Montana Bureau of Mines and Geology
A Department of Montana Tech of The University of Montana

Montana Ground-Water Assessment Atlas No. 1, Part B, Map 6
October 1998
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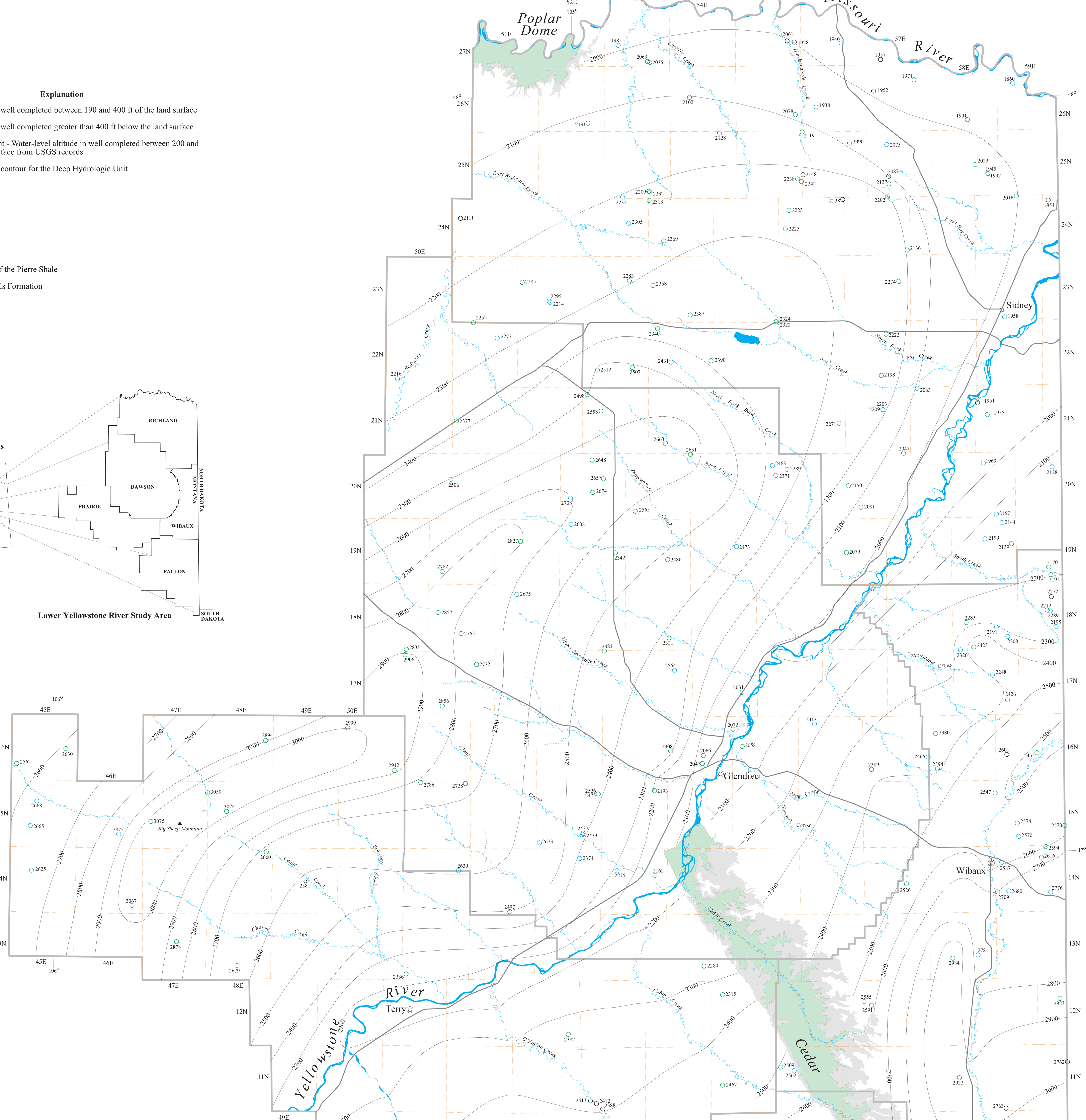
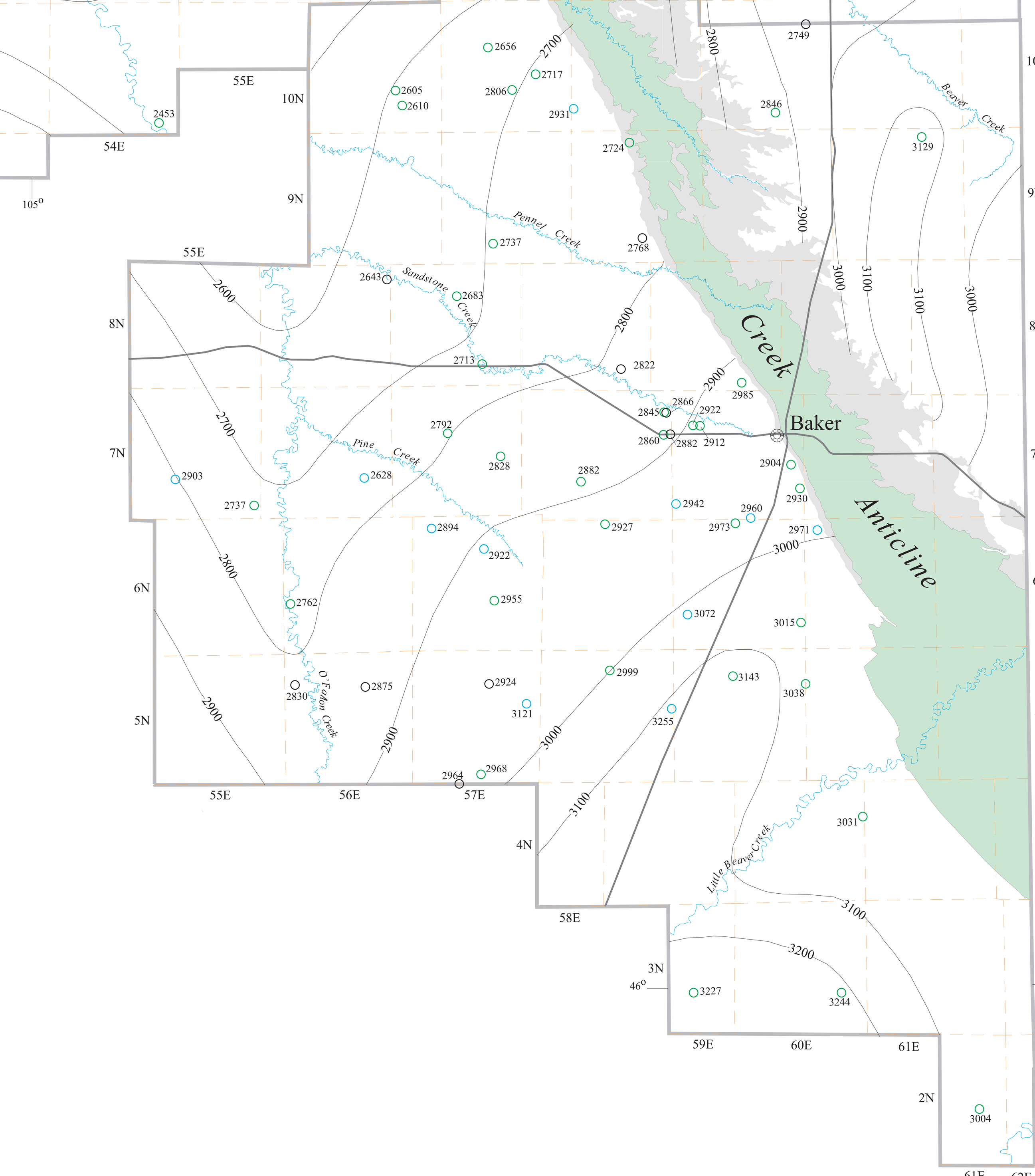
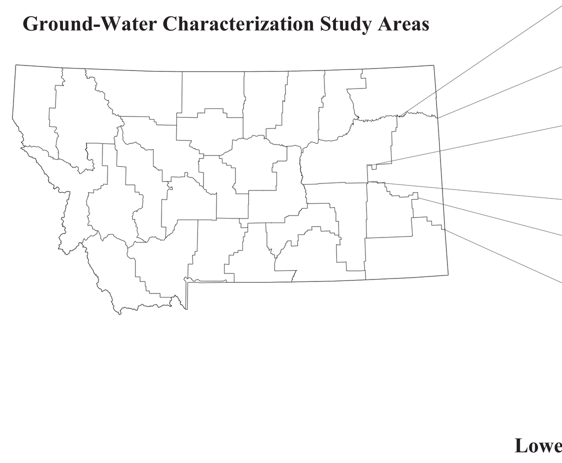




