WATER RESOURCES OF THE BROWNING-STARR SCHOOL AREA, BLACKFEET INDIAN RESERVATION, NORTHWESTERN MONTANA

By M.R. Cannon

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4.047	square meter
cubic foot per second	0.028317	cubic meter per second
foot	0.3048	meter
gallon per minute	0.06309	liter per second
inch	25.4	millimeter
mile	1.609	kilometer
square mile	2.59	square kilometer

Temperature can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 9/5\ (°C) + 32$$

Sea level: In this report, "sea level" refers to the 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 Sea Level Datum of 1929.

Water year: The 12-month period from October 1 through September 30. A water year is identified by the calendar year in which it ends.

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ABSTRACT

The Blackfeet Indian Reservation is located in northwestern Montana adjacent to Glacier National Park and Alberta, Canada. Browning, the largest town within the reservation, is the center of Blackfeet Tribal government and health services, and is the primary service and trade center within the reservation. Growth in Browning has increased demands on the public water-supply system, and additional water is needed to meet demands during periods of peak water use.

The U.S. Geological Survey, in cooperation with the Blackfeet Water Resources Department, conducted a field investigation of shallow ground-water resources and surface-water resources in the area between Browning and Starr School. This report describes those resources and presents the data collected. Quaternary and Tertiary unconsolidated-deposit aquifers identified in the study area are (1) gravel deposits of Starr School Flat, (2) till with buried channels and lenses of sand and gravel, and (3) alluvium of Cut Bank Creek.

Two unconsolidated-deposit aquifers are used for public water supplies. The gravel aquifer of Starr School Flat is used as a source of drinking water in the community of Starr School. Wells in the gravel aquifer can produce 100 gallons per minute, although in most of Starr School Flat, wells produce much less because of the small thickness of saturated gravel. Sand and gravel deposits in buried channels and lenses of sand and gravel between till units are used as a source of drinking water for Browning. Sand and gravel in buried channels can yield 150 gallons per minute or more to properly constructed wells. Alluvium of Cut Bank Creek is a coarse gravel and cobble aquifer that probably could yield more than 300 gallons per minute to properly constructed wells. Cretaceous bedrock aquifers, consisting of fine-grained sandstone, seldom yield more than 15 gallons per minute to wells.

Cut Bank Creek is the primary surface-water resource in the study area. Cut Bank Creek originates in the mountains of Glacier National Park and has a dependable perennial flow of high-quality water.

INTRODUCTION

Browning, the cultural and trade center of the Blackfeet Indian Reservation in northwestern Montana, has an increasing population along with rapid growth in construction of new homes and businesses. The addition of many new homes and businesses on the Browning public water-supply system has greatly increased the demand for water for domestic and industrial uses and for fire protection.

Ground water is the primary source of drinking water in Browning, in the nearby community of Starr School, and in most individual rural homes in the Browning area. The Browning public water-supply system has well fields in three locations, but the quantity of ground water supplied by these well fields is inadequate to meet demand during periods of peak water use or during times of prolonged drought. Meeting the present and future water needs requires the development of a dependable, large capacity, ground-water supply or the construction of a surface-water treatment plant to treat water imported from a large perennial stream such as Cut Bank Creek (Lyle Meeks, Neil Consultants, Inc., Great Falls, Mont., written commun., 1993). Developing a source of ground water is likely the least-costly and therefore preferred alternative, provided aquifers in the area are capable of supplying the larger water demand (Lyle Meeks, written commun., 1993). A good understanding of the water resources of the Browning area is needed to enable planners to make sound decisions about water-system planning and development.

A reconnaissance-level study of geology and ground-water resources of the entire Blackfeet Reservation was conducted from 1990 to 1993 by the U.S. Geological Survey in cooperation with the Blackfeet Water Resources Department (Cannon, 1996). That study identified unconsolidated-deposit aquifers in the Browning area that have the potential for water development. The unconsolidated-deposit aquifers include gravel deposits near Starr School, till with buried channels and lenses of sand and gravel in the Willow Creek and Flatiron Creek areas, and alluvium in the Cut Bank Creek valley. To better define the extent and water-yielding characteristics of unconsolidated-deposit aquifers in the Browning area, the U.S. Geological Survey in cooperation with the Blackfeet Water Resources Department began a field investigation of aquifers in the area between Browning and Starr School in July 1993.

Purpose and Scope

The purpose of this report is to describe the water resources of the area between Browning and Starr School and to present data collected during a study of the water resources. The report contains a geologic map and describes geology and geomorphology in the Browning area, ground-water resources in the general area, and surface-water resources of Cut Bank Creek. The study area consists of about 45 square miles of the Cut Bank Creek drainage basin between Browning and Starr School (fig. 1). Aquifers were studied in most detail near Starr School in secs. 24 and 25, T. 33 N., R. 12 W., because of favorable aquifer characteristics for water development in that area.

Geographic Setting

The Blackfeet Indian Reservation is located in northwestern Montana on the eastern slopes of the Northern Rocky Mountains (fig. 1). The reservation is bounded on the north by Alberta, Canada, and on the west by Glacier National Park. The reservation encompasses nearly 2,400 square miles in Glacier and Pondera Counties, Montana. In 1990, the population of the reservation was approximately 8,550 (U.S. Bureau of the Census, 1991).

Browning, the largest town within the Blackfeet Indian Reservation, in 1990 had a population of approximately 4,550, slightly more than half of the total reservation population. Browning is the center of Blackfeet Tribal government and health services, the home of Blackfeet Community College, and the primary service and trade center within the reservation. The town is located near the intersection of U.S. Highway 2, U.S. Highway 89, and the Burlington Northern Railroad. Because Browning is on a major transportation route to Glacier National Park, thousands of tourists pass through the town each year.

Browning is situated about 4 miles south of Cut Bank Creek. The general area is drained by Flatiron Creek, Willow Creek, and Depot Creek. These small streams flow easterly, where they merge and flow into Cut Bank Creek near the center of the reservation. Cut Bank Creek is the largest stream in the study area. Cut Bank Creek flows easterly from its headwaters in the mountains of Glacier National Park through the Blackfeet Indian Reservation, to the town of Cut Bank, at the eastern boundary of the reservation. Cut Bank Creek is extensively used for irrigation and stock watering in the Blackfeet Reservation, and is used for municipal water supply in the town of Cut Bank. Within the study area, Cut Bank Creek and its flood plain are incised below the level of the adjacent till and gravel-capped uplands forming steep valley walls 40 to 60 feet high.

GEOLOGY AND GEOMORPHOLOGY

Bedrock in the study area consists of Cretaceous mudstone, soft shale, and fine-grained sandstone. Formations present are the Virgelle Sandstone and Telegraph Creek Formation, Two Medicine Formation, Horsethief Sandstone, and St. Mary River Formation (fig. 2). These formations are exposed in some places along the valley of Cut Bank Creek and in some roadcuts. Bedrock of the study area has undergone intense faulting and deformation. As a result of thrust faulting, bedrock units dip steeply (20 to 70 degrees) to the southwest and have a general strike of N. 25 degrees W. In most of the study area, bedrock is covered by unconsolidated gravel deposits of Quaternary and Tertiary age, and glacial till and alluvium of Quaternary age (fig. 3).

Land forms in the Browning area are diverse as a result of regional uplift, thrust faulting, extensive erosion, deposition from glaciers, and renewed erosion after deglaciation. The Northern Rocky Mountain area was undergoing uplift and faulting about 72 to 46 million years ago, during Late Cretaceous and early Tertiary time. The amount of uplift likely exceeded 45,000 feet and horizontal movement along thrust faults exceeded 29 miles (Mudge, 1970). Erosion of the uplifted area during middle and late Tertiary time (38 to 2 million years ago) wore down the mountains to nearly their present level and sculptured the plains east of the mountains into vast pediments that slope north-

