STATE OF MONTANA
Thomas L. Judge, *Governor*

BUREAU OF MINES AND GEOLOGY
S. L. Groff, *Director*

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GROUND-WATER RESOURCES IN THE LIBBY AREA, NORTHWESTERN MONTANA

Arnold J. Boettcher and Kathleen R. Wilke

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Conversion factors

For readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below.

English	Multiply by	Metric
inches (in)	25.40	millimeters (mm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
acres	0.004047	square kilometers (km^2)
acre-feet (acre-ft)	1233	cubic meters (m^3)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meters per second per square kilometer [$(m^3/s)/km^2$]
feet squared per day (ft^2/d)	0.0929	meters squared per day (m^2/d)
gallons per minute (gal/min)	0.06309	liters per second (L/s)

Degrees Celsius (°C) = 0.556(°F − 32)

GROUND-WATER RESOURCES IN THE LIBBY AREA, NORTHWESTERN MONTANA

By

Arnold J. Boettcher and Kathleen R. Wilke

ABSTRACT

Glacial deposits and alluvium form the major aquifer in the Libby area. The glacial deposits are composed of Precambrian rocks that were broken and crushed, and then deposited as till by moving ice. The alluvium is composed of reworked glacial deposits that have been deposited by water, thereby sorting and increasing the permeability of the deposits.

Ground water is generally available for domestic use throughout the Libby area. Most wells that tap the glacial deposits yield less than 30 gallons per minute. Some wells that tap the alluvium yield more than 500 gallons per minute, but most yield less than 100 gallons per minute.

Water levels in wells tapping the glacial deposits and the alluvium along the Kootenai River and Libby Creek valleys respond rapidly to changes in stream stages. During the January 1974 flood, the water level in a well west of Libby rose 4 feet in three days.

The chemical quality of the ground water is satisfactory for drinking. Dissolved-solids concentration of the water ranges from 32 to 370 milligrams per liter; the major constituents are calcium, magnesium, and bicarbonate. Areas where the nitrate (as NO_3) concentration in ground water equals or exceeds 1.5 milligrams per liter are believed to be affected by septic-tank effluent.

INTRODUCTION

The 1970 population in the Libby area was 12,045, including 3,286 persons in the city of Libby. The population of the area increased 64 percent and the population of the city increased 16 percent from 1960 to 1970. Most new residences were outside the city limits and were served by individual wells and sewage facilities. In 1964 many residents believed that an unusual number of cases of infectious hepatitus could be traced to contamination of the ground water by effluent from septic systems. As a result, interest was expressed in a ground-water study to determine the type and characteristics of the rocks in the subsurface and the quality of the water. Also, the South Libby Water and Sewer District was established to design municipal water and sewer facilities for the area south of Libby.

PURPOSE AND SCOPE

This report describes the ground-water system and the quality of water in the Libby area. The study was made by the U. S. Geological Survey in cooperation with the Montana Bureau of Mines and Geology. The objectives of this investigation were to (1) describe the location, extent, and water-bearing characteristics of the aquifers; (2) describe areas of interchange of water between the ground- and surface-water systems; (3) describe the chemical quality of ground water and determine whether septic-tank effluent is adversely affecting the quality; and (4) establish a network of observation wells that could be used after completion of the project to monitor long-term changes in water levels.

Field data were collected from July 1972 to June 1974. About 300 wells and 8 springs were inventoried (Table 2). Variations of depth to water were measured in 15 observation wells (Table 3). Chemical analyses were made on water samples collected from 91 wells, 2 springs, and 4 stream sites (Table 4), and from 11 wells after the January 1974 flood (Table 1).

LOCATION AND EXTENT

The project area includes about 85 square miles in Lincoln County in northwestern Montana (Fig. 1). The city of Libby, near the center of the project, is about 20 miles east of the Idaho-Montana state line and about 45 miles south of the United States-Canada boundary. About 52 square miles of the project area is in the Kootenai National Forest; most of the rest of the land is privately owned.

PREVIOUS INVESTIGATIONS

Alden (1953) and Wright and Frey (1965) described the Pleistocene geology of the Libby area. The surficial geology of the Libby area was mapped and described by Gibson, Jenks, and Campbell (1941), Gibson (1948), and Johns (1959; 1970). Kleinkopf, Harrison, and Zartman (1972) incorporated aeromagnetic data and geology in their study, which included the Libby area. Johnson and Omang (1974) reported on an unseasonal flood in the Libby area in January 1974.

Table 1.—Chemical analyses of water from wells, January 1974.

[Analyses by U.S. Geological Survey except as indicated.]

Well number	Well depth (feet)	Total nitrogen (NO_3) (mg/L)	Total kjeldahl nitrogen (NO_3) (mg/L)	Total nitrite plus nitrate (NO_3) (mg/L)	Temperature (°C)	1973 Nitrate (NO_3) (mg/L)[1]
30N31W3CBA	33	4.0	3.2	0.79	5.0	Not previously sampled
30N31W4ACB	43	3.4	.57	2.8	3.0	1.5
30N31W4CCB	67	1.9	.22	1.7	6.0	1.4, 1.2
30N31W9ADD3	7	.62	.40	.22	3.5	.2
30N31W10DBC	67	31	2.0	29	7.5	21, 19
30N31W23BAD	55	1.4	.31	1.1	7.0	.7
30N31W24CBB2	12	22	1.7	21	4.0	2.1, 2.9
30N31W24CBD	80	8.8	.70	7.9	4.0	Not previously sampled
30N31W26ADA	40	23	1.0	22	5.5	26, 23
31N31W32DDA	45	1.7	.09	1.6	7.0	1.8, 1.1
31N31W33DCC	30	7.9	1.9	6.2	9.0	2.0, 1.7

[1] Analyses by Montana Bureau of Mines and Geology.

ACKNOWLEDGMENTS

The authors express their gratitude to the well owners who permitted measurements to be made in their wells, gave information about their wells, and allowed access to their land. Special thanks are given to personnel of B and B Drilling Co. and C and L Plumbing and Heating Inc., who provided well and water-level data. The investigation was greatly aided by Dave Marshall, Lincoln County Sanitarian, and Robert MacKenzie, M.D., Lincoln County Public Health Officer, who both contributed valuable information about water-well and sewage-disposal conditions in the project area. Much credit is due to Ron King, summer field assistant, who collected most of the field data. Valuable information was obtained from the South Libby Water and Sewer District and Morrison-Maierle Inc., consulting engineers, who permitted U.S. Geological Survey personnel to participate in an aquifer test.

SYSTEM FOR SPECIFYING GEOGRAPHIC LOCATIONS

Geographic locations of wells, springs, and sampling sites referred to in this report have been assigned numbers and letters based on the General Land Office system of land subdivision. This system identifies the location by township, range, section, and position within the section. The

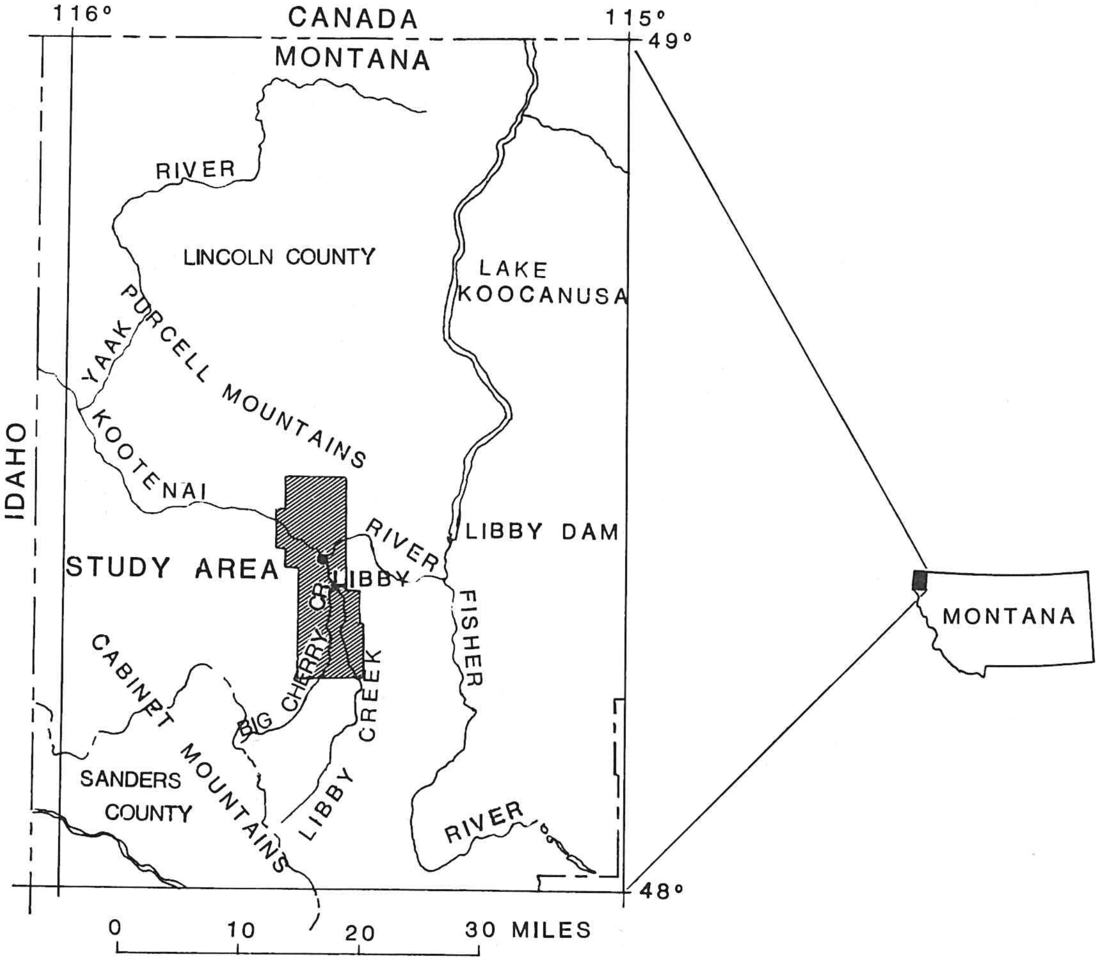

Figure 1.—Index map showing location of study area.

first three characters specify the township, the next three characters the range, the next number the section, and the next three letters indicate the location within the quarter section (160 acres), quarter-quarter section (40 acres), and quarter-quarter-quarter section (10 acres). The letters (A, B, C, and D) subdividing the section are assigned in a counterclockwise direction beginning with "A" in the northeast quarter of the section. If more than one data site is within a 10-acre tract, consecutive numbers beginning with 2 are added to the location number. For example, a well numbered 30N31W15ADA2 indicates the second data site inventoried in the NE¼ of the SE¼ of the NE¼ of section 15, Township 30 North, Range 31 West. An example of this system is shown in Figure 2.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

The project area is mountainous. The altitude of the peaks adjacent to the project area exceeds 7,500 feet. Altitudes within the project area range from 2,020 feet where the Kootenai River leaves the Libby Creek valley to 4,650 feet in the northeastern part. The steep mountains rise as much as 2,000 feet per mile.

High terraces are prominent mainly in the Libby Creek and Kootenai River valleys. A terrace east of Libby, which is formed on silt that was deposited in a glacial lake, is 300 feet high.

The Kootenai River flows into Lake Koocanusa about 40 miles north of the international boundary. The lake extends south to Libby Dam, which is about 20 miles east of Libby (Fig. 1). From the mouth of the Fisher River, 3 miles downstream from Libby Dam, the Kootenai River flows northwest through the project area into Idaho, then north from Idaho back into Canada, where it joins the Columbia River. In the project area, the Kootenai valley ranges in width from ¼ mile where the river enters the project area to 1½ miles where it leaves the area west of Libby. Most of the flow of the Kootenai at Libby is regulated by Libby Dam.

The major tributaries to the Kootenai River in the study area are, in downstream order, Libby, Flower, Parmenter, Pipe, and Bobtail Creeks. About 10 miles of the Libby Creek valley is in the project area; the average slope is 50 feet per mile. The valley width is three quarters of a mile at the confluence with the Kootenai and about a quarter of a mile at the southern end of the project area.

Big Cherry Creek is the principal tributary to Libby Creek. About 8 miles of its length is in the project area; the average slope is 70 feet per mile. The valley width is half a mile where Big Cherry Creek flows into Libby Creek valley and about 750 feet where Big Cherry Creek comes into the project area east of Little Hoodoo Mountain.

Both Bobtail and Pipe Creeks have eroded narrow gorges through the glacial material in the northern part of the project area. Each creek flows through about 6 miles of the project area and has an average slope of about 100 feet per mile.

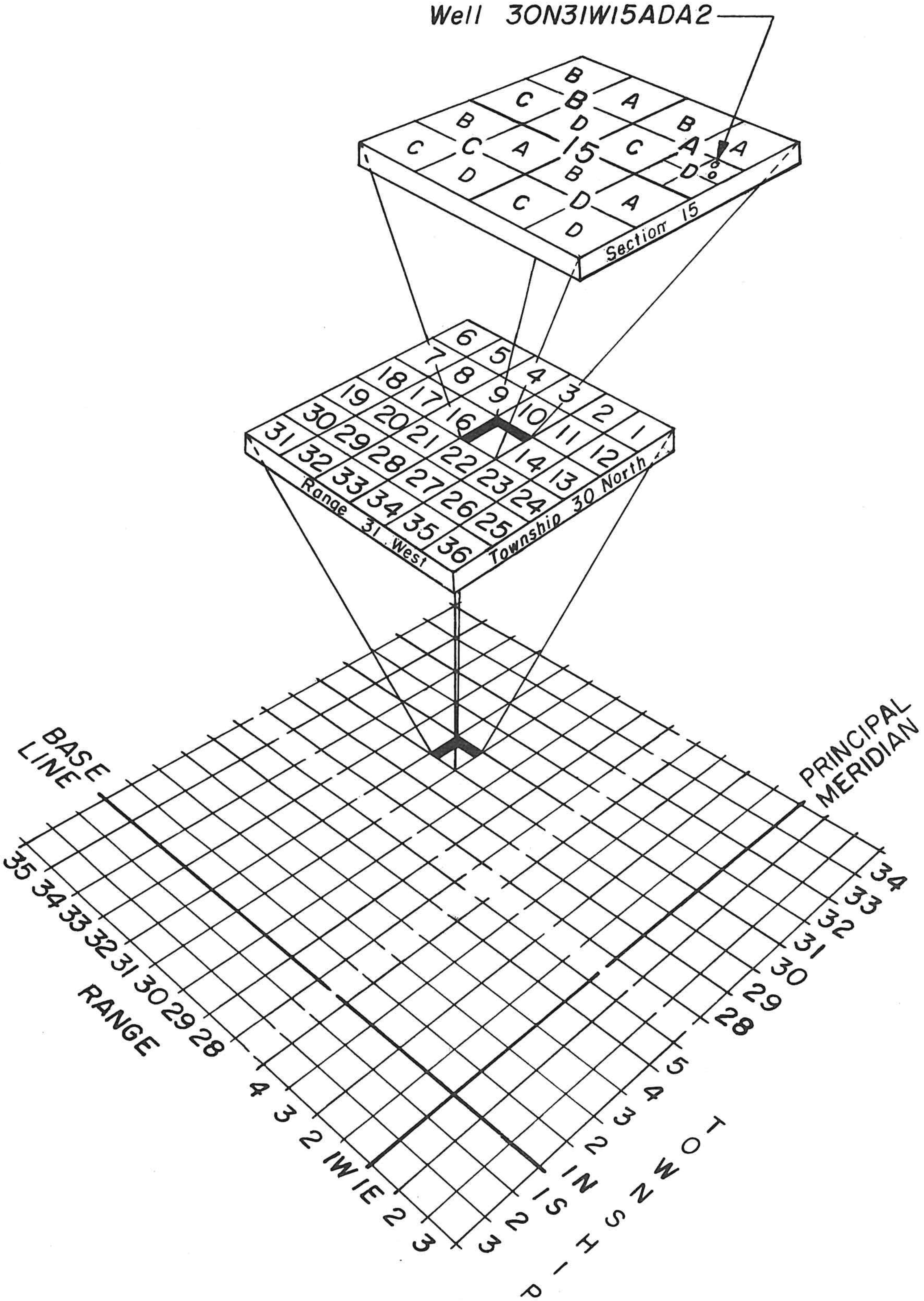

Figure 2.—Diagram showing system of specifying geographic locations

CLIMATE

The climate in the study area is characteristic of the Pacific Northwest—relatively warm dry summers and cloudy humid winters. Temperature and precipitation records have been collected at Libby for more than 60 years. Figure 3 shows the average monthly temperature and precipitation at Libby for 1941-70. Temperature extremes of —38°F and 109°F have been recorded at Libby. The annual precipitation has ranged from 12.04 to 25.56 inches. The average annual precipitation for 1941-70 is 19.4 inches (G. V. Cordell, Jr., National Weather Service, oral commun., April 30, 1974). Forty-seven percent of the precipitation occurs from October through January, and much of this moisture falls as snow. No continuous temperature records are available for the higher altitudes, but annual precipitation in the mountains west of Libby exceeds 100 inches.

