WATER RESOURCES AND EFFECTS OF POTENTIAL SURFACE COAL MINING ON DISSOLVED SOLIDS IN HANGING WOMAN CREEK BASIN, SOUTHEASTERN MONTANA

By M.R. Cannon

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CONVERSION FACTORS

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

Multiply inch-pound unit	By	To obtain metric unit
	Length	
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
	Weight	
ton (short)	0.9072	megagram
	Flow	
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
gallon per minute (gal/min)	0.06309	liter per second
	Gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer
	Hydraulic Conductivity	
foot per day (ft/d)	0.3048	meter per day
	Transmissivity	
foot squared per day	0.09290	meter squared per day
	Load	
ton per day (ton/d)	0.9072	megagram per day
ton per year (ton/yr)	0.9072	megagram per year

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

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

National Geodetic Vertical Datum of 1929 (NGVD of 1929)--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level."

WATER RESOURCES AND EFFECTS OF POTENTIAL SURFACE COAL MINING ON DISSOLVED SOLIDS IN HANGING WOMAN CREEK BASIN, SOUTHEASTERN MONTANA

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ABSTRACT

Hanging Woman Creek, a tributary to the Tongue River, drains an area of 472 square miles in the coal-rich Powder River structual basin of southeastern Montana and northeastern Wyoming. A 2-year study was conducted in the Montana part of the Hanging Woman Creek basin to characterize the ground-water and surface-water resources of the area and to assess the effects that large-scale surface coal mining could have on the dissolved solids of these water resources.

Ground-water resources of the area include Holocene and Pleistocene alluvial aquifers in the Hanging Woman Creek valley and sandstone, coal, and clinker aquifers in the Tongue River Member of the Paleocene Fort Union Formation. Aquifers of the area supply water for stock and domestic use. Surface-water resources are composed of Hanging Woman Creek and its tributaries, plus many small stock ponds. Water from Hanging Woman Creek is used for watering livestock and limited irrigation of crops.

Dissolved-solids concentrations in ground water ranged from 200 to 11,000 milligrams per liter. Generally, water in alluvial aquifers had the largest concentrations and water in clinker aquifers had the smallest concentrations. Dissolved-solids concentrations in Hanging Woman Creek generally were largest in the upstream part of the study area and smallest in the downstream part. Near its mouth, Hanging Woman Creek had a median dissolved-solids concentration of about 1,800 milligrams per liter.

Mining of the 20- to 35-foot-thick Anderson coal bed and the 3- to 16-foot-thick Dietz coal bed from a large part of the drainage would have the potential to increase the dissolved-solids concentrations in shallow aquifers and in Hanging Woman Creek through the leaching of soluble minerals from mine spoils. Analysis of saturated-paste extracts from 158 coal-overburden samples from 29 sites indicated that water moving through mine spoils would have a median increase in dissolved-solids concentration of 3,700 milligrams per liter. This concentration would result in an additional dissolved-solids load to Hanging Woman Creek of about 3.0 tons per day.

Hanging Woman Creek near Birney (located near the stream mouth) could have an annual post-mining dissolved-solids load of about 3,415 tons at median discharge. The increased load to the stream from mine spoils would be a 47-percent increase from the pre-mining load of 2,320 tons. Monthly loads of Hanging Woman Creek near Birney, at median discharge, could have a post-mining increase ranging from 26 percent in April to

129 percent in August. Post-mining concentrations of dissolved solids, at median discharge, could range from 2,380 milligrams per liter in March to 3,940 milligrams per liter in August, compared to median pre-mining concentrations that ranged from 1,700 milligrams per liter in July, November, and December to 2,060 milligrams per liter in May. Post-mining concentrations would be greater than these monthly values for discharge less than the median and would be smaller for discharge greater than the median. Post-mining concentrations and loads in Hanging Woman Creek near Birney would be smaller than predicted if the Anderson and Dietz coal beds were not mined from all delineated areas.

INTRODUCTION

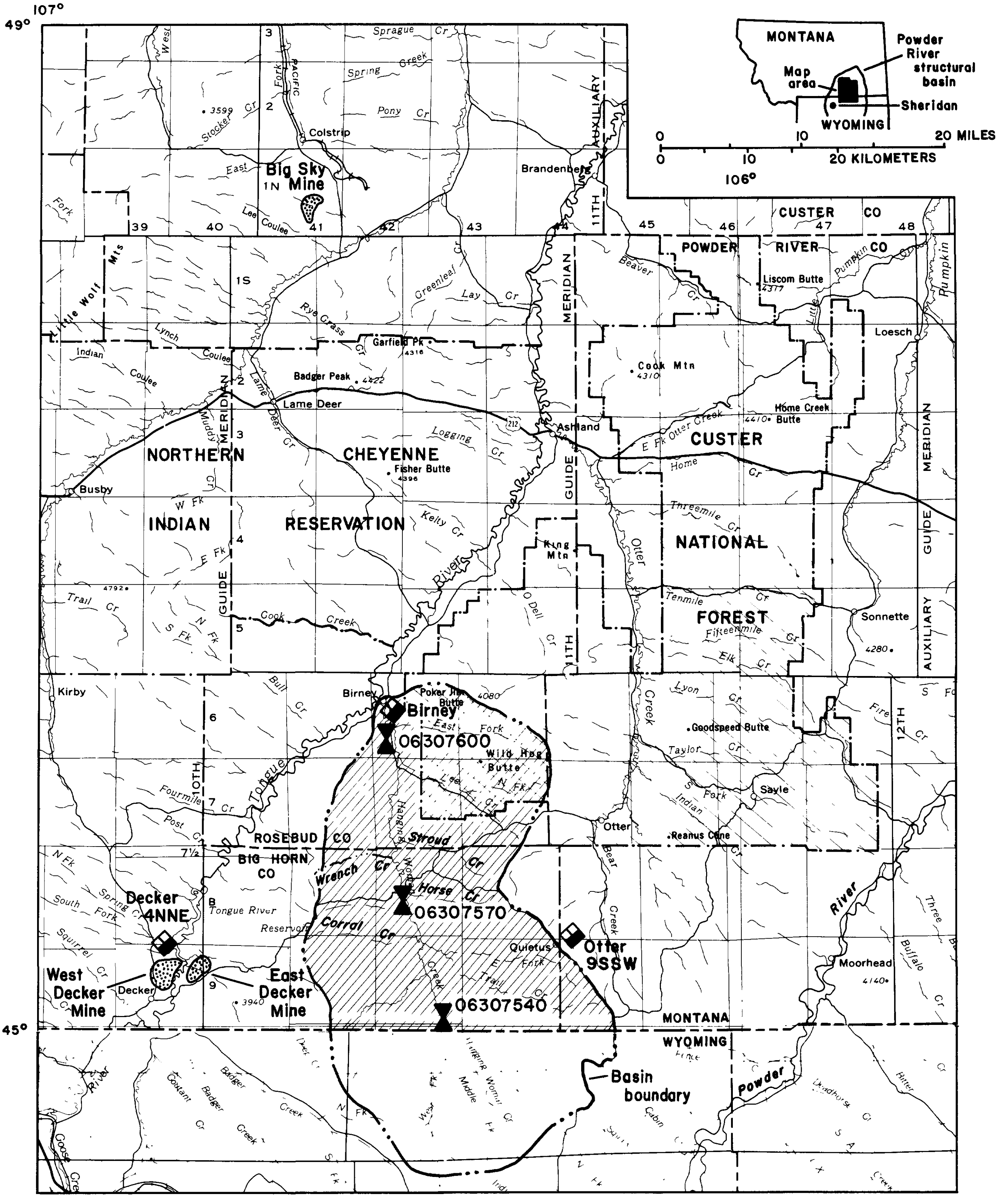
Hanging Woman Creek is a small perennial tributary to the Tongue River in the coal-rich Powder River structural basin in southeastern Montana and northeastern Wyoming (fig. 1). Within the Hanging Woman Creek basin are vast reserves of low-sulfur surface-minable coal that have a good potential for future development. The thickest and most accessible coal deposits are within the Montana part of the basin, where most of the coal is Federally owned and much of the land surface is privately owned.

Surface coal mining in the Hanging Woman Creek basin has the potential to increase the salinity of water in shallow aquifers and in Hanging Woman Creek, thereby decreasing the suitability of the water for agriculture and domestic supply. Surface coal mining would remove coal and sandstone aquifers and replace them with mine spoils. After mining, ground water would flow through mine spoils and could transport large concentrations of dissolved solids to downgradient aquifers and Hanging Woman Creek. An increase in salinity in Hanging Woman Creek would add to the dissolved-solids load of the Tongue River, potentially affecting many downstream water users.

Prior to leasing of Federal coal, the U.S. Bureau of Land Management is required to evaluate the environmental effects of coal leasing and mine development. In 1986, the U.S. Geological Survey, in cooperation with the Bureau of Land Management, initiated a study in the Hanging Woman Creek area to identify water resources and evaluate potential effects of mining on the water resources. Results of the study will be used by the Bureau of Land Management to aid in coal-leasing decisions and long-term management of the coal resources.

EXPLANATION FOR FIGURE 1

(hatched box)	STUDY AREA
Big Sky Mine	COAL MINE AND NAME
06307600	COMBINATION STREAMFLOW-GAGING AND QUALITY-OF-WATER STATION AND NUMBER
Otter 9SSW	PRECIPITATION STATION--Name and number



Base modified from U.S. Geological Survey State base map, 1:500,000, 1968

Figure 1.--Location of the Hanging Woman Creek study area.

Purpose and Scope

The purpose of this report is to present the results of a 2-year study to identify the water resources in the Hanging Woman Creek basin of Montana and to assess the effects that large-scale surface mining of the Anderson and Dietz coal beds could have on the dissolved-solids concentrations of these water resources. Specific objectives were to: (1) identify the availability and use of water in shallow (near-surface) aquifers and in Hanging Woman Creek, (2) determine the quality of water in shallow aquifers and in Hanging Woman Creek, with emphasis on dissolved-solids concentrations, (3) estimate the increase in dissolved-solids concentrations that could occur in water moving through mine spoils, and (4) estimate the post-mining dissolved-solids load transported from the Hanging Woman Creek basin.

The water resources of the Hanging Woman Creek area were characterized from many existing data and from new data collected during water years 1986-87 (Oct. 1985 through Sept. 1987). Ground-water data were obtained for 167 wells and springs; 10 of these wells were installed during this study. Streamflow and water-quality data for Hanging Woman Creek were obtained for water years 1974-84 and 1986-87.

Overburden samples consisting of soil and rock from 29 test holes and wells were analyzed in a laboratory to determine concentrations of soluble minerals. Concentrations of soluble minerals in the overburden were used to estimate the concentrations of dissolved solids that could develop in water of mine spoils. The post-mining loads of dissolved solids in Hanging Woman Creek were calculated by adding the potential dissolved-solids load from mine spoils to the pre-mining loads of Hanging Woman Creek near Birney (station 06307600).

Location and Description of Area

The Hanging Woman Creek study area consists of about 329 mi^2 of the Hanging Woman Creek drainage basin in Big Horn, Rosebud, and Powder River Counties, Montana (fig. 1). The study area is bounded by the drainage basin divide on the west, north, and east, and by the Montana-Wyoming State line on the south. The Wyoming part of the drainage basin has an area of about 143 mi^2, but was not included in the study area because it does not contain known reserves of surface-minable coal (U.S. Geological Survey, 1974). The northeastern part of the study area is within the Custer National Forest. Much of the national forest contains surface-minable coal, but the forest was not studied in detail because the coal cannot be mined, as stated in the "Surface Mining Control and Reclamation Act of 1977" (Public Law 95-87).

The community of Birney is located at the northern end of the study area, where Hanging Woman Creek enters the Tongue River. Sheridan, Wyoming, located about 25 mi southwest of the study area, is the largest population center of the region. The coal mines near Decker, which are located about 9 mi west of the study area near the Tongue River, are the nearest active coal mines. The mines are large surface-coal mines that produced 10.4 million tons of sub-bituminous coal in 1987 (Montana Department of Labor and Industry, 1987).

Topography and Drainage

Hanging Woman Creek is a northward-flowing tributary to the Tongue River and has a drainage area of 472 mi^2. The downstream reach of Hanging Woman Creek, from

Trail Creek to the mouth, is perennial except during extended drought; the reach upstream from Trail Creek commonly is dry or has only ponded water by late summer. Almost all tributaries to Hanging Woman Creek are ephemeral, flowing only in response to rainfall or snowmelt. Some tributaries receive water from springs and contain flowing water for short distances.

The land surface in much of the southern (upstream) one-half of the basin is characterized by a continuous expanse of grass-covered ridges and valleys with many small buttes along ridgetops. The general slope of this part of the basin is moderate (60-110 ft/mi), rising from an altitude[1] of about 3,600 ft along Hanging Woman Creek to about 4,500 ft along the higher parts of the drainage divide in Wyoming.

The land surface in the northern part of the basin is more rugged and partly forested, with many steep-sided ridges and buttes and narrow valleys. On the west side of Hanging Woman Creek, tributaries 2 to 4 mi long steeply descend from an altitude of about 3,950 ft along the drainage divide to about 3,150 ft in Hanging Woman Creek valley. Hanging Woman Creek meanders within a relatively flat alluvial valley. Generally, the valley floor has a width of 1,000 to 2,000 ft and slopes about 22 ft/mi. The valley has an altitude of about 3,120 ft at its northern end where Hanging Woman Creek flows into the Tongue River.

Climate

The Hanging Woman Creek area has a semiarid climate typical of the northern Great Plains. Average annual precipitation within the basin is 13 to 19 in., and the higher altitudes receive the greatest precipitation. Mean annual precipitation for 1974-87 (fig. 2) was 13.1 in. near Decker (3,500 ft altitude), 13.9 in. at Birney (3,160 ft altitude), and 19.0 in. near Otter (4,060 ft altitude). May and June generally have the greatest monthly precipitation and together receive about 35 percent of the annual precipitation (fig. 3). The average annual lake evaporation is about 40 in., or almost 3 times as much as the average annual precipitation (Farnsworth and others, 1982). Air temperatures have an annual range from about -35° to +100 °F. The monthly average air temperatures range from about 19 °F in January to about 72 °F in July (National Oceanic and Atmospheric Administration, 1974-87).

General Geology

Sedimentary rocks of the Tongue River Member of the Fort Union Formation (Paleocene age) are exposed at the surface in most of the study area and underlie the entire area. In the southern part of the area, sedimentary rocks of the Wasatch Formation (Eocene age) cap the higher buttes and ridges (see pl. 1). The valleys of Hanging Woman Creek and its tributaries contain alluvium (Holocene and Pleistocene age) derived from sandstone, shale, and clinker of the Fort Union and Wasatch Formations.

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[1]Altitude, as used in this report, refers to distance above the National Geodetic Vertical Datum of 1929.

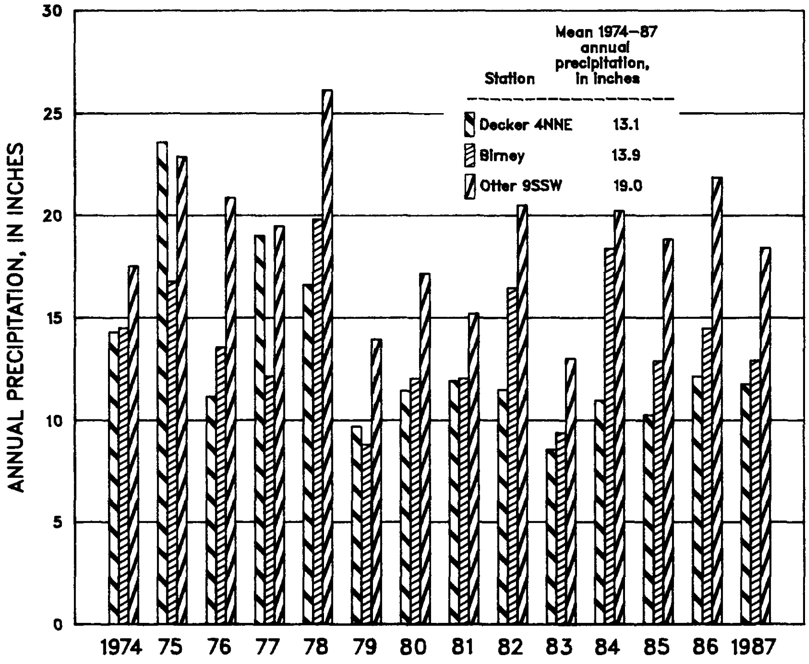

Figure 2.--Annual precipitation at three climatological stations near the Hanging Woman Creek basin. The location of the stations is shown in figure 1. Data from National Oceanic and Atmospheric Administration (1974-87).

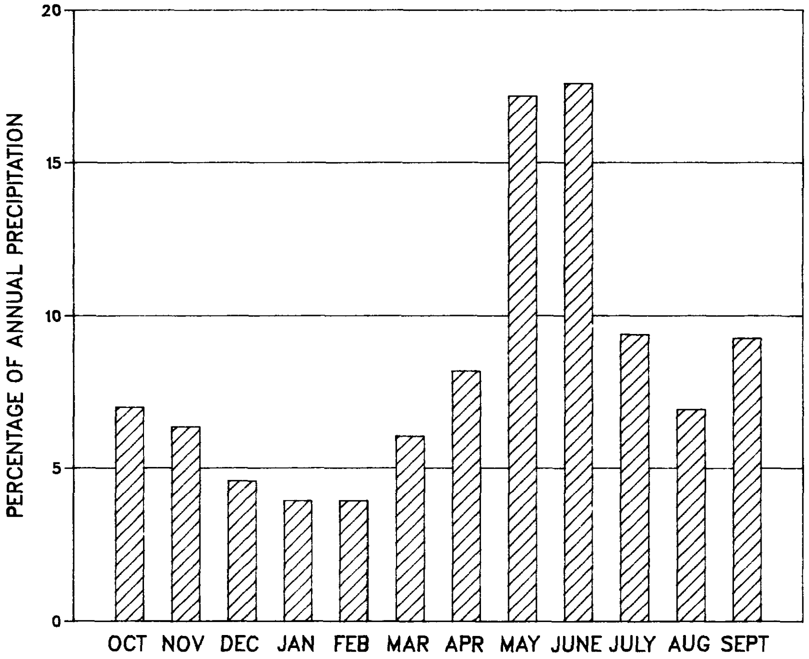

Figure 3.--Mean monthly distribution of precipitation at Birney, 1974-87. Data from National Oceanic and Atmospheric Administration (1974-87).

The Tongue River Member consists of light-yellow to gray sandstone, sandy shale, gray shale, and coal. The member contains numerous coal beds (fig. 4) ranging in thickness from about 1 to 35 ft. Total thickness of the member generally is 1,400 to 1,600 ft. In the study area, the upper 1,100 ft of the Tongue River Member is exposed, which includes the interval from the base of the Brewster-Arnold coal bed to the top of the Roland coal bed (see fig. 4 and pl. 2 for names of coal beds). Thick beds of fractured, red clinker are present where the Anderson and Dietz coal beds have burned along their outcrops.

The Wasatch Formation consists of grayish-brown and gray shale, some carbonaceous shale, and thin beds of brown calcareous sandstone (Bryson and Bass, 1973). Clam and snail shells are abundant in several sandstone beds. The boundary between the Fort Union and Wasatch Formations is placed at the top of the Roland coal bed. Only about 250 ft of the basal part of the Wasatch Formation is present in the study area. However, the interval is thicker in the higher parts of the Hanging Woman Creek basin in Wyoming.

Alluvium underlying the valley of Hanging Woman Creek and many of its tributary valleys consists of sand, silt, gravel, and clay. Alluvium penetrated during drilling in Hanging Woman Creek valley has a thickness ranging from 0 to 65 ft. At some locations, the alluvium contains a large thickness of well-sorted, coarse sand and gravel derived from fragments of hard clinker.

The study area is in the northern part of the Powder River structual basin and is nearly centered on the north-south axis of the basin. Rocks of the study area dip predominantly to the south, generally at less than 3 degrees. Because the area is nearly centered on the axis of the basin, rocks in the western part of the area dip south-southeast and those in the eastern part of the area dip south-southwest. Regional dips of the area are readily apparent in the hydrogeologic sections (pl. 2). Several northeast-trending normal faults are located in the southern part of the study area (pl. 1). The largest of these faults has displaced the rocks on the south side downward as much as 260 ft.

Previous Investigations

Hanging Woman Creek and the surrounding area have been the focus of many investigations, primarily because of the vast coal reserves of the region. The study area includes parts of three coal fields that were studied and described in detail by the U.S. Geological Survey as part of a systematic study and classification of western coal lands. The northernmost part of the study area is within the Birney-Broadus coal field (Warren, 1959), the eastern part is in the Moorhead coal field (Bryson and Bass, 1973), and the western part is in the northward extension of the Sheridan coal field (Baker, 1929). Matson and Blumer (1973) described the quality and quantity of surface-minable coal in the Hanging Woman Creek area in a comprehensive report on surface-minable coal deposits of southeastern Montana. The geology of the Anderson and Dietz coal beds was described in a report by Cole and Sholes (1980). Coal sections and detailed geologic maps at a scale of 1:24,000 have been completed for much of the area including the Stroud Creek quadrangle (Culbertson and others, 1976), the Pine Butte School quadrangle (Mapel, 1978), the Forks Ranch quadrangle (Culbertson and Klett, 1979a), and the Quietus quadrangle (Culberton and Klett, 1979b). Lithologic logs for drill holes in the area were published in reports by the U.S. Geological Survey and the Montana Bureau of Mines and Geology (1977, 1982). Correlation of coal beds from lithologic logs of many drill holes in the area was reported by Hansen and Culbertson (1985).

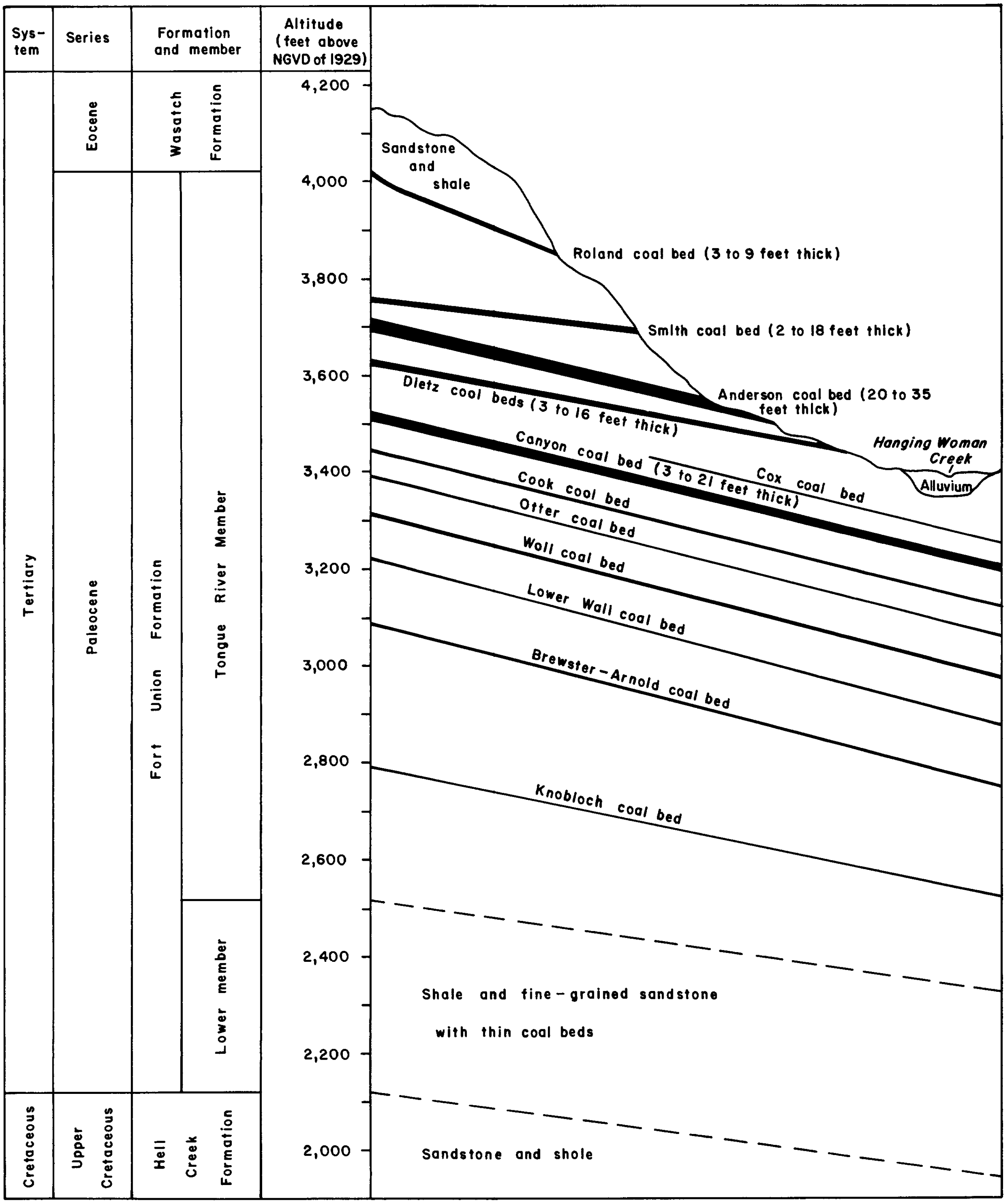

Figure 4.--Idealized composite section of the Hanging Woman Creek basin showing relative positions of coal beds in the Tongue River Member of the Fort Union Formation.

