Prepared in cooperation with
GALLATIN LOCAL WATER
QUALITY DISTRICT

Ground-Water Resources of the Gallatin Local Water Quality District, Southwestern Montana

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Ground water provides domestic supplies for about 17,000 residents of the Gallatin Local Water Quality District (GLWQD), Montana. As a result, ground water is an important source of drinking water. This Fact Sheet describes ground-water availability, flow, and quality within the GLWQD.

The 816-square mile GLWQD encompasses most of the Gallatin Valley, where Bozeman, Belgrade, and Manhattan, Montana, are located, and extends into the surrounding mountains (fig. 1). Flood plains of the Gallatin and East Gallatin Rivers merge near the center of the valley. West of the flood plain is the Madison Plateau, a broad bench more than 5,000 feet in altitude. Along the eastern and southern valley margins are smaller benches, or terraces. East and southeast of the Gallatin Valley, the Bridger and Gallatin Ranges rise to more than 10,000 feet. The Gallatin River and its tributaries drain the GLWQD.

Land use in the Gallatin Valley is primarily agricultural (fig. 2). In most of the valley and the Madison Plateau, irrigated agriculture is the dominant land use, whereas on the eastern benches, dryland farming is the dominant land use. In the mountainous parts of the GLWQD, which are mostly steep and densely forested, land uses include timber harvesting, cattle grazing, and recreation. During the past 40 years, residential and commercial developments have replaced some agricultural land as the population of the GLWQD has increased.

WHAT IS GROUND WATER?
Ground water is water that fills pores, cracks, or other voids underground. Ground water flows slowly through the voids, typically toward a stream. **Wells** obtain ground water from **aquifers**, which are the saturated **geologic** material--either sediment or rocks--that contain the water-filled voids. The top of the ground-water surface is called the **water table**. Water seeping down from the land surface replenishes, or **recharges**, ground water, which raises the water table. **Ground-water flow** normally occurs as slow seepage through the pore spaces or through networks of fractures, joints, and cavities.

