Shallow Groundwater Altitude in Bedrock Units of the Carbon–Stillwater Study, Carbon and Stillwater Counties, Montana

by

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Carbon–Stillwater Ground Water Characterization Area

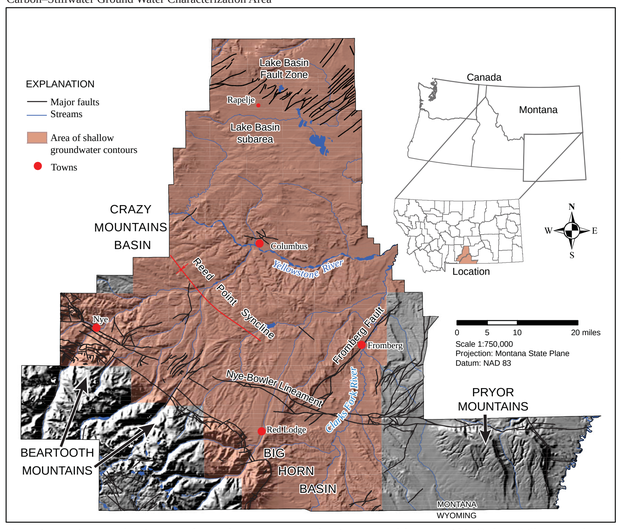

Figure 1. Location map showing area of groundwater contours and major structural features within Carbon–Stillwater study area.

Author's Note: This map is part of the Montana Bureau of Mines and Geology (MBMG) Ground Water Assessment Atlas for the Carbon–Stillwater area. It is intended to stand alone and describe a single hydrogeologic aspect of the study area, although many of the area's hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Carbon–Stillwater area, the reader is referred to other maps and reports of Montana Ground Water Assessment Atlas 6.

Introduction

This map portrays the shallow potentiometric surface of bedrock units in the Carbon–Stillwater MBMG Ground Water Characterization Program (GWCP) study area from 2001 to 2005. The potentiometric surface represents the altitude to which water will rise in wells. Generally, the potentiometric surface is a subdued representation of topography where the highest groundwater altitudes coincide with topographic highs and the lowest groundwater altitudes with topographic lows. Groundwater flows downgradient from potentiometric high altitudes to potentiometric low altitudes.

Most water wells in the area are completed in bedrock aquifers or unconsolidated alluvium associated with the major drainages. Residents of Carbon and Stillwater counties rely heavily on shallow groundwater for domestic use; 90 percent of wells are completed within 200 ft of the land surface and approximately 97 percent are completed within 400 ft of land surface. This area is within the Rocky Mountain and Northern Great Plains physiographic provinces and split by the Yellowstone River. The southern part is bounded by the Beartooth Mountain Front (the Front), the Big Horn Basin, and the Pryor Mountains. North of the Yellowstone River is the internally drained Lake Basin subarea. The Yellowstone River and its tributaries—Clarks Fork of the Yellowstone, Red Lodge Creek, Rock Creek, Rosebud Creek, and the Stillwater River—have incised into bedrock and deposit alluvium in their valley bottoms. Cold winters and hot summers characterize the climate; typically, April, May, and June are the wettest months. During this study, the population of Carbon and Stillwater counties was 9,921 and 9,481, respectively. Cities and towns (from largest in population to smallest) in Carbon and Stillwater counties are Red Lodge, Columbus, Bridger, Joliet, and Fromberg (Montana Department of Commerce, 2013).

Map Construction

The potentiometric surface was mapped by contouring measured water-level altitudes collected by Montana Bureau of Mines and Geology researchers. Water-level measurements were obtained from: (1) the GWCP Carbon-Stillwater study and (2) the MBMG 319 study of the Lake Basin subarea between June 2001 and November 2005 (Carstarphen and others, 2007). Most wells inventoried were less than 200 ft deep; however, some were as deep as 400 ft. Supplemental water-level data from previous investigations were used where they provide additional detail; driller-reported water level values were used where measured data were sparse. Driller-reported water-level data were obtained from the Ground Water Information Center (GWIC). Additionally, GWIC land-surface altitudes of spring sites were used to construct the potentiometric surface.