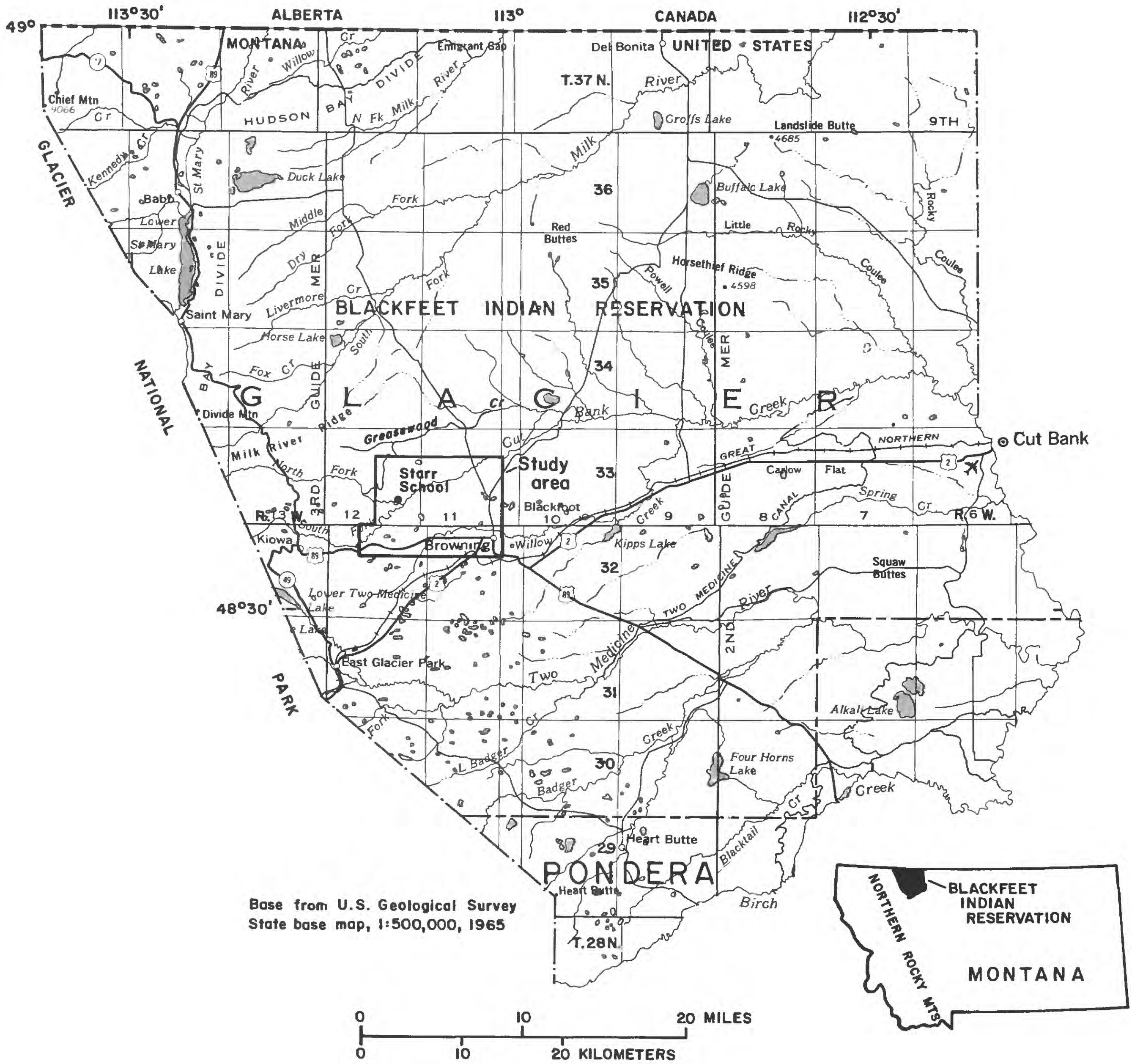

Figure 1. Location of study area.

FIGURE 2 EXPLANATION

EXPLANATION

Ksm ST. MARY RIVER FORMATION (UPPER CRETACEOUS)--Nonmarine mostly greenish-gray to grayish-olive mudstone and shale interbedded with thin beds of fine-grained sandstone

Kh HORSETHIEF SANDSTONE (UPPER CRETACEOUS)--Gray to grayish-brown, fine- to medium-grained marine sandstone

Ktm TWO MEDICINE FORMATION (UPPER CRETACEOUS)--Nonmarine mudstone and shale with sandstone. Upper and middle parts mostly grayish-green to gray mudstone. Lower part contains many thick beds of sandstone interbedded with mudstone

Kvt VIRGELLE SANDSTONE AND TELEGRAPH CREEK FORMATION (UPPER CRETACEOUS)--The Virgelle Sandstone is light-gray, fine-grained marine sandstone. Titaniferous magnetite sandstone is present at the top of the formation. The Telegraph Creek Formation consists mainly of gray mudstone and shale interbedded with fine-grained sandstone

A———A' TRACE OF HYDROGEOLOGIC SECTION

——— CONTACT--Approximately located

━━━ THRUST FAULT--Upper plate on western side of fault

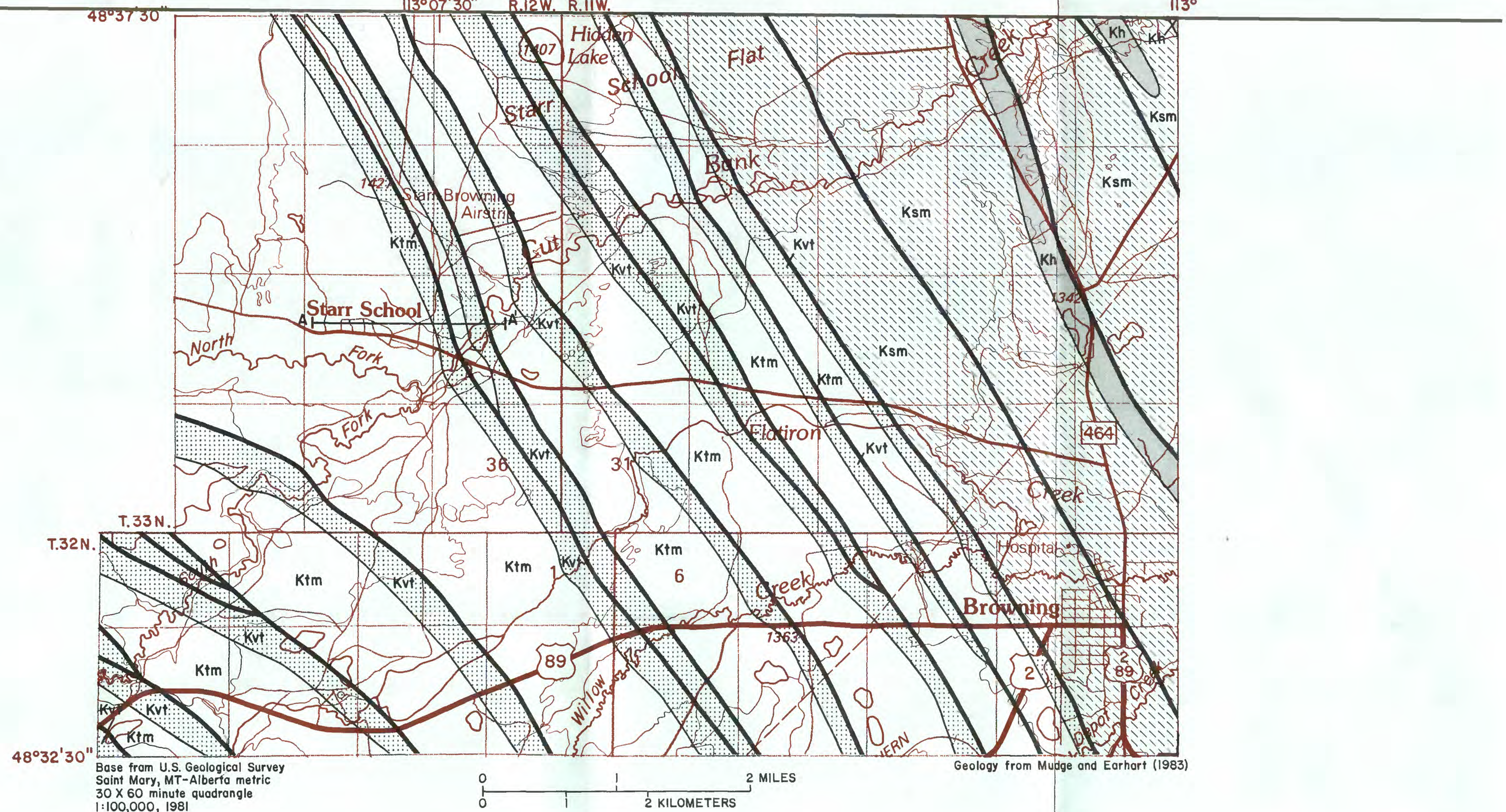

Figure 2. Bedrock geology of the Browning-Starr School area, northwestern Montana.

FIGURE 3 EXPLANATION

EXPLANATION

Qal ALLUVIUM (HOLOCENE AND PLEISTOCENE)--Gravel, cobbles, sand, and silt beneath the channel and flood plain of Cut Bank Creek

Qt TILL DEPOSITED BY PIEDMONT GLACIERS (PLEISTOCENE)--Gravelly to clayey till in ground moraine and terminal moraine. Includes sand and gravel deposits in buried channels and meltwater channels

QTg PEDIMENT GRAVEL (PLEISTOCENE AND PLIOCENE)--Coarse gravel and cobbles with some sand and silt

