongue River Member of Fort Union Formation]

Well No. (pl. 1)	Date sample collected	Depth of contributing aquifer (feet below land surface)	Onsite specific conductance (microsiemens)	Onsite pH	Water temperature (degrees Celsius)	Hardness (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)
0-6	08/17/82	7-15	725	7.6	11.0	160	28	23	92	3.5
0-8	08/10/82	3.5-11	4,210	7.3	9.5	1,600	170	280	600	6.6
0-9	08/13/82	9.5-18	4,280	7.1	9.5	1,600	180	280	570	6.2
0-10	08/16/82	14.8-22	3,300	7.2	9.5	1,300	150	220	390	4.7
0-14	07/25/82	28.1-32.5	2,800	7.3	10.0	930	140	140	350	5.0
0-15	08/14/82	13.8-18.5	2,700	7.2	9.0	970	140	150	310	4.3
0-16	09/23/82	11.5-14	2,750	7.2	9.0	960	120	160	350	4.9
0-17	07/30/82	11.1-13	2,800	--	9.0	980	130	160	340	4.7
0-18	08/11/82	10.5-15	2,800	7.2	9.0	940	130	150	340	4.8
0-19	07/27/82	9.5-14	2,900	7.4	9.0	890	110	150	380	5.5
0-20	08/12/82	18.4-23.5	3,050	7.3	10.5	1,000	130	170	370	5.0
0-21	10/20/82	12.6-19.9	2,900	7.4	10.6	1,100	160	170	330	4.3
0-22	10/19/82	17.1-25.5	2,800	7.6	10.6	1,100	140	170	320	4.3
0-23	09/23/82	19.9-29	2,700	7.5	9.9	1,000	140	160	330	4.5
0-26	06/23/82	18.9-20.5	4,000	7.5	10.0	1,600	190	280	430	4.7
0-27	06/24/82	22-26.6	4,200	7.4	10.0	1,600	180	280	480	5.2
0-28	06/23/82	15.6-17.4	11,000	7.1	10.0	3,100	300	580	2,300	18
0-29	06/22/82	6-10	5,800	7.4	10.0	1,100	160	180	980	13
0-30	06/24/82	6.7-10.5	5,100	7.2	9.0	2,000	250	320	640	6.3
P-9	06/26/80	10±-51±	2,300	7.3	10.0	1,200	150	190	150	1.9
0-39	06/22/82	8.6-13	3,600	7.3	9.1	900	120	140	540	7.8
0-40	09/24/82	15.2-19.5	3,550	7.2	9.5	920	120	150	580	8.3

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CaCO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, sum of constituents	Remarks
7.6	291	--	239	140	6.2	1.3	24	470	Clinker and clinker gravel water.
17	833	--	683	2,100	20	.8	20	3,620	
14	800	--	656	2,100	20	.7	19	3,580	
13	790	--	648	1,400	14	.9	19	2,600	
8.6	594	--	487	1,200	9.1	1.0	20	2,160	
5.6	584	--	479	1,100	9.7	.5	18	2,020	
6.2	627	--	514	1,200	9.5	1.1	20	2,180	
6.1	620	--	508	1,200	9.6	.9	19	2,170	
6.7	616	--	505	1,100	9.8	.9	19	2,060	
8.8	661	--	542	1,200	10	1.4	17	2,200	
5.5	606	--	497	1,300	10	.5	18	2,310	Mixture of alluvial and Anderson coal-bed waters.
5.3	604	--	495	1,300	10	.5	18	2,290	Mixture of alluvial and Anderson coal-bed waters.
5.1	621	--	509	1,200	10	.5	19	2,170	Mixture of alluvial and Anderson coal-bed waters.
7.3	613	--	503	1,100	11	.6	21	2,070	Mixture of alluvial and Anderson coal-bed waters; probably predominantly coal-bed waters.
4.2	654	0	536	2,000	15	.9	12	3,260	
4.3	677	0	555	2,100	16	1.0	12	3,440	
24	1,070	0	881	6,400	38	1.8	13	10,100	Mixture of alluvial and weathered Anderson coal-bed waters.
10	915	0	750	2,600	19	.9	14	4,360	
8.2	644	0	528	2,700	23	.7	13	4,270	
4.7	526	0	431	1,000	17	.2	11	1,780	Probably equal mixture of alluvial and TRM sandstone waters.
4.3	687	0	563	1,500	19	1.4	14	2,710	
11	1,030	--	844	1,400	16	.9	11	2,800	

Table 9.--*Hydrologic data for springs in and near the Little Bear Creek area*

[gal/min, gallons per minute]