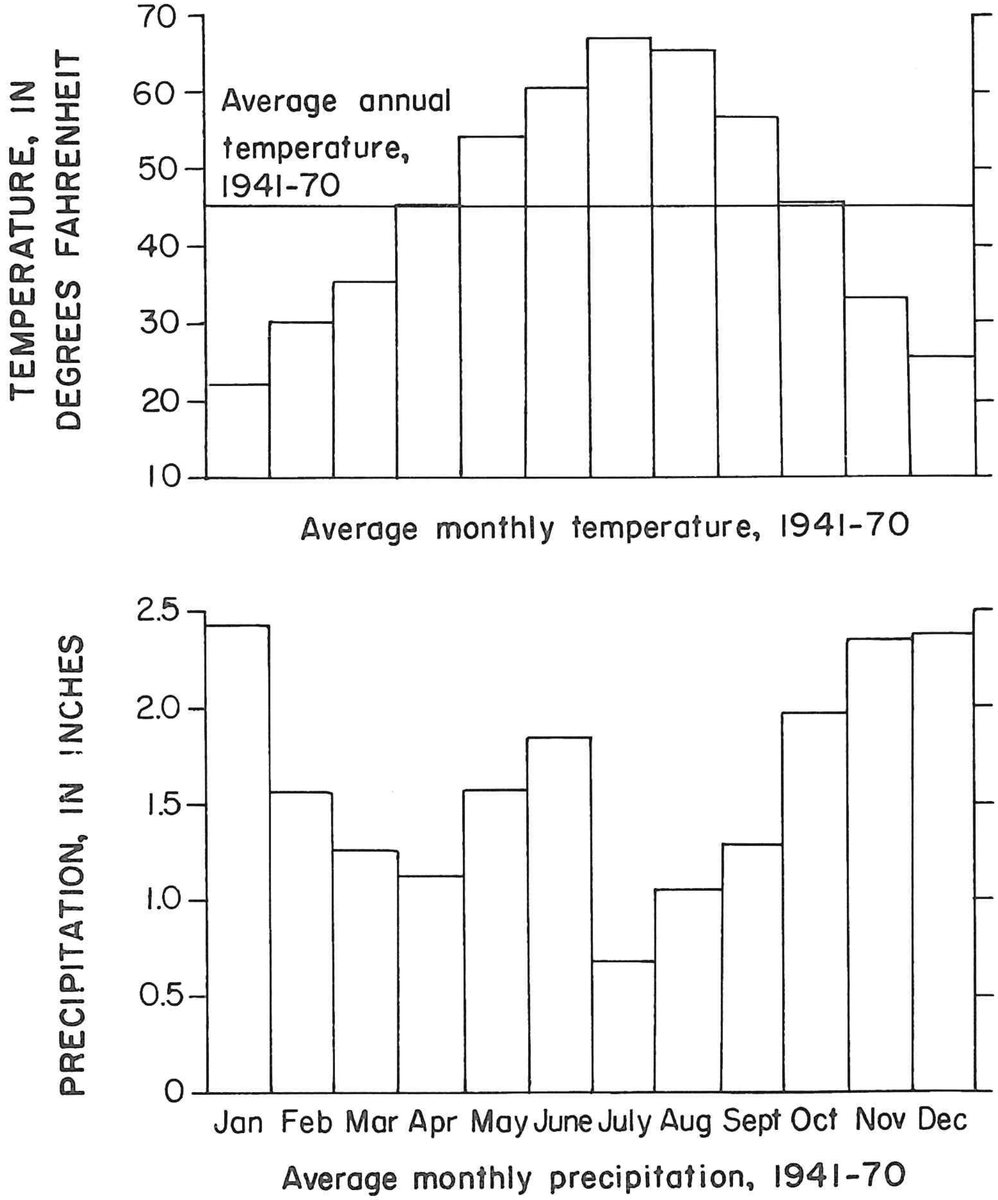

Figure 3.—Average monthly temperature and precipitation at Libby.

QUATERNARY GLACIATION

The mode of deposition of the Quaternary glacial deposits is a key factor to understanding and interpreting the hydrology. During Pleistocene time, the advances and retreats of the Cordilleran ice sheet and local valley glaciers left a complex assortment of glacial deposits in the Libby area. The ice sheet moved southwestward down Pipe and Bobtail Creeks and southward up Libby Creek beyond the project area. The tops of the adjacent mountains were covered. Glacial deposits in the valleys seem to be products of local glaciers, which headed to the southwest in the rugged Cabinet Mountains (Alden, 1953). Later, when the climate began to warm, the glacier advance halted. Gradual thinning of the ice sheet caused exposure of the mountain ridges and segregation of the ice into individual valley lobes (Wright and Frey, 1965).

As the glacier began to melt, water was ponded behind a lobe of ice in the Purcell Trench in Idaho, and glacial Lake Kootenai was formed in the valleys of the Kootenai River and its tributaries. Continued warming caused the lake level to rise above 2,600 feet above sea level. Silt and clay from till deposited by the glaciers were washed into the lake and settled to the bottom, forming lakebed deposits. The water in the lake eventually topped the ice dam; subsequent erosion breached the dam and drained the lake. The Kootenai River and its tributaries eroded the lakebed deposits, leaving terraces along the valleys at about the 2,600-foot altitude.

GEOLOGIC UNITS AND WATER-BEARING CHARACTERISTICS

The geology of the Libby area provides major controls on the movement of ground water. Determination of the type, distribution, and water-bearing characteristics of the rocks is necessary to make quantitative judgments concerning the hydrology.

The surface distribution of the geohydrologic units is shown on Plate 1. A discussion of the lithology and water-bearing properties of the rock units follows. The glossary in the appendix may be consulted for the definitions of geohydrologic terms used in this report.

PRECAMBRIAN ROCKS

The Precambrian rocks of the Belt Supergroup underlie the entire area. These rocks consist of bluish-gray, green, and light-gray argillite; red, purple, and green shale; red sandstone; and dark-gray quartzite. These rocks are estimated to be 20,000 feet thick (Gibson and others, 1941). The Precambrian strata exposed in the Libby area are, in ascending order, the Wallace, Striped Peak, and Libby Formations. These formations are discussed in detail by Gibson, Jenks, and Campbell (1941) and Johns (1970). In this report these formations are collectively called Precambrian rocks.

Structural deformation has produced generally north- to northwest-trending folds, faults, and fracture systems in the Precambrian rocks. Small amounts (5 to 10 gal/min) of water are probably available to wells from the open fractures, but no wells are known to tap the Precambrian rocks; larger quantities of water are available from the overlying alluvium or glacial deposits.

GLACIAL DEPOSITS

The glacial deposits unconformably overlie the Precambrian rocks. Most of the glacial deposits are composed of Precambrian rocks that were broken and crushed, and then deposited as till by the moving ice, but in a few places melt water has deposited sand, gravel, and cobbles. Kame fields are present west of Big Cherry Creek in the southwestern part of the project area.

The glacial deposits are composed of poorly sorted beds of boulders, gravel, sand, silt, and clay; the silt and clay generally form lenses. The thickness of the glacial deposits is estimated to exceed 500 feet in the middle of Libby Creek valley. Few wells have completely penetrated the glacial deposits; thus, variations in thickness are not known.

All wells tapping the glacial deposits obtain adequate quantities of water for domestic use. Most wells produce less than 30 gal/min because the glacial deposits contain a large amount of silt and clay of low permeability.

LAKEBED DEPOSITS

Overlying the glacial deposits are the lakebed deposits of clay, silt, and fine sand. Locally, gravel is found at the top and at the base of the lakebeds. The basal gravel may be a remnant of deposits by glacial streams or a remnant of gravel from the underlying till (Gibson, 1948). Gravel at the top of the lakebeds has washed down from the surrounding glacial deposits. Lakebed deposits underlie the prominent high flat terraces of Libby Creek valley. A 300-foot cliff east of Libby has resulted from downcutting of Libby Creek and the Kootenai River through the lakebed deposits. In places, the lakebeds are more than 350 feet thick.

Lakebed deposits yield little or no water to wells because of their low permeability and because the formation has been extensively drained owing to the downcutting of Libby Creek and the Kootenai River. Wells drilled into the lakebed deposits generally penetrate them completely and obtain water from the underlying glacial deposits.

ALLUVIUM

The alluvium in the creek valleys and the Kootenai River valley consists of relatively well sorted silt, sand, gravel, and cobbles reworked from glacial deposits by streams. Generally, reworking separates the finer from the coarser materials; the coarser materials are deposited in the stream channels and the finer are carried away or deposited along stream edges. The streams have traversed back and forth across the valleys depositing alluvium unevenly on the glacial deposits. Therefore, the alluvium ranges widely in thickness and grain size. The alluvium is estimated from an analysis of well logs to be 100 feet thick locally, but the maximum thickness is not known.

Because of its coarse-grained texture, the alluvium is more permeable than the glacial deposits. Locally, the alluvium yields more than 500 gal/min of water to wells, but yields of less than 100 gal/min are more common. Variable yields are due mainly to the variable thickness of the beds of sand and gravel. Many wells in the Libby Creek valley probably tap both the alluvium and the glacial deposits; both units together are regarded as the major ground-water reservoir.

GROUND WATER

Ground water is an important resource for many of the residents of the Libby area. A reservoir on Flower Creek supplies water to residents living generally within the Libby city limits, but the rest of the residents depend on individual wells, which are estimated to number 1,500 in the project area. An understanding of the ground-water hydrology of the area involves knowledge of the interrelationships of ground-water recharge, movement, and discharge; streamflow; and quality of water. This information is necessary to evaluate the effects of water use by man in the Libby area.

Ground water occurs in the interstices of the rocks within the saturated zone. The water is held in temporary storage within the rocks, and it moves from areas of recharge to areas of natural discharge, such as streams or springs, or to points of artificial discharge, such as wells.

MOVEMENT

The configuration of the water table is shown by lines (contours) connecting points of equal altitude (Pl. 2). The general direction of ground-water movement in the unconsolidated deposits can be determined from the contours. The alluvium and glacial deposits are hydraulically connected and are treated as one aquifer. In aquifers of uniform composition, and where the withdrawals or additions of water are uniformly spaced, ground-water flow paths trend downgradient approximately at right angles to the contours drawn on the potentiometric surface, and the contours are evenly spaced. In the Libby area, however, where the transmissivity of the aquifer varies considerably, the contours are unevenly spaced and the flow may be at an acute angle to the contours as it trends in the direction of greatest transmissivity. In general, the wider the contour spacing the higher the transmissivity. The contours have the greatest spacing in the alluvium along the Kootenai River and near the mouth of Libby Creek; thus, transmissivity is probably highest in these areas.

The general configuration of the water-table contours shown on Plate 2 may be influenced by water levels that are not representative of the regional aquifer. Most of the drilled wells do not have perforated casing and do not fully penetrate the aquifer. Therefore, the water level reflects only the head of the aquifer at the bottom of the well. If the bottom of a well is above a silt or clay lens several hundred square feet in extent, which impedes or confines the downward flow of water, the water level is representative of a perched aquifer and may be higher than the water level in an adjacent well where the casing is perforated below the clay lens and the water level is representative of the regional aquifer. Figure 4 illustrates this effect. Variations of the situation illustrated occur in the project area.

WATER-LEVEL FLUCTUATIONS

The distance between a well and a stream can be an important control on water-level fluctuations in the well. Where the stream and the aquifer are hydraulically connected, wells close to the stream respond rapidly to changes in stream stage. Conversely, the fluctuations in wells distant from the stream lag behind and are smaller than changes in stream stage.

Water levels in wells in the valleys of the Kootenai River, Libby Creek, and Big Cherry Creek respond rapidly to changes in stream stage, as seen by the hydrograph of well 31N31W33CCB (Fig. 5). Well 31N31W33CCB is part of a network of observation wells that was established for periodic measurement of water levels; selected water levels measured during this project are listed in Table 3. Fluctuations in water level in well 31N31W33CCB are representative of fluctuations in water levels in wells in the study area that are less than about 60 feet deep.

Water levels in wells begin to rise in the spring in response to increased stage in the streams as a result of snowmelt runoff. During May and June the stream stages are high from the remaining snowmelt and increased rainfall. Simultaneously, water levels in wells are generally at their highest. The water table generally begins to decline in July when runoff decreases and evaporation and transpiration increase. The largest amount of pumping by wells is during the summer; this pumping also contributes to declining water levels. Water levels generally rise slightly in October or November in response to an increase in precipitation and to lower evapotranspiration rates. The water level generally declines during winter because precipitation is stored as snow and frost and does not reach the water table until melting occurs. Small rises in water levels may occur in winter, however, from recharge due to short periods of thaw.

In January 1974, water levels in wells rose dramatically in response to unseasonal flooding (Johnson and Omang, 1974) along Libby, Big Cherry, Parmenter, and Flower Creeks (Table 2). Water levels in shallow wells nearest the streams showed the greatest response to flooding. The water level in well 31N31W33CCB, which is 40 feet deep, rose 4 feet in three days (Fig. 5).