BR BEDROCK (CRETACEOUS)--Rock outcrops or bedrock with a thin cover of soil

BURIED CHANNEL

MELTWATER CHANNEL--Arrow shows direction of flow

A A' TRACE OF HYDROGEOLOGIC SECTION

CONTACT

4 5 6 SEISMIC REFRACTION LINE AND NUMBER

SITE AND NUMBER

WL-2 WELL AND NUMBER

SP-2 SPRING AND NUMBER

TH-1 TEST HOLE AND NUMBER

ST-2 06098500 STREAM MEASUREMENT SITE AND NUMBER

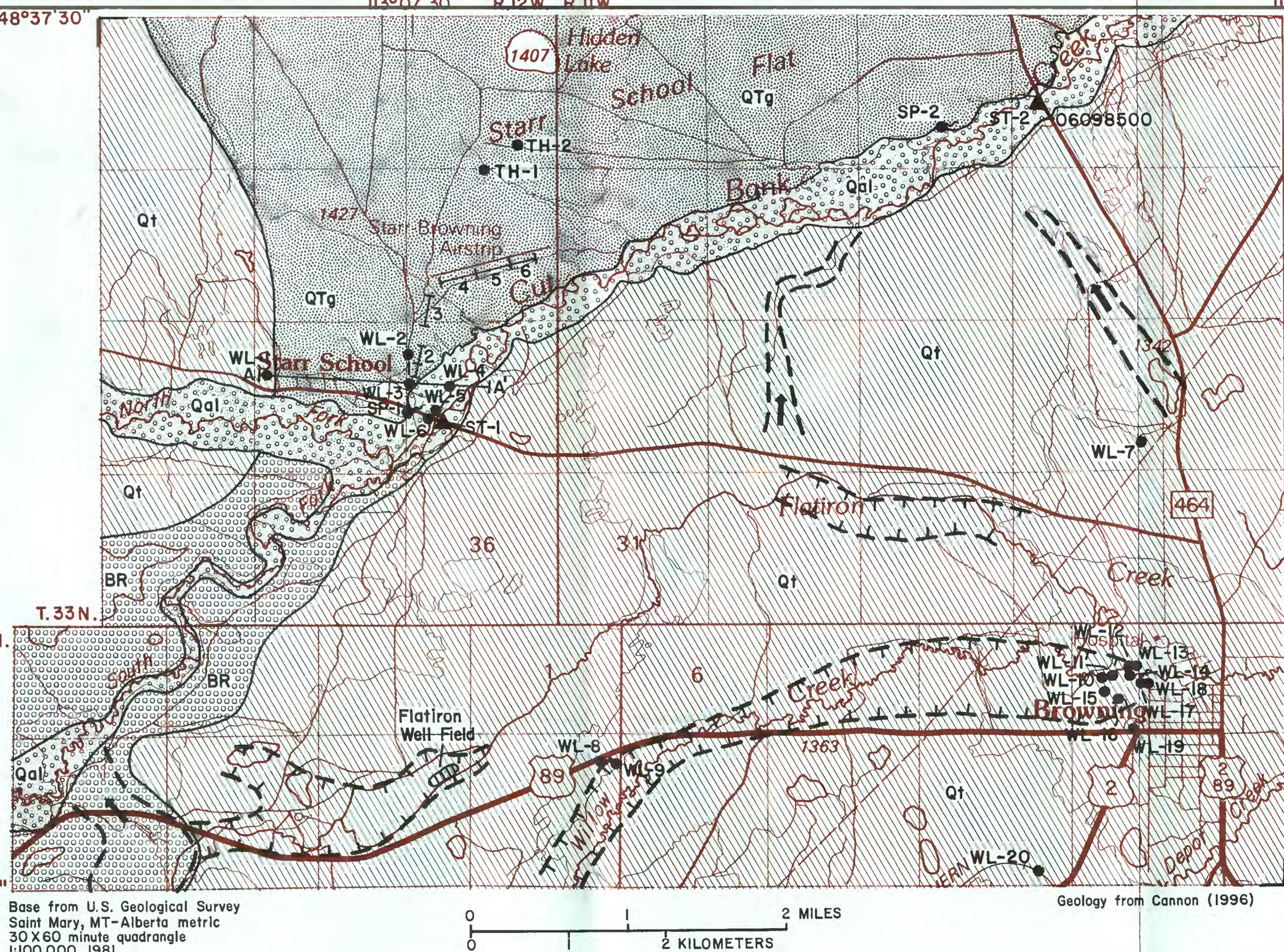

Figure 3. Surficial geology of the Browning-Starr School area, northwestern Montana.

eastward away from the mountain front. The pediments are capped with coarse gravel, cobbles, and sand deposited by many high-energy streams flowing eastward from the high mountains to the west. Glaciers covered much of the study area during various periods from about 2 million to 10,000 years ago. Glaciers are responsible for many of the present landforms, lakes, and drainage patterns in the Browning area. After glaciers melted from the area, streams such as Cut Bank Creek resumed erosion of their channels and flood plains.

GROUND-WATER RESOURCES

Ground-water resources of the area consist of aquifers in unconsolidated deposits and in near-surface bedrock units. Aquifers in unconsolidated deposits supply most drinking water in the Browning-Starr School area and have the greatest potential for development of additional water supplies. Aquifers in bedrock units supply only small quantities of water to most wells, based on well records at the Indian Health Service office in Browning. Water from bedrock aquifers generally is of poorer quality than water from unconsolidated-deposit aquifers (Cannon, 1996).

Unconsolidated-Deposit Aquifers

Three unconsolidated-deposit aquifers are located in the study area. The aquifers are (1) gravel deposits of Starr School Flat, (2) till with its associated buried channels and lenses of sand and gravel, and (3) alluvium of Cut Bank Creek.

Gravel Aquifer of Starr School Flat

Starr School Flat is a broad, eastward-sloping pediment mantled with coarse gravel and cobbles. The gravel deposits range from about 5 to 45 feet thick and extend from Starr School, northward about 3.5 miles to Greasewood Creek (north of the study area boundary), then northeastward about 6 miles. The gravel deposits of Starr School Flat are overlapped on the west by till deposited from the Cut Bank glacier (fig. 3). The westward extent of the gravel beneath the till is unknown. The highest parts of Starr School Flat lie about 60 to 100 feet above the valley of Cut Bank Creek. The gravel-capped pediment ends in a sharp escarpment along its southern margin, where it has been truncated by erosion from Cut Bank Creek. The creek creates a distinct boundary between the rolling till-covered plain to its south and the unglaciated gravel-capped pediment to its north. In this area, the Cut Bank Creek valley was formed through erosion of a deep channel by a large stream flowing along the northern margin of the Two Medicine glacier.

Cobble and gravel deposits of Starr School Flat appear to form a highly permeable aquifer that is readily recharged by rain and snowmelt. Leakage from ditches used to convey stock and irrigation water diverted from North Fork Cut Bank Creek also recharges the aquifer. The aquifer discharges to many seeps and springs along the Cut Bank Creek valley. Streamflow measurements made in the area of Starr School Flat at sites ST-1 and ST-2 (fig. 3) consistently showed an increase in flow along that reach of Cut Bank Creek. Four sets of measurements made between October 1990 and May 1995 indicated gains of 1.5 to 16.8 cubic feet per second, with an average gain of 6.8 cubic feet per second. Most of the gains probably can be attributed to discharge of ground water to Cut Bank Creek.

Because of evidence for significant water discharge from the gravel aquifer of Starr School Flat, the area was studied to determine aquifer thickness and potential for water development. The study focused mainly on the southern part of the aquifer between Cut Bank Creek and Hidden Lake (fig. 3). To determine aquifer thickness, water quality, and potential for water development, existing wells and springs were inventoried, a test well was drilled east of Starr School, and seismic refraction lines were run in secs. 24 and 25, T. 33 N., R. 12 W. Several wells completed in the gravel aquifer supply water for the community of Starr School. One well on the west side of Starr School (well WL-1 in table 1) is capable of producing 100 gallons per minute. This public water-supply well is located on the terminal moraine deposited by the Cut Bank glacier. The well penetrates about 42 feet of till overlying the gravel aquifer and is screened in gravel from 51 to 56 feet below land surface. The hole for this well was drilled to a depth of 80 feet and encountered clay beneath the gravel and then sandstone from 70 to 80 feet (see hydrogeologic section A-A' of fig. 4).