Solid black symbols represent inventoried wells with measured water levels, whereas hollow black circles represent supplemental GWIC wells. Solid black circles with an asterisk following the water-level elevation represent inventoried wells where a water-level measurement could not be obtained. In this case, the land-surface altitude and driller-reported water level values were used to estimate the water-level elevation. Inventory site locations were determined with handheld GPS units and are generally accurate to within 50 ft. Land-surface altitudes at inventoried wells were interpreted from U.S. Geological Survey 1:24,000 topographic maps and are generally accurate to 10 ft (20 ft contour interval). Water-level measurements were made using electric or steel tapes; the accuracy of most measurements is 0.01 ft. Map contour accuracy is affected by data distribution, field measurement errors, accuracy of well locations, and errors in interpretation. The groundwater altitude portrayed here is expected to be accurate within one-half the contour interval (50 ft).

County and township boundaries, major streams and roads, population centers, and major irrigation ditches were obtained from the Natural Resources Information System (NRIS) at http://nris.mt.gov. Surface geology was obtained from Berg and others (1999), Lopez (2000a, 2000b, 2000c, 2001, 2005), and Wilde and Porter (2000, 2001). USGS topographic maps were obtained from NRIS. Map construction was completed by hand-contouring water levels from primary and supplemental datasets. Where the density of inventoried wells is high (i.e., within Red Lodge city limits), some data symbols were eliminated to improve map readability. Water-level data used to complete this map are available from the MBMG Ground Water Information Center.

Geology

The Yellowstone River flows west to east, splitting the map area into two geologic settings. South of the Yellowstone River the area is structurally complex and contains the Beartooth Mountain Front, faults of the Nye-Bowler Lineament, the Fromberg Fault Zone, and the axis of the Reed Point Syncline (fig. 1). The bedrock units exposed near the Front range in age from Tertiary to Cambrian. Tertiary to Upper Cretaceous rocks generally dip southwest towards the Front, while Lower Cretaceous through Cambrian rocks are near vertical along the Front. In places, terrace gravel flanks the Front and alluvium exists in the modern floodplains (Lopez, 2000a, b, c, 2001, 2005). Terrace gravel along drainages south of the Yellowstone River represent changes of stage and drainage patterns resulting from uplift. The thickest terrace gravels are near Red Lodge and form prominent benches above Rock Creek. Ritter (1967) and Darlinton (1969) have extensively studied the terrace gravel near Red Lodge and along the northern flank of the Front.

Generally, bedrock units north of the Yellowstone River are flat-lying, less faulted, and not as structurally complex compared to those in the south (fig. 1). The Lake Basin subarea is a prominent internally drained depression (Reiten and others, in prep.) containing Quaternary stream and lake deposits. The topographic depression forming the Lake Basin appears to be associated with the Lake Basin Fault Zone. Alluvium is also found in modern floodplains of tributary streams to the Yellowstone River; however, it is not as thick as alluvium south of and along the Yellowstone River.

The Tertiary Fort Union Formation is exposed over much of the southern map area and consists of consolidated sandstone, shales, clays, and some coal. Tertiary and Cretaceous intrusive rocks, and the Sliderock Mountain Volcanics, also crop out exclusively south of the Yellowstone River near the upper reaches of Stillwater River and Fishtail Creek. Upper Cretaceous rocks alternate between shale and sandstone formations, while Lower Cretaceous rocks consist of shales and siltstones of the Colorado Group. Unconsolidated Quaternary terrace gravel and graded fluvial sand and gravel (alluvium) occur in and surrounding the floodplains of major drainages. The geologic setting and hydrogeologic framework of the Carbon-Stillwater study area is described in detail in MBMG Ground Water Assessment Atlas 6, Map 2 (in prep.).