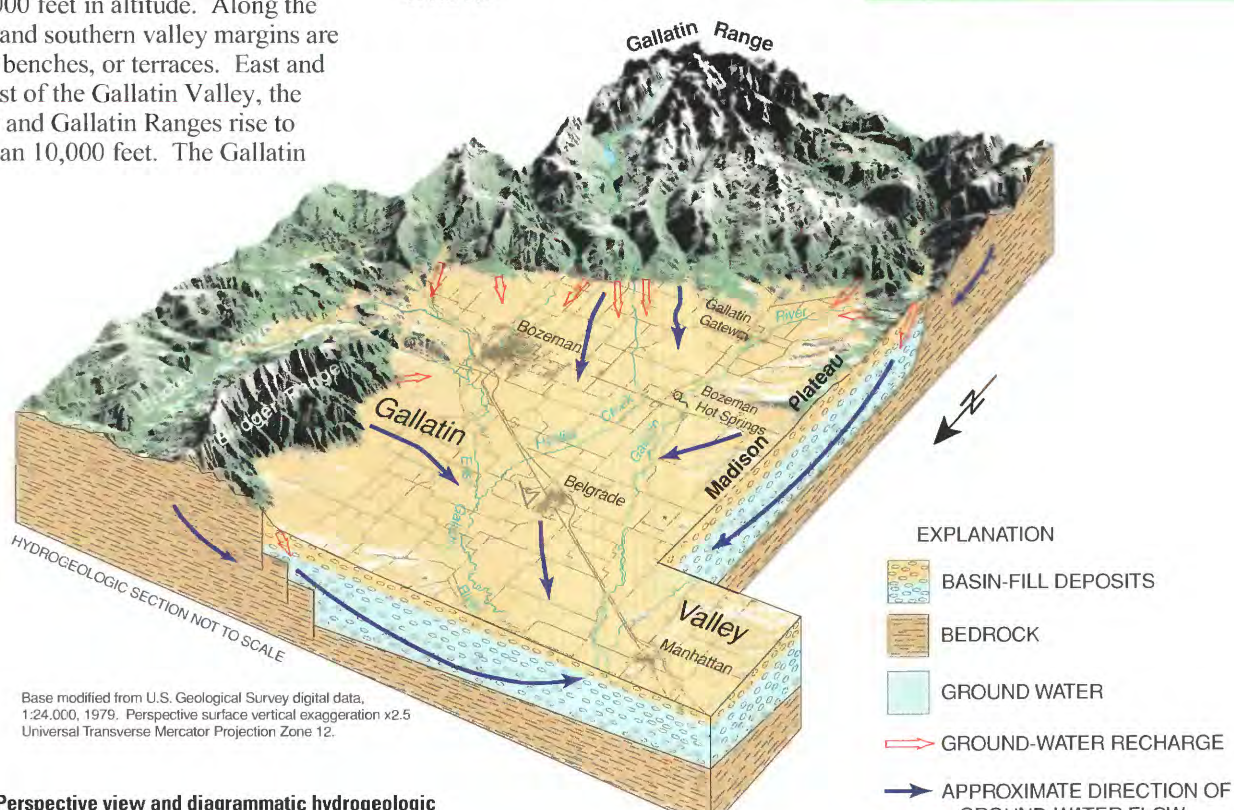


Figure 1. Perspective view and diagrammatic hydrogeologic section showing ground-water recharge and flow in the Gallatin Local Water Quality District, Montana.

Land use (see fig. 2) can affect ground-water quality. A key consideration in managing ground-water resources is their vulnerability to sources of contamination that are located primarily at or near the land surface.

EXPLANATION OF GENERALIZED LAND USE MAP (figure 2)

Land use	Potential effects on ground water
Irrigated agriculture	Excess irrigation water can recharge ground water. Agricultural chemicals and fertilizers can leach into aquifers.
Dryland farming	Crop fallowing can increase ground-water recharge and can leach nitrate into aquifers.
Forest and rangeland	Seepage through soils recharges ground water. Timber harvests can generate nitrogen-rich runoff.
Residential and commercial development	Domestic septic-system effluent, household and industrial chemicals, and lawn fertilizers can leach into aquifers.

GROUND-WATER AVAILABILITY

The GLWQD is underlain by a variety of geologic materials. Some of these materials contain aquifers from which ground water is obtained, whereas others restrict the flow of ground water. Figure 3 shows the distribution of geologic materials within the GLWQD, and the table below figure 3 describes the water-bearing and water-quality characteristics of these geologic materials.

The availability of ground water depends on the size of the voids in the aquifer and how well the voids are connected. Water flows between sand and gravel grains in basin-fill deposits, whereas water moves primarily through weak, broken zones such as fractures, joints, and cavities in bedrock. Therefore, the ability of basin-fill deposits to yield water to wells depends primarily on the size of the particles that compose these aquifers. In contrast, yields from bedrock depend on the occurrence and extent of weak, broken zones in the rock. Alluvium generally is the most permeable hydrogeologic unit and the most reliable source of ground water in the GLWQD.

Wells in mountainous parts of the GLWQD can have low yields. For example, in the Bridger Canyon area, relatively soft, silty rocks restrict ground-water flow and wells generally are not as productive as in the Gallatin Valley.

Ground-Water Flow

Rainfall and snowmelt throughout the GLWQD contribute some water to aquifers. Recharge to basin-fill deposits probably is greatest along mountain fronts, where rivers and streams cross from dense bedrock to the more porous basin-fill deposits and lose water (fig. 1). Additional recharge comes from irrigation water that leaks from canals and excess water applied to fields.

Land use in the Gallatin Valley is primarily agricultural.

After entering an aquifer, ground water generally moves from high to low altitudes. In the GLWQD, ground water flows from mountain bedrock aquifers into basin-fill deposits, then toward the Gallatin and East Gallatin Rivers, and northwestward toward Manhattan (fig. 1). Local flow directions, however, may differ from figure 1, depending on nearby conditions such as recharge from irrigation water or the Gallatin River.

Ground water leaves, or discharges from, aquifers into rivers, streams, wells, and irrigation drains, or as underground flow into adjacent aquifers. Also, some ground water is consumed by plants such as cottonwoods, willows, and alfalfa that have roots that extend below the water table.