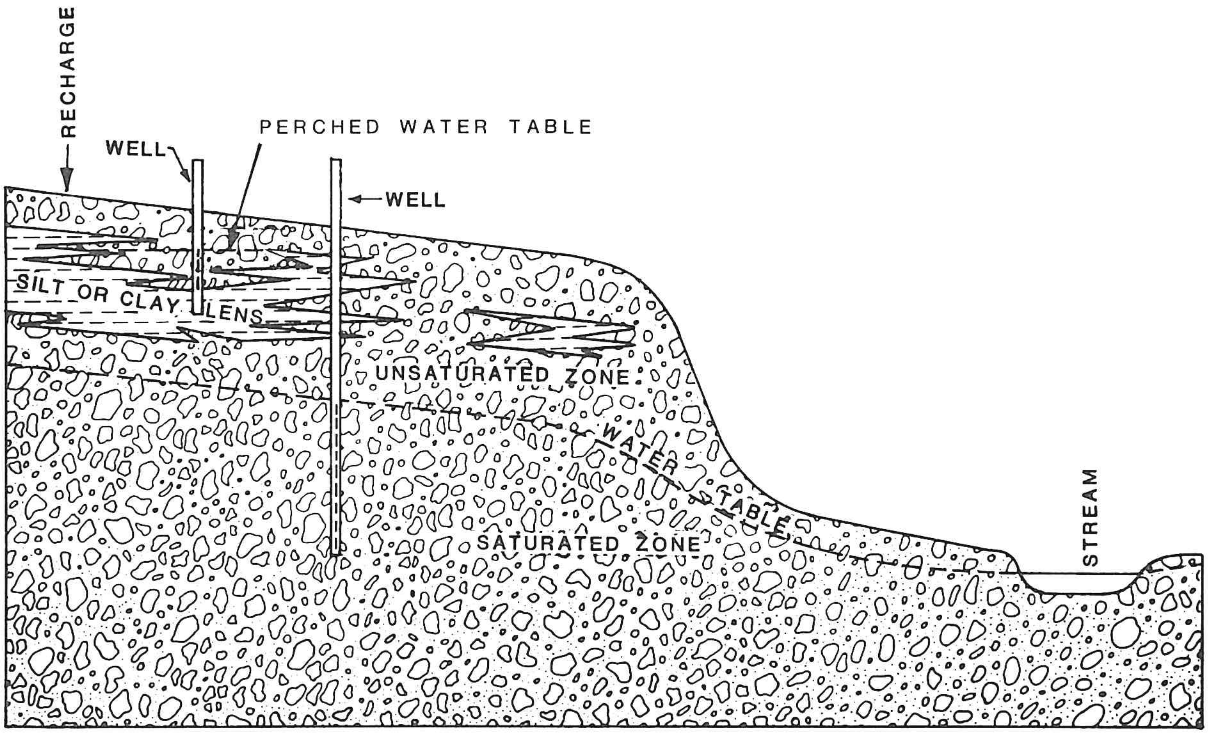

Figure 4.—Diagrammatic section showing the effect of a perched water table on water levels in wells.

Ground-water levels throughout the observation-well network rose an average of about 2.6 feet. Most water levels remained higher than normal for several months after the flood. Only in well 31N31W26BCD, which is 347 feet deep, did water levels not respond to the flooding.

Declines of water levels with time indicate a decrease in the amount of water stored in the aquifer, often the result of pumping by wells. An estimated 1,500 acre-feet of ground water is pumped annually in the project area; probably 65 percent of the total is from the south Libby area. The largest amount of ground water pumped is in the McGrade School area (sec. 25 and 26, T. 30 N., R. 31 W.). Water levels are declining only in a small area around the McGrade School (Pl. 2), where more water is being pumped than is being recharged to the aquifer. In the rest of the area, long-term water levels are constant, indicating that the amount of water in storage is not greatly affected by present amounts of pumping. Therefore, more ground water can be used than is being used, and the increased use would not cause a marked depletion of storage.

AQUIFER CHARACTERISTICS

Aquifer properties can be determined from the results of data collected while pumping from the aquifer. A pumping test was made on well 30N31W25BDB, owned by the South Libby Water and Sewer District, to determine the water-transmitting capacity of the aquifer near Libby Creek. The well was drilled and cased to 198 feet and perforated from 135 to 140 feet below land surface. The well did not completely penetrate the aquifer, and the casing was not perforated opposite all permeable zones of the aquifer.

Figure 5.—Hydrograph of water-level fluctuations in well 31N31W33CCB.

The well was pumped at an average rate of 236 gal/min for 350 minutes, was turned off for 60 minutes, and then was pumped at 330 gal/min for 140 minutes. The recovery of the water level in the pumped well is shown on Figure 6. This test indicates that the aquifer transmissivity is 4,000 ft^2/d. Transmissivity was determined by the Theis recovery method as described by Ferris, Knowles, Brown, and Stallman (1962).

As now constructed, this well could probably yield more than 500 gal/min, but the yield could possibly be doubled if the casing were perforated or screened in all permeable zones throughout the saturated zone. Induced recharge from Libby Creek, about 1,000 feet east of the well, could stabilize the water level during prolonged pumping.

GROUND-WATER SURFACE-WATER RELATIONSHIPS

Water moves freely between the ground-water system and the surface-water system in the Libby area. During May through August the surface-water system is maintained by runoff, whereas from September through April the flow of streams is maintained by ground-water discharge from the Precambrian rocks at the headwaters and from the alluvium and glacial deposits in the project area.

A losing reach of stream is one in which water leaves the stream and enters the aquifer. Losses from the stream could result from ground-water withdrawals near the stream, but they may also occur where the stream flows from a consolidated rock bottom onto a bottom consisting of unconsolidated sand and gravel.

A gaining reach of a stream is one in which water leaves the aquifer and enters the stream. Gaining and losing reaches of a stream can generally be detected by the configuration of a water-table contour (Pl. 2) where it crosses a stream. If the stream is gaining or losing the contours will form a "V" where they cross the stream. If the apex of the "V" points upstream, the stream is gaining; if the apex points downstream, the stream is losing. A reach of a stream that is losing during low-flow conditions may become gaining during periods of high flow.

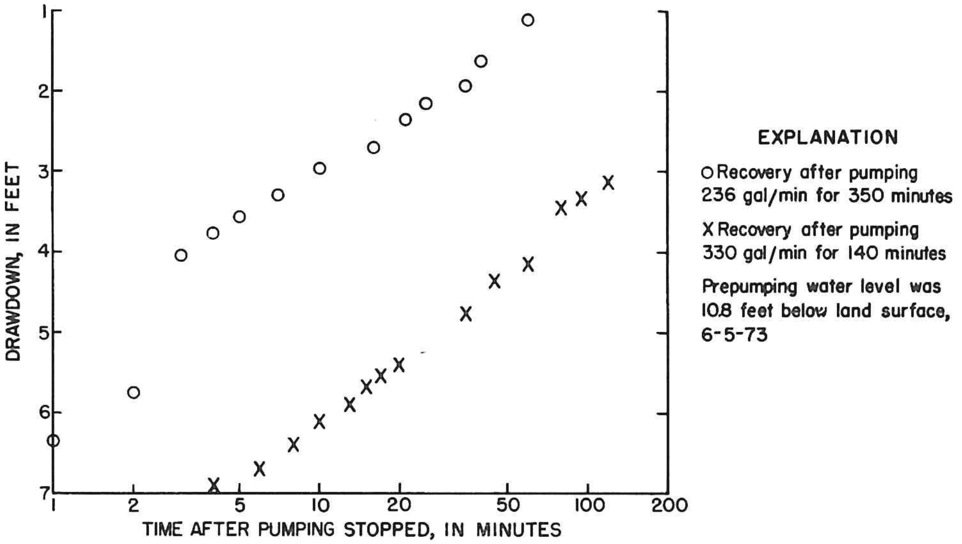

Figure 6.—Graph showing recovery of water level in well 30N31W25BDB.

A low-flow investigation of Libby Creek and all its tributaries in the project area was made September 26 and 27, 1972. During the investigation, air temperatures were cool, plant growth was slow, and little, if any, water was being lost by evapotranspiration. Also, little or no snowmelt occurred in the mountains, and no precipitation contributed to the streams. Therefore, surface flow during this period was from ground water.

Figure 7 shows the location of the measurement sites for the low-flow investigation and the amount of gain or loss at each location. Libby Creek is a gaining stream from the southern project boundary to approximately the Libby Fisheries Station, which corresponds to the northern edge of the outcrop of glacial deposits along Libby Creek (Pl. 1). In the reach underlain by glacial deposits, streams on the east side of the valley cease flowing where they enter the valley. This water infiltrates the glacial deposits, becomes ground water, and subsequently discharges as springs along the creek and into the creek.

Libby Creek is a losing stream from the fish hatchery downstream to the confluence of Swede Gulch. This reach is adjacent to an area of extensive well pumping and an area where the alluvium is wider. Thus, the reach could be losing because of both natural and man-caused factors.

Libby Creek is gaining from Swede Gulch to the confluence with the Kootenai River. Lakebed deposits, which underlie much of the area adjacent to Libby Creek, are less permeable than the alluvium or glacial deposits, allowing relatively less recharge to the aquifer. Some underflow from the alluvium from Big Cherry Creek might also cause part of the gain.

South of the project boundary, the Big Cherry Creek channel is underlain by consolidated rock. Where Big Cherry Creek enters the study area, the stream loses water to the aquifer of alluvium and glacial deposits. Big Cherry Creek is a gaining stream below the confluence of Granite Creek. This is about the location where the stream alluvium is bordered by lakebed deposits. Big Cherry Creek is a losing stream from Prospect Creek to the confluence with Libby Creek, probably owing to ground-water withdrawal and the fact that the alluvium is wider.

RECHARGE AND DISCHARGE

Natural recharge to the ground-water system in the Libby area is from precipitation, streamflow, or underflow from areas outside the project area. Most of the precipitation runs off or is evapotranspired. In the spring the snow melts, which saturates the soil, and some of the water percolates to the ground-water table. Artificial or man-caused recharge results from lawn irrigation or the effluent from sewage systems.

Natural discharge occurs at springs, by evapotranspiration, as underflow from the area, and as flow into streams. Man-caused discharge occurs from pumping wells. Wells withdraw small amounts of water; an estimated half of the pumped water returns to the aquifer through sewage systems or lawn irrigation. Large withdrawals of water from wells south of Libby would decrease streamflow in both Libby and Big Cherry Creeks.

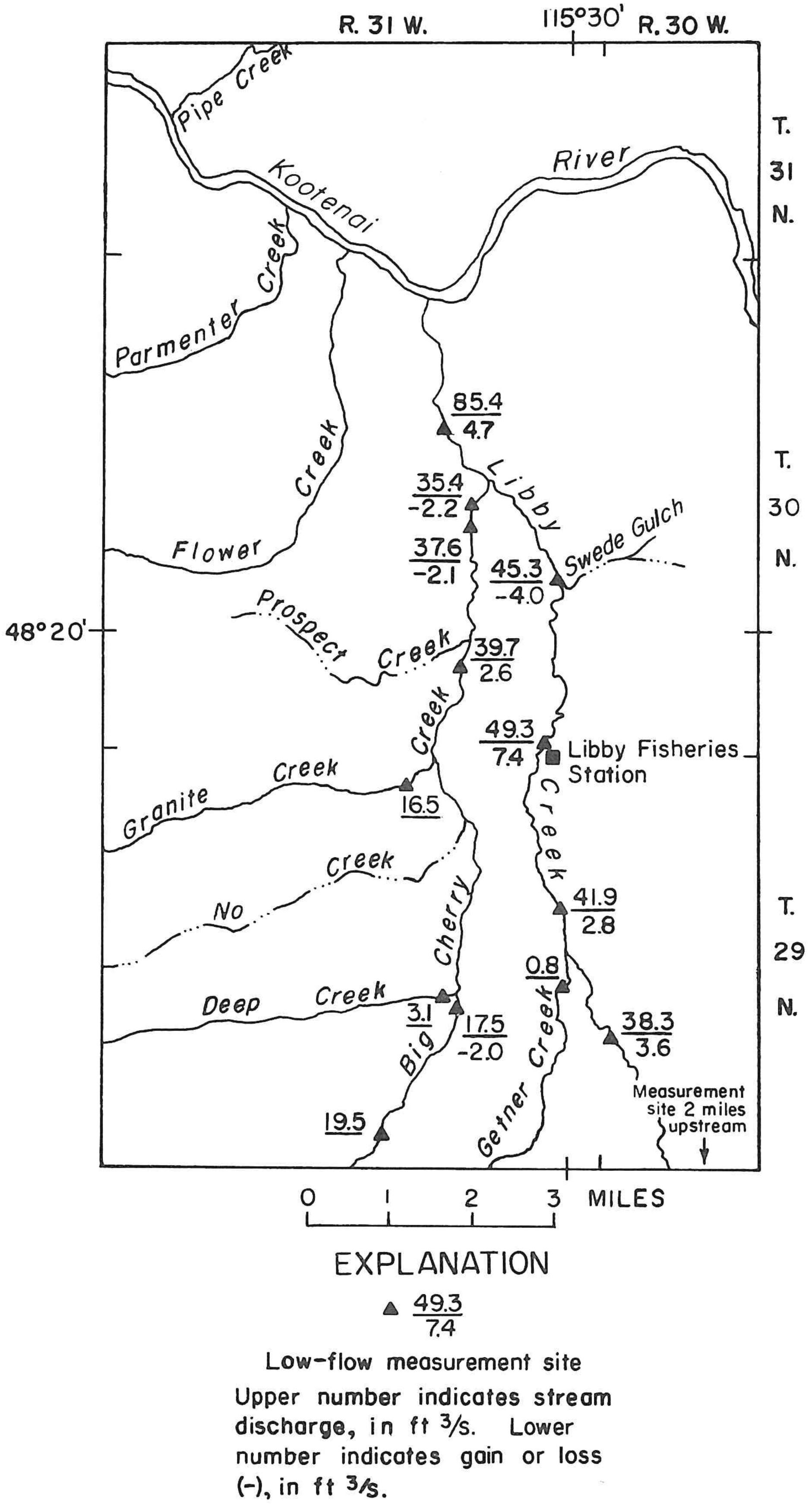

Figure 7.—Map showing location of low-flow-investigation measurement sites.

WELL CONSTRUCTION

Although most wells yield enough water for their intended purpose, greater yields could be obtained by using other than the common well-completion techniques. Well casings in many wells are not perforated; such wells admit water only through the bottom of the casing. Perforating or screening the casing opposite the coarse materials in the saturated zone permits more of the aquifer to be open to the well and generally results in greater yield and efficiency.

Many wells do not fully penetrate the aquifer. The well yield may be adequate but the drawdown is large, resulting in increased pumping cost. By drilling a well to tap as much of the aquifer as possible, maximum well yields are obtained with a minimum drawdown.

Upon completion of drilling and casing, wells should be pumped or bailed to clear the water that is produced. A clear discharge indicates that most of the fine materials have been removed from the aquifer near the perforations and the coarse materials have formed a natural gravel pack adjacent to the casing. If the water does not clear, such methods as intermittent pumping, use of a surge block, or compressed air can be used to remove the fine material and clear the water.

WATER QUALITY

The U.S. Public Health Service (1962) established standards of concentration of chemical substances in drinking water used on interstate carriers and by others subject to federal regulations. Public Health Service limits for substances measured in this study are:

Substance	**Concentration**	
Chloride (Cl)	250	mg/L (milligrams per liter)
Fluoride (F)	1.3[1]	mg/L
Iron (Fe)	300	μg/L (micrograms per liter)
Manganese (Mn)	50	μg/L
Nitrate (NO_3) as NO_3	45	mg/L
Sulfate (SO_4)	250	mg/L
Dissolved solids	500	mg/L

[1] Maximum concentration is based on the annual average maximum daily air temperature for the Libby area.

During 1972 and 1973, 140 water samples were analyzed for several dissolved chemical constiuents to determine the general chemical character of the water. Temperature and specific conductance were measured at the time of collection. The chemical analyses, including 21 analyses for nitrate (as No_3) and phosphate (as PO_4) only, were made by the Montana Bureau of Mines and Geology. Results of these analyses are given in Table 4. Water samples collected from 11 wells (Table 1) after the January 1974 flood were analyzed by the U.S. Geological Survey. Plate 2 shows locations of wells, springs, and stream-sampling sites.

SURFACE WATER

Water-quality data from the Kootenai River at Libby have been collected by the Geological Survey since July 1969 (U. S. Geological Survey, issued annually). From July 1969 to September 1972, the dissolved-solids concentration of monthly samples ranged from 93 to 259 mg/L. Flow in the Kootenai River has been controlled by Libby Dam since March 21, 1972.

Individual water samples from Libby Creek at sites 30N31W3DAA, 30N31W36CDD, and 30N31W36DCB had a dissolved-solids concentration of 80, 83, and 90 mg/L, respectively (Table 4).

GROUND WATER

General chemical character of water

Dissolved-solids concentration of well water in the Libby area (Table 4) ranged from 51 to 370 mg/L and averaged 187 mg/L for August 1972 (21 samples). The dissolved-solids concentration ranged from 32 to 353 mg/L and averaged 171 mg/L for July and August 1973 (73 samples). Calcium, magnesium, and bicarbonate are the major dissolved constituents in the ground water, but some samples contained significant amounts of sodium, nitrate, chloride, and sulfate in addition to the above-mentioned ions.

