Briar, D.W., and others, 1996, Ground-water levels in intermontane basins of the Northern Rocky Mountains, Montana and Idaho

INTRODUCTION

The Regional Aquifer-System Analysis (RASA) program is a series of studies by the U.S. Geological Survey (USGS) to analyze regional ground-water systems that compose a major portion of the Nation's water supply (Sun, 1986). The Northern Rocky Mountains Intermontane Basins is one of the study regions in this national program. The main objectives of the RASA studies are to (1) describe the ground-water systems as they exist today, (2) analyze the known changes that have led to the system's present condition, (3) combine results of previous studies in a regional analysis, where possible, and (4) provide means by which effects of future ground-water development can be estimated.

The purpose of this study, which began in 1990, was to increase understanding of the hydrogeology of the intermontane basins of the Northern Rocky Mountains area. This report is Chapter B of a three-part series and shows the general distribution of ground-water levels in basin-fill deposits in the study area. Chapter A (Tuck and others, 1996) describes the geologic history and generalized hydrogeologic units. Chapter C (Clark and Dutton, 1996) describes the quality of ground and surface waters in the study area.

Ground-water levels shown in this report were measured primarily during summer 1991 and summer 1992; however, historical water levels were used for areas where more recent data could not be obtained. The information provided allows for the evaluation of general directions of ground-water flow, identification of recharge and discharge areas, and determination of hydraulic gradients within basin-fill deposits.

LOCATION AND GENERAL FEATURES

The Northern Rocky Mountains Intermontane Basins study area encompasses about 77,500 mi² in western Montana and central and northern Idaho (fig. 1). The study area extends from near the eastern front of the Rocky Mountains in Montana westward to the basalt plains of the Columbia Plateau in western Idaho. In the south, the study area extends from the Snake River Plain in Idaho northward to the United States-Canada border. The Continental Divide separates the study area into two major drainage systems—the Missouri River drainage to the east and the Columbia River drainage to the west. Major tributaries of the Missouri River drainage in the study area include the Beaverhead, Ruby, Big Hole, Jefferson, Madison, and Gallatin Rivers. Major tributaries of the Columbia River drainage in the study area include the Kootenai, Blackfoot, Bitterroot, Flathead, Clark Fork/Pend Oreille, Spokane, Salmon, Selway, Lochsa, South Fork Clearwater, and North Fork Clearwater Rivers.

Topography in the study area is varied. Land-surface altitudes range from about 2,000 ft in the Kootenai River Valley in the northwestern part of the study area to more than 12,000 ft in the Lost River Range in the south-central part of the study area. In northwestern Montana and west-central Idaho, mountain ranges typically are separated by narrow, steep-sided valleys that have little or no basin-fill deposits. In contrast, the ranges of southwestern Montana and east-central and northern Idaho are separated by wide, relatively level valleys that are deeply filled with sediment. Valley-floor altitudes range from about 2,000 ft in the Kootenai River Valley to about 7,000 ft in the Sawtooth Valley in south-central Idaho.

The climate is characterized by cold winters and mild summers. Annual precipitation ranges from about 8 in. for basins in east-central Idaho to about 100 in. for some mountainous parts of Montana. Most valleys receive about 10 to 30 in. of precipitation per year, with more than one-half falling in winter and spring. Large winter snowpacks in the mountains gradually release their water content as snowmelt that maintains streamflow well into summer.

Major physiographic features in the study area include 54 generally northerly to northwesterly trending intermontane basins (or valleys) (fig. 1). In this report, "basin" refers to topographic, as well as geologic structural, basins. The perimeters of the basins are approximated from topography, geologic structure, extent of basin fill, and results of previous studies. The intermontane basins range in area from less than 10 to more than 700 mi² and are filled with unconsolidated to poorly consolidated Tertiary to Quaternary continental deposits. Intermontane basins compose about 16 percent of the study area. All basins have through-flowing perennial streams with recent flood plains. In most southern basins, these flood plains are adjacent to older river terraces that grade into pediments or alluvial fans that meet mountain fronts with an abrupt change in slope. In northern basins, recent flood plains are adjacent to glacial deposits that extend to mountain fronts; in some areas, the glacial deposits reach an altitude of as much as 6,000 ft. Mountain fronts commonly coincide with faults or fault systems along which the basins have been downdropped relative to the mountains.