Ground-Water Quality

The chemical characteristics, or quality, of ground water depend upon the natural and human-affected environments through which the water has passed. For example, rainfall and snowmelt runoff dissolve natural minerals, organic materials, and residues from domestic, agricultural, and industrial activities. Percolation beneath the land surface causes water to dissolve additional substances from soils and geologic material. The most common dissolved mineral substances in water are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and fluoride. When added together, the concentration of these substances (the dissolved solids) can indicate the suitability of water for domestic, stock, or irrigation purposes. The quality of ground water in most parts of the GLWQD is acceptable for most uses, and almost all ground water in the GLWQD is safe for human consumption.

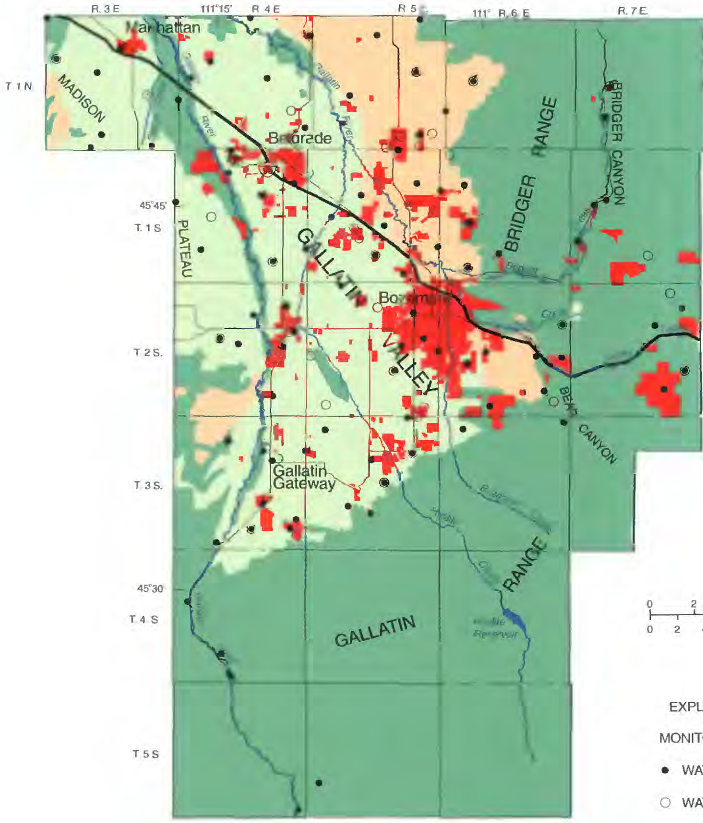
Much of the ground water in the GLWQD is considered hard because it contains a high proportion of calcium and magnesium. The hardness of water is expressed in terms of an equivalent amount of calcium carbonate--the principal constituent of limestone. Water is considered soft if it contains 0 to 60 mg/L of hardness, moderately hard if it contains from 61 to 120 mg/L, hard between 121 to 180 mg/L of hardness, and very hard if more than 180 mg/L of hardness. Hardness of ground water of the GLWQD ranges between 6 to 340 mg/L.