Manganese concentration in three ground-water samples (Table 4) exceeded drinking-water limits recommended by the U.S. Public Health Service (1962). With that exception, chemical concentrations in all samples were at or below recommended limits.

As the concentration of dissolved constituents in water increases, the specific conductance also increases. In the Libby area, the concentration of dissolved solids in milligrams per liter is about 65 percent of the specific conductance in micromhos. Therefore, field determinations of specific conductance can be related to dissolved solids.

Specific conductance of the ground water collected in 1973 ranged from 53 to 569 micromhos and averaged 282 micromhos. Specific conductance varied greatly within short distances and this variation probably indicated the variable composition of the Quaternary alluvial-glacial aquifer. The few wells drilled into lakebed deposits generally yield water having high specific conductance and corresponding high dissolved-solids concentration, whereas wells drilled into the alluvium of Libby or Flower Creeks generally yield water of lower conductivity. Because very little is known about the variable subsurface geology, water quality cannot be predicted, particularly in the area of the South Libby Water and Sewer District.

Effects of man

The 1963-64 epidemic of infectious hepatitus was generally believed by the residents of Libby to have been the result of contaminated ground water, according to reports received by the Montana Bureau of Mines and Geology (S. L. Groff, oral commun., 1972) and by the Lincoln County Sanitarian (D. E. Marshall, oral commun., 1973). Infectious hepatitus virus or other pathogens can be introduced into ground water from improperly designed sewage-disposal systems, such as "dry wells" used by many homes outside of Libby. A "dry well" is a hole dug about 8 to 10 feet deep and about 16 to 24 inches in diameter and back-filled with gravel. This installation allows sewage effluent to percolate directly into the ground without natural treatment of liquid effluent by the soil in leach fields, as would occur if septic tanks were used. If the depth to water is shallow, the wastes mix directly with the ground water. Realizing the problem of contamination of the ground water by this type of disposal system, the Lincoln County Sanitarian banned the installation of "dry wells" in the Libby area after 1971.

Septic-tank effluent[1] also contains dissolved chemical constituents that could be harmful if consumed. Nitrate, the highest oxidized form of nitrogen, may be toxic to small infants in large concentrations (U.S. Public Health Service, 1962). Nitrate concentrations in natural ground water are generally negligible. Because nitrate is known to occur in large concentrations in septic-tank effluent and can be transported relatively freely through an aquifer, it was used in this study as an indicator of septic-tank effluent and, therefore, indirectly as an indicator of possible contamination of the aquifer by pathogenic organisms.

Another possible source of nitrate in the study area is lawn fertilizer. Because the distribution of lawn fertilizer is similar to that of septic-tank effluent, the occurrence of nitrate indicates the combined effect of septic-tank effluent and lawn fertilizer. In the Libby area, nitrate from lawn fertilizer is probably a minor part of the total nitrate in ground water.

In order to use nitrate as an indicator of septic-tank effluent contamination, some idea of natural background levels of nitrate in ground water had to be obtained. Biesecker, Hofstra, and Hall (1973) used two techniques to define "natural" concentrations of constituents in ground water: (1) analyses of base flow of small streams in areas yet unaffected by man's activities, and (2) frequency-distribution analysis of various constituents.

Although the first technique was not used in this study, available analyses of stream samples collected during base-flow periods were examined. These analyses of Libby Creek and Kootenai River are not representative of natural background conditions, however, because both streams are affected by man's activities. In addition to the effects of logging and mining operations along the streams, the ground-water contribution to base flow is undoubtedly affected by septic-tank effluent. Nitrate concentrations of three water samples from Libby Creek in September 1972 averaged less than 0.1 mg/L. Published records for 11 analyses of samples from the Kootenai River at Libby for the low-flow period October 1969 through January 1972 show that the nitrate concentration averaged 0.1 mg/L. Analyses for the Kootenai River show that substantial amounts of other ionic forms of nitrogen are present at times. These nitrogen forms can eventually be converted to the nitrate ion, thus representing a potentially larger concentration of nitrate.

The second technique used by Biesecker, Hofstra, and Hall (1973) was frequency-distribution analysis. In this approach the median nitrate concentration of all ground-water samples is considered to be a "natural background concentration". Although the median concentration is not the minimum or absolute background level, we believe that it is a reasonable estimate of the natural background concentration.

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[1] Septic tank effluent is used in this report to include leachate from septic tanks, drainfields, and "dry wells" or other types of private sewage-disposal systems.

Most ground-water samples for this study were collected in July or August of 1972 and 1973; some wells sampled in 1972 were resampled in 1973 (Table 4). In samples collected in August 1972, 44 percent (18 of 41) contained less than 1.0 mg/L nitrate, 71 percent (29 of 41) contained less than 3.0 mg/L, and 83 percent (34 of 41) contained less than 10.0 mg/L; the median was 1.5 mg/L. In samples collected in July and August 1973, 48 percent (35 of 73) contained less than 1.0 mg/L, 75 percent (55 of 73) contained less than 3.0 mg/L, and 93 percent (68 of 73) contained less than 10 mg/L; the median was 1.1 mg/L.

Therefore, we judged that nitrate concentrations greater than 1.5 mg/L indicate the presence of septic-tank effluent in ground water. In 1972, nitrate concentrations were greater than 1.5 mg/L in 49 percent of the samples, and in 1973, in 37 percent of the samples. Thirteen of 32 (41 percent) samples having more than 1.5 mg/L nitrate were from wells located within the South Libby Water and Sewer District. Plate 2 shows areas where nitrate concentrations equal or exceed 1.5 mg/L in the ground water. At the time of writing (1975), concentration of nitrate greater than 1.5 mg/L coincides with the high-density rural housing areas. More work is needed to determine whether 1.5 mg/L is a realistic estimate of natural background concentration in the Libby area.

Nitrate concentrations in the ground water vary greatly over short distances. This variability probably is caused in part by the diverse geology of the aquifer. Other factors tending to limit nitrate concentration in unconsolidated-sediment aquifers are the retention of nitrate ions by fine-grained sediments (''screening'' effect) and the dilution of nitrate in the aquifer as it moves away from its source.

During the flood of January 1974, eleven wells in the Libby area were sampled, two of which had not been previously sampled. The water was analyzed for total kjeldahl nitrogen (which is ammonia plus organic nitrogen) and total nitrite plus nitrate (Table 1). Because nitrite concentration is generally negligible in ground water, the total nitrite plus nitrate determination is comparable to other nitrate determinations made during this study. For comparison, 1973 nitrate analyses of the same wells are included in Table 1. Of the nine wells previously sampled, six of the January 1974 nitrate analyses were higher than previous analyses, two were nearly the same, and one was slightly lower. These data are not sufficient to determine whether the effects of flooding (and accompanying rises in ground-water levels) contribute to water-quality degradation in the Libby area, but undoubtedly, flooding increases the potential for microbial as well as chemical contamination.

In conclusion, no direct evidence was found that would show whether or not mircobial contamination of the ground water has occurred in the past or will occur in the future. On the basis of the preceding discussion, however, and in consideration of the areas of high nitrate concentration outlined on Plate 2, there is indirect evidence that pathogens from the septic systems could enter the ground water at these points.

OUTLOOK FOR THE FUTURE

The need for additional hydrologic data both to assist in solving water-related problems in the Libby area and to provide a sound basis for the inclusion of water-related facilities in the growth planning of the community has become apparent as a result of the study. The needs are summarized as follows:

More hydrogeologic data are needed in the south and west Libby areas. Permanently installed test wells drilled to bedrock in these areas would provide information on geology, aquifer permeability, water quality, and water-level changes with time. This information would help community planners answer such questions as—what is the availability of ground water in relation to future needs, where should additional water and (or) sewer facilities be located, and what would be the effects on the system from either or both of these facilities?

Increased development in the area can be accompanied by certain problems. These include well interference, if wells are too closely spaced, and water contamination, if current practices of household sewage disposal are continued. Data in this report provide a basis for evaluating these conditions as they existed during the investigation. Information derived from continuous monitoring of water levels in the observation-well network established during this project (Table 3) and periodic analysis of water-quality samples taken from selected wells and springs (Table 4) would aid planners in making management decisions, such as whether the aquifer should be used for disposal of septic-tank effluent, for water supply only, or for a combination of both.

SUMMARY AND CONCLUSIONS

Ground water is generally available for domestic use throughout the project area. Most wells that tap glacial deposits yield less than 30 gallons per minute. Several wells that tap alluvium yield more than 500 gal/min, but most yield less than 100 gallons per minute. These unconsolidated deposits are the most productive aquifer and the only one capable of large-scale development of ground water in the area.

Water levels in wells in the Libby area rise during the spring in response to runoff from rain and melting snow. The water levels are usually highest in May and June. During the summer, water levels decline because of evapotranspiration and because of pumping from wells. The decline generally ceases and a small rise occurs in October owing to a killing frost, increased precipitation, and reduced pumping. Small rises in water levels may occur in the winter for short periods of snowmelt. Water levels are generally at their lowest prior to spring runoff.

Water-level fluctuations in wells that tap the alluvium and glacial deposits are closely related to fluctuations in the stage of streams and to the distance between the well and the stream. During January 1974, water levels in observation wells throughout the area rose an average of about 2.6 feet in response to flooding along Libby, Big Cherry, Parmenter, and Flower Creeks.

Water moves freely between the ground-water system and the surface-water system in the Libby area. During May through August the surface-water system is maintained by runoff, whereas from September through April the flow of streams is maintained by ground-water discharge from Precambrian rocks at the headwaters of the streams and from the aquifer in the project area. Libby Creek is a gaining stream, except from the fish hatchery downstream to the confluence with Swede Gulch, where it is losing. Big Cherry Creek is a losing stream, except from the confluence with Granite Creek to the confluence with Prospect Creek.

Natural recharge and discharge exceed withdrawals from the ground-water system, which indicates that the system could support more pumping by wells. The water levels in wells would decline as a result of the increased pumping, but they would recover as a result of recharge from spring runoff. Also, additional pumping of the aquifer system could affect the flow in both Libby and Big Cherry Creeks. During late summer and winter, the discharge in these creeks could decline, and parts of some streams could cease flowing.

A network of 15 observation wells has been established during this project for the measurement of water levels, and about two years of record was obtained. Continued monitoring of these wells would provide additional water-level data that could be important to the solution of water-related management problems in the Libby area in the future.

The chemical quality of the ground water is satisfactory for most uses. Dissolved-solids concentration of the water analyzed ranges from 32 to 370 mg/L. Calcium, magnesium, and bicarbonate are the major dissolved constituents in ground water. Locally, nitrate concentrations in the water indicate contamination from septic tanks. At the time of writing (1975), concentrations of nitrate (as NO_3) greater than 1.5 mg/L coincide with the high-density rural housing areas. The dilution in the aquifer and the filtering action of the fine-grained sediments minimize the effects of contamination of the ground-water system. With a few exceptions, for the constituents analyzed, most of the water sampled would not be rejected for public drinking supplies, according to standards of the U.S. Public Health Service (1962).

APPENDIX

GLOSSARY

Aquifer—A formation that contains sufficient saturated permeable material to yield water to wells and springs.

Bailing—Process for removing water and drill cuttings from a well by lowering and raising a bailer. The bailer is a section of pipe with a check valve at the bottom.

Belt Supergroup—A formal name for a thick sequence of Precambrian rock formations.

Discharge—The outflow of water from an aquifer.

Drawdown—The lowering of the water level in a well by withdrawing water from the aquifer.

Evapotranspiration—Water withdrawn from the soil and water surfaces by evaporation and by transpiration from growing plants.

Kame—A glacial deposit occurring as a mound, at least one side of which was in contact with the glacier ice. Kames are diverse in size and shape and are characterized by unusually hummocky (hilly) terraine.

Permeability—A measure of the relative ease with which a porous medium can transmit water under a potential gradient.

Potentiometric surface—A surface that is defined by the levels to which water will rise in tightly cased wells. The water table is a specific potentiometric surface.

Reach—Any length of a river.

Recharge—Water that moves into the aquifer.

Saturated zone—All voids in the formation ideally are filled with water. The water table is the top of the saturated zone.

Specific conductance—A measure of the ability of water to conduct an electrical current; expressed in micromhos per centimeter at 25°C.

Streamflow—The flow that occurs in a natural channel.

Transmissivity—The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Unsaturated zone—The zone in the formation between the land surface and the water table. Perched water bodies may exist within the unsaturated zone.

Table 2.—Records of selected wells and springs.

Depth to water below or above (+) land surface:
R, reported; P, pumping.

Remarks: Y2, reported yield in number of gallons per minute; C, chemical analysis; P126-130, perforated interval in feet below land surface; D, dug well; O, observation well.

Location	Owner or tenant	Year completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet)	Depth to water below or above (+) land surface (feet)	Date of measurement	Temperature (°C)	Remarks
29N30W6BBC	James Judkins	1972	197	6	2500	89.2	8- 4-72	15.0	Y2
29N30W6BCB	James Tolle	1971	68	6	2500	61 R	--	--	Y8
29N30W6BCB2	Fay Tisher	1962	73	4	2480	43.4	8- 4-72	14.5	
29N30W6CBB	H. D. Greenup	1970	96	6	2510	54.2	7-29-73	11.0	C; Y10
29N30W7CCD	Lincoln Co. Airport	1969	157	6	2599	121.1	8- 1-72	11.0	C; Y20
29N30W17BCC	Jerry Kenelty	--	--	--	2680	0	--	14.5	Spring
29N30W18ABC	Leo Beck	1973	190	6	2607	126.1	7-31-73	13.0	Y3
29N30W18ACB	Lusher	1973	200	6	2611	121.0	7-30-73	12.5	C; Y30
29N30W19ABA	Leonard Koskela	1961	100	6	2620	87.7	7- -73	10.0	
29N30W19ABB	Robert Halvorsen	--	206	6	2605	142.5	7-29-73	15.0	
29N30W19ABD	Ed Carothers	1961	232	6	2617	106.7	7-29-73	11.0	Y10
29N30W19ADA	Dennis Tandberg	1970	130	6	2630	51.4	7- -72	13.0	P126-130; Y10
29N30W19ADB	Jack Murer	1969	170	6	2625	128.8	7-29-73	11.0	C
29N30W19BCB	Karl Norvell	1966	12	36	2560	4.0	7- -72	14.0	D
29N30W19BCD	Ray Jellesed	1972	39	6	2575	19.9	7-27-73	15.0	P36-39; Y30
29N30W19BDA	Morigeau	1956	50	6	2590	28.4	7- -72	12.0	
29N30W19BDB	Fred O. Bache	1966	12	4	2558	3.2	7- -72	15.5	C
29N30W19CAB	Don Swartout	1963	5	--	2575	1.8	7-27-73	15.0	D
29N30W19CBD	W. G. Maurer	1959	12	36	2598	10.5	7- -72	15.0	D
29N30W19CCA	Lee Towne	1973	80	6	2605	16.5	7-27-73	--	
29N30W19DBC	Tim Eickman	1972	222	6	2580	39.4	7-27-73	11.5	C; Y3
29N30W30BAA	Henry Anderson	1972	40	6	2622	17.2	7- -72	10.5	Y60
29N31W1BAB	Robert Duff	--	55	6	2390	+ 1	7-28-73	15.0	
29N31W1BAB2	Earl Messick	1969	60	6	2380	+ 1	7-28-73	--	Y3
29N31W1BBD	Gene Thompson	1968	68	6	2400	1.2	8- 1-72	10.0	P38-55; Y2
29N31W1DBB	Fish Hatchery Spring	--	--	--	2432	0	9-27-72	9.0	C; Spring
29N31W2ABD	Clifford Kelley	--	12	36	2480	0	7- -72	10.0	D
29N31W2ACC	Dave Roden	1968	10	--	2520	2.9	7- -72	18.0	C; D
29N31W2BAC	E. L. Hewitt	1965	160	4	2520	112.4	7- -72	15.0	
29N31W2BDB	--	--	--	--	2438	0	7- -72	15.0	Spring