GENERALIZED HYDROGEOLOGY

The study area has a complex geologic history of sedimentation, compressional deformation, igneous activity, and, most recently, extensional block faulting. The complex geologic history of the area has resulted in a diverse assemblage of bedrock that, for this report, has been grouped into five general categories on the basis of areal distribution, age, lithology, and hydrologic character. In ascending order, the bedrock units are (1) primarily Archean metamorphic rocks, (2) Middle Proterozoic metasedimentary rocks, (3) Paleozoic through Mesozoic sedimentary rocks, (4) Cretaceous through Tertiary intrusive igneous rocks, and (5) Cretaceous througn Quaternary volcanic rocks. The generalized distribution of these rocks is shown in figure 2.

Primarily Archean metamorphic rocks which consist of marble, quartzite, schist, and gneiss, presumably underlie the entire area but crop out only in the southeastern part of the study area (Wilson, 1983). These rocks generally are a barrier to ground-water flow. However, the upward migration of deep-circulating water associated with faults in the bedrock is expressed by thermal wells and springs in some basins.

Middle Proterozoic metasedimentary rocks are exposed in isolated areas in the southern part and throughout most of the northern part of the study area where maximum thickness exceeds 60,000 ft (Harrison and others, 1974). These rocks originated as fine-grained terrigenous and carbonate sediment in a subsiding basin but have undergone regional low-grade metamorphism to argillite and quartzite. These rocks supply unquantified but potentially large volumes of subsurface flow to basin-fill aquifers through fractures.

Several thousand feet of Paleozoic through Mesozoic sedimentary rocks crop out in the southern and eastern parts of the study area where they have been extensively folded and thrust faulted. The Paleozoic rocks mostly are marine carbonates and are generally nonporous (Perry, 1988). However, cavernous limestone in parts of the Mississippian Madison Group might be an important source of recharge water to basin-fill aquifers and a possible conduit for interbasin ground-water flow. The Mesozoic rocks primarily are marine shale interbedded with nonmarine mudstone and sandstone. Although primarily fine grained, Mesozoic rocks can transmit water in areas where more permeable conglomerate and sandstone layers are present.

During Cretaceous to early Tertiary time, magma intruded bedrock of the Northern Rocky Mountains area which produced the Idaho Batholith in central Idaho and the Boulder Batholith in southwestern Montana. Intermontane basins generally are absent from the batholithic terrane. Several episodes of volcanic activity related to the intrusions emplaced thousands of feet of volcanic rocks on top of and adjacent to the intrusive rocks. Permeability of the intrusive and volcanic rocks generally is less than that of the basin fill; however, fractures in these rocks may store and transmit substantial amounts of water in places.

Episodes of extensional block faulting and basin subsidence occurred intermittently throughout the Tertiary Period. The intermontane basins of the Northern Rocky Mountains are thought to have attained their modern configurations during the Miocene Epoch, when Basin and Range tectonics created an area of broadly distributed crustal extension characterized by an extensive number of normal faults. As the crust extended, downthrown fault blocks became basins, while upthrown blocks became the intervening mountains (Eaton, 1979). Most of the basins trend northerly to northwesterly, roughly parallel to basin-marginal normal faults and perpendicular to regional extension. In the southern part of the study area, basin-marginal faults define the few east–west-trending intermontane basins adjacent to the Snake River Plain. These basins are related more closely to extension and uplift associated with the Snake River Plain than to Basin and Range tectonics (Johnson, 1981; Sonderegger and others, 1982).