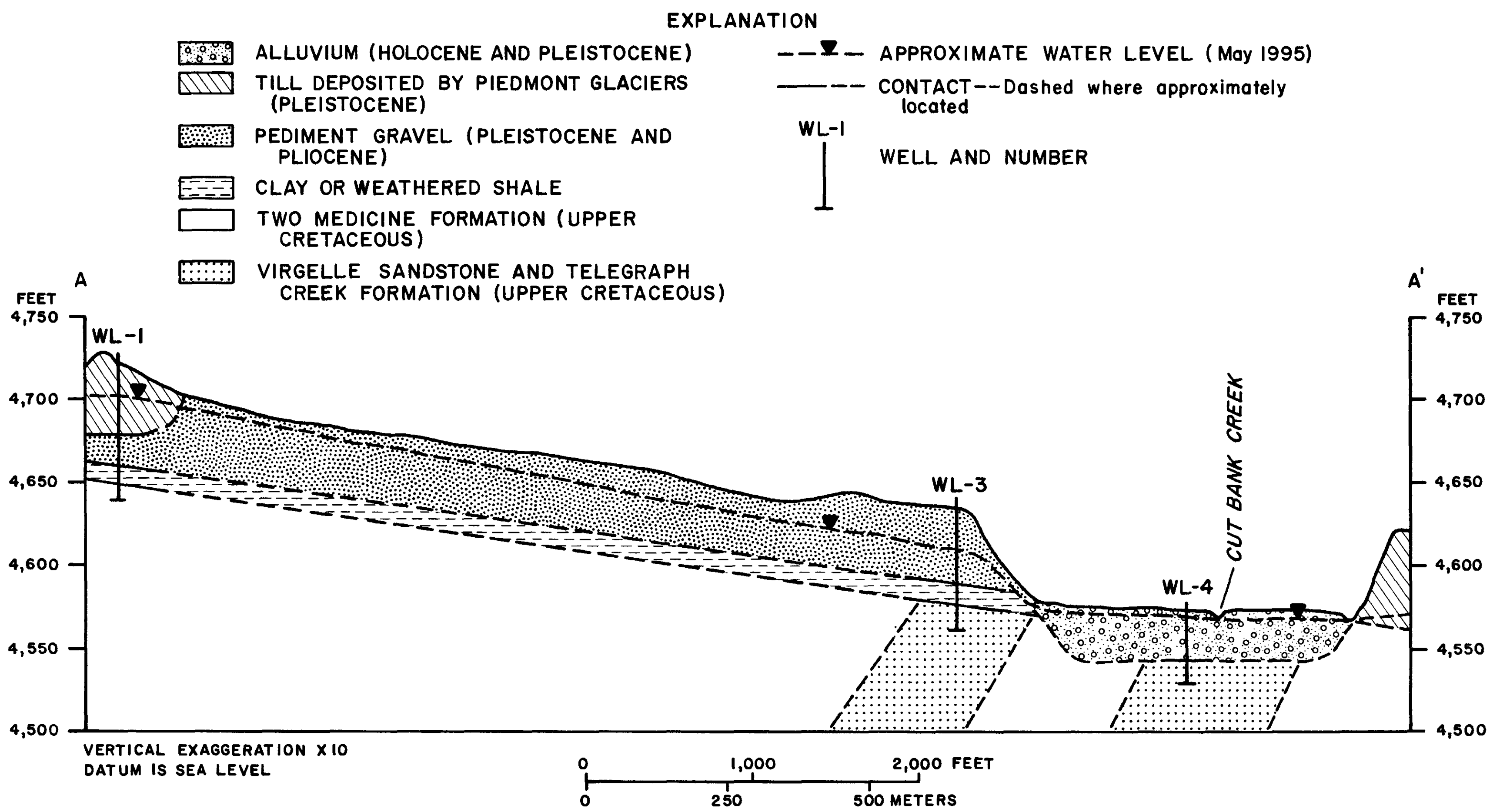

Figure 4. Hydrogeologic section A-A' through the Starr School area, northwestern Montana. Trace of section shown in figures 2 and 3.

Table 1. Records of selected wells, springs, test holes, and streamflow-measurement sites in the Browning-Starr School area, northwestern Montana

[Site number: letters preceding number indicate site type (WL, well; SP, spring; TH, test hole; ST, streamflow-measurement site). Abbreviation: USGS, U.S. Geological Survey. Symbol: --, no data or not applicable. See Supplemental Data for additional well information]

Site number (fig. 3)	Latitude and longitude	Location	Altitude of land surface, in feet above sea level	Drilled depth, in feet below land surface	Completed well depth, in feet below land surface	Aquifer	Use of water	Comments
WL-1	483527 1130845	NW1/4 SW1/4 NW1/4 sec. 26, T.33 N., R.12 W.	4,720	80	60	Gravel of Starr School Flat	Public	Starr School public-supply well
WL-2	483534 1130732	SW1/4 NW1/4 NW1/4 sec. 25, T.33 N., R.12 W.	4,635	--	29	Gravel of Starr School Flat	Domestic	Domestic well
WL-3	483524 1130731	NW1/4 SW1/4 NW1/4 sec. 25, T.33 N., R.12 W.	4,635	75	51.5	Gravel of Starr School Flat	Unused	Test well BL93-1
WL-4	483523 1130711	SW1/4 SE1/4 NW1/4 sec. 25, T.33 N., R.12 W.	4,575	45	33	Alluvium of Cut Bank Creek	Unused	Starr School north test well
WL-5	483515 1130718	NE1/4 NW1/4 SW1/4 sec. 25, T.33 N., R.12 W.	4,585	40	33	Alluvium of Cut Bank Creek	Unused	Starr School center test well
WL-6	483512 1130722	NE1/4 NW1/4 SW1/4 sec. 25, T.33 N., R.12 W.	4,588	38	37	Alluvium of Cut Bank Creek	Unused	Starr School south test well
WL-7	483503 1130113	NW1/4 SE1/4 SE1/4 sec. 27, T.33 N., R.11 W.	4,370	--	90	Glacial deposits and bedrock of St. Mary River Formation	Domestic	Domestic well
WL-8	483313 1130553	SE1/4 NE1/4 NE1/4 sec. 12, T.32 N., R.12 W.	4,555	75	75	Sand and gravel in buried channel	Public	Willow Creek well 1
WL-9	483314 1130545	SE1/4 NE1/4 NE1/4 sec. 12, T.32 N., R.12 W.	4,545	58	58	Sand and gravel in buried channel	Public	Willow Creek well 2
WL-10	483342 1130135	NE1/4 NW1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,390	--	35	Sand and gravel in buried channel	Domestic	Domestic well
WL-11	483343 1130128	NW1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,385	70	70	Sand and gravel in buried channel and bedrock of St. Mary River Formation	Public	Browning public-supply well 7
WL-12	483346 1130120	NE1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,385	70	70	Sand and gravel in buried channel and bedrock of St. Mary River Formation	Public	Browning public-supply well 3
WL-13	483346 1130117	NE1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,390	85	78	Sand and gravel in buried channel and bedrock of St. Mary River Formation	Public	Browning public-supply well 1
WL-14	483343 1130120	NE1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,380	62	62	Sand and gravel in buried channel and bedrock of St. Mary River Formation	Public	Browning public-supply well 2

Table 1. Records of selected wells, springs, test holes, and streamflow-measurement sites in the Browning-Starr School area, northwestern Montana (Continued)

Site number (fig. 3)	Latitude and longitude	Location	Altitude of land surface, in feet above sea level	Drilled depth, in feet below land surface	Completed well depth, in feet below land surface	Aquifer	Use of water	Comments
WL-15	483337 1130133	SE1/4 NW1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,390	70	70	Sand and gravel in buried channel and bedrock of St. Mary River Formation	Public	Browning public-supply well 8
WL-16	483335 1130126	SW1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,385	70	70	Sand and gravel in buried channel and bedrock of St. Mary River Formation	Public	Browning public-supply well 6
WL-17	483340 1130114	SE1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,380	81	81	Sand and gravel in buried channel and bedrock of St. Mary River Formation	Public	Browning public-supply well 4
WL-18	483340 1130111	SE1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,375	104	104	Sand and gravel in buried channel and bedrock of St. Mary River Formation	Public	Browning public-supply well 5
WL-19	483325 1130119	SE1/4 SE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	4,385	150	150	Two Medicine Formation	Domestic	Museum well
WL-20	483236 1130208	NW1/4 SE1/4 SE1/4 sec. 9, T.32 N., R.11 W.	4,495	195	115	Virgelle Sandstone and Two Medicine Formation	Stock	Test well BL91-5
SP-1	483514 1130733	NW1/4 NW1/4 SW1/4 sec. 25, T.33 N., R.12 W.	4,600	--	--	Gravel of Starr School Flat	Domestic	Starr School spring
SP-2	483651 1130256	SW1/4 NW1/4 SE1/4 sec. 16, T.33 N., R.11 W.	4,440	--	--	Gravel of Starr School Flat	Stock	Spring on north side of Cut Bank Creek
TH-1	483637 1130652	SW1/4 SW1/4 SE1/4 sec. 13, T.33 N., R.12 W.	4,625	95	0	Gravel of Starr School Flat and shale of Two Medicine Formation	Unused	Test hole BL91-6
TH-2	483646 1130635	NW1/4 SE1/4 SE1/4 sec. 13, T.33 N., R.12 W.	4,645	255	0	Virgelle Sandstone	Unused	Test hole BL91-7
ST-1	483512 1130715	SW1/4 NW1/4 SE1/4 sec. 25, T.33 N., R.12 W.	4,585	--	--	--	Multiple use	Cut Bank Creek near Starr School
ST-2	483700 1130206	NE1/4 NW1/4 SW1/4 sec. 15, T.33 N., R.11 W.	4,380	--	--	--	Multiple use	Cut Bank Creek north of Browning (USGS streamflow-gaging station 06098500)

Test well WL-3 was drilled east of Starr School near the valley of Cut Bank Creek and penetrated gravel and cobbles to a depth of 45 feet, clay and silt from 45 to 61 feet, and shale from 61 to 75 feet. The test well was cased to 51.5 feet and was perforated from 25 to 45 feet for monitoring water levels in the gravel aquifer. A test hole drilled about 1.5 miles northeast of Starr School (TH-1 in fig. 3) penetrated gravel and cobbles to 18 feet, clay from 18 to 74 feet, and shale from 74 to 95 feet. The 18 feet of gravel and cobbles contained no significant quantity of water. Six seismic refraction lines were run north and northeast from test well WL-3 to explore the bedrock surface for possible erosional channels that could contain thick gravel deposits. If located, thick gravel deposits would be a favorable location to explore for water. However, the seismic exploration did not indicate any large depressions in the bedrock surface, so additional wells were not drilled into the gravel aquifer on Starr School Flat. On the basis of well, spring, and seismic data, the gravel deposits of Starr School Flat appear to form a relatively thin aquifer.