29N31W2BDC	Jack Reed	1966	12	48	2438	3.7	7- -72	19.0	D
29N31W2DDA	Erickson	--	--	--	2515	0	7- -72	14.5	Spring
29N31W2DDB	Ray Keeler	1972	96	6	2550	83.9	7-28-73	20.0	Y15
29N31W2DDB2	Duane Erickson	1972	337	6	2535	118.7	7-26-73	--	C; Y3
29N31W2DDB3	William Wagner	1966	157	6	2540	77.2	7-20-72	13.5	P153-157; Y7
29N31W2DDC	Yakima Food Produce	1973	235	6	2540	108.1	7-26-73	--	
29N31W3BAA	Donald Cripe	1960	12	48	2515	7.5	7- -73	13.0	C; D
29N31W13ABC	Raymond Bache	1958	10	2	2500	6.8	7-28-73	14.0	
29N31W13ACC	Seeley Bache	1943	12	4	2515	5.9	7-28-73	15.0	
29N31W13DAC	Frank Bache	1968	465	8	2525	72.1P	7-28-73	14.5	C
29N31W13DCA	Norman Sorochuk	1972	210	6	2560	105.9P	7-28-73	10.5	Y1
29N31W13DDB	Bruce Hudson	1960	20	2	2545	8.6	7-27-73	13.0	
29N31W13DDB2	Robert Koke	1966	38	6	2540	4.7	7-27-73	--	O
29N31W13DDC	Richard Denison	1962	200	6	2590	28.6	7-19-72	11.5	C
29N31W14BDD	Eugunio Carpio	1964	17	24	2590	3.4	7-27-73	14.0	C; D
29N31W23BBD	Alvin Randall	1970	9	36	2690	4.0	7-27-73	15.0	C; D
29N31W26BAD	Harry Priester	1959	9	48	2820	6.3	7- -73	--	D
30N31W2ABB	Stu Swenson	--	38	6	2065	17.2	7- 5-73	15.0	
30N31W2ACB	Hugh Slausen	1972	98	--	2066	14.4	8- 1-72	13.0	Y20
30N31W2ACC	Virgil Dutton	1965	40	6	2068	11.3	8- 1-72	13.5	P36-40; Y40
30N31W2BAB	Tom Bonde	1971	44	6	2090	28 R	--	13.0	C; Y15
30N31W2BAC	Stu Swenson	1968	62	6	2090	24.1	7- 2-73	14.5	
30N31W2BBA	Robert Luces	1972	43	6	2095	32.6	7- 2-73	12.0	
30N31W2BDB	Tom Adkins	1972	48	6	2077	20.5	7- 2-73	12.0	C
30N31W2CBD	St. Regis Paper Co.	--	4	48	2070	.5	8- -72	14.0	C; D
30N31W3AAB	William McGlumphy	1964	63	6	2105	42.3	8- 4-72	11.5	
30N31W3ABB	T. F. Pacheco	--	92	6	2120	--	--	11.0	C
30N31W3ABB2	T. F. Pacheco	--	96	6	2120	70.8	7-24-73	--	
30N31W3ABC	Mark Schoknecht	1960	97	8	2080	25.7	8- 5-72	17.0	Y300
30N31W3ADB	Hugill	--	28	8	2080	18.3	8- -72	10.0	
30N31W3ADD	Maurice Post	1935	40	4	2080	--	--	14.0	
30N31W3CBA	Lincoln County Library	--	33	6	2078	11.2	9-12-72	--	O
30N31W3DAB	U.S. Geol. Survey	1973	9	1 1/4	2070	5.7	10-12-72	--	O
30N31W3DDB	U.S. Geol. Survey	1973	11	1 1/4	2072	6.3	10-12-72	--	O
30N31W4AAC	First Church Nazerine	1969	39	6	2068	14.1	7- -72	21.0	Y15
30N31W4ACB	T. H. Wells	--	43	4	2085	23.1	8- 5-72	10.0	C
30N31W4ACD	Deshazer	1951	34	2	2077	14.6	7- -72	12.5	
30N31W4BBB	School Dist. No. 4	1960	65	6	2076	7.9	7-13-72	--	
30N31W4CAC	Paul J. Jones	1951	42	4	2096	32.3	8- 5-72	10.5	C
30N31W4CCB	Howard Pape	1955	67	6	2112	51.5	7- -72	11.5	C
30N31W4CDC	Robert Fuller	1954	38	4	2097	30.5	7- -72	11.0	
30N31W4DDB	City of Libby	1971	77	8	2100	31.7	7- -72	--	P67-77; Y70
30N31W8AAD	Roy Orsburn	1962	257	6	2465	254.3	7-30-73	16.0	C
30N31W8ABC	R. Teeple	1972	30	6	2320	4.2	7-31-73	--	P27-30; Y10
30N31W9ADB	Lonny Hansen	1972	50	6	2185	17.7	7- -72	22.5	

Table 2.—Records of selected wells and springs.—Continued

Location	Owner or tenant	Year completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet)	Depth to water below or above (+) land surface (feet)	Date of measurement	Temperature (°C)	Remarks
30N31W9ADD	Leo Osborn	1972	59	6	2185	27.7	7- -72	12.5	C
30N31W9ADD2	James Hurley	1970	14	12	2180	3.3	7- -72	--	D; O
30N31W9ADD3	Fritz Bignali	--	7	4	2195	3.8	7-31-73	15.0	C
30N31W9CAA	Erwin McLaury	1969	250	6	2406	129.9	7-30-73	13.5	Y5
30N31W9CBA	Charles Berget	1972	230	6	2480	209.6	7-30-73	15.0	C
30N31W9CBA2	Johnny McKay	1970	100	4	2460	92.5	7-30-73	11.5	Y6
30N31W9CBB	Leon Hukill	1972	209	6	2465	194 R	--	15.0	P203-209; Y8
30N31W9DBC	Harry Spear	--	30	6	2400	30 R	--	--	D
30N31W9DBD	Ron Leonard	--	24	2	2335	4.1	7-30-73	--	
30N31W10CCC	Robert Pane	--	15	36	2280	4.3	8- 2-72	14.0	D
30N31W10DBB	J. J. Robertson	--	68	6	2120	31.4	8- 1-73	13.0	C
30N31W10DBC	Harold Hatlen	1950	67	6	2130	30.6	7- -72	13.5	C; Y31
30N31W10DCA	Don Bill	1950	82	6	2140	38.0	7- -72	11.5	C; Y33
30N31W14BCB	Fred Thompson	1959	--	--	2144	--	7- -72	15.5	Y30
30N31W14BCC	G. Pomeroy	1961	40	6	2147	17.6	7- -72	9.0	C
30N31W14BCD	Jim Irwin	1964	47	6	2147	18.5	7- -72	9.5	
30N31W14CBB	Otis Moholt	1963	40	6	2155	20.5	7- -72	13.0	P34-40; Y25
30N31W14CBB2	Fay Tisher	1966	113	6	2160	37.5	8- -72	9.5	C
30N31W14CBC	Raymond Munro	1954	30	2	2161	--	--	15.5	Y10
30N31W14CBD	John Boyd	1950	24	4	2160	7.9	7- -72	13.0	
30N31W14CCA	Frank Ramsey	1956	55	6	2180	8.2	7- -72	9.0	Y100
30N31W14CCD	Ida Adams	1965	84	6	2194	9.6	8- 3-72	12.5	C; O
30N31W14CDB	E. Smith	1968	72	--	2183	0 R	--	13.0	Flowing well
30N31W14CDB2	E. Smith	1967	45	--	2184	0 R	--	14.0	Flowing well
30N31W15AAA	Ralph Spencer	1950	84	6	2140	50.6	7- -72	11.0	C; Y20
30N31W15AAD	Meinerd Torpen	1969	165	6	2147	32.4	7- -72	12.0	C; Y10
30N31W15ADA	Wayne Hartman	--	247	6	2150	191.5	8- -72	12.0	
30N31W15ADA2	L. J. Smith	--	95	6	2156	19.8	8- 3-72	9.5	
30N31W15DAA	Church of LDS	1962	580	--	2170	20.2	7-13-72	15.5	Y7
30N31W22AAB	James Hogan	1954	170	4	2406	26.4	8- -72	15.0	C; Y20
30N31W22DDB	Gerald E. Nixon	1955	145	6	2420	31.6	7-26-73	9.5	C
30N31W23ACA	Ralph Bursell	1967	84	6	2215	11.9	7-16-72	12.5	Y15
30N31W23ADA	Wilhelm Darsow	1955	67	6	2208	12.6	7- -72	10.5	C
30N31W23ADD	Lyle Coon	1970	102	6	2211	18.6	7- -72	12.0	C; Y15
30N31W23ADD2	Homer Frazey	--	12	36	2215	7.8	7- -72	15.0	D

30N31W23BAD	Hoofard	1972	55	6	2215	7.8	7- -72	16.0	C
30N31W23CAC	Raymond Schuck	1973	197	6	2405	170.1	7-26-73	15.5	C; P169-190;Y
30N31W23CBB	Joe St. Onye	1968	175	6	2405	153.8	8- -72	10.5	Y10
30N31W23CCB	Robert Orr	1973	7	36	2410	5.4	7-26-73	24.0	D
30N31W23CCC	Leslie Larsen	1970	103	6	2411	85.7	7-26-73	14.0	Y10
30N31W23CCC2	Frank Gill	1972	100	6	2415	78.1	7-26-73	9.5	Y10
30N31W23DAB	R. E. Brown	1963	14	2	2223	11.4	7- -72	13.0	C; Y20
30N31W23DAB2	David Marshall	--	--	--	2226	--	--	11.0	C
30N31W23DAD	Ron Doubek	1950	45	6	2234	15.1	7- -72	14.0	C
30N31W23DBD	Harold Seiward	--	60	4	2233	34.8	7- -72	12.0	
30N31W23DDA	Oberem	1955	46	4	2235	11.7	7- -72	12.5	C
30N31W23DDC	Howard Thompson	1967	117	6	2247	38.6	7- -72	13.0	C
30N31W23DDD	Paul Griffin	1972	100	6	2247	41.0	7- -72	13.0	C
30N31W23DDD2	Donald Hayden	1957	103	6	2247	35.6	7- -72	13.0	C; Y10
30N31W24CAC	Herman Wilkonson	1966	8	24	2220	4.2	8- 4-72	15.0	C; D
30N31W24CAD	Doug Jellesed	--	--	--	2213	0	8- -72	11.0	Spring
30N31W24CBB	Bob Barnes	1969	85	6	2217	4.4	8- 4-72	14.5	
30N31W24CBB2	Simonson	1956	12	36	2220	7.2	7-22-73	--	C; D
30N31W24CBC	W. M. Curnow	--	46	6	2229	9.4	7- -72	10.5	C
30N31W24CBD	Vicks Trailer Court	--	80	24	2222	4.4	8- -72	12.0	D
30N31W24CCA	Don Oberem	1962	93	6	2233	43 R	--	12.0	P87-93; Y8
30N31W24CDB	Dan Brossman	--	15	24	2224	6.2	7- -72	12.0	C; D
30N31W24CDC	Emil Voves	1970	51	6	2238	6.5	7- -72	14.5	C; Y15
30N31W25BBA	Herman Sand	1962	93	6	2252	37.9	7- -72	15.0	C; P87-93;Y10
30N31W25BBC	Donald Johnson	--	75	6	2260	33.7	8- -72	10.0	
30N31W25BBC2	Donald Johnson	--	75	6	2260	13.0	8- 4-72	--	
30N31W25BBC3	Dale Jantz	1963	130	6	2267	67.8	7- -72	12.0	P122-130;Y10
30N31W25BBC4	E. R. Hunt	1966	114	6	2261	90 R	--	11.5	P100-114;Y30
30N31W25BCB	McGrade School	1967	169	8	2272	59.7	11-19-73	12.5	C
30N31W25BCD	Woodie Bowen	1968	137	6	2273	8.7	7- -72	10.0	
30N31W25BDB	S. Libby Water & Sewer District	1973	198	8	2267	9.8	6- 5-73	--	C;O;P135-140; Y330(Measured
30N31W25CAC	Herschel Collier	1967	23	24	2288	8.0	7- -72	14.0	C; D
30N31W25CBB	F. G. Williams	1942	132	6	2300	22 R	--	9.5	
30N31W25CBD	Lloyd Tow	1966	160	6	2305	24 R	--	15.0	Y20
30N31W25CCD	Bill Manahan	1968	100	6	2310	27.8	7-29-73	18.0	
30N31W25CDC	Lawrence Marchant	1952	18	--	2305	12.4	7- -72	11.0	
30N31W25CDD	Dan Goins	--	--	--	2296	0	7- -72	16.5	Spring
30N31W26AAB	Gary Gibson	1956	30	36	2260	7.8	7-17-72	12.0	C; D
30N31W26ADA	Elmer Schmidt	1969	40	6	2272	23.8	7- -72	14.5	C; Y15
30N31W26ADB	Carroll Rice	--	70	6	2278	28.0	7- -72	12.5	
30N31W26ADB2	Shiflett	1964	32	36	2270	14.0	7- -72	12.0	D
30N31W26ADC	Fred Fisher	1964	61	6	2300	41.8	7- -72	13.0	P55-61;Y25
30N31W26ADC2	C. E. Miller	1966	101	6	2310	42.6	8- 1-72	13.0	C;P97-101;Y25
30N31W26ADC3	C. E. Miller	1972	100	6	2310	--	--	10.0	C;P75-85
30N31W26ADD	Merle Milner	1971	125	6	2279	63.5	7-30-73	12.5	

Table 2.—Records of selected wells and springs.—Continued.