Basin subsidence, mountain uplift, and volcanism throughout the Tertiary Period resulted in basin-fill deposits as thick as 16,000 ft. Names for Tertiary deposits vary within the study area; however, the stratigraphy is correlative from a regional perspective. In southwestern Montana, Tertiary deposits have been grouped into two units—a lower, predominantly fine-grained unit and an upper, predominantly coarse-grained unit. Most of the lower unit comprises lacustrine sediments that consist primarily of ash and freshwater shale and marl deposited in broad, sometimes closed ancestral basins (Fields and others, 1985). The lower unit generally is considered to be too deep and impermeable to be a viable aquifer. In contrast, the upper unit consists of locally derived, unconsolidated, coarse clastic material that resulted from Miocene to Pliocene basin development (Fields and others, 1985). Localized gravel deposits in the upper unit form the most productive deep aquifers in the basins (Noble and others, 1982). In some areas, Tertiary deposits extend outside the present basin boundaries owing to differential uplift.

Quaternary fluvial and glacial deposits typically overlie Tertiary deposits. In southern basins, Quaternary deposits primarily consist of alluvium along rivers and streams and colluvial and alluvial-fan deposits near mountain flanks. Quaternary alluvium that underlies the flood plains of rivers and streams contains some of the most productive shallow aquifers in the basins. In the northern basins, glaciers reworked pre-Pleistocene surfaces and contributed large volumes of glaciolacustrine deposits, till, and outwash. Glaciolacustrine deposits and till commonly provide a limited source of water owing to the poorly sorted, fine-grained nature of the deposits. Although outwash commonly also is poorly sorted, it is typically coarse grained and is a productive aquifer in places.

GROUND-WATER FLOW

Ground-water flow in intermontane basins is largely restricted to individual basins with little or no direct ground-water transfer between adjacent basins. Bedrock mountains that surround the basins generally are impermeable, thereby restricting ground-water flow between basins. Bedrock mountains also are topographically higher than the basins and, therefore, commonly supply recharge to basin-fill aquifers. Lastly, most basin-fill aquifers in the study area are constricted within bedrock canyons at the downgradient ends of the basins, which effectively limits ground-water flow to sediments of adjacent downstream basins.

Some ground water might flow between basins through zones of permeable bedrock. Deep circulation of meteoric water along Tertiary and Quaternary extensional faults (Perry, 1988; Wallace and others, 1990) or through permeable geologic units, such as cavernous limestone or fractured volcanic rocks, might allow limited interbasin transfer of ground water. Although interbasin ground-water flow might occur in some areas, it is thought to be a minor portion of the total ground-water budget.

Basin-fill aquifers can be classified as unconfined, leaky confined, or confined. The basin-fill aquifers that consist of Quaternary alluvium commonly are unconfined and highly productive. In the northern parts of the study area, some basin-fill aquifers are confined by overlying glaciolacustrine deposits or till. Fine-grained layers within Tertiary deposits restrict the flow into or out of more permeable layers, which result in leaky-confined or confined aquifers. With depth, these fine-grained layers become more consolidated and, therefore, less permeable. Some Tertiary basin-fill deposits contain productive aquifers that have been recently developed; however, hydrogeologic characteristics of these aquifers are poorly defined. Basin-fill aquifers in Quaternary and Tertiary deposits within a basin generally are assumed to be hydraulically connected.

Basin-fill aquifers are recharged by direct infiltration of precipitation, leakage from streams, and subsurface flow from surrounding bedrock, which is primarily recharged by melting snowpack. In some areas, infiltration of applied irrigation water and leakage from irrigation canals provide a significant component of recharge to basin-fill aquifers. The largest component of discharge from most basin-fill aquifers is seepage to rivers and streams. Evapotranspiration, withdrawals by wells, and flow to springs generally are smaller components of discharge.

GROUND-WATER LEVELS AND DIRECTION OF GROUND-WATER FLOW

Ground-water levels shown in figure 3 are based on measurements of 1,804 wells completed in basin-fill deposits. Water levels for an additional 130 wells located outside the basin boundaries also are depicted. Of the 1,934 water levels used, 1,873 were measured by USGS personnel in summer 1991, and 18, in summer 1992. Historical water-level measurements in 43 wells were used in areas where more recent data could not be obtained. Companion reports (Dutton and others, 1995; Stone and others, 1996), present detailed information for these and other wells in the study area. Water-level contours were manually interpreted at a scale of 1:250,000. The location of contours between data points was constrained by topography, altitude of rivers, streams, and springs, and recently published potentiometric-surface maps of selected areas. Complexities of ground-water flow owing to local lithologic differences and geologic structure are poorly defined and are not shown in figure 3.