Water from the gravel aquifer of Starr School flat has a chemical quality suitable for domestic use, as indicated by water samples from well WL-1 and springs SP-1 and SP-2 (table 2). The water is a calcium-magnesium bicarbonate type with a dissolved-solids concentration of 168 to 266 milligrams per liter (three samples).

Till with Buried Channels and Lenses of Sand and Gravel

Till, a heterogeneous mixture of clay, silt, sand, gravel, and boulders, mantles most of the study area south of Cut Bank Creek and west of Starr School. In the study area, till commonly contains a large proportion of gravel and cobbles and ranges from about 5 to 45 feet thick. Till was deposited in the area by large glaciers that flowed from the high mountains west of Browning onto the adjacent plains. As the glaciers advanced over the plains, they buried many existing stream drainages with till, covering channels containing gravel and sand (buried channels). Lenses of sand and gravel also exist between some till units, where they were deposited by running water from melting glacial ice. Till yields little or no water to wells because of its low permeability, but sand and gravel in buried channels and in lenses between till units are important aquifers.

Buried channels are mapped by Cannon (1996) west and northwest of Browning, along parts of Flatiron Creek and Willow Creek (fig. 3). The buried channels along Flatiron Creek and Willow Creek mark the probable pre-glacial course of South Fork Cut Bank Creek. The South Fork probably once flowed eastward from sec. 9, T. 32 N., R. 12 W., toward Browning. During Pleistocene time, the advancing Two Medicine glacier buried the ancient stream valley and forced Cut Bank Creek into its present position. Today, parts of Flatiron Creek and Willow Creek meander over wide valleys that approximately overlie the pre-glacial channel of South Fork Cut Bank Creek. An irrigation ditch that diverts water from the South Fork to Flatiron Creek also follows the course of the buried channel.

Lenses of sand and gravel are present between till layers and at the base of till in some areas. The sand and gravel lenses were deposited by glacial meltwater and later became buried with till as glaciers advanced over them. Water from melting glaciers also eroded shallow channels in the till (meltwater channels in fig. 3) and deposited a thin, surficial layer of sand and gravel on the north side of Browning in secs. 34 and 35, T. 33 N., R. 11 W. Gravel has been mined at several gravel pits located in that area.

Sand and gravel deposits in buried channels and lenses of sand and gravel within till are the most utilized aquifers in the study area. The Browning public water-supply system has well fields in three locations and all are completed in sand and gravel deposits along buried channels. The oldest well field consists of three wells plus an infiltration gallery located near Flatiron Creek in sec. 11, T. 32 N., R. 12 W. (fig. 3). The shallow wells and the infiltration gallery at the Flatiron site were the primary source of ground water for Browning before an additional well field was drilled on the west side of Browning (sec. 3, T. 32 N., R. 11 W.) in 1988.

The Browning well field consists of eight wells that range in depth from 62 to 104 feet (wells WL-11 through WL-18 in table 1). The wells are perforated in sand and gravel and in the underlying bedrock. Bedrock penetrated by the wells consists of mudstone and fine-grained sandstone that yield only a small quantity of water. Most water produced from the wells comes from the sand and gravel deposits. Several of the wells in the Browning well field have reported yields of more than 100 gallons per minute. However, long-term pumping of the wells causes considerable drawdowninterference among the wells and greatly reduces the combined capacity of the well field.

In 1994, two additional wells were drilled for the Browning water-supply system. The two wells were drilled about 4 miles west of Browning in sec. 12, T. 32 N., R. 12 W. (wells WL-8 and WL-9 in fig. 3) and are located near the margin of buried channel. Well WL-8 is perforated in gravel and sand at a depth of 55 to 65 feet and well WL-9 is perforated in coarse gravel and sand from 45 to 55 feet. Each well is pumped at about 147 gallons per minute (Robert DesRosier, Town of Browning, oral commun., 1995).

Sand and gravel deposits within buried channels and lenses of sand and gravel between till units can yield 150 gallons per minute or more to properly completed wells. However, long-term pumping of wells at their maximum discharge rate typically depletes water stored within the sand and gravel aquifer and significantly lowers the water level near the wells. Recharge to the aquifer is limited because of the low permeability of the overlying till. Slow recharge to the sand and gravel aquifer is the limiting factor for water production at the Flatiron and Browning well fields. At the Flatiron well field, surface water diverted from South Fork Cut Bank Creek has been used to increase recharge to the aquifer. At the Browning well field, recharge to the aquifer was increased by temporarily damming Willow Creek with sandbags. Water from Willow Creek spread over part of the well field, increasing ground-water recharge and water levels in the wells while the dam was in place.

Results of water-quality analyses of samples collected from wells WL-14, WL-15, WL-17, and WL-18 as part of previous investigations are listed in table 2. Water commonly is a calcium-magnesium bicarbonate type with a dissolved-solids concentration of 291 to 740 milligrams per liter (four samples). Water from well WL-15 had a larger quantity of sulfate than water from the other wells, probably contributed by the underlying bedrock aquifer, which also is penetrated by the well.

Alluvium of Cut Bank Creek

Alluvium, consisting of gravel, cobbles, sand, and silt, is present beneath the channel and flood plain of Cut Bank Creek (figs. 3 and 4). The alluvium typically is composed of very coarse gravel and rounded cobbles, indicating deposition by a high-energy stream. From Starr School northeastward to the downstream boundary of the study area, the valley of Cut Bank Creek was formed by an ice-marginal stream. Glacial meltwater flowing along the northern margin of the Two Medicine glacier scoured a channel in the underlying shale and sandstone, creating a channel about 500 to 2,000 feet wide (fig. 4). Cut Bank Creek and glacial meltwater deposited about 10 to 40 feet of coarse alluvium in the channel.

Surficial geologic mapping and investigation of wells and springs in the area indicate that alluvium in the valley of Cut Bank Creek could be a highly productive aquifer. The alluvial aquifer is hydraulically connected to Cut Bank Creek and receives a large flow of ground water from adjacent aquifers. To investigate the alluvial aquifer as a potential water supply, plans were made to drill three test wells and install one high-capacity well where the test wells indicated favorable aquifer properties.

In October 1994 three test wells (wells WL-4, WL-5, and WL-6) were drilled into the alluvium near Cut Bank Creek to determine thickness of the alluvium, potential for development of high-capacity water wells in the alluvial aquifer, and quality of water in the aquifer. Well WL-4 (also known as Starr School north test well) penetrated gravel, cobbles, and sand from 0 to 33 feet and dark gray shale from 33 to 45 feet below land surface. The well was completed with 5-inch diameter PVC casing to a depth of 33 feet; the casing was slotted from 23 to 33 feet below land surface. Well WL-5 (also known as Starr School center test well) penetrated gravel, cobbles, and sand from 0 to 33 feet and dark-gray shale from 33 to 40 feet. Well WL-5 was completed with 5-inch diameter PVC casing to a depth of 33 feet; the casing was slotted from 23 to 33 feet below land surface. Well WL-6 (also known as Starr School south test well) penetrated gravel, cobbles, and sand from 0 to 36 feet and dark-gray shale from 36 to 38 feet. Well WL-6 was completed with 5-inch diameter PVC casing to a depth of 37 feet; the casing was slotted from 25 to 35 feet below land surface.

After completion of drilling and casing, the test wells were pumped with a centrifugal pump to develop the wells and measure water discharge and drawdown. Well WL-4 (north test well) was pumped at 276 gallons per minute with a drawdown of 7.9 feet after about 1 hour of pumping. The static water level in well WL-4 was 2.6 feet below land surface on Oct. 7, 1994, prior to pumping the well. Well WL-6 (south test well) was pumped at 120 gallons per minute with a drawdown of 9 feet after about 1 hour of pumping. The static water

Table 2. Quality of water in selected wells, springs, and streams in the Browning-Starr School area, northwestern Montana

[Constituents are dissolved and concentrations are reported in milligrams per liter. Site number: letters preceding number indicate site type (WL, ground water; SP, spring; ST, surface water). Abbreviations: µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; USGS, U.S. Geological Survey. Symbols: <, less than; --, no data]