Explanation

- Water-level altitude in well completed between 190 and 400 ft of the land surface
- Water-level altitude in well completed greater than 400 ft below the land surface
- Supplemental data point - Water-level altitude in well completed between 200 and 400 feet of the land surface from USGS records
- 2200 Potentiometric surface contour for the Deep Hydrologic Unit
- County boundary
- Township boundary
- County seat
- Major road
- Principal stream
- Outcrop and subcrop of the Pierre Shale
- Outcrop of the Fox Hills Formation

Ground-Water Characterization Study Areas



Lower Yellowstone River Study Area

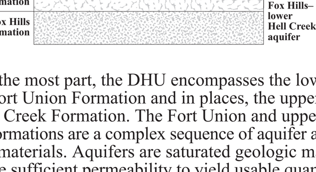
Potentiometric Surface Map for the Deep Hydrologic Unit, Lower Yellowstone River Area: Dawson, Fallon, Prairie, Richland, and Wibaux Counties, Montana

by

John I. LaFave

Introduction

The Deep Hydrologic Unit (DHU) is defined as all aquifers and non-aquifers that occur at depths greater than 200 feet below land surface, and lie stratigraphically above the regionally extensive claystone and shale in the upper part of the Hell Creek Formation.



For the most part, the DHU encompasses the lower part of the Fort Union Formation and in places, the upper part of the Hell Creek Formation. The Fort Union and upper Hell Creek formations are a complex sequence of aquifer and non-aquifer materials. Aquifers are saturated geologic materials that have sufficient permeability to yield usable quantities of water to wells and springs; non-aquifers (confining beds) are low-permeability, geologic materials that restrict the movement of water between aquifers and do not yield water to wells. The aquifers in the DHU are primarily sandstone and coal in the Fort Union Formation and sandy zones in the upper part of the Hell Creek formation. The aquifers vary in thickness, are laterally discontinuous, and are often separated by non-aquifer shale and claystone layers. However, on a regional scale there is sufficient hydraulic continuity to consider the DHU a single entity in terms of ground-water flow. It is typically greater than 200 feet thick; however, the thickness ranges from less than 200 to more than 1,400 feet.

The top of the DHU is not defined by a continuous geologic or hydrologic marker, but is transitional with the Shallow Hydrologic Unit (SHU). The SHU consists of all aquifers and non-aquifers within 200 feet of the land surface (Patton *et al.* 1998). The two units were differentiated to facilitate meaningful hydrogeologic interpretations, given the scale of this investigation and the available data. Differences in water quality and ground-water flow were used to justify separating the units at about 200 feet below land surface. The water table surface of the SHU closely mimics the land-surface topography; flow paths are short, beginning at local topographic highs and ending in adjacent valley bottoms; while the potentiometric surface for the DHU is a much-subdued representation of the regional topography, with longer flow paths.

In the five-county Lower Yellowstone Area, about 900 wells are completed in the DHU and compose approximately 12% of all wells in the area. Ground water from this unit is used primarily for domestic and stockwater purposes. Water from the DHU is generally a sodium-bicarbonate or sodium-sulfate type water with dissolved-constituent concentrations ranging from about 1,300 to 3,000 mg/L. Most reported well yields are less than 15 gallons per minute.