Location	Owner or tenant	Year completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet)	Depth to water below or above (+) land surface (feet)	Date of measurement	Temperature (°C)	Remarks
30N31W26CDC	Springer	--	15	--	2333	1.8	8- 1-72	13.5	D
30N31W26DBA	Richard Peltier	1966	159	6	2303	60.5	7-17-72	12.0	P105-108,119-126; Y5
30N31W26DCA	Margaret Eringer	1967	185	6	2405	148.9	7- -72	17.0	P172-185; Y9
30N31W27DAC	Dave Schikora	1964	68	6	2438	32.9	8- -72	11.0	P62-68; Y30
30N31W27DDD	John Lybyer	1958	18	24	2400	3.6	7-25-73	16.0	D
30N31W34BBD	Paul Collier	1966	110	6	2530	80.4	7-25-73	15.0	C;P104-110;Y1
30N31W34CAA	George Gerard	1971	140	6	2480	74.0	7-25-73	10.5	Y4
30N31W34CAB	Robert Spooner	1973	156	6	2497	78.2	7-25-73	14.5	C
30N31W34DBA	General Jones	1966	103	6	2475	65.6	8- -72	13.0	Y10
30N31W34DBB	James Manley	--	280	6	2540	139.8	7-25-73	15.0	
30N31W34DCA	George Powell	1968	23	6	2475	9.4	7-25-73	10.0	C; Y12
30N31W35AAB	Roy Runkle	1965	227	6	2415	122.1	7- -72	12.5	C;P223-227;Y2
30N31W35ABC	Alan Lamey	1971	167	6	2422	105.8	7- -72	12.5	Y9
30N31W35ADC	Lyman's Trailer Court	1965	201	6	2427	117.2	7- -72	11.0	P195-201; Y25
30N31W35ADD	Gary Zajanc	1958	21	36	2415	10.2	7-19-72	13.0	C; D; Y10
30N31W35DBD	Walter Zajanc	1950	150	4	2437	71.3	7- -72	15.0	Y10
30N31W35DCD	Ken Kochler	1962	127	6	2460	107.9	7- -72	12.0	
30N31W36BBA	Paul W. Miller	1954	204	4	2313	48.2	7- -72	10.0	C
30N31W36BBA2	Paul Miller	1964	11	48	2313	9.4	7- -72	--	D; O
30N31W36BBD	F. S. Eggert	1954	138	6	2319	19.9	7-29-73	13.0	
30N31W36BBD2	Paul Thomas	1967	105	6	2328	8.6	7- -72	11.0	Y20
30N31W36BDA	Hal Crill	1970	20	--	2318	5.8	7- -72	11.0	D
30N31W36CAD	C. E. Pierce	--	15	--	2343	9.0	7- -72	11.0	D
30N31W36CDA	Marion Huston	1967	90	6	2342	7.4	7-29-73	12.5	
30N31W36CDB	Frank Feist	1955	9	2	2357	3.6	7-28-73	--	
30N31W36CDB2	Walt Wuest	1973	145	6	2354	25.2	7-28-73	--	C
31N31W2AAC	Francis Sichting	1966	52	6	2640	45.7	8- 1-73	--	O
31N31W2ACA	Andrew Hetle	1945	85	6	2630	29.8	7- 3-73	14.0	
31N31W2ACC	David James	1965	52	6	2610	20.1	7- 5-73	13.0	C
31N31W2BCD	Bob Fitzpatrick	1968	47	6	2615	29.9	7- 6-73	9.5	
31N31W2BDA	George Calkin	1963	38	6	2620	10.4	7- 6-73	8.0	
31N31W2BDA2	Rocky White	1966	45	--	2604	--	--	8.0	
31N31W2BDA3	Philip Miron	1962	36	6	2605	13.0	7- -73	16.0	
31N31W2BDC	Paul Evans	1963	78	6	2615	31.0	7- 3-73	13.0	
31N31W2BDD	Fred Sichting	1959	50	8	2610	24.6	7- 6-73	11.0	

31N31W2BDD2	Dan Snyder	1973	34	4	2610	17.7	7- 3-73	8.0	
31N31W2BDD3	Thomas Miller	1963	40	6	2610	11.4	7- -73	13.5	C
31N31W2CAB	Evans	--	60	6	2602	23.9	7- 6-73	13.5	
31N31W2CAB2	Fred McFalls	1968	45	6	2602	21.2	7- 3-73	9.0	
31N31W2CAB3	Chris Freeman	--	48	6	2600	17.9	7- 6-73	17.0	O
31N31W2CBB	Martin Edwards	1965	50	6	2600	32.0	7- 4-73	11.5	
31N31W2CBD	Miles Briggs	1968	27	6	2580	17 R	--	14.0	
31N31W2CDB	Don Hutton	1965	50	6	2601	--	--	10.0	C
31N31W4BCB	Raymond Johnson	1965	55	6	2658	39.8	7- 4-73	12.0	
31N31W5AAC	F. M. Swanstrom	1972	15	36	2575	7.0	7- -73	15.0	D
31N31W5ABD	Robert Dugger	1972	15	36	2560	8.1	7- -73	14.5	C; D
31N31W5ABD2	W. Hardgrove	1969	15	--	2566	--	--	13.0	
31N31W10BBB	N. Goucher	1967	397	6	2563	359.7	7-31-73	11.0	C
31N31W10CDB	Bernice Iverson	1961	378	6	2540	161.1	7- 4-73	11.5	C
31N31W19DDD	N. V. Day	1970	28	6	2060	--	--	12.5	
31N31W20CCC	Delbert Bowe	1971	45	4	2080	31.1	7- 6-73	15.0	
31N31W20CCC2	Ray Bitterman	1967	38	6	2068	20.7	7- 6-73	13.0	
31N31W20CCD	G. H. Fuhlendorf	--	40	6	2080	33.8	7- 6-73	11.0	
31N31W20CDB	Lance Schelvan	1966	48	4	2105	30.2	7- 6-73	25.0	
31N31W20CDD	Clyde Carpenter	1965	43	6	2084	28.3	7- 7-73	11.5	C; Y10
31N31W26BCC	Perry Brown	--	230	6	2308	--	--	16.0	
31N31W26BCD	Charles Croucher	1973	347	6	2335	254.6	10-17-73	14.5	C; O
31N31W26CAB	Robert Schmasow	1970	280+	--	2332	--	--	13.5	
31N31W26CBA	Gerald Cassidy	1970	65	6	2315	60.2	7- 5-73	13.5	
31N31W26CBA2	James Cosgriff	1972	67	4	2315	59.6	7- 5-73	10.5	
31N31W26CBA3	Gerald Bunton	1971	61	6	2317	60.4	7- 3-73	9.5	C; Y2
31N31W26CBB	Leland Hansen	1965	70	6	2313	63.7	7- 3-73	12.0	C; Y15
31N31W26CBB2	George Taylor	1970	65	4	2314	61.9	7- 5-73	12.0	Y5
31N31W26CBB3	Robert Stickney	1971	65	4	2315	57.7	7- 5-73	17.0	C; Y10
31N31W29AAB	James Erickson	1968	73	6	2120	55.3	8- 5-72	16.0	O; Y12
31N31W29AAC	Dennis Faris	1970	50	6	2079	26.2	7- 8-73	11.5	Y15
31N31W29AAD	William Noble	1967	97	6	2127	66.4	7- 7-73	12.0	
31N31W29ABB	Pete Huchala	1970	75	6	2090	55 R	--	13.0	Y15
31N31W29ABC	L. B. Campbell	--	40	6	2077	17.7	7- 8-73	11.5	
31N31W29ABD	Jack Daggett	1968	40	6	2077	17.6	7- 8-73	10.5	
31N31W29ACC	James Willcut	1969	37	6	2074	6.3	7-21-73	13.0	
31N31W29ACD	Albert Eldridge	1968	40	6	2075	19.9	7- 8-73	9.5	
31N31W29ADB	Harold Shrewseberry	1967	45	6	2078	25.1	7- 8-73	10.0	
31N31W29ADD	George Earl, Jr.	--	100+	6	2125	75.1	7- 7-73	11.0	
31N31W29BAA	Alford Miron	1967	42	6	2083	27.0	7- 7-73	11.5	Y200
31N31W29BAD	Lawrence O'Bleness	--	45	6	2078	24.8	7-21-73	8.5	
31N31W29BBA	Bill Diederick	1971	38	6	2065	17.8	8- 4-72	11.5	Y15
31N31W29BBA2	R. Taubert	1967	28	6	2065	17.3	7- 6-73	14.0	
31N31W29BBC	Robert Burdick	1961	65	6	2080	43.7	7- 9-73	9.5	
31N31W29BBD	Elmer Jones	1969	36	6	2070	22.3	7-21-73	11.5	

Table 2.—Records of selected wells and springs.—Continued.

Location	Owner or tenan	Year completed	Depth of well (feet)	Diameter of well (inches)	Altitude of land surface (feet)	Depth to water below or above (+) land surface (feet)	Date of measurement	Temperature (°C)	Remarks
31N31W29BCC	Jerry Ledum	1968	28	6	2055	14.1	7- 9-73	11.5	Y15
31N31W29BCD	Raymond Enders	1964	61	6	2083	47.1	7- 9-73	9.5	
31N31W29CAB	Lyle Stephens	1964	68	6	2088	53.8	7-12-73	11.5	
31N31W29CAB2	Dan Spencer	1967	65	6	2095	54.6	7- 9-73	12.0	
31N31W29CBA	John Schlecht	1968	66	6	2085	46.7	8- -72	9.5	Y15
31N31W29CBB	Minnie Margo	1966	38	6	2056	15.2	7- 9-73	9.5	
31N31W29CBC	Henry Howe	1972	36	10	2050	14.6	7- 9-73	--	O; Y100
31N31W29CBD	Carl Robbe	1971	25	--	2056	16.7	7- 9-73	--	D
31N31W29CBD2	Carl Robbe	1965	35	6	2040	--	--	15.0	
31N31W29CBD3	Wendell Magee	1968	30	6	2080	22.0	7- 9-73	--	Y12
31N31W29CBD4	Henry Howe	1966	66	6	2088	51.0	7- 9-73	10.0	C; O; Y30
31N31W29CCA	Wendell Magee	--	46	6	2080	31.2	7- 9-73	9.0	C; Y25
31N31W29CCA2	Bruce May	1968	30	6	2050	22.4	7- 9-73	10.5	C
31N31W29CDA	James Hopkins	1972	64	6	2085	42.2	7- 8-73	11.0	
31N31W29CDB	Walter Shriner	1966	42	6	2080	36.8	7- 8-73	13.5	
31N31W29CDB2	Thomas Creighton	--	49	6	2069	34.0	7- 9-73	12.5	
31N31W29CDD	Charles Westlund	--	44	6	2075	36.3	7- 9-73	11.0	
31N31W29DAA	Ed Benoit	--	70	36	2100	35.1	7- 7-73	11.5	D
31N31W29DAB	D. A. Brown	1967	40	6	2070	17.0	8- 5-73	8.5	
31N31W29DAC	Carl M. Lundstrom	--	45	4	2078	16.3	7- 8-73	11.5	
31N31W29DAD	Don Quinn	1968	100	6	2122	88.4	7- 7-73	10.0	
31N31W29DBA	Richard Johnson	--	25	4	2073	17.3	7- 8-73	10.5	
31N31W29DBB	Charles Hammill	1968	57	6	2085	43.4	7-21-73	11.5	
31N31W29DBC	Michael Quinn	1965	62	4	2090	44.2	7- 8-73	10.0	
31N31W29DCA	Marjorie Swanson	1961	65	6	2084	33.5	7- 8-73	14.0	
31N31W29DCC	William Douglas	--	58	6	2083	41.7	7-21-73	14.0	
31N31W29DDA	John Luger	1960	65	6	2100	47.1	7- -73	12.0	
31N31W29DDB	Luther Krupp	1966	38	6	2080	25.7	7- 8-73	11.0	
31N31W29DDB2	Arthur Schauer	1964	40	6	2075	19.2	7- 8-73	13.5	C
31N31W29DDC	Arthur Rose	1958	30	4	2070	20.4	7- 8-73	11.5	
31N31W29DDC2	Unknown	--	--	--	2060	--	--	6.5	C; Spring
31N31W29DDD	Dean Crabtree	1968	90	6	2116	69.1	8- -72	11.0	Y10
31N31W30AAC	George Elletson	--	10	18	2038	7.8	7- 7-73	9.5	C; D
31N31W32ABB	Murry Crabtree	1964	52	6	2063	17 R	--	10.5	C
31N31W32ABC	H. C. Burrell	1968	33	6	2040	16.4	7- -72	14.0	C; Y12

31N31W32BDB	Elaine Powers Salon	1971	28	6	2055	13.3	7- -72	13.5	C
31N31W32DCA	Mylo Hansen	1964	35	2	2064	8.6	7- -72	11.0	
31N31W32DDA	Charles Mercer	1957	45	6	2067	11.9	7-13-72	13.0	C; Y7
31N31W33ACC	Harvey Noble	1945	25	48	2050	13.9	8- 5-72	12.0	C; D; Y10
31N31W33BBA	Tom Bitterman	1967	104	6	2120	83.3	7-21-73	12.0	Y15
31N31W33BDA	R. D. Mackenzie	1955	123	6	2140	113.6	7-21-73	15.0	C; Y70
31N31W33CBB	Charles Lundin	1958	35	6	2050	30 R	--	--	Y500
31N31W33CBC	Glen Stokound	1967	60	6	2057	9.8	8- 3-72	9.5	C
31N31W33CCB	Bill Lake	--	40	6	2059	9.9	9- -72	--	O
31N31W33DCC	R. T. Roberts	1960	30	2	2061	10.8	7- -72	14.5	C
31N31W33DCC2	R. T. Roberts	1966	33	2	2060	4.6	7- -72	--	
31N31W33DCC3	R. T. Roberts	1968	28	2	2060	10.5	7-13-72	--	O
31N31W33DCD	Al Grambauer	1960	28	2	2062	--	--	11.0	Y70
31N31W34BCC	Harold Hodges	1962	95	6	2120	78.4	7- 3-73	11.0	Y9
31N31W34CBA	Harold Dow	--	80	6	2125	73.8	7- 3-73	15.0	
31N31W34CCA	H. Remp	1961	150	6	2160	120 R	--	11.0	
31N31W34CCB	N. Woodward	1967	142	6	2164	123.2	7-24-73	10.5	
31N31W34DAD	U.S. Forest Service	1958	129	8	2160	102 R	--	15.0	Y10
31N31W35AAC	Rick Brabec	1967	270	6	2220	167.8	7- 2-73	12.0	
31N31W35AAD	Donna Roberts	1964	100	6	2150	84.7	7-24-73	13.0	
31N31W35AAD2	C. Collinson	1971	101	6	2140	89.3	7-24-73	15.0	Y15
31N31W35BDC	Lloyd Bache	--	--	--	2198	0	7- 2-73	10.5	Spring
31N31W35CAC	Robert L. Brown	1973	57	6	2095	36.9	7- 5-73	--	Y25
31N31W35CBC	Eickman & Johnston	1971	95	8	2120	50 R	--	15.0	Y33
31N31W35CBC2	Seventh Day Adventist Ch.	1973	70	6	2116	45.6	7- 5-73	--	Y15
31N31W35DBC	Bill Crismore	1972	51	6	2089	34.9	7- 2-72	13.0	C; Y90
31N31W36BBA	Don Erickson	1962	91	6	2148	--	--	11.0	
31N31W36BBB	Leroy Lykins	1965	135	6	2155	71.9	7- 2-73	11.5	
31N31W36BBC	C. Peterson	1960	95	8	2150	79.7	7- 2-73	14.5	
31N31W36BCB	Ruth Foster	1958	40	6	2070	9.5	7- 3-73	12.5	C

Table 3.—Selected water-level measurements in observation wells.
(in feet below land surface)

Date	Depth to water
30N31W3CBA	
9-12-72	11.2
10-12-72	12.1
11-21-72	12.2
12-12-72	13.5
3-07-73	13.7
4-18-73	12.2
7-01-73	12.3
8-01-73	12.9
9-06-73	13.9
10-17-73	14.5
11-20-73	12.5
1-22-74	7.1
4-10-74	9.4
5-15-74	9.2
30N31W3DAB	
10-12-72	5.7
11-21-72	6.5
12-12-72	8.7
1-31-73	8.9
4-18-73	8.5
7-11-73	8.5
8-01-73	8.7
9-06-73	7.2
10-17-73	8.7
11-20-73	8.6
1-22-74	6.2
4-10-74	6.2
5-15-74	5.9
30N31W3DDB	
10-12-72	6.3
11-21-72	6.5
12-12-72	6.8
1-31-73	6.9
4-18-73	6.7
7-11-73	6.9
8-01-73	6.8
9-06-73	6.9
10-17-73	7.7
11-20-73	6.7
1-22-74	5.1
4-10-74	5.4
5-15-74	5.4
30N31W9ADD2	
7-13-72	3.3
9-12-72	3.6
11-21-72	2.9
7-01-73	3.5
8-01-73	4.4
10-17-73	4.2
11-20-73	3.9
1-22-74	3.5
4-09-74	3.8
5-15-74	3.7
30N31W14CCD	
8-03-72	9.6
9-12-72	9.4
11-21-72	9.0
4-18-73	8.4
7-01-73	10.1
8-01-73	11.7
9-07-73	10.4
10-17-73	9.9
11-20-73	9.3
1-22-74	5.6
4-09-74	5.0
5-15-74	7.0
30N31W25BDB	
6-05-73	9.8
10-15-73	8.5
11-20-73	8.3
1-22-74	5.6
4-09-74	6.2
5-15-74	7.1
30N31W36BBA2	
7-13-72	9.4
9-12-72	9.5
7-01-73	9.4
8-01-73	9.9
9-07-73	9.7
10-17-73	9.5
11-20-73	9.4
1-22-74	6.8
4-09-74	9.5
5-15-74	9.0

Table 3.—Continued

Date	Depth to water
31N31W2AAC	
8-01-73	45.7
9-06-73	46.5
10-17-73	47.4
11-20-73	47.8
4-10-74	23.3
5-16-74	21.3
31N31W2CAB2	
7-06-73	17.9
8-01-73	19.4
9-06-73	21.4
10-17-73	23.4
11-20-73	23.1
1-21-74	15.4
4-10-74	11.7
5-16-74	11.6
31N31W26BCD	
8-01-73	254.8
9-06-73	256.0
10-17-73	254.6
11-20-73	254.1
4-10-74	254.2
5-16-74	253.8
31N31W29AAB	
8-05-72	55.3
8-01-73	56.5
9-06-73	56.0
10-17-73	56.0
11-20-73	59.3
1-21-74	57.5
4-10-74	56.7
5-16-74	53.9
31N31W29CBC	
7-09-72	14.6
10-17-73	12.6
11-20-73	13.1
1-21-74	11.4
4-10-74	11.8
5-16-74	10.9
31N31W29CBD4	
7-09-73	51.0
8-02-73	51.4
9-06-73	49.8
10-11-73	50.2
11-20-73	50.4
1-21-74	49.0
4-10-74	49.1
5-16-74	50.7
31N31W33CCB	
10-12-72	9.2
11-21-72	10.5
12-12-72	12.3
1-31-73	13.4
3-07-73	13.0
7-01-73	10.6
8-01-73	11.6
9-06-73	12.2
11-20-73	11.4
1-21-74	8.4
4-10-74	9.2
5-16-74	8.8
31N31W33DCC3	
7-13-72	10.5
9-12-72	12.3
10-12-72	11.2
11-21-72	12.1
12-12-72	14.2
1-31-73	15.4
3-07-73	14.1
4-18-73	12.4
6-05-73	11.3
7-01-73	11.5
8-01-73	13.5
9-06-73	15.0
10-17-73	15.7
11-20-73	13.2
1-22-74	8.3
4-10-74	9.7
5-15-74	9.5

Table 4.—Chemical analyses of water from selected wells, springs, and streams.