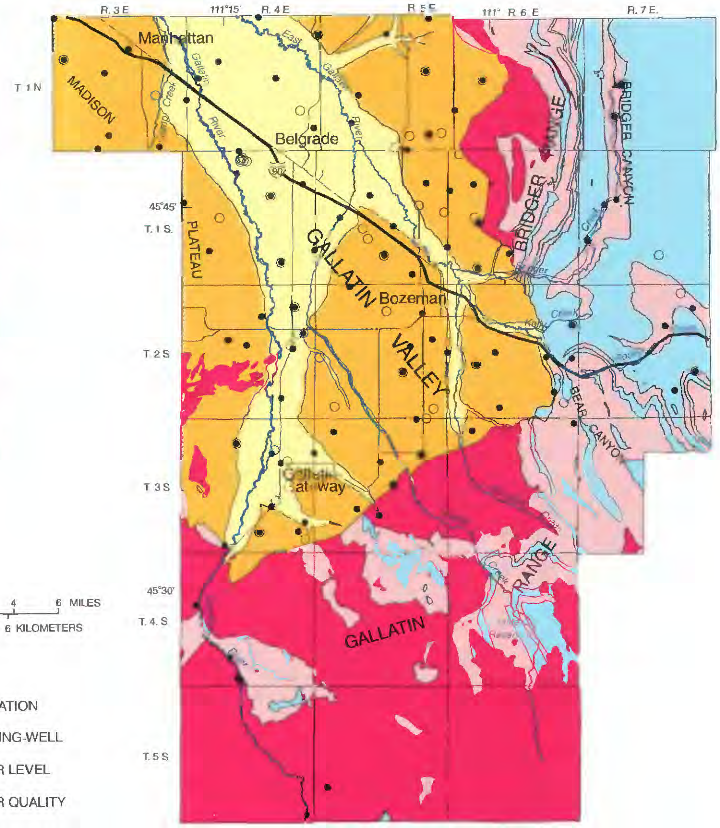
Nitrate in ground water is derived from natural and human sources. Typically, the quantity of nitrate derived from natural sources is low compared to that from human sources. High concentrations of nitrate (greater than 10 mg/L as nitrogen) are known to cause adverse health effects in infants. Nitrate concentrations generally are low in ground water of the GLWQD and range from <0.05 to 13 mg/L. Median concentrations in alluvium and sediments along the flood plains, benches, and Madison Plateau (fig. 3) are less than about 3 mg/L. Nitrate concentrations in only 2 of the 96 sites sampled (10 and 13 mg/L) equal or exceed the Maximum Contaminant Level of 10 mg/L established by the U.S. Environmental Protection Agency for public drinking-water supplies. Seasonal variations in nitrate concentration were determined in water from some wells.

Fluoride is naturally present in most ground water and can reduce the incidence of tooth decay. Fluoride concentrations in ground water of the GLWQD range from <0.1 to 11 mg/L; ground water commonly contains less fluoride than the 0.8 to 1.2 mg/L considered optimum for dental health.

MONITORING FOR THE FUTURE

This Fact Sheet describes conditions that were present in 1997-98. However, because land uses in the GLWQD are changing, ground-water conditions are expected to change as well. Continued monitoring of ground-water conditions will provide information to evaluate ground-water quantity and quality and support informed





0 2 4 6 MILES
0 2 4 6 KILOMETERS

EXPLANATION

MONITORING WELL

● WATER LEVEL

○ WATER QUALITY

Figure 2. Generalized land use map.

Figure 3. Generalized geologic map.

EXPLANATION OF GENERALIZED GEOLOGIC MAP (figure 3)

Geologic material	General character and extent	Water-bearing characteristics	Water-quality characteristics
		BASIN-FILL DEPOSITS	
Alluvium	Unconsolidated stream-laid gravel, sand, silt, and clay. Mainly present in the flood plains of the Gallatin and East Gallatin Rivers. Thickness ranges from 70 to as much as 800 feet.	Generally the most reliable source of ground water. Wells typically are less than 100 feet deep and can provide sufficient supplies for most uses.	Chemical quality of water is acceptable for most uses. Dissolved-solids concentrations range from 176 to 333 milligrams per liter (mg/L). Water is hard to very hard and hardness ranges from 140 to 250 mg/L.
Sediments (undifferentiated)	Unconsolidated to consolidated gravel, sand, silt, and clay. Mainly present beneath the eastern and southern parts of the valley, and along the Madison Plateau. Also found beneath alluvium in the center of the GLWQD. Thickness as much as 6,000 feet.	West of Bozeman, wells typically are less than 100 feet deep and can yield as much as 100 gpm. Near the Bridger Range, wells typically are 100 to 300 feet deep; well yields are variable and the depth to water fluctuates seasonally by as much as 50 feet. On the Madison Plateau, wells are 200 to 500 feet deep and can yield more than 2,000 gpm.	Chemical quality of water is acceptable for most uses. Dissolved-solids concentrations range from 149 to 405 mg/L. Water is moderately hard to very hard and hardness ranges from 91 to 290 mg/L.
		BEDROCK	
Sedimentary bedrock that contains potential aquifers	Mostly sandstone, conglomerate, or limestone with some interbedded fine-grained rocks such as shale. Mainly crops out in the eastern part of the GLWQD. Thickness varies.	Wells typically are less than 300 feet deep. In some areas, these wells yield sufficient water for domestic supplies. However, rugged terrain and deep water tables may restrict development of these supplies.	Limited data indicate the chemical quality of water is acceptable for most uses. Dissolved-solids concentrations range from 176 to 438 mg/L. Water is moderately hard to very hard and hardness ranges from 100 to 190 mg/L.
Sedimentary bedrock that contains confining units	Mostly fine-grained rocks such as shale, mudstone, and siltstone. Mainly crops out in the mountainous parts of the GLWQD where rocks are complexly folded and faulted. Thickness varies.	Most wells typically are less than 300 feet deep. In some areas, these wells yield sufficient water for domestic supplies (10 gpm). However, dry or low-yielding wells are common. Ground water generally is not readily available in many areas where this material is found.	Limited data indicate the chemical quality of water is acceptable for most uses. Dissolved-solids concentrations range from 127 to 409 mg/L. Water is moderately hard to very hard and hardness ranges from 77 to 340 mg/L.
Igneous and metamorphic bedrock	Mostly dense rocks such as andesite, basalt, volcanic tuff, and gneiss. Mainly crops out in the southern part of the GLWQD and the western flank of the Bridger Range. Thickness can be more than 9,000 feet.	These rocks might yield water where fractures are saturated and interconnected.	Water-quality characteristics generally are unknown. One sample from the Bozeman Hot Springs yielded a dissolved-solids concentration of 456 mg/L and a hardness concentration of 6 mg/L.