The vital water resources of the area have been the subject of many studies. Ground-water resources and the hydrologic characteristics of rocks were studied by Lewis and Roberts (1978) and Stoner and Lewis (1980). Ground-water data from wells in the region have been compiled by Slagle and Stimson (1979) and Wood (1984). Slagle and others (1983) prepared a comprehensive summary of hydrologic data for Hanging Woman Creek and the surrounding region. Chemical quality of ground water and geochemical processes that control the quality of water in the Fort Union Formation have been investigated by Lee (1979, 1981) and Dockins and others (1980). Streamflow characteristics for all gaged streams in the area were reported by Omang (1984) and quality of streamflow was reported by Knapton and Ferreira (1980).

Concerns that coal mining may degrade water resources or conflict with traditional uses of water in the region have spawned a number of studies to determine effects of coal mining on ground and surface waters. Van Voast (1974) and Van Voast and Hedges (1975) studied the effects of coal mining on water resources in the Decker area. Woods (1981) developed a computer model to assess potential increases in dissolved-solids concentration in the Tongue River as a result of leaching of mine spoils. Another study of the effects of mining on the water quality of the Tongue River was conducted by Van Voast and Thompson (1982). McClymonds (1984, 1985) studied the potential effects of surface coal mining on the hydrology of the drainage basins of Corral Creek and Horse Creek, which are tributaries of Hanging Woman Creek. East Trail Creek, another tributary of Hanging Woman Creek, was the site of a comprehensive study of the hydrology and geochemistry of a potential coal-lease tract (U.S. Department of the Interior, 1978).

Well and Spring Numbering System

In this report, well and spring locations are numbered according to geographic position within the rectangular grid system used by the U.S. Bureau of Land Management (fig. 5). The number consists of 14 characters. The first three characters specify the township and its position south (S) of the Montana Base Line. The next three characters specify the range and its position east (E) of the Montana Principal Meridian. The next two characters are the section number. The next four characters designate the quarter section (160-acre tract), quarter-quarter section (40-acre tract), quarter-quarter-quarter section (10-acre tract), and quarter-quarter-quarter-quarter section (2.5-acre tract), respectively, in which the well or spring is located. The subdivisions of the section are designated A, B, C, and D in a counterclockwise direction, beginning in the northeast quadrant. The last two characters form a sequence number. For example, as shown in figure 5, well 08S43E16CCDA01 is the first well inventoried in the NE1/4SE1/4SW1/4SW1/4 sec. 16, T. 8 S., R. 43 E.

Acknowledgments

The author wishes to acknowledge the cooperation of residents in the study area who provided access to their lands and information about wells and springs. Special acknowledgment goes to Arthur and Marilynn Hayes, James and Sally Gilliland, and the Kendrick Cattle Company.

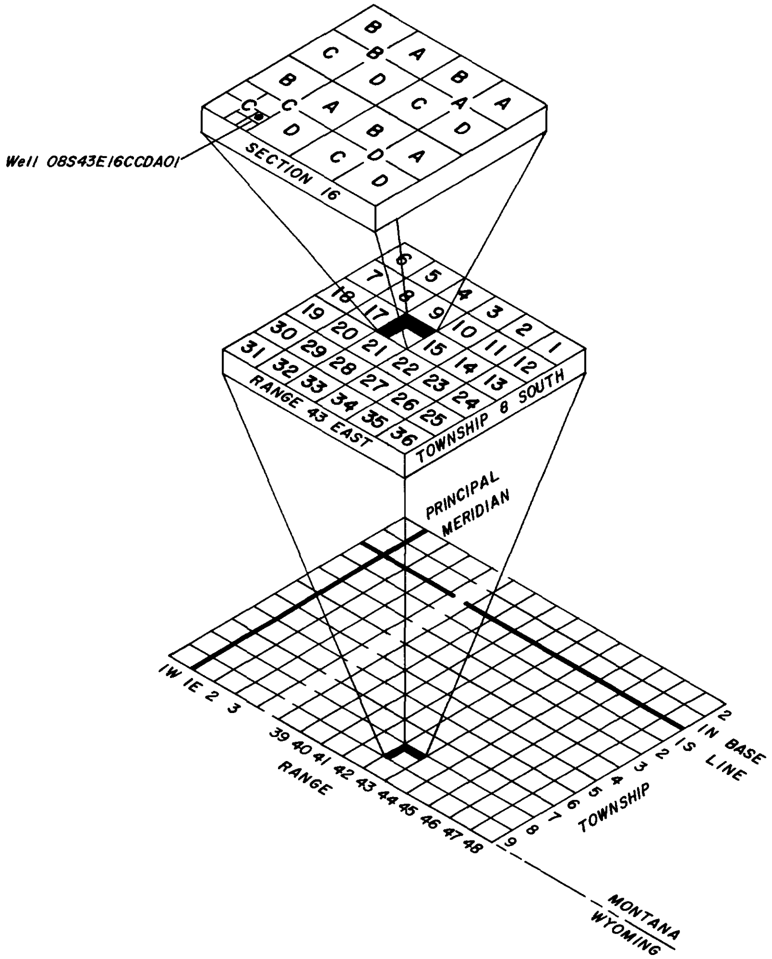

Figure 5.--Well and spring numbering system.

GROUND-WATER RESOURCES

Water Supply and Use

Principal aquifers in the Hanging Woman Creek area exist in alluvium, coal, sandstone, and clinker. Alluvial aquifers are located in the valleys of Hanging Woman Creek and its principal tributaries, including East Fork, Lee Creek, Horse Creek, Corral Creek, and Trail Creek. Alluvial aquifers in these valleys typically are from 10 to 50 ft thick and contain sufficient saturated sand and gravel for development of stock wells. Wells completed in alluvium generally yield 2 to 30 gal/min. Water from alluvial aquifers is used primarily for livestock; generally it is not used for domestic purposes because it is very hard and has concentrations of dissolved solids that exceed 2,000 mg/L (milligrams per liter).

Aquifers in coal and sandstone are present throughout the area and collectively compose the most extensive aquifer zone for stock and domestic wells. Sandstone beds in the Tongue River Member of the Fort Union Formation generally are lenticular and interbedded with shale, resulting in discontinuous sandstone aquifers. However, the many lenticular beds of sandstone, combined with the many beds of fractured coal, create an aquifer zone where water supplies can readily be obtained. Yields of wells in coal and sandstone aquifers generally range from 1 to 20 gal/min, although larger yields are possible from wells penetrating large saturated thicknesses. Most stock and domestic wells in the area are completed in coal or sandstone beds. Water from these wells generally is soft and contains concentrations of dissolved solids in excess of secondary drinking water standards established by the U.S. Environmental Protection Agency (1986), but the water is considered by local residents to be adequate for most domestic purposes. Water from most wells completed in coal and sandstone aquifers had concentrations of dissolved sodium greater than 500 mg/L, making it unsuitable for continuous irrigation of lawns and gardens.

Thick beds of Anderson clinker form aquifers in the central part of the study area where the Anderson coal bed has burned extensively along its outcrop (see pl. 1). Clinker forms discontinuous, generally perched, aquifers because it is very permeable and easily drained of water along the base of its outcrop. Clinker generally is water bearing only in locations favorable to the retention of recharge, and usually only the basal part of the clinker is saturated. Few wells are completed in clinker aquifers because of the extreme difficulty of drilling in clinker and because of the small saturated thickness normally present. Many small springs issue from the Anderson clinker, making it a reliable source of water for livestock. Some clinker springs also are used as a domestic water source because of the relatively good water quality.

Hydrogeologic Properties of Aquifers

Properties of aquifers were determined from a network of 75 observation wells located throughout the Hanging Woman Creek study area. The wells were used for conducting aquifer tests, monitoring water levels, and collecting water samples. Ten of these wells were installed during this study (lithologic logs are presented in table 14; all tables are at the back of the report); the other observation wells were installed during earlier studies of parts of the Hanging Woman Creek basin. In addition to the network of observation wells, data on water levels and water quality were collected from many private wells in the area. All wells having water-level data are listed in tables 1 and 2 and are shown on plate 3.

Alluvial Aquifers

The valley of Hanging Woman Creek contains an extensive alluvial aquifer that is affected by streamflow of Hanging Woman Creek and by ground-water flow systems in adjacent coal and sandstone aquifers. To determine hydraulic properties of the alluvium, aquifer tests were performed at several locations (hydraulic data are presented in table 3). A line of four wells was installed across the valley of Hanging Woman Creek near Birney in sec. 19, T. 6 S., R. 43 E., to evaluate aquifer properties at the downstream end of the valley. Multiple-well drawdown tests (wells AL-1, AL-2, AL-3, and AL-4) at this location indicated hydraulic-conductivity values of 5 to 90 ft/d, which is within the range expected for the silty to clean sand and gravel layers penetrated by the wells. At the upstream end of the study area, in sec. 2, T. 10 S., R. 43 E., single-well drawdown tests were performed at two alluvial wells (wells AL-52 and AL-53). Hydraulic conductivity of the alluvium was 30 ft/d at well AL-52 and 4 ft/d at well AL-53. Two wells (AL-7, AL-8) installed in the valley near the center of the study area in sec. 17, T. 8 S., R. 43 E., were completed in thin layers of silty sand and gravel. Hydraulic conductivity calculated from single-well drawdown tests was 7 ft/d at well AL-7 and 5 ft/d at well AL-8. Two other single-well drawdown tests were performed at wells AL-5 and AL-6 in the downstream part of the Hanging Woman Creek valley. Calculated hydraulic conductivity was 60 ft/d at well AL-5 and 50 ft/d at well AL-6. Both of these wells penetrated relatively clean layers of gravel.

Hydraulic properties of alluvium in several tributaries to Hanging Woman Creek were measured in earlier studies. In the Horse Creek valley, hydraulic-conductivity values from 15 wells ranged from 0.02 to 660 ft/d (McClymonds, 1985). In the Corral Creek area, hydraulic-conductivity values from 15 alluvial wells ranged from 0.4 to 80 ft/d (McClymonds, 1984). Two aquifer tests in alluvium of East Trail Creek yielded hydraulic-conductivity values of 83 and 92 ft/d (U.S. Department of the Interior, 1978).

In general, alluvium of Hanging Woman Creek and its tributaries contains relatively permeable layers of sand and gravel, although in some locations these coarse-grained layers are absent. The geometric mean of hydraulic-conductivity values from 42 alluvial wells is 21 ft/d, with a range of 0.02 to 660 ft/d. Storage coefficients measured from multiple-well drawdown tests in alluvium ranged from 1×10^{-4} to 6×10^{-2} (dimensionless). The small storage coefficients indicate semiconfined conditions in the aquifer. The semiconfined conditions result from the interlayering of fine-grained sediments with the sand and gravel beds in the alluvium.

Aquifers in the Tongue River Member

Data from aquifer tests conducted on 33 wells were used to determine hydraulic properties of coal and sandstone aquifers in the Tongue River Member of the Fort Union Formation. Although coal and sandstone aquifers probably exist throughout the area, most aquifer tests were concentrated in areas of surface-minable coal, so that aquifer characteristics could be determined better for areas that might be mined. Of the 33 wells tested, 29 were completed in coal beds, 2 were completed in sandstone, and 2 were completed in both sandstone and coal (table 3).

Most aquifer tests in coal were single-well drawdown tests in the Anderson or Dietz beds. Multiple-well drawdown tests were made at two sites in the Anderson coal bed. Storage coefficients calculated from the multiple-well tests were 4×10^{-5} at well TR-89 and 5×10^{-4} at well TR-90. Hydraulic-conductivity values of the coal beds ranged from 0.02 to 11 ft/d and had a geometric mean of 0.44 ft/d. Both the smallest and largest values of hydraulic conductivity were measured in the Anderson coal bed. The geometric mean hydraulic conductivity of coal aquifers in the Hanging Woman Creek area compares closely with the geometric mean of 0.90 ft/d determined from 193 hydraulic-conductivity values from Paleocene coal beds at 13 mine sites in the Northern Great Plains (Rehm and others, 1980).

Hydraulic-conductivity values of fine-grained sandstone aquifers in the Tongue River Member are not substantially different from those of coal aquifers. Hydraulic conductivity calculated from single-well drawdown tests was 0.2 ft/d at well TR-28 and 4 ft/d at well TR-66. Mean hydraulic conductivity of sandstone in the Hanging Woman Creek area probably is similar to the geometric mean of 0.35 ft/d reported by Rehm and others (1980) for 70 values of calculated hydraulic conductivity for Paleocene sandstone aquifers in the Northern Great Plains.

Hydraulic-conductivity values from all aquifer tests in Tongue River Member sandstones, coal beds, and combined sandstone-coal beds (33 aquifer tests) have a geometric mean of 0.47 ft/d and a median of 0.40 ft/d. In this report, for calculations of ground-water flow, coal and sandstone aquifers are assumed to have a hydraulic conductivity of 0.47 ft/d.

No values of hydraulic conductivity are available for clinker aquifers in the area. The thick beds of Anderson clinker are extremely fractured and likely have a larger hydraulic conductivity than any other soils or rocks of the area.

Recharge and Discharge

Alluvial Aquifers

Sources of recharge to alluvium in the Hanging Woman Creek valley are lateral flow from adjacent alluvial, coal, sandstone, and clinker aquifers; percolation of precipitation; and infiltration of streamflow. Discharge from alluvium primarily is to streamflow and evapotranspiration, with some discharge downvalley through the alluvium.

Adjacent aquifers provide the major source of recharge to alluvium during much of the time from August to February, when monthly precipitation is least and Hanging Woman Creek has only base flow. Clinker aquifers and coarse-grained alluvial aquifers in tributaries that drain large areas of clinker appear to be the major sources of lateral flow to alluvium along Hanging Woman Creek, based on substantial increases in streamflow where clinker is abundant. Recharge to alluvium directly from percolation of precipitation probably occurs infrequently because of the semiarid climate and the relatively impermeable character of the silty soils that cover most of the coarse-grained alluvial sediments in the Hanging Woman Creek valley. Some areas of valley alluvium receive recharge from streamflow when Hanging Woman Creek normally has its largest annual flows--generally from late February to June.

Movement of water in alluvium is toward Hanging Woman Creek (see water-level contours, pl. 3), where ground-water discharge sustains a small base flow. During most years, net discharge from alluvium to Hanging Woman Creek is estimated to range from 0.3 to 2.0 ft^3/s, as determined from streamflow records at the streamflow-gaging station near Birney (station 06307600).

Evapotranspiration from subirrigated lands in the Hanging Woman Creek valley appears to be a large source of discharge from alluvium. Subirrigated lands comprise about 160 acres for each mile of the Hanging Woman Creek valley; during the growing season, subirrigated vegetation is estimated to consume about 12 in. of water from the alluvial aquifer (Cannon, 1985, p. 15; Lenfest, 1987, p. 9). Mean annual discharge to evapotranspiration, based on these values, is equivalent to 0.22 ft^3/s per mile of valley or 5.3 ft^3/s for the entire Hanging Woman Creek valley in the study area.

Discharge downvalley through the alluvium was calculated for the downstream end of the valley near Birney. In sec. 19, T. 6 S., R. 43 E., four wells (AL-1, AL-2, AL-3, AL-4) and a drill hole (HWC-86-10) were drilled in a line across the valley (lithologic logs in table 14). Discharge, calculated using the Darcy equation (Darcy, 1856; see Lohman, 1972, p. 10) and hydraulic properties measured at the four wells, was 0.07 ft^3/s.

Aquifers in the Tongue River Member

Recharge to coal, sandstone, and clinker aquifers is from percolation of precipitation. The average rate of recharge to coal and sandstone aquifers is very small, because of the small annual precipitation relative to evapotranspiration and the generally small permeability of the fine-grained sediments of the Tongue River Member. Mean annual recharge to the shallow coal and sandstone aquifers is estimated to be in the range of 0.01 to 0.1 in., based on the calculated rates of discharge from these aquifers.

Recharge to clinker aquifers is much greater than to coal and sandstone aquifers, because clinker beds are extremely fractured and more permeable, allowing rapid infiltration of precipitation. Mean annual recharge to clinker probably is in the range of 1 to 2 in.; an annual recharge rate of 1.2 in. was calculated for a clinker aquifer in the Tongue River Member by Woessner and others (1981).

Discharge from shallow coal and sandstone aquifers primarily is to alluvium in Hanging Woman Creek and its tributaries. Additional discharge is to stock and domestic wells, to small seeps and springs, and by downward flow to deeper aquifers. The general direction of ground-water flow, from the upland areas toward discharge areas in the alluvial valleys, is indicated by the water-level contours on plate 3 and the flow-direction arrows on plate 4. Rates of discharge from coal and sandstone aquifers in areas that could be surface mined are shown on plate 4.

Discharge from clinker aquifers is to seeps and springs, to adjacent alluvial aquifers, and to underlying coal and sandstone aquifers. Clinker formed from the burning of the Anderson coal bed is the thickest and most extensive clinker in the area. Many small springs and seeps discharge from the Anderson clinker, especially in the northern part of the Hanging Woman Creek basin where the clinker occupies much of the upland area and crops out along the hillsides. In the upstream part of Stroud Creek basin, small but perennial streamflow is sustained by discharge from the Anderson clinker.

Water Quality

Quality of ground water was determined from the analyses of 56 water samples from 43 wells completed in alluvial aquifers and 108 water samples from 68 wells and 7 springs that produce water from the Tongue River Member of the Fort Union Formation. The water-quality samples were collected between October 1973 and May 1987 as part of several hydrologic studies in the area. Water-quality data for these samples are given in tables 4 and 5. The location of all water-quality sampling sites is shown on plate 3.

The median and mean values of dissolved-solids concentration were calculated for water in aquifers in alluvium and the Tongue River Member. To avoid overemphasizing wells having multiple samples, the median and mean values were computed using one value per well; where there were multiple samples for a well, the mean concentration for the well was used in computing the median and mean of the population.

Alluvial Aquifers

A distinctive characteristic of water from most alluvial aquifers in the study area is the large concentration of dissolved solids. Dissolved-solids concentrations in water from 43 wells ranged from 2,100 mg/L at well AL-8 to 11,000 mg/L at well AL-34. The median concentration was 3,800 mg/L and the mean was 4,680 mg/L.

Wells having the smallest concentration of dissolved solids generally are downgradient from areas of Anderson clinker. The discharge of relatively high quality water from clinker aquifers appears to result in small concentrations of dissolved solids in some alluvial aquifers. The effect of water from the clinker on the dissolved-solids concentration of water in alluvium is distinct in Horse Creek, a major tributary to Hanging Woman Creek. In the upstream part of Horse Creek basin, dissolved-solids concentrations in alluvium were 9,500 and 9,700 mg/L (wells AL-23 and AL-24). In the central part of the basin at wells AL-14 through AL-18, downgradient from the outcrop of the Anderson clinker, dissolved-solids concentrations ranged from 3,400 to 5,800 mg/L. Near the mouth of the basin at wells AL-9 through AL-13, downgradient from a large area of Anderson clinker, water in the alluvium had dissolved-solids concentrations ranging from 2,300 to 2,900 mg/L.

Water in alluvium along Hanging Woman Creek also contains the smallest concentrations of dissolved solids in areas downstream from the Anderson clinker. Wells AL-52 and AL-53, located upgradient from clinker (near the Montana-Wyoming border), produced samples with dissolved-solids concentrations of 7,000 and 6,800 mg/L. Wells AL-1 through AL-8, which are downstream from clinker beds, produced water samples with dissolved-solids concentrations ranging from 2,100 to 4,400 mg/L.

Alluvial water of the area characteristically had large concentrations of magnesium, sodium, and sulfate ions; most would be classified as sodium magnesium sulfate or sodium sulfate type waters. Magnesium concentrations in the 56 water samples ranged from 120 to 720 mg/L. Sodium concentrations ranged from 290 to 2,100 mg/L. Concentrations of sulfate in the samples ranged from 1,000 to 7,300 mg/L.

Water from alluvium is unsuitable for domestic use according to the secondary drinking-water standards established by the U.S. Environmental Protection Agency (1986). The secondary standards apply to all public drinking-water supplies, unless no better supply is available. The secondary standards recommend a maximum concentration of 500 mg/L of dissolved solids and 250 mg/L of sulfate. All water samples from alluvium greatly exceeded these standards.

The suitability of water from alluvium for livestock watering ranges from good to unfit according to a classification system developed by Montana State College, (now Montana State University), Agricultural Experiment Station (McKee and Wolf, 1971, p. 113). The classification system is based on the dissolved-solids concentration of the water: water having a concentration of 0-2,500 mg/L is excellent to good, water having a concentration of 2,500-3,500 mg/L is fair, water having a concentration of 3,500-4,500 is poor, and water having a dissolved-solids concentration greater than 4,500 is classified as unfit. Another classification system, which lists maximum dissolved-solids concentrations for different types of livestock watering, indicates that horses can tolerate about 6,400 mg/L and beef cattle can tolerate about 10,000 mg/L (McKee and Wolf, 1971, p. 112).

Water from alluvial aquifers generally would be classified as not suitable for watering of plants, although plants appear to grow well in some subirrigated parts of the Hanging Woman Creek valley. According to McKee and Wolf (1971, p. 107) the maximum concentration of dissolved solids considered suitable for best crop growths of all types of plants, including salt-susceptible plants, is about 1,000 mg/L. A dissolved-solids concentration of about 3,150 mg/L generally is the maximum for the safe watering of any plant, provided that drainage is excellent and each watering is of sufficient volume to leach the root zone.

Aquifers in the Tongue River Member

Water from coal, sandstone, and clinker aquifers in the Tongue River Member of the Fort Union Formation has a wide range of dissolved-solids concentrations. Dissolved-solids concentrations in water from 68 wells and 7 springs ranged from 200 mg/L at spring SP-4 to 9,500 mg/L at well TR-90 (table 5). The median concentration was 1,900 mg/L and the mean was 2,840 mg/L. Spring SP-4 discharges from the Anderson clinker.

Water samples from coal and sandstone aquifers in the area typically had large concentrations of sodium and generally were sodium bicarbonate or sodium sulfate type waters. Water samples that had the largest concentrations of dissolved solids generally were a sodium sulfate type, similar to water in some alluvial aquifers.

Most water samples collected from aquifers in the Tongue River Member exceeded the secondary drinking-water standards for concentrations of dissolved solids and sulfate (U.S. Environmental Protection Agency, 1986, p. 588). Water samples that did not exceed the secondary standards were from springs SP-4 and SP-6 and well TR-51.