[Analyses by Montana Bureau of Mines and Geology.
Constituents are dissolved and in milligrams per liter, except as indicated.]

Location	Depth of well (feet)	Date of collection	Silica (SiO2)	Iron, total (Fe) (µg/L)	Manganese (Mn) (µg/L)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Hydroxide (OH)
29N30W6CBB	96	7-29-73	19	30	0	46	24	7.1	1.3	240	11	0
29N30W7CCD	157	8- 2-73	10	0	0	33	13	2.9	.7	150	6	0
29N30W18ACB	200	8- 2-73	16	0	20	46	19	5.9	1.1	200	17	0
29N30W19ADB	170	7-29-73	14	0	10	38	20	7.0	1.9	220	0	0
29N30W19BDB	12	8-31-72	9.0	20	0	16	6.8	1.6	.4	81	0	0
		7- 9-73	8.1	0	0	14	4.7	1.2	.5	65	0	0
29N30W19DBC	222	7-27-73	16	0	0	37	20	5.2	.7	220	0	0
29N31W2ACC	10	8-31-72	40	20	10	81	32	4.8	3.0	410	0	0
		7- 5-73	32	0	0	36	34	4.6	3.1	260	8	0
29N31W2DDB2	337	7-26-73	17	0	30	12	6.2	17	.6	99	0	0
29N31W3BAA	12	7-25-73	26	0	0	13	4.8	4.8	1.3	59	0	0
29N31W13DAC	465	7-28-73	19	0	0	23	15	29	1.2	170	13	0
29N31W13DDC	200	8-31-72	28	0	0	18	14	28	.6	180	9	0
29N31W14BDD	17	7-27-73	4.7	0	0	6.3	2.5	.7	.3	31	0	0
29N31W23BBD	9	7-27-73	14	0	280	12	3.8	4.9	1.7	65	0	0
30N31W2BAB	44	7-12-73	12	0	0	39	14	6.1	1.6	180	0	0
30N31W2BDB	48	7-12-73	12	0	0	65	20	9.4	1.6	230	19	0
30N31W2CBD	4	8-29-72	13	20	0	48	21	13	1.6	260	0	0
		7- 9-73	12	0	0	46	19	12	1.6	210	21	0
30N31W3ABB	92	7-24-73	15	0	10	67	22	9.3	2.4	260	18	0
30N31W4ACB	43	8-29-72	--	--	--	--	--	--	--	--	--	-
		7- 5-73	9.6	0	0	34	8.3	3.5	.9	150	0	0
30N31W4CAC	42	8-29-72	--	--	--	--	--	--	--	--	--	-
		7- 9-73	9.6	0	0	18	5.5	2.2	.9	84	0	0
30N31W4CCB	67	8-29-72	13	30	0	33	11	5.0	1.2	150	0	0
		6- 5-73	11	0	0	30	9.5	5.1	1.1	110	12	0
		7- 9-73	11	0	0	29	11	4.4	1.1	130	4	0
30N31W8AAD	257	8- 2-73	16	0	0	29	16	7.2	1.4	180	0	0
30N31W9ADD	59	8-29-72	9.0	30	0	9.0	4.1	1.4	.6	43	0	0
		7- 9-73	8.3	200	10	9.1	3.7	1.3	.6	46	0	0
30N31W9ADD3	7	8- 2-73	8.1	130	10	9.2	2.8	1.1	.7	41	0	0
30N31W9CBA	230	7-30-73	15	0	0	58	38	13	2.2	390	0	0
30N31W10DBB	68	8- 1-73	11	0	0	62	40	12	4.3	360	22	0
30N31W10DBC	67	8-29-72	--	--	--	--	--	--	--	--	--	--
		6- 6-73	22	0	0	34	35	21	4.3	250	0	0
		7- 5-73	21	0	0	56	34	19	4.1	300	7	0
30N31W10DCA	82	8-30-72	23	60	0	51	25	12	1.8	280	0	0
		7- 5-73	22	0	0	47	22	11	1.9	260	0	0
30N31W14BCC	40	8-30-72	--	--	--	--	--	--	--	--	--	--
		7- 5-73	23	0	0	31	12	11	1.8	160	8	0
30N31W14CBB2	113	8-30-72	17	50	10	37	15	9.5	1.6	200	0	0
		7- 5-73	17	0	10	37	14	8.6	1.8	180	7	0
30N31W14CCD	84	8-30-72	24	20	0	33	13	12	1.5	180	0	0
30N31W15AAA	84	8-30-72	--	--	--	--	--	--	--	--	--	--
30N31W15AAD	165	8-30-72	--	--	--	--	--	--	--	--	--	--
30N31W22AAB	170	8- 2-73	18	0	10	47	23	7.9	1.9	250	11	0
30N31W22DDB	145	7-26-73	8.9	0	20	21	7.1	7.6	1.6	100	4	0
30N31W23ADA	67	8-30-72	--	--	--	--	--	--	--	--	--	--
30N31W23ADD	102	8-30-72	19	50	0	28	11	9.8	1.1	150	0	0
		7-12-73	18	0	0	27	12	8.3	1.2	160	0	0
30N31W23BAD	55	8-30-72	21	20	10	58	21	17	1.5	300	0	0
		6- 6-73	20	0	10	55	12	14	1.6	230	12	0
30N31W23CAC	197	7-26-73	22	0	20	47	12	25	1.9	230	12	0
30N31W23DAB	14	8-30-72	--	--	--	--	--	--	--	--	--	--
		3- 8-73	14	0	0	15	4.0	10	1.4	32	0	0
		7- 5-73	12	0	0	14	4.6	10	1.6	40	0	0
30N31W23DAB2	--	3- 8-73	17	0	0	12	3.7	3.4	1.2	54	0	0
30N31W23DAD	45	8-30-72	15	50	0	14	4.4	4.9	1.0	44	0	0
		7- 9-73	15	0	0	16	5.4	6.7	1.4	41	0	0
30N31W23DDA	46	8-30-72	--	--	--	--	--	--	--	--	--	--
		7- 5-73	12	0	0	16	5.5	9.6	2.1	67	0	0
30N31W23DDC	117	8-30-72	19	30	0	11	3.8	3.6	1.1	58	0	0
		7- 2-73	17	0	0	12	3.9	3.3	1.1	54	0	0
30N31W23DDD	100	8-30-72	--	--	--	--	--	--	--	--	--	--
30N31W23DDD2	103	8- 2-73	16	0	0	14	5.8	5.0	1.4	64	0	0
30N31W24CAC	8	8-30-72	11	50	0	22	8.8	2.6	.6	110	0	0
30N31W24CBB2	12	8-31-72	--	--	--	--	--	--	--	--	--	--
		7- 2-73	10	0	200	19	6.8	8.3	3.1	93	0	0
		8- 2-73	13	0	50	26	9.8	11	3.6	120	8	0
30N31W24CBC	46	8- 2-73	14	0	0	15	5.5	5.9	1.6	65	0	0
30N31W24CDB	15	8- 2-73	9.0	0	0	20	8.7	2.8	.6	110	0	0
30N31W24CDC	51	8-31-72	--	--	--	--	--	--	--	--	--	--
30N31W25BBA	93	8-31-72	15	20	0	36	14	10	1.4	170	0	0
		7- 5-73	12	0	0	42	16	8.3	1.7	180	11	0

Alkalinity as $CaCO_3$, total[3]	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids[1]	Hardness as $CaCO_3$		Sodium adsorption ratio	Specific conductance (µmhos/cm at 25°C)	pH (units)	Temperature (°C)
							Carbonate	Noncarbonate				
220	11	1.0	0.0	1.0	--	236	210	0	0.2	392	8.4	11.0
130	5.1	.4	.0	.2	--	150	140	0	.1	252	8.4	15.0
190	8.5	.9	.0	1.1	--	216	190	0	.2	352	8.6	12.5
180	7.7	.4	.0	.0	--	192	170	0	.2	340	7.4	11.0
67	3.9	.0	.0	10	0.03	89	67	2	.1	133	7.9	17.5
53	2.6	.3	.0	.1	--	63	53	1	.1	113	7.5	16.0
180	5.6	.5	.0	.1	--	190	180	0	.2	327	8.3	11.5
340	5.4	1.3	.1	.9	.06	370	330	0	.1	581	8.1	19.0
230	9.0	3.5	.0	.0	--	264	230	0	.1	400	8.4	14.5
81	4.2	.6	.0	.0	--	127	56	0	1.0	158	8.2	16.5
48	9.7	1.0	.0	1.9	--	91	48	4	.3	125	8.0	13.0
160	19	.7	.9	.7	--	204	120	0	1.1	321	8.6	14.5
160	2.3	1.0	.3	.1	--	185	100	0	1.2	--	8.6	16.0
25	2.2	.6	.0	.0	--	32	25	1	.1	53	6.9	14.0
53	.8	1.6	.0	.7	--	71	46	0	.3	108	6.8	15.0
150	19	4.4	.0	3.1	--	185	140	10	.2	305	8.1	9.0
220	30	5.3	.0	5.8	--	282	240	0	.3	439	8.8	9.5
210	19	.9	.0	.8	.06	245	200	0	.4	404	8.1	16.5
210	15	.6	.0	.0	--	227	190	0	.4	377	8.7	12.5
240	15	9.2	.0	4.3	--	287	260	0	.3	486	8.4	11.0
--	--	--	--	4.4	.08	--	--	--	--	--	--	11.0
120	6.7	.9	.0	1.5	--	137	120	0	.1	242	7.9	10.5
--	--	--	--	2.2	.03	--	--	--	--	--	--	10.5
69	4.5	.8	.0	.7	--	83	68	0	.1	146	7.6	11.5
120	12	1.0	.0	2.6	.06	154	120	2	.2	249	8.0	13.5
110	8.2	1.9	.0	1.4	--	134	110	0	.2	225	8.4	8.5
110	8.3	.7	.0	1.2	--	135	120	0	.2	269	8.4	9.5
150	6.2	.3	.2	.8	--	166	140	0	.3	282	8.1	15.5
35	3.4	.3	.0	2.2	.14	51	35	4	.1	80	7.0	11.0
38	2.1	.3	.0	.3	--	49	38	0	.1	81	7.5	11.0
34	2.2	.3	.0	.2	--	45	34	0	.1	73	6.9	15.0
320	11	1.2	.1	.2	--	330	300	0	.3	560	7.8	11.5
330	8.2	4.7	.2	2.8	--	341	320	0	.3	562	8.7	13.0
--	--	--	--	18	.12	--	--	--	--	--	--	15.0
210	19	24	.0	21	--	305	210	22	.6	505	8.2	11.0
260	24	23	.0	19	--	353	270	9	.5	569	8.4	13.5
230	11	5.0	.0	11	.06	275	230	1	.3	433	7.9	9.5
210	10	4.9	.0	5.1	--	256	210	0	.3	428	8.2	14.0
--	--	--	--	.3	.08	--	--	--	--	--	--	9.5
140	6.0	.4	.1	.5	--	175	130	0	.4	275	8.4	11.5
160	11	1.0	.1	.3	.09	191	160	0	.3	303	7.9	11.0
160	4.2	.7	.1	.0	--	184	150	0	.3	304	8.4	9.0
150	13	.5	.0	.3	.09	192	140	0	.5	270	8.1	14.5
--	--	--	--	.3	.06	--	--	--	--	--	--	14.5
--	--	--	--	.7	.14	--	--	--	--	--	--	14.0
220	3.5	.4	.2	.2	--	237	210	0	.2	392	8.5	12.0
89	1.7	.4	.2	.0	--	104	81	0	.4	177	8.3	9.5
--	--	--	--	.3	.22	--	--	--	--	--	--	18.5
120	11	1.0	.1	.8	.12	160	120	0	.4	239	7.9	12.5
130	5.8	.7	.2	1.1	--	147	120	0	.3	249	8.2	11.5
250	20	1.1	.2	.3	.08	288	230	0	.5	429	8.0	15.0
210	8.8	2.4	.2	.7	--	239	190	0	.5	398	8.7	--
210	7.1	1.3	.2	.0	--	244	170	0	.8	375	8.5	15.5
--	--	--	--	27	.06	--	--	--	--	--	--	16.0
26	15	10	.0	26	--	112	26	28	.6	165	6.6	10.5
33	11	9.7	.0	29	--	109	32	22	.6	165	6.6	13.0
44	2.7	1.8	.0	3.6	--	72	44	1	.2	100	7.0	11.0
36	6.4	7.2	.0	14	.06	89	36	16	.3	131	7.2	15.5
34	6.9	11	.0	21	--	106	34	28	.4	168	6.7	15.0
--	--	--	--	5.2	.03	--	--	--	--	--	--	17.0
55	14	9.1	.0	7.4	--	110	55	8	.5	162	7.9	14.0
48	2.8	.3	.0	.9	.14	72	43	0	.2	93	7.5	12.5
44	7.4	.2	.0	.6	--	73	45	1	.2	92	8.1	10.5
--	--	--	--	.6	.08	--	--	--	--	--	--	18.5
52	3.2	5.1	.0	7.8	--	90	52	8	.3	143	8.0	11.5
90	4.8	.1	.0	.4	.02	106	91	1	.1	174	7.8	16.5
--	--	--	--	3.1	.11	--	--	--	--	--	--	14.5
76	9.2	6.4	.0	2.1	--	112	75	0	.4	170	8.2	14.0
110	9.0	5.1	.0	2.9	--	146	100	0	.5	249	8.4	14.5
53	5.6	6.3	.0	9.4	--	95	53	7	.3	152	7.1	10.0
90	4.9	.6	.0	.9	--	101	86	0	.1	168	8.0	14.0
--	--	--	--	.5	.02	--	--	--	--	--	--	12.5
140	19	3.5	.0	6.0	.11	192	140	5	.4	293	7.8	13.5
170	15	4.0	.1	3.2	--	205	170	0	.3	323	8.5	14.0

Table 4.—Chemical analyses of water from selected wells, springs, and streams.—Continued.