The contours shown in figure 3 generally represent water levels in the depth interval of basin fill in which the majority of wells in the area are completed. Water levels vary with well depth in areas that have a vertical component of ground-water flow. Recharge areas along the basin margins commonly have a downward component of flow, whereas discharge areas near streams and rivers in the central parts of the basin have an upward component of flow. Consequently, water-level measurements in individual wells might differ from water levels shown in figure 3 by tens of feet in some areas.

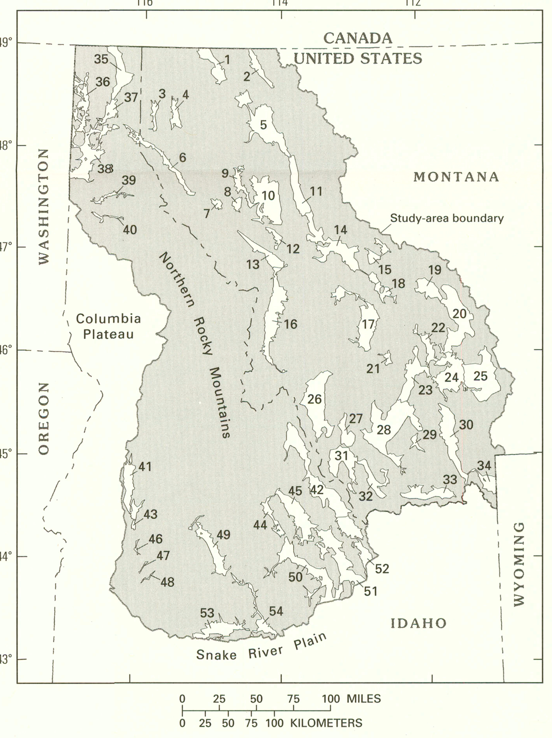
Regionally, ground-water flow is perpendicular to the water-level contours and downgradient. Given this, the direction of flow in most of the intermontane basins is diagonally downvalley from recharge areas along the basin margins near the mountain front toward discharge areas in the center of the basin. The configuration of water levels generally is similar to the topography, with steep gradients in areas along the mountain front and more gradual gradients in areas along the flood plains of rivers. The direction of flow in deeper aquifers might be different from that shown owing to confining strata, faults, or other deep structural controls.

Water-level contours show recent hydrologic conditions and development in the basins. Seasonal water-level fluctuations in most wells typically range from a few feet to a few tens of feet. The limited predevelopment water-level data available do not indicate significantly different water levels than current conditions. Of the many potential effects of development, withdrawals from wells for irrigation and leakage from irrigation canals supplied by diverted surface water probably have had the greatest effect on water levels. Although many factors influence water levels in the basin-fill deposits, these influences do not significantly change the location or shape of the water-level contours at the scale shown.

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
square mile (mi²)	2.59	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

