Montana Ground-Water Assessment Atlas No. 3, Part B, Map 3
Open-File Version 2005

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

Characterization of Alluvial Aquifers in Treasure and Yellowstone Counties, Middle Yellowstone River Area, Montana

by

John L. Olson

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Atlas organization
The Montana Ground-Water Assessment Atlas for the Middle Yellowstone River Area (Atlas 3) consists of a descriptive overview (Part A) and seven hydrogeologic maps (Part B). This map is intended to be a stand-alone document, and describes a single hydrogeologic unit (the alluvial aquifers) within the study area. To obtain a more integrated understanding of the area’s hydrogeology, see Part A and the other Part B maps.

Introduction
The alluvial aquifers are the most utilized sources of ground water in Yellowstone and Treasure Counties and provide water to about 5,300 wells. Most of these wells are located in the Yellowstone River valley in or near the cities of Billings and Laurel (see Well density). The primary uses of the wells are for domestic potable water and, to a much lesser degree, for stockwater and irrigation (see Well use).

Geologic setting
The alluvial aquifers consist of water-saturated sand and gravel in alluvial deposits of the Yellowstone River and its tributaries. The alluvium has been deposited over older bedrock units, and thickness ranges from 0 to more than 100 ft. In some locations underlying sandstone aquifers are available as alternative water sources. However, much of the area is underlain by non-water-bearing shale, making the alluvium the sole source of ground water.

In general, the alluvial deposits in the Yellowstone River valley consist of a basal layer of coarse-grained alluvium overlain by a mantle of fine-grained alluvium. The basal sand and gravel is typically 10- to 20-ft-thick but can be as much as 40-ft-thick because of channel scouring. The coarse-grained alluvium consists of sand and gravel, and is the primary water-bearing unit in the Yellowstone River valley.

The fine-grained alluvium overlies the coarse-grained alluvium and is as much as 100-ft thick. Generally, the fine-grained alluvium is thick near the valley margins and near streams draining uplands where shale is exposed. This fine-grained alluvium may also be water-saturated but does not produce yields sufficient for use.

Erosion and deposition by the Yellowstone River has formed seven Quaternary terrace surfaces above the modern floodplain. Five of the terraces were originally

Map locations
The Middle Yellowstone River Area consists of Yellowstone and Treasure Counties exclusive of the Crow Indian Reservation. Maps of the Yellowstone River valley alluvial deposits are split into western and eastern segments (shown above). Between the two areas there is a 36-mile gap where there are few wells completed in the alluvial aquifer due to very low population and possible preference for relatively soft water attainable from underlying bedrock units.

Potentiometric surface
The potentiometric surface (ground-water altitude) map shown at right was completed using static water levels from 319 inventoried wells. Reported water-levels in non-inventoried wells were also used on a qualitative basis to assist in contouring. This map shows the altitude (in feet above mean sea level) to which ground water will rise in a well. Ground-water flow is perpendicular to the potentiometric contours, from high altitudes to low altitudes. The directions of flow are depicted by blue arrows.

Stratigraphic and potentiometric data indicate that distinct aquifers are formed under Terraces 2, 2A, 3, and 4A. These aquifers are separated by either discontinuities between the sand and gravel deposits or thinning of the saturated thickness at the terrace scarp. Direct flow between terraces is either limited or absent. Ground water under the modern alluvium and Terrace 1 appears to be hydraulically connected.

The flow patterns indicate that ground water in the

Well density
There are about 5,300 wells completed in alluvial or terrace deposits (Ground-Water Information Center, GWIC); most wells are situated in or near the cities of Billings and Laurel.

Well use
Most wells completed in the water to individual residences. Others provide water for stock purposes.

Well use
Most wells completed in the water to individual residences. Others provide water for stock purposes.
The alluvial aquifers provide numerous sources for domestic purposes, irrigation, and monitoring.

Map A: Potentiometric surface

Map B: Potentiometric surface
Geologic cross sections

Lithologic relationships of the alluvial deposits are shown in the three geologic cross sections (A–A', B–B', and C–C') below. Cross section A–A' is located west of Billings, B–B' is near Shepherd, and C–C' is east of Hysham. Locations of the cross sections are shown on the Potentiometric surface maps A and B.

The cross sections were developed from well data and geologic mapping. They show bedrock topography, thickness of the sand and gravel, and thickness of fine-grained alluvium. They also demonstrate that in many cases gravel sheets underlying terraces are discontinuous, and show how terrace separation increases eastward.

Explanation
- Surface water
- Fine-grained alluvium
- Modern alluvium
- Sand and gravel
- Shale
- Sandstone
- Vertical exaggeration = 50X

Well drilling depths

These maps show probable well depths at locations within the alluvial aquifers. The estimates consider depth to water, thickness of the overlying fine-grained alluvium, and penetration of 10 ft into the aquifer. Most wells in the project area are about 30 ft deep. Wells deeper than 30 ft are usually located near the valley margins and at other locations where overlying fine-grained alluvium is thick. The aquifer may be thin (less than 10 ft) along the southwestern part of the project area.
Aquifer productivity

Data from 2,778 of 5,300 alluvial wells in the project area were evaluated to provide the aquifer productivity statistics shown in the tables below. The population percentile is the percentage of the sample data that is less than the given value. The 50th percentile is the median value.