Hydrogeology

This plate represents a regional shallow potentiometric surface based on data observed in aquifers and aquitards (confining units); undoubtedly, local variations exist. Detailed hydrogeologic studies have been completed in the area investigating topics such as surface-water/groundwater interactions near municipal water supplies (Rose, 2000, 2000a), groundwater chemistry along the Clarks Fork River (Levings, 1986), and groundwater quantity in Stillwater and Rosebud watersheds (Kuzara and others, 2012). Figure 2 shows the location and areal extent of the previous investigations. Groundwater is an important source for domestic, stock, and municipal use in the study area. The bedrock aquifer system contains alternating aquifers and aquitards. Groundwater can be obtained from the bedrock units throughout the study area. However, bedrock locations near alluvial valleys or irrigated lands provide better yields than do locations away from irrigation or surface-water influences. Wells located in upland island areas topographically separated from the Front generally yield less; groundwater contours in these areas are drawn as approximate (i.e. T. 5 S., R. 19 E. or T. 4 S., R. 20 E.).

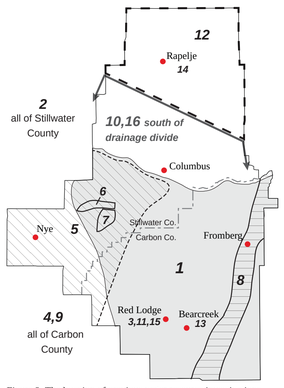

Figure 2. The location of previous water resource investigations. Numbers in the figure relate to numbers in the References section. The size of number relates to the areal extent of the investigation (i.e. # 4 covers Carbon County whereas #13 was a municipal water supply investigation for the town of Bearcreek).

The Tertiary Fort Union Formation is a regional source of groundwater; however, it mainly exists in the southern part of the map area. Water-bearing materials (sandstone or coal) in the Fort Union Formation can be laterally discontinuous, causing difficulty predicting drilling depths. In areas topographically separated from the Front, well depths can vary across short distances. The older Cretaceous formations alternate between shale and sandstone. The Hell Creek aquifer (Hell Creek, Lance and Fox Hills Formations combined), the Judith River aquifer (Judith River Formation), and Eagle Sandstone aquifer (Eagle Sandstone and Telegraph Creek Formation combined) are the other main bedrock aquifers. These units underlie most of the map area, but are generally only accessed where they are exposed at, or close to the surface. Confining units include the Bearpaw Shale, Claggett Shale, and Colorado/Montana groups; however, near the outcrop these units do yield small amounts of water to wells. Jurassic through Cambrian rocks crop out in small areas near the Front; these outcrops are nearly vertical. Due to the limited outcrops in the map area and their vertical nature, wells completed in Jurassic through Cambrian age rocks were not used in map construction (see Hydrostratigraphic column).

Figure 3 summarizes the driller-reported yields from wells completed in bedrock aquifers. Median yields range from 10 to 15 gallons per minute (gpm). Reported yields from Hell Creek and intrusive rock aquifers have the largest range, whereas yields from the Eagle Sandstone and Judith River aquifers have the smallest range.

Figure 3. Distribution of driller-reported well yields among Fort Union (Tfu), intrusive rock (TKi), Hell Creek (Khc), Judith River (Kjr), and Eagle Sandstone (Ket) aquifers. Most bedrock wells yield less than 20 gpm.

The main sources of aquifer recharge are infiltration of precipitation, stream losses, and irrigation. Most recharge occurs in the spring and summer during snowmelt runoff and storm events. Precipitation is most abundant along the Front and in the uplands surrounding the Lake Basin subarea. Irrigation canals provide significant recharge to bedrock and overlying alluvial aquifers along Rock Creek near Red Lodge. Aquifer discharge is primarily to streams, springs, evapotranspiration, and wells. Groundwater generally flows from high-altitude recharge areas toward low-altitude discharge areas.

South of the Yellowstone River, several upland areas are topographically separated from the high-altitude recharge area along the Front. Wells in these areas are recharged locally, generally yield less, and are more sensitive to land-use changes or climatic variability (fig. 4). The figure shows shallow groundwater in the Fort Union aquifer where the water table generally mimics topography; locally, impermeable layers create a perched water table. Discharge from the perched system forms an intermittent spring. The cross section in figure 4 includes two topographic highs separated from the Front. The groundwater surface is probably mounded beneath these areas of local recharge, but there are no data to estimate water-level elevations.