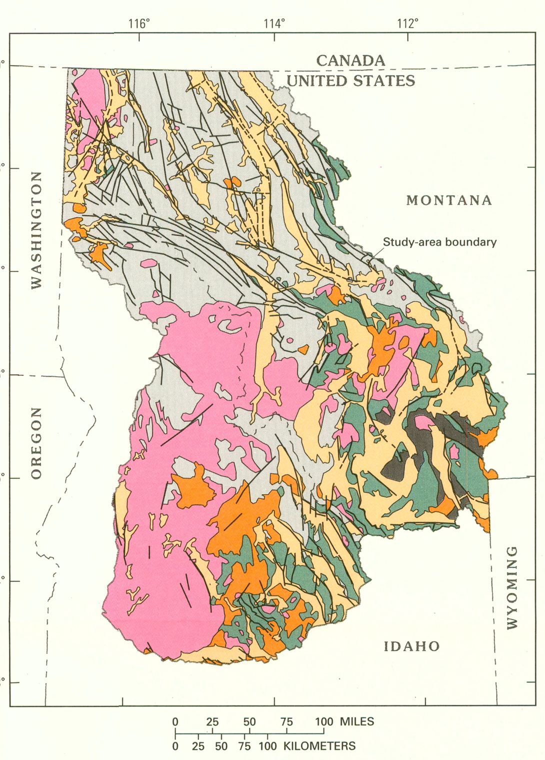


EXPLANATION

BASIN NAMES

1.	Tobacco Valley	28.	Beaverhead Valley
2.	North Fork Flathead River Valley	29.	Upper Ruby Valley
3.	Lake Creek Valley	30.	Madison River Valley
4.	Libby Creek Valley	31.	Horse Prairie Valley
5.	Kalispell Valley	32.	Red Rock Valley
6.	Lower Clark Fork Valley	33.	Centennial Valley
7.	Plains Valley	34.	Upper Madison River Valley
8.	Camas Prairie Basin	35.	Kootenai River Valley
9.	Little Bitterroot Valley	36.	Priest River Valley
10.	Mission Valley	37.	Pack River Valley
11.	Swan Valley	38.	Rathdrum Prairie area
12.	Jocko River Valley	39.	Coeur d'Alene River Valley
13.	Missoula Valley	40.	St. Joe River Valley
14.	Blackfoot-Clearwater Valley	41.	Long Valley
15.	Upper Blackfoot River Valley	42.	Lemhi Valley
16.	Bitterroot Valley	43.	Round Valley (Payette)
17.	Upper Clark Fork Valley	44.	Round Valley (Challis)
18.	Avon Valley	45.	Pahsimeroi Valley
19.	Helena Valley	46.	Garden Valley
20.	Townsend Valley	47.	Grimes Creek Valley
21.	Silver Bow Creek Valley	48.	Mores Creek Valley
22.	Boulder Valley	49.	Sawtooth Valley
23.	Jefferson River Valley	50.	Big Lost River Valley
24.	Western Three Forks Valley	51.	Little Lost River Valley
25.	Gallatin Valley	52.	Birch Creek Valley
26.	Big Hole Basin	53.	Camas Prairie
27.	Grasshopper Valley	54.	Big Wood River-Silver Creek area

Figure 1. Location of study area and intermontane basins.



EXPLANATION

QUATERNARY THROUGH TERTIARY BASIN-FILL DEPOSITS
QUATERNARY THROUGH CRETACEOUS VOLCANIC ROCKS
TERTIARY THROUGH CRETACEOUS INTRUSIVE IGNEOUS ROCKS
MESOZOIC THROUGH PALEOZOIC SEDIMENTARY ROCKS
MIDDLE PROTEROZOIC METASEDIMENTARY ROCKS
PRIMARILY ARCHEAN METAMORPHIC ROCKS
FAULT—Dashed where inferred

Figure 2. Generalized geology of the study area.

Base from U.S. Geological Survey State base maps, Montana and Idaho 1:500,000, 1968. Shaded relief derived from digital elevation model of published 1:250,000-scale topographic maps. Hydrography digitized from U.S. Geological Survey digital line graphs, 1:100,000

EXPLANATION

INTERMONTANE BASIN

WATER-LEVEL CONTOUR—Dashed where approximately located. Contour interval is 100 feet with supplemental 50-foot contours in the Kalispell and Centennial Valleys. Datum is sea level

WELL USED FOR CONTROL IN CONTOURING WATER LEVELS

MULTIPLE WELLS AT SAME GENERAL LOCATION USED FOR CONTROL IN CONTOURING WATER LEVELS

WELL OUTSIDE AREA OF WATER-LEVEL CONTOURS—Number is water level altitude, in feet above sea level

MULTIPLE WELLS AT SAME GENERAL LOCATION OUTSIDE AREA OF WATER-LEVEL CONTOURS—Number is water-level altitude, in feet above sea level

Figure 3. Ground-water levels in the intermontane basins.

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GROUND-WATER LEVELS IN INTERMONTANE BASINS OF THE NORTHERN ROCKY MOUNTAINS, MONTANA AND IDAHO

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