Reported yield is the rate (in gallons per minute [gpm]) pumped by the well driller after completion. Yields in the alluvial aquifer are adequate for household and lawn irrigation uses but may be insufficient for municipal, crop irrigation, or industrial uses.

Specific capacity is the yield per foot of drawdown in a well. Specific capacity is a function of aquifer characteristics and well construction. The higher the value, the more productive the well. Low specific capacity in wells causes excessive drawdown, sand intake, and well deterioration.

Hydraulic conductivity is the flow of water through a unit area of aquifer under a gradient of 1 ft/ft. The actual flow rate (in cubic ft per square foot of aquifer) can be calculated by multiplying the gradient by the hydraulic conductivity. Values for hydraulic conductivity have been obtained through evaluation of pumping test data (see Summary of pumping test results) and were estimated from specific-capacity data (see Aquifer productivity statistics). Both data sets show similar ranges of values. Results from pumping tests are more accurate but are limited in number and distribution.

Therefore, the more numerous specific capacity data may be more useful on a regional basis. Evaluation of the data grouped by terrain level and east-west location does not show significant differences or trends between the groups and the overall data population.

Aquifer productivity statistics

<table>
<thead>
<tr>
<th>Specific capacity (gpm/ft)</th>
<th>Reported yield (gpm)</th>
<th>Hydraulic conductivity (ft/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>95%</td>
<td>34</td>
<td>750</td>
</tr>
<tr>
<td>75%</td>
<td>13</td>
<td>250</td>
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<tr>
<td>50%</td>
<td>6.7</td>
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<tr>
<td>25%</td>
<td>3.3</td>
<td>44</td>
</tr>
<tr>
<td>15%</td>
<td>1.4</td>
<td>12</td>
</tr>
</tbody>
</table>

*Hydraulic conductivity calculated by the following formula:

\[ K = 10^{-b} \times (c \times (a^{b} + (a^{b} \times \log_{10} (a))^{2})) \]  

Using the following values:

1 = specific capacity (gpm/ft),  
2 = gradient (ft/ft),  
3 = specific gradient (ft/ft),  
4 = well radius (ft),  
5 = aquifer storage (ft),  
K = hydraulic conductivity (ft/ft).

Proportions of common ions

The plot (on the right) shows the relative proportions of common ion constituents in terms of milliequivalents per liter (meq/L). The size of the dot is proportional to the dissolved constituent concentration and the color of the dot is related to the thickness of the fine-grained alluvium overlying the aquifer.

Explanation:

- Fine-grained sediment thickness
  - Less than 10 ft
  - 10-20 ft
  - More than 30 ft

Scale of radii proportional to dissolved constituent concentration (meq/L).

Distribution of dissolved constituents

Waters within the alluvial aquifers is important in determining if, and how much, water treatment may be necessary for a given use. In some areas, water quality may be prohibitively bad. Water typically does not become too salty to drink until dissolved constituent concentrations exceed 2,000 mg/L, and is unsuitable for most uses where concentrations exceed about 3,000 mg/L.

Water may be characterized by the types and concentrations of its dissolved constituents. This map shows the distribution of the sum of dissolved constituents (Ca+Mg+Na+K+HCO$_3$+SO$_4$), shown by color) and the concentrations of individual common ions (shown on the accompanying diagrams).

The general trend in the alluvial aquifers is for water to evolve from a relatively fresh bicarbonate-dominated water to a highly mineralized sulfate-dominated water. The trend seems related to the thickness of fine-grained alluvium overlying the aquifer. Where fine-grained
Conclusions

The alluvial aquifers in the Middle Yellowstone River Area provide water to approximately 5,300 wells mostly for domestic potable water. The aquifers may be too thin at some locations to provide a sufficient well yield. Terrace deposits above the irrigated valley likely are not water bearing. However, where the aquifer is present and thick enough, it can be expected to provide yields of 20–30 gpm, adequate for most domestic and stockwater uses. Ground water in the alluvial aquifers is typically hard and has dissolved constituent concentrations ranging from 200 mg/L to more than 10,000 mg/L. With minimal treatment, water with dissolved constituent concentrations less than 2,000 mg/L may be still usable for domestic purposes. Water with dissolved constituent concentrations greater than 3,000 mg/L is not suitable for most uses without significant treatment. Where ground water of adequate yield and quality is not available in the alluvial aquifers, it may be available from underlying sandstone aquifers (refer to other maps of this atlas). However, in many locations the alluvial aquifer is underlain by thick shale units. In these locations the alluvial aquifer is likely the sole source of water.

Data sources

Geographic features:
Digital coverages of streams and public land-survey grids were obtained from the Montana Natural Resource Information System (NRIS). Geologic coverages were obtained through the Montana Bureau of Mines and Geology’s State Map program.