Ground-Water Flow

Ground water generally moves down the slope of the potentiometric surface, from higher altitude to lower altitude, perpendicular to the contours. In general, the DHU potentiometric surface is a subdued representation of the regional topography; the highest ground-water altitudes coincide with the regional topographic highs and the lowest altitudes with the regional topographic lows. Therefore, ground-water flow is predominately away from major drainage divides, such as the Big Sheep Mountain area in northwest Prairie County, toward the Yellowstone and Missouri rivers.

On this map, ground-water flow in the DHU appears to be horizontal, but there also are important vertical flow components. Vertical ground-water flow is indicated by differing water-level altitudes in closely spaced wells that are completed at various depths. Vertical flow may be upward or downward, depending on the position in the flow system, geologic framework, and hydraulic continuity with the overlying SHU. Recharge areas, discharge areas, and places where low-permeability units separate aquifers are all settings where vertical flow can occur. Where downward leakage recharges the DHU, shallower wells have higher water levels indicating a downward gradient and downward flow. Where water-level altitudes increase with greater depth, there is an upward gradient causing vertical flow. Prominent recharge areas are northwest Prairie County (near Big Sheep Mountain) and southeast Fallon County where the potentiometric surface is more than 3,000 feet above sea level. Upward flow occurs in discharge areas coincident with the major stream valleys where the potentiometric surface altitude is higher than the water table (or the land surface), such as along the Yellowstone and Missouri rivers and where Little Beaver Creek exits the study area.

Water-level anomalies may occur where fine-grained, low-permeability layers separate aquifers. In these areas, nearby wells completed in different aquifers may have discordant water levels. For example, between the towns of Wibaux and Baker (10N 59E–11N 61E) there are three wells completed beneath a confining layer more than 400 feet below the surface. Nearby, other wells completed between 200 and 300 feet below the surface have water levels more than 100 feet higher in altitude than those of the deeper wells. The discrete water levels in these two horizons suggests that there are separate aquifers in this area.

Map Use

The potentiometric surface map is useful in estimating the distance to water below the land surface and the general direction of ground-water flow. If, for a given point, the land-surface altitude at a location is known, subtraction of the potentiometric surface altitude from the land surface altitude yields an approximate level at which water will stand in a well completed in the DHU.

To estimate the direction of ground-water flow near a location, lines that cross potentiometric contours should be drawn at right angles. Ground-water flows from high altitude to low altitude along these lines. The inset map at the right illustrates how ground-water flow direction can be interpreted.

Map Construction

This map was constructed by hand contouring measured water-level altitudes. Two data sets were used in the map compilation. The primary data set consists of 192 water-level measurements taken from wells visited between October 1993 and November 1995. Most measurements are from wells that were completed at depths more than 200 feet below land surface, but measurements were included from 12 representative wells that were completed at depths between 190 and 200 feet. Ground-water altitudes from wells completed 200 to 400 feet below land surface (green circles) were given most weight and were generally honored by the contours. In places, water levels from deeper wells (greater than 400 feet, black circles) were discordant and not always honored.

A supplemental data set containing static water levels for 76 wells, where the water-level measurements were made by the USGS, was also used (blue circles). All these wells are perforated between 200 and 400 feet below land surface, and most of the measurements were made between 1973 and 1977. Because ground-water flow in the DHU is stable and temporal water-level fluctuations are small relative to the 100-foot contour interval used on the map, the supplemental data were used to assist in defining the flow system. The supplemental data were useful in areas where the primary data were sparse. Approximately, two-thirds of the supplemental data were honored by the contours and one-third conflicted with the primary data-set measurements. In this case, preference was given to the primary data set.

Map accuracy is affected by data availability, field measurement errors, accuracy of well locations, and errors in interpretation. Points at which water levels have been measured are distributed unevenly across the map, and map accuracy is greatest near the points of measurement. Well locations are accurate to the 2.5-acre level, and all locations of the primary data set have been visited in the field. Land-surface altitudes at well locations were interpreted from USGS 1:24,000 topographic maps and are generally accurate to ± 5 to 10 feet (based on 10- and 20-foot contour intervals). Land-surface altitudes used in contouring were obtained from USGS 1:250,000 topographic maps with 100-foot contour intervals. The contoured potentiometric surface is expected to be accurate to ± 50 ft at any given point.

Acknowledgements

Well owners who allowed collection of the data necessary for this map, and the people who collected the data are all gratefully acknowledged. Reviews of this report by Tom Patton, Larry Smith, James Rose, Wayne Van Voast, and Bob Bergantino improved its clarity.

Data Sources

Geographic features:

Population center locations and roads are from 1:100,000-scale U.S. Geological Survey (USGS) Digital Line Graph files available from the Natural Resources Information System (NRIS) at the Montana State Library, Helena, Montana. Hydrography has been simplified from the 1:100,000 Digital Line Graph files. Township boundaries are from 1:250,000-scale U.S. Geological Survey mapping and are available from NRIS.

Point data:

Well location and water-level altitude data for the primary data set were obtained by Ground-Water Characterization Program personnel, altitude of the points was determined from USGS 7.5-min. quadrangles; well location and water-level altitude data for the supplemental data set were obtained from the USGS. All point data used on this map are available from the Ground-Water Information Center (GWIC) at the Montana Bureau of Mines and Geology, Montana Tech of The University of Montana, Butte.

References

Bergantino, R. N., and Wilde, E. M. 1998a. The preliminary geologic map of the Culbertson 30 x 60-min. quadrangle, Montana. Montana Bureau of Mines and Geology 359. Scale 1:100,000.
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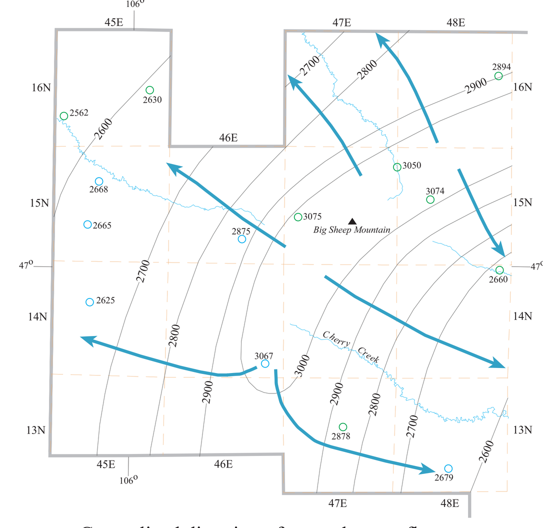
Patton T., Rose, J. C., LaFave, J. I., and Smith, L. N. 1998. Potentiometric surface map for the Shallow Hydrologic Unit, Lower Yellowstone River Area, Montana, MBMG Ground-Water Assessment Atlas No. 1, Part B, Map 5. Scale 1:250,000.
Vuke-Foster, S. M., Colton, R. B., Stickney, M. C., Wilde, E. M., Robocker, J. E., and Christensen, K. C. 1986. Geology of the Baker and Wibaux 30 x 60-min. quadrangles, eastern Montana and adjacent North Dakota: Montana Bureau of Mines and Geology Geologic Map No. 41. Scale 1:100,000.
Wilde, E. M., and Vuke-Foster, S. M. 1994. Preliminary geologic map of the Glendive 1 x 2-degree quadrangle: Montana Bureau of Mines and Geology Open-File Report 295. Scale 1:250,000.



Generalized direction of ground-water flow

The area near Big Sheep Mountain, northwest of Terry, provides an example of how the potentiometric surface map can be used to estimate general directions of ground-water flow. Flow arrows drawn perpendicular to the contours show that ground water moves northwest and southeast away from the regional topographic high near Big Sheep Mountain.

Author's Note: This map is part of the Montana Bureau of Mines and Geology (MBMG) Ground-Water Assessment Atlas for the Lower Yellowstone River Area ground-water characterization. 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 Lower Yellowstone River Area the reader is referred to Part A (descriptive overview) and Part B (maps) of the Montana Ground-Water Assessment Atlas No. 1.

Geographic information system production by Joel Hall and Larry Smith. Digital cartography by Don Mason.