decisions about water-resource management.

The GLWQD established a ground-water monitoring network that consists of 156 privately owned wells (shown in figures 2 and 3). Water levels are measured to document natural fluctuations in the water table, to provide information needed to determine the direction and rate of ground-water flow, and to assess water availability. Water-quality samples are analyzed for constituents such as nitrate and chloride that can indicate possible human-induced changes.

Measurements of water levels in wells provide important information about ground water, including its direction and rate of flow and its availability.

Snowmelt from the Bridger Range recharges aquifers in the Gallatin Local Water Quality District, Montana.

SUGGESTIONS FOR FURTHER READING

Centers for Disease Control and Prevention, 1985, Perspectives in disease prevention and health promotion dental caries and community water fluoridation trends--United States: Morbidity and Mortality Weekly Report, v. 34, no. 6, accessed February 3, 2001 at URL http://www.cdc.gov/mmwr/preview/mmwrhtml/00000483.htm

Hackett, O.M., Visher, F.N., McMurtrey, R.G., and Steinhilber, W.L., 1960, Geology and ground-water resources of the Gallatin Valley, Gallatin County, Montana, *with a section on* Surface-water resources by Frank Stermitz and F.C. Boner, *and a section on* Chemical quality of the water by R.A. Krieger: U.S. Geological Survey Water-Supply Paper 1482, 282 p.

Kendy, Eloise, 2001, Magnitude, extent, and potential sources of nitrate in ground water in the Gallatin Local Water Quality District, southwestern Montana, 1997-98: U.S. Geological Survey Water-Resources Investigations Report 01-4037, 66 p.

Kendy, Eloise, and Tresch, R.E., 1996, Geographic, geologic, and hydrologic summaries of intermontane basins of the Northern Rocky Mountains, Montana: U.S. Geological Survey Water-Resources Investigations Report 96-4025, p. 73-82.

Slagle, S.E., 1995, Geohydrologic conditions and land use in the Gallatin Valley, southwestern Montana, 1992-93: U.S. Geological Survey Water-Resources Investigations Report 95-4034, 2 sheets, scale 1:100,000.

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http://montana.usgs.gov/

The National USGS homepage is:

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This Fact Sheet summarizes information contained in U.S. Geological Survey Water-Resources Investigations Report 01-4037, “Magnitude, extent, and potential sources of nitrate in ground water in the Gallatin Local Water Quality District, southwestern Montana, 1997-98,” by Eloise Kendy. Copies of that report can be purchased from U.S. Geological Survey, Branch of Information Services, Box 25286, Denver, CO, 80225-0286.

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