Site number	Location	Date sampled	Laboratory name[1]	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Calcium	Magnesium	Sodium	Potassium
WL-1	NW1/4 SW1/4 NW1/4 sec. 26, T.33 N., R.12 W.	05-08-84	A&L	275	8.1	--	25	11	3	3
WL-4	SW1/4 SE1/4 NW1/4 sec. 25, T.33 N., R.12 W.	10-17-94	M.E. Lab	312	7.5	--	43	16	3.2	--
WL-5	NE1/4 NW1/4 SW1/4 sec. 25, T.33 N., R.12 W.	10-18-94	M.E. Lab	260	7.6	--	37	13	2.8	--
WL-6	NE1/4 NW1/4 SW1/4 sec. 25, T.33 N., R.12 W.	10-20-94	M.E. Lab	276	7.4	--	35	14	2.8	--
WL-7	NW1/4 SE1/4 SE1/4 sec. 27, T.33 N., R.11 W.	07-29-92	MBMG	660	8.0	8.5	27	23	86	1.1
WL-10	NE1/4 NW1/4 SW1/4 sec. 3, T.32 N., R.11 W.	07-29-92	MBMG	611	7.6	8.0	69	28	22	1.7
WL-14	NE1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	06-09-92	MBMG	519	7.8	6.0	60	21	17	1.2
WL-15	SE1/4 NW1/4 SW1/4 sec. 3, T.32 N., R.11 W.	06-17-88	N. Engineering	1,070	7.4	--	111	43	49	3
WL-17	SE1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	06-01-88	N. Engineering	522	7.5	--	65	23	12	1
WL-18	SE1/4 NE1/4 SW1/4 sec. 3, T.32 N., R.11 W.	06-16-88	N. Engineering	538	7.5	--	59	22	10	2
WL-20	NW1/4 SE1/4 SE1/4 sec. 9, T.32 N., R.11 W.	05-07-92	MBMG	1,400	8.2	7.5	11	4.8	330	1.1
SP-1	NW1/4 NW1/4 SW1/4 sec. 25, T.33 N., R.12 W.	07-09-91	MBMG	285	7.5	9.5	38	15	3.0	.30
SP-2	SW1/4 NW1/4 SE1/4 sec. 16, T.33 N., R.11 W.	07-29-92	MBMG	465	8.0	9.0	47	28	12	.70
ST-2	NE1/4 NW1/4 SW1/4 sec. 15, T.33 N., R.11 W.	06-16-92	USGS	167	8.1	11.0	20	7.9	1.9	.40

[1]A&L, A&L Mid West Agricultural Laboratories Inc., Omaha, Neb.
M.E. Lab, Montana Environmental Laboratory, Kalispell, Mont.
MBMG, Montana Bureau of Mines and Geology, Butte, Mont.
N. Engineering, Northern Engineering and Testing, Inc., Billings, Mont.
USGS, U.S. Geological Survey Central Laboratory, Denver, Colo.

Site number	Bicar-bonate	Sul-fate	Chlo-ride	Fluo-ride	Silica	Dis-solved solids	Nitrate, as nitro-gen	Iron	Manga-nese	Zinc	Comments
WL-1	128	11	4	0.28	--	183	2	--	0.17	--	Starr School public-supply well
WL-4	218	3.8	--	<.1	--	--	.12	0.02	.07	--	Starr School north test well
WL-5	177	3.3	--	<.1	--	--	.07	<.01	<.01	--	Starr School center test well
WL-6	178	3.5	--	<.1	--	--	.05	<.01	<.01	--	Starr School south test well
WL-7	320	85	2.2	.36	8.3	394	<.10	<.003	.002	0.005	Domestic well
WL-10	320	58	6.0	.22	11	354	.11	.021	.002	.013	Domestic well
WL-14	290	39	1.8	.30	9.1	291	.22	.051	.052	.010	Browning public-supply well 2
WL-15	319	307	7	.12	--	740	.48	.75	.07	--	Browning public-supply well 8
WL-17	276	43	3	1.34	--	312	.16	.88	.06	--	Browning public-supply well 4
WL-18	284	29	2	.10	--	300	.06	.30	.10	--	Browning public-supply well 5
WL-20	740	140	8.1	.50	7.8	872	.19	.014	.028	.009	Test well BL91-5
SP-1	200	5.2	1.1	.07	7.1	168	.25	.034	.002	.064	Starr School spring
SP-2	300	7.6	1.2	.49	10	266	2.0	.004	<.002	.002	Spring on north side of Cut Bank Creek
ST-2	100	4.8	.40	<.1	4.1	89	--	--	--	.005	Cut Bank Creek north of Browning (USGS streamflow-gaging station 06098500)

level in well WL-6 was 8.5 feet below land surface on Oct. 6, 1994, prior to pumping the well. Well WL-5 (center test well) was pumped at a later date by the drilling contractor and had a reported yield and drawdown similar to well WL-6. The static water level in well WL-5 was 5.51 feet below land surface on Nov. 22, 1994. The proposed high-capacity well was not drilled because of problems with access to the site.

The alluvial aquifer probably could yield more than 300 gallons per minute to properly constructed wells, on the basis of limited pumping of the test wells. Prolonged pumping of wells completed in the alluvium would induce recharge to the aquifer from Cut Bank Creek. Because of the large volume of water in storage in the alluvial aquifer, and large volume of recharge from Cut Bank Creek and adjacent aquifers, the alluvial aquifer probably would be a dependable source of ground water, even during times of drought. Additional pumping of the test wells is needed to accurately predict the effects of long-term pumping on the alluvial aquifer.

Water samples were collected from test wells WL-4, WL-5, and WL-6 by the drilling contractor and were sent to Montana Environmental Laboratory in Kalispell, Mont., for analysis. Results of the water-quality analyses are listed in table 2. Water from the alluvial aquifer is a calcium bicarbonate type and has a relatively low dissolved-solids concentration as indicated by the specific-conductance values of 260 to 312 microsiemens per centimeter at 25 degrees Celsius (three samples).

Bedrock Aquifers

Bedrock units consisting primarily of mudstone, shale, and fine-grained sandstone underlie the study area to a depth of several thousand feet. The mudstone and shale yield almost no water to wells; some of the sandstone beds yield a small quantity of water to wells. Sandstone beds are present in the Virgelle Sandstone, the lower part of the Two Medicine Formation, the Horsethief Sandstone, and the St. Mary River Formation. Sandstone beds that underlie the study area seldom yield more than 15 gallons per minute to wells, although some fractured sandstone beds that underlie saturated glacial till and gravel deposits can yield as much as 50 gallons per minute to properly constructed wells.

The Madison Group of Mississippian age, which forms an important aquifer in some areas of Montana, underlies the study area at a depth of 7,900-8,600 feet below land surface (Feltis, 1984). The aquifer was not investigated as part of this study because of its great depth below land surface. Water samples collected from the Madison Group by the petroleum industry had dissolved-solids concentrations that ranged from 3,000 to 5,000 milligrams per liter (Feltis, 1980).

Many wells in the Browning area penetrate bedrock and are completed in both bedrock and the overlying glacial deposits or alluvium. The eight public-supply wells located on the west side of Browning (wells WL-11 through WL-18) are completed in sand and gravel and the underlying bedrock of the St. Mary River Formation. However, most of the yield from these wells comes from the sand and gravel aquifer. Most wells that are completed only in bedrock have small yields. Well WL-20, completed in the Virgelle Sandstone and Two Medicine Formation, was test pumped at 5.4 gallons per minute and had 50 feet of drawdown after 90 minutes of pumping. Test hole TH-2 was drilled to a depth of 255 feet in the Virgelle Sandstone and produced only 3.4 gallons per minute.

Water from bedrock aquifers generally is more mineralized than water from unconsolidated-deposit aquifers. A water sample collected from well WL-20 was a sodium bicarbonate-sulfate type with a dissolved-solids concentration of 872 milligrams per liter (table 2).

SURFACE-WATER RESOURCES

The primary surface-water resource of the study area is Cut Bank Creek. Daily discharge of Cut Bank Creek is determined from data collected by the U.S. Geological Survey at streamflow-gaging station 06098500, located 20 feet downstream from the bridge on Montana Secondary Highway 464 (Duck Lake Road), about 4 miles north of Browning. Altitude of the gage is 4,380 feet above sea level. The drainage area of Cut Bank Creek above the gaging station is about 123 square miles. Water is diverted above the gaging station for stock water and irrigation. Seasonal records were collected at the station from April 1918 to October 1925; continuous records have been collected from April 1991 to present (1996).

Daily discharge values for Cut Bank Creek are published by the U.S. Geological Survey in water-data reports for Montana (U.S. Geological Survey, issued annually). Monthly mean discharge for Cut Bank Creek for April 1991 through September 1996 is summarized in table 3. On the basis of the discharge records for 1991-96, the average of the monthly mean discharge ranges from 36.2 cubic feet per second in January to 478 cubic feet per second in June. May and June have the greatest discharge and account for more than 50 percent of the annual runoff.

A flow-duration analysis was made of daily mean discharge for water years 1992 through 1996 (October 1991-September 1996), which are the only years for which a complete flow record is available at the gaging station. For water years 1992-96, Cut Bank Creek had a discharge of 24 cubic feet per second or more for 90 percent of the time, a discharge of 65 cubic feet per second or more for 50 percent of the time, and a discharge of 335 cubic feet per second or more for 10 percent of the time. The gaging station recorded no days of zero flow. The highest daily mean discharge was 3,400 cubic feet per second on June 7, 1995, and the highest instantaneous peak discharge was 5,480 cubic feet per second on June 7, 1995.

Water in Cut Bank Creek was sampled at site ST-2 on June 16, 1992, and results of the water-quality analysis are shown in table 2. The specific conductance of the sample was 167 microsiemens per centimeter at 25 degrees Celsius and the dissolved-solids concentration was 89 milligrams per liter. Additional measurements of specific conductance at site ST-2 (64 samples collected between October 1990 and August 1996) had a range of 138 to 320 and a median of 236 microsiemens per centimeter. The specific conductance measurements indicate that water in Cut Bank Creek generally has a smaller dissolved-solids concentration than does ground water in the study area. Water sampled from Cut Bank Creek was a calcium bicarbonate type, suitable for most domestic, livestock, irrigation, and industrial uses.

Table 3. Monthly mean discharge for Cut Bank Creek near Browning, Mont., station 06098500

[Discharge measured in cubic feet per second. Symbol: --, no data]

Year	Jan	Feb	Mar	Apr	May	June
1991	--	--	--	194	740	740
1992	27.9	28.5	44.6	121	248	184
1993	20.8	18.4	55.5	102	398	247
1994	34.4	24.9	83.1	199	464	277
1995	24.2	62.9	70.0	60.5	349	793
1996	73.8	139	109	217	379	627
Average	36.2	54.7	72.4	149	430	478

Year	July	Aug	Sept	Oct	Nov	Dec
1991	312	94.6	36.9	31.6	49.6	34.6
1992	154	34.8	51.3	82.4	45.5	21.8
1993	200	78.0	81.8	53.1	41.0	41.2
1994	91.5	32.7	17.8	29.8	35.9	30.7
1995	228	77.3	65.3	136	216	157
1996	257	75.0	33.0	--	--	--
Average	207	65.4	47.7	66.6	77.6	57.0

CONCLUSIONS

Aquifers in unconsolidated deposits supply most drinking water in the Browning-Starr School area and have the greatest potential for development of additional ground-water supplies. Quaternary and Tertiary unconsolidated-deposit aquifers in the study area are (1) gravel deposits of Starr School Flat, (2) till with buried channels and lenses of sand and gravel, and (3) alluvium of Cut Bank Creek.

The gravel aquifer of Starr School Flat is used as a source of drinking water in the community of Starr School. A public-supply well at Starr School is capable of producing 100 gallons per minute, although wells in most of Starr School Flat would produce much less because of the small thickness of saturated gravel. Water from the gravel aquifer is a calcium-magnesium bicarbonate type with a dissolved-solids concentration of 168 to 266 milligrams per liter (three samples).

Sand and gravel deposits in buried channels and lenses of sand and gravel between till units are the most utilized aquifers in the Browning area. Buried channels are mapped west and northwest of Browning, along parts of Flatiron and Willow Creeks. The Browning public water-supply system has three well fields completed in the sand and gravel deposits. The well fields are located near Flatiron Creek, near Willow Creek about 4 miles west of Browning, and along Willow Creek on the west edge of Browning. The sand and gravel deposits can yield 150 gallons per minute or more to properly constructed wells. However, till overlying the sand and gravel limits the rate of recharge to the aquifer and long-term pumping of wells can significantly lower the water level near the wells. Water from the sand and gravel deposits typically is a calcium-magnesium bicarbonate type with a dissolved-solids concentration of 291 to 740 milligrams per liter (four samples).

Alluvium underlying the channel and flood plain of Cut Bank Creek is a very coarse gravel and cobble aquifer that is hydraulically connected to Cut Bank Creek. East of Starr School, the alluvial aquifer is about 33 feet thick and 2,000 feet wide. The alluvial aquifer probably could yield more than 300 gallons per minute to properly constructed wells, on the basis of limited pumping of three test wells. The alluvial aquifer probably would be a dependable source of ground water, even during times of drought, because of the large volume of ground water in storage and the large volume of recharge available from Cut Bank Creek and the gravel aquifer of Starr School Flat. Water from the alluvial aquifer is a calcium bicarbonate type and has a relatively low dissolved-solids concentration as indicated by the specific-conductance values of 260 to 312 microsiemens per centimeter at 25 degrees Celsius.

Cretaceous bedrock underlies the area and consists of mudstone, shale, and fine-grained sandstone. The mudstone and shale yield almost no water to wells, and the sandstone beds seldom yield more than 15 gallons per minute to wells. Water from bedrock aquifers generally is more mineralized than water from unconsolidated-deposit aquifers.

Cut Bank Creek is the primary surface-water resource of the study area. A streamflow-gaging station operated by the U.S. Geological Survey (station 06098500) is located on Cut Bank Creek about 4 miles north of Browning. For water years 1992-96, Cut Bank Creek had a discharge of 24 cubic feet per second or more for 90 percent of the time; a discharge of 65 cubic feet per second or more for 50 percent of the time; and a discharge of 335 cubic feet per second or more for 10 percent of the time. The gaging station recorded no days of zero flow. Water from Cut Bank Creek is a calcium bicarbonate type (one sample) and has a dissolved-solids concentration that generally is smaller than the dissolved-solids concentration of ground water in the area.

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SUPPLEMENTAL DATA

LOGS FOR WELLS AND TEST HOLES LISTED IN TABLE 1
(no logs were available for sites WL-7 and WL-10)

INFORMATION FOR SITE WL-1

Latitude: 483527

Longitude: 1130845

Date Drilled: April 16, 1984

Driller: Hall Drilling

Other Identifier: Starr School public-supply well

Casing: Steel casing, 10-inch diameter.

Screen, 80 slot, set from 51-56 feet below land surface.

Water level: About 18 feet below land surface on 5-10-84, as determined from driller's logs.

Lithology:	Depth (feet below land surface)
Top soil and boulders	0-20
Brown clay and boulders	20-42
Red clay and gravel (pea gravel from 48-55 feet)	42-58
Brown clay	58-70
Sandstone	70-80

INFORMATION FOR SITE WL-2

Latitude: 483534

Longitude: 1130732

Date Drilled: June 1994

Driller: Nicka Well Drilling

Other Identifier: Domestic well

Casing: Steel casing, 6-inch diameter.

Measured well depth of 29 feet below land surface.

Water level: 12.32 feet below land surface on 8-2-94

16.39 feet below land surface on 5-3-95

Lithology:	Depth (feet below land surface)
No data	

INFORMATION FOR SITE WL-3

Latitude: 483524

Longitude: 1130731

Date Drilled: August 16 and 17, 1993

Driller: Poverty Well Drilling, Great Falls, Mont.

Other Identifier: Test well BL93-1

Casing: Steel casing, 6-inch diameter, set to 51.5 feet below land surface.

Perforated from 25-45 feet below land surface.

Water level: 23.36 feet below land surface on 9-22-93

26.42 feet below land surface on 5-3-95

Lithology:	Depth (feet below land surface)
Gravel and cobbles; sandy	0-45
Silt and clay; sandy, light-brown	45-54
Clay; silty, gray	54-61
Shale; gray, with some siltstone	61-75

INFORMATION FOR SITE WL-4

Latitude: 483523

Longitude: 1130711

Date Drilled: October 6, 1994

Driller: Grizzly Construction, Browning, Mont.

Other Identifier: Starr School north test well

Casing: PVC casing, 5-inch diameter, set to 33 feet below land surface.
Saw slots in casing from 23-33 feet below land surface.
Measured well depth of 32.3 feet; some sediment in well.

Water level: 2.6 feet below land surface on 10-7-94
2.92 feet below land surface on 11-22-94
2.61 feet below land surface on 5-3-95

Lithology:	Depth (feet below land surface)
Gravel, cobbles, and sand	0-33
Dark-gray shale; soft, weathered	33-45

INFORMATION FOR SITE WL-5

Latitude: 483515

Longitude: 1130718

Date Drilled: October 4, 1994

Driller: Grizzly Construction, Browning, Mont.

Other Identifier: Starr School center test well

Casing: PVC casing, 5-inch diameter, set to 33 feet below land surface.
Saw slots in casing, from 23-33 feet below land surface.
Measured well depth of 31 feet; some sediment in well.

Water level: 5.51 feet below land surface on 11-22-94
5.18 feet below land surface on 5-3-95

Lithology:	Depth (feet below land surface)
Gravel, cobbles, and sand	0-33
Dark-gray shale; soft, weathered	33-40

INFORMATION FOR SITE WL-6

Latitude: 483512

Longitude: 1130722

Date Drilled: October 5, 1994

Driller: Grizzly Construction, Browning, Mont.

Other Identifier: Starr School south test well

Casing: PVC casing, 5-inch diameter, set to 37 feet below land surface.
Saw slots in casing from 25-35 feet below land surface.
Measured well depth of 35.4 feet; some sediment in well.

Water level: 8.5 feet below land surface on 10-6-94
8.76 feet below land surface on 11-22-94
8.38 feet below land surface on 5-3-95

Lithology:	Depth (feet below land surface)
Gravel, cobbles, and sand	0-36
Dark-gray shale; soft, weathered	36-38

INFORMATION FOR SITE WL-8

Latitude: 483313

Longitude: 1130553

Date Drilled: April 5, 1994

Driller: Rising Wolf Construction

Other Identifier: Willow Creek Well 1

Casing: Steel casing, 8-inch diameter, set to 75 feet below land surface.
Perforated from 55-65 feet below land surface.

Water level: 18.8 feet below land surface on 4-25-94

Lithology:	Depth (feet below land surface)
Top soil	0-3
Fine gravel and sand mixed with clay	3-14
Clay	14-23
Shale, dark-brown	23-41
Gravel and sand	41-41.5
Shale, brown	41.5-55
Gravel and sand	55-65
Shale	65-75

INFORMATION FOR SITE WL-9

Latitude:	483314
Longitude:	1130545
Date Drilled:	April 22, 1994
Driller:	Rising Wolf Construction
Other Identifier:	Willow Creek well 2

Casing: Steel casing, 8-inch diameter, set to 58 feet below land surface.
Perforated from 45-55 feet below land surface.

Water level: 9.6 feet below land surface on 4-25-94

Lithology:	Depth (feet below land surface)
Top soil	0-4
Boulders, gravel, and sand mixed with clay	4-20
Quartz	20-21
Gravel and sand mixed with clay	21-36
Gravel and sand, coarse (water bearing)	36-57
Cobbles and boulders	57-58

INFORMATION FOR SITE WL-11

Latitude: 483343

Longitude: 1130128

Date Drilled: 1988

Driller: Tim Adair

Other Identifier: Browning public-supply well 7

Casing: Steel casing, 6-inch diameter, set to 70 feet below land surface.

Screen, 250 slot, from 18-28 feet and 55-60 feet below land surface.

Water level: 20.3 feet below land surface on 4-1-92

Lithology:	Depth (feet below land surface)
No data	

INFORMATION FOR SITE WL-12

Latitude: 483346

Longitude: 1130120

Date Drilled: 1988

Driller: Tim Adair

Other Identifier: Browning public-supply well 3

Casing: Steel casing, 6-inch diameter, set to 70 feet below land surface.

Screen, 250 slot, from 17-32 feet and 55-60 feet below land surface.

Water level: 16.0 feet below land surface on 4-1-92

Lithology:	Depth (feet below land surface)
No data	

INFORMATION FOR SITE WL-13

Latitude: 483346

Longitude: 1130117

Date Drilled: July 30, 1980

Driller: Hall Drilling

Other Identifier: Browning public-supply well 1

Casing: Steel casing, 8-inch diameter, set to 78 feet below land surface.

Screen, 150 slot, from 25-35 feet below land surface.

Perforations from 35-78 feet below land surface.

Water level: 19.3 feet below land surface on 4-1-92

Lithology:	Depth (feet below land surface)
Topsoil	0-12
Gravel and sand	12-35
Brown sandy clay	35-46
Sandstone	46-58
Gray sandy clay	58-59
Sandstone	59-81
Dark-gray oil shale	81-85

INFORMATION FOR SITE WL-14

Latitude: 483343

Longitude: 1130120

Date Drilled: 1980

Driller: Hall Drilling

Other Identifier: Browning public-supply well 2

Casing: Steel casing, 8-inch diameter, set to 62 feet below land surface.

Screen, 150 slot, from 20-30 feet below land surface.

Perforations from 30-62 feet below land surface.

Water level: 17.1 feet below land surface on 4-1-92

Lithology:	Depth (feet below land surface)
Top soil	0-5
Gravel and boulders	5-33
Sandstone	33-42
Gray clay	42-45
Sandstone	45-47
Brown clay with gravel	47-58
Dark-gray oil shale	58-62

INFORMATION FOR SITE WL-15

Latitude:	483337
Longitude:	1130133
Date Drilled:	June 15, 1988
Driller:	Tim Adair
Other Identifier:	Browning public-supply well 8

Casing: Steel casing, 6-inch diameter, set to 70 feet below land surface.

Screen, 100 slot, set from 19-29 and 55-60 feet below land surface.

Water level: 22.7 feet below land surface on 4-1-92

Lithology:	Depth (feet below land surface)
Top soil	0-1.5
Clay; gravelly till	1.5-20
Sand and gravel; medium to coarse	20-29
Clay	29-49
Shattered rock	49-70

INFORMATION FOR SITE WL-16

Latitude: 483335

Longitude: 1130126

Date Drilled: 1988

Driller: Tim Adair

Other Identifier: Browning public-supply well 6

Casing: Steel casing, 6-inch diameter, set to 70 feet.

Screen, 250 slot, set from 18-28 and 55-60 feet below land surface.

Water level: 22.0 feet below land surface on 4-1-92

Lithology:	Depth (feet below land surface)
No data	

INFORMATION FOR SITE WL-17

Latitude: 483340

Longitude: 1130114

Date Drilled: June 3, 1988

Driller: Tim Adair

Other Identifier: Browning public-supply well 4

Casing: Steel casing, 6-inch diameter, set to 81 feet below land surface.

Screen, 100 slot, set from 19-34 and 66-71 feet below land surface.

Water level: 16.2 feet below land surface on 4-1-92

Lithology:	Depth (feet below land surface)
Top soil	0-2
Clay, gravel, and rock	2-17
Gravel; coarse	17-30
Clay and gray shale	30-66
Shattered rock	66-71
Gray clay shale	71-81

INFORMATION FOR SITE WL-18

Latitude: 483340

Longitude: 1130111

Date Drilled: June 10, 1988

Driller: Tim Adair

Other Identifier: Browning public-supply well 5

Casing: Steel casing, 6-inch diameter, set to 104 feet below land surface.

Screen, 100 slot, set from 20-35 and 94-99 feet below land surface.

Water level: 14.6 feet below land surface on 4-1-92

Lithology:	Depth (feet below land surface)
Top soil	0-1.5
Clay and gravel	1.5-20
Gravel and rock	20-35
Clay and gravel	35-37
Gray clay (shale)	37-40
Rock	40-45
Gray clay shale	45-90
Shale and broken rock	90-104

INFORMATION FOR SITE WL-19

Latitude: 483325

Longitude: 1130119

Date Drilled: April 1972

Driller: Billmayer

Other Identifier: Museum well

Casing: Steel casing, 10-inch diameter, set to 73 feet below land surface.

Steel casing, 8-inch diameter, set from 70-150 feet below land surface.

Perforations from 65-70 and 90-140 feet below land surface.

Water level: 6 feet below land surface on 4-27-72

Lithology:	Depth (feet below land surface)
Surface gravel and sand	0-15
Clean gravel	15-23
Shale and gravel	23-33
Shale	33-60
Sandstone	60-90
Shale and sandstone	90-100
Gravel and shale	100-105
Sandstone and shale	105-120
Sandstone	120-140
Shale	140-150

INFORMATION FOR SITE WL-20

Latitude: 483236

Longitude: 1130208

Date Drilled: September 27, 1991

Driller: U.S. Geological Survey

Other Identifier: Test well BL91-5

Casing: PVC casing, 4-inch diameter, set to 115 feet below land surface.

PVC screen, 35 slot with gravel pack from 35-55 and 75-115 feet below land surface.

Water level: 0.6 feet above land surface on 9-28-91

0.93 feet below land surface on 5-7-92

Lithology:	Depth (feet below land surface)
Till; gravelly, light-brown	0-30
Sandstone; fine- to medium-grained, hard	30-33
Sandstone and siltstone; soft to hard, fractured, gray	33-44
Sandstone; fine- to medium-grained, gray	44-74
Shale; sandy, gray	74-75
Sandstone; fine- to medium-grained, gray, thin carbonaceous shale bed at 82 feet	75-93
Shale and sandstone; fractured, soft, gray	93-101
Sandstone; fine- to medium-grained, soft, silty, light gray	101-106
Sandstone; fine- to medium-grained, light-gray, some calcite in fractures	106-117
Shale; dark-gray, fractured, sandy in lower 15 feet	117-147
Sandstone; fine- to medium-grained, gray	147-169
Shale; gray and greenish-gray, sandy from 187 to 190 feet (Two Medicine Formation)	169-195

INFORMATION FOR SITE TH-1

Latitude:	483637
Longitude:	1130652
Date Drilled:	September 28, 1991
Driller:	U.S. Geological Survey
Other Identifier:	Test hole BL91-6

Casing: None

Water level: No data

Lithology:	Depth (feet below land surface)
Gravel and cobbles	0-18
Clay; silty, sandy, light-brown	18-40
Clay with silt and sand layers; gray	40-74
Shale; sandy, gray	74-95

INFORMATION FOR SITE TH-2

Latitude: 483646

Longitude: 1130635

Date Drilled: September 28, 1991

Driller: U.S. Geological Survey

Other Identifier: Test hole BL91-7

Casing: None

Water level: No data

Lithology:	Depth (feet below land surface)
Sand; fine-grained, light-brown (weathered from Virgelle Sandstone)	0-12
Sandstone; fine-grained, soft, light-brown	12-21
Sandstone; fine-grained, hard, light-gray	21-22
Sandstone; fine-grained, light-brown (water at 35 feet)	22-58
Sandstone with thin shale beds; fine-grained, gray	58-78
Sandstone; fine- to medium-grained, gray, calcite in fractures	78-90
Shale; sandy, gray, calcite in fractures	90-158
Sandstone; fine- to medium-grained, gray, calcite in fractures	158-225
Shale; gray	225-226
Sandstone; fine-grained, gray (hole producing 3.4 gallons per minute)	226-255

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