Groundwater contours generally mimic topography, with groundwater divides coincident with major topographic ridges and river bottoms. South of the Yellowstone River, the potentiometric surface slopes north, northeast, and east away from the Front toward the major river valleys. North of the Yellowstone River, the potentiometric surface slopes either southward to the Yellowstone River Valley or from all directions into the Lake Basin. Depth to water in wells varies from about 250 ft in the uplands to about 10 ft below land surface in the river valleys.

Figure 4. Conceptual hydrogeologic cross section showing relationships among shallow groundwater, the Fort Union Formation, topography, and streams draining the Beartooth Mountain Front (modified from Slagle, 1986). The water table is dashed where confidence is low.

Hydrostratigraphy

	Labels	Map Units / Square Miles	Lithology and water availability
Quaternary Unconsolidated Units	Qsc	Sediments, coarse-grained 466	Alluvial sand and gravel, found in recent river valleys and on abandoned floodplains (terraces). Also includes terraces deposited by glacial meltwater streams.
	Qsf	Sediments, fine-grained 189	Sandy silt or clay deposited as slope wash or glacial till. Includes modern lake, older lake, and landslide deposits. Not an aquifer.
1.8 Ma			
Tertiary Bedrock Units	Tfu	Fort Union Aquifer 606	Tan- to yellowish-gray sandstone, sandy claystone, claystone, shale, and coal. Coalbeds are mostly found between the Beartooth Mountain Front and Yellowstone River. The Linley Conglomerate is a reddish-brown to gray-brown interbedded, conglomerate, coarse-grained sandstone, siltstone, and mudstone. The formation thickens as much as 5,000 ft near the Beartooth Mountain Front. Widely used aquifer contains saturated, laterally discontinuous sandstone and coal that yield water to wells, seeps, and springs. Wells completed in the Linley Conglomerate produce poorly and drillers' logs often discribe drill cuttings as "granite." Well drillers report a median yield of 11 gpm with a median DWE and TD of 64 and 150 ft, respectively.
	TKi	Intrusive Rocks Local Aquifer 82	Sliderock Mountain stratovolcanic rocks, and diorite or diorite porphyry combined with Tertiary or Late Cretaceous age felsic rocks. Intrusive rocks are not generally extensive enough to be considered regional aquifers, but locally do yield water to wells, seeps, and springs from saturated fractures. Well drillers report a median yield of 15 gpm with a median DWE and TD of 60 and 85 ft, respectively.
65 Ma			
Cretaceous Bedrock Units	Khc	Hell Creek Aquifer 412	Interbedded, light-brownish-gray, cliff-forming, fine-grained, thin- to thick-bedded sandstone; gray mudstones and fissile shale. Sandstone beds are generally thicker east of the Clarks Fork of the Yellowstone River than to the west. Total thickness ranges from 350 to 1,000 ft. Laterally continuous aquifer with saturated sandstone that yields water to wells. Well drillers report a median yield of 10 gpm with median DWE and TD of 50 and 110 ft, respectively. Hell Creek aquifer wells are generally near the outcrop and relatively few wells penetrating overlying units to access the aquifer.
	Kb	Bearpaw Shale Confining Unit 200	Dark-gray, fissile, thin, mostly greenish-gray shale. Bentonite beds, near the middle; thin sandstone beds at the top. Thins from approximately 800 ft in the eastern part of the study area to 100 ft in the west. Laterally continuous, but not an aquifer except near outcrop where sandstone may yield poor-quality water to properly constructed wells. Well drillers report a median yield of 15 gpm with a median DWE and TD of 40 and 70 ft, respectively.
	Kjr	Judith River Aquifer 315	Brownish-gray, sandy shale and light-brown to pale yellowish-brown clayey, very-fine- to fine-grained lenticular sandstone beds up to 10 ft thick. Contains greenish and maroon-gray mudstones, and poor quality coal. Sandstone generally occurs near top. Total thickness from 700 to 1,000 ft. Laterally continuous aquifer with sandstone yielding groundwater to wells. Well drillers report a median yield of 10 gpm with a median DWE and TD of 60 and 125 ft, respectively.
	Kcl	Claggett Shale Confining Unit 66	Brownish-gray, fissile, shale and minor clayey sandstone. Total thickness ranges from 100 to 300 ft. Laterally continuous, but not an aquifer, except near outcrop where sandstone may yield water to wells.
	Ket	Eagle Sandstone Aquifer 150	Light-gray, brownish-gray to pale orange, very fine- to medium-grained sandstone with interbedded brownish-gray to medium dark gray shale, sandy shale, siltstone and sandstone. Telegraph Creek sandstones thicken upward becoming cliff- and ridge-forming Eagle Sandstone. Total thickness from 300 to 450 ft. Laterally continuous aquifer with sandstone yielding water to wells, seeps, and springs. Well drillers report a median yield of 12 gpm with median DWE and TD of 90 and 200 ft, respectively. Wells often penetrate through the Claggett confining unit to access the Eagle Sandstone aquifer. However, most wells are located near the outcrop.
	Kmg	Montana Group <1	Bearpaw Shale through Telegraph Creek Formation undivided. Occurs in T. 6 S., R. 18 E., and T. 7 S., R. 18 E. only. Aquifer potential unknown.
	Kcg	Colorado Group Confining Unit 95	Niobrara Formation through Thermopolis Shale; Fall River Sandstone. Laterally continuous but not an aquifer except near outcrop where sandstone beds may yield water to wells.
Cambrian through Jurassic Bedrock Units	Kk	Kootenai Aquifer*	
144 Ma	J-P	Jurassic through Pennsylvanian aquifers; non-aquifers*	
	Mm	Madison Aquifer*	
	D-C	Devonian through Cambrian aquifers; non-aquifers*	
543 Ma	Agn	Granitic rocks; non-aquifer*	