Spring No. (pl. 1)	Spring name	Location	Materials from which spring issues	Remarks
S-1	"Hoover" spring	NE¼SE¼SE¼SE¼ sec. 25, T. 7 S., R. 44 E.	Anderson clinker	Discharge -- 0.4 gal/min in June 1984. Pipe into hillside.
S-2	"Wilcox" spring	NE¼SW¼NW¼NW¼ sec. 33, T. 7 S., R. 44 E.	Anderson clinker	Discharge -- 5 gal/min in October 1980. Pipe into hillside.
S-3	Little Bear Creek Spring	NE¼SE¼SW¼SW¼ sec. 36, T. 7 S., R. 44 E.	Anderson clinker	Discharge variable. Multiple openings. Pipe into hillside on southwest side; other openings across valley to northeast.
S-4	"Dynamite Dugout" spring	NE¼NW¼SW¼SW¼ sec. 31, T. 7 S., R. 45 E.	Anderson clinker	Discharge variable -- was 0.07 gal/min in August 1982. Pipe crosses valley to southwest hillside, then up hill to trench.
S-5	Handley Spring	NE¼SE¼NW¼SE¼ sec. 31, T. 7 S., R. 45 E.	Anderson clinker	Discharge reported stable -- was 0.6 gal/min in June 1980. Pipe into hillside toward northwest.
S-6	"Tanner" spring	NE¼SE¼NW¼NW¼ sec. 2, T. 8 S., R. 44 E.	Anderson clinker	Discharge variable -- was 11 gal/min in November 1973, 3 gal/min in June 1980, and almost zero in August 1982.
S-7	"Homestead" spring	SE¼SE¼NW¼SE¼ sec. 9, T. 8 S., R. 44 E.	Alluvium and sandstone beds above Anderson coal bed.	Not developed. Discharge variable; seeps into Little Bear Creek channel.

Table 9.--*Hydrologic data for springs in and near the Little Bear Creek area*--Continued

Spring No. (pl. 1)	Spring name	Location	Materials from which spring issues	Remarks
S-8	"Middle Davidson Draw" spring	NE¼NE¼SW¼NE¼ sec. 12, T. 8 S., R. 44 E.	Probably alluvium.	Discharge seasonally variable -- was 7 gal/min in February 1974, 5.5 gal/min in June 1980, and 4.0 gal/min in June 1982. Pipe into side of terrace.
S-9	Mud Springs	NW¼SE¼NW¼SE¼ sec. 25, T. 8 S., R. 44 E.	Sandstone near top of Tongue River Member.	Discharge -- 5 gal/min in November 1974.
S-10	"Lower Davidson Draw" spring	NE¼NE¼NW¼NW¼ sec. 6, T. 8 S., R. 45 E.	Alluvium; water probably from Canyon coal bed.	Discharge fairly constant -- was 3.4 gal/min in October 1982. Pipe into side of terrace.

Table 10.--*Chemical quality of water from springs and a stream in and near the Little Bear Creek area*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviation: microsiemens, microsiemens per centimeter at 25° Celsius]

Site No. (pl. 1)	Designation	Date sample collected	Onsite specific conductance (microsiemens)	Onsite pH	Water temperature (degrees Celsius)	Hardness (as $CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)
S-1	"Hoover" spring	06/30/84	965	7.4	12.0	260	52	30	120	3
S-2	"Wilcox" spring	10/07/80	1,600	7.9	11.0	440	73	64	250	5
S-3	Little Bear Creek Spring	07/23/82	835	8.9	10.0	240	30	39	100	3
S-4	"Dynamite Dugout" spring	08/16/82	1,060	7.6	10±	320	55	45	120	3
S-5	Handley Spring	06/29/80	600	7.1	10±	230	51	26	44	1
S-6	"Tanner" spring	06/26/80	1,650	8.2	9.0	270	28	48	290	8
S-8	"Middle Davidson Draw" spring	06/22/82	4,600	7.2	8.5	1,900	260	290	510	5
S-9	Mud Springs	02/27/74	--	7.2	10±	810	180	200	410	5
S-10	"Lower Davidson Draw" spring	10/20/82	4,200	7.9	11.0	1,500	190	250	550	6
SW-1	Little Bear Creek flow near well O-8	08/16/82	3,620	7.9	--	1,200	120	230	470	6

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CaCO_3$)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, sum of constituents	Remarks
7.4	501	0	411	110	3.3	0.9	16	594	Developed. Used for watering stock.
10	522	0	428	530	6.7	1.0	27	1,210	Developed. Used for domestic water.
8.6	210	--	172	270	2.9	.9	12	567	Developed. Used for watering stock.
6.8	476	--	390	210	7.6	2.3	19	701	Developed. Used for watering stock.
7.0	279	0	229	92	5.0	.6	27	390	Developed. Used for watering stock.
9.3	512	12	439	410	13	2.8	21	1,080	Developed. Used for watering stock.
8.9	627	0	514	2,500	19	.8	15	3,880	Developed. Used for watering stock.
7.1	986	0	809	1,300	8.3	.2	15	3,160	Developed. Used for watering stock.
14	685	--	562	2,000	17	.6	19	3,380	Developed. Used for watering stock.
14	649	--	532	1,700	16	.7	11	2,880	Stream at low flow.