The suitability of water from aquifers in the Tongue River Member for livestock watering ranges from excellent to unfit, based on the dissolved-solids concentration (McKee and Wolf, 1971, p. 113). However, more than one-half of the sites sampled had dissolved-solids concentrations less than 2,500 mg/L and would be classified as excellent to good for all types of livestock watering.

SURFACE-WATER RESOURCES

Water Supply and Use

Hanging Woman Creek and its tributaries, plus many small stock ponds, compose the surface-water resources of the area. Surface water is used primarily for livestock watering and limited irrigation of crops. Most tributaries flow for only short periods after intense rainfall or snowmelt; however, small dams constructed along the tributaries capture the infrequent runoff for use by livestock. Irrigation of crops is limited to the downstream part of Hanging Woman Creek, from about Wrench Creek to the confluence with the Tongue River. Water is diverted from Hanging Woman Creek for irrigation of about 1,240 acres. Generally, irrigation is feasible only during times of greatest runoff in spring or early summer. In some years, runoff is insufficient for even limited irrigation.

Flow Characteristics

Flow characteristics of Hanging Woman Creek were determined from data obtained from a continuous streamflow-gaging station (station 06307600, pl. 4) near Birney, periodic discharge measurements of Hanging Woman Creek below Horse Creek (station 06307570), and occasional inspection of flow in the upstream part of the study area near the Montana-Wyoming border (station 06307540). In general, data collected from these stations indicate that Hanging Woman Creek is characterized by a small but perennial flow downstream from Trail Creek, ephemeral or intermittent flow in the upstream part of the basin, and a small annual runoff coefficient--less than 1 percent of precipitation.

Monthly and annual discharge for Hanging Woman Creek near Birney is summarized in table 6. Monthly mean discharge, computed from 13 years of flow data, ranged from 0.64 ft^3/s in September to 10 ft^3/s in March. About 66 percent of the annual runoff occurred from February through May. Mean annual discharge was 3.9 ft^3/s, which is equivalent to an annual runoff of 0.11 in. over the entire drainage basin. Median discharge for each month was smaller than the mean discharge, indicating the large effect that flows of short duration, but large discharge, have on the mean value.

Maximum discharge during the 13 years of data collection at station 06307600 was 2,060 ft^3/s on May 19, 1978. No flow was reported on many days during the period of record, including most days in August and September 1981 and July, August, and September 1983. Daily mean discharge of Hanging Woman Creek during this study (water years 1986-87) is shown in figure 6.

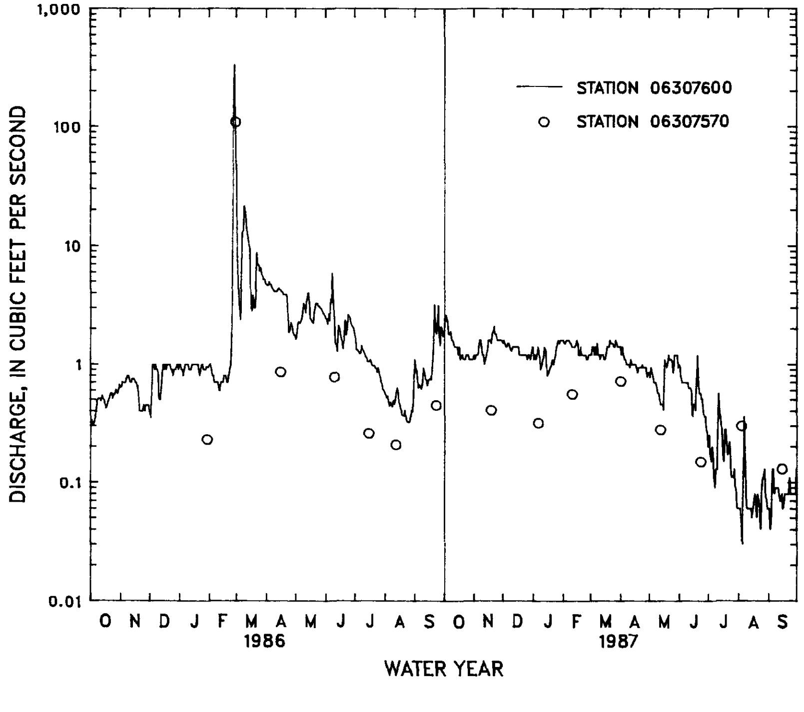

Figure 6.--Daily mean discharge of Hanging Woman Creek near Birney (station 06307600) and measured discharge of Hanging Woman Creek below Horse Creek (station 06307570), water years 1986 and 1987.

The percentage of time that a given discharge was equalled or exceeded is shown by the flow-duration curve for Hanging Woman Creek near Birney (fig. 7). The

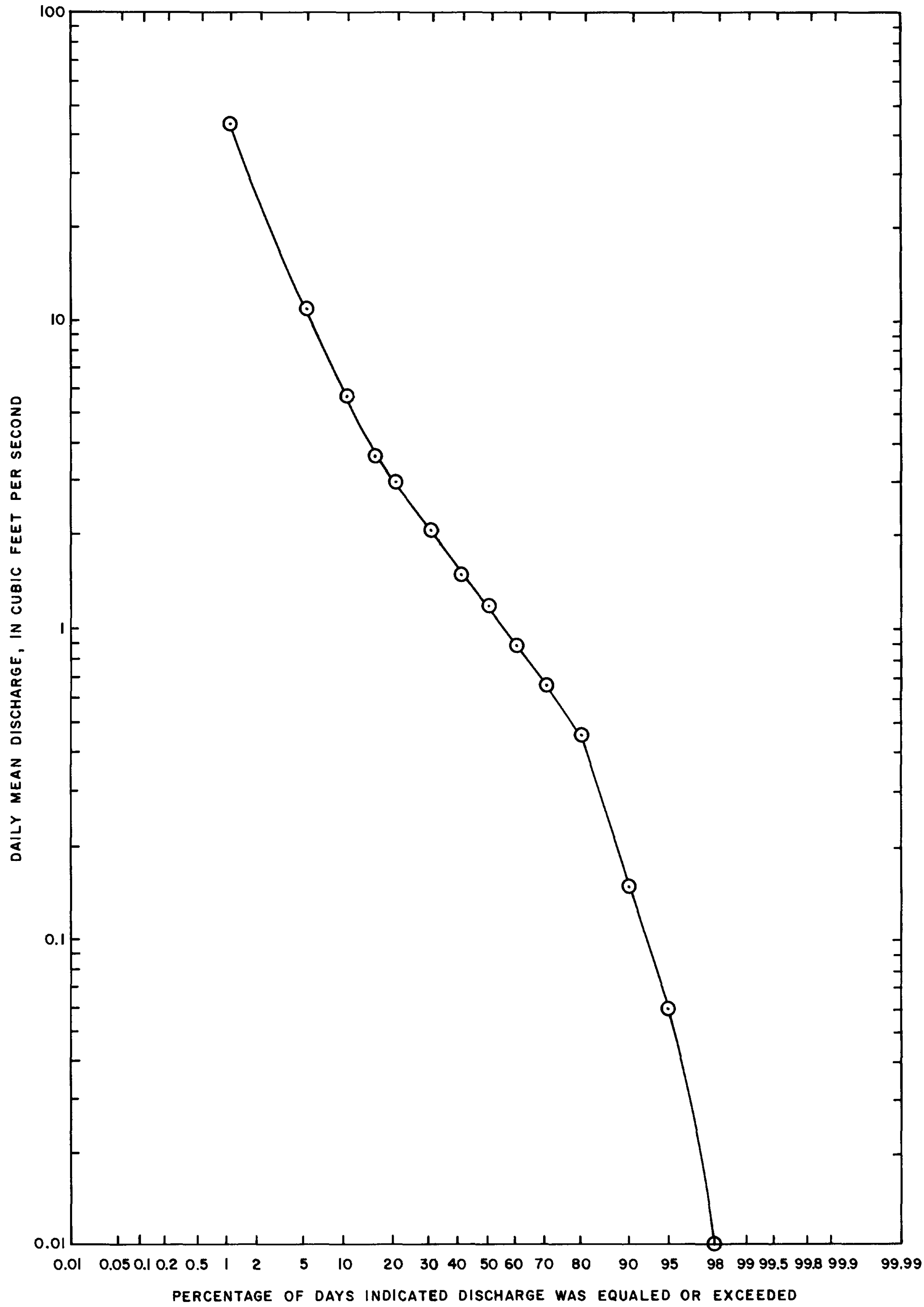

Figure 7.--Flow-duration curve of Hanging Woman Creek near Birney (station 06307600). Curve based on data from water years 1974-84 and 1986-87.

curve indicates that 90 percent of the time, discharge was 0.15 ft^3/s or greater; 50 percent of the time, discharge was 1.2 ft^3/s or greater; and 10 percent of the time, discharge was 5.7 ft^3/s or greater.

Discharge was periodically measured on Hanging Woman Creek at station 06307570, located about 13.2 mi south of Birney and downstream from the mouth of Horse Creek. Discharge data were collected at the station from 5 to 9 times per year, for water years 1978-83 and 1986-87. Discharge measurements made during this study are shown in figure 6.

Inspection of Hanging Woman Creek near the Montana-Wyoming border indicated that there commonly was no flow during much of the summer and fall. Water remained in the stream channel, but it was ponded or stagnant.

Water Quality

Quality of water in Hanging Woman Creek was determined from analysis of water samples collected periodically at three sites, plus daily measurements of specific conductance at one of these sites. The water-quality sites (pl. 4) are located on Hanging Woman Creek near Birney (station 06307600), Hanging Woman Creek below Horse Creek (station 06307570), and Hanging Woman Creek at the State line (station 06307540). Daily measurements of specific conductance were made at the Birney station, the only station that also recorded daily data for computation of stream discharge. Daily values of specific conductance for water years 1986-87 are shown in graphical form in figure 8. Water-quality data for samples collected during this study at stations 06307600 and 06307570 are given in tables 7 and 8. Water-quality data for station 06307540 at the State line were collected prior to this study and are given in table 9.

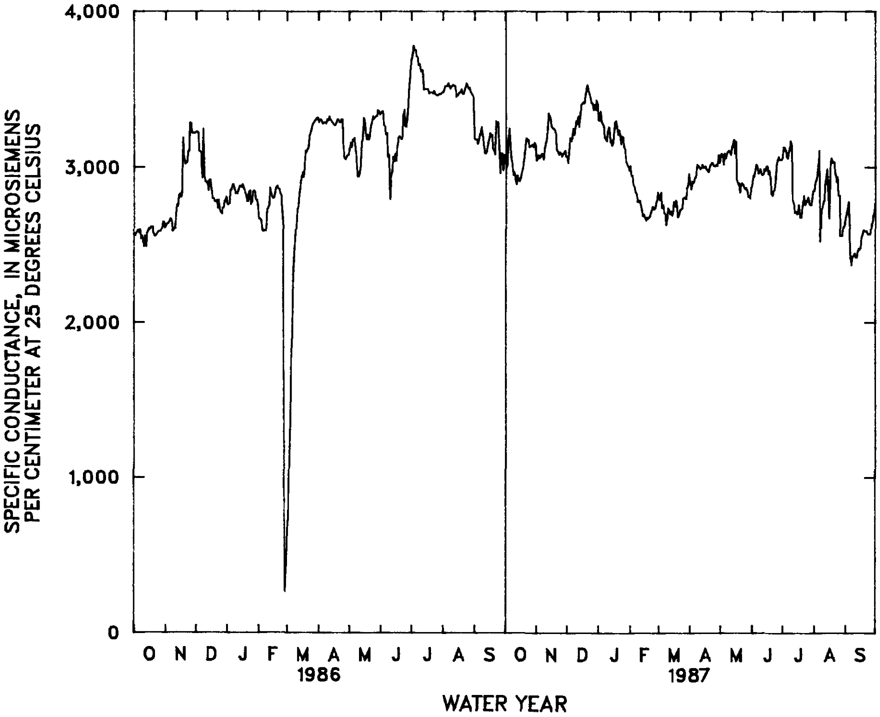

Figure 8.--Daily specific conductance of Hanging Woman Creek near Birney (station 06307600), water years 1986 and 1987.

Dissolved-Solids Concentrations and Loads

Dissolved-solids concentrations in Hanging Woman Creek vary greatly with location in the drainage basin and with magnitude of discharge. In general, concentrations decrease downstream and also decrease during large increases in streamflow. The largest concentration of dissolved solids (14,000 mg/L) was measured at station 06307540 near the Montana-Wyoming State line on June 8, 1983 (table 9). Hanging Woman Creek near the State line commonly has very large concentrations of dissolved solids during the summer, when streamflow is small or the water becomes ponded or stagnant. White salt deposits accumulate along the streambanks during extended periods of low streamflow or stagnant water.

At station 06307570 below Horse Creek, dissolved-solids concentrations are substantially smaller than at the State line. Sixty-three water samples collected at the station between October 1977 and September 1987 had dissolved-solids concentrations that ranged from 310 to 5,900 mg/L, with a median concentration of 3,300 mg/L. The smallest concentration occurred during rapid snowmelt when streamflow was 109 ft^3/s.

At station 06307600 near Birney and the mouth of Hanging Woman Creek, dissolved-solids concentrations were substantially smaller than at upstream stations. Analysis of 117 water samples collected at the station between October 1974 and November 1987 at discharges that ranged from 0.01 to 360 ft^3/s showed that dissolved-solids concentrations ranged from 180 to 3,200 mg/L, with a median concentration of 1,800 mg/L.

The downstream decrease in dissolved-solids concentrations can be explained by the downstream increase in streamflow derived from ground-water discharge. The downstream part of the Hanging Woman Creek basin has a much greater area of clinker beds than the upstream part and discharges more ground water having a smaller concentration of dissolved solids.

Dissolved-solids loads were calculated for Hanging Woman Creek near Birney station 06307600) using daily specific conductance and stream-discharge data for water years 1981-83 and 1986-87--the 5 years for which data were available. Specific-conductance values (in microsiemens per centimeter at 25 degrees Celsius) were converted to dissolved-solids concentrations (in milligrams per liter) using the equation: dissolved solids = 0.785 (specific conductance) - 142. This regression equation was based on 117 water samples collected from Hanging Woman Creek at Birney between October 1974 and November 1987. Monthly median specific-conductance values and monthly median dissolved-solids concentrations for the Birney station are listed in table 10 and monthly dissolved-solids loads are listed in table 11. From table 10, it is evident that median dissolved-solids concentrations were fairly consistent from month to month, and ranged from 1,700 mg/L in July, November, and December to 2,060 mg/L in May. Monthly loads, which were much more variable than monthly dissolved-solids concentrations, ranged from 0 during months of no flow to about 1,283 tons in March 1986. Analysis of the daily data indicates that the large load variations are due to a small number of days with large stream discharge.

Major Chemical Characteristics

Water in Hanging Woman Creek typically contains large concentrations of magnesium, sodium, and sulfate, especially in the upstream part near the Montana-Wyoming border. The water is alkaline, with pH values generally in the range of 7.9 to 8.4. Generally, chloride concentrations are less that 50 mg/L and fluoride concentrations are in the range of 0.1 to 1.3 mg/L.

Magnesium concentrations in Hanging Woman Creek usually were larger than calcium concentrations, and both ions had the largest concentrations at the upstream station at the State line (station 06307540) and the smallest concentrations near Birney (station 06307600). Except during high streamflow, magnesium concentrations were 80-180 mg/L near Birney and 130-310 mg/L below Horse Creek (station 06307570); calcium concentrations were 46-230 mg/L near Birney and 70-200 mg/L below Horse Creek.

Sodium concentrations measured near Birney (station 06307600) ranged from 29 to 500 mg/L (table 7). The smallest concentration occurred during a time of rapid runoff in February 1986, when stream discharge was 360 ft^3/s. All other measured concentrations of sodium exceeded 220 mg/L. Sodium concentrations measured below Horse Creek (station 06307570) were greater than near Birney and ranged from 52 to 920 mg/L (table 8). Sodium concentrations in the upstream part of Hanging Woman Creek near the State line (station 06307540) were as large as 2,700 mg/L in June 1983 (table 9). The sodium-adsorption ratio, which is used to express the relative activity of sodium ions in exchange reactions with soils, ranged from 1 during high streamflow near Birney to 17 near the State line. The sodium-adsorption ratios of water in Hanging Woman Creek indicate a medium to high salinity hazard for irrigation of crops (U.S. Salinity Laboratory Staff, 1954, p. 80) except during periods of high streamflow, when dissolved-solids and sodium concentrations are smaller.

Sulfate was the dominant anion in all samples from Hanging Woman Creek. Sulfate concentrations ranged from 98 mg/L during high streamflow near Birney to 9,900 mg/L at the State line. Sulfate concentrations decrease downstream, similar to concentrations of other major ions.

EFFECTS OF MINING ON DISSOLVED SOLIDS

After mining of coal beds and placement of spoils in the mine pits, ground-water flow systems would become established in much of the spoils material. Water entering the mine spoils would dissolve soluble minerals, generally resulting in an increase in dissolved-solids concentrations of water in the mine spoils. Water having increased dissolved-solids concentrations would move downgradient from the spoils, affecting the quality of water in alluvial aquifers, in aquifers of the Tongue River Member, and in Hanging Woman Creek.

Post-Mining Dissolved Solids in Water in Mine Spoils

Increased concentrations of dissolved solids in water in spoils have been documented by studies at existing coal mines in southeastern Montana and western North Dakota. In a study at the West Decker Mine at Decker, Montana, Davis (1984, p. 1) reported that the dissolved-solids concentration was about 2,500 mg/L in spoils water and about 1,400 mg/L in coal-aquifer water. At the Big Sky Mine near Colstrip, Montana, dissolved-solids concentration was about 3,700 mg/L in spoils water and about 2,700 mg/L in coal-aquifer water (Davis, 1984, p. 2). Van Voast and others (1978, p. 45) reported that in the Colstrip, Montana, area, theoretical mean dissolved-solids concentrations in spoils water are 820 to 1,800 mg/L greater than those in nearby stock and domestic supplies. For surface coal-mine sites in western North Dakota, Groenewold and others (1983, p. 146) reported that spoils water at the study sites typically was 2 to 3 times as mineralized as ground water in undisturbed settings at the same study sites.

Assumptions

To estimate the increase in dissolved-solids concentrations of water moving through mine spoils and the dissolved-solids loads from mined areas, several assumptions were made:

1. The Anderson and Dietz coal beds would be surface mined from the six subareas delineated on plate 4. The maximum overburden thickness for delineated areas of Anderson coal is about 150 feet.

2. Ground-water flow would become established in mine spoils similar to flow systems in the pre-mining aquifers, and rates of ground-water recharge would be unchanged.

3. Dissolved-solids concentrations in spoils water would be greater than in pre-mining aquifers and the increase in dissolved-solids concentration would be equivalent to the median dissolved-solids concentration in saturation extracts prepared from overburden samples.

4. Post-mining increases in dissolved-solids loads from mined areas can be calculated using pre-mining rates of ground-water flow through the mine area and the median dissolved-solids concentration calculated from saturated-paste extracts.

Assumption 1, that the Anderson and Dietz coal beds would be mined from all six subareas, creates a worst-case condition for dissolved solids in Hanging Woman Creek. However, because the total area of minable coal is divided into subareas, dissolved-solids loads to Hanging Woman Creek could be calculated for any combination of subareas simply by summing the loads from each subarea.

Calculations of the dissolved-solids load from mine spoils are based on the assumption that the rate of ground-water flow through the spoils would be equivalent to the pre-mining flow rate through the Anderson and Dietz coal aquifers and through the sandstone aquifers in the overburden. This assumption is supported by hydraulic-conductivity data for coal aquifers and mine spoils in the region. Studies by the Montana Bureau of Mines and Geology indicate that hydraulic-conductivity values of mined lands are extremely variable but similar to those in the pre-mining system (Van Voast, 1985, p. 867).

Saturated-Paste Extracts from Overburden

The saturated-paste-extract method is a laboratory procedure used to measure the content of salts in a soil or sediment sample (U.S. Salinity Laboratory Staff, 1954, p. 83-88). The sample is mixed with distilled water to form a saturated paste, which is allowed to sit for a given time. The quantity of water required to saturate a dry sample varies with the texture and composition of the sample. After the saturated sample sits for a given time, extracts are recovered from the pastes by filtration and are analyzed for specific conductance and major cations.

Saturated-paste extracts have been used by Van Voast and Hedges (1975) and Van Voast and Thompson (1982) to evaluate the post-mining quality of water in spoils in Montana and Wyoming. For predicting post-mining quality of water in spoils in the upstream part of the Tongue River area in Montana and Wyoming, Van Voast and Thompson (1982) assumed that dissolved-solids concentrations of saturated-paste extracts were potential additions to concentrations in ground waters that would enter and eventually discharge from the mine spoils. In the method used by Van Voast and Thompson, log-normal mean concentrations of cations were determined from analyses of saturated-paste extracts; dissolved-solids concentrations were computed from the ion concentrations and these concentrations were used in conjunction with ground-water flow rates to compute the added dissolved-solids load from mining. Dissolved-solids concentrations indicated by saturated-paste extracts were assumed to be potential additions to the pre-mining concentrations, based on actual quality of aquifer and spoils water at mine sites in southeastern Montana. At the Big Sky and West Decker Mines in Montana, log-normal mean concentrations of cations in spoils water were consistently 2 to 3 times greater than log-normal mean concentrations of cations in saturated-paste extracts (Van Voast and others, 1978). Studies of spoils waters, saturated-paste extracts of mine spoils and overburden, and quality of water in undisturbed aquifers in southeastern Montana indicate an empirical relation between the dissolved-solids concentration in spoils water and the sum of dissolved-solids concentrations in aquifer water and saturated-paste extracts.

Saturated-paste extracts also have been used to evaluate mine-spoils water quality in Montana by Woessner and others (1979), in North Dakota by Groenewold and others (1983), and in Colorado by McWhorter and others (1975). In a publication of procedures for predictive analysis of hydrologic effects of surface mining, McWhorter (1982, p. 12) stated that "...probably the most reasonable estimate of concentration of dissolved solids in subsurface runoff from mined land can be made from a judicious study of the quality of spoils water from nearby mines in a similar geochemical environment." He adds that the dissolved-solids concentration in extracts from saturated drill cuttings will provide a reasonable lower limit for dissolved-solids concentration in subsurface runoff from mined land; however, if the dissolved solids are derived mainly from readily soluble sodium salts, concentrations in spoils water can be expected to be greater than the saturated-paste-extract value, perhaps by as much as a factor of 3.

Saturated-paste-extract data for 158 overburden samples from 29 drill holes and wells were analyzed to evaluate concentrations of dissolved solids that could occur in water in mine spoils if the Hanging Woman Creek area were mined. The location of each of 29 sampling sites is shown on plate 4 and the saturated-paste-extract data are listed in table 12.

Specific-conductance values for the samples had a wide range--890 μS/cm (microsiemens per centimeter at 25 degrees Celsius) in sample KR-218-2 to 18,700 μS/cm in sample KR-101-3. The pH of most saturated pastes was 7.0 or greater, indicating neutral to slightly alkaline conditions. However, 15 percent of the paste samples had acidic pH values; the two smallest values were 4.7 in sample KR-102-3 and 5.0 in sample HWC-23-11.

Sodium generally was the dominant cation in the saturated-paste extracts, just as it was in water from aquifers in the Tongue River Member. Concentrations of magnesium (in milliequivalents per liter) generaly were greater than those of calcium.

Sulfate was analyzed for some of the saturated-paste extracts and was the only anion included in sample analysis (table 12). Although bicarbonate concentrations were not analyzed, comparison of total cations with sulfate indicates that bicarbonate concentrations generally would be much less than sulfate concentrations.