* aquifers and non-aquifers not used to generate groundwater contours
TD = total depth, DWE = depth water enters (usually top of well screen)
Ma = millions of years before present

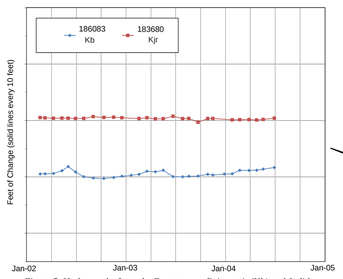

Figure 5. Hydrographs from the Bearpaw confining unit (Kb) and Judith River aquifer (Kjr) show minor seasonal fluctuations from 2002 to 2004 (6-digit GWIC identification numbers).

EXPLANATION FOR MAP

- Contours show lines of equal water level altitude in feet above mean sea level for bedrock units. Contour interval is 100 feet and dashed where approximated. (— 4,800 —)
- Inventoried spring
- 4838 / 4831 Inventoried bedrock well with measured water level in feet above mean sea level. At some locations, water levels were measured twice as indicated by two water-level altitudes.
- 4831* Inventoried bedrock well with driller-reported water level in feet above mean sea level.
- 4831 Supplemental bedrock well with driller-reported water level in feet above mean sea level.
- Lakes
- River/stream
- Township boundary
- Towns

Maps may be obtained from: Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4174
Fax: (406) 496-4451
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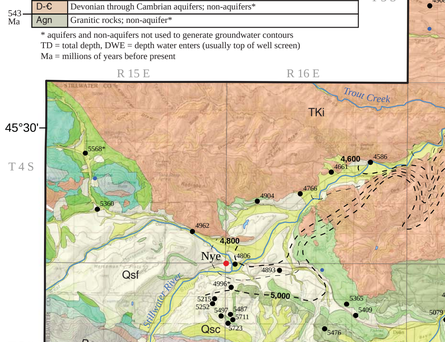

Figure 6. Hydrographs from the Fort Union (Tfu) and Hell Creek (Khc) aquifers show similar seasonal fluctuations from 2002 to 2006 (6-digit GWIC identification numbers).