Point Data:
Well-location and water-level altitude data were obtained by Ground-Water Characterization Program staff. Measuring-point altitudes were measured from 1,240,000 scale topographic maps. All point data presented on this map are available through the Ground-Water Information Center (GWIC) at http://mbmngvic.mtech.edu.

Acknowledgments

Well owners who allowed collection of the data necessary for this map and the people who collected the data are gratefully acknowledged. Reviews by Tom Deaton, Larry Smith, and Wayne Van Voast are also appreciated.

References


Water-quality ranges

The median and range (5th and 95 percentile) of water-quality parameters in ground water from the alluvial aquifers are shown at right. The upper range of chloride, iron, manganese, sodium, sulfate, and total dissolved solids (TDS) concentrations exceeded secondary maximum contaminant levels (SMCL; in blue print). Parameters that exceed an SMCL may cause aesthetic or other problems but are not generally health threats. The upper range of nitrate + nitrite and selenium concentrations exceeded maximum contaminant levels (MCL; in red print). Water containing parameters exceeding the MCLs may need treatment to prevent adverse human health impacts.
### Concentrations of water-quality parameters

<table>
<thead>
<tr>
<th>Common ion (mg/L)</th>
<th>Number of samples</th>
<th>Population percentile</th>
<th>MCL (5%)</th>
<th>SMCL</th>
<th>Trace element (μg/L)</th>
<th>Number of samples</th>
<th>Population percentile</th>
<th>MCL (5%)</th>
<th>SMCL</th>
<th>Other constituents of samples</th>
<th>Number</th>
<th>Population percentile</th>
<th>MCL (5%)</th>
<th>SMCL</th>
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</thead>
<tbody>
<tr>
<td>Nitrate (NO₃⁻)</td>
<td>170</td>
<td>210</td>
<td>424</td>
<td>1,006</td>
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<td>Field pH</td>
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<td>Sulfate (SO₄²⁻)</td>
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<td>168</td>
<td>41</td>
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<td>Field SC (μhos/cm)</td>
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<td>-</td>
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<td>Water temperature (deg C)</td>
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<td>14.5</td>
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<td>Barium (Ba)</td>
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<td>22</td>
<td>460</td>
<td>250</td>
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<td>-</td>
<td>-</td>
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<td>Sum of dissolved constituents (mg/L)</td>
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<td>456</td>
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<td>0.015</td>
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<td>Total dissolved solids (mg/L)</td>
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<td>&lt;20</td>
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<td>-</td>
<td>-</td>
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<td>-</td>
<td>Explanation</td>
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<td>6.5 - 8.5</td>
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<td>-</td>
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<td>Arsenic (As)</td>
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<td>&lt;2</td>
<td>6</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>MCL = maximum contaminant level (EPA)</td>
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<tr>
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<td>&lt;2</td>
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<td>-</td>
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<td>SMCL = secondary maximum contaminant level (EPA)</td>
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<td>Beryllium (Be)</td>
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<td>&lt;1</td>
<td>&lt;1</td>
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<tr>
<td>Boron (B)</td>
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<td>Bromine (Br)</td>
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<td>Degrees Celsius</td>
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<td>&lt;2</td>
<td>5</td>
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<td>ppm = parts per million</td>
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<tr>
<td>Cobalt (Co)</td>
<td>81</td>
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<td>&lt;2</td>
<td>5</td>
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<tr>
<td>Copper (Cu)</td>
<td>83</td>
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<td>&lt;2</td>
<td>5</td>
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<td>μg/L = micrograms per liter</td>
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<tr>
<td>Cobalt (Co)</td>
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<td>&lt;2</td>
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<td>mg/L = milligrams per liter</td>
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<tr>
<td>Cobalt (Co)</td>
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<td>Calcium (Ca)</td>
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<td>Lithium (Li)</td>
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<td>&lt;25</td>
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<tr>
<td>Molybdenum (Mo)</td>
<td>83</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>36</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Nickel (Ni)</td>
<td>83</td>
<td>&lt;2</td>
<td>&lt;2</td>
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<td>15</td>
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<tr>
<td>Sodium (Na)</td>
<td>165</td>
<td>34</td>
<td>190</td>
<td>1,274</td>
<td>250</td>
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<tr>
<td>Silver (Ag)</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;2</td>
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<td>μg/L = micrograms per liter</td>
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</tr>
<tr>
<td>Strontium (Sr)</td>
<td>91</td>
<td>385</td>
<td>1,390</td>
<td>4,734</td>
<td>-</td>
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<tr>
<td>Titanium (Ti)</td>
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<td>&lt;10</td>
<td>&lt;100</td>
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<td>-</td>
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<td>Vanadium (V)</td>
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<td>&lt;5</td>
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<td>Zinc (Zn)</td>
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<td>3</td>
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<tr>
<td>Zirconium (Zr)</td>
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<td>mg/L = milligrams per liter</td>
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</tr>
</tbody>
</table>

*Explanations:*
- MCL = maximum contaminant level (EPA)
- SMCL = secondary maximum contaminant level (EPA)
- mg/L = milligrams per liter
- μg/L = micrograms per liter
- ppm = parts per million
- °C = degrees Celsius
- Specific conductance