Dissolved-solids concentrations (in milligrams per liter) of saturated-paste extracts were calculated from the specific conductance (in microsiemens per centimeter) using the regression equation: dissolved solids = 0.837 (specific conductance) - 341. This equation, with a coefficient of determination of 0.94, was derived from the specific-conductance values and dissolved-solids concentrations of 108 water samples from wells completed in the Tongue River Member of the Fort Union Formation. Because water from aquifers in the Tongue River Member and water in saturated-paste extracts from Tongue River Member overburden are of similar type, the regression equation probably is a good predictor where specific-conductance values are in the range of 800 to 10,000 μS/cm. However, for water samples that have specific-conductance values greater than 10,000 μS/cm and have sulfate as the predominant anion, the dissolved-solids concentration appears to be underestimated using this equation.

Predicted dissolved-solids concentrations in saturated-paste extracts ranged from 403 to 15,300 mg/L, with a median of 3,700 mg/L. The distribution of dissolved-solids concentrations in saturated-paste extracts is shown in figure 9, along with the distribution of dissolved-solids concentrations in water samples from aquifers in the Tongue River Member. More than 40 percent of the saturated-paste extracts had dissolved-solids concentrations in the range of 2,000-4,000 mg/L, whereas more than 50 percent of water samples from aquifers in the Tongue River Member had dissolved-solids concentrations in the range of 200-2,000 mg/L. The median

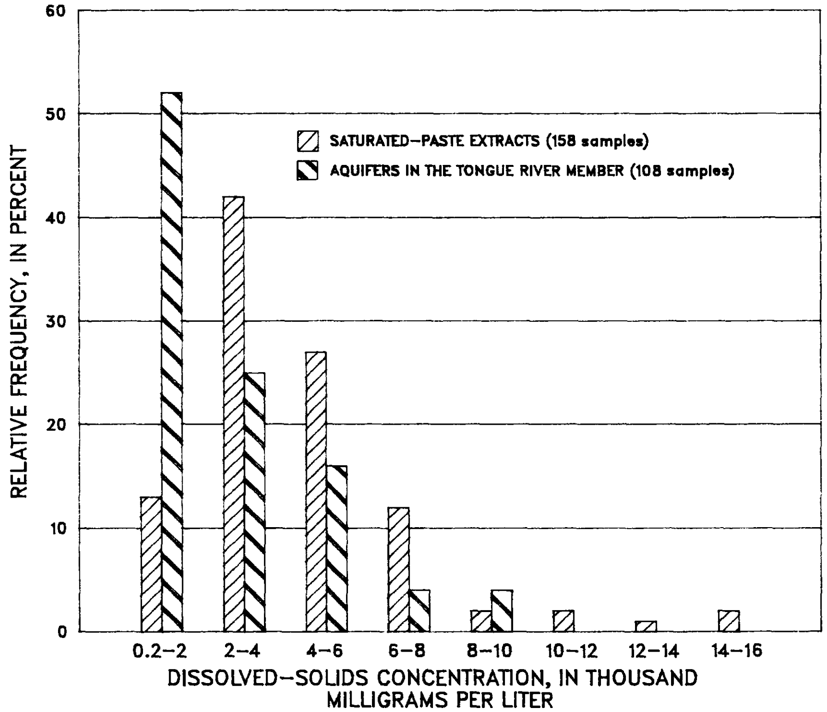

Figure 9.--Frequency distribution of dissolved-solids concentrations in saturated-paste extracts and aquifers in the Tongue River Member.

dissolved-solids concentration in saturated-paste extracts (3,700 mg/L) was nearly double the median concentration in water samples from aquifers in the Tongue River Member (1,900 mg/L) and was nearly equal to the median concentration in water samples from alluvial aquifers (3,800 mg/L).

Load Calculations for Subareas

To calculate post-mining loads of dissolved solids from mined lands, the total area of potential coal mining was divided into six subareas (pl. 4), with subarea boundaries selected to include aquifers having similar ground-water flow characteristics. For each subarea, natural rates of ground-water flow were calculated for all coal and sandstone aquifers that would be disturbed by mining; flow rates were multiplied by the median dissolved-solids concentration from saturated-paste extracts (3,700 mg/L) to obtain dissolved-solids loads that mining could add to the ground-water flow systems. Dissolved-solids loads calculated by this method represent the initial pore volume of water moving through mine spoils. Loads might decrease with time as subsequent pore volumes of water flow through the mine spoils.

The general method used to calculate rates of ground-water flow through subareas was: (1) To select a cross section through the subarea that was perpendicular to the direction of ground-water flow--this section was located where coal and sandstone beds were fully saturated or where mining would intersect the largest thickness of saturated coal and sandstone; and (2) to compute flow rate through the cross-section using Darcy's equation: Flow rate = KIA. Hydraulic conductivity (K) was calculated from aquifer tests and a value of 0.47 ft/d was used for all coal and sandstone aquifers. Gradient (I) was determined from water levels shown on plate 3. Area (A) of the cross-section was computed from the total saturated thickness of coal aquifers plus sandstone aquifers in the overburden, multiplied by the length of the cross section. Ground-water flow rates and dissolved-solids loads for each subarea are described below and are shown on plate 4.

Subarea 1 has an area of 9.7 mi^2 and includes parts of Corral Creek basin, Waddle Creek basin, and Hanging Woman Creek valley. Surface-minable coal resources at subarea 1 primarily are in the Anderson coal bed. The Dietz coal bed is thin and deeply buried and probably would not be surface mined. The Anderson coal bed is surface minable from most of the subarea and has an average thickness of about 28 ft. The Anderson coal bed is saturated; however, near the Anderson coal-clinker contact, only the lower part of the coal is saturated. Where the Anderson coal bed is surface minable, about 10 ft of sandstone aquifer exists in the overburden. The area of coal and sandstone aquifers perpendicular to ground-water flow is about 1,045,000 ft^2. Assuming a hydraulic conductivity of 0.47 ft/d, and an average gradient of 0.006, the ground-water flow rate is about 0.034 ft^3/s. Assuming an increase in dissolved-solids concentration of 3,700 mg/L, the additional load from mine spoils would be about 0.34 ton/d.

Subarea 2 has an area of 20.2 mi^2 and includes parts of the Trail Creek basin and the Hanging Woman Creek valley. Surface-minable coal resources are in the Anderson and Dietz coal beds. The Anderson coal bed has an average thickness of about 30 ft and is surface minable in most of the area. The Dietz coal bed is surface minable in the East Trail Creek area where it has an average thickness of about 10 ft. Both coal beds are saturated. Where both the Anderson and Dietz are surface minable, sandstone aquifers in the overburden have a combined thickness of about 20 ft. Where only the Anderson is surface minable, about 10 ft of sandstone aquifer exists in the overburden. The area of coal and sandstone aquifers perpendicular to ground-water flow is about 1,266,000 ft^2 and the average gradient is 0.006. Assuming an average hydraulic conductivity of 0.47 ft/d, the ground-water flow rate is about 0.041 ft^3/s. The added load from mine spoils would be about 0.41 ton/d, assuming an increase in dissolved-solids concentration of 3,700 mg/L.

Subarea 3 has an area of 15.2 mi^2 and includes parts of the First Creek and PK Creek basins. Surface minable coal resources are in the Anderson and Dietz coal beds. The Anderson coal bed has an average thickness of about 29 ft and is surface minable from the coal-clinker contact to the boundary of the subarea where overburden thickness is about 150 ft. The Dietz coal bed has a thickness of about 12 ft and is surface minable from its outcrop to the outcrop of the Anderson clinker, and beneath the Anderson clinker in some areas. Where the Anderson coal bed is in contact with clinker, it is dry or is saturated only in the lower part. In the upstream parts of the subarea, where the overburden is thicker, the entire thickness of Anderson coal is saturated. The Dietz coal bed also is saturated, except near its outcrop. A sandstone aquifer within the Anderson overburden has a thickness of about 6 ft. The area of coal and sandstone aquifers perpendicular to ground-water flow is about 816,700 ft^2 and the average gradient is 0.02. Assuming an average hydraulic conductivity of 0.47 ft/d, the ground-water flow rate is about 0.089 ft^3/s. The added load from mine spoils would be 0.89 ton/d assuming an increase in dissolved-solids concentration of 3,700 mg/L. If a large area of Anderson clinker were removed for recovery of the Dietz coal bed, post-mining recharge rates could be substantially smaller than pre-mining rates, and the dissolved-solids load could be smaller than the calculated load.

Subarea 4 has an area of 10.8 mi^2 and includes much of the Horse Creek basin. Surface minable coal resources are in the Anderson and Dietz coal beds. The Anderson coal bed has an average thickness of about 30 ft and is surface minable from the coal-clinker contact to the boundary of the subarea, where overburden thickness is about 150 ft. The Dietz coal bed has an average thickness of about 12 ft, is located 40 to 50 ft below the Anderson bed, and is surface minable in most of the subarea. The Anderson coal bed is saturated in most of its extent, although near the Anderson coal-clinker contact the coal is dry or is saturated only in the lower part. The Dietz coal bed is saturated except near its outcrop. Sandstone aquifers within the overburden have a combined thickness of about 20 ft. The area of coal and sandstone aquifers perpendicular to ground-water flow is about 930,000 ft^2 and the average gradient is 0.012. Assuming an average hydraulic conductivity of 0.47 ft/d and an increase in dissolved-solids concentration of 3,700 mg/L, the ground-water flow rate is about 0.061 ft^3/s and the added load from mine spoils would be about 0.61 ton/d. If a large area of Anderson clinker were removed for recovery of the Dietz coal, post-mining recharge rates could be substantially smaller than pre-mining rates and the dissolved-solids load could be smaller than the calculated load.

Subarea 5 has an area of 6.0 mi^2 and includes surface minable coal in the Wrench Creek basin and along the Hanging Woman Creek drainage basin divide. Surface minable coal resources are in the Anderson and Dietz coal beds. The Anderson coal bed is about 27 ft thick and is surface minable along a relatively narrow band in the upstream part of the subarea. The Dietz coal bed is about 10 ft thick and is surface minable in much of the subarea. The Anderson and Dietz coal beds appear to be dry in the northern part of the area where they occupy the drainage divide. In the southern part of the subarea, the Dietz coal bed appears to be saturated, except near its outcrop, and the Anderson coal bed probably is saturated in its lower part. No saturated sandstones occur in the overburden, based on the log of a coal-exploration hole. The area of coal aquifer perpendicular to ground-water flow is about 125,100 ft^2 and the average gradient is 0.02. Assuming an average hydraulic conductivity of 0.47 ft/d and an increase in dissolved-solids concentration of 3,700 mg/L, the ground-water flow rate is about 0.014 ft^3/s and the added load from mine spoils would be about 0.14 ton/d.

Subarea 6 has an area of 29.3 mi^2 and includes parts of the Stroud Creek and Lee Creek basins. Surface minable coal resources are in the Anderson and Dietz coal beds. The Anderson coal bed is about 32 ft thick and is surface minable in the higher parts of the subarea; in other parts of the subarea, the Anderson has burned along its outcrop, forming an extensive and thick bed of clinker. The Dietz coal bed is about 14 ft thick and is surface minable along its outcrop and in some areas where it underlies the Anderson clinker or Anderson coal bed. The Anderson coal bed is saturated in its entire thickness in a small part of the subarea, where it is farthest from clinker. Anderson coal near the coal-clinker contact appears to be dry or is saturated only in its lower part. Much of the Anderson clinker in this subarea contains a perched aquifer that discharges to many small springs. The Dietz coal bed appears to be dry along its outcrop and saturated in the higher parts of the subarea where the coal is distant from its outcrop. On the basis of logs of drill holes and water-level data, sandstones in the Anderson overburden contain no substantial saturated thickness. The area of coal aquifer perpendicular to ground-water flow is about 800,000 ft^2 and the average gradient is 0.013. Assuming an average hydraulic conductivity of 0.47 ft/d and an increase in dissolved-solids concentration of 3,700 mg/L, the ground-water flow rate is about 0.057 ft^3/s and the added load from mine spoils would be about 0.57 ton/d. If a large area of Anderson clinker were removed for recovery of the Dietz coal, post-mining recharge rates could be substantially smaller than pre-mining rates and the dissolved-solids load could be smaller than the calculated load. Removal of Anderson clinker in this subarea also would eliminate the flow of many small springs.

For all subareas, the total rate of ground-water flow through surface minable Anderson and Dietz coal aquifers and sandstone aquifers in the overburden is 0.3 ft^3/s. The added load of dissolved solids from mine spoils in all subareas would be about 3.0 ton/d.

Post-Mining Dissolved Solids in Water Resources

After ground-water flow systems have developed in the post-mining landscape, water would flow from the mine spoils, through undisturbed aquifers in the Tongue River Member and alluvium, and eventually discharge to Hanging Woman Creek. Dissolved-solids concentrations in Hanging Woman Creek would increase as a result of the increase in the dissolved-solids loads originating in the mine spoils. Increased concentrations of dissolved-solids also would occur in aquifers downgradient from mine spoils.

The following estimates of dissolved-solids concentrations in Hanging Woman Creek are based on the assumption that loads from mine spoils would discharge to the stream at a steady state and the loads leaving the mine spoils will not change in magnitude because of geochemical processes during transport to Hanging Woman Creek. The assumption that the entire increase in dissolved-solids load will reach Hanging Woman Creek probably represents the worst-case condition. In a study of the geochemistry and geohydrology of coal mines in southeastern Montana, Davis (1984, p. 2) indicated that the dissolved-solids concentration of water from mine spoils may decrease several hundred milligrams per liter if the spoils water flows through a coal aquifer. In the Hanging Woman Creek area, some spoils water would move through coal before reaching the stream.

Aquifers in Alluvium and the Tongue River Member

Dissolved-solids concentrations in water in alluvium along Hanging Woman Creek and in coal and sandstone aquifers downgradient from mine spoils would increase as water from mine spoils moved through them. Aquifers affected by increases in dissolved-solids concentrations would be the shallow aquifers along ground-water flow paths from the mined areas to the discharge area along Hanging Woman Creek. Deeper aquifers, those 300 ft or more below the water table, probably would be unaffected by mining because of the small vertical permeability of shales in the Tongue River Member and the predominant hydraulic gradient toward the valley of Hanging Woman Creek.

In subareas 1 and 2, spoils water would move directly into alluvium because surface minable coal reserves are adjacent to alluvial deposits in the Hanging Woman Creek valley. A large increase in dissolved-solids concentration in water in the alluvium would be likely, possibly affecting the growth of subirrigated vegetation. Post-mining concentrations of dissolved solids in water in this reach of alluvium probably would be similar to those in spoils water. However, the alluvium has other sources of recharge, including streamflow and precipitation, and water in the aquifer could have a wide spatial variation in dissolved-solids concentrations.

In subareas 3, 4, 5, and 6, spoils water would move through undisturbed sandstone, coal, or clinker aquifers before reaching the alluvium along Hanging Woman Creek. Generally, water in these aquifers would have a large increase in dissolved-solids concentration; however, because of the complex recharge and flow system created by clinker beds in the area, water from wells and springs in some locations might have no change in dissolved-solids concentrations, whereas water from other springs and wells might become unsuitable for its present use.

Saline seeps might develop downgradient from mine spoils in subareas 3-6. In these areas, such seeps are likely to develop where permeable clinker beds overlie relatively impermeable shale near mined areas. The Anderson clinker in these subareas, and especially in subarea 6, discharges to many small seeps and springs. After mining of the Anderson coal, many of these seeps and springs could discharge saline spoils water. If the Anderson clinker is removed for recovery of the underlying Dietz coal, many small seeps and springs would be destroyed, ground-water recharge rates would be decreased, and surface runoff rates probably would be increased. The cumulative effects on dissolved-solids concentrations in Hanging Woman Creek caused by removing the Anderson clinker in these subareas cannot be predicted with available data; estimates are based on the assumptions that large areas of Anderson clinker would not be removed and rates of ground-water recharge would be unchanged. Additional study of ground-water recharge and flow through clinker beds would be warranted if actual mining plans call for the removal of large areas of Anderson clinker.

Alluvium in the Hanging Woman Creek valley that is adjacent to subareas 3-6 would receive an increased load of dissolved solids from the mined areas, increasing the dissolved-solids concentration in the water by an undetermined quantity. Water in alluvial aquifer in this reach of valley likely would have a large spatial variation in dissolved-solids concentration, with some areas containing water unfit for livestock watering (greater than 4,500 mg/L of dissolved solids).

Water in the alluvial aquifer in the downstream reach of Hanging Woman Creek, from about Lee Creek to the confluence with the Tongue River, probably would have little or no increase in dissolved-solids concentration because the aquifer receives recharge from adjacent aquifers in the Tongue River Member that would be unaffected by mining. Also, Hanging Woman Creek appears to be a gaining stream through this reach, which would prevent streamflow from recharging the alluvium; any recharge would take place during high flow when dissolved-solids concentrations are smallest.

Hanging Woman Creek

Increases in dissolved-solids loads and concentrations in Hanging Woman Creek were estimated for the downstream end of the study area near Birney and assume completed mining in all six subareas. To most accurately represent the general increase in dissolved-solids concentrations in Hanging Woman Creek, the additional load from mine spoils was added to the monthly load of Hanging Woman Creek near Birney (station 06307600) for median streamflow. Calculated post-mining dissolved-solids loads and concentrations for Hanging Woman Creek near Birney are presented in table 13, along with a summary of pre-mining loads and concentrations.

The monthly loads of Hanging Woman Creek near Birney (station 06307600) could have a maximum post-mining increase of 129 percent in August when the dissolved-solids load would be about 165 tons and the median discharge 0.50 ft^3/s. The minimum post-mining increase would be 26 percent in April when the dissolved-solids load would be about 436 tons and the median discharge 2.2 ft^3/s. The annual load of dissolved solids (at median discharge) could be about 3,415 tons, a 47-percent increase from the pre-mining load of 2,320 tons.

Post-mining concentrations of dissolved solids, at median discharge, could range from 2,380 mg/L in March to 3,940 mg/L in August. Post-mining concentrations would be greater than these monthly values for stream discharge less than the median and would be smaller for discharge greater than the median. Post-mining concentrations and loads in Hanging Woman Creek also would be smaller than those given in table 13 if the Anderson and Dietz coal beds were not mined from all subareas. The monthly post-mining dissolved-solids concentrations listed in table 13 are similar to post-mining concentrations modeled by Woods (1981, p. 40) in a study of dissolved solids in the Tongue River drainage basin. Monthly dissolved-solids concentrations of Hanging Woman Creek (table 13) range from 14 percent smaller to 21 percent larger than monthly concentrations for Hanging Woman Creek predicted by the Tongue River model (Woods, 1981, p. 40).

Post-mining concentrations of dissolved solids would be greater in some upstream reaches of Hanging Woman Creek than at the downstream station near Birney because of smaller streamflow and larger pre-mining dissolved-solids concentrations. For example, at station 06307570 below Horse Creek, stream discharge commonly was less than one-half the discharge near Birney (see fig. 6) and dissolved-solids concentrations were greater. Additional dissolved-solids load from mining would create a larger increase in dissolved-solids concentrations, primarily because of the smaller streamflow available to dilute the additional load.

CONCLUSIONS

Shallow aquifers in the Hanging Woman Creek area exist in alluvium, coal, sandstone, and clinker. Alluvial aquifers are located in the valleys of Hanging Woman Creek and its principal tributaries. Coal and sandstone aquifers are present throughout the area and collectively compose the most extensive aquifer zone for stock and domestic wells. Clinker beds, formed where the Anderson coal bed has burned along its outcrop, are aquifers in the central part of the study area. Many small seeps and springs issue from the Anderson clinker, making it a reliable source of water for livestock. Water from coal, sandstone, and clinker aquifers discharges to the Hanging Woman Creek valley, where it moves through alluvium and eventually discharges to Hanging Woman Creek.

Hanging Woman Creek and its tributaries, plus many small stock ponds, compose the surface-water resources of the area. Hanging Woman Creek is characterized by a small but perennial flow downstream from Trail Creek, ephemeral or intermittent flow in the upstream part of the basin, and a small annual runoff coefficient--less than 1 percent of precipitation. The mean annual discharge of Hanging Woman Creek near Birney (station 06307600), computed from 13 years of record, was 3.9 ft^3/s; the median annual discharge was 1.2 ft^3/s. Water from Hanging Woman Creek is used for livestock watering and limited irrigation of about 1,240 acres in the downstream part of the valley.

Water from alluvium generally had large concentrations of dissolved solids. Water samples from 43 wells had dissolved-solids concentrations that ranged from 2,100 to 11,000 mg/L; the median concentration was 3,800 mg/L. Water from coal, sandstone, and clinker aquifers had a wide range of dissolved-solids concentrations. Water samples from 68 wells and 7 springs had dissolved-solids concentrations that ranged from 200 to 9,500 mg/L; the median concentration was 1,900 mg/L. The smallest dissolved-solids concentration was measured in spring SP-4, which discharges from the Anderson clinker.

Dissolved-solids concentrations in Hanging Woman Creek vary greatly with location in the drainage basin and with magnitude of discharge. In general, concentrations decrease downstream and also decrease during large increases in streamflow. Monthly median dissolved-solids concentrations, computed for Hanging Woman Creek at Birney (station 06307600), ranged from 1,700 mg/L in July, November, and December to 2,060 mg/L in May. Monthly dissolved-solids loads at Birney, computed using the median discharge, ranged from 72 tons for August to 346 tons for April. Annual load, for the median discharge, is 2,320 tons.

Surface mining of the Anderson and Dietz coal beds from the area would remove coal, sandstone, and clinker aquifers and replace them with mine spoils. After mining, ground-water flow systems would become established in the spoils material. Water entering the mine spoils would dissolve soluble minerals, increase the dissolved-solids concentration in aquifers downgradient from spoils, and eventually discharge to Hanging Woman Creek, thereby increasing the dissolved-solids load in the stream.

Analysis of saturated-paste extracts from 158 overburden samples from 29 sites indicated that water moving through mine spoils could have a median increase in dissolved-solids concentration of 3,700 mg/L. The increased dissolved-solids concentration in mine-spoils water would result in an additional dissolved-solids load to Hanging Woman Creek of 3.0 ton/d. Calculations of the added load from mine spoils were made by multiplying the ground-water flow rates through the six subareas of surface minable coal by the increase in dissolved-solids concentration from mine spoils.

The additional dissolved-solids load to Hanging Woman Creek would result in increased dissolved-solids load from the drainage basin and increased concentrations of dissolved solids in the stream. Hanging Woman Creek near Birney (station 06307600) could have an annual post-mining dissolved-solids load of about 3,415 tons (at median discharge), a 47-percent increase from the pre-mining load of 2,320 tons. Monthly loads of Hanging Woman Creek near Birney, at median discharge, could have a post-mining increase ranging from 26 percent in April to 129 percent in August. Post-mining concentrations of dissolved solids, at median discharge, could range from 2,380 mg/L in March to 3,940 mg/L in August. Post-mining concentrations would be greater than these monthly values for discharge less than the median, and would be smaller for discharge greater than the median. Post-mining concentrations and loads in Hanging Woman Creek near Birney would be smaller than predicted if the Anderson and Dietz coal beds were not mined from all subareas.

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SUPPLEMENTAL DATA

Table 1.--*Water-level data for wells completed in alluvial aquifers*

Well number	Location number	Altitude of land surface (feet above NGVD of 1929)	Water level (feet below land surface)	Date of level measurement (month-day-year)	Altitude of water level (feet above NGVD of 1929)	Remarks
AL-1	06S43E19DACD01	3,170	7.20	10-08-86	3,163	Observation well HWC-86-9
AL-2	06S43E19DDBA01	3,170	7.04	10-05-86	3,163	Observation well HWC-86-7
AL-3	06S43E19DDBA02	3,170	6.89	10-08-86	3,163	Observation well HWC-86-8
AL-4	06S43E19DDBD01	3,170	6.19	10-05-86	3,164	Observation well HWC-86-6
AL-5	07S43E05ACCA01	3,230	8.32	10-08-86	3,222	Observation well HWC-86-11
AL-6	07S43E08ABBB01	3,265	19.49	10-08-86	3,246	Observation well HWC-86-12
AL-7	08S43E17DDCA01	3,460	19.07	10-02-86	3,441	Observation well HWC-86-2
AL-8	08S43E17DDDC01	3,455	14.40	10-02-86	3,441	Observation well HWC-86-5
AL-9	08S43E21BBDA01	3,455	7.18	08-01-84	3,448	Observation well HC-1
AL-10	08S43E21BBDD01	3,455	5.13	08-01-84	3,450	Observation well HC-2
AL-11	08S43E21BBDD02	3,480	25.38	08-01-84	3,455	Observation well HC-3
AL-12	08S43E21BBDD03	3,455	4.73	10-09-86	3,450	Observation well HC-5
AL-13	08S43E21BCAA01	3,480	24.10	07-01-84	3,456	Observation well HC-4
AL-14	08S43E23CABD01	3,570	14.21	08-01-84	3,556	Observation well HC-8
AL-15	08S43E23CABD02	3,577	21.39	08-01-84	3,556	Observation well HC-9
AL-16	08S43E23CACA01	3,580	23.83	08-01-84	3,556	Observation well HC-6
AL-17	08S43E23CACA02	3,570	14.41	08-01-84	3,556	Observation well HC-7
AL-18	08S43E23CACA03	3,570	12.81	10-09-86	3,557	Observation well HC-10
AL-19	08S44E19CBCB01	3,670	15.05	08-01-84	3,655	Observation well HC-12
AL-20	08S44E19CBCB02	3,680	24.98	10-09-86	3,655	Observation well HC-13
AL-21	08S44E19CBCB03	3,682	28.95	08-01-84	3,653	Observation well HC-14
AL-22	08S44E19CBCC01	3,670	15.24	08-01-84	3,655	Observation well HC-11
AL-23	08S44E20CBCC01	3,755	9.90	08-01-84	3,745	Observation well HC-15
AL-24	08S44E20CCBB01	3,765	18.70	08-01-84	3,746	Observation well HC-16
AL-25	09S42E01BCAD01	3,652	25.02	07-01-84	3,627	Observation well CC-16
AL-26	09S42E01BCAD02	3,650	23.56	10-08-86	3,626	Observation well CC-17
AL-27	09S42E01BCAD03	3,655	27.78	07-01-84	3,627	Observation well CC-18
AL-28	09S42E02BBBD01	3,705	16.64	04-04-84	3,688	Observation well CC-21
AL-29	09S42E02BBCA01	3,720	28.72	04-04-84	3,691	Observation well CC-20
AL-30	09S42E11BDCA01	3,700	29.12	07-01-84	3,671	Observation well CC-13
AL-31	09S42E11BDCA02	3,700	33.04	07-01-84	3,667	Observation well CC-15
AL-32	09S42E12BCAA01	3,655	16.60	10-14-73	3,638	Stock well
AL-33	09S42E36BCAB01	3,730	9	11-16-73	3,721	--
AL-34	09S43E04ABDB01	3,515	3.38	07-01-84	3,512	Observation well CC-5
AL-35	09S43E04ABDD01	3,525	12.65	05-07-86	3,512	Observation well CC-1
AL-36	09S43E04ABDD02	3,525	13.18	10-09-86	3,512	Observation well CC-2
AL-37	09S43E04ABDD03	3,515	5.01	07-01-85	3,510	Observation well CC-4
AL-38	09S43E04ACAA01	3,525	13.05	07-01-84	3,512	Observation well CC-3
AL-39	09S43E06DDBD01	3,585	17.80	07-01-84	3,567	Observation well CC-8
AL-40	09S43E06DDBD02	3,585	18.15	07-01-84	3,567	Observation well CC-9
AL-41	09S43E06DDBD03	3,585	17.20	07-01-84	3,568	Observation well CC-11
AL-42	09S43E06DDCA01	3,585	17.34	07-01-84	3,568	Observation well CC-10
AL-43	09S43E12AACC02	3,580	6.35	09-19-77	3,574	Observation well HWC-36
AL-44	09S43E12ADBB01	3,578	9.63	11-16-77	3,568	Observation well HWC-37
AL-45	09S43E12ADBB02	3,590	15.40	10-09-86	3,575	Observation well HWC-38
AL-46	09S43E12ADBD01	3,600	24.27	11-16-77	3,576	Observation well HWC-39
AL-47	09S43E27AAAC01	3,590	32	01-01-77	3,558	--
AL-48	09S44E07AADD01	3,622	4.47	11-16-77	3,618	Observation well HWC-32
AL-49	09S44E07ADAB01	3,621	4.43	11-16-77	3,617	Observation well HWC-33
AL-50	09S44E07ADAD01	3,621	4.46	06-07-77	3,617	Observation well HWC-34
AL-51	09S44E09CBBD01	3,680	34.65	10-12-77	3,645	Observation well HWC-31
AL-52	10S43E02ACDA01	3,640	13.29	10-08-86	3,627	Observation well HWC-86-15
AL-53	10S43E02ACDC01	3,630	9.99	10-08-86	3,620	Observation well HWC-86-13

Table 2.--*Water-level data for springs and wells completed in aquifers of the Tongue River Member*

[--, no data]

Well or spring number	Location number	Altitude of land surface (feet above NGVD of 1929)	Water level (feet below or above (+) land surface)	Date of level measurement (month-day-year)	Altitude of water level (feet above NGVD of 1929)	Remarks
TR-1	06S43E18BABC01	3,150	+63	03-02-74	3,213	Flowing well, domestic water supply
TR-2	06S44E29BCBD01	3,580	36	07-29-76	3,544	Stock well
TR-3	07S43E04DBCA01	3,290	31.74	07-28-79	3,258	Stock well
TR-4	07S43E10DBCD01	3,396	48	06-12-61	3,348	Stock well
TR-5	07S44E26CDDC01	3,895	105	09-30-77	3,790	Stock well
SP-1	07S44E33BBCA01	3,795	--	--	3,795	Spring in Tongue River Member, domestic water supply
TR-6	07S44E34BAAD01	3,805	54.47	10-09-86	3,751	Observation well BC-3
TR-7	07S44E34BAAD02	3,805	116.68	06-07-83	3,688	Observation well BC-4
TR-8	08S42E02ADDD01	3,629	108.98	08-02-77	3,520	--
SP-2	08S42E10AADC01	3,870	--	--	3,870	Spring in Tongue River Member
TR-9	08S42E14ADCB01	3,680	16	11-18-73	3,664	--
TR-10	08S42E14DBAD01	3,740	151.71	06-01-86	3,588	Observation well HWC-13
TR-11	08S42E14DBAD02	3,740	50.06	10-08-86	3,690	Observation well HWC-14
TR-12	08S42E15CBBA01	3,830	40	11-19-73	3,790	--
TR-13	08S42E21AAAB01	3,960	220	11-19-73	3,740	--
TR-14	08S42E22CAAC01	3,988	120	11-18-73	3,868	--
TR-15	08S42E23BDBC01	3,880	75	11-18-73	3,805	--
TR-16	08S42E26CBBB01	3,810	92	11-15-73	3,718	Domestic water supply
TR-17	08S42E28CAAA01	3,940	80	11-14-73	3,860	--
TR-18	08S42E35DDDB01	3,755	246.55	07-01-84	3,508	Observation well CC-22
TR-19	08S42E35DDDB02	3,755	106.45	07-01-84	3,649	Observation well CC-23
TR-20	08S43E05CBAC01	3,375	15	10-31-73	3,360	--
TR-21	08S43E09ADCC01	3,725	83	10-06-67	3,642	Stock well
TR-22	08S43E11CDBD01	3,787	143	11-13-73	3,644	Stock well
TR-23	08S43E13ACCA01	3,865	78	11-13-73	3,787	Stock well
TR-24	08S43E14BCCA01	3,810	184.42	07-01-84	3,626	Observation well HC-21
SP-3	08S43E15CCAA01	3,625	--	--	3,625	Spring in Tongue River Member, stock water supply
TR-25	08S43E16CCDA01	3,510	--	--	--	Domestic water supply
SP-4	08S43E16CDBD01	3,600	--	--	3,600	Spring in Tongue River Member, domestic and stock water supply

Table 2.--*Water-level data for springs and wells completed in aquifers of the Tongue River Member*--Continued

Well or spring number	Location number	Altitude of land surface (feet above NGVD of 1929)	Water level (feet below or above (+) land surface)	Date of level measurement (month-day-year)	Altitude of water level (feet above NGVD of 1929)	Remarks
TR-26	08S43E20DABA01	3,530	89.89	10-09-86	3,440	Observation well HWC-1
TR-27	08S43E21BDBB01	3,500	56.28	10-09-86	3,444	Observation well HC-23
TR-28	08S43E21BDBB02	3,500	48.07	10-09-86	3,452	Observation well HC-24
SP-5	08S43E22CBAA01	3,520	--	--	3,520	Spring in Tongue River Member, stock water supply
TR-29	08S43E23CDAA01	3,605	49.70	10-09-86	3,555	Observation well HC-19
TR-30	08S43E23CDAA02	3,605	166.89	10-09-86	3,438	Observation well HC-20
TR-31	08S43E23DBCC01	3,600	35.80	08-01-84	3,564	Observation well US-7790, sampling site for saturated-paste extracts
TR-32	08S43E23DBDB01	3,607	--	--	--	Water-quality data available
TR-33	08S43E25DBBB01	3,850	286.49	07-01-84	3,564	Observation well HC-17
TR-34	08S43E25DBBB02	3,850	231.27	07-01-84	3,619	Observation well HC-18
TR-35	08S43E28CACD01	3,495	17	10-26-73	3,478	Stock well
TR-36	08S43E29DABC01	3,521	15	10-26-73	3,506	Stock well
TR-37	08S43E30BBCD01	3,620	38	10-01-73	3,582	--
TR-38	08S43E31BBDA01	3,735	129.15	10-08-86	3,606	Observation well FC-1
TR-39	08S43E31BBDA02	3,736	241.49	10-08-86	3,495	Observation well FC-2
TR-40	08S43E32BBDA01	3,682	104.35	09-14-83	3,578	Observation well US-7777, sampling site for saturated-paste extracts
TR-41	08S44E05BABB01	3,855	54	11-16-73	3,801	Stock well
TR-42	08S44E06CBAC01	3,720	30	10-06-67	3,690	Stock well
TR-43	08S44E07BBBB01	3,755	19	11-13-73	3,736	Stock well
TR-44	08S44E18ABAC01	3,880	16	11-13-73	3,864	Stock well
TR-45	08S44E18ABDB01	3,900	205	11-12-73	3,695	Domestic water supply
TR-46	08S44E18BCCC01	3,930	280	11-01-58	3,650	Well not used
TR-47	08S44E18BDCC01	3,865	173	11-15-73	3,692	--
TR-48	08S44E19CBBB01	3,720	157.67	10-09-86	3,562	Observation well BC-10
TR-49	08S44E19CBBB02	3,720	77.23	10-09-86	3,643	Observation well BC-11
TR-50	08S44E32DDAB01	3,740	104.91	10-19-77	3,635	Observation well HWC-28
TR-51	08S44E35ADDC01	4,016	--	--	--	Stock well
TR-52	09S42E02ADBB01	3,685	29.0	10-30-75	3,656	Stock well
TR-53	09S42E03AADA01	3,720	34	11-14-73	3,686	--
TR-54	09S42E04BABA01	3,875	86.80	09-14-83	3,788	Observation well CC-25

Table 2.--*Water-level data for springs and wells completed in aquifers of the Tongue River Member*--Continued

Well or spring number	Location number	Altitude of land surface (feet above NGVD of 1929)	Water level (feet below or above (+) land surface)	Date of level measurement (month-day-year)	Altitude of water level (feet above NGVD of 1929)	Remarks
TR-55	09S42E05AAAD01	3,891	105.0	05-10-41	3,786	Stock well
TR-56	09S42E11BDAA01	3,710	144.05	10-08-86	3,566	Observation well HWC-12
TR-57	09S42E25DCAD01	3,700	16	11-16-73	3,684	--
TR-58	09S43E02BBBB01	3,665	157.59	10-12-77	3,507	Observation well HWC-21
TR-59	09S43E02BBBB02	3,665	125.90	10-12-77	3,539	Observation well HWC-22
TR-60	09S43E03CBCD01	3,530	88.62	09-21-76	3,441	Observation well HWC-2
TR-61	09S43E03CBCD02	3,530	30.19	04-13-77	3,500	Observation well HWC-3
TR-62	09S43E04ABCA01	3,520	11.16	07-01-84	3,509	Well not used
TR-63	09S43E04CBAB01	3,590	68.81	10-09-86	3,521	Observation well CC-6
TR-64	09S43E04CBAB02	3,591	41.61	07-01-84	3,549	Observation well CC-7
TR-65	09S43E07BCAD01	3,627	15	11-14-73	3,612	Stock well
TR-66	09S43E07CADB01	3,655	57.90	10-08-86	3,597	Observation well US-7770
TR-67	09S43E07CADB02	3,656	86.67	10-08-86	3,569	Observation well CC-24
TR-68	09S43E10BBAD01	3,520	12	03-20-74	3,508	Stock well
TR-69	09S43E12AACC01	3,580	7.47	11-16-77	3,573	Observation well HWC-35
TR-70	09S43E13BCAA01	3,610	48.56	10-12-77	3,561	Observation well HWC-17
TR-71	09S43E13CAAA01	3,595	65.93	09-21-76	3,529	Observation well HWC-6
TR-72	09S43E13CAAA02	3,595	28.92	08-05-75	3,566	Observation well HWC-7
TR-73	09S43E14DDBB01	3,710	137.69	08-08-77	3,572	Observation well HWC-27
TR-74	09S43E15DABC01	3,579	--	--	--	Stock well
TR-75	09S43E21AADA01	3,575	4	10-28-73	3,571	Stock well
TR-76	09S43E21BADA01	3,615	98.18	10-08-86	3,517	Observation well HWC-10
TR-77	09S43E21BADA02	3,610	50.32	10-08-86	3,560	Observation well HWC-11
TR-78	09S43E22ACCA01	3,600	29.50	10-08-86	3,570	Observation well HWC-15
SP-6	09S43E25BADC01	3,680	--	--	3,680	Spring in Tongue River Member, stock water supply
TR-79	09S43E27CDCA01	3,760	--	--	--	Stock well
TR-80	09S43E27DABB01	3,660	58.73	10-12-77	3,601	Observation well HWC-16
TR-81	09S43E29DBAB01	3,627	4	11-16-73	3,623	--
TR-82	09S43E35BBCD01	3,630	26	06-01-75	3,604	Stock well
TR-83	09S43E35CADC01	3,621	6	06-01-75	3,615	Stock well
TR-84	09S44E01ADAA01	4,000	287	11-14-73	3,713	Stock well

Table 2.--*Water-level data for springs and wells completed in aquifers of the Tongue River Member*--Continued

Well or spring number	Location number	Altitude of land surface (feet above NGVD of 1929)	Water level (feet below or above (+) land surface)	Date of level measurement (month-day-year)	Altitude of water level (feet above NGVD of 1929)	Remarks
TR-85	09S44E06BBBB01	3,730	136.80	10-19-77	3,593	Observation well HWC-23, sampling site for saturated-paste extracts
TR-86	09S44E06BBBB02	3,700	177.90	06-24-80	3,522	Observation well HWC-24
TR-87	09S44E07ADAA01	3,625	--	--	--	Stock well
TR-88	09S44E07ADDC01	3,679	126.38	09-29-83	3,553	Observation well HWC-8
TR-89	09S44E07ADDC03	3,680	55.56	10-12-77	3,624	Observation well HWC-20, sampling site for saturated-paste extracts
TR-90	09S44E07BBCC01	3,615	45.07	08-13-81	3,570	Observation well HWC-29
TR-91	09S44E07BBCC03	3,620	44.85	10-09-86	3,575	Observation well HWC-29B
TR-92	09S44E08BBAA01	3,670	101.41	10-12-77	3,569	Observation well HWC-25
TR-93	09S44E08BBAA02	3,670	55.62	10-12-77	3,614	Observation well HWC-26
TR-94	09S44E08BDDD01	3,700	20	10-12-77	3,680	Observation well HWC-18
TR-95	09S44E09CCAB01	3,700	45	10-12-77	3,655	Observation well HWC-30
TR-96	09S44E10CBAD01	3,721	10	10-20-73	3,711	Stock well
TR-97	09S44E11BDAA01	3,791	26	11-17-73	3,765	Well not used
TR-98	09S44E20DCAA01	3,670	25	10-27-73	3,645	Stock well
TR-99	09S44E27ABCB01	3,715	20	01-01-57	3,695	--
SP-7	09S44E28CDCA02	3,720	--	--	3,720	Spring in Tongue River Member, domestic and stock water supply
TR-100	09S44E28CDCD01	3,720	23	09-01-63	3,697	Domestic water supply
TR-101	09S44E33BADB01	3,702	15	01-01-66	3,687	Stock well
TR-102	09S45E07CCAD01	3,900	--	--	--	Domestic water supply
TR-103	09S45E20ACCD01	4,090	395	09-06-67	3,695	Stock well
TR-104	09S45E27BBBB01	4,170	200	09-06-67	3,970	Stock well
TR-105	10S43E02AABA01	3,641	--	--	--	Water-quality data available
TR-106	10S43E02BAAA01	3,640	30	10-29-75	3,610	--
TR-107	10S43E06ABAC01	3,800	35	11-15-73	3,765	--

Table 3.--*Hydraulic properties of alluvial, coal, and sandstone aquifers*

[Data from U.S. Department of the Interior (1978), McClymonds (1984,1985), and this study. --, no data]

Well number	Location number	Date of aquifer test (month-day-year)	Aquifer material	Hydraulic conductivity (feet per day)	Transmissivity (feet squared per day)	Storage coefficient	Well discharge (gallons per minute)	Remarks
AL-1	06S43E19DACD01	05-14-87	Alluvium	5	170	--	8.3	Observation well HWC-86-9
AL-2	06S43E19DDBA01	05-13-87	Alluvium	50	2,700	0.0004	25.0	Observation well HWC-86-7
AL-3	06S43E19DDBA02	05-12-87	Alluvium	90	5,000	.003	25.0	Observation well HWC-86-8
AL-4	06S43E19DDBD01	05-14-87	Alluvium	30	1,100	.0002	7.9	Observation well HWC-86-6
AL-5	07S43E05ACCA01	05-13-87	Alluvium	60	2,300	--	25.0	Observation well HWC-86-11
AL-6	07S43E08ABBB01	05-13-87	Alluvium	50	2,200	--	11.1	Observation well HWC-86-12
AL-7	08S43E17DDCA01	05-12-87	Alluvium	7	110	--	4.7	Observation well HWC-86-2
AL-8	08S43E17DDDC01	05-12-87	Alluvium	5	70	--	3.0	Observation well HWC-86-5
AL-9	08S43E21BBDA01	09-22-81	Alluvium	200	1,000	--	16.9	Observation well HC-1
AL-10	08S43E21BBDD01	09-26-81	Alluvium	170	1,200	.005	24.9	Observation well HC-2
AL-11	08S43E21BBDD02	06-19-82	Alluvium	660	4,000	--	13.0	Observation well HC-3
AL-12	08S43E21BBDD03	09-23-81	Alluvium	240	1,200	.003	7.2	Observation well HC-5
AL-13	08S43E21BCAA01	09-22-81	Alluvium	70	420	--	15.6	Observation well HC-4
AL-14	08S43E23CABD01	09-28-81	Alluvium	12	100	--	3.0	Observation well HC-8
AL-15	08S43E23CABD02	09-24-81	Alluvium	16	100	--	6.6	Observation well HC-9
AL-16	08S43E23CACA01	09-24-81	Alluvium	10	40	--	3.0	Observation well HC-6
AL-17	08S43E23CACA02	06-18-82	Alluvium	150	900	--	2.9	Observation well HC-7
AL-18	08S43E23CACA03	09-30-81	Alluvium	220	2,000	.06	23.9	Observation well HC-10
AL-19	08S44E19CBCB01	06-18-82	Alluvium	11	80	--	3.6	Observation well HC-12

Well number	Location number	Date of aquifer test (month-day-year)	Aquifer material	Hydraulic conductivity (feet per day)	Transmissivity (feet squared per day)	Storage coefficient	Well discharge (gallons per minute)	Remarks
AL-20	08S44E19CBCB02	06-21-82	Alluvium	16	100	--	10.9	Observation well HC-13
AL-22	08S44E19CBCC01	06-16-82	Alluvium	60	300	--	2.3	Observation well HC-11
AL-23	08S44E20CBCC01	07-14-81	Alluvium	1	3	--	.4	Observation well HC-15
AL-24	08S44E20CCBB01	07-14-81	Alluvium	.02	.1	--	.03	Observation well HC-16
AL-25	09S42E01BCAD01	06-16-81	Alluvium	4	25	--	1.6	Observation well CC-16
AL-26	09S42E01BCAD02	06-13-81	Alluvium	.4	2	--	.4	Observation well CC-17
AL-27	09S42E01BCAD03	06-10-81	Alluvium	.7	3	--	.4	Observation well CC-18
AL-28	09S42E02BBBD01	09-14-80	Alluvium	80	500	--	7.3	Observation well CC-21
AL-29	09S42E02BBCA01	09-15-80	Alluvium	50	260	--	12.0	Observation well CC-20
AL-31	09S42E11BDCA02	06-15-81	Alluvium	60	350	--	9.4	Observation well CC-15
AL-34	09S43E04ABDB01	09-11-80	Alluvium	30	180	--	3.8	Observation well CC-5
AL-35	09S43E04ABDD01	10-07-80	Alluvium	25	300	.001	4.2	Observation well CC-1
AL-36	09S43E04ABDD02	07-23-80	Alluvium	4	40	.0004	2.5	Observation well CC-2
AL-37	09S43E04ABDD03	10-08-80	Alluvium	5	50	--	4.8	Observation well CC-4
AL-38	09S43E04ACAA01	07-21-80	Alluvium	15	120	--	4.6	Observation well CC-3
AL-39	09S43E06DDBD01	06-09-81	Alluvium	10	150	--	15.0	Observation well CC-8
AL-40	09S43E06DDBD02	06-13-81	Alluvium and Anderson coal bed	40	1,400	--	20.8	Observation well CC-9
AL-41	09S43E06DDBD03	06-11-81	Alluvium	40	600	--	5.7	Observation well CC-11
AL-42	09S43E06DDCA01	06-15-81	Alluvium	70	1,000	.0001	19.7	Observation well CC-10

Table 3.--*Hydraulic properties of alluvial, coal, and sandstone aquifers*--Continued

Well number	Location number	Date of aquifer test (month-day-year)	Aquifer material	Hydraulic conductivity (feet per day)	Transmissivity (feet squared per day)	Storage coefficient	Well discharge (gallons per minute)	Remarks
AL-43	09S43E12AACC02	09-19-77	Alluvium	83	1,250	.002	4.4	Observation well HWC-36
AL-50	09S44E07ADAD01	09-29-77	Alluvium	92	1,650	--	17.7	Observation well HWC-34
AL-52	10S43E02ACDA01	05-11-87	Alluvium	30	700	--	11.4	Observation well HWC-86-15
AL-53	10S43E02ACDC01	05-11-87	Alluvium	4	120	--	3.9	Observation well HWC-86-13
TR-18	08S42E35DDDB01	06-14-81	Lower Dietz coal bed	.05	.15	--	.02	Observation well CC-22
TR-19	08S42E35DDDB02	06-14-81	Anderson coal bed	.02	.15	--	.02	Observation well CC-23
TR-24	08S43E14BCCA01	06-21-82	Dietz coal bed	.05	.5	--	.15	Observation well HC-21
TR-26	08S43E20DABA01	07-16-80	Canyon coal bed	.3	4	--	7.5	Observation well HWC-1
TR-27	08S43E21BDBB01	09-22-81	Canyon coal bed and sandstone	1.5	15	--	17.1	Observation well HC-23
TR-28	08S43E21BDBB02	09-23-81	Sandstone	.2	5	--	8.0	Observation well HC-24
TR-29	08S43E23CDAA01	06-20-82	Dietz coal bed	10	140	--	3.5	Observation well HC-19
TR-30	08S43E23CDAA02	09-30-81	Canyon coal bed	.6	12	--	8.0	Observation well HC-20
TR-31	08S43E23DBCC01	06-17-82	Sandstone and Dietz coal bed	.3	2	--	.34	Observation well US-70
TR-33	08S43E25DBBB01	06-20-82	Dietz coal bed	.03	.4	--	.39	Observation well HC-17
TR-34	08S43E25DBBB02	09-29-81	Anderson coal bed	.15	4	--	2.2	Observation well HC-18
TR-38	08S43E31BBDA01	06-16-81	Anderson coal bed	.05	.2	--	.03	Observation well FC-1; only lower 4 feet of coal is saturated
TR-48	08S44E19CBBB01	06-19-82	Dietz coal bed	.8	10	--	2.1	Observation well BC-10
TR-49	08S44E19CBBB02	06-16-82	Anderson coal bed	1.5	50	--	2.9	Observation well BC-11

Table 3.--*Hydraulic properties of alluvial, coal, and sandstone aquifers*--Continued

Well number	Location number	Date of aquifer test (month-day-year)	Aquifer material	Hydraulic conductivity (feet per day)	Transmissivity (feet squared per day)	Storage coefficient	Well discharge (gallons per minute)	Remarks
TR-50	08S44E32DDAB01	07-07-77	Anderson coal bed	5	160	--	4.4	Observation well HWC-28
TR-54	09S42E04BABA01	06-12-81	Smith coal bed	.4	7	--	3.6	Observation well CC-25
TR-56	09S42E11BDAA01	07-17-80	Anderson coal bed	.3	10	--	2.1	Observation well HWC-12
TR-60	09S43E03CDDA01	06-10-75	Canyon coal bed	1.2	23	--	2.4	Observation well HWC-2
TR-61	09S43E03CDDA02	10-08-74	Dietz coal bed	6	80	--	10.5	Observation well HWC-3
TR-62	09S43E04ABCA01	07-24-80	Anderson coal bed	.05	1	--	1.0	Private well
TR-63	09S43E04CBAB01	07-19-80	Upper Dietz coal bed	.2	1	--	2.0	Observation well CC-6
TR-64	09S43E04CBAB02	07-20-80	Anderson coal bed	.7	20	--	6.6	Observation well CC-7
TR-66	09S43E07CADB01	07-18-80	Sandstone	4	60	--	6.8	Observation well US-7770
TR-67	09S43E07CADB02	06-14-81	Anderson coal bed	.07	2	--	2.8	Observation well CC-24
TR-70	09S43E13BCAA01	04-19-77	Anderson coal bed	1.4	33	--	6.9	Observation well HWC-17
TR-73	09S43E14DDBB01	09-14-77	Anderson coal bed	1.5	43	--	2.9	Observation well HWC-27
TR-78	09S43E22ACCA01	06-22-77	Anderson coal bed	11	280	--	10.0	Observation well HWC-15
TR-80	09S43E27DABB01	09-13-77	Anderson coal bed	.7	18	--	--	Observation well HWC-16
TR-88	09S44E07ADDC01	04-28-77	Dietz coal bed	.1	1	--	.3	Observation well HWC-8
TR-89	09S44E07ADDC03	04-26-77	Anderson coal bed	.1	3	.00004	.3	Observation well HWC-20
TR-90	09S44E07BBCC01	09-27-77	Anderson coal bed	.3	8	.0005	3.0	Observation well HWC-29
TR-93	09S44E08BBAA02	04-21-77	Anderson coal bed	6	210	--	4.6	Observation well HWC-26
TR-94	09S44E08BDDD01	04-28-77	Anderson coal bed	3	92	--	8.9	Observation well HWC-18

Table 4.--*Quality of water from wells completed in alluvial aquifers*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviations: µS/cm, microsiemens per centimeter at 25 degrees Celsius. --, no data]

Well number	Location number	Date sample collected (month-day-year)	On-site specific conductance (µS/cm)	Onsite pH (standard units)	Hardness (as $CaCO_3$)	Solids, dissolved, sum of constituents	Calcium (Ca)	Magnesium (Mg)
AL-1	06S43E19DACD01	05-14-87	2,930	7.5	840	2,200	130	120
AL-2	06S43E19DDBA01	05-13-87	3,750	7.4	1,200	3,000	160	190
AL-3	06S43E19DDBA02	05-12-87	3,030	7.6	960	2,400	150	150
AL-4	06S43E19DDBD01	05-14-87	5,050	7.4	1,600	4,400	230	260
AL-5	07S43E05ACCA01	05-13-87	3,190	7.6	960	2,500	120	160
AL-6	07S43E08ABBB01	05-13-87	3,690	7.5	1,300	3,100	170	220
AL-7	08S43E17DDCA01	05-12-87	2,930	7.6	840	2,300	130	130
AL-8	08S43E17DDDC01	05-12-87	2,700	7.4	780	2,100	110	120
AL-9	08S43E21BBDA01	09-17-80	3,550	7.2	1,100	2,500	150	170
		09-22-81	3,200	7.8	1,100	2,500	150	180
AL-10	08S43E21BBDD01	09-26-81	3,400	7.4	1,100	2,500	150	180
AL-11	08S43E21BBDD02	09-24-81	3,850	7.5	1,300	2,800	170	210
		06-19-82	3,520	7.3	1,200	2,800	170	200
AL-12	08S43E21BBDD03	09-23-81	3,150	7.5	1,100	2,500	150	180
		05-05-86	2,820	7.3	1,000	2,300	130	160
AL-13	08S43E21BCAA01	09-22-81	3,800	7.5	1,400	2,900	180	220
AL-14	08S43E23CABD01	09-28-81	5,800	7.7	1,700	4,200	170	300
AL-15	08S43E23CABD02	09-30-80	4,600	--	1,400	3,400	180	240
		09-24-81	5,400	7.3	1,400	3,500	180	240
AL-16	08S43E23CACA01	09-24-81	8,100	7.5	2,700	5,800	330	460
AL-17	08S43E23CACA02	09-26-81	6,600	7.4	2,500	5,400	290	420
		06-18-82	6,200	7.3	2,100	5,200	260	360
AL-18	08S43E23CACA03	09-30-80	5,800	--	2,000	4,900	220	340
		09-30-81	6,400	7.5	1,900	4,700	220	340
AL-19	08S44E19CBCB01	06-18-82	9,000	7.3	3,400	8,100	360	610
AL-20	08S44E19CBCB02	06-21-82	8,500	7.3	3,200	7,700	340	580
AL-22	08S44E19CBCC01	06-16-82	9,700	7.2	3,800	8,900	390	680
AL-23	08S44E20CBCC01	07-14-81	12,000	7.3	3,900	9,500	370	720
AL-24	08S44E20CCBB01	07-14-81	13,000	7.5	3,700	9,700	380	680
AL-25	09S42E01BCAD01	10-08-80	4,400	7.8	1,100	3,200	170	170
		06-16-81	4,200	7.4	1,200	3,200	180	180
AL-26	09S42E01BCAD02	10-09-80	4,600	7.8	1,300	3,700	190	190
		06-13-81	4,800	7.5	1,300	3,700	200	190
AL-27	09S42E01BCAD03	10-09-80	4,000	7.7	1,500	3,100	210	230
		06-10-81	4,200	7.4	1,500	3,400	220	230
AL-28	09S42E02BBBD01	09-14-80	3,900	7.2	1,300	2,700	200	190
AL-29	09S42E02BBCA01	09-15-80	4,700	--	1,800	3,800	250	290
AL-31	09S42E11BDCA02	06-15-81	4,100	7.4	1,700	3,400	250	260
		09-13-80	4,300	7.1	1,700	3,400	250	250
AL-34	09S43E04ABDB01	09-11-80	14,800	7.1	4,000	11,000	410	710
AL-35	09S43E04ABDD01	10-07-80	7,100	7.3	2,700	6,100	330	450
AL-36	09S43E04ABDD02	07-23-80	8,600	7.1	2,300	6,300	330	350
		05-07-86	8,200	7.4	2,600	6,200	310	430
AL-37	09S43E04ABDD03	10-08-80	8,000	7.3	2,800	7,000	290	510
AL-38	09S43E04ACAA01	07-21-80	5,200	7.2	2,000	4,500	220	340
AL-40	09S43E06DDBD02	09-10-80	4,900	8.1	1,400	3,200	190	220
AL-41	09S43E06DDBD03	06-11-81	3,300	7.4	1,200	2,500	170	180
AL-42	09S43E06DDCA01	09-12-80	2,900	7.0	1,200	2,400	180	190
		06-15-81	2,900	7.4	1,300	2,400	190	200
AL-43	09S43E12AACC02	06-21-77	7,200	7.7	2,600	5,900	330	440
		09-20-77	7,200	7.7	2,500	5,700	300	420
AL-45	09S43E12ADBB02	05-06-86	7,600	7.2	3,200	7,500	370	560
AL-49	09S44E07ADAB01	09-13-77	4,410	7.8	1,800	3,800	240	300
AL-50	09S44E07ADAD01	09-29-77	5,170	7.6	2,100	4,600	280	330
AL-52	10S43E02ACDA01	05-11-87	6,900	7.1	2,700	7,000	420	400
AL-53	10S43E02ACDC01	05-11-87	7,000	7.1	2,500	6,800	420	360

Sodium (Na)	Sodium adsorption ratio (SAR)	Potassium (K)	Bicarbonate (onsite or laboratory)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Well number
430	7	15	770	1,100	19	1.2	30	AL-1
550	7	19	810	1,700	20	1.2	25	AL-2
420	6	15	620	1,300	16	1.0	22	AL-3
780	9	27	770	2,600	28	.2	32	AL-4
460	7	18	710	1,300	19	.8	25	AL-5
460	6	18	630	1,800	18	1.0	30	AL-6
440	7	11	680	1,200	15	.8	21	AL-7
400	6	11	670	1,000	15	.9	18	AL-8
390	5	11	630	1,400	12	.7	20	AL-9
400	5	10	630	1,400	13	.8	19	
400	5	11	650	1,400	13	.9	20	AL-10
430	5	10	620	1,600	13	.7	21	AL-11
430	5	11	580	1,700	18	.8	22	
400	5	10	630	1,400	13	.8	20	AL-12
380	5	9.0	630	1,300	13	.6	20	
430	5	11	640	1,700	13	.7	20	AL-13
760	8	11	660	2,600	17	.7	17	AL-14
590	7	13	730	2,000	23	.9	23	AL-15
600	7	12	710	2,100	15	.6	20	
840	7	9.0	600	3,800	21	.6	16	AL-16
830	7	10	640	3,500	20	.6	17	AL-17
830	8	10	640	3,400	19	.8	16	
800	8	11	670	3,100	31	.6	17	AL-18
780	8	10	670	3,000	16	.7	17	
1,300	10	7.0	710	5,400	31	.7	11	AL-19
1,200	9	7.0	730	5,200	32	.8	11	AL-20
1,400	10	7.0	760	6,000	32	.8	10	AL-22
1,600	11	9.0	740	6,400	24	.7	9.3	AL-23
1,700	12	15	850	6,500	29	.8	10	AL-24
640	8	8.0	650	1,900	13	.5	11	AL-25
610	8	8.0	660	1,900	14	.8	11	
720	9	9.0	680	2,200	14	.5	11	AL-26
710	9	9.0	680	2,200	16	.8	10	
460	5	6.0	600	1,900	13	.4	11	AL-27
530	6	8.0	610	2,100	11	.6	11	
430	5	6.0	550	1,600	21	.4	12	AL-28
510	5	6.0	580	2,400	20	.4	11	AL-29
440	5	5.0	470	2,200	16	.5	11	AL-31
470	5	5.0	480	2,200	16	.4	11	
2,100	15	13	1,010	7,300	72	.7	16	AL-34
930	8	9.0	620	4,000	40	.6	18	AL-35
980	9	8.0	180	4,500	26	.8	18	AL-36
1,000	9	7.5	720	4,000	25	2.1	18	
1,200	10	11	780	4,500	43	.7	15	AL-37
740	7	10	700	2,800	17	.8	19	AL-38
560	7	6.0	690	1,900	14	.5	11	AL-40
380	5	5.0	600	1,400	14	.7	11	AL-41
310	4	4.0	530	1,400	7.3	.4	11	AL-42
290	4	4.0	530	1,400	8.7	.5	11	
930	8	9.0	850	3,700	26	.4	12	AL-43
960	9	9.0	840	3,600	26	.3	15	
1,200	9	9.8	900	4,900	26	2.7	16	AL-45
540	6	7.8	680	2,300	13	1.9	14	AL-49
700	7	7.7	690	2,800	22	.4	15	AL-50
1,200	11	12	870	4,500	13	.1	14	AL-52
1,200	11	13	950	4,300	9.0	.2	14	AL-53

Table 5.--*Quality of water from wells and springs that produce water from the Tongue River Member of the Fort Union Formation*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Abbreviations: µS/cm, microsiemens per centimeter at 25 degrees Celsius; MBMG, Montana Bureau of Mines and Geology; USGS, U.S. Geological Survey. Symbol <, less than; --, no data]

Well or spring number	Location number	Date sample collected (month-day-year)	Onsite specific conductance (µS/cm)	Onsite pH (standard units)	Hardness (as $CaCO_3$)	Solids, dissolved, sum of constituents	Calcium (Ca)	Magnesium (Mg)
TR-1	06S43E18BABC01	03-02-74	1,430	--	6	990	2.2	0.20
SP-1	07S44E33BBCA01	10-07-80	1,600	7.9	450	1,200	73	64
TR-6	07S44E34BAAD01	06-17-75	2,710	8.0	36	1,600	8.2	3.6
		05-12-76	3,050	8.0	35	1,800	5.8	4.2
TR-7	07S44E34BAAD02	06-17-75	3,150	7.8	29	1,900	5.6	3.5
		06-09-76	2,890	8.4	32	2,400	6.5	3.7
SP-2	08S42E10AADC01	11-10-76	1,300	--	780	1,100	100	130
TR-10	08S42E14DBAD01	06-01-86	2,230	8.4	17	1,400	3.5	1.9
TR-11	08S42E14DBAD02	05-31-86	2,450	7.1	660	1,900	93	100
TR-12	08S42E15CBBA01	11-10-76	2,720	--	1,800	2,900	180	320
TR-16	08S42E26CBBB01	11-15-73	4,300	8.2	670	2,800	110	96
TR-18	08S42E35DDDB01	06-14-81	2,450	8.4	63	1,900	12	7.8
TR-19	08S42E35DDDB02	06-14-81	6,200	7.4	930	4,700	140	140
TR-23	08S43E13ACCA01	06-19-75	958	--	330	580	43	53
TR-24	08S43E14BCCA01	06-21-82	9,750	7.5	470	7,800	92	59
SP-3	08S43E15CCAA01	06-26-80	840	7.1	270	540	61	29
TR-25	08S43E16CCDA01	06-19-82	2,460	7.2	450	1,600	58	73
SP-4	08S43E16CDBD01	06-19-82	320	7.2	140	200	28	17
TR-26	08S43E20DABA01	06-04-74	2,770	--	100	1,800	17	15
		06-20-74	2,690	--	94	1,900	18	12
		06-24-75	2,690	8.2	33	1,500	7.7	3.2
		06-09-76	2,480	8.1	29	1,800	6.3	3.0
		07-16-80	2,450	7.8	23	1,600	4.8	2.6
		05-07-86	2,800	8.1	21	1,600	4.4	2.4
TR-27	08S43E21BDBB01	09-22-81	2,400	8.5	19	1,600	4.5	1.9
TR-28	08S43E21BDBB02	09-23-81	2,600	8.2	17	1,600	3.9	1.7
SP-5	08S43E22CBAA01	06-26-80	4,100	7.9	1,500	3,600	170	260
TR-29	08S43E23CDAA01	10-01-81	5,050	7.5	740	4,200	100	120
		06-20-82	6,250	7.3	830	4,600	120	130
TR-30	08S43E23CDAA02	09-30-81	2,650	8.0	26	1,800	5.9	2.7
TR-31	08S43E23DBCC01	10-01-81	4,650	8.0	1,500	3,800	190	240
		06-17-82	4,650	7.3	1,500	3,900	200	250
TR-32	08S43E23DBDB01	06-17-82	7,000	7.3	2,600	6,200	290	460
		02-26-74	5,500	--	1,900	4,800	220	330
TR-33	08S43E25DBBB01	09-29-81	3,400	8.3	72	2,100	14	9.1
		06-20-82	3,250	7.9	67	2,000	12	8.9
TR-34	08S43E25DBBB02	09-29-81	4,200	7.7	66	2,500	14	7.5
TR-35	08S43E29DABC01	05-05-76	1,720	7.5	650	1,300	110	92
TR-37	08S43E30BBCD01	11-15-73	1,550	7.8	610	1,100	74	100
TR-38	08S43E31BBDA01	06-16-81	6,500	7.8	190	4,400	39	22
TR-39	08S43E31BBDA02	06-16-81	3,400	8.1	270	2,300	35	43
TR-48	08S44E19CBBB01	05-31-86	3,050	7.7	41	1,900	8.0	5.0
TR-49	08S44E19CBBB02	06-16-82	3,630	7.5	75	2,300	15	9.1
		05-31-86	3,600	7.5	87	2,500	17	10
TR-51	08S44E35ADDC01	02-03-74	660	7.8	390	460	79	48
		06-19-75	750	--	390	440	80	46
		06-19-75	742	7.3	390	440	80	46
TR-52	09S42E02ADBB01	09-15-80	4,200	--	1,600	3,400	240	250
TR-53	09S42E03AADA01	09-15-80	4,000	--	1,700	3,500	240	270
TR-54	09S42E04BABA01	06-12-81	3,200	7.2	820	2,400	130	120
TR-55	09S42E05AAAD01	06-12-81	3,650	7.3	1,200	2,900	200	160
TR-56	09S42E11BDAA01	07-17-80	2,700	7.5	30	1,700	6.1	3.5
TR-57	09S42E25DCAD01	06-03-75	7,250	--	1,900	5,300	280	280
TR-60	09S43E03CBCD01	06-16-75	2,670	8.1	41	1,600	6.0	6.1
		06-04-74	2,600	--	31	1,800	11	.90
TR-61	09S43E03CBCD02	06-16-75	10,500	8.1	680	6,700	57	130
		06-09-76	10,500	8.3	490	6,400	110	50
		08-08-74	6,280	--	790	4,900	36	170
		10-08-74	5,950	--	280	3,700	34	48
TR-62	09S43E04ABCA01	07-24-80	9,500	7.5	2,900	8,700	300	520

Sodium (Na)	Sodium adsorption ratio (SAR)	Potassium (K)	Bicarbonate (onsite or laboratory)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Agency analyzing sample	Well or spring number
430	78	2.0	1,090	0.5	4.3	6.0	7.8	MBMG	TR-1
250	5	10	520	530	6.7	1.0	27	MBMG	SP-1
610	46	5.1	1,100	430	15	5.1	9.1	--	TR-6
680	54	5.0	1,180	540	17	4.7	8.9	--	
780	65	6.3	2,080	10	30	5.1	7.9	--	TR-7
770	61	11	2,000	9.0	30	5.0	8.3	--	
48	.8	18	340	570	6.0	.7	21	MBMG	SP-2
530	58	3.0	950	330	9.4	4.4	9.4	MBMG	TR-10
390	7	7.7	680	900	12	.6	13	MBMG	TR-11
280	3	7.0	700	1,700	22	.5	9.4	MBMG	TR-12
720	12	12	1,140	1,300	7.7	.2	12	MBMG	TR-16
730	41	9.0	1,440	450	16	3.2	8.3	MBMG	TR-18
1,200	17	14	1,190	2,600	40	.9	9.3	MBMG	TR-19
93	2	7.0	470	130	8.7	.5	12	MBMG	TR-23
2,400	49	16	1,520	4,400	24	1.6	11	MBMG	TR-24
78	2	5.0	320	180	2.9	.9	27	MBMG	SP-3
440	9	8.0	1,200	430	19	1.9	14	MBMG	TR-25
16	.6	2.0	180	17	1.2	1.5	25	MBMG	SP-4
670	29	7.0	1,560	270	22	2.6	9.6	MBMG	TR-26
690	32	7.0	1,450	290	28	2.7	8.9	MBMG	
630	50	5.3	1,650	28	23	3.6	8.8	--	
620	52	5.0	1,450	8.6	21	3.7	8.2	--	
670	63	5.0	1,720	14	26	3.7	8.8	MBMG	
690	68	4.0	1,830	2.8	22	3.4	9.6	MBMG	
670	69	3.0	1,730	2.8	23	4.0	8.9	MBMG	TR-27
670	73	3.0	1,760	3.8	25	4.9	8.0	MBMG	TR-28
600	7	12	650	2,200	18	.4	7.3	MBMG	SP-5
1,100	18	15	830	2,400	25	1.4	9.1	MBMG	TR-29
1,200	18	16	830	2,700	17	1.5	9.4	MBMG	
730	64	3.0	1,950	16	27	3.7	9.9	MBMG	TR-30
630	7	16	530	2,400	20	1.2	9.8	MBMG	TR-31
670	8	18	530	2,500	20	1.5	11	MBMG	
920	8	10	1,000	4,000	21	.8	17	MBMG	TR-32
790	8	8.4	600	3,100	20	.5	15	MBMG	
850	45	7.0	2,130	86	40	2.6	7.1	MBMG	TR-33
780	43	9.0	2,170	42	40	3.1	7.3	MBMG	
990	55	4.0	2,160	410	42	2.1	12	MBMG	TR-34
180	3	9.0	460	650	7.0	--	--	--	TR-35
140	2	7.3	320	630	6.4	.5	18	MBMG	TR-37
1,400	46	22	1,270	2,300	24	1.4	9.5	MBMG	TR-38
720	20	15	1,160	840	20	2.4	8.9	MBMG	TR-39
800	56	4.8	2,110	2.1	33	2.2	8.8	MBMG	TR-48
900	46	6.0	2,250	240	31	2.1	9.6	MBMG	TR-49
980	47	6.1	2,260	360	30	1.8	10	MBMG	
20	.4	2.0	420	71	6.7	.6	16	MBMG	TR-51
17	.4	2.0	420	55	6.0	.6	14	MBMG	
17	.4	1.7	420	55	6.0	.6	13	MBMG	
480	5	5.0	590	2,100	28	.4	11	MBMG	TR-52
480	5	6.0	570	2,200	25	.4	11	MBMG	TR-53
480	7	7.0	680	1,300	15	.5	12	MBMG	TR-54
480	6	--	600	1,700	14	.5	11	MBMG	TR-55
700	57	5.0	1,850	2.5	21	3.1	8.8	MBMG	TR-56
1,000	10	7.0	650	3,400	20	.4	11	MBMG	TR-57
640	45	5.3	1,610	130	22	2.9	7.5	USGS	TR-60
710	58	5.0	1,690	120	28	2.5	8.4	MBMG	
1,900	32	18	1,230	3,900	28	1.5	8.0	USGS	TR-61
1,900	39	20	--	3,600	28	1.5	7.8	USGS	
1,400	22	11	1,480	2,500	30	2.0	8.0	MBMG	
1,300	34	9.0	1,370	1,600	33	1.8	7.8	MBMG	
1,700	14	13	900	5,700	24	1.2	12	MBMG	TR-62

Table 5.--*Quality of water from wells and springs that produce water from the Tongue River Member of the Fort Union Formation*--Continued

Well or spring number	Location number	Date sample collected (month-day-year)	Onsite specific conductance (µS/cm)	Onsite pH (standard units)	Hardness (as $CaCO_3$)	Solids, dissolved, sum of constituents	Calcium (Ca)	Magnesium (Mg)
TR-63	09S43E04CBAB01	07-14-80	2,400	7.9	25	1,500	4.8	2.9
TR-64	09S43E04CBAB02	07-20-80	9,000	6.8	2,200	6,000	330	340
TR-65	09S43E07BCAD01	10-30-73	2,310	7.8	1,000	1,900	120	170
		09-15-80	2,700	--	1,300	2,200	200	190
TR-66	09S43E07CADB01	07-18-80	5,600	7.2	540	4,000	74	85
		05-06-86	4,800	7.5	630	3,600	81	100
TR-67	09S43E07CADB02	06-14-81	2,450	7.5	29	1,500	5.8	3.5
		05-06-86	2,400	7.8	28	1,500	5.5	3.4
TR-68	09S43E10BBAD01	02-26-74	5,450	7.2	1,700	4,700	270	260
TR-69	09S43E12AACC01	06-21-77	7,000	7.5	2,200	5,200	260	380
TR-70	09S43E13BCAA01	04-27-77	3,920	7.0	770	3,000	110	120
		04-19-77	4,000	7.5	740	2,900	99	120
TR-72	09S43E13CAAA02	04-29-77	5,940	7.5	1,100	4,900	170	170
		04-29-77	6,080	7.2	1,100	5,000	170	170
TR-73	09S43E14DDBB01	07-08-77	3,740	7.8	98	2,600	19	12
TR-74	09S43E15DABC01	10-28-73	2,250	8.8	32	1,600	5.7	4.4
TR-78	09S43E22ACCA01	06-23-77	2,300	8.5	28	1,400	5.5	3.4
		05-07-86	2,120	7.9	26	1,400	5.1	3.2
SP-6	09S43E25BADC01	02-28-74	750	7.3	380	480	64	53
TR-79	09S43E27CDCA01	10-28-73	1,900	8.2	30	1,200	5.5	4.0
TR-80	09S43E27DABB01	09-13-77	2,200	--	28	1,300	5.6	3.3
TR-82	09S43E35BBCD01	06-25-75	2,270	8.0	41	1,300	11	3.2
		05-05-76	1,870	7.9	33	1,300	6.5	4.0
TR-83	09S43E35CADC01	06-25-75	2,050	8.4	41	1,200	9.1	4.2
		05-05-76	1,720	8.1	34	1,300	6.4	4.3
TR-84	09S44E01ADAA01	02-28-74	2,300	8.6	48	1,700	11	4.9
TR-87	09S44E07ADAA01	10-30-73	4,340	7.7	1,800	4,100	190	320
		04-28-77	5,650	7.3	2,400	4,600	320	380
		02-28-74	4,960	7.3	2,000	4,400	280	320
TR-88	09S44E07ADDC01	04-28-77	2,530	7.9	47	1,600	9.4	5.5
		04-28-77	2,520	8.2	45	1,600	8.7	5.5
TR-89	09S44E07ADDC03	04-26-77	2,900	--	58	1,800	11	7.2
		04-28-77	2,750	--	46	1,600	9.0	5.5
TR-90	09S44E07BBCC01	09-27-77	9,940	7.3	3,300	9,500	490	500
		09-28-77	9,860	7.5	3,300	9,400	480	500
TR-91	09S44E07BBCC03	05-06-86	8,500	6.9	3,200	8,800	470	490
TR-93	09S44E08BBAA02	04-28-77	4,840	7.6	1,200	3,800	180	180
TR-94	09S44E08BDDD01	04-28-77	2,220	8.2	33	1,400	6.3	4.2
		04-28-77	2,230	7.8	34	1,400	6.8	4.1
TR-96	09S44E10CBAD01	06-04-75	7,400	7.9	2,600	5,900	270	460
TR-97	09S44E11BDAA01	06-03-75	1,080	7.7	480	630	72	72
TR-98	09S44E20DCAA01	06-04-75	8,450	7.8	2,800	6,800	380	450
TR-99	09S44E27ABCB01	06-04-75	7,200	7.3	2,300	5,800	380	330
SP-7	09S44E28CDCA02	10-27-73	2,720	--	1,400	2,200	230	190
TR-100	09S44E28CDCD01	10-27-73	2,450	8.1	44	1,600	9.8	4.7
TR-102	09S45E07CCAD01	02-02-74	1,950	8.1	40	1,300	9.8	3.8
		06-26-75	2,150	8.0	39	1,300	8.9	4.0
TR-105	10S43E02AABA01	10-29-73	1,910	8.2	32	1,200	8.3	2.7

Sodium (Na)	Sodium adsorption ratio (SAR)	Potassium (K)	Bicarbonate (onsite or laboratory)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Agency analyzing sample	Well or spring number
620	57	4.0	1,630	4.3	26	3.1	7.9	MBMG	TR-63
1,100	10	25	1,030	3,700	22	.4	14	MBMG	TR-64
230	3	4.0	320	1,200	5.5	.1	11	MBMG	TR-65
220	3	4.0	490	1,300	7.0	.3	12	MBMG	
1,200	23	10	1,380	1,900	35	1.2	10	MBMG	TR-66
1,000	18	8.4	1,460	1,600	28	.9	9.6	MBMG	
620	52	4.0	1,710	4.3	21	1.7	8.6	MBMG	TR-67
640	54	3.8	1,720	1.2	19	1.6	9.0	MBMG	
810	9	28	490	3,000	56	.3	8.2	MBMG	TR-68
880	8	10	910	3,200	33	.4	14	MBMG	TR-69
700	11	11	670	1,700	13	1.0	11	USGS	TR-70
720	12	10	690	1,600	16	.6	11	MBMG	
1,200	16	13	1,180	2,700	47	.6	10	MBMG	TR-72
1,200	16	14	1,180	2,800	17	.8	13	USGS	
900	41	6.4	1,150	1,100	18	1.4	8.6	MBMG	TR-73
640	50	5.0	1,480	59	19	.9	7.7	MBMG	TR-74
550	47	4.0	1,590	.1	25	2.0	8.3	MBMG	TR-78
590	52	3.4	1,560	<.5	18	1.6	9.3	MBMG	
27	.6	2.0	340	150	4.9	.6	12	MBMG	SP-6
500	41	3.7	1,260	45	22	1.1	7.6	--	TR-79
560	48	4.0	1,510	1.2	17	.4	9.9	MBMG	TR-80
560	40	4.8	1,490	5.5	20	1.5	8.9	--	TR-82
540	42	4.6	1,480	<1.0	19	2.2	8.1	--	
490	35	5.3	1,310	5.9	20	1.9	7.1	--	TR-83
470	36	4.3	1,060	6.3	19	2.3	6.8	--	
650	42	5.0	1,660	.5	16	2.1	8.4	MBMG	TR-84
650	7	7.9	380	2,700	14	<.1	13	--	TR-87
540	5	7.4	650	3,000	16	.4	12	USGS	
620	6	7.0	600	2,800	14	.2	12	MBMG	
660	43	5.8	1,720	43	25	1.7	10	USGS	TR-88
650	44	5.7	1,740	45	26	1.5	9.6	MBMG	
700	41	5.0	1,840	60	47	.8	9.2	MBMG	TR-89
640	43	5.0	1,680	47	54	1.5	9.9	MBMG	
1,800	14	22	980	6,100	38	.4	15	MBMG	TR-90
1,800	14	18	1,030	6,100	26	.4	14	MBMG	
1,700	13	17	1,070	5,600	21	3.3	13	MBMG	TR-91
880	11	12	1,400	1,800	40	.6	14	MBMG	TR-93
580	45	4.4	1,590	.3	24	1.7	9.7	MBMG	TR-94
590	45	4.5	1,570	9.2	24	1.8	12	USGS	
910	8	8.0	720	3,800	18	.3	10	MBMG	TR-96
35	.7	4.0	330	270	4.0	.6	8.3	MBMG	TR-97
1,100	9	12	850	4,400	29	.4	12	MBMG	TR-98
930	9	8.0	760	3,600	140	.3	11	MBMG	TR-99
210	3	9.0	730	1,100	12	.2	--	MBMG	SP-7
660	45	5.0	1,730	.2	13	.1	--	MBMG	TR-100
530	38	4.0	1,420	.8	15	2.0	8.4	MBMG	TR-102
520	37	5.0	1,420	5.5	17	2.0	8.5	USGS	
510	41	4.2	1,360	.1	17	1.0	8.1	--	TR-105

Table 6.--*Monthly and annual discharge of Hanging Woman Creek near Birney (station 06307600)*

[Computed from daily discharge for water years 1974-84 and 1986-87. Drainage area = 470 square miles. Abbreviation: ft^3/s, cubic feet per second]

Month	Mean maximum (ft^3/s)	Mean minimum (ft^3/s)	Mean (ft^3/s)	Median (ft^3/s)	Standard deviation (ft^3/s)	Coefficient of variation	Percent of annual runoff[1]
October	3.0	0.04	0.98	0.85	0.77	0.79	2.1
November	3.1	.18	1.2	1.0	.79	.66	2.5
December	3.1	.06	1.3	1.2	.86	.68	2.7
January	21	.30	4.1	1.0	6.3	1.5	8.7
February	22	.60	7.5	1.8	8.5	1.1	16.0
March	93	.66	10	1.9	25	2.4	22.0
April	17	.61	3.6	2.2	4.4	1.2	7.7
May	99	.52	9.7	1.6	27	2.8	20.4
June	13	.34	4.5	2.0	4.6	1.0	9.6
July	11	.01	2.5	.90	3.1	1.2	5.3
August	2.1	.00	.81	.50	.74	.91	1.7
September	2.3	.00	.64	.54	.69	1.1	1.4
Annual	14	.62	3.9	1.2	4.0	1.0	100

[1]Total rounded to nearest whole percent.

Table 7.--*Quality of water from Hanging Woman Creek near Birney (station 06307600)*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by U.S Geological Survey. Abbreviations: ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius. Symbol <, less than; --, no data]

Date	Discharge, instantaneous (ft^3/s)	Onsite specific conductance (μS/cm)	Onsite pH (standard units)	Hardness ($CaCO_3$)	Alkalinity, laboratory ($CaCO_3$)	Solids, dissolved, sum of constituents	Calcium (Ca)
Oct 1985 15...	0.50	2,910	8.2	780	528	2,000	100
Nov 06...	.67	2,720	8.4	830	528	2,000	120
Dec 19...	1.0	2,790	7.9	850	536	2,100	95
Jan 1986 29...	.95	2,910	--	1,100	542	2,300	230
Feb 27...	360	245	7.9	85	50	200	16
Mar 05...	2.4	1,810	8.1	510	347	1,300	74
Apr 16...	4.2	3,370	8.2	850	343	2,300	60
Jun 11...	1.6	2,880	8.2	880	402	2,100	140
Jul 16...	1.1	3,500	8.2	1,000	513	2,700	120
Nov 19...	1.5	3,320	8.0	1,000	538	2,500	120
Jan 1987 07...	1.4	3,300	8.1	1,100	564	2,500	190
Feb 11...	1.4	2,840	8.1	1,000	454	2,800	130
Apr 02...	1.4	2,840	8.3	810	469	2,200	110
May 13...	.49	3,220	8.1	940	404	2,300	130
Jun 24...	.58	2,170	8.1	730	515	1,800	78
Aug 05...	.03	3,110	8.3	700	507	2,100	48
Sep 16...	.05	2,430	8.4	570	467	1,800	46
Nov 04...	.70	2,470	8.2	770	524	1,900	93

Date	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)
Oct 1985 15...	130	380	6	16	990	24	1.1	13
Nov 06...	130	370	6	14	990	28	1.1	14
Dec 19...	150	390	6	14	1,100	7.8	1.1	19
Jan 1986 29...	130	380	5	14	1,200	50	1.0	16
Feb 27...	11	29	1	6.2	98	4.0	<.1	3.0
Mar 05...	80	220	4	14	640	9.3	.7	13
Apr 16...	170	450	7	15	1,400	16	1.0	13
Jun 11...	130	340	5	17	1,200	14	.8	8.8
Jul 16...	180	470	6	19	1,500	140	1.0	6.4
Nov 19...	170	480	7	16	1,400	13	1.0	17
Jan 1987 07...	160	410	5	16	1,300	18	.9	18
Feb 11...	170	500	7	11	1,700	15	.8	12
Apr 02...	130	390	6	14	1,200	15	.9	15
May 13...	150	450	6	18	1,300	18	1.2	11
Jun 24...	130	430	7	16	830	18	1.0	5.8
Aug 05...	140	490	8	17	1,100	16	1.3	1.9
Sep 16...	110	390	7	17	930	15	1.2	1.3
Nov 04...	130	330	5	15	960	13	1.2	24

Table 8.--*Quality of water from Hanging Woman Creek below Horse Creek (station 06307570)*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by U.S Geological Survey. Abbreviations: ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius. Symbol <, less than; --, no data]

Date	Discharge, instantaneous (ft^3/s)	Onsite specific conductance (μS/cm)	Onsite pH (standard units)	Hardness ($CaCO_3$)	Alkalinity, laboratory ($CaCO_3$)	Solids, dissolved, sum of constituents	Calcium (Ca)
Jan 1986							
29...	0.23	4,180	--	1,200	552	3,300	160
Feb							
28...	109	473	7.9	120	60	310	20
Apr							
15...	.86	4,550	8.3	1,100	352	3,400	70
Jun							
10...	.78	4,850	8.1	1,500	452	4,100	180
Jul							
15...	.26	3,800	8.1	1,200	509	3,000	140
Aug							
12...	.21	5,270	8.2	1,100	--	--	130
Sep							
23...	.45	5,700	8.2	1,800	428	4,800	190
Nov							
19...	.41	4,450	7.9	1,400	492	3,700	170
Jan 1987							
06...	.32	4,650	7.9	1,400	597	4,100	180
Feb							
10...	.56	3,640	8.0	780	455	2,100	100
Apr							
01...	.72	5,300	8.4	1,700	386	4,700	200
May							
12...	.28	4,910	8.1	1,400	317	3,800	170
Jun							
23...	.15	4,720	8.1	1,300	518	4,000	140
Aug							
04...	.30	4,500	8.0	1,200	525	3,400	120
Sep							
15...	.13	4,050	8.1	1,100	316	3,000	110

Date	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)
Jan 1986								
29...	200	600	8	13	2,000	19	0.8	14
Feb								
28...	17	52	2	8.6	170	2.8	<.1	4.0
Apr								
15...	220	680	9	12	2,200	17	.8	9.4
Jun								
10...	250	760	9	15	2,600	19	.7	4.5
Jul								
15...	200	540	7	16	1,800	4.0	.8	8.3
Aug								
12...	200	620	8	18	2,100	19	.8	10
Sep								
23...	310	920	10	17	3,100	22	.6	6.3
Nov								
19...	240	660	8	14	2,200	66	.7	10
Jan 1987								
06...	240	740	9	14	2,500	21	.9	16
Feb								
10...	130	380	6	13	1,200	16	.9	15
Apr								
01...	280	900	10	12	3,000	25	.6	5.6
May								
12...	230	710	8	15	2,500	21	.8	7.2
Jun								
23...	220	740	9	25	2,500	23	.8	9.2
Aug								
04...	220	670	9	18	2,000	17	.9	9.5
Sep								
15...	190	560	8	17	1,900	18	.8	7.8

Table 9.--*Quality of water from Hanging Woman Creek at State line (station 06307540)*

[Constituents are dissolved and concentrations are reported in milligrams per liter. Analyses by U.S Geological Survey. Abbreviations: ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius. Symbol <, less than; --, no data]

Date	Discharge, instantaneous (ft^3/s)	Onsite specific conductance (μS/cm)	Onsite pH (standard units)	Hardness ($CaCO_3$)	Alkalinity, laboratory ($CaCO_3$)	Solids, dissolved, sum of constituents	Calcium (Ca)
Feb 1980							
20...	9.7	2,710	7.8	730	--	2,000	95
May 1982							
19...	.02	11,000	8.5	3,700	620	--	330
Nov							
04...	.01	10,000	8.4	3,800	682	11,000	340
Feb 1983							
01...	3.5	785	7.2	190	85	560	30
24...	.68	1,680	7.6	500	164	1,300	82
Apr							
20...	.04	11,000	8.4	3,500	677	11,000	340
Jun							
08...	.01	12,500	8.9	4,700	582	14,000	370

Date	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)	Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)
Feb 1980								
20...	120	360	6	14	1,300	13	0.2	9.1
May 1982								
19...	690	2,200	16	17	7,800	25	.3	<1.1
Nov								
04...	720	2,200	16	17	7,600	42	.4	1.5
Feb 1983								
01...	27	100	3	14	320	6.7	<.1	8.5
24...	72	220	4	11	810	5.4	.2	7.9
Apr								
20...	650	2,000	15	13	7,100	32	.3	1.2
Jun								
08...	910	2,700	17	13	9,900	23	.3	1.2

Table 10.--*Monthly median specific conductance and dissolved-solids concentration for Hanging Woman Creek near Birney (station 06307600)*

[--, no data]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Median specific conductance (in microsiemens per centimeter at 25 degrees Celsius)[1]												
1980	--	--	--	--	--	--	--	--	--	--	2,220	2,220
1981	2,350	2,490	2,370	2,500	2,340	1,770	1,720	1,490	1,475	1,440	2,030	2,290
1982	2,190	2,045	1,920	2,075	2,260	2,210	1,910	1,950	1,925	1,980	2,285	2,300
1983	2,270	2,055	2,730	2,650	2,800	2,650	2,345	--	--	--	--	--
1985	--	--	--	--	--	--	--	--	--	2,580	2,825	2,850
1986	2,840	2,735	2,940	3,290	3,190	3,205	3,500	3,500	3,170	3,070	3,100	3,370
1987	3,210	2,755	2,740	3,000	3,020	2,975	2,790	2,890	2,575	--	--	--
[1]Median for all days	2,390	2,465	2,460	2,650	2,800	2,650	2,345	2,355	2,475	2,365	2,345	2,350

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Median dissolved-solids concentration (in milligrams per liter)[2]											
1,730	1,790	1,790	1,940	2,060	1,940	1,700	1,710	1,800	1,710	1,700	1,700

[1]Monthly median values for specific conductance were computed from once-daily values for indicated years.

[2]Median values for dissolved-solids concentrations were calculated from specific-conductance values (median for all days) using the regression equation: dissolved solids = 0.785(specific conductance) -142. Coefficient of determination = 0.95, number of samples = 117.

Table 11.--*Monthly dissolved-solids loads for Hanging Woman Creek near Birney (station 06307600)*

[Data for water years 1981-83 and 1986-87. Loads in tons. --, no data]

Year	Jan.	Feb.	Mar.	Apr.	May	June
1980	--	--	--	--	--	--
1981	109.45	137.95	120.15	120.41	130.10	64.25
1982	62.54	112.84	75.14	74.21	71.60	253.16
1983	73.85	986.70	255.30	182.29	170.62	53.90
1985	--	--	--	--	--	--
1986	164.59	507.07	1,282.53	722.82	550.06	443.30
1987	237.76	212.49	226.16	180.26	155.62	106.79
Mean	130	391	392	256	216	184

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.
1980	--	--	--	--	108.11	110.96
1981	9.64	1.86	0.09	14.30	51.84	53.76
1982	477.11	59.78	18.10	45.49	58.80	41.16
1983	1.31	.00	.00	--	--	--
1985	--	--	--	76.58	103.09	149.13
1986	240.88	98.08	235.48	278.54	277.15	272.78
1987	33.98	14.09	12.40	--	--	--
Mean	153	35	53	104	120	126

Table 12.--*Saturated-paste-extract data for overburden samples*

[Unless indicated otherwise, constituents are dissolved and concentrations are reported in milligrams per liter. Abbreviation: μS/cm, microsiemens per centimeter at 25 degrees Celsius]

Sample number	Paste pH	Specific conductance (μS/cm)	Saturation (percent)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)	Sulfate (SO_4)	Dissolved solids, calculated	Sample interval (feet below land surface)
HWC-20- 1	8.2	3,930	48.0	2.1	11.4	37.6	14	44.6	2,950	8-15
(well 2	8.0	3,600	50.4	3.0	11.7	30.6	11	40.9	2,670	15-24,26-28
TR-89) 3	7.6	3,000	56.4	2.3	5.3	27.2	14	28.1	2,170	38-45
4	6.4	6,600	54.4	20.3	38.1	46.4	9	97.6	5,180	45-55
5	6.9	7,000	58.2	19.0	28.5	55.8	12	96.0	5,520	55-62
6	6.6	7,400	52.9	21.9	33.4	54.6	10	104	5,850	65-75
HWC-23- 1	7.1	7,500	66.8	21.4	57.9	40.4	6	115	5,940	14-25
(well 2	6.2	5,000	57.7	28.5	38.7	24.2	4	78.8	3,840	25-35
TR-85) 3	6.9	5,600	55.9	18.9	37.2	24.6	5	79.5	4,350	35-45
4	6.9	5,150	71.3	11.3	24.6	36.8	9	64.0	3,970	45-55
5	7.5	3,300	48.3	2.2	4.3	33.0	18	29.2	2,420	55-65
6	7.0	8,100	58.0	19.0	30.7	73.4	15	112	6,440	65-75
7	6.7	8,950	61.6	19.7	23.5	84.8	18	117	7,150	75-82
8	6.7	8,500	39.8	19.0	27.8	80.4	17	115	6,770	86-95
9	7.1	7,900	56.5	14.4	15.7	80.8	21	101	6,270	95-105
10	6.8	8,850	59.8	16.4	20.6	89.4	21	109	7,070	105-115
11	5.0	13,400	54.6	20.1	78.4	101	14	195	10,870	115-125
12	6.3	6,100	58.0	5.3	10.1	66.6	24	62.9	4,760	125-138
US-7760-1	7.4	2,130	31.2	7.2	11.9	9.0	3	14.1	1,440	0-30
2	6.1	4,500	52.7	25.0	44.2	8.0	1	63.3	3,420	30-50
3	6.3	4,450	59.1	15.6	25.2	24.4	5	46.3	3,380	50-80
4	7.3	3,200	54.1	3.6	4.8	30.6	15	25.0	2,340	80-110
5	7.7	3,200	61.3	1.7	1.6	36.2	28	25.2	2,340	110-140
6	7.7	3,540	69.0	1.4	1.6	41.2	34	25.2	2,620	140-170
US-7763-1	7.5	8,700	62.3	20.5	57.7	61.4	10	131	6,940	0-30
2	7.3	8,050	52.2	20.7	64.8	43.6	7	126	6,400	30-70
3	7.1	5,750	52.8	20.8	25.7	36.0	8	77.3	4,470	70-100
US-7764-1	7.2	4,800	46.5	22.0	36.0	15.2	3	72.7	3,680	0-35
2	7.6	2,060	50.1	3.0	4.1	17.4	9	14.1	1,380	35-70
US-7765-1	7.3	5,800	48.5	22.1	42.3	25.4	4	85.6	4,510	0-40
2	7.3	2,900	37.1	8.0	14.6	14.2	4	33.3	2,090	40-80
3	7.5	3,260	47.4	3.0	4.1	32.2	17	27.4	2,390	80-120
US-7771-1	7.2	3,750	48.3	6.0	13.5	29.2	9	35.7	2,800	0-40
2	7.6	3,400	51.4	3.9	9.7	29.8	11	34.0	2,500	40-70
3	7.5	4,400	56.9	2.9	3.9	47.2	26	40.3	3,340	70-110
US-7772-1	7.8	7,500	38.6	19.1	49.8	49.6	8	118	5,940	0-30
2	7.3	3,100	45.2	9.5	18.1	12.8	3	37.6	2,250	30-60
US-7776-1	7.8	6,000	39.7	11.6	27.5	47.4	11	80.8	4,680	0-3
2	7.4	2,930	43.7	5.7	12.6	18.2	6	31.4	2,110	30-6
3	7.2	4,000	33.3	2.9	5.6	40.8	20	32.6	3,010	60-9
4	7.8	3,550	28.5	2.7	5.0	37.4	19	32.2	2,630	90-120
5	7.0	5,250	48.4	4.7	5.8	57.0	25	50.2	4,050	120-150
US-7777-1 (well TR-40)	7.4	6,050	52.0	13.8	31.8	40.6	8	84.0	4,720	0-50
US-7778-1	7.4	5,800	44.4	20.0	21.5	39.0	9	78.5	4,510	0-50
US-7780-1	7.3	2,680	43.9	4.0	7.0	20.6	9	21.3	1,900	0-50
2	7.7	3,600	56.6	1.5	1.7	43.8	35	32.6	2,670	50-100
3	7.0	5,250	55.9	2.5	2.9	66.2	40	43.6	4,050	100-160
US-7782-1	7.8	12,100	47.5	17.5	40.5	125	23	170	9,790	0-40
US-7784-1	7.6	5,650	64.9	10.8	25.6	41.8	10	75.4	4,390	0-30
2	7.9	4,090	61.7	2.9	3.8	40.6	22	38.8	3,080	30-60
3	7.5	4,800	60.1	4.3	6.4	51.6	22	50.4	3,680	60-100
US-7785-1	7.9	12,300	45.4	19.5	43.4	125	22	178	9,950	0-30
2	7.0	12,500	51.4	20.7	39.5	130	24	173	10,100	30-60

Table 12.--*Saturated-paste-extract data for overburden samples*--Continued

Sample number	Paste pH	Specific conductance (µS/cm)	Saturation (percent)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)	Sulfate (SO_4)	Dissolved solids, calculated	Sample interval (feet below land surface)
US-7787-1	6.8	6,700	52.1	21.0	29.7	47.4	9	91.9	5,270	0-30
2	6.8	7,500	49.1	19.4	20.1	66.4	15	97.1	5,940	30-70
US-7789-1	7.4	6,750	41.1	21.3	27.5	50.8	10	94.8	5,310	0-40
US-7790-1	6.4	8,750	52.4	24.2	71.8	48.2	7	129	6,980	0-50
(well 2	6.4	3,700	38.8	8.9	11.0	29.8	9	37.2	2,760	60-100
TR-31) 3	6.8	5,600	32.7	9.2	12.9	48.2	14	64.5	4,350	100-150
4	7.3	4,440	35.0	2.0	2.7	49.4	32	41.8	3,380	150-200
US-7791-1	7.6	7,600	47.0	14.9	37.7	57.6	11	105	6,020	0-30
2	7.6	6,900	59.1	7.5	17.3	65.0	18	82.0	5,430	30-60
3	6.7	7,000	61.8	12.2	11.9	70.0	20	80.2	5,520	60-90
US-7793-1	7.6	8,500	65.7	19.0	42.1	61.2	11	120	6,770	0-30
2	7.3	8,150	71.3	20.1	44.1	54.0	10	110	6,480	30-60
US-7798-1	7.9	5,900	90.8	4.1	6.7	62.0	27	65.3	4,600	0-40
2	7.4	4,840	67.8	2.4	2.5	52.0	33	45.4	3,710	40-90
KR-99- 1	7.9	8,760	28.7	15.8	26.1	93.1	20	--	6,990	0-10
2	7.9	5,770	22.3	10.1	14.5	47.6	14	--	4,490	10-20
3	7.8	3,590	23.8	5.8	8.4	27.4	10	--	2,660	20-30
4	8.0	2,870	22.5	5.9	6.6	21.5	9	--	2,060	30-35
5	7.7	3,230	55.6	5.5	7.8	24.0	9	--	2,360	35-45
6	7.6	4,440	67.3	5.1	5.8	42.7	18	--	3,380	45-55
7	7.8	5,190	82.4	2.9	3.3	48.4	28	--	4,000	55-60
8	7.7	4,550	75.4	2.4	3.1	42.4	26	--	3,470	60-70
9	7.6	4,750	76.5	2.5	3.3	42.6	27	--	3,630	70-80
KR-100- 1	7.9	3,500	70.1	1.1	2.0	35.9	29	--	2,590	0-5
2	7.7	5,350	35.9	4.9	7.0	43.0	18	--	4,140	5-15
3	7.6	6,650	35.6	17.2	32.8	55.1	11	--	5,220	15-20
4	7.8	6,870	42.8	15.7	32.3	43.6	9	--	5,410	20-25
5	7.8	6,450	51.5	8.8	18.5	48.2	13	--	5,060	25-30
6	7.6	5,650	66.1	9.2	14.3	39.6	12	--	4,390	30-40
7	7.8	4,430	46.2	4.7	4.7	34.7	16	--	3,370	40-45
8	7.7	5,770	65.0	4.1	3.7	32.8	17	--	4,490	45-55
KR-101- 1	8.0	6,930	51.1	13.1	7.9	63.5	20	--	5,460	0-10
2	8.0	17,800	54.6	28.9	84.4	140	19	--	14,600	10-20
3	8.0	18,700	49.1	30.8	72.7	154	21	--	15,300	20-30
4	8.0	17,100	27.8	29.0	37.3	101	18	--	14,000	30-40
5	7.9	6,740	24.6	18.8	17.6	58.2	14	--	5,300	40-45
6	7.9	4,570	57.2	7.1	9.0	34.7	12	--	3,480	45-55
7	7.6	4,080	56.5	5.7	6.8	32.5	13	--	3,070	55-60
8	7.5	5,510	48.9	8.6	11.7	45.5	14	--	4,270	60-65
KR-102- 1	7.7	9,960	74.8	24.9	69.7	72.5	10	--	8,000	0-10
2	7.6	9,340	90.2	24.7	67.9	54.1	8	--	7,480	10-15
3	4.7	15,000	100	28.5	104	127	16	--	12,200	15-20
4	7.5	5,270	65.6	4.1	15.3	42.2	14	--	4,070	20-30
5	8.0	3,400	82.0	1.3	3.0	27.5	19	--	2,500	30-40
6	7.9	4,540	67.8	4.9	6.2	35.2	15	--	3,460	40-45
7	7.8	5,090	60.1	5.0	8.2	40.1	16	--	3,920	45-50
8	7.8	2,960	64.8	1.6	3.1	22.3	14	--	2,140	50-60
9	8.0	2,880	90.6	1.6	1.7	23.6	18	--	2,070	60-70
10	8.7	1,670	111	.9	.9	14.2	15	--	1,060	70-80
11	8.5	1,190	138	.6	.4	12.9	18	--	655	80-90
12	8.7	1,190	143	.5	.2	12.6	21	--	655	90-100
13	6.8	9,060	74.6	22.5	15.9	85.9	20	--	7,240	100-105
14	7.0	4,950	62.2	12.3	14.9	31.9	9	--	3,800	105-110
15	7.6	4,000	67.4	7.4	8.1	26.6	10	--	3,010	110-115
16	8.4	2,100	81.8	.8	1.0	19.7	21	--	1,420	115-125
17	7.6	5,390	70.3	5.7	4.8	45.7	20	--	4,170	125-130
18	8.1	1,760	118	1.0	.9	23.8	24	--	1,130	130-135
19	7.1	4,860	92.0	1.2	2.4	45.1	34	--	3,730	135-140
20	8.0	3,090	55.5	1.9	2.3	25.2	18	--	2,240	140-145
21	8.4	2,210	78.0	1.2	1.6	17.5	15	--	1,510	145-150
22	7.3	2,130	91.2	.4	.6	17.9	25	--	1,440	150-160
23	7.2	3,060	90.0	1.9	2.2	24.9	17	--	2,220	160-170

Table 12.--*Saturated-paste-extract data for overburden samples*--Continued

Sample number	Paste pH	Specific conductance (μS/cm)	Saturation (percent)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium adsorption ratio (SAR)	Sulfate (SO_4)	Dissolved solids, calculated	Sample interval (feet below land surface)
KR-103- 1	7.9	9,660	60.3	27.3	36.8	75.4	13	--	7,740	0-10
2	7.9	8,570	54.3	27.4	35.9	63.1	11	--	6,830	10-20
3	7.8	3,600	41.6	9.4	12.8	19.6	6	--	2,670	20-30
4	7.8	3,100	30.1	8.0	8.5	17.8	6	--	2,250	30-40
5	7.8	6,830	59.3	23.2	28.3	38.8	8	--	5,380	40-50
6	7.8	6,810	34.9	17.9	22.8	48.4	11	--	5,360	50-60
7	7.3	5,730	81.5	8.7	10.6	46.1	15	--	4,460	60-70
KR-164- 1	8.2	4,140	57.6	2.7	8.1	30.4	13	--	3,120	0-5
2	8.4	2,150	68.4	1.0	2.7	16.9	12	--	1,460	5-15
3	8.3	1,740	52.5	1.9	2.6	11.8	8	--	1,120	15-20
4	8.2	1,530	65.7	1.1	2.0	10.7	9	--	939	20-25
5	7.8	3,420	83.0	3.8	5.8	22.3	10	--	2,520	25-35
6	8.0	3,510	63.6	2.3	2.9	27.1	17	--	2,600	35-45
7	7.6	5,760	35.7	10.2	10.6	43.5	14	--	4,480	45-55
8	7.6	9,470	58.9	20.8	29.7	84.3	17	--	7,580	55-65
9	7.7	8,900	71.3	16.2	23.1	83.1	19	--	7,110	65-75
10	7.2	13,100	65.3	25.8	35.5	131	24	--	10,620	75-85
KR-218- 1	8.1	1,070	31.0	2.1	5.9	4.2	2	--	554	0-10
2	7.9	890	69.9	1.7	3.2	3.0	2	--	403	10-20
3	7.9	2,130	78.0	2.5	5.9	12.1	6	--	1,440	20-25
4	6.4	7,120	74.6	23.2	44.5	30.7	5	--	5,620	25-30
5	7.9	4,860	46.7	11.3	21.6	27.2	7	--	3,730	30-35
6	6.8	6,670	73.0	22.0	29.9	35.9	7	--	5,240	35-45
7	7.8	4,400	39.8	8.3	11.8	27.4	9	--	3,340	45-55
8	7.6	4,060	91.6	4.6	5.9	29.5	13	--	3,060	55-65
9	7.8	2,410	74.5	1.2	1.4	19.2	17	--	1,680	65-75
KR-229- 1	8.0	8,570	80.4	18.2	41.8	57.2	10	--	6,830	0-10
2	8.0	3,290	84.1	2.4	4.0	26.6	15	--	2,410	10-15
3	8.0	3,690	87.8	2.6	8.7	24.2	10	--	2,750	15-20
4	7.8	4,280	75.2	4.5	11.2	28.2	10	--	3,240	20-25
5	6.9	7,360	60.2	18.3	35.1	40.9	8	--	5,820	25-30
6	7.8	4,020	70.7	4.7	7.6	29.0	12	--	3,020	30-40
7	7.7	4,610	62.9	7.1	12.8	27.7	9	--	3,520	40-45
8	7.9	3,530	74.2	3.2	4.3	24.7	13	--	2,610	45-55
9	8.1	2,660	83.9	1.7	1.9	19.5	15	--	1,880	55-65
10	7.9	3,290	83.7	2.2	2.4	24.5	16	--	2,410	65-70
11	7.9	3,640	96.2	2.8	3.1	28.0	16	--	2,710	70-75
12	8.1	3,090	87.1	2.5	2.5	23.4	15	--	2,240	75-80
13	8.1	2,460	95.6	1.1	1.4	20.3	18	--	1,720	80-85
14	7.0	5,730	101	7.9	5.6	44.7	17	--	4,460	85-90
15	7.8	3,620	85.8	2.4	2.1	28.1	19	--	2,690	90-100
16	7.6	3,970	81.8	3.1	3.0	29.4	17	--	2,980	100-105
17	8.0	2,760	92.0	1.4	1.4	23.5	20	--	1,970	115-125

Table 13.--*Monthly and annual post-mining dissolved-solids loads and concentrations in Hanging Woman Creek near Birney (station 06307600)*

[Abbreviation: ft^3/s, cubic feet per second; mg/L, milligrams per liter]

		Pre-mining		Post-mining			
Month	Median dis-charge[1] (ft^3/s)	Median dis-solved-solids concen-tration[2] (mg/L)	Load at median dis-charge and median dissolved-solids concen-tration[3] (tons)	Addi-tional load from mine spoils (tons)	Dissolved-solids concen-tration at median discharge (mg/L)	Load at median dis-charge (tons)	Percent increase in dissolved-solids load at median discharge
Jan.	1.0	1,730	145	93	2,840	238	64
Feb.	1.8	1,790	244	84	2,410	328	34
Mar.	1.9	1,790	285	93	2,380	378	33
Apr.	2.2	1,940	346	90	2,450	436	26
May	1.6	2,060	276	93	2,760	369	34
June	2.0	1,940	314	90	2,490	404	29
July	.90	1,700	128	93	2,930	221	73
Aug.	.50	1,710	72	93	3,940	165	129
Sept.	.54	1,800	79	90	3,860	169	114
Oct.	.85	1,710	122	93	3,020	215	76
Nov.	1.0	1,700	138	90	2,810	228	65
Dec.	1.2	1,700	171	93	2,630	264	54
Annual	1.2		2,320	1,095		3,415	47

[1]Period of record for discharge is water years 1974-84 and 1986-87 (from table 6).

[2]Calculated from monthly specific conductance (median for all days, table 10) for Nov. 1980 through July 1983 and Oct. 1985 through Sept. 1987.

[3]The factor for converting the product of cubic feet per second and milligrams per liter to tons per day is 0.0027.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*

[Altitude, in feet above National Geodetic Vertical Datum of 1929; depth, in feet below land surface; water level, in feet below land surface; casing, in feet below land surface except where + indicates casing in feet above land surface. Abbreviations: ft, feet; in., inches; gal/min, gallons per minute; PVC, polyvinyl chloride]

Hole number: HWC-86-1
Location number: 08S43E17DDCD01
Altitude: 3,450 ft
Date drilled: Sept. 29, 1986

Depth (ft)	Description
0-4	Sand, medium to coarse; with silt and gravel, reddish-brown; contains fragments of clinker
4-15	Gravel and sand, silty, reddish-brown
15-21	Sand, medium, silty, clayey
21-22	Coal, weathered
22-27	Clay, silty, gray (Tongue River Member of Fort Union Formation)
27-29	Sand, fine, soft
29-35	Sandstone, hard, and gray shale

Notes: Drilled with mud. Hole was cased but did not produce water. Pulled casing and plugged hole.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number:	HWC-86-2
Well number:	AL-7
Location number:	08S43E17DDCA01
Altitude:	3,460 ft
Date drilled:	Sept. 29, 1986
Water level:	19.07 ft on Oct. 2, 1986

Depth (ft)	Description
0-14	Silt, sandy, clayey, light-brown to reddish-brown
14-26	Silt, sandy; with some gravel, clayey, reddish-brown
26-30	Gravel, silty, sandy; most gravel is sandstone or clinker
30-41	Gravel and clay lenses, silty, brown
41-50	Clay, silty, gray (Tongue River Member)

Casing: +1.2-50 ft, PVC casing, 4 in. diameter; slotted interval 25-40 ft

Notes: Drilled with air to 40 ft; with mud 40-50 ft. Well produced about 4 gal/min during development.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-3
Location number: 08S43E17DDDB01
Altitude: 3,460 ft
Date drilled: Sept. 30, 1986

Depth (ft)	Description
0-12	Sand, very fine, silty, light-gray
12-16	Silt, sandy, light-brown
16-20	Sand, silty, clayey, reddish-brown, moist
20-31	Gravel, silty, sandy, wet
31-37	Clay and silt, light-gray
37-39	Coal
39-50	Silt, clayey, light-gray (Tongue River Member)

Notes: Hole drilled with air to 31 ft; with mud 31-50 ft. Hole was plugged and abandoned because of little production. Gravel layer at 20-31 ft was wet but produced only 1-2 gal/min.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-4
Location number: 08S43E17DDDA01
Altitude: 3,465 ft
Date drilled: Sept. 30, 1986

Depth (ft)	Description
0-11	Sand, very fine, silty, light-brown
11-28	Sand and gravel, silty, clayey (more gravel toward bottom of interval)
28-34	Sand, fine, silty, light-brown; water production 2-3 gal/min
34-50	Clay, silty, gray; thin coal stringer at 37 ft (Tongue River Member)

Notes: Drilled with air to 50 ft; with water injection below 30 ft. Hole produced very little water from zone 25-34 ft. Hole plugged and abandoned because of little production.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-5
Well number: AL-8
Location number: 08S43E17DDDC01
Altitude: 3,455 ft
Date drilled: Sept. 30, 1986
Water level: 14.40 ft on Oct. 2, 1986

Depth (ft)	Description
0-10	Sand, very fine, silty, clay lenses, light-brown
10-27	Gravel, sandy, silty; mostly large clinker fragments, producing some water
27-29	Clay, silty, light-gray
29-30	Coal
30-34	Clay (Tongue River Member)
34-35	Sandstone, hard
35-40	Clay, silty

Casing: +1.3-33 ft, PVC casing, 4 in. diameter; slotted interval 13-28 ft

Notes: Drilled with air to 27 ft; with mud below 27 ft. Well produced about 5 gal/min during development.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-6
Well number: AL-4
Location number: 06S43E19DDBD01
Altitude: 3,170 ft
Date drilled: Oct. 3, 1986
Water level: 6.19 ft on Oct. 5, 1986

Depth (ft)	Description
0-4	Sand, fine to very fine, silty, light-brown
4-8	Gravel and sand, silty; contains clinker fragments
8-17	Sand, fine to very fine, silty, light-brown, saturated
17-57	Gravel, medium size, fairly well sorted; hole caving below 18 ft
57-70	Clay, silty, gray (Tongue River Member)

Casing: +1.3-61 ft, PVC casing, 4 in. diameter; slotted interval 26-56 ft

Notes: Drilled with air to 20 ft; with mud below 20 ft. Well produced about 15 gal/min during development.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number:	HWC-86-7
Well number:	AL-2
Location number:	06S43E19DDBA01
Altitude:	3,170 ft
Date drilled:	Oct. 4, 1986
Water level:	7.04 ft on Oct. 5, 1986

Depth (ft)	Description
0-2	Silt; sandy, brown
2-61	Gravel; medium size, some thin clay lenses
61-66	Clay; silty, light gray (Tongue River Member)
66-67	Sandstone; hard
67-80	Clay; silty

Casing: +1.3-71, PVC casing, 4 in. diameter; slotted interval 20-60 ft

Notes: Drilled with mud. Well produced 25-30 gal/min during development. Could not case on first try because of caving gravels. Drilled hole to 80 ft before casing second time.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-8
Well number: AL-3
Location number: 06S43E19DDBA02
Altitude: 3,170 ft
Date drilled: Oct. 5, 1986
Water level: 6.89 ft on Oct. 8, 1986

Depth (ft)	Description
0-6	Silt, sandy, brown
6-17	Gravel and sand, mostly small gravel and coarse sand; probably silty based on speed of drilling
17-25	Gravel, medium to coarse
25-48	Gravel and sand, mostly small gravel and coarse sand
48-55	Sand, coarse
55-63	Gravel and sand, as above
63-70	Clay, silty, gray; sandstone bed from 66-67 ft (Tongue River Member)

Casing: +1.3-67 ft, PVC casing, 4 in. diameter; slotted interval 16-61 ft

Notes: Drilled with mud. Well produced about 30 gal/min during development.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-9
Well Number: AL-1
Location number: 06S43E19DACD01
Altitude: 3,170 ft
Date drilled: Oct. 5, 1986
Water level: 7.20 ft on Oct. 8, 1986

Depth (ft)	Description
0-11	Silt, sandy, clayey, brown
11-40	Gravel and sand, mostly small gravel and coarse sand; clay lens at 18 ft. (hole caves easily from 20-40 ft)
40-60	Clay, silty, sandy (Tongue River Member)

Casing: +1.3-44 ft, PVC casing, 4 in. diameter; slotted interval 14-39 ft

Notes: Drilled with mud. Well produced about 20 gal/min during development.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-10
Location number: 06S43E19DACD02
Altitude: 3,170 ft
Date drilled: Oct. 5, 1986

Depth (ft)	Description
0-11	Silt, sandy, brown
11-41	Gravel and sand, silty and clayey, very dirty; hole stays open well while drilling)
41-50	Clay, silty, gray (Tongue River Member)

Notes: Drilled with mud. Did not case because of dirty formation. Hole did not appear to produce more than 2-3 gal/min.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-11
Well number: AL-5
Location number: 07S43E05ACCA01
Altitude: 3,230 ft
Date drilled: Oct. 6, 1986
Water level: 8.32 ft on Oct. 8, 1986

Depth (ft)	Description
0-6	Silt, sandy, clayey, brown
6-17	Gravel and sand, silty, mostly small gravel and coarse sand; thin clay lenses
17-48	Gravel, sandy, cleaner than above; some clay lenses in upper part
48-60	Clay, silty, light-gray (Tongue River Member)

Casing: +1.4-58 ft, PVC casing, 4 in. diameter; slotted interval 18-48 ft

Notes: Drilled with mud. Well produced 20-30 gal/min during development.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-12
Well number: AL-6
Location number: 07S43E08ABBB01
Altitude: 3,265 ft
Date drilled: Oct. 6, 1986
Water level: 19.49 ft on Oct. 8, 1986

Depth (ft)	Description
0-18	Silt, sandy, clayey, light-brown (possibly colluvium)
18-40	Gravel, silty, clayey in upper part
40-64	Gravel, cleaner than above, mostly medium size gravel; hole caves easily
64-68	Clay; thin, hard sandstone bed at 65 ft
68-70	Sandstone, soft (Tongue River Member)
70-80	Clay, silty, gray (Tongue River Member)

Casing: +1.4-68 ft, PVC casing, 4 in. diameter; slotted interval 33-53 ft

Notes: Drilled with air to 50 ft; with mud below 50 ft. About 10 ft of hole caved; screen about 5 ft higher than wanted. Well produced about 20 gal/min during development.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-13
Well number: AL-53
Location number: 10S43E02ACDC01
Altitude: 3,630 ft
Date drilled: Oct. 7, 1986
Water level: 9.99 ft on Oct. 8, 1986

Depth (ft)	Description
0-20	Silt, clayey, sandy, light-brown; wet below 15 ft.
20-39	Sand, very fine, silty, brown
39-46	Sand, coarse, with fine gravel; sand and gravel mostly fragments of sandstone
46-49	Sand, fine; contains coal fragments
49-60	Clay, sandy, silty, gray (Tongue River Member)

Casing: +1.2-53 ft, PVC casing, 4 in. diameter; slotted interval 38-48 ft

Notes: Drilled with air to 40 ft; with mud below 40 ft.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-14
Location number: 10S43E02ACDD01
Altitude: 3,630 ft
Date drilled: Oct. 7, 1986

Depth (ft)	Description
0-16	Silt and clay, brown
16-25	Sand, very fine, silty, brown; some small gravel
25-30	Clay, silty, brown
30-41	Thin beds of clay, silt, and small gravel
41-54	Gravel, small to medium size, sandy (mostly sandstone fragments)
54-65	Clay, silty, sandy, gray (Tongue River Member)

Notes: Drilled with mud. Cased hole but well would not produce water. Casing was pulled and hole was plugged. Apparently gravel zone contains considerable silt or clay.

Table 14.--*Lithologic logs of wells and drill holes drilled in 1986 in alluvium of the Hanging Woman Creek valley*--Continued

Hole number: HWC-86-15
Well number: AL-52
Location number: 10S43E02ACDA01
Altitude: 3,640 ft
Date drilled: Oct. 8, 1986
Water level: 13.29 ft on Oct. 8, 1986

Depth (ft)	Description
0-19	Silt and clay, brown
19-32	Sand, very fine to coarse, poorly sorted, clayey with clay lenses
32-58	Sand and gravel, clayey, mostly medium to coarse sand and small gravel, brown; mostly sandstone fragments and some clinker, many small fossil shells, mostly gravel toward bottom
58-60	Sand, clayey
60-66	Clay, silty, gray (Tongue River Member)
66-68	Coal, hard
68-70	Clay, silty, gray

Casing: +1.4-60 ft, PVC casing, 4 in. diameter; slotted interval 35-55 ft

Notes: Drilled with mud. Well produced about 30 gal/min during development.

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