Water levels in wells fluctuate in response to changes in aquifer storage. The magnitude of the fluctuation depends on the balance between recharge and discharge, as well as aquifer storativity. Water levels rise when recharge exceeds discharge and decline when the opposite occurs. Representative hydrographs show different patterns throughout the map area. Lake Basin subarea hydrographs from wells completed in the Judith River aquifer and Bearpaw Shale confining unit show little seasonal change (fig. 5), suggesting recharge equals discharge. South of the Yellowstone River, hydrographs from wells completed in Fort Union and Hell Creek aquifers show approximate seasonal fluctuations with similar timing (fig. 6). Water levels rise during the spring in response to precipitation/runoff, and drop in the fall because of decreased recharge and evapotranspiration. Domestic well pumping may contribute to the somewhat erratic shape of some hydrographs. Hydrographs in the Red Lodge area (fig. 7) show more consistent seasonal fluctuations compared to the hydrographs in figure 6. The hydrographs shown in figure 6 are from water wells northwest of Red Lodge in areas topographically separated from the Front; these wells show little influence from irrigation.

Water levels in bedrock aquifers near Red Lodge show a uniform response, suggesting recharge is strongly controlled by leakage from overlying alluvial aquifers and irrigation canals. Figure 7 shows two hydrographs from Fort Union aquifer wells on opposite sides of Rock Creek, and a shallow well completed in unconsolidated Quaternary alluvium. The timing and magnitude of water-level change for each well is consistent during the period of record. However, the magnitude of annual fluctuation varies; the alluvial well shown in figure 7 fluctuates as much as 35 ft annually, whereas the east bench Fort Union well fluctuates about 12 ft, and the west bench Fort Union well fluctuates about 7 ft per year. In contrast, water-level fluctuations in two Fort Union and one Hell Creek wells east of the Clarks Fork of the Yellowstone show little or no seasonal fluctuation (fig. 8). These wells are located away from irrigation canals and in a dry part of the study area.

Map use

This map presents the distribution of MBMG inventoried wells, generalized surface geology, and groundwater altitude within 200 ft of the land surface. The map intends to give the user a regional overview of groundwater occurrence and altitude, and aid with initial conceptual models for large-scale investigations. Groundwater contours shown here are intended to be accurate within one contour interval. Contours may be less accurate in areas with high topographic relief.

Figures 3, 5, 6, 7, and 8 show descriptive statistics of driller-reported yields per aquifer, and representative hydrographs for areas along the Front and from the Lake Basin subarea. Water-well drillers measure yields using different methods, which can lead to errors. Groundwater contours portray conditions from August 2001 to November 2005 within 200 ft of the land surface. Water-well and borehole records are continuously submitted to GWIC; up-to-date information can be accessed to supplement the data presented here at http://mbmggwic.mtech.edu. This map is not intended to be used at scales larger than 1:150,000.

Acknowledgments

The authors appreciate the assistance from many individuals and organizations in the completion of this map. Funding for this work was provided by the MBMG Ground Water Characterization Program. Well owners who allowed collection of the data necessary for map construction and MBMG researchers who collected the data are gratefully acknowledged. Susan Smith (MBMG) lent her cartographic skills to construct figures and cross sections and Paul Thale (MBMG) provided technical assistance and with the GIS analysis. Reviews by MBMG staff: John Metesh, Tom Patton, John LaFave, James Madison, Jon Reiten, Phyllis Hargrave, and Monte Smith (DEQ) added to the clarity of map and text.

Figure 7. Hydrographs from the Fort Union (Tfu) aquifer show similar timing but different magnitude of seasonal fluctuations when compared to unconsolidated sediments (Qsc, diamonds and blue line) from 2002 to 2006. The similar response in each year suggests irrigation canal leakage is an important source of groundwater recharge in this area (6-digit GWIC identification numbers).

Figure 8. Hydrographs from the Fort Union (Tfu) and Hell Creek (Khc) aquifers show little or no seasonal fluctuation from 2002 to 2005 (6-digit GWIC identification numbers).

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