Location	Depth of well (feet)	Date of collection	Silica (SiO_2)	Iron, total (Fe) (μg/L)	Manganese (Mn) (μg/L)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Hydroxide (OH)
30N31W25BCB	169	6- 6-73	15	10	0	51	20	13	1.6	270	0	0
30N31W25BDB	198	6- 5-73	14	0	0	23	16	8.6	1.3	140	6	0
30N31W25CAC	23	8-31-72	--	--	--	--	--	--	--	--	--	--
30N31W26AAB	30	8-30-72	--	--	--	--	--	--	--	--	--	--
30N31W26ADA	40	8-31-72	--	--	--	--	--	--	--	--	--	--
		6- 6-73	21	0	0	22	11	11	2.6	80	0	0
		7- 9-73	21	0	0	23	12	11	2.7	82	0	0
30N31W26ADC2	101	8-30-72	21	0	0	45	18	13	1.7	240	0	0
30N31W26ADC3	100	7- 3-73	18	0	0	49	18	11	1.8	210	18	0
30N31W34BBD	110	8- 2-73	14	0	10	27	11	5.7	1.6	140	0	0
30N31W34CAB	156	7-25-73	16	0	0	59	24	13	2.6	340	0	0
30N31W34DCA	23	7-25-73	22	0	10	13	3.3	3.6	2.0	58	0	0
30N31W35AAB	227	8-31-72	--	--	--	--	--	--	--	--	--	--
		7- 2-73	23	0	0	28	11	9.0	1.4	54	0	0
30N31W35ADD	21	8-31-72	33	20	40	56	28	10	2.9	300	0	0
		7- 9-73	--	--	--	--	--	--	--	--	--	--
30N31W36BBA	204	8-31-72	15	20	0	38	16	11	1.0	210	0	0
		7- 2-73	14	0	0	39	14	9.1	1.1	170	15	0
30N31W36CDB2	145	7-28-73	14	0	50	32	18	27	.8	190	13	0
31N31W2ACC	52	7-12-73	13	0	10	27	7.9	2.1	.9	110	6	0
31N31W2BDD3	40	7-12-73	15	0	0	26	7.2	2.3	1.0	110	5	0
31N31W2CDB	50	7-12-73	21	0	0	50	13	3.8	1.9	190	16	0
31N31W5ABD	15	7-12-73	11	0	0	18	9.3	1.5	1.0	100	0	0
31N31W10BBB	397	7-12-73	17	0	0	56	15	8.8	1.5	220	23	0
31N31W10CDB	378	7-12-73	9.4	0	0	39	17	7.4	1.3	190	13	0
31N31W20CDD	43	7-12-73	11	0	0	27	7.1	3.0	.8	110	6	0
31N31W26BCD	347	4-18-73	12	0	20	47	26	8.0	1.2	280	0	0
31N31W26CBA3	61	7-12-73	20	0	60	25	29	13	2.2	220	5	0
31N31W26CBB	70	7-12-73	27	0	0	68	22	8.4	2.2	290	20	0
31N31W26CBB3	65	7-12-73	23	0	0	57	24	9.8	1.7	280	13	0
31N31W29CBD4	66	7-12-73	14	0	10	45	14	3.8	1.2	210	0	0
31N31W29CCA	46	7-12-73	13	0	0	42	12	3.6	1.1	160	13	0
31N31W29CCA2	30	7-12-73	13	0	0	38	12	4.2	1.1	170	4	0
31N31W29DDB2	40	7-12-73	14	0	0	42	17	6.2	1.6	200	10	0
31N31W30AAC	10	7-12-73	15	0	0	28	11	2.2	1.1	120	6	0
31N31W32ABB	52	8-29-72	15	20	0	50	15	4.8	1.6	230	0	0
		6- 5-73	14	0	0	49	11	4.9	1.3	180	12	0
		7- 2-73	14	0	0	32	13	4.6	1.2	150	4	0
31N31W32ABC	33	8-29-72	12	50	0	41	14	8.1	1.1	190	0	0
		6- 5-73	9.6	10	0	54	2.1	6.0	1.1	170	0	0
		7- 3-73	10	0	0	35	12	5.5	1.1	150	0	0
31N31W32BDB	28	8-29-72	--	--	--	--	--	--	--	--	--	--
31N31W32DDA	45	8-29-72	--	--	--	--	--	--	--	--	--	--
		6- 5-73	8.6	0	0	17	6.3	4.1	.8	73	0	0
		7- 5-73	8.5	0	0	16	5.5	4.7	.6	65	0	0
31N31W33ACC	25	8-29-72	--	--	--	--	--	--	--	--	--	--
		6- 5-73	14	0	0	19	24	17	1.9	170	13	0
		7- 5-73	15	0	0	35	25	16	2.0	250	0	0
31N31W33BDA	123	3- 8-73	17	0	0	50	25	17	1.6	300	0	0
		6- 5-73	14	10	0	19	22	18	1.8	170	11	0
31N31W33CBC	60	8-29-72	--	--	--	--	--	--	--	--	--	--
		3- 8-73	10	0	0	21	8.2	4.9	.7	87	0	0
		7- 9-73	8.0	0	0	22	8.0	5.3	.9	90	2	0
31N31W33DCC	30	8-29-72	11	30	0	22	8.1	2.9	.7	100	0	0
		6- 5-73	8.6	0	0	22	5.9	3.9	.8	94	0	0
		7- 2-73	9.2	0	0	22	6.3	2.9	.8	92	0	0
31N31W35DBC	51	7-12-73	13	0	0	64	24	7.5	1.9	240	24	0
31N31W36BCB	40	7-12-73	8.6	0	0	43	15	7.0	1.2	180	0	0
						Springs						
29N31W1DBB	--	9-27-72	12	0	0	39	15	3.7	.9	190	0	0
31N31W29DDC2	--	7-13-72	11	20	0	28	9.3	3.4	.7	140	0	0
		10-12-72	17	0	0	34	11	3.5	.9	160	0	0
		6- 5-73	11	0	0	27	7.0	3.2	.8	120	0	0
						Surface water						
29N30W17ADD [2]	--	9-28-72	16	0	0	44	20	4.0	.9	230	0	0
30N31W3DAA [3]	--	9-28-72	9	0	0	18	5.9	1.8	.7	83	0	0
30N31W36CDD [4]	--	9-27-72	7	0	0	18	7.6	1.5	.4	90	0	0
30N31W36DCB [5]	--	9-27-72	9	0	0	20	7.9	1.7	.5	95	0	0

[1] Calculated sum of constituents
[2] McMillan Creek
[3] Libby Creek at mouth
[4] Libby Creek above fish hatchery spring effluent
[5] Libby Creek below fish hatchery spring effluent

Alkalinity as $CaCO_3$, total	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids[1]	Hardness as $CaCO_3$		Sodium adsorption ratio	Specific conductance (µmhos/cm at 25°C)	pH (units)	Temperature (°C)
							Carbonate	Noncarbonate				
220	14	1.2	.2	.4	--	254	210	0	.4	422	8.2	12.5
120	8.5	.9	.0	1.0	--	150	120	0	.3	249	8.3	8.5
--	--	--	--	.5	.02	--	--	--	--	--	--	16.0
--	--	--	--	.8	.16	--	--	--	--	--	--	16.5
--	--	--	--	19	.01	--	--	--	--	--	--	15.0
66	14	20	.2	26	--	169	66	37	.5	260	8.2	9.5
67	18	22	.0	23	--	170	68	37	.5	253	8.3	12.0
200	17	2.3	.0	1.5	.11	236	190	0	.4	367	8.0	14.5
200	11	2.8	.1	1.5	--	235	190	0	.4	373	8.7	11.5
110	8.7	.6	.1	.3	--	140	110	0	.2	237	7.8	11.0
280	11	1.1	.1	.2	--	290	250	0	.4	491	8.2	14.5
48	3.7	1.4	.0	.0	--	78	46	0	.2	104	8.0	10.0
--	--	--	--	.9	.07	--	--	--	--	--	--	16.5
44	86	.7	.2	.8	--	187	44	70	.4	232	7.9	12.5
250	27	4.5	.3	13	.13	322	250	10	.3	471	8.2	14.0
--	--	--	--	11	--	--	--	--	--	--	--	16.5
170	16	.5	.2	1.3	.11	201	160	0	.4	314	8.3	10.5
160	11	1.0	.3	.7	--	190	160	0	.3	303	8.7	10.0
180	25	.8	.5	1.2	--	228	150	0	.9	375	8.3	13.0
100	2.2	.6	.0	.6	--	117	100	0	.1	192	8.6	9.0
100	2.3	.4	.0	.3	--	110	93	0	.1	182	8.5	15.5
180	4.3	.6	.0	1.3	--	201	180	0	.1	317	8.7	9.0
82	3.9	.2	.0	.3	--	97	84	0	.1	167	7.8	15.0
220	5.2	.8	.2	.8	--	234	200	0	.3	371	8.8	11.0
180	6.5	.7	.0	.8	--	188	170	0	.2	317	8.7	11.0
100	5.5	1.2	.0	.4	--	114	96	0	.1	189	8.5	8.5
230	12	1.2	.2	.6	--	243	220	0	.2	407	8.0	15.5
190	6.9	3.4	.0	9.4	--	226	180	0	.4	371	8.3	13.5
270	7.9	2.4	.1	3.0	--	302	260	0	.2	461	8.8	10.0
250	6.0	1.7	.1	3.1	--	280	240	0	.3	447	8.4	15.0
170	4.3	.9	.0	2.0	--	191	170	0	.1	326	7.9	15.0
150	6.7	1.0	.0	1.0	--	169	150	0	.1	282	8.6	9.0
150	7.4	.6	.0	2.2	--	165	140	0	.2	277	8.3	8.5
180	9.6	1.4	.0	1.5	--	198	170	0	.2	325	8.5	11.0
110	4.2	.8	.0	.5	--	133	110	0	.1	219	8.5	10.0
190	6.9	1.1	.0	2.8	.05	208	190	0	.2	342	8.0	12.0
170	6.9	1.8	.0	2.6	--	193	170	0	.2	316	8.5	10.0
130	8.2	1.8	.0	2.3	--	158	130	0	.2	262	8.4	8.5
160	20	1.5	.0	2.3	.07	189	150	7	.3	309	7.9	13.0
140	18	2.0	.0	1.4	--	174	140	4	.2	288	8.1	9.5
120	20	2.4	.0	.9	--	164	120	11	.2	262	8.2	11.5
--	--	--	--	2.2	.11	--	--	--	--	--	--	7.0
--	--	--	--	1.7	.06	--	--	--	--	--	--	8.5
60	13	1.5	.0	1.8	--	89	60	8	.2	145	8.0	8.5
53	16	1.4	.0	1.1	--	85	53	8	.3	143	8.1	8.0
--	--	--	--	1.5	.08	--	--	--	--	--	--	18.0
160	14	1.8	.1	.7	--	193	150	0	.6	326	8.5	12.0
200	17	2.0	.0	1.1	--	240	190	0	.5	399	8.2	12.0
250	20	1.2	.0	.6	--	276	230	0	.5	455	7.8	13.0
160	14	2.0	.1	.8	--	183	140	0	.7	310	8.5	11.0
--	--	--	--	5.1	.03	--	--	--	--	--	--	7.5
71	14	4.8	.0	4.4	--	110	71	14	.2	185	6.9	11.0
77	13	4.0	.0	4.4	--	113	80	9	.2	193	8.3	10.0
82	6.4	1.0	.0	2.4	.05	104	83	4	.1	174	7.6	9.5
77	6.7	2.0	.0	2.0	--	98	77	1	.2	165	8.3	11.0
75	6.8	1.8	.0	1.7	--	96	75	4	.1	163	8.2	9.5
240	34	2.5	.1	3.3	--	293	260	0	.2	437	8.7	8.5
150	29	2.1	.1	2.2	--	200	150	17	.2	328	8.3	12.0
Springs												
160	6.4	.6	.0	.4	--	175	160	0	.1	299	8.0	9.0
110	5.2	.3	.0	.6	--	125	110	0	.1	208	7.9	6.5
130	3.8	.5	.0	.0	--	144	130	0	.1	246	7.5	8.0
98	3.6	1.1	.1	.5	--	112	96	0	.1	190	8.1	6.5
Surface water												
190	7.6	.6	.0	.1	--	205	190	1	.1	346	8.3	4.5
68	3.3	.5	.0	.0	--	80	68	1	.1	138	7.3	9.5
74	3.8	.2	.0	.1	--	83	74	2	.1	148	7.8	11.0
78	3.8	.4	.0	.0	--	90	78	3	.1	159	7.6	11.0

SELECTED REFERENCES

ALDEN, W. C., 1953, Physiography and glacial geology of western Montana and adjacent areas: U.S. Geological Survey Professional Paper 231, 200 p.

BIESECKER, J. E., HOFSTRA, W. E., and HALL, D. C., 1973, Ground-water quality, West Jefferson County, Colorado, *in* Proceedings of the 21st Annual Hydraulics Division Specialty Conference, Hydraulic Engineering and the Environment, Bozeman, Montana: American Society of Civil Engineers, p. 417-425.

FERRIS, J. G., KNOWLES, D. B., BROWN, R. H., and STALLMAN, R. W., 1962, Theory of aquifer tests: U.S. Geological Survey Water-Supply Paper 1536-E, p. 69-174.

GIBSON, RUSSELL, 1948, Geology and ore deposits of the Libby quadrangle, Montana: U.S. Geological Survey Bulletin 956, 131 p.

GIBSON, RUSSELL, JENKS, W. F., and CAMPBELL, IAN, 1941, Stratigraphy of the Belt Series in Libby and Trout Creek quadrangles, northwestern Montana and northern Idaho: Geological Society of America Bulletin, v. 52, p. 363-379.

JOHNS, W. M., 1959, Progress report on geologic investigations in the Kootenai-Flathead area, northwest Montana: Montana Bureau of Mines and Geology Bulletin 12, 56 p.

____________1970, Geology and mineral deposits of Lincoln and Flathead Counties, Montana: Montana Bureau of Mines and Geology Bulletin 79, 182 p.

JOHNSON, M. V., and OMANG, R. J., 1974, Floods of January 15-17, 1974, in northwestern Montana: U.S. Geological Survey Open-File Report 74-38, 10 p.

KLEINKOPF, M. D., HARRISON, J. E., and ZARTMAN, R. E., 1972, Aeromagnetic and geologic map of part of northwestern Montana and northern Idaho: U.S. Geological Survey Geophysical Investigations Map GP-830.

LOHMAN, S. W., and others, 1972, Definitions of selected ground-water terms—Revisions and conceptual refinements: U.S. Geological Survey Water-Supply Paper 1988, 21 p.

STOKES, W. L., and VARNES, D. J., 1955, Glossary of selected geologic terms: Colorado Scientific Society Proceedings, v. 16, 165 p.

U.S. BUREAU OF THE CENSUS, 1970 census of population, Montana—Advance report: U.S. Department of Commerce Publication PC(VI)-28, 8 p.

U.S. GEOLOGICAL SURVEY, issued annually, Water resources data for Montana, Pt. 2, Water quality records (1969-72): Helena, Montana, Water Resources Division.

U.S. PUBLIC HEALTH SERVICE, 1962, Drinking water standards, 1962: U.S. Public Health Service Publication 956, 61 p.

WRIGHT, H. E., JR., and FREY, D. G. (editors), 1965, The Quaternary of the United States: Princeton University